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INSECT SUCCESSION AND DECOMPOSITION PATTERNS OF CARCASSES IN SARAWAK, MALAYSIAN BORNEO

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Abstract: Insect succession and decomposition process on three types of carcasses were conducted in peat swamp forest in Kota Samarahan, Sarawak, Malaysia, from August 2007 until January 2008. Nine fresh animal carcasses were used as carcass model in forensic entomological research. Three experiments were conducted and using three species of animals, namely plantain squirrels, *Callosciurus notatus,* chickens, *Gallus gallus,* and toads, *Duttaphrynus melanostictus.* The objectives of this study are to determine the decomposition stages and the insect succession with decomposition of different types of carcass in a peat swamp forest. Five decomposition stages were observed during this study which were fresh, bloated, active decay, advanced decay and dry remains stages. A total of 38 species of insects (seven Orders and 14 families) were collected from the nine carcasses. The common species that visit all three types of carcasses were *Chrysomya megacephala* and *C. rufifacies (Calliphoridae).* Ambient temperatures and relative humidity showed a reciprocal relationship in all the locations where the readings were recorded from the carcasses. These data may be used as a reference for further studies in ecology and forensic entomology in Malaysia.

Keywords: carcasses, decomposition stages, peat swamp forest, forensic entomology

Introduction

Every living organism will eventually die and the body will undergo decomposition process. Decomposition process is a process of chemical breakdown of organic matter into its constituents by the action of decomposer (Oxford Dictionary of Biology, 2004). Some arthropods play important roles as decomposer beside bacteria and fungi. They help in maintaining and balancing the ecosystem by decomposing organic matters including carcasses; they can be used as tools in determining elapsed time since death (Anderson, 1999; Lee *et al.,* 2004). However, the ecological data of insects that are involved in the decomposition process in a particular area, such as in Sarawak, are still lacking in information and need to be established.

The type and composition of taxa that are attracted to a carcass usually change in a predictable pattern as decomposition progresses through different stages (Smith, 1986). The pattern of succession of insects is specific to the location and environmental conditions in which the carcass occurs (Payne, 1965). Taxanomic of fauna can varies greatly with locality, thus it is important for estimation of the post-mortem interval (PMI) to identify the forensically important insects that are specific to an area (Tabor *et al.,* 2005).

Sarawak is the largest state in Malaysia and it covers about 11.6% (1.6 million ha) of peat swamp forest (Phillips, 1998; Abang & Hill; 2006). Peat swamp forest in Malaysia (Sabah and Sarawak) is known to harbour varies species of flora and fauna, and also serves as a key habitat for the unique endemic species such as proboscis monkey, *Nasalis larvatus* and treeshrew, *Tupaia picta* and some invertebrates (Abang & Hill; 2006; Phillipps & Phillipps, 2016). Studies of carrion arthropods to determine the species composition and the successional pattern have been done in several regions of the world (Tabor *et al.,* 2005), a few similar studies have been done in Malaysia, mostly in Peninsular Malaysia (Lee *et al.,* 2004; Heo *et al.,* 2008; Azwandi & Abu Hasan, 2009; Rumiza *et al.,* 2010; Azwandi *et al.*, 2013). Currently, in Sarawak there are few published data on forensically important insect species recorded using monkey and rabbit carcasses (Robin & Nor-Aliza, 2015a, 2015b), but no study on comparison using different types of carcasses has been done. Thus, in this study, the selected three taxa of animals were used as model carcasses in order to know the duration time of decomposition and the effect of insect succession; whether insect succession is influenced by the taxa of the animal carcasses.

There is a need to establish an ecological data of insect that decompose organisms for this region. With little information on forensic entomology in Sarawak, the present study will review and update the list of insect succession on different types of carcasses in peat swamp forest of Sarawak. This information may provide the data on important insect decomposers and can serve as a reference for forensic entomology investigation.

Material and Methods

Study Site Description

This review data is from carrion decomposition studies that were conducted in Kota Samarahan, Sarawak, Malaysia, located approximately between 01°27'N, 110°27'E with an altitude of 46ft above sea level. This region has an average annual temperature of 27.0°C and average annual rainfall 3,900 mm. The selected study sites were located in the east campus of Universiti Malaysia Sarawak (UNIMAS) from 28th August 2007 to 17th January 2008 (Figure 1). The study area was located in a peat swamp forest with the ground surface of the forest covered with a layer of dead leaves and plant material and was occasionally flooded after heavy rain and is about 24 km from Kuching. The carcasses were placed in a wired metal cage in a shaded area and received moderate sunlight.

Preparation of Animal Models (Carcasses)

A total of nine carcasses were used in this experiment. There were three plantain squirrels, *Callosciurus notatus* with an average weight of 217.09g, three chickens, *Gallus gallus* with average weight of 2033.33g, and three toads, *Duttaphrynus melanostictus* with average weights of 67.54g. These three species are selected based on the different categories of taxonomy represented by each species. For plantain squirrels, it represents mammalian taxa, Chickens from Avian (birds) taxa and toads from amphibians taxa. All the animal carcasses were euthanized by exposure to excess carbon dioxide and then were placed in metal cages (40cm×40cm×40cm, with 5cm×2.5cm wire mesh) except for toad carcases which were placed in small metal cages (40cm×40cm×10cm, with 5cm×2.5cm wire mesh) because of their small size. All the cages were fixed to the ground using wood holders to prevent the carcasses from being disturbed by other vertebrate scavengers. The cages were located 50 m apart from each other. Plantain squirrels were located at N 01°27.632', E 110°27.405', Alt 882ft while chickens and toads were located at N 01°27.620', E 110°27.412', Alt 718ft and N 01°27.540', E 110°27.479', Alt 2ft. The experiments were conducted three times within the period from 28th August 2007 to 17th January 2008 with each experiment using three different types of carcasses were observed for insect successions at same time.

