ECTOPARASITES FAUNA OF RODENTS AND SCANDENTS AT DIFFERENT HABITATS OF SARAWAK, MALAYSIA

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ABSTRACT

Field surveys of ectoparasites fauna on small mammals (Rodentia and Scandentia) were conducted since 2008 until 2019 in 12 localities of Sarawak, Malaysia (Borneo). The objectives of these field surveys are to obtain checklist on the distribution of ectoparasites and their hosts (rodents and scandents) in Sarawak, and to determine the ectoparasites that are of known public health importance. Throughout these surveys, seven types of habitat had been recorded from 12 localities of study sites, namely lowland dipterocarp forest, mixed dipterocarp forest, hill dipterocarp forest, riverine forest, limestone forest, secondary forest, and urban area. A total of 50 to 100 cage traps were used to traps hosts for five to six consecutive days per site and ectoparasites were extracted from each host caught using fine comb and forceps. Identification of ectoparasites was based on morphology from available taxonomic keys and published taxonomic drawings. A total of 148 animals comprising 22 species of rodents and scadents were caught and screened for ectoparasites. Of these hosts, 46 species of ectoparasites were identified from a total of 2463 individuals collected. Among the ectoparasites found, six species collected are of known medical importance namely *Ixodes granulatus* (ticks) *Laelaps nuttalli* (mesostigmatid mites), *Leptotrombidium deliense* (trombiculid mites), *Sarcoptes scabiei* (astigmatid mites), *Polypax spinulosa*, and *Hoplopleura dissicula* (lice). Further surveys are recommended for more comprehensive inventory of ectoparasites in different locations and habitats that can build up extensive wealth of information on various aspects such as host-parasite relationship, biology and ecology.

Keywords: Ectoparasites, small mammals, Rodentia, Scandentia, Malaysian Borneo

ABSTRAK

Tinjauan lapangan fauna ektoparasit pada mamalia kecil (Rodentia dan Scandentia) telah dijalankan sejak dari tahun 2008 hingga 2019 di 12 lokasi di Sarawak, Malaysia (Borneo). Objektif tinjauan lapangan ini adalah untuk mendapatkan senarai semak awal mengenai taburan ektoparasit dan perumahnya (Rodent dan Scandents) di Sarawak dan untuk mengetahui ektoparasit yang penting untuk kesihatan awam. Sepanjang tinjauan ini, tujuh jenis habitat telah dicatatkan dari 12 lokasi kawasan kajian iaitu hutan dipterocarp dataran rendah, hutan dipterocarp campuran, hutan dipterocarp bukit, hutan sungai, hutan batu kapur, hutan sekunder, dan kawasan urban. Sebanyak 50 hingga 100 perangkap telah digunakan untuk memerangkap perumah selama lima hingga enam hari berturut-turut dan ektoparasit diekstrak dari setiap perumah yang ditangkap menggunakan sikat halus dan forsep. Pengenalpastian ektoparasit adalah berdasarkan morfologi dari kunci yang ada, gambar dan rujukan taksonomi yang telah diterbitkan. Sejumlah 148 haiwan yang terdiri daripada 22 spesies rodents dan scadents telah ditangkap dan disaring untuk kehadiran ektoparasit. Daripada haiwan perumah ini, 46 spesies ektoparasit telah dikenal pasti daripada jumlah keseluruhan 2,463 individu yang telah dikumpulkan. Antara ektoparasit yang dijumpai, lima spesies yang dikumpulkan mempunyai kepentingan perubatan iaitu *Ixodes granulatus* (sengkenit), *Laelaps nuttalli* (hama mesostigmatid), *Leptotrombidium deliense* (tungau), *Sarcoptes scabiei* (hama astigmatid), *Polypax spinulosa* dan *Hoplopleura disicula* (kutu). Tinjauan lebih lanjut adalah disarankan untuk persediaan kajian ektoparasit yang lebih komprehensif di lokasi dan habitat yang berbeza yang supaya dapat mengumpulkan banyak maklumat mengenai pelbagai aspek seperti hubungan parasit-perumah, biologi dan ekologi.

Kata kunci: Ektoparasit, mamalia kecil, Rodentia, Scandentia, Borneo Malaysia

INTRODUCTION

Ectoparasite is one of the broad arrays of invertebrates externally parasitic on animals, and many of them are blood feeders in at least one stage of their life cycles (Barnes 1962). Ectoparasitic arthropods that infest mammals can be categorised either as insects or acarines (Kettle 1985). Since 1981, about 6000 species of external parasites (ectoparasites) of warm-blooded vertebrates (mammals and birds) as adults have been described (Marshall 1981). Ectoparasitism among insects that infest small mammals are particularly lice and fleas, while ectoparasitism among arachnids are particularly ticks and mites (Marshall 1981; Nadchatram 2008). In Malaysia, ectoparasites of non-volant small mammals have been classified into various groups, namely, ticks, mesostigmatid mites, listrophorid mites, trombiculid mites (chiggers), lice, fleas, myobiids and cheyletid mites (Azima et al. 2007; Madinah et al. 2011; 2013, 2014; Mariana et al. 2006, 2008, 2009; Paramasvaran et al. 2009).

There are more than 50 species of ectoparasitic insects (mostly fleas) that have been described in Malaysia (Abang & Hassan 1988; Malul 1987). For ectoparasitic arachnids, there are 40 species of ticks, 100 species of mesostigmata, 50 species of house dust mites and several parasitic astigmatid and prostigmatid mites have been recorded in Malaysia, mostly reported by the Institute for Medical Research (IMR). According to surveys carried out by Nadchatram (2008) on ectoparasites species recorded in Malaysia, over 158 species have not yet been identified and all ectoparasitic arachnids are known to be potential medical and veterinary pests.

Malaysian tropical rainforests are noted for their richness in species diversity. However, systematic studies particularly on the ectoparasites in non-volant small mammals (Rodentia and Scandentia) are very much lacking in certain part of Malaysia such as in Sarawak, Malaysian Borneo (Madinah et al. 2013; Muul & Lim 1974). Thus, this study was conducted because of the importance of the field as it can contribute information on various aspects such as host-parasites relationship, biology and ecology. The aims of this study thus to obtain a preliminary checklist on the distribution of ectoparasites and their hosts (non-volant small mammals) in Sarawak and to determine the ectoparasites that are of known public health importance.

MATERIALS AND METHODS

Trapping of non-volant small mammals was conducted at 12 sites in the state of Sarawak, Malaysia from 2008 until 2019 (Figure 1). Seven types of habitat had been recorded from 12 study sites. These include secondary forest (RTNM, BAJP and HSK), lowland dipterocarp forest (NNP), riverine forest (SBNM), mixed dipterocarp forest (SBLEWS and SMLEWS), hill dipterocarp forest (KNP and BPS), limestone forest (GRP and KGP) and urban area (DIKS) (Table 1).

