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A Study on Wild Rats and their Endoparasite Fauna from the Endau Rompin National Park, Johor

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ABSTRACT A survey of the Endau Rompin National Park's wild terrestrial rats and related helminth parasites was carried out to determine the current population and biodiversity. A total of 128 rats were trapped, identified and examined for endoparasites. Prevalence and mean abundance of different parasites were calculated. A total of eight rat species were identified, namely, *Leopoldamys sabanus, Maxomys rajah, Maxomys surifer, Maxomys whiteheadii, Rattus exulans, Rattus rattus diardii, Rattus tiomanicus* and *Sundamys muelleri*. Endoparasite fauna recovered from all rats consists of 23 nematode species (*Angiostrongylus malaysiensis, Capillaria hepatica, Cyclodonstomum purvisii*, Filarioidea fam. gen. sp., *Globocephalus connorfilii, Gongylonema neoplasticum, Heligmonoides bulbosus, Heterakis spumosa, Mastopharus muris, Macrostrongylus ratti, Malaystrongylus odontospicularis, Maxomystrongylus* sp., *Nippostrongylus brasiliensis, Orientostrongylus* sp., *Paraheligmonelloides* sp., Physalopteridae gen. sp., *Rattustrongylus odontoconus, Rattustrongylus rotundoconus, Reticularia tanii, Strongyloides ratti, Strongyloides venezuelensis, Subulara andersoni*, and *Syphacia muris*), three cestode species (*Hymenolepis diminuta, Rodentolepis nana* and *Taenia taeniaformis*), two trematode species (*Fibricola ramachandrani* and *Zonorchis* sp.) and one pentastomide species (*Armillifer moniliformis*). Overall prevalence was 90.63% with Heligmonellidae parasites being the dominant helminth. New rat hosts of several parasites were also identified. Changes in the types of parasites between the present survey and an earlier study of the same area are believed to have been caused by the intrusion of commensal rats, particularly *Rattus tiomanicus*, into the park. The current qualitative composition of rats and related endoparasites can be attributed to the ongoing human activities at the park. Therefore it is the aim of the present study to provide the much needed baseline data to design an appropriate programme for environmental monitoring and biomedical research within the park.

ABSTRAK Kajian mengenai tikus-tikus liar dan endoparasit yang berkaitan telah dijalankan di Taman Negara Endau Rompin bagi menentukan populasi dan kepelbagaian spesies semasa. Sebanyak 128 ekor tikus telah ditangkap, dikenalpasti dan diperiksa bagi menentukan kehadiran endoparasit. Kelaziman jangkitan dan purata individu endoparasit bagi keseluruhan populasi tikus ditentukan. Kehadiran lapan spesies tikus telah dikenalpasti, iaitu *Leopoldamys sabanus, Maxomys rajah, Maxomys surifer, Maxomys whiteheadii, Rattus exulans, Rattus rattus diardii, Rattus tiomanicus* and *Sundamys muelleri*. Spesies – spesies endoparasit yang ditemui terdiri daripada 23 spesies nematoda (*Angiostrongylus malaysiensis, Capillaria hepatica, Cyclodonstomum purvisii*, Filarioidea fam. gen. sp., *Globocephalus connorfilii, Gongylonema neoplasticum, Heligmonoides bulbosus, Heterakis spumosa, Mastopharus muris, Macrostrongylus ratti, Malaystrongylus odontospicularis, Maxomystrongylus* sp., *Nippostrongylus brasiliensis, Orientostrongylus* sp., *Paraheligmonelloides* sp., Physalopteridae gen. sp., *Rattustrongylus odontoconus, Rattustrongylus rotundoconus, Reticularia tanii, Strongyloides ratti, Strongyloides venezuelensis, Subulara andersoni*, and *Syphacia muris*), tiga spesies Cestoda (*Hymenolepis diminuta, Rodentolepis nana* and *Taenia taeniaformis*), dua speies Trematoda (*Fibricola ramachandrani* and *Zonorchis* sp.) and satu spesies Pentastomida (*Armillifer moniliformis*). Kelaziman keseluruhan adalah 90.63% dan parasit-parasit Heligmonellidae adalah helmin tikus yang paling dominan. Perumah-perumah baru bagi beberapa parasit turut dikenalpasti. Perubahan pada jenis endoparasit hasil kajian ini dan survey sebelumnya pada lokasi yang sama dipercayai disebabkan oleh kemunculan tikus-tikus komensal, khususnya *Rattus tiomanicus*. Komposisi populasi dan diversiti semasa tikus serta endoparasit berkait dipercayai dipengaruhi oleh aktiviti manusia sekitar hutan simpan ini. Oleh itu, kajian ini dilaksanakan

dengan tujuan menyediakan maklumat asas untuk membentuk program pemantauan persekitaran dan penyelidikan bioperubatan di hutan simpan ini.

(Endau Rompin, primary lowland forests, biodiversity, wild rats, rat helminths)

INTRODUCTION

The Endau Rompin National Park is located near the border of two states in Malaysia, Johor and Pahang, and is the second forest reserve in Peninsular Malaysia. The park was gazetted in 1993 and is managed by the Johor National Parks Corporation (JNPC). To reach Endau, travelers may begin their journey from Selai, the western part of the reserve. Travelers will then pass through rubber and oil palm plantations before arriving in Kampung Peta, a native peoples (Orang Asli) village. From there the journey would continue along hilly dirt tracks across dense jungle to reach Lubuk Tapah Base Camp, the designated area for park visitors. Lubuk Tapah is located near the confluence of the Jasin and Endau rivers.

Endau Rompin is home to many endangered animals such as the Sumatran rhinoceros, the binturong and the white-handed gibbon. Over the years, the park has attracted nature enthusiasts and researchers alike from all over the world. As human activities within the park steadily increase, there has also been a growing sense of concern if the natural environment of the park has been adversely affected.

In virgin forests such as Endau Rompin, the presence of commensal rats may be seen a direct result of the changes brought upon by unrestricted human activities within the area. Commensal rats are omnivorous terrestrial rodents that live in close proximity to humans. These characteristics are often shown in the rat's distinct endoparasite fauna.

The endoparasite fauna of wild terrestrial rats from primary forests habitats in Peninsular Malaysia has been well recorded [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14]. Prior studies have provided additional insights into the rats' habitat and behavior. Changes to the rat hosts' surroundings are often reflected in the rat endoparasites' diversity and population. Incidentally several rat-borne endoparasites are known to be capable of infecting humans. A collection of small vertebrates and their endoparasites