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Adult carrion arthropod community in a tropical rainforest of Malaysia: Analysis on three common forensic entomology animal models

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Abstract. Decomposing carrion provides a temporary microhabitat and food source for a distinct community of organisms. Arthropods constitute a major part of this community and can be utilized to estimate the postmortem interval (PMI) of cadavers during criminal investigations. However, in Malaysia, knowledge of carrion arthropod assemblages and their succession is superficial. Therefore, a study on three types of forensic entomology animal model was conducted from 27 September 2010 to 28 October 2010 in a tropical rainforest at National University of Malaysia, Bangi, Selangor, Malaysia. Over one month collections of arthropods were made on nine animal carcasses: three laboratory rats (*Rattus norvegicus*, mean weight: 0.508 ± 0.027kg), three rabbits (*Oryctolagus cuniculus*, mean weight: 2.538 ± 0.109kg) and three long tailed macaque (*Macaca fascicularis*, mean weight: 5.750 ± 0.551kg). A total of 31 433 arthropods belonging to eight orders and twenty-eight families were collected from all carcasses. Among 2 924 of adults flies collected, approximately 19% were calliphorids with *Chrysomya megacephala* (Fabricius, 1794) being the most abundant. Arthropod taxon richness was lower on rat carcasses compared to that of rabbit and monkey carcasses, and this was more apparent during the first week of decomposition. However, there were no significant differences in Shannon-Weiner index (*H'*), Simpson dominance index (*C*) and Pielou's Evenness index (*J*) between different animal model. The arthropod assemblages associated to animal model were different significantly ($p<0.05$) while decomposition stage was a significant factor influencing insect assemblages ($p<0.05$). Analysis on the arthropods succession indicated that some taxa have a clear visitation period while the others, particularly Coleoptera, did not show a clear successional pattern thus require futher insect succession study. Although human bodies were not possible for the succession study, most of the arthropods collected are necrophagous, and will also possibly colonize human cadaver, and potentially be useful in assisting in estimates of PMI in future forensic cases in Malaysia.

INTRODUCTION

Arthropods make significant contributions to the community structure and function of most ecosystems. This is derived from their high diversities, densities and reproductive rates, as well as from their occupation of many consumer trophic categories within communities. The arthropod carrion community structure in tropical rainforest particularly in Malaysia may be more complex than in more temperate areas because species diversity, trophic diversity and population densities of arthropod in tropical region are frequently much larger (Stork, 1995). Despite this complexity, an understanding of carrion fauna such as their occurrence time and temporal succession can be useful for forensic entomology especially for time since death estimation. This requires reliable database of the local corpse fauna composition, their succession and the time during which individual of relevant species are present. However, most data originate from simulated field experiments usually using carrion as a surrogate for human corpses. These include rats (Tomberlin & Adler, 1998; Kocarek, 2003), dogs (Reed, 1958), rabbits (De Jong & Chadwick, 1999) and pigs (Anderson & VanLaerhoven, 1996; Carvalho & Linhares, 2001). In Malaysia, most common animals used were rabbit (*Oryctolagus cuniculus*) (Azwandi *et al.*, 2004; Mahat *et al.*, 2009), monkey/long tailed macaque (*Macaca fascicularis)* (Omar *et al.*, 1994; Azwandi & Abu Hassan, 2009; Chen *et al.*, 2010; Ahmad *et al.*, 2011) and pigs (*Sus scrofa*) (Chin *et al.*, 2007). However, there are only few published papers tested inter-animal effect on carrion community and arthropod assemblages (Watson & Carlton, 2003, 2005; Simmons *et al.*, 2010). Futhermore, there have been limitednumber of studies to date on the fauna associated with carrion in Malaysia. Therefore the present study looks into this gap, systematically designed to measure the effect of carcass types on carrion community, its diversity in tropical forest habitat and to refine or update carrion arthropod record for future local forensic entomology references.

MATERIALS AND METHODS

Study site

Carrion decomposition studies were conducted from 27 September to 28 October 2010 in a tropical rainforest adjacent to Forensic Science Research Facility, National University of Malaysia (West of Malaysia peninsular: 2.9°N, 101.8°E, at an altitude 42m above sea level). The carcasses were placed in a shaded forest area and received moderate sunlight.