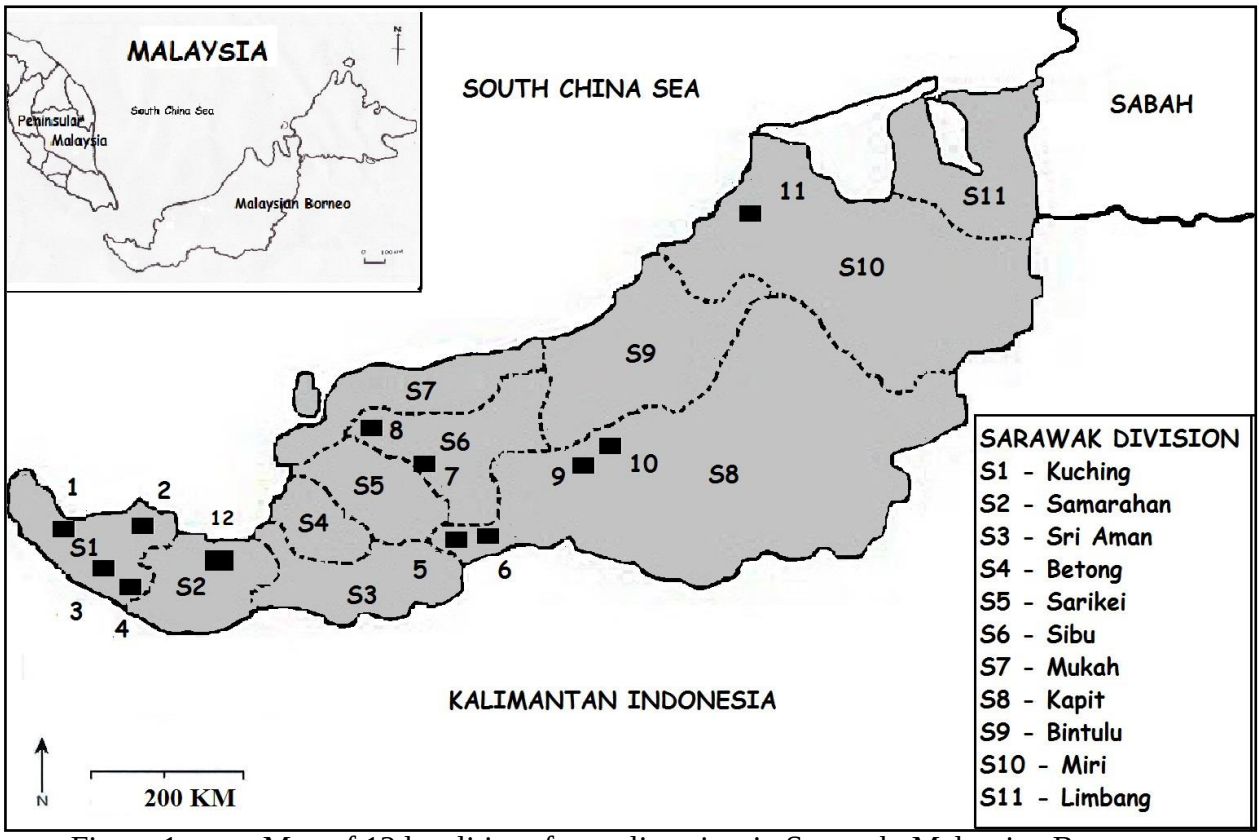

Figure 1. Map of 12 localities of sampling sites in Sarawak, Malaysian Borneo

Table 1. Summary 12 locations of study sites in Sarawak, Malaysian Borneo with coordinate and habitat types of each location

Map point	Location		Code	Coordinate		Habitat type
	Division	Sites		North	East	
1	Kuching	Bukit Pueh, Sematan	BPS	N 01º49’	E 109º42’	Hill dipterocarp forest
2	Kuching	Kubah National Park	KNP	N 01º36’	E 110º11’	Hill dipterocarp forest
3	Kuching	Kampung Giam, Padawan	KGP	N 01°19.022’	E 110°16.577’	Orchard, Limestone forest
4	Kuching	Gunung Regu, Padawan	GRP	N 01°12’	E 110°17’	Limestone forest
5	Kapit	Sungai Menyarin, Lanjak Entimau Wildlife Sanctuary	SMLEWS	N 01º40’	E 112º08’	Mixed dipterocarp forest
6	Kapit	Sungai Bloh, Lanjak Entimau Wildlife Sanctuary	SBLEWS	N 01°36’	E112°15’	Mixed dipterocarp forest
7	Sibu	Human Settlement, Kanowit	HSK	N 02°07.526”	E 112°08.489”	Rubber plantation, Secondary forest, Peat swamp
8	Sibu	Bukit Aup Jubilee Park	BAJP	N 02°21’17.61”	E 111°49’51.79”	Secondary forest
9	Kapit	Rumah Temuai Nanga Merit	RTNM	N 02º17.407’	E 113º08.073’	Orchard, Secondary forest
10	Kapit	Sungai Beletik Nanga Merit	SBNM	N 02º18.970’	E 113º07.088’	Riverine forest
11	Miri	Niah National Park	NNP	N 03°48'20"	E 13°45'68"	Lowland dipterocarp forest
12	Samarahan	Desa Ilmu, Kota Samarahan	DIKS	N 01°27’	E 110°27’	Urban area

Animals were captured using a total of 100 cage traps each study sites except for BPS, where 50 cage traps were used for five to six consecutive days per site which resulted in 6600 trap-nights. Traps were baited with bananas, oil palm fruits, tapioca or salted fish. The traps were checked and the baits were replenished twice daily, once in the morning and evening. Trapped animals were placed in cloth bags and brought back to the field laboratory in all study sites for further processing.

The animals caught were identified individually following Medway (1983), Payne et al. (2005), Francis (2008), and Phillipps and Phillipps (2016). During this study, various methods were used for the collection of ectoparasites. The animals selected for molecular phylogenetic and biomedical studies were anesthetised individually using chloroform or excess isoflurane in sterile killing jars or separate zip log plastic bag or cloth bag before screening for ectoparasites. Host of ectoparasites screening were carried out individually and separately to prevent contamination of two ectoparasites and host (Bittencourt & Rocha 2002). The anesthetised animal was removed from killing jar or bag, placed on a white enamel white tray and combed thoroughly with a fine tooth comb to dislodge ectoparasites from the animal onto the tray (Madinah et al. 2013). Contents of the tray were then carefully examined and any ectoparasites seen were collected and preserved in a collection vial containing 75% ethanol. A separate vial was used for each animal. The vial containing ectoparasites were labeled with information such as host species, location, ecology, sex and date of collection (Madinah et al. 2011, 2013).

For unanesthetised animals, ectoparasites were collected directly from eye-lids, ear-lobes, ear fringes, chin, muzzle and other parts of the body using fine forceps. The animals were released after data on species, weight, sex and morphology were recorded. The captured animals were tagged with nail varnish on his nail to prevent recapture. All ectoparasites collected were preserved in 75% ethanol in separate vials for each animal with proper labeled and were brought back to the laboratory in Zoological Museum in Universiti Malaysia Sarawak for mounting and identification. They were later identified to genera or species level using available keys, published taxonomic drawings and references (Baker et al. 1962; Domrow 1976; Durden 1990; Jameson 1965; Johnson 1964; Kohls 1957; Nadchatram & Dohany 1974; Strandtmann & Mitchell 1963; Uchikawa & Suzuki 1980). All procedures were approved by the Universiti Malaysia Sarawak Animal Ethics Committee along with permit number UNIMAS/AEC/R/F07/038.

RESULTS

A total of 148 individuals of non-volant small mammals, comprised of three species of squirrels (Sciuridae), 12 species of rats (Muridae), and seven species of tree shrews (Tupaiidae) from 12 locations of Sarawak, Malaysian were caught and examined for ectoparasites. The most common species of non-volant small mammals caught were Asian house rat (*Rattus tanezumi*), followed by Muller's rat (*Sundamys muelleri*) and Brown spiny rat (*Maxomys rajah*) with 40, 37 and 12 individuals respectively. Secondary forest recorded the highest total number of animals caught compared to other types of habitats.

