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Biodiversity and macroparasitic distribution of the wild rat population of Carey Island, Klang

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Abstract. A study to determine the diversity and distribution of ectoparasites and endoparasites infesting wild rat population of Carey Island was carried out from June to December 2010. A total of 81 rats were captured from various locations on Carey Island. Four rat species were identified namely, *Rattus tiomanicus* (45.7%), *Rattus rattus diardii* (25.9%), *Rattus argentiventer* (16%) and *Rattus norvegicus* (12.3%). Low diversity of ecto and endoparasites were observed infecting the rodent population with 8 ecto and 8 endoparasites species recorded. The ectoparasites recovered fell under 3 broad groups, namely mites (*Laelaps nuttali*, *Laelaps echidninus*, *Laelaps sculpturatus*, *Listrophoroides* sp. and *Ornithonyssus bacoti*), lice (*Polyplax spinulosa* and *Hoplopleura pacifica*) and tick (*Ixodes granulatus*) while endoparasites recovered were cestodes (*Taenia taeniaformis* and *Hymenolepis diminuta*) and nematodes (*Nippostrongylus brasiliensis*, *Angiostrongylus malaysiensis*, *Mastophorus muris*, *Heterakis spumosa*, *Hepatojarakus malayae* and *Syphacia muris*). The rat population was observed harbouring more than one parasite species. Analysis of data also showed neither intrinsic (host age, host sex) nor extrinsic (season) factors influenced the macroparasites community structure.

INTRODUCTION

Parasitic infections in humans acquired from wild rat presents a huge problem in tropical countries like Malaysia. Wild rats carry a number of diseases which are widespread and difficult to control due to the highly-adaptable and unpredictable nature of wild rats combined with climate most favorable for parasite growth. Today, through the country's development in sanitation, health care and education, have managed and contained, if not controlled this problem.

Rats are one of the most successful groups of mammals as they have evolved to exploit a wide variety of habitats and environments throughout the world. In many places rats have adapted living in close association with humans, using our agriculture and waste as their own food resources and our buildings as their homes. Studies on parasite infections of wild rats have been conducted over the years investigating rat populations from urban cities to plantations in peninsular Malaysia (Sandosham, 1957; Sinniah *et al.*, 1978; Leong *et al.*, 1979). More recent studies have added additional data to the distribution of endo and ecto-parasites in urban rodents in different locations of peninsula Malaysia (Paramasvaran *et al.*, 2009a; Paramasvaran *et al.*, 2009b; Mohd Zain *et al.*, 2012).

In the early 1900s, Carey Island known as Pulau Si Alang (or Pulau Bangsar) was only inhabited by the Mah Meri tribe. Presently, this island is known as Carey Island after an English planter, Edward Valentine John Carey who acquired this place to grow rubber trees. Geographically, this island is separated from the mainland by a river and presently palm oil is grown as the main crop. Over the past several decades, general expansion and urbanization across this area has resulted in serious ecological changes that have irrevocably altered the composition and structure of terrestrial rats as well as their parasite population. Changes to the rats surroundings are often reflected in the rat endoparasites' diversity and population. Port Klang, previously known as Port Swettenham now serves as the largest and busiest port in the country. Due to the close proximity to this port, the objectives for this study here were to investigate the current terrestrial rat and rat borne macroparasite diversity changes and to assess if either intrinsic and extrinsic factors affected the parasite distribution.

MATERIALS AND METHODS

Study site

Carey Island (101º22' E and 2º52' N) is situated on the south of Port Klang and north to Klang River in Kuala Langat District of Selangor. It is separated from the mainland by the Langat River and connected by a bridge from Chodoi near Banting. This island spans a total area of 16, 000 hectare and more than three quarters (11, 700 hectare) of the area is cultivated with oil palm. The island is populated by *Orang Asli* (local aborigine), Malay and Indian settlers. Climate ranges between 25.5 to 28.6ºC with a variation of 3ºC (Malaysian Meteorological Department). This study was divided into two periods to represent the dry (January-March and June-September) and wet (April-May and October-December) seasons.