Experimental Design

We used three animal types: laboratory rats (*Rattus norvegicus*), rabbits (*O. cuniculus*) and long tailed macaques/monkeys (*M. fascicularis*). The average weight of these carcasses were 0.508 ± 0.027 kg, 2.538 ± 0.109 kg and 5.750 ± 0.551 kg (mean ± SD) respectively with a mass ratio of 1:5:11. The rats and rabbits were obtained from the Animal House Facility, Faculty of Medicine, National University of Malaysia while monkeys were provided by Department of Wildlife of Federal Territory of Malaysia (PERHILITAN). Prior to placement, all animals were euthanized by fatal dose of intravenous injection of sodium pentobarbital (Dorminal). The euthanasia procedure fulfilled the animal ethic guidelines approved by the Animal Ethic Committee, Faculty of Medicine, National University of Malaysia (FSKB/2010/Baharudin/17-March/297-March-2010-April-2012). There was n=3 for each animal types. All rats, rabbits and monkey carcasses were numbered as T1-T3, A1-A3 and M1-M3, respectively. To prevent vertebrate scavenging disturbance, a wire mesh cage (76cm x 76cm x 76cm) was staked 10 cm into the ground surrounding each carcass. Each carcass was placed on a wire mesh platform to facilitate weighing process. The carcasses were placed 30m apart in an alternate sequence, ensuring that they all received the same light intensity, shading, ambient and soil temperature. This distance between each carcass was sufficient for minimizing an overlapping effect of arthropod attraction to the carcass (Tullis & Goff, 1987). Carcass locations had similar topography, microclimate and exposure conditions.

Data collection

Throughout the study period, ambient temperature and relative humidity (RH) were recorded using a temperature and relative humidity automated data logger (Lascar Electronics Inc, UK). The instruments were placed in a small cage covered with inverter plastic container, located at the centre of the study site, one meter above the ground and named as a forest environmental station. Cumulative rainfall data were collected using a rain gauge placed at an exposed area 50m from the carcasses site. Images of carcasses throughout decomposition study were captured using a digital camera (Canon Powershoot G11, Japan). Arthropods were collected using aerial nets, hand collections and pitfall traps. Adults flies were sampled by five aerial net sweeps above and around the carcasses in ten minutes duration while crawling arthropods were sampled by hands and pitfall traps. Preservative solution for pitfall trap was ethylene glycol. Two pitfall traps were set up at dorsal and ventral position of each carcass at a distance 20cm from carcass body and left for 24 hours before collection. Additionally, those arthropod species that could be identified visually on site visits were also recorded. The sampling frequency was as follows: once a day at 1500 during the first 14d, alternate day onward until day 22 and every three days until day 31, made up a total of 22 sampling days. Approximately 30 minutes was spent at each carcass for arthropod collections and observations.

Insect Identifications

Collected adults Diptera were killed using ethyl acetate and then pinned for identification. Specimens collected using pitfall traps were kept in vials containing 70% ethanol and later examined in the laboratory. Using a stereomicroscope, specimens were sorted and identified to the lowest possible taxon, either order, family, genus or species using the following keys: (Van Emden, 1965; Borror *et al.*, 1989; Kurahashi *et al.*, 1997; Almeida & Mise, 2009). Unidentified taxa were assigned unique identification codes which were categorized as morphospecies according to the definition of Oliver & Beattie (1996).

Arthropod Succession Table

Arthropod succession or presence-absence table were developed by combining data from hand net collections, pitfall trap collections and our careful observations. Data from same type of animals (n=3) were combined to produce arthropod presence-absence tables (Table 2-4). Therefore a total of three presence-absence or succession tables were developed, one for each animal type. This approach was done to minimize number of species that were present but not being sampled/observed.

Data Analysis

One way analysis of variance (ANOVA) was performed using the Statistical Package for Social Science software (SPSS) version 16. Alpha taxa diversity for insect community was calculated using two diversity indices, Shannon H' index and Simpson dominance index using the following formulae:

Shannon-Weiner index: $H' = -\Sigma\, p_i \log p_i$

Simpson dominance: $C = \Sigma\, p_i^2$

Where p_i is the proportion of the ith species from the total pool of species

Shannon-Weiner index is a measurement of the information with which the diversity of a system is determine according to the degree of order (or disorder) present in the system-community.

Simpson dominance is the probability that two randomly chosen individuals will be different species. This measure is little affected by addition or loss of rare species and it emphasizes common species. Therefore it is relatively stable with sample size. High Simpson dominance index indicate high diversity.