Six groups of ectoparasites were recovered from non-volant small mammals caught. The ectoparasites were ticks, mesostigmatid mites, chiggers, listrophorid mites, astigmatid mites and lice (Table 2). The rates of infestation of each ectoparasites ranged from 1.4% to 66.2%. The utmost infestation was with mesostigmatid mites while the least infestation

occurred with astigmatid mites. These ectoparasites were recovered from 22 host species, but not every species was infested (Table 2).

Forty-six species of ectoparasites were identified from a total of 2463 individuals of ectoparasites collected (Table 3). Of these, 96.8% was ectoparasitic acarines whereas the remaining 3.2% was ectoparasitic insects. Of ectoparasitic acarines, a total of 2,385 individuals comprising of six families, namely, Ixodidae (ticks), Trombiculidae (chiggers), Atopomelidae (hair mites), Sarcoptidae (itch mites), Laelapidae and Hirstionyssidae (mesostigmatid mites) were collected and identified. While for ectoparasitic insects, a total of 78 individuals were collected, and they belonged to two families, namely, Hoplopleuridae and Polyplacidae. Family Laelapidae was dominating other families with 65.3% (1,608 individuals), followed by the family Atopomelidae 13.4% (330 individuals) and family Trombiculidae 12.7% (312 individuals).

Six species in five genera of ticks, 17 species in five genera of mesostigmatid mites, eight species in six genera of chiggers, eight species in two genera of listrophorid mites, six species in five genera of lice and one species of astigmatid mites were collected (Table 3). The genus *Laelaps* dominated other genera in composition of species with 24.0% domination, followed by the genus *Listrophoroides* (15.2%) and *Haemolaelaps* (6.5%). The highest number of species collected was *Laelaps sedlaceki* (723 individuals) while the lowest were *Amblyomma* sp., *Echinonyssus nasutus*, *Hirstionyssus* sp., *Laelaps echidninus*, *Listrophoroides* sp. 5, *Listrophoroides* sp. 6 and *Ancistroplax nasuta* with one individual of each species collected (Table 3). Among 46 species ectoparasites recorded, six species were known as medically important namely, *Ixodes granulatus* (Tick), *Laelaps nuttalli* (Mesostigmatid mites), *Leptotrombidium deliense* (Trombiculid mites), *Sarcoptes scabiei* (Astigmatid mites), *Polypax spinulosa*, and *Hoplopleura dissicula* (Lice) (Figure 2).

The small mammals and their ectoparasites were sampled from seven types of habitats, namely, secondary forest, lowland dipterocarp forest, riverine forest, mixed dipterocarp forest, hill dipterocarp forest, limestone forest and urban area. Among the seven types of habitat, limestone forest recorded the highest number of host species (11 species) and ectoparasites species (31 species) that have been identified meanwhile riverine forest resulted the lowest host species (one species only) namely *Callosciurus notatus* and ectoparasites species (2 species) which are *Haemolaelaps* sp. and *Hirstionyssus* sp. that have been reported subsequently the lowest number of animals caught (Figure 3).

Table 2. Infestation rates of ectoparasites and habitat types on non-volant small mammals in Sarawak, Malaysian Borneo

Order	Family	Species name	Total caught	No. of host positive with ectoparasites	No. of host infested						Habitat Types
					Tick	Mesostigmatids	Chiggers	Lice	Listrophorids	Astigmatid mites	
Rodentia	Sciuridae	*Callosciurus notatus*	6	5	0	3	1	2	0	0	A,C
		Sundasciurus lowii	2	1	0	1	0	0	0	0	E
		Lariscus insignis	1	0	0	0	0	0	0	0	E
		Total	9	6 (66.7%)	0	4 (44.4%)	1 (11.1%)	2 (22.2%)	0	0	
	Muridae	*Leopoldamys sabanus*	3	3	0	2	2	1	1	0	F
		Maxomys ochraceiventer	5	4	0	4	1	1	3	0	F
		Maxomys rajah	12	11	6	11	0	0	0	0	A,E
		Maxomys surifer	1	1	0	1	0	0	0	0	D
		Maxomys whiteheadi	7	7	0	7	1	0	2	0	A,D,E
		Niviventer cremoriventer	7	7	3	5	0	0	0	0	A,B,F,
		Niviventer rapit	4	4	0	4	0	0	0	0	D,F
		Rattus exulans	2	2	1	2	0	1	1	0	F
		Rattus tanezumi	40	20	1	19	0	7	0	0	G
		Rattus tiomanicus	1	0	0	0	0	0	0	0	A
		Rattus sp.	6	6	1	5	0	0	0	0	A,F
		Sundamys muelleri	37	37	12	33	6	4	14	2	A,B,D,F
		Total	125	102 (81.6%)	24 (19.2%)	93 (74.4%)	10 (8.0%)	14 (11.2%)	21 (16.8%)	2 (1.6%)	
Scandentia	Tupaiidae	*Ptilocercus lowii*	1	1	1	0	0	0	0	0	D
		Tupaia dorsalis	1	1	0	0	1	0	0	0	E
		Tupaia glis	6	6	3	0	4	0	0	0	E,F
		Tupaia gracilis	1	1	0	0	1	0	0	0	E
		Tupaia minor	2	2	1	0	1	0	0	0	E,F
		Tupaia picta	1	1	0	0	1	0	1	0	E
		Tupaia tana	2	1	1	1	0	0	0	0	F
		Total	14	13	6	1	8	0	1	0	

	(92.9%)	(42.9%)	(7.1%)	(57.1%)		(7.1%)		
	121	30	98	19	16	22	2	
Grant total 148	(81.8%)	(20.3%)	(66.2%)	(12.8%)	(10.8%)	(14.8%)	(1.4%)	

A-Secondary forest; B-Lowland dipterocarp forest; C-Riverine forest; D-Mixed dipterocarp forest; E- Hill dipterocarp forest; F-Limestone forest; and G- Urban area. (%)-percentage of infestation rates.

Table 3. Taxonomic list and number of ectoparasites found on rodents and scandents in Sarawak (2008-2019)

		Rodentia														**Scandentia**								
		Sciuridae			**Muridae**											**Tupaiidae**							**TOTAL**	**Habitat Types**
	Family/Genus/ Species	*Callosciurus notatus*	*Sundasciurus lowii*	*Lariscus insignis*	*Leopoldamys sabanus*	*Maxomys ochraceiventer*	*Maxomys rajah*	*Maxomys surifer*	*Maxomys whiteheadi*	*Niviventer cremoriventer*	*Niviventer rapit*	*Rattus exulans*	*Rattus tanezumi*	*Rattus tiomanicus*	*Rattus* sp.	*Sundamys muelleri*	*Ptilocercus lowii*	*Tupaia dorsalis*	*Tupaia glis*	*Tupaia gracilis*	*Tupaia minor*	*Tupaia picta*	*Tupaia tana*		
Ectoparasitic acarines	**Ticks**																							
	Family: Ixodidae																							
	Amblyomma sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	**1**	D
	Dermacentor spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	13	-	47	-	-	**65**	A,F
	Haemaphysalis spp.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	4	-	-	1	-	-	-	-	**6**	A,E,F
	Ixodes sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	2	-	-	-	-	**7**	A,F
	Ixodes granulatus	-	-	-	-	-	-	-	-	3	-	2	2	-	2	22	-	-	-	-	-	-	1	**32**	A,F,G
	Rhipicephalus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	-	-	-	**4**	B,F
	Mesostigmatid mites																							
	Family: Laelapidae																							
	Echinonyssus nasutus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	**1**	F