Host trapping

Trapping was divided into two phases; phase one was conducted between 24^{th}–28^{th} June 2010 (dry season) while the second phase was carried out from 14^{th}–31^{st} December 2010 (wet season). Wire traps (16.5" X 6" X 6") and oil palm fruits (as baits) were used for trapping the rats. A total of 50 traps were laid out overnight over a span of 4 days 3 nights on the island, in the vicinity for Mangrove Research Center and plantation including the surrounding areas of the *Orang Asli* villages. All rats captured were collected in the morning and brought to the laboratory for further investigation. Rats were sacrificed by placing them in a cloth bag containing cotton wool soaked with chloroform and identified based on descriptions from Medway (1983) and Payne & Francis (1998). Morphometric measurements of the head-body, tail, ear, hind foot lengths and weight were recorded for all rats to enable the establishment of age classes. Rats were allocated to two age class based on their body weight as described by Brookes & Rowe (1987).

Ectoparasite collection and identification

The ectoparasites were collected by thoroughly combing through the fur using a fine tooth comb onto a plain white paper. Forceps were used to remove ticks and mites from the skin of rats when it was difficult to dislodge them by combing. The ectoparasites were collected, counted, preserved in 70% alcohol and labeled for identification. Mesostigmatid mites and lice were cleared in lactophenol and mounted with Hoyer's medium.

Post-mortem and endoparasites collection

Post-mortem examination was performed with the removal of the entire gut, beginning from esophagus to anus. Each section of the gut was placed into separate Petri dish, slit lengthwise and dissected in saline solution using a dissecting microscope. Stomach and cecal contents if excessive were filtered. All endoparasites recovered were collected, counted and preserved in 70% alcohol before further identification. Nematodes recovered were fixed and cleared with lactophenol as temporary mounts and observed under microscope while cestodes were first hydrated, stained, dehydrated and mounted in Canada balsam. The microhabitat and intensity of each endoparasite species was recorded.

Data analysis

Data compiled was analyzed using the software Quantitative Parasitology 3.0 (Rózsa *et al.*, 2000) to assess whether intrinsic (host age and host sex) and extrinsic (season) affected the parasite burden in the rodent population. The prevalence, intensity and abundance were calculated and assessed (Margolis *et al.*, 1982). Simpson's Index of species diversity was calculated using the Species Diversity and Richness IV software (Seaby & Henderson, 2006).

RESULTS

Rat population

A total of 81 wild rats were captured comprised of four rat species, *Rattus tiomanicus*, *Rattus rattus diardii*, *Rattus argentiventer* and *Rattus norvegicus* in the surrounding area of plantation and villages. More females were captured (59.5%) compared to males (40.5%) with higher number of adults (82.7%) as compared to juveniles (17.3%). More rats were captured during the wet (71.6%) as compared to dry season (28.4%). *Rattus tiomanicus* was the dominant rat species (45.7%) followed by *R. rattus diardii* (25.9%), *R. argentiventer* (16.1%) and *R. norvegicus* (12.3%).

Ectoparasites infestation

High numbers of rats (93.8%) were infested with ectoparasites. The ectoparasites recovered consisted of 3 groups namely mites (*Laelaps nuttali*, *Laelaps echidninus*, *Ornithonyssus bacoti*, *Laelaps sculpturatus* and *Listrophoroides* sp.), lice (*Polyplax spinulosa* and *Hoplopleura pacifica*) and tick (*Ixodes granulatus*) (Table 1). Each infested rat harboured a minimum of one species and up to a maximum of six species of ectoparasites with most having 2 species (30.9%) (Fig. 1). *Laelaps nuttali* (60.5%, 49.4-70.8) was the most prevalent while *O. bacoti* had the lowest prevalence with 7.4% (3.28-15.3) rats infected. The lice species, *P. spinulosa* was the most abundant with 5.05 per infected rat.