For taxa evenness measurement, Pielou's Evenness index with the following formulae was used:

Pielou's Evenness: $J = H'/\log S$

Where H' is the Shannon-Weiner diversity measure and S is the average species richness.

Evenness measures attempt to quantify unequal representation against a hypothetical community in which all species are equally common. When all species have equal abundances in the community, evenness is maximal. Alpha taxa diversity indices and Pielou's evenness mentioned above were calculated using PCORD software version 6.

Beside the above mentioned indices, arthropod assemblages data were analysed using multivariate statistical technique using PCORD software version 6. A permutation approach using multivariate analysis of variance (PERMANOVA), which compares distance or similarity matriches, was used to test for variation in arthropod assemblages between animal types and decomposition stages. PERMANOVA is a flexible and robust test that can be used with any distance similarity matrix as an alternative to MANOVA where the assumption of MANOVA tests cannot be met by the multivariate data analysed (McCune & Grace, 2002). PERMANOVA compares an observed test statistic (pseudo *F*) generated under a null hypothesis using permutation (random reordering of the data) and partitions variation in multivariate assemblage data in a similar way to a univariate analysis of variance (ANOVA).

RESULTS

Over the study period, the temperature ranged from 22.5°C to 31.5°C (Mean ± SD: 25.60 ± 0.64) and relative humidity (RH) ranged from 82.9% to 98.7% (Mean ± SD: 94.25 ± 3.66). Cumulative rainfall was 228.9mm. Five decomposition stages were observed in all carcasses: fresh, bloated, decay, post decay and dry. A total of 31 433 arthropods comprised of eight orders and twenty-eight families were collected from all nine carcasses over study period. There were 3 131, 14 506 and 13 796 individuals collected from rats, rabbits and monkey carcasses respectively (Table 1). Among 68 arthropods taxa captured on the carcasses, 49 were collected from rat carcasses, 57 from rabbit and 56 from monkey carcasses. Formicidae was the most abundant family that made up more than 80% of total arthropods collected and among the earliest invaders. Among 2 924 of adults flies collected, approximately 19% were calliphorids with *Chrysomya megacephala* (F.) as being the most abundant blowflies.

There were more adult flies belonging to the Calliphoridae, Muscidae, Piophilidae, Sphaeroceridae and Phoridae collected from monkey carcasses compared to those of rats and rabbits (Table 1). Among Calliphoridae, *Ch. megacephala* and *Chrysomya rufifacies* (Macquart) were the most abundant. *Hydrotaea spinigera* (Stein) and *Atherigona orientalis* (Schin) were the most commonly recovered adult muscid flies. Approximately almost equal numbers of adult sepsid flies were caught from rabbit and monkey carcass and represented by five taxa with *Sepsis* sp. being the most abundant. Piophilidae, represented by only one species, *Piophila casei* (L.), was collected in substantial numbers at monkey carcasses (Table 1). Among Stratiomyidae, only *Hermetia illucens* (L.) and *Ptecticus melanurus* (Walker) were collected. Among coleopteran, Staphylinidae family was represented by eight taxa and was the most abundant family in rabbit (Total=92) and monkey carcass (Total=143) while Bostrichidae was more in rat carcass (Total=56) (Table 1). Of the non-insect taxa, Araneae was most dominant followed by Chilopoda.

The highest taxa richness (number of taxa collected) was observed in monkey carcasses (Total=36), while the lowest was in rat carcasses (Total=26). By referring to combined taxa richness through day, maximum taxa richness recorded was in monkey carcass on day 9 (28 taxa), while maximum taxa richness in rat and rabbit carcass occurred earlier on day 7 (21 and 26 taxa respectively) (Figure 1). There were three visible increments of taxa richness: first increment from day 1-3, second increment from day 5-9 and last increment from day 11-12 (Figure 1). In all carcasses, peaked of taxa richness occurred on the second increment.