Haemolaelaps audyi	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**6**	E
Haemolaelaps traubi	5	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	**6**	A
Haemolaelaps sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	**2**	A,C
Laelaps aingworthae	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**10**	D
Laelaps echidninus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	**1**	F
Laelaps flagellifer	-	-	-	-	6	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**21**	A,F
Laelaps insignis	-	-	-	-	16	39	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**58**	E,F
Laelaps mercedeae	-	-	-	-	29	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**44**	E,F
Laelaps nuttalli	-	-	-	8	-	-	-	-	-	4	13	5	-	-	4	-	-	-	-	-	-	-	-	**34**	A,F,G
Laelaps rex	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**4**	F
Laelaps sanguisugus	-	-	-	-	-	97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**97**	E
Laelaps sculpturatus	-	-	-	-	2	-	-	110	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	**114**	A,D,E,F
Laelaps sedlaceki	-	-	-	-	-	-	-	-	5	1	-	80	-	48	589	-	-	-	-	-	-	-	-	**723**	A,B,D.F,G
Laelaps turkestanicus	-	-	-	-	-	-	-	-	77	84	-	-	-	12	197	-	-	-	-	-	-	-	-	**370**	A,B,D,F
Longolaelaps longulus	-	-	-	-	-	-	-	116	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	**117**	A,D,E,F
Family: Hirstionyssidae																									
Hirstionyssus sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	C
Trombiculid mites (chiggers)																									
Family: Trombiculidae																									
Ascoschoengastia sp.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	**2**	A,D
Gahrliepia (gahrliepia) sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	**6**	E
Gahrliepia (walchia) sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	**6**	A,F
Leptotrombidium deliense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	12	6	8	4	-	-	**47**	B,E,F
Leptotrombidium spp.	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	-	3	6	-	-	-	-	-	**13**	A,E,F
Microtrombicula sp.	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**	F
Siseca spp.	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**3**	A,F
Walchiella spp.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	198	-	-	1	15	-	18	-	-	**233**	A,B,D,E,F
Listrophorid mites (hair																									

	mites)																									
	Family: Atopomelidae																									
	Listrophoroides sp.1	-	-	-	-	1	-	-	14	-	-	-	-	-	-	113	-	-	-	-	-	-	-	**128**	A,B,D,E,F
	Listrophoroides sp.2	-	-	-	-	10	-	-	-	-	-	-	-	-	-	114	-	-	-	-	-	-	-	**124**	A,B,F
	Listrophoroides sp.3	-	-	-	7	-	-	-	35	-	-	1	-	-	-	23	-	-	-	-	-	-	-	**66**	A,B,D,E,F
	Listrophoroides sp.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	**3**	A
	Listrophoroides sp.5	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	F
	Listrophoroides sp.6	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	F
	Listrophoroides sp.7	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**4**	F
	Lynxacarus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	**3**	E
	Astigmatid mites (itch mites) **Family: Sarcoptidae**																									
	Sarcoptes scabiei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	-	**19**	A
ectoparasitic insects	**Lice**																									
	Family: Hoplopleuridae																									
	Ancistroplax nasuta	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	F
	Hoplopleura dissicula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	**9**	A,B
	Hoplopleura sp.	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	**5**	G
	Neohaematopinus callosciuri	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**7**	A
	Family: Polyplacidae																									
	Polypax spinulosa	-	-	-	3	-	-	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	**53**	F,G
	Sathrax sp. (nymph)	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	**3**	F
	Total	**16**	**6**	**0**	**25**	**73**	**166**	**10**	**280**	**86**	**89**	**22**	**142**	**0**	**62**	**1337**	**1**	**3**	**42**	**21**	**55**	**25**	**2**	**2463**		

A-Secondary forest; B-Lowland dipterocarp forest; C-Riverine forest; D-Mixed dipterocarp forest; E- Hill dipterocarp forest; F-Limestone forest; and G- Urban area.