Insect Collection and Identification

All carcasses were observed twice daily, once in the morning (8-10 am) and once in the evening (4-6 pm) and the duration for each replicate of these experiments to complete the decomposition stage is 15 days. Daily observations include physical appearance and weather. Ambient and body temperatures were measured using a digital thermometer. Humidity reading was done using a psychrometer. Five decomposition stages were observed in all carcasses and the days for the five stages (fresh, bloated, active decay, advanced decay and dry remains stages) were recorded following Wolff *et al.* (2001). Adult insects were collected using aerial net sweeps above and around the carcasses and placed in the killing jar containing cotton soaked with ethyl acetate as the killing agent. Insects were pinned using insect pin and kept in the collection box for further identification. Maggots and other immature specimens were picked by forceps and put in vials that contain 75% ethanol for preservation and identification. All specimens were labelled according to the days and date the specimens were collected.

Most specimens were identified according to Cheong *et al.* (1971), Mahadevan *et al.* (1980), Holldobler and Wilson (1990), Kurahashi *et al.* (1997) and Hill and Fatimah (2005). Some adult specimens were brought to the Sarawak Museum for identification based on voucher specimens at the Sarawak Museum.

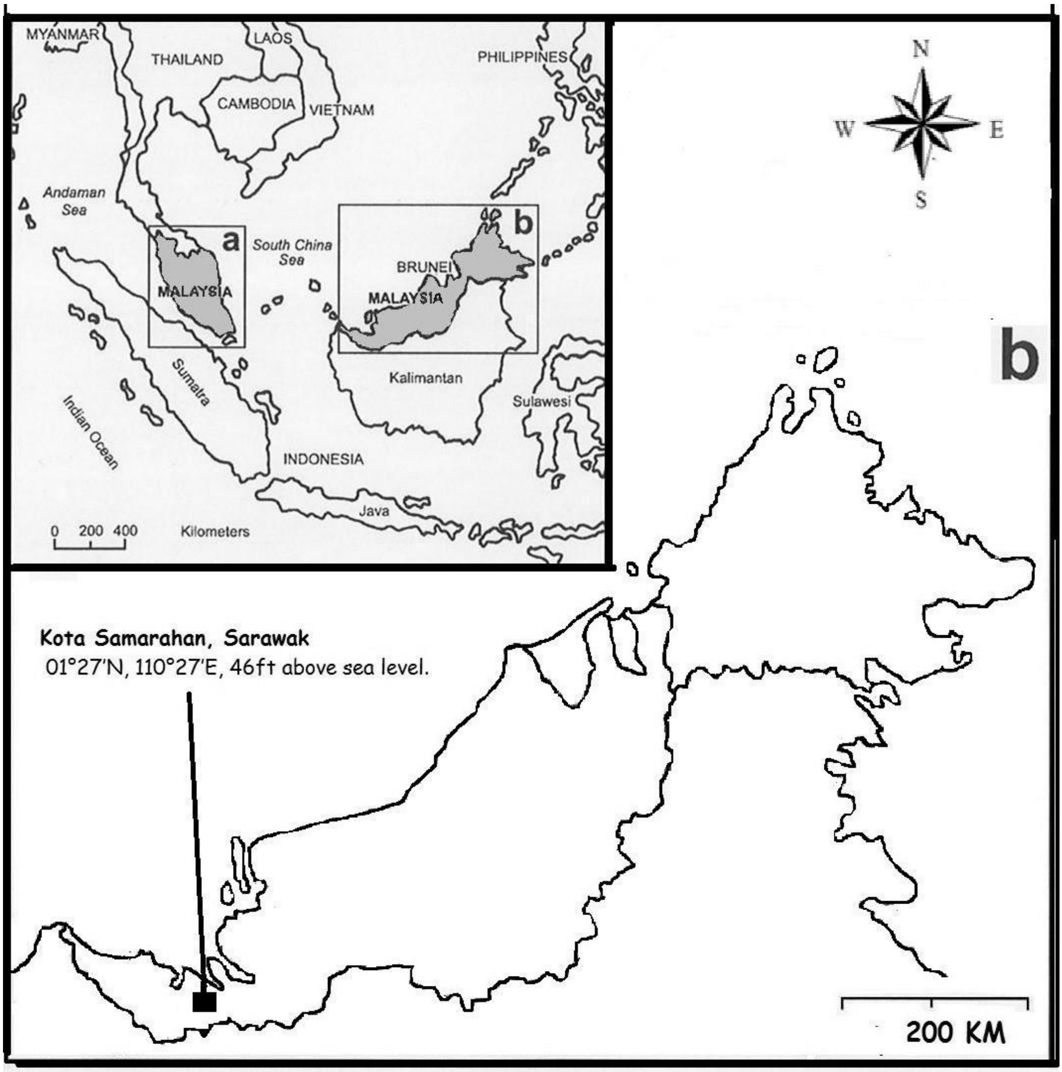


Figure 1: Maps of the study area. The bold square indicates the exact location of peat swamp forest in Kota Samarahan, (a) Peninsular Malaysia and (b) Malaysian Borneo.