One way ANOVA was performed to test the hypothesis that arthropod diversity differed between the carcass type using Shannon-Weiner index (*H*'), Simpson Dominance index (*C*), and Pielou's evenness index (*J*). Results indicated that there was no significant difference in Shannon Weiner index ($F = 0.090$; df = 2, 6; $p = 0.915$), Simpson Dominance index ($F = 0.607$; df = 2, 6; $p = 0.576$) and Pielou's evenness index ($F = 3.904$, df = 2, 6; $p = 0.082$) between carcass type. Only taxa richness was found statistically different ($F = 4.932$; df = 2, 6; $p < 0.05$). In contrast, arthropod community assemblages associated to different types of carcass were significantly different (PERMANOVA: $F = 3.54$; df = 2, 44; $p < 0.05$). Decomposition stage was a significant factor influencing arthropod community assemblages (PERMANOVA: $F = 2.43$, df = 4, 44; $p < 0.05$). In pairwise tests between each decomposition stage, there were no significant difference in insects assemblages between fresh and bloated, fresh and decay, bloated and decay, decay and post decay and post decay and dry.

Table 1. The number of arthropods recovered from rat, rabbit, and monkey carcasses exposed in a tropical forest in Malaysia

Order	Family	T1	T2	T3	Total	A1	A2	A3	Total	M1	M2	M3	Total
Diptera	Calliphoridae	39	0	17	**56**	33	27	30	**90**	134	134	144	**412**
	Sarcophagidae	0	1	0	**1**	0	1	0	**1**	1	0	0	**1**
	Muscidae	16	25	15	**56**	81	34	26	**141**	211	120	118	**449**
	Piophilidae	0	13	8	**21**	45	42	93	**180**	176	112	100	**388**
	Sphaeroceridae	9	11	18	**38**	21	13	40	**74**	88	11	11	**110**
	Sepsidae	28	28	35	**91**	46	88	126	**260**	175	46	46	**267**
	Neriidae	0	2	0	**2**	2	3	1	**6**	2	1	1	**4**
	Micropezidae	0	2	0	**2**	0	0	0	**0**	1	0	0	**1**
	Stratiomyidae	0	1	0	**1**	0	0	1	**1**	0	0	1	**1**
	Dolicophodidae	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**
	Drosophilidae	0	0	0	**0**	0	1	0	**1**	5	0	0	**5**
	Phoridae	1	7	4	**12**	13	10	28	**51**	139	25	28	**192**
	Platystomatidae	0	0	1	**1**	0	0	1	**1**	0	1	0	**1**
	Otitidae	1	1	0	**2**	0	0	1	**1**	1	1	0	**2**
Hymenoptera Coleoptera	Formicidae	403	457	1 752	**2 612**	751	4 973	7 738	**13 462**	1 853	3 833	5 962	**11 648**
	Scarabaeidae	2	8	7	**17**	9	5	1	**15**	2	5	1	**8**
	Nitidulidae	0	3	3	**6**	5	5	3	**13**	4	40	7	**51**
	Staphylinidae	4	9	23	**36**	18	41	33	**92**	39	59	45	**143**
	Carabidae	1	0	7	**8**	0	3	9	**12**	2	10	2	**14**
	Bostrichidae	49	3	4	**56**	5	7	2	**14**	1	2	7	**10**
	Histeridae	0	1	0	**1**	0	1	3	**4**	7	2	1	**10**
	Trogidae	0	0	0	**0**	0	2	2	**4**	2	0	0	**2**
	Silphidae	0	0	1	**1**	0	1	1	**2**	1	1	2	**4**
Others		50	34	27	**111**	58	14	9	**81**	18	34	20	**72**
Total		**603**	**606**	**1 922**	**3 131**	**1 087**	**5 271**	**8 148**	**14 506**	**2 862**	**4 437**	**6 497**	**13 796**