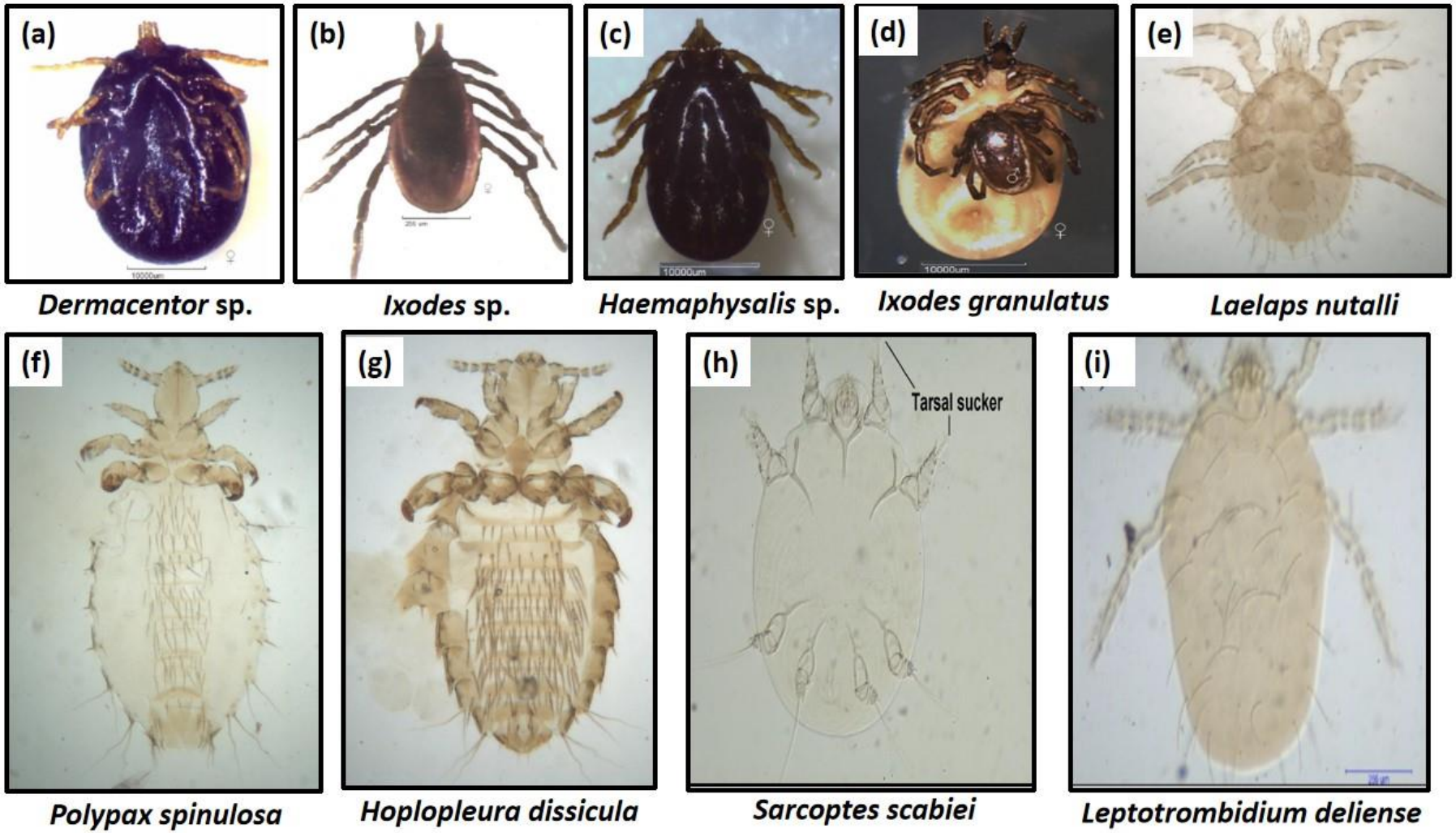

Figure 2. List of ectoparasites know as medical importance

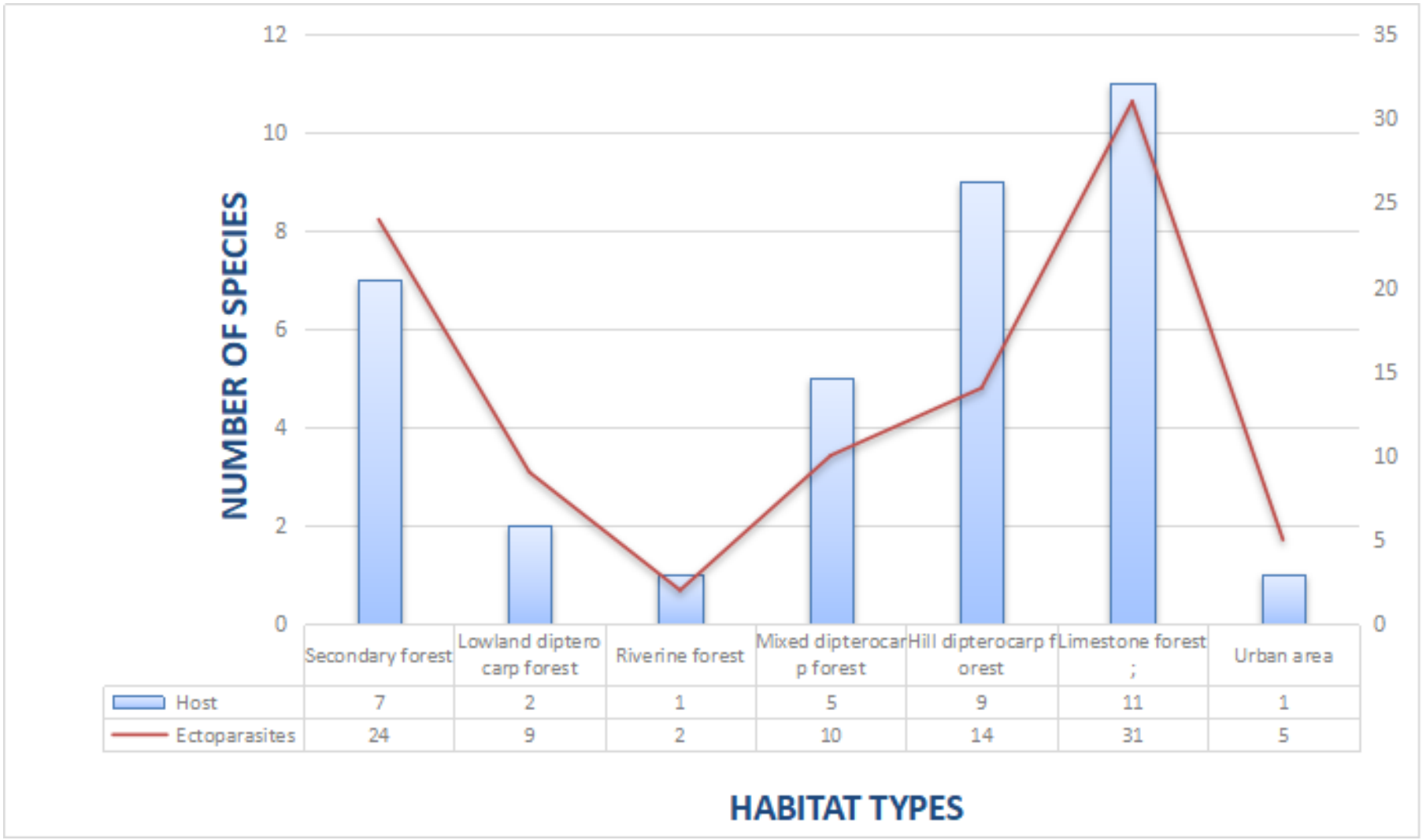

Figure 3. Graph number of host and ectoparasites versus habitat types

DISCUSSION

The specimens collected and recorded in this study provide the first extensive documentation of the taxonomy, geography, and host distribution of ectoparasites infesting rodents and scandents in 12 selected areas in Sarawak. Most ectoparasites species collected in this study have been found and reported in previous studies in Peninsular Malaysia (Ahmad et al. 2020; Chuluun et al. 2005; Nadchatram 2008; Mariana et al. 2006; 2008; 2009; Mohd-Zain et al. 2015; Mohd-Taib et al. 2018; Paramasvaran et al. 2009). However, some species such as *Laelaps flagellifer, L. turkestanicus*, *L. rex*, and *Longolaelaps longulus* are new distributional record reported in Sarawak and this further adds to our knowledge on the distribution of ectoparasites in Sarawak. This is because the studies and information on ectoparasites of small mammals in Sarawak were lacking compared to studies in Peninsular Malaysia. In Sarawak, the information of ectoparasites and their host was only recorded until 1974 and then, no current or published data have been reported (Kohls 1957; Muul & Lim 1974; Traub & Audy 1954a, 1954b; Strandtmann & Mitchell 1963) except for current survey on ectoparasites in urban park and western Sarawak (Ng et al. 2017; Madinah et al. 2013). There are two possibilities why some species were not recorded in previous studies in Malaysian Borneo. It is either the species were under represented or the species were appeared as additional new records in the present study.

Rattus tanezumi is the most frequently caught host for this study. It was not surprising to recover this species because it was known as Asian house rat and widely distributed in eastern, southern and south-eastern Asia and also can be found in many man-made habitats including agricultural and urban areas (Phillipps & Phillipps 2016). Most of this species was caught in urban areas. Different ecological habitats have influenced the taxonomic composition of host species (Madinah et al. 2014). Besides that, other factors such as food availability and changing of habitat structure has influenced the changing pattern of the composition of small mammals and their ectoparasites (Traub & Wisseman 1972).

Some of the host species, such as *M. ochraceiventer*, *T. dorsalis*, *T. gracilis*, *T. picta* and *T. tana* are endemic to Borneo and do not occur in Peninsular Malaysia (Francis 2008; Medway 1983; Payne et al. 2005; Phillipps & Phillipps 2016). Hence, there are possibilities that they carry newly recorded species of ectoparasites in Sarawak. This is because some ectoparasites species are host specific that chooses a specific species or genus as host to complete their life cycle (Gannon & Willig 1995). However, during this study, no new species were recorded, with the exception of the addition checklist and new distribution records of ectoparasite species in Sarawak.