According to season, more ectoparasites were recovered during the wet (100%) compared to dry season (78.3%). Post-mortem examinations recovered a total of 1,439 specimens, with abundance value of 18.9 ectoparasites per infected rat. More number of adult were infested (>90%) compared to juveniles (86.5%) (Fig. 2 & 3). However, statistical analysis showed no significant difference ($p > 0.05$) observed between host-sex and age apart from season for *P. spinulosa* only where infestation was significantly higher during wet season ($p < 0.05$) (Table 2). Surprisingly, no *L. sculpturatus*, *O. bacoti*, *H. pacifica* and *I. granulatus* were recorded during dry season. Overall, the Simpsons Diversity Index showed low ectoparasite diversity (4.94) with marked difference in females (5.97) compared to males rats (3.72) and in adult rats (5.04). Higher diversity index was also apparent during the wet season (4.31) compared to the dry season (2.38) (Table 5).

Endoparasites infections

Helminth parasites were recovered from 73 rats (90.1%) with each rat harbouring a

Table 1. The life stage, intensity, prevalence, abundance and range of ectoparasites in the total rat population at Carey Island

Ectoparasites	Stages	Intensity	Prevalence (95% CL)	Abundance (95% CL)	Range
Mites					
L. nuttali	Adult	198	60.5% (49.39-70.77)	2.44 (1.78-3.31)	1-16
L. echidninus	Adult	81	25.9% (17.12-36.48)	0.84 (0.51-1.36)	1-9
L. sculpturatus	Adult	57	27.2% (18.39-38.21)	0.70 (0.43-1.20)	1-10
Listrophoroides sp.	Adult	86	11.1% (5.72-20.2)	1.06 (0.22-3.70)	1-56
O. bacoti	Adult	12	7.4% (3.28-15.28)	0.15 (0.05-0.43)	1-6
Lice					
P. spinulosa	Adult & nymph	409	54.3% (43.18-64.87)	5.05 (3.26-9.33)	1-97
H. pacifica	Adult & nymph	382	43.2% (32.65-54.33)	4.72 (2.49-12.17)	1-144
Tick					
I. granulatus	Adult & nypmh	214	33.3% (23.8-44.42)	2.64 (1.58-3.99)	1-34

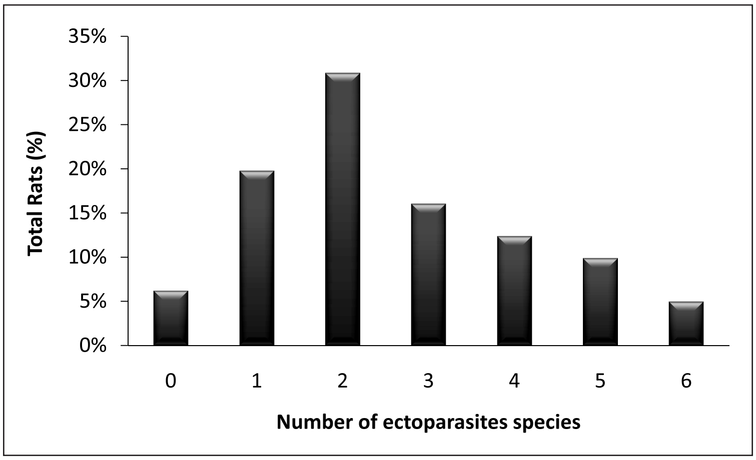

Figure 1. Frequency distribution of infracommunity richness of total ectoparasites species in the rat population of Carey Island

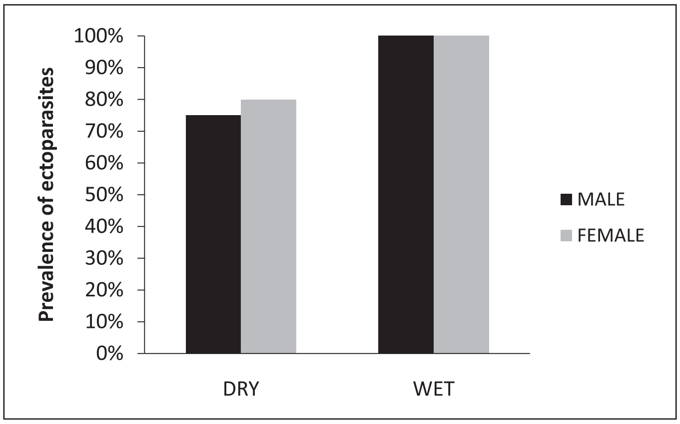

Figure 2. Prevalence of total ectoparasites infections according to host sex and season in the rat population at Carey Island