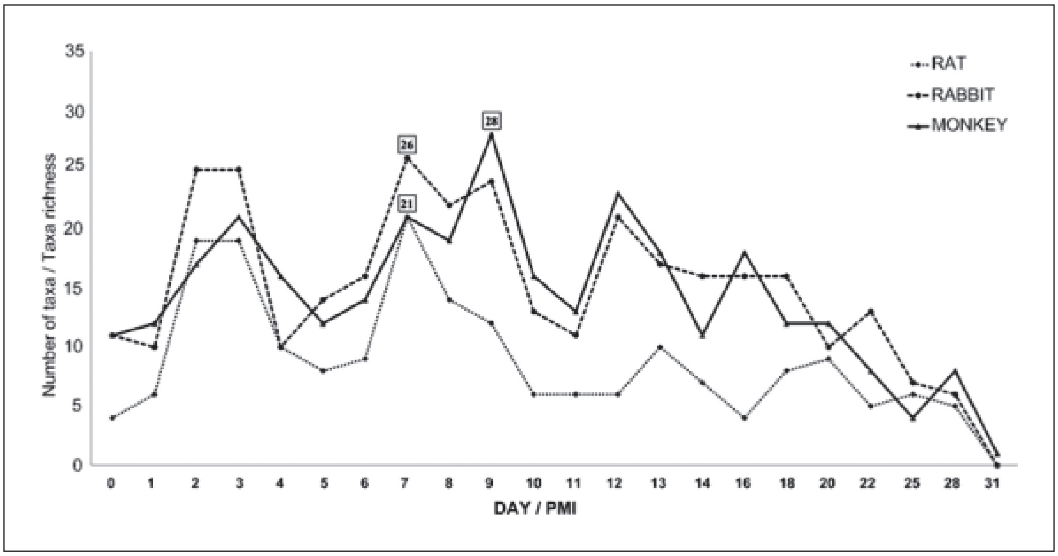

Figure 1. Arthropod taxa richness from pooled data collected in/on rat, rabbit and monkey carcasses

Arthropod taxa presence-absence tables were used to visualize taxa occurence shifts during carrion decomposition (Table 2-4). The earliest visitors on rat carcasses were *Ch. megacephala*, *Ch. rufifacies*, *Pheidole* sp., *Pheidole megacephala* and unidentified araneae. In rabbit carcasses earliest arthropods were represented by *Ch. megacephala*, *Ch. rufifacies*, *Pheidole* sp., *Heteroponera* sp., *Crematogaster* sp., Bostrichidae species and unidentified araneae. In monkey carcasses 12 pioneer arthropods were recognized consisting of *Ch. megacephala*, *Ch. rufifacies*, *Pheidole* sp., *Heteroponera* sp., *P. megacephala*, *Crematogaster* sp., *Nitidulidae* sp., *Belonuchus* sp., *Philonthus* sp. and species of Carabidae and Bostrichidae, and an unidentified araneae. *Sepsis* sp. was first observed in monkey carcass on day five which was later than on rat and rabbit carcass (Table 4). Consistent colonization by *Pheidole* sp. (ants) were observed in all carcasses and they were found predating dipteran larvae and emerged adult throughout all stages of decomposition. Similar to that *Pheidole* sp., some coleopteran species primarily staphylinids were a predator on dipteran larvae. In general, coleopteran colonization period was relatively longer than dipterans, however it was found intermittently (many gaps along colonization period) (Table 2-4).

DISCUSSION

Arthropods that visit carcasses can be classified as necrophagous species, predators and parasites of necrophagous species or adventitious species that exploit the carcasses as habitat. Adult *Ch. megacephala* and *Ch. rufifacies* were the most common necrophagous species captured during fresh and bloated stage and are considered important forensic indicators. Both species are common in the peninsular Malaysian (Hamid *et al.*, 2003; Lee *et al.*, 2004). Previous succession studies in Malaysian oil palm plantations revealed fewer arthropods species compared to our study (Chin *et al.*, 2007; Azwandi & Abu Hassan, 2009). Moura *et al.* (2005) found that carrion left in a forested area had a higher species richness than that left at urban site. Our study also demonstrated that carcasses in the forest habitat lack a blowfly species, *Lucilia cuprina* (Weidemann, 1830), that regularly colonizes carcasses in human habitation and also known as a highly synanthropic fly species (Chaiwong *et al.*,