Among six groups of ectoparasites collected, mesostigmatid mites showed the highest infestation rates compared to other groups. It was evident in this study because mesostigmatid mites was the most common and predominant groups of ectoparasites infesting small mammals and this consistent with previous record (Madinah et al. 2011, 2014; Mariana et al. 2006, 2008; Muul & Lim 1974; Shabrina et al. 1989; Paramasvaran et al. 2009). Mesostigmatid mites are known as nest dwellers and have high relative prevalence on non-volant small mammals (Shabrina et al. 1989). They live in the nests of host such as rodents and scandents and feed occasionally on the host (Nadchatram 2008).

Ticks, chiggers, lice, listrophorids and astigmatid mites' groups recorded in this study was concordance with previous study, as this groups have been known as the groups of ectoparasites that infest the mammalian host such as non-volant small mammals (rodents and

scandents) (Marshall 1981). Fleas were not recorded in this study and this finding was differing with previous studies and this group of ectoparasites was known to infest the mammalian host (Marshall 1981; Paramasvaran et al. 2009; Wells et al. 2011). Thus, further surveys are necessary to be conducted in order to answers the cause of absence.

Among 23 genera recorded in this study, genus *Laelaps* was the highest species collected. This is concordance with Strandtmann and Mitchell (1963) because this genus was the dominant genus collected among ectoparasitic mites collected in their studies. Along with 46 species of ectoparasites encountered, *Laelaps sedlaceki* represented the highest number of individuals recorded (723 individuals) followed by *L. turkestanicus* (370 individuals). In contrast, study in Peninsular Malaysia documented that *L. echidninus* and *L. nuttalli* were the dominant species (Azima et al. 2007; Shabrina 1991; Shabrina & Salleh 1995; Nadchatram 2008; Mariana et al. 2006; Paramasvaran et al. 2009; Zahedi et al. 1996). In this study, both species were collected but not as predominant species recorded. *Laelaps sedlaceki* was reported as a dominant species and most species were found in Borneo (Sabah and Sarawak) (Strandtmann & Mitchell 1963) and their finding was parallel with our finding.

Various species of ectoparasites have been observed in limestone forests and have been extracted from the highest number of hosts captured in this study compared to other habitat types. This finding was relevant because the distributions of ectoparasites were influenced by the host species caught. The hosts (rodents and scandents) play important roles as the habitat (home) created by host skin for ectoparasites growth or to complete their life cycles (Marshall 1976). Hence, various species and different types of ectoparasites were closely related to their host species (Marshall 1976). The ectoparasite occurrences were also influenced by habitats. According to Gettinger and Ernest (1995), the existence of an ectoparasitic species will depend upon the choice of habitat by its host. If a habitat is disturbed, the composition and movements of small mammals will change, leading to the migration of ectoparasites from host to host close to their micro-habitat. Therefore, the relation between ectoparasites, their hosts and suitable habitat influenced the distribution of ectoparasites. Moreover, rodents and scandents together with their ectoparasites in certain habitats can play important roles in distributions and pattern of epidemiological disease such as rickettsial, plague, leptospirosis and spirochaetosis (Manson & Stanko 2005).

In terms of host specificity, some ectoparasites such as lice are known to be host specific (Ibarra 1993). The results of this study indicate that lice are also detected on a host-specific basis. All lice species observed in this study infest only one host species. Meanwhile, compared to some ectoparasites such as ticks, laelapid mites and chiggers, they have shown not host specific whereas generalist. Ticks species such as *Ixodes granulatus*, laelapid mites such as *Laelaps nuttalli* and *L. sedlaceki* and chiggers such as *Leptotrombidium deliense* have been observed to be infested more than one species of host. Other studies also showed similar findings in which ticks appeared to be generalist (Madinah et al. 2014) and their host specificity was estimated to be similarly low for all ticks in tropical rainforest (Wells et al. 2013). Laelapid mites also often share different host species (Bittencourt & Rocha 2003; Madinah et al. 2014). This is because laelapid mites were often reported to be associated with hosts at higher taxonomic level (family, genera and species) (Furman 1972). The occurrence of a particular ectoparasite species living on more than one host species may be related to the intra and interspecific relationships, behaviour and the microhabitats utilised by the host (Bittencourt & Rocha 2003).

Amongst the ectoparasites found *Ixodes granulatus, Laelaps nuttalli, Leptotrombidium* sp., *Leptotrombidium deliense, Sarcoptes scabiei, Polypax spinulosa,* and *Hoplopleura dissicula* are of known public health importance. Generally genus of *Dermacentor* sp., *Haemaphysalis* sp., *Ixodes* sp., were known as of medical importance because they were associated with many other tick-borne zoonotic diseases in many parts of the world (Roberts & John 2001; Mariana et al. 2006). Besides that, *Ixodes granulatus* has been observed as being a vector of Langat virus (Smith 1956) in Malaysia, the species also known to transmit other pathogens and involved in the cycles of tick typhus and Q fever in climax forest of Peninsular Malaysia (Marchette 1965). The first reported of the Langat virus (similar to those of the Russian Spring-Summer Encephalitis Complex (RSSE) was isolated from *I. granulatus,* documented in 1956 which infested *S. muelleri* and *L. sabanus* (Smith 1956; Nadchatram 2008).

Among *Laelaps* species, only *L. nuttalli* was known as of medical importance. It was reported to attack and bite humans (Azad 1986; Sandosham & Keling 1967), thus causes occasional irritation (Azad 1986). Although many species of mesostigmatid mites are reported to come into contact with humans, there are no authenticated reports of mites serving as vectors of infections to humans (Nadchatram 2008). As they are parasites to wild rodents in the tropical forest, the probability of the exchange process and the spread of infection will occur, leading to a zoonotic cycle in an area (Nadchatram 2008).

Unfed chiggers were usually found attached to lalang (weed) awaiting a suitable host (Azima et al. 2007). *Leptotrombidium* sp. and *L. deliense* isolated from this study is of significant medical importance. *Leptotrombidium deliense* was known of public health importance from previous studies (Azima et al. 2007; Mariana et al. 2006). In fact, *L. deliense* was one of the main vectors of scrub typhus caused by bacteria *Orientia tsutsugamushi* in Peninsular Malaysia (Azima et al. 2007; Nadchatram 2008; Traub & Wisseman 1974). It was reported to occur in forest fringes, secondary forest (shrubs areas), forest with leaf litter, or even in deep forest (Nadchatram 2008; Oaks et al. 1983).

Sarcoptes scabiei is also known to be of public health importance where it can cause scabies either to human or other animals (Nadchatram 2008). These mites are widespread in the world and in Malaysia, the mites have been found deep in the ears of animals (Normaznah 1995). Interestingly, these mites infected two individuals of *S. muelleri* in the human settlement at Kanowit. Lice such as *Polypax spinulosa, Hoplopleura disscula* and *Hoplopleura* sp. were considered to be of public health importance because they are known to harbor plague bacilli and transmit tularemia and bartonellosis to humans, and also play important roles in transmiting the murine typhus and plague from rat to rat (Paramasvaran et al. 2009; Zahedi et al. 1984).

Although this study did not cover the whole division of Sarawak, the documented data of ectoparasites species, their hosts and different ecological habitats were reliable enough to reflect the distribution pattern. This study also updated the current information on ectoparasites in Sarawak after 1974 (Kohls 1957; Muul & Lim 1974; Strandtmann & Mitchell 1963; Traub & Audy 1954a, 1954b). Many species of small mammals live in the same general habitats in the tropical rain forest of Sarawak. However, each was exploiting a slightly different ecological niche, thus the differences may reflect in their parasite's prevalence (Betterton & Lim 1975).