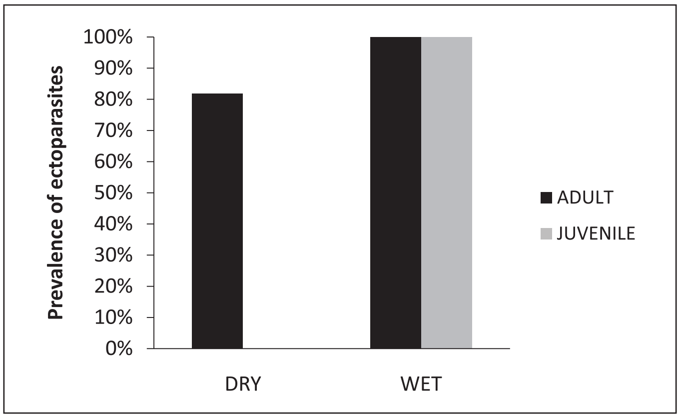

Figure 3. Prevalence of total ectoparasites infection according to host age and season in the rat population at Carey Island

Table 2. The prevalence (%) of infection of ectoparasites species in the total rat population from Carey Island relative to host sex, host age and season

Parasite species	Host sex			Host age			Season		
	Male	Female	*P* value	Adult	Juvenile	*P* value	Dry	Wet	*P* value
Laelaps nuttali	61.8	59.6	0.887	62.7	50.0	0.585	56.5	62.1	0.294
Laelaps echidninus	23.5	25.5	0.437	28.4	14.3	0.371	8.70	32.8	0.107
Laelaps sculpturatus	29.4	25.5	0.798	29.9	14.3	0.399	0	37.9	0.016*
Listrophoroides sp.	5.89	14.9	0.507	13.4	0	0.500	30.1	0	0.117
Ornithonyssus bacoti	8.82	6.40	0.750	7.46	7.14	0.667	0	10.3	0.250
Polyplax spinulosa	70.6	42.6	0.166	53.7	57.1	0.655	34.8	62.1	0.038*
Hoplopleura pacifica	58.8	31.9	0.129	37.3	71.4	0.875	0	60.3	0.009*
Ixodes granulatus	26.5	38.3	0.668	32.8	35.7	0.641	0	46.6	0.006*

* significant

Table 3. The microhabitat, intensity, prevalence and abundance of endoparasites species from Carey Island

Endoparasites	Microhabitat	Intensity	Prevalence (95% CL)	Abundance (95% CL)
Cestodes				
Taenia taeniaformis	Liver	17	16.1% (8.83-25.89)	0.21 (0.11-0.33)
Hymenolepis diminuta	Small intestines	35	16.1% (9.17-25.81)	0.43 (0.2-0.85)
Nematodes				
Nippostrongylus brasiliensis	Small intestines	5341	66.7% (55.58-76.2)	65.94 (46.33-93.83)
Angiostrongylus malaysiensis	Heart and Lung	30	14.8% (8.47-24.55)	0.37 (0.17-0.84)
Mastophorus muris	Stomach	22	11.1% (5.72-20.2)	0.27 (0.11-0.58)
Heterakis spumosa	Caecum	488	55.6% (44.43-66.11)	6.02 (4.11-9.56)
Hepatojarakus malayae	Liver	3	2.5% (0.45-8.46)	0.04 (0.0-0.11)
Syphacia muris	Caecum	33	6.2% (2.47-13.99)	0.41 (0.07-1.53)

Table 4. The prevalence (%) of infection of endoparasites species in the total wild rat population from Carey Island relative to host sex, host age and season