Table 2. Adult arthropod presence-absence record of rat carcasses

ORDER	FAMILY	*TAXA	DAY/PMI																					
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	25	28	31
Diptera	Calliphoridae	*Chrysomya megacephala*	+	+	+	+	+		+	+	+													
		Chrysomya rufifacies	+	+	+	+	+																	
		Chrysomya villeneuvi																						
		Chrysomya nigripes			+	+																		
	Sarcophagidae	*Parasarcophaga* sp.			+	+																		
	Muscidae	*Hydrotaea spinigera*			+	+	+	+		+										+	+			
		Hydrotaea chalcogaster				+																		
		Morellia sp.				+	+							+										
		Atherigona orientalis		+	+	+	+	+	+	+	+	+	+		+	+	+							
		Atherigona sp.			+	+			+	+	+	+												
	Piophilidae	*Piophila casei*			+	+		+	+	+	+	+							+					
	Sphaeroceridae	*Leptocera* sp.							+	+	+		+	+	+	+	+		+					
	Sepsidae	*Sepsis* sp.			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					
		Allosepsis indica												+						+				
		Telostylinus lineolatus			+							+	+											
	Micropezidae	*Mimegralla albimana*										+							+	+				
	Stratiomyidae	*Ptecticus melanurus*			+					+					+									
	Phoridae	*Phoridae* sp.			+							+		+	+	+								
		Megaselia scalaris								+		+												
	Platystomatidae	*Scholates* sp.			+						+	+												
		Otitidea sp.								+	+				+									
Hymenoptera	Formicidae	*Pheidole* sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Heteroponera sp.		+					+		+			+		+		+		+		+	+	+
		Pheidole megacephala	+	+	+	+	+	+		+	+			+		+	+	+	+	+	+	+	+	+
		Crematogaster sp.		+			+					+	+				+					+		
Coleoptera	Nitidulidae	*Nitidulidae* sp.						+	+	+						+			+	+		+	+	
	Staphylinidae	*Belonuchus* sp.														+								
		Gauropterus sp.			+	+				+														
		Philonthus sp.		+	+																			
		Aleochara sp.				+	+			+							+							
		Staphylinidae sp.				+		+				+		+			+				+	+	+	
	Carabidae	*Carabidae* sp.				+		+		+												+		
	Bostrichidae	*Bostrichidae* sp.				+							+			+		+	+	+	+	+	+	
Orthoptera	Gryllidae			+						+	+			+							+		+	
Araneae			+	+	+	+		+	+		+	+				+	+	+	+	+		+		

*Only selected taxon are listed in the table

Table 3. Adult arthropod presence-absence record of rabbit carcasses

ORDER	FAMILY	*TAXA	DAY/PMI																					
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	25	28	31
Diptera	Calliphoridae	*Chrysomya megacephala*	+	+	+	+						+	+											
		Chrysomya rufifacies	+	+	+	+									+	+	+			+				
		Chrysomya villeneuvi			+	+								+	+	+								
		Chrysomya nigripes		+	+	+	+	+							+	+	+							
	Sarcophagidae	*Parasarcophaga* sp.																+		+				
	Muscidae	*Hydrotaea spinigera*		+	+	+	+	+	+	+	+								+	+	+			
		Hydrotaea chalcogaster				+			+	+	+													
		Morellia sp.			+	+				+	+			+	+			+						
		Atherigona orientalis		+	+	+	+		+	+	+	+			+	+	+							
		Atherigona sp.			+	+				+	+	+												
	Piophilidae	*Piophila casei*			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
	Sphaeroceridae	*Leptocera* sp.			+	+	+		+	+	+	+	+	+	+		+	+			+			
	Sepsidae	*Sepsis* sp.			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
		Allosepsis indica				+			+	+	+	+	+	+	+	+			+					
		Telostylinus lineolatus				+				+		+	+		+	+			+					
	Micropezidae	*Mimegralla albimana*								+		+			+									
	Stratiomyidae	*Ptecticus melanurus*						+	+	+	+	+	+		+				+					
	Phoridae	*Phoridae* sp.			+			+	+	+	+	+	+	+	+	+	+	+	+		+			
		Megaselia scalaris			+						+			+	+	+					+			
	Platystomatidae	*Scholates* sp.										+												
		Otitidea sp.									+	+							+					
Hymenoptera	Formicidae	*Pheidole* sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Heteroponera sp.	+	+	+	+	+	+	+	+			+	+		+	+	+	+	+	+	+	+	+
		Pheidole megacephala			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					
		Crematogaster sp.	+	+	+	+										+	+	+	+	+	+	+	+	+
Coleoptera	Nitidulidae	*Nitidulidae* sp.				+		+			+	+		+				+	+		+	+	+	
	Staphylinidae	*Belonuchus* sp.		+	+	+	+	+		+	+		+	+	+	+		+		+			+	
		Gauropterus sp.			+	+	+		+						+									
		Philonthus sp.			+			+	+	+	+	+	+											
		Aleochara sp.			+	+	+	+	+	+	+	+	+											
		Staphylinidae sp.		+	+	+						+							+	+	+	+		
	Carabidae	*Carabidae* sp.		+	+	+		+		+														
	Bostrichidae	*Bostrichidae* sp.	+																+		+	+	+	
Orthoptera	Gryllidae				+	+		+		+		+				+		+						
Araneae			+		+	+			+				+		+		+	+	+		+	+	+	