Further studies should be carried out to cover a wider geographical area in other division of Sarawak including others habitats such as mangrove, coastal and montane areas to get a better comparison and information of the ecological relationship among ectoparasites, their hosts and habitat preferences and to produce extensive data. Future studies should also include both combinations of morphological and genetic approach to resolve the taxonomic status of unidentified species. Changing patterns of habitat distribution and species composition through time would also be important to study. Sarawak is undergoing rapid environmental degradation resulting from human development such as land use for plantation and urbanization and the current changes may alter the ecology of ectoparasites and their hosts. Thus, future study is important, not only in diversity of ectoparasites and their hosts, but it can also give information pertaining to the vector of zoonotic diseases and the possible pattern of epidemiology in state of Sarawak, Malaysia.

CONCLUSION

This study has successfully provided new distribution records of host and their ectoparasites species diversity in 12 selected localities of Sarawak. A total of 46 species (24 genera) of ectoparasite species and its distributions in contrasting habitats in Sarawak have been successfully provided. Limestone forests recorded the highest number of host and ectoparasites species, while riverine forest recorded the lowest number of host and ectoparasites species. Further surveys with more sampling effort (days, sampling sites) are recommended for more extensive information of ectoparasites, their host and their distribution pattern which is useful for sustainable management of natural resources and to control the spread on zoonotic diseases throughout the Sarawak and Malaysia.

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REFERENCES

Abang, F. & Hassan, F. 1988. Notes on the taxonomy of fleas based on collection from Kinabalu Park. *Sabah Museum and Archives Journal* 1(2): 62-67.

Ahmad, N.I.I., Rahim, N.A.A., Roslan, A., Adrus, M., Ahamad, M., Hassan, M., Lola, M.S., Ramlee, M.N.A., Zahidin, M.A. & Abdullah, M.T. 2020. Data on ectoparasites infestation on small mammals from different habitats in east-coast Peninsular Malaysia. *Data in Brief* 30: 105621.

Azad, A.F. 1986. *Vector Control Series Training and Information Guide XIII. Mites of Public Health Importance and Their Control*. Baltimore: World Health Organization (Vector Biology and Control Division)

Azima, L.H., Hazar, S.A.I. & Ho, T.M. 2007. Ectoparasites of small mammals in coastal areas of Selangor. *Journal of Wildlife and Parks* 24: 49-55.

Baker, E.W., Traub, R. & Evans, T.M. 1962. Indo-Malayan *Haemolaelaps* with description of new species (Acarina: Laelaptidae). *Pacific Insects* 4(1): 91-100.

Barnes, A.M. 1962. Ectoparasite control in public health. *Proceedings of the 1st Vertebrates Pest Conferences* 19: 250-270.

Betterton, C. & Lim, B.L. 1975. Digenetic trematodes from rats, squirrels and treeshrews in Malaysia. *Southeast Asian Journal of Tropical Medicine and Public Health* 6: 358.

Bittencourt, E.B. & Rocha, C.F.D. 2002. Spatial use of rodents (Rodentia: Mammalia) host body surface by ectoparasite. *Brazilian Journal of Biology* 62(3): 419-425.

Bittencourt, E.B. & Rocha, C.F.D. 2003. Host-ectoparasite specificity in a small mammal community in an area of Atlantic Rain Forest (Ilha Grande, State of Rio de Janeiro), Southeastern Brazil. *Memorias do instituto Oswaldo Cruz, Rio de Janeiro* 98(6): 793-798.

Chuluun, B., Mariana, A., Ho, T.M. & Mohd Kulaimi, B. 2005. A preliminary survey of ectoparasites of small mammals in Kuala Selangor Nature Park. *Tropical Biomedicine* 22 (2): 243-247.

Domrow, R. 1976. Oriental Mesostigmata (Acari) 3. A new species of *Echinonyssus* from Selangor. *Oriental Insect* 10 (2): 179-183.

Durden, L.A. 1990. The Genus *Hoplopleura* (Anoplura: Hoplopleuridae) from murid rodents in Sulawesi, with description of three new species and notes on host relationships. *Entomological Society of America* 27(3): 269-281.

Francis, C.M. 2008. *Field Guide to the Mammals of South-East Asia*. London: Princeton Press.

Furman, D.P. 1972. Laelapid mites (Laelapidae: Laelapinae) of Venezuela. *Brigham Young Universities Science Bulletin* 17: 1-57.

Gannon, M.R. & Willig, M.R. 1995. Ecology of ectoparasites from tropical bats. *Journal Environmental Entomology* 24(6): 1495-1503.

Gettinger, D. & Ernest, K.A. 1995. Small-mammals community structure and the specificity of ectoparasite association in Central Brazil. *Revista Brasileira de Biologia* 55: 331-341.

Ibarra, J. 1993. Lice (Anoplura). In Lane, R.P., Crosskey, R.W. (eds). *Medical Insects and Arachnids*, pp. 517-528. Netherlands: Springer, Dordrecht.

Jameson, Jr.E.W. 1965. The Genus *Laelaps* (Acarina: Laelaptidae) in Taiwan. *Journal of Medical Entomology* 2(1): 41-53.

Johnson, P.T. 1964. The Hoplopleurid lice of the Indo-Malayan subregion (Anoplura: Hoplopleuridae). *Miscellaneous Publication of the Entomological Society of America* 4(3): 68-101.

Kettle, D.S. 1985. *Medical and Veterinary Entomology*. New York: Wiley-Interscience.

Kohls, G.M. 1957. Tick (Ixodoidae) of Borneo and Malaya. *Malaysian Parasites XVIII* (28): 65-94.

Madinah, A., Fatimah, A., Mariana, A. & Abdullah, M.T. 2011. Ectoparasites of small mammals in four localities of wildlife reserve in Peninsular Malaysia. *Southeast Asian Journal of Tropical Medicine and Public Health* 42(4): 803-813.

Madinah, A., Mariana, A., Fatimah, A. & Abdullah, M.T. 2013. A preliminary field survey of ectoparasites of rodents in urban park, Sarawak, Malaysian Borneo. *Tropical Biomedicine* 30(3): 1-5.

Madinah, A., Abang, F., Mariana, A., Abdullah, M.T. & Mohd-Azlan, J. 2014. Interaction of ectoparasites-small mammals in tropical rainforest of Malaysia. *Community Ecology* 15(1): 113-120.

Malul, I. 1987. Kajian taksonomi fauna pijal (Siphonaptera) di kawasan Tambunan, Sabah. Tesis Sarjana Muda Sains (Kepujian) dalam Bidang Biologi, Universiti Kebangsaan Malaysia, Bangi.

Manson, P. & Stanko, M. 2005. Mesostigmatid mites (Acari) and fleas (Siphonaptera) associated with nest of Mound-building Mouse, *Mus spicilegus* Petenyi, 1882 (Mammalia, Rodentia). *Acta Parasitologica* 50(3): 228-234.

Marchette, N.J. 1965. Rickettsiosis (Tick Typhus, Q-fever, Urban-typhus) in Malaya. *Journal of Medical Entomology* 2: 339-371.