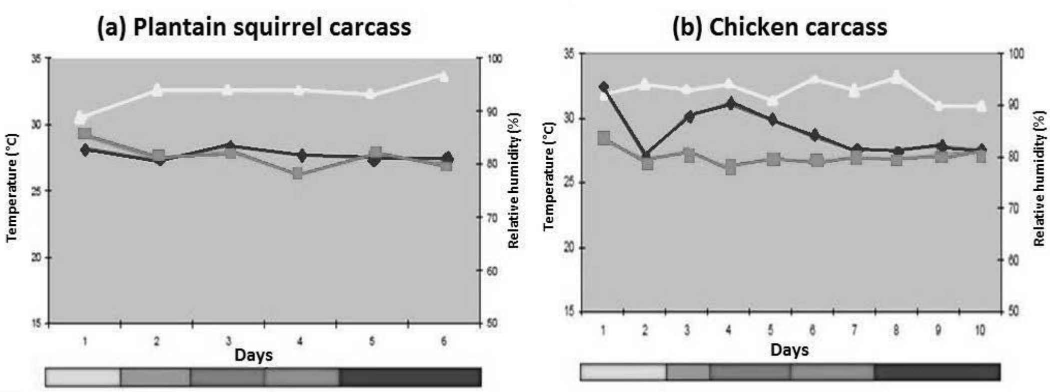
Data Analysis

All the recorded parameter data collected were made in form of a line graph using Excel 2007 according to the ambient temperature, body temperature and relative humidity for each types of carcasses and relate with each five decomposition stages. SPSS 11.5 software was used for the ANOVA test to compare the significance different of body temperature during insect succession at three different types carcasses.

RESULTS

During the observation periods, the ambient temperature range, the relative humidity range and the daily body temperature range for the type of carcasses are shown in Figure 2. Five decomposition stages were observed and recorded in all carcasses: fresh, bloated, active decay, advanced decay and dry remains stages. During the fresh stage, the body temperature started with high temperature (28.3-32.3°C). However, the body temperature decreased during the bloated stage (27.3-30.6°C). During active decay stage, body temperature increased again (28.4-31.1°C) and started to decrease during the advanced decay stage (27.3-28.6°C). During the dry remains stage, body temperatures become similar to ambient temperature (26.9-27.6°C) (Figure 2). The changes of body temperature of plantain squirrel and chicken carcasses were significantly different ($p<0.05$) from that of toad. The p value for plantain squirrel carcass and chicken carcass were 0.013 and 0.001 respectively. However, toad carcass body temperature showed that, there were no significant ($p>0.05$) changes in body temperature during the decomposition process (p-value = 0.403).

The duration of the decomposition stages for each carcass were different. The decomposition stages of chickens need more days (10 days) to complete as compared to that of plantain squirrels (8 days) and toads (6 days). The duration of the five stages of decomposition were different in each type of carcasses. Chicken carcass took the longest time to complete the decomposition stages with the duration as follows: fresh (1-2 days), bloated (3 days), active decay (4-5 days), advanced decay (6-7 days), and dry remains (8-10 days) (Figure 3). Plantain squirrel need around 8 days to complete the decomposition stages with the duration as follows: fresh (1-2 days), bloated (3 days), active decay (4 days), advanced decay (5 days), and dry remains (6-8 days) (Figure 4). Toad required the shortest time to complete the decomposition stages with the duration as follows: fresh (1day), bloated (2 days), active decay (3 days), advanced decay (4 days), and dry remains (5-6 days) (Figure 5).



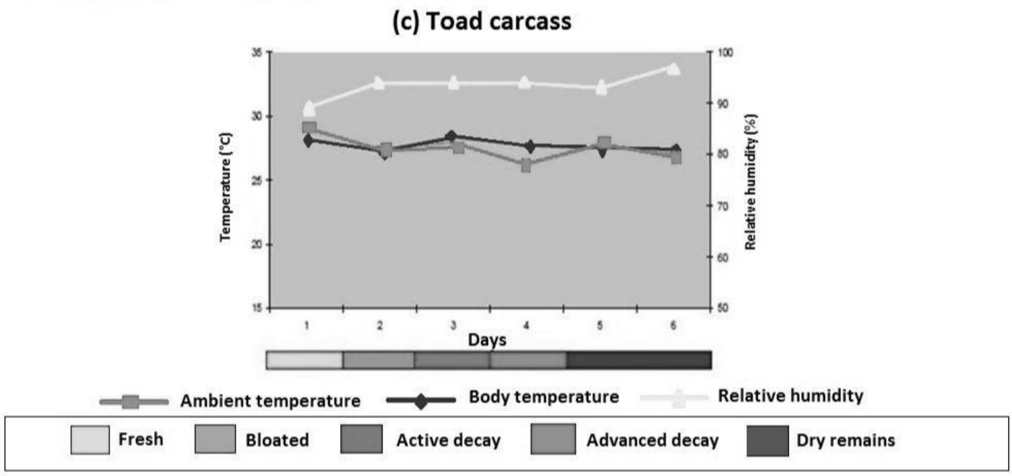


Figure 2: Summary of daily ambient temperature, body temperature and relative humidity in relation to the decomposition stages of (a) plaintain squirrel carcass, (b) chicken carcass, and (c) toad carcass.