* Only selected taxon are listed in the table

Table 4. Adult arthropod presence-absence record of monkey carcasses

ORDER	FAMILY	*TAXA	DAY/PMI																					
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	25	28	31
Diptera	Calliphoridae	*Chrysomya megacephala*	+	+	+	+	+				+	+	+	+	+									
		Chrysomya rufifacies	+	+	+	+	+								+	+	+	+						
		Chrysomya villeneuvi				+						+	+	+	+	+	+							
		Chrysomya nigripes		+	+	+	+	+					+	+	+	+	+							
	Sarcophagidae	*Parasarcophaga* sp.													+									
	Muscidae	*Hydrotaea spinigera*		+	+	+	+	+	+	+	+	+							+	+				
		Hydrotaea chalcogaster				+		+	+	+	+	+												
		Morellia sp.				+					+				+	+				+				
		Atherigona orientalis			+	+	+		+	+	+	+	+	+	+	+	+	+	+				+	
		Atherigona sp.			+	+	+		+	+	+	+												
	Piophilidae	*Piophila casei*				+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
	Sphaeroceridae	*Leptocera* sp.								+	+	+	+			+	+	+						
	Sepsidae	*Sepsis* sp.						+	+	+	+	+	+	+	+	+		+		+				
		Allosepsis indica							+	+		+	+					+		+				
		Telostylinus lineolatus										+			+	+		+	+	+	+			
	Micropezidae	*Mimegralla albimana*				+					+	+			+	+				+				
	Stratiomyidae	*Ptecticus melanurus*									+	+	+		+	+		+						
	Phoridae	*Phoridae* sp.			+	+	+		+	+	+	+	+	+		+	+	+	+					+
		Megaselia scalaris			+	+				+	+	+			+									
	Platystomatidae	*Scholates* sp.			+					+	+	+			+									
		Otitidea sp.								+	+				+	+		+						
Hymenoptera	Formicidae	*Pheidole* sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Heteroponera sp.	+	+	+	+	+	+				+						+		+	+	+	+	+
		Pheidole megacephala	+	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Crematogaster sp.	+			+			+								+	+	+	+	+	+		
Coleoptera	Nitidulidae	*Nitidulidae* sp.	+					+		+			+		+	+		+	+	+	+		+	
	Staphylinidae	*Belonuchus* sp.	+	+	+	+	+	+	+	+	+	+	+		+	+		+		+	+			
		Gauropterus sp.				+	+	+		+		+						+						
		Philonthus sp.	+	+	+	+	+	+	+		+	+	+											
		Aleochara sp.		+	+	+	+	+	+	+			+					+						
		Staphylinidae sp.					+	+				+		+		+				+	+		+	
	Carabidae	*Carabidae* sp.	+	+	+	+						+	+		+	+	+							
	Bostrichidae	*Bostrichidae* sp.	+		+				+	+									+	+	+		+	
Orthoptera	Gryllidae			+	+	+	+	+		+		+							+	+	+	+	+	
Araneae			+	+			+						+	+		+	+		+			+	+	

* Only selected taxon are listed in the table

2012). This knowledge is beneficial because in a typical corpse movement case where death occurred in human habitations and shifted to a forest habitat, the presence of species exclusive to human habitation would be a reliable indicator of the carcass movement.

Other than our study, there have been numerous carrion studies from tropical region. For example, Carvalho & Linhares (2001) carried out a decomposition study using pig carcasses in an urban forest in Brazil, but due to difference in continents, most Diptera species found in Brazil were different from our study. As such we found only two Diptera species that were the same, *Ch. megacephala* and *Hydrotaea chalcogaster* (Weidemann, 1824). In Brazil, *Ch. megacephala* species was always found in many succession study but it was not a predominant species (Souza & Linhares, 1997; Carvalho *et al.*, 2000; Carvalho & Linhares, 2001; Oliviera & Vanconselos, 2010). We noted that Calliphoridae species in Malaysia are more similar to those in the Hawaiian Islands where *Ch. megacephala* and *Ch. rufifacies* are predominant (Early & Goff 1986; Goff *et al.*, 1986; Tullis & Goff, 1987; Goff, 1991; Shalaby *et al.*, 2000).