Mariana, A., Zuraidawati, Z., Ho, T.M., Mohd Kulaimi, B., Saleh, I., Shukor, M.N. & Shahrul-Anuar, M.S. 2006. Fauna ektoparasit pada beberapa altitud di Hutan Simpan Gunung Jerai, In Shaharuddin, M.I., Wan Yusoff, W.A., Jalil, M.S., Yusoff, M. & Latiff, A. (eds). *Hutan Simpan Gunung Jerai, Kedah: Pengurusan, Persekitaran*

Fizikal, Biologi dan Sosio-ekonomi, pp. 317-327. Malaysia: Siri Kepelbagaian Biologi Hutan.

Mariana, A., Zuraidawati, Z., Ho, T.M., Mohd Kulaimi, B., Saleh, I., Shukor, M.N. & Shahrul-Anuar, M.S. 2008. Ticks (Ixodidae) and other ectoparasites in Ulu Muda Forest Reserve, Kedah, Malaysia. *Southeast Asian Journal of Tropical Medicine and Public Health* 39(3): 496-506.

Mariana, A., Mohd Kulaimi, B., Halimaton, I., Suhaili, Z.A., Ho, T.M., Shahrul-Anuar, M.S. & Nor Zalipah, M. 2009. Ektoparasit akarin di Hutan Simpan Panti. In Razani, U. (eds). *Hutan Simpan Panti, Johor: Pengurusan Hutan, Persekitaran Fizikal & Kepelbagaian Biologi*, pp. 174-178. Malaysia: Siri Kepelbagaian Biologi Hutan.

Marshall, A.G. 1976. Host-specificity amongst arthropods ectoparasitic upon mammals and birds in the new hebrides. *Journal of Ecological Entomology* 1: 189-199.

Marshall, A.G. 1981. *The Ecology of Ectoparasitic Insects*. London: Academic Press Inc.

Medway, L. 1983. *The Wild Mammals of Malaya (Peninsular Malaysia and Singapore).* Kuala Lumpur: Oxford University Press.

Mohd-Taib, F.S., Lasim, A.M., Asyikha, R., Ali, R. & Ishak, S.N. 2018. A preliminary survey of ectoparasites of small mammals in Pangkor Island, Perak, Malaysia. *Serangga* 23(2): 73-82.

Mohd-Zain, S.N., Amdan, S.A.S.K., Braima, K.A., Abdul-Aziz, N.M., Wilson, J.J., Sithambaran, P. & Jeffery, J. 2015. Ectoparasites of murids in Peninsular Malaysia and their associated disease. *Parasites and Vectors* 8: 254-261.

Muul, I. & Lim, B.L. 1974. Habitat distribution and ectoparasites of small mammals in Sarawak. *Sarawak Museum Journal* 20: 359-366.

Nadchatram, M. & Dohany, A.L. 1974. A pictorial key to the subfamilies, genera and subgenera of Southeast Asian chiggers (Acari, Prostigmata, Trombiculidae). *Bulletin Institute of Medical Research Malaysia* (16): 1-67.

Nadchatram, M. 2008. The beneficial rain forest ecosystem with environmental effects on zoonoses involving ticks and mites (Acari), a Malaysian perspective and review. *Tropical Biomedicine* 25(2): 1-92.

Ng, Y.L., Hamdan, N.E.S., Tuen, A.A., Mohd-Azlan, J. & Chong, Y.L. 2017. Co-infections of ectoparasite species in synanthropic rodents of western Sarawak, Malaysian Borneo. *Tropical Biomedicine* 34(3): 723-731.

Normaznah, Y. 1995. *Sarcoptes scabiei*: Parasite of the skin. *Bulletin Institute for Medical Research: May issue* 33: 7-10.

Oaks, S.C., Ridgway, R.L., Shirai, A. & Twartz, J.C. 1983. Scrub Typhus. *Bulletin Institute for Medical Research* 21: 98.

Paramasvaran, S., Sani, R.A., Hassan, L., Krishnasamy, M., Jeffery, J., Oothuman, P., Salleh, I., Lim, K.H., Sumarni, M.G. & Santhana, R.L. 2009. Ectoparasite fauna of rodents and shrews from four habitats in Kuala Lumpur and the states of Selangor and Negeri Sembilan, Malaysia and its public health significance. *Tropical Biomedicine* 26(3): 303-311.

Payne, J. Francis, C.M. & Phillips, K. 2005. *A Field Guide to the Mammals of Borneo*. Kota Kinabalu: The Sabah Society.

Phillipps, Q. & Phillipps, K. 2016. *Phillipps's Field Guide to The Mammals of Borneo and Their Ecology*. Kota Kinabalu: Natural History Publication.

Robert, S.L. & John, R.A. 2001. Research on animal-borne parasites and pathogens helps prevent human diseases. *California Agriculture* 55: 13-18.

Sandosham, A.A. & Keling, M.N. 1967. Animal parasites of animals which affect man in Malaysia. *Medical Journal of Malaya* 22: 25.

Shabrina, S., Anan, S. & Hamid, R. 1989. Ectoparasites of small mammals from Bukit Lanjan and Air Hitam Forest Reserves, Selangor. *Journal of Wildlife and Parks* 9: 31-35.

Shabrina, S. 1991. Some ectoparasites of rodents and bats captured at Gua Musang, Kelantan. *Journal of Wildlife and Parks* 11: 33-43.

Shabrina, S. & Salleh, I. 1995. A Study on the parasitofauna of rodents and bats at Serting, Negeri Sembilan. *Journal of Wildlife and Parks* 14: 33-47.

Smith, C.E.G. 1956. A virus resembling Russian Spring-summer Encephalitis Virus from an Ixodid tick in Malaya. *Nature* 178: 581-582.

Strandtmann, R.W. & Mitchell, C.J. 1963. The Laelaptine mites of the *Echinolaelaps* complex from the Southwest Pacific Area (Acarina: Mesostigmata). *Pacific Insects* 5(3): 541-576.

Traub, R. & Audy, J.R. 1954a. Malaysian Parasites IV. Species of *Trombicula* (Acarina, Trombiculidae) from Borneo. *Studies from the Institute for Medical Research, Federation of Malaya* 26: 45-76.

Traub, R. & Audy, J.R. 1954b. Malaysian Parasites V. Species of *Euschongastia* sensu lato (Acarina: Trombiculidae) from Borneo. *Studies from the Institute for Medical Research, Federation of Malaya* 26: 77-88.

Traub, R. & Wisseman, C.L.JR. 1972. Diminution in the endemicity of Scrub Typhus with the passage of time. *Journal of Medical Entomology* 9: 590.

Uchikawa, K. & Suzuki, H. 1980. Studies on the parasite fauna of Thailand 3. Mites associated with Thailand mammals. *Tropical Medicine* 22(1): 13-25.

Wells, K., Lakim, M.B. & Beaucournu, J.C. 2011. Host specificity and niche partitioning in flea-small mammals networks in Bornean rainforests. *Medical and Veterinary Entomology* 25: 311-319.

Zahedi, M., Jeffery, J., Krishnasamy, M. & Bharat, V.K. 1984. Ectoparasites fauna of *Rattus rattus diardii* from an urban and semi urban environment. *Journal of the Malaysian Society of Health* 4(2): 25-27.

Zahedi, M., Jeffery, J., Krishnasamy, K. & Bharat, V.K. 1996. Ectoparasites of *Rattus rattus diardii* from Kuala Lumpur city, Malaysia. *Proceeding of the Second International Conference on Urban Pest*, pp. 437-439.