Parasite species	Host sex			Host age			Season		
	Male	Female	*P* value	Adult	Juvenile	*P* value	Dry	Wet	*P* value
Taenia taeniaformis	14.7	17.0	0.953	17.9	7.14	0.274	26.1	12.1	0.132
Hymenolepis diminuta	14.7	17.0	0.913	14.9	21.4	0.415	17.4	15.5	0.221
Nippostrongylus brasiliensis	61.8	70.2	0.936	65.7	71.4	0.841	65.2	67.2	0.115
Angiostrongylus malaysiensis	11.8	17.0	0.215	14.9	14.3	0.643	4.34	18.9	0.325
Mastophorus muris	11.8	10.6	0.958	11.9	7.14	0.431	0	15.5	0.139
Heterakis spumosa	55.9	55.3	0.421	59.7	35.7	0.442	47.8	58.6	0.135
Hepatojarakus malayae	0	4.26	0.253	0	14.3	0.002*	0	3.44	0.399
Syphacia muris	8.82	4.26	0.572	5.97	7.14	0.051	0	8.62	0.397

* significant

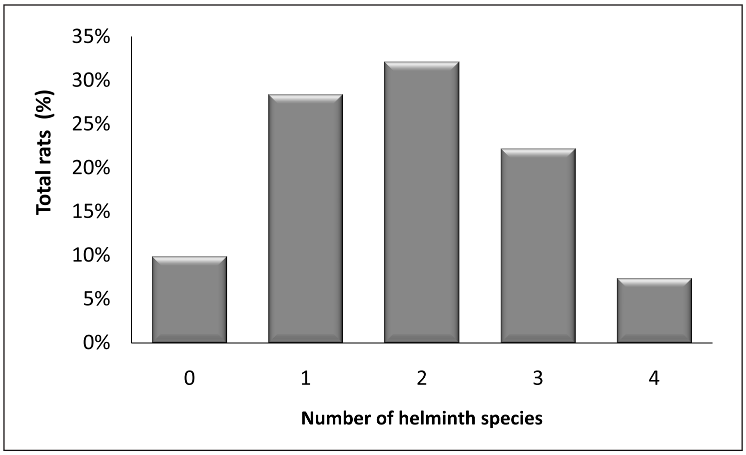

Figure 4. Frequency distribution of infracommunity richness of total helminth species in the rat population at Carey Island

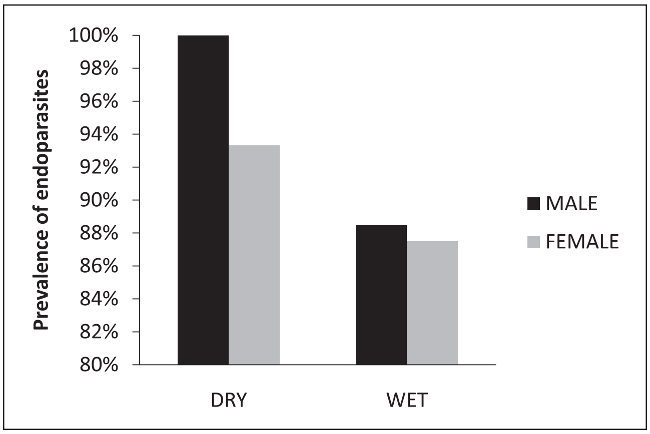

Figure 5. Prevalence of total endoparasites according to host sex and season in the rat population at Carey Island

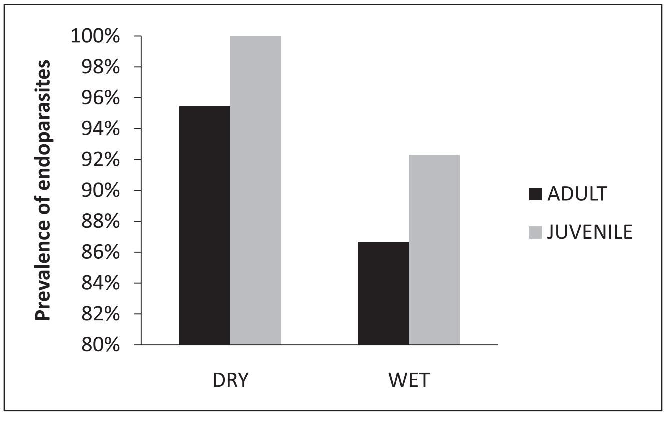

Figure 6. Prevalence of total endoparasites according to host age and season in the rat population at Carey Island