A total of 38 species (7 orders and 14 families) were collected and identified from nine carcasses. The seven orders were included Diptera, Coleoptera, Hymenoptera, Lepidoptera, Odonata, Dictyoptera, and Hemiptera. Among seven orders, only three orders (Diptera, Coleoptera and Hymenoptera) were collected on all three types of carcass. On plantain squirrel carcass, five orders (Diptera, Coleoptera, Hymenoptera, Lepidoptera, and Dictyoptera), belonging to eight families and 19 species of insects were recorded (Table 1). A total of 327 individuals of insects were collected from chicken carcass, there were five orders (Diptera, Coleoptera, Hymenoptera, Lepidoptera, and Odonata) belonging to eight families and 26 species of insects (Table 1). Meanwhile on toad carcass, four orders (Diptera, Coleoptera, Hymenoptera, and Hemiptera), eight families and 19 species of insects were recorded (Table 1).

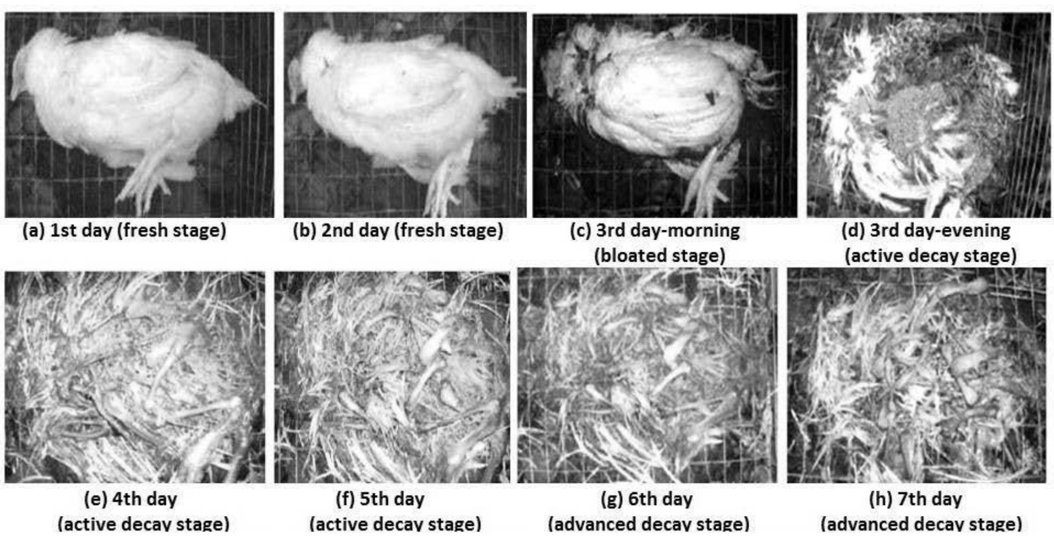


Figure 3: Decomposition stages of chicken, *Gallus gallus* carcass in peat swamp forest of UNIMAS.

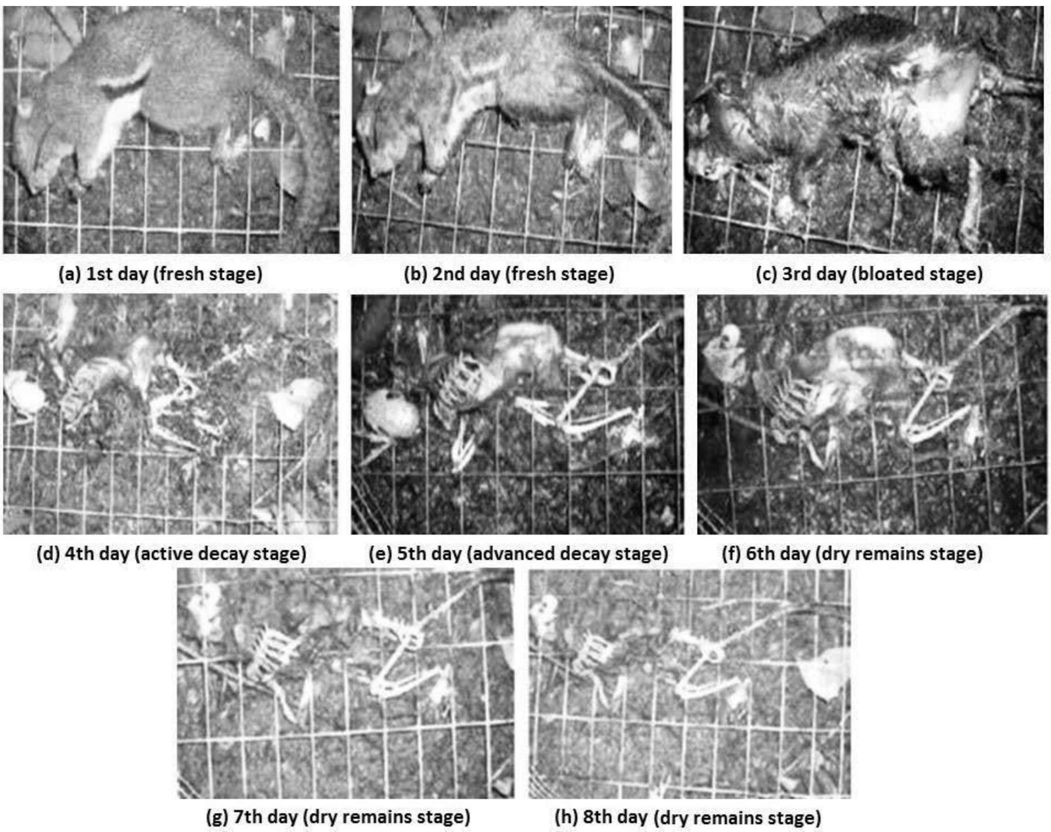


Figure 4: Decomposition stages of plantain squirrel, *Callosciurus notatus* carcass in peat swamp forest of UNIMAS.