In a carrion study in Thailand *Ch. rufifacies* was the predominant species comprised of 87.65% of insect collected (Vitta *et al.*, 2007). However, in a forensic entomology case study review in the same region, Sukontason *et al.* (2007) reported that *Ch. rufifacies* being the second most predominant species after *Ch. megacephala*. Among Stratiomyidae family, only two species, *P. melanurus* and *H. illucens* were encountered in our study both of which have been previously recorded from monkey carrion in an oil palm plantation in a northern region of peninsular Malaysia (Azwandi & Abu Hassan, 2009). In Brazil and the United States, *H. illucens* species has been used in estimating postmortem intervals (Lord *et al.*, 1994; Pujol-Luz *et al.*, 2008) but *Ptecticus* sp. has not been reported in any forensic cases. Nevertheless, the occurrence of *Ptecticus* sp. in our carrion could indicate the possibility of the species infesting human corpse and could be important in estimating minimum PMI in the future.

Coleopteran colonization in the present study was variable and there was not a clear succession pattern with many breaks being observed. There is little consistency in the literature with some authors reporting unbroken succession (Tantawi *et al.*, 1996; Kocarek, 2003) whilst others, like ourselves, found there to be breaks in succession (Tabor *et al.*, 2004; Wang *et al.*, 2008; Segura, 2009). We suggest that breaks in succession might be related to two reasons. Firstly, for taxa, in which adult activity is strongly weather dependent, breaks in colonization may have been due simply to weather conditions such as temperature decline or strong rainfall. Secondly, competition of food may prompt some taxa, especially Coleoptera, to disperse and then reappear in search of food when competition reduced.

Watson & Carlton (2003) compared species composition on the corpses of black bear, white tailed deer, alligator and swine and proved differences in species number collected. They found eleven out of 46 families that were absent in alligator carcass appeared in other carcasses. Such variation was also found in our study with lesser species number in rat carcass (47 taxa) compared to rabbit (55 taxa) and monkeys (54 taxa). However, the variation is not fully understood because every animal type used have their own physical characteristic that is not limited to size difference only but also to thickness of fur, diet and site specific factors. All carrion diversity indices recorded in our study were almost equal to the carrion study on rabbit carcass in Andean region of Colombia (Ordonez *et al.*, 2008) and in Guangzhou, China (Shi *et al.*, 2009). With regards to tropical rainforest habitat, a cumulative of 68 taxa of arthropods collected in our study is relatively higher than carrion study in Oahu Island, Hawaii where only 45 arthropod taxa were found (Tullis & Goff, 1987). Low number of carcass samples could be a possible cause for the fewer arthropod taxa discovered by Tullis and Goff (1987) who used only three carcasses.

In the present study, arthropod community assemblages were found to differ between animal types. This could be attributed to two reasons: the amount of food and period of decomposition. For instance, monkey carcass (which is larger and has more tissue) provide large amount of food (e.g. from body fluid and tissue) to many necrophagous species and these subsequently supported predators and parasites making carrion microhabitat become enriched significantly. Monkey carcasses also decomposed slower thereby prolonging the time of residency, thus more arthropod were collected during the study period. The progressive change of arthropod community assemblages over time in our monkey carcass was found to be similar to that previously described by Voss *et al.* (2009) on pig carcasses in Western Australia.

Animal models for decay study should include adequate numbers of replicates to strengthen statistical interpretation and to develop a reliable understanding of the arthropod succession pattern. In Central Europe, Matuszweski *et al.* (2010) suggested that a replication greater than four carcasses should be used for higher statistical power. DeJong & Hoback (2006) used 196 rat carcasses in their carrion study but this sort of number is not feasible when using larger (and therefore more realistic in a forensic context) animals owing to the financial cost, labour involved and the practicalities of exposing so many dead animals to the environment. Three replication of carcasses used in our study were considered minimal for statistical analysis yet helpful in preventing error interpretation caused by sampling error.

In conclusion, our study has documented a more complete forensic entomology database of arthropod succession for a tropical rainforest habitat in Malaysia. However, for forensic entomology purpose (i.e PMI estimation) results of this study alone is insufficient, thus we suggest that there is a need for more systematically designed ecological studies on carrion communities in different types of habitat in Malaysia (i.e. shaded vs exposed) and conditions (i.e. buried, wrapped etc). Although human bodies were not possible for the succession study due to ethical reasons, most of the arthropods collected and reported here are necrophagous, and will also colonize other carrion, such as human corpses, and potentially be useful in assisting in estimates of PMI in future forensic cases.

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