Table 5. Simpsons D Diversity Index value in each factor

Factors		Ectoparasites	Endoparasites
Host sex	Male	3.723	1.265
	Female	5.973	1.219
Host age	Adult	5.038	1.24
	Juvenile	4.206	1.228
Seasons	Dry	2.382	1.227
	Wet	4.306	1.241
Rat species	*R. tiomanicus*	4.634	1.124
	R. norvegicus	5.167	1.427
	R. rattus diardii	5.05	1.294
	R. argentiventer	3.469	1.473
Total population		4.94	1.239

minimum of one species and up to a maximum of four species with most having 2 species of infection (32.1%) (Fig. 4). A total of 8 helminth species were recovered consisting of 2 cestodes and 6 nematodes species (Table 3). Post-mortem examinations yielded 5,969 helminths, with abundance value of 81.8 endoparasites per infected rat. The following helminths species were recovered; *Nippostrongylus brasiliensis* (66.7%), *Heterakis spumosa* (55.6%), *Angiostrongylus malaysiensis* (14.8%), *Taenia taeniaformis* (16.1%), *Hymenolepis diminuta* (16.1%), *Mastophorus muris* (11.1%) and *Syphacia muris* (6.2%). The least prevalent helminth species was *Hepatojarakus malayae* (2.5%). *Nippostrongylus brasiliensis* was the most abundant with 65.94 per infected rat.

No statistically significant findings ($p >$ 0.05) were observed between host-sex, host-age and seasons in the prevalence of all helminths apart from *H. malayae* (Table 4). Although, infection was higher during the dry season (95.7%) compared to the wet (87.9%) with more males (91.2%) than females (89.4%) infected (Fig. 5) with slightly less number of adults (89.6%) were infected compared to juveniles (92.9%) (Fig. 6) Overall, the Simpson Overall Diversity Index showed low endoparasites diversity (1.24) with intrinsic (host-age and host-sex) and extrinsic (season) factors almost similar (Table 5).

DISCUSSION

There have been a substantial number studies on rat borne studies with emphasis on geographical and habitat distribution of the various rat species (Dhaliwal, 1961; Medway, 1966; Saharudin *et al.*, 1989). Observation of the wild rat population composition and structure have been reported from primary forest, plantations, islands and forest reserves from various locations in peninsular Malaysia (Chasen, 1933; Singh & Cheong, 1971; Yap *et al.*, 1977; Leong *et al.*, 1979; Sinniah, 1979; Zahedi *et al.*, 1984; Mohd Zain, 2008; Madinah *et al.*, 2011). In light of the severe and pervasive man-made environmental changes occurring throughout the landscape, continuous investigations into the country's present wild rat communites have become relevant.

The present rat population in Carey Island was represented by four commensal rat species, *R. tiomanicus*, *R. rattus diardii*, *R. argentiventer* and *R. norvegicus* with *R. tiomanicus*, the dominant species. Sinniah (1979) recorded higher number of rodents species with up to 9 species captured from various habitats including oil palm estates in peninsular Malaysia. However, dominance of *R. tiomanicus* was consistent with study by Krishnasamy *et al.* (1980) given that this rat species is commonly associated with scrub, secondary forest and plantations, particularly oil-palm estates (Ow-Yang, 1971). This large number of commensal rat is undoubtedly maintained by the continuous human activities, food supply and infrastructure in the surrounding area. Prior to this study, there are no records of *R. argentiventer* and *R.norvegicus* inhabiting oil palm plantation (Ow-Yang, 1971; Krishnasamy, 1980). This indicates that the two species are highly adaptable and able to establish in overlapping niches. The relatively small number of *R. norvegicus* was expected that the rat species are more commonly associated with coastal habitat (Harrison, 1957). The presence of *R. argentiventer* commonly found in cultivated areas such as rubber plantations, paddy fields and grassland also indicates that they expanded their niche and adapted well to thrive in this environment.

Similarly as reported by Krishnasamy *et al.* (1980), more female rats were captured compared to males, suggesting that females were more active in foraging for food. However, studies by Paramaswaran *et al.* (2005), Syed Arnez & Mohd Zain (2006), Mohd Zain (2008) and Mohd Zain *et al.* (2012) showed almost equal numbers between males and females captured highlighting the scavenging behaviour of commensal rats were independent from one another.

However, the lower success of trapping juveniles can be attributed to inherently limited activity and home range. It is also suggested that the greater number of adult rats generates imbalanced social competition, restricting the overall movement of the juveniles. Other findings with similar observations for host age were also reported by Paramaswaran *et al.* (2005), Syed Arnez & Mohd Zain (2006), Mohd Zain (2008) and Mohd Zain *et al.* (2012).

Despite, the overall low population diversity, the rodents were highly infested with ectoparasites contrary to studies by Nadchatram *et al.* (1966) and Paramasvaran *et al.* (2009b). The ectoparasites comprised of mainly cosmopolitan species and thought to be brought into the plantation with the migration of commensal rats. Two mite species, *L. nuttali* and *L. echidninus* were the most predominant and this result concurred with studies by Ho & Krishnasamy (1990) and Paramasvaran *et al.* (2009b). Among others, *O. bacoti* and *L. scuplturatus* were also recorded. *Ornithonyssus bacoti* is rarely found on Malaysian rats despite worldwide distribution and has been incriminated to cause pruritic dermatitis in man. The first authentic case of dermatitis caused by *O. bacoti* in Malaysia was reported by Nadchatram & Ramalingam (1974). Paramasvaran *et al.* (2009b) recorded both species on urban and forest rats while Zahedi *et al.* (1984) recovered only *O. bacoti* on one rat from Kuala Lumpur.

Present study notes the first recorded observation of *L. sculpturatus* on commensal rats from this site. *Laelaps sculpturatus* have been frequently recorded on wild rats from forest and wildlife reserves. This observation was consistent with the available information from previous studies (Domrow & Nadchatram, 1963; Ho & Krishnasamy, 1990; Mariana *et al.*, 2005, 2011; Paramasvaran *et al.*, 2009b; Madinah *et al.*, 2011).

The cosmopolitan lice, *P. spinulosa* and *H. pacifica* were the two common lice species recovered indicating the wide distribution of this ectoparasites among the rat population. Zahedi *et al.* (1984) found *P. spinulosa* infecting the rat populations of Ulu Klang while Paramasvaran *et al.* (2009b) reported this two species infesting urban rats. Similarly, Chuluun *et al.* (2005) reported the presence of 3 louse species namely, *Hoplopleura pectinata*, *P. spinulosa* and *H. pacifica*. Louse is known to be host specific (Shabrina, 1990) and considered to be of public health importance because they harbour zoonotic diseases such as plague bacilli and transmit tularemia and bartonellosis to humans and play an adjunctive role in the transmission of murine typus and plague from rat to rat (Zahedi *et al.*, 1984).

Ixodes granulatus, the most common tick species on rodents was also recorded here and concurred with previous studies (Audy *et al.*, 1960; Mariana *et al.*, 2005, 2008; Madinah *et a*l., 2011). Distribution of *I. granulatus* is known to extend from Malaysia to Southeast Asia, eastern India and China (Nadchatram, 2008).

In his study, Abu-Madi *et al.* (2001) showed intrinsic factor such as, season can attribute to the ectoparasite infestation where infestation was observed higher during the summer months. The warm and wet climate in Malaysia with no marked contrasting seasons comparable to those experienced in temperate climate countries could be the reason why this trend was not visible here. It was noted higher burdens were observed for *L. sculpturatus*, *P. spinulosa*, *H. pacifica* and *I. granulatus* during the wet season, a condition suitable for the survival of ectoparasites especially the mites and lice. Mites thrive in moist circumstances and are unable to survive for more than a few days in low humidity.

This study also did not find any strong independent effects of host sex and host age on the prevalence of ectoparasites although more females were observed infested compared to males.

The endoparasitic fauna of wild rodents have been well documented from various habitats ranging from primary forest to urban habitat, however, less well studied in island habitats (Yeh, 1955; Dunn *et al.*, 1968; Ow-Yang, 1971; Yap *et al.*, 1977; Sinniah, 1979; Krishnasamy *et al.*, 1980; Syed Arnez & Mohd Zain, 2006; Mohd Zain, 2008; Paramasvaran *et al.*, 2009a; Mohd Zain *et al.*, 2012).