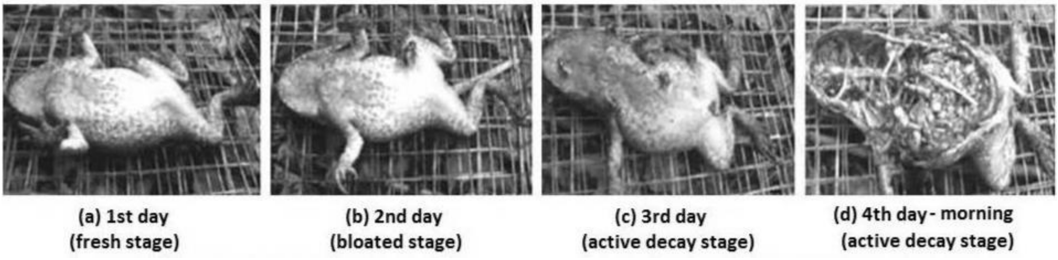


Figure 5: Decomposition stages of toad *(Duttaphrynus melanostictus)* carcass in peat swamp forest of UNIMAS.

There is some similarity in the succession of insects visiting the three different types of carcasses throughout the observation. Two species and five genera were recorded on all the three types of carcass. They were *Chrysomya megacephala* and *C. rufifacies* (Diptera: Calliphoridae), *Atherigona* sp. and *Myospila* sp. (Diptera: Muscidae), *Sarcophaga* sp. (Diptera: Sarcophagidae) and *Crematogaster* sp., *Lophomyrmex* sp. (Hymenoptera: Formicidae). However, some species were not recorded in each different carcass. This can be seen in Table 1 where some species such as *Phumosia nigronitens* (Diptera: Calliphoridae) and *Dichaetomyia quadrata* (Diptera: Muscidae) were collected from toad carcass only.

Then, some species that are only collected on chicken carcass are *Hydrotaea spinigera* (Diptera: Muscidae), *Anomalomyrma* sp. and *Dolichoderus* sp. (Hymenoptera: Formicidae), *Ionolyce helicon merguiana*, and *Acytolepis puspa mygdonia* (Lepidoptera: Lycaenidae) and *Amphicnemis wallaci* (Odonata: Coenagrionida). While some species that only can collected on plantain squirrel carcass, are *Discophora necho cheops* (Lepidoptera: Satyridae) and species C (unidentified) (Coleoptera: Staphylinidae). Then, species such as *Hemipyrellia ligurriens* (Diptera: Calliphoridae) were collected from chicken carcass and toad carcass only but not collected from plantain squirrel carcass.

Table 1: Species of insects associated with each stage of decaying plantain squirrel, chicken and toad carcasses.

Order	Family	Genus/Species	Types of carcasses / Decomposition stages														
			Plantain squirrel (*Callosciurus notatus*)					**Chicken (*Gallus gallus*)**					**Toad (*Duttaphrynus melanostictus*)**				
Order	**Family**	**Genus/Species**	**Fresh (Day 1-2)**	**Bloated (Day 3)**	**Active (Day 4)**	**Advanced (Day 5)**	**Dry remains (Day 6-8)**	**Fresh (Day 1-2)**	**Bloated (Day 3)**	**Active (Day 4-5)**	**Advanced (Day 6-7)**	**Dry remains (Day8-10)**	**Fresh (Day 1)**	**Bloated (Day 2)**	**Active (Day 3)**	**Advanced (Day 4)**	**Dry remains (Day5-6)**
Diptera	Calliphoridae	*Chrysomya megacephala*	-	I,A	I	I,A	-	A	I,A	I,A	I,A	-	-	A	I,A	I,A	-
		Chrysomya rufifacies	-	A	I	-	-	-	A	I	I,A	I	-	-	A	-	-
		Hemipyrellia ligurriens	-	-	-	-	-	A	-	-	-	-	-	-	-	A	-
		Hypopygiopsis violacea	-	-	-	-	-	A	-	-	-	-	-	A	A	A	-
		Phumosia nigronitens	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-
	Muscidae	*Atherigona sp.*	-	-	-	A	-	-	A	A	-	-	-	-	A	A	-
		Dichaetomyia quadrata	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-
		Hydrotaea chalcogaster	-	-	-	A	-	-	A	A	-	-	-	-	-	-	-
		Hydrotaea spinigera	-	-	-	-	-	-	A	A	A	-	-	-	-	-	-
		Myospila sp.	-	-	A	-	-	A	-	-	A	A	A	-	-	-	-
	Sarcophagidae	*Sarcophaga sp.*	A	-	-	-	-	-	A	-	-	-	-	-	A	I	I
Coleoptera	Staphylinidae	Species A (unidentified)	-	A	A	A	-	-	-	-	A	-	-	-	-	-	-
		Species B (unidentified)	-	-	-	-	-	-	-	-	A	-	-	-	-	-	-
		Species C (unidentified)	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-
	Silphidae	Species A (unidentified)	-	-	-	A	-	-	-	-	-	A	-	-	-	-	-
		Species B (unidentified)	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chrysomelidae	unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	A	A
Hymenoptera	Formicidae	*Anomalomyrma sp.*															
		Crematogaster sp.															
		Dolichoderus sp.															
		Dorylus sp.															
		Euprenolepis sp.															
		Leptogenys sp.															
		Lophomyrmex sp.															
		Odontomachus sp.															
		Species A (unidentified)	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-
		Species B (unidentified)	-	-	-	-	-	-	-	A	A	-	-	-	-	-	A
		Species C (unidentified)	A	-	-	-	-	A	-	-	-	-	-	-	-	-	-

			Types of carcasses / Decomposition stages														
			Plantain squirrel ***(Callosciurus notatus)***					**Chicken** ***(Gallus gallus)***					**Toad** ***(Duttaphrynus melanostictus)***				
Order	**Family**	**Genus/Species**	**Fresh (Day 1-2)**	**Bloated (Day 3)**	**Active (Day 4)**	**Advanced (Day 5)**	**Dry remains (Day 6-8)**	**Fresh (Day 1-2)**	**Bloated (Day 3)**	**Active (Day 4-5)**	**Advanced (Day 6-7)**	**Dry remains (Day 8-10)**	**Fresh (Day 1)**	**Bloated (Day 2)**	**Active (Day 3)**	**Advanced (Day 4)**	**Dry remains (Day 5-6)**
		Species D (unidentified)	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Species E (unidentified)	-	-	-	A	A	A	-	-	-	A	-	-	-	-	-
	Apidae	unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-
	Vespidae	unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-
Lepidoptera	Lycaenidae	*Ionolyce helicon merguiana*	-	-	-	-	-	-	A	-	-	-	-	-	-	-	-
		Acytolepis puspa mygdonia	-	-	-	-	-	-	-	A	-	-	-	-	-	-	-
	Satyridae	*Discophora necho cheops*	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-
Odonata	Coenagrionida	*Amphicnemis wallaci*	-	-	-	-	-	A	-	-	-	A	-	-	-	-	-
Dictyoptera	Blattidae	unidentified	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hemiptera	Reduviidae	unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A

*I – Immature phase, A – Adult phase

During the fresh stage, all animal carcasses did not release any odour. Physical appearance of carcasses also did not change much, but the internal part had begun to decay because of cellular death and microbial activities. The first insect that visit the carcasses were ants (Hymenoptera: Formicidae). This can be observed within 30 to 60 minutes after death for all types of carcasses. There are a total 13 different species of ants that have been collected from three different carcasses. Eleven species of ants were found visiting chicken carcass. Out of the eleven species of ants collected, five species were collected in the fresh stage. On plantain squirrel carcass, there were seven different species of ants collected, four in the fresh stage. Six different species of ants were collected from toad carcass, with only two species collected during the fresh stage (Table 1). Adult *Myospila* sp. (Diptera: Muscidae) was observed from chicken and toad carcass but not from plantain squirrel carcass during the fresh stages. *Sarcophaga* sp. (Diptera: Sarcophagidae) only arrived in the fresh stages of squirrel carcass. Other than that, chicken carcass shows the presence of *C. megacephala*, *Hemipyrellia ligurriens* and *Hypopygiopsis violacea* (Diptera: Calliphoridae).

During the bloated stage, more flies were observed flying near the carcasses. In this stage, bad odour was detected and the carcasses started to bloat. Many adult flies, especially *C. megacephala* (Diptera: Calliphoridae) arrived at all types of carcasses. Immature (larva) of *C. megacephala* were found in plantain squirrel carcass and chicken carcass but not in toad carcass. *C. rufifacies* (Diptera: Calliphoridae) adults were seen around all carcasses but the larvae stages were found only on plaintain squirrel and chicken. Order Coleoptera from the family Staphylinidae and Silphidae were collected from plantain squirrel carcass. However, no Coleoptera was recorded from chicken and toad carcass during this stage. *Hydrotaea spinigera*, *Hydrotaea chalcogaster* and *Atherigona* sp.

(Diptera: Muscidae), *Sarcophaga* sp. (Diptera: Sarcophagidae) and *Ionolyce helicon merguiana* (Lepidoptera: Lycaenidae) were collected from chicken carcass during this stage. Dipterans *Hypopygiopsis violacea* (Calliphoridae) and *Dichaetomyia quadrata* (Muscidae) were found only on toad carcass during this stage. Ants (Hymenoptera: Formicidae) of various species were found on chicken and toad carcasses during this stage (Table 1).

Active decay stages occurred on the 4_{th} day to the 5_{th} day in chicken and only on 4_{th} day in squirrel. Active decay stage occured earlier (3_{rd} day) in toad carcass. During this stage, strong odour was detected from all the carcasses. This is due to gases released by the active decomposition activities of bacteria. Many larvae appeared on the all types of carcasses. Ants (Hymenoptera: Formicidae) were still visible even though many maggots were observed on the carcasses. *C. megacephala* and *C. rufifacies* were dominant flies on all types of carcass. They can be found either in immature stages or adult stage. During the active stage, the Order Lepidoptera was among these seen visiting the plantain squirrel and chicken carcass.

Following the active decay stages is the advanced decay stage. During advanced decay, maggot activities are less as compared to that of active stage. Odour began to fade and most part of the soft tissue has been removed. But immature and adult of *C. megacephala* and *C. rufifacies* can still be found during this stage on all types of carcasses. During this stage, larvae of flies can also be found under the carcass. They migrated under the carcass and into the ground to pupate. Besides that, ants also can be found during this stage. Order Coleoptera and Hymenoptera (Apidae and Vespidae) were found visiting toad carcass but not chicken and plantain squirrel carcass.

During the dry remains stage, less adult flies and larvae were present. In chicken and plantain squirrel, larvae mostly can be found under the carcasses. In toad carcasses, only bones remain. Ants were still present during this stage on all carcasses. Some adventive species (incidentals) such as *Amphicnemis wallaci* (Odonata: Coenagrionida), were collected on chicken carcass (Table 1). During this study, eggs were hard to collect. The majority of insects collected were in the adult stages. Immature stages were also found during decomposition stages. Majority of immature stage belonged to dipterans. In general, larvae of dipterans were found during bloated stage, three days after death. Then, the larvae moulted to become pupa during advanced decay stage (six days after death). Pupas are only present and collected on the ground beneath all carcasses.

Discussion

Decomposition is a natural process to return organic material back into the ecosystem (Richards & Goff, 1997). Decomposition process by decomposers is an important process that contributes to the carbon cycle. Without decomposition process the entire world would be knee-deep with dead animal, and most of life as we know it would no longer exist. Dead animal or corpses are suitable microhabitat for certain organisms because of its food sources and shelter (Tullis & Goff, 1987).

This study shows that there are seven orders, 14 families and 38 species associated with decomposition process of three types of carcass. The results show the differences from the study done by Robin and Nor-Aliza (2015a) using rabbit carcass. In their study, only two orders, six families and 15 species of insects were involved during the decomposition process. A study done by Azwandi *et al.* (2013), using three different carcasses which were rat, rabbit and monkey carcasses also showed the differences with this study. In their study, there were eight orders, 28 families and 68 arthropod taxa collected during the decomposition process. This shows that the number of orders, families and species were different due to the differences in location that were studied. This situation is proven by Payne (1965) which stated that the pattern of succession of insects is specific to the location and environmental conditions in which carcass occurs.

From this study, families of Diptera that have been collected were from the family of Calliphoridae, Muscidae, and Sarcophagidae which are the main families that involved in the decomposition process of all types of carcass. This is similar to other findings which the same three main families have been reported by using rat, rabbit and monkey carcasses (Azwandi *et al.*, 2013; Robin & Nor-Aliza, 2015a; 2015b). Studies by Vitta *et al.* (2007) also showed similar findings of Dipteran families. In their study, they also reported that Calliphoridae, Muscidae and Sarcophagidae as the main families that involved though decomposition process using pig carcass. However, two other main families, Faniidae and Piophilidae that were reported in their studies were not collected in this study.

Among the insect species that have been collected in this study were *C. megacephala* and *C. rufifacies.* This finding is similar to other studies whereas both species are dominant species that were associated with different types of carcass that was located in Malaysia region (Azwandi *et al.,* 2013; Robin & Nor-Aliza, 2015a; 2015b). *Chrysomya megacephala* was the main adult fly and *C. rufifacies* was the main fly larvae associated with the pig carcass (Chin *et al.*, 2007). However, in this study, *C. megacephala* adults and fly larvae were the main insects that associate with all three types of carcasses. Research done by Lee *et al.* (2004) identified maggots of both species in 63% of murdered human corpse. Although fly species associated with carcass may belong to several different genera, the predominant genus that associate with carcass were those of Chrysomya (Lee *et al.*, 2004). *C. megacephala* may be among the dominant species in Malaysia during decomposition process because it was reported also studies by Chin *et al.* (2007). A similar study also happens in a study done by Vitta *et al.* (2007) which *C. megacephala* was collected. However, *C. rufifacies* was a dominant fly that collected in their study. *C. rufifacies* was collected in this study but it was less dominant that *C. megacephala* on all three types of carcasses. Besides that, some species of fly such as *Myospila* sp. and *Hydrotaea chalcogaster* was not known reported elsewhere. This shows that certain species might be specific to a certain location. During the decomposition process there are several stages. Some studies classify the stages into four (Lee & Marzuki, 1993) and several others classify them into five different stages (Martinez *et al.* 2006; Vitta *et al.* 2007, and Chin *et al.*, 2007).

In this study, five stages to describe the decomposition process of three different carcasses were used based on Wolff *et al.* (2001). Five stages of decomposition process were classified which are fresh stage, bloated stage, active decay stage, advance decay stage and dry remains stage. The five stages classification was also used by Arnaldos *et al.* (2004) on human cadavers and Bharti and Singh (2003) who used rabbit carcass. In this study, the observation on decomposition stages was different with the study done in Malaysia by Lee and Marzuki (1993). In their study, four stages classification were observed. There are as fresh stage, decay stage, dry stage and remains stage by using monkey carcasses. There are difficulties when observe the decomposition stage. These difficulties may due to temperature variation. Different location or area has different temperature. Other factors affected decomposition rates included the age of corpse, constitution, cause of death, ventilation and humidity (Campobasso *et al.,* 2001).

The duration for three types of carcasses through decomposition stages are different from each other. The range for the decomposition process to complete took 6 to 10 days. This is may be due to the different sizes of the carcasses used. Another study that used bigger carcass, for example pig, (Martinez *et al.,* 2006) require up to 83 days to complete the succession process. This shows that, the duration of decomposition stages taken is influenced by the size of carcass used. The general pattern of arthropods succession on carcasses in this study was quite similar to the five general patterns of arthropod succession on corpses that was stated by Carvalho *et al.* (2000).

Ants were the first insects that appear on carcass during the fresh stage. The succession was followed by flies which started to lay eggs on the carcass. The decomposition process started when the larva hatches and feed on the carcass flesh causing the carcasses begin to lose weight. This is known as the bloated and active decay stages. During the next stage, classified as the advanced decay stage, some beetles appeared. Other insects such as demerstid and halatids were recorded. During the final stage or dry remains stage, some necrophagous insects appeared. The number of insect associated with the carcass decrease tremendously during the final stage.

Diptera was the most dominant order of insects that colonized the carcass throughout the decomposition process in this study. Diptera and Coleoptera were the dominant insect orders that can be found on the carcass (Turchetto & Vanin, 2004). However, in this study there were only few Coleopterans have been collected. This may be due to the duration of the decomposition process was shorter than compared to the duration for the decomposition process for bigger size carcass such as pig. Coleopterans are late comers during the decomposition process, so they may not able to lay eggs on the remains if the decomposition process is too short (Castro *et al.*, 2013). Moreover, Coleopterans take two months to complete their life cycle (Kulshrestha & Satpathy, 2001). This may be the reason why in this study no beetle larvae were collected.

The larva stage plays an important role to decompose the carcass. Ants are the first insects that visited the carcass during the decomposition process because they are also attracted to fresh carcass (Omar *et al.*, 1994). However, ants are normally not considered to be a forensically significant species (Vitta *et al.* 2007). Adults of Lepidoptera were also collected during sampling. This is because some of the Lepidoptera feed on decomposition fluids (Haskell & Catts, 1990). Odonata which belong to *Amphicnemis wallaci* (Odonata: Coenagrionida) was also recorded in this study. However, Odonata is considered as an adventive species present at the same place the experiment was conducted (Tabor *et al.*, 2005). It was found on chicken carcass because the chicken carcasses were located near a swampy area. The pond is a habitat for this species to survive (Hill & Fatimah, 2005). Hence, this may be the reason why this species was recorded on chicken carcass and not on plantain squirrel or toad carcasses.

Besides that, this study reports the first finding of *Phumosia nigronitens* in peat swamp forest. This species habitat is normally found in a rainforest (Kurahashi *et al.*, 1997). In this study, egg specimens are hard to collect. Only immature and adult individuals of dipterans were collected. No eggs were collected or identified. This is because eggs that were laid are hidden inside the body of the carcass. Eggs that were hatched will later grow to become larvae. During the larval stages, there are three instars of larval stage. The instars of the larval stage were different where the larva sheds its cuticle to allow growth for the next instar (Gabre *et al.*, 2005). Then, the larvae moults to the pupa stage and finally moult to become adult flies.

The decomposition processes are affected by several factors such as ambient temperature, humidity, total rainfall and the presence of arthropods (Mann *et al.*, 1990). In Malaysia, including Borneo, the ambient temperature, humidity and total rainfall are different from temperate countries. Borneo is also an island where the fauna of insects may differ slightly with the other parts of Malaysia. Borneo is located on the equatorial line and has two seasons, the dry and wet season. Throughout the year, Borneo has high diversity of flora and fauna including insects. Thus, the decomposition process may involve diverse insect species. Peat swamp forest is a waterlogged forest growing on a layer of dead leaves and plant materials up to 20 meters thick comprised of an ancient and unique ecosystem characterized by low nutrients and dissolved oxygen levels in acidic water regimes (Leete *et al.*, 2006). Since this study was carried out in a peat swamp forest, this is one reason why relatively low ambient temperatures (26.2 °C to 29.1 °C) and higher humidity (90% to 97%) have been noted in this study.

There are reciprocal relationship between ambient temperature and relative humidity during this study. The higher relative humidity is due to rainy or cloudy days causing the temperature to drop. Ambient temperature and humidity were recorded only throughout the decomposition process. However basically, ambient temperatures can affect the succession of insects during the decomposition process. Fewer flies will visit and lay eggs. Anderson, (1999) stated that, temperature can affect the decomposition rate by decreasing the maggot mass present. Without the presence of insects or arthropods as decomposers the decomposition processes were slow but when insects or arthropods are present the decomposition process can be rapid (Keh, 1985).

Other than that, lower temperatures can also affect the growth of the maggots. This is because insects are poikilothermic and depend on temperature to successfully grow. Higher temperatures show higher degree of decomposition as compared to at lower temperature (Keh, 1985). Hence, during sunny days the decomposition rate may increase. Since maggots play important roles as decomposers of carcass, a favorable ambient temperature and humidity are crucial for optimum rate of decomposition (Benecke, 2001).

There were several limitation of the study. Even though carcass was placed in a metal cage, scavenger or unknown predators still can disturb and eat the carcass. Hence, the solution is to alter the cage with small wire mesh, so predators cannot enter and eat the carcass. Bad weather is also a limitation to this study. This is because during bad weather such as rainy days and thunderstorm, data collection is not possible. Other than that, some species of insects could not to be unidentified due to insufficient key for identification. Borneo contains a remarkable range of environment and contains a variety of habitats available for carrion flies and beetle. Among the different habitats, there are some habitats such as mangrove forest, beach forest and mix dipterocarp forest that can be found in Borneo. Therefore, it is necessary to carry out an ecological study of the entomofauna associated with decomposition process this area. This kind of studies will help establish baseline data for forensic entomology investigation for Borneo.

Conclusion

The insect succession in three different types of carcasses in peat swamp forest shows a quite similarity in insect species. *C. megacephala* were recorded the dominant species of insect throughout of the decomposition process during this study and has been found on all three types of carcasses. Even though all types of carcasses have decomposed following five decomposition stages, the duration of the decomposition stages for each carcass were different. The days needed to complete the decomposition stage are different because of the size of animal carcasses used. This study is the first baseline study of insect decomposition especially in peat swamp area. For the future, this study should be continued by utilizing different animal models that resemble more to human beings such as pig or goat in order to get a more accurate and additional results. Future studies should also consider extending to other parts of Borneo, not only on low-laying areas but also on high areas such as hills to get more ecological data on forensically important insects. The data on succession of insects may be important in forensic and poaching activities investigation.

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