Sinniah (1979) recorded 18 species of helminth infecting rats from various habitats which included an oil palm estate in comparison to only eight species identified in Carey Island. The helminth community here belonged to two groups; 2 cestodes (*T. teniaformis*, *H. diminuta*) and 6 nematodes (*N. brasiliensis*, *A. malaysiensis*, *M. muris*, *H. spumosa*, *S. muris* and *H. malayae*), all of which were cosmopolitan parasites suggesting that commensal species had established in the habitat. Despite similar number of helminth species recorded, the overall infection rate for the most dominant rat species, *R.tiomanicus* was 79.2%, much lower prevalence than that seen by Krishnasamy *et al.* (1980) at 94% indicating the infection level decreasing over the years.

The nematode, *N. brasiliensis* was the dominant helminth species in the rat population here as previously reported (Leong *et al.*, 1979; Syed Arnez & Mohd Zain, 2006, Mohd Zain, 2008; Paramasvaran *et al.*, 2009a). As most rats feed and live within the same area, infections can be easily maintained among the population. The presence of *H. spumosa* here indicated the ecological distribution of this parasite also extended to rats inhabiting oil palm plantation. High infestation of this species in rats may be due to their direct lifecycle which occurs relatively easier, conceivably also in a more consistent manner (Bellocq, 2003). The relatively high rainfall and humidity climate in Malaysia was suitable for the eggs to hatch before the infective larvae penetrated or were eaten by the host.

Infections of *A. malaysiensis*, *M. muris*, *H. malayae* and *S. muris* have also been recorded in commensal rats from other habitats in peninsular Malaysia (Leong *et al.*, 1979; Sinniah, 1979; Krishnansamy *et al.*, 1980; Ambu *et al.*, 1996; Paramasvaran *et al.*, 2005, 2009a; Syed Arnez & Mohd Zain, 2006; Mohd Zain *et al.*, 2012). The occurrence of *A. malaysiensis* in some rodents indicated a diet that includes the intermediate host snails. The presence of *S. muris* and *H. malayae* was also previously recorded by Singh & Cheong (1971) and Yeh (1955).

Parasmavaran *et al.* (2009) reported higher diversity with up to six cestodes species recovered from urban rats, namely *Hymenolepis nana*, *H. diminuta*, *Hymenolepis sabnema*, *Hymenolepis* sp., *Raillietina* sp. and *T. taeniaformis* of which *H. diminuta* and *T. taeniaformis* are known to be zoonotic in nature (Miyazaki, 1991) while only 2 species were recorded here (*T. taeniaformis* and *H. diminuta)*. While, Sinniah *et al.* (1978) reported infections of *H. diminuta* and *H. nana* from oil palm estate workers indicating transmission of the parasites from rats to human hosts. Rats are known to function as intermediate hosts for *T. taeniaformis* (Iwaki *et al.*, 1994) while *H. diminuta* infection depended on the ingestion of insect intermediate host to complete its lifecycle.

Consistent to previous studies, endo-parasite infections were found higher in males compared to female rats, (Mohd Zain *et al.*, 2012; Abu-Madi *et al.*, 2001). One possible explanation is that the male sex hormone has an immunodepressive effect on male rats (Ferrari *et al.*, 2004). Female host bias has been observed previously in Wertheim's study (1963).

Presently, more juvenile rats were heavily infected despite lower numbers captured suggesting that juveniles were actively foraging, thus increasing their exposure to infection. Neither intrinsic (seasonal) or extrinsic (host-age and sex) factors affected the helminth burdens significantly in the rodent population.

Carey Island is viewed as one of the islands which had been transformed into fully agricultural land over recent decades and constitutes a relatively small portion of the Malaysia cultural landscape, however the high rat numbers can often turn into serious pests by destroying the fruits and young trees. In line with better pest management practices, the macroparasitic community in rodents showed a decline in diversity and burden. However, long term monitoring is still necessary as *H.diminuta* still represent a health risk to the population nearby. Studies on the ecological demands and population dynamics of the present local wild rat populations have offered a glimpse of potentially beneficial application in the long-term conservation efforts, pest control and environmental impact assessments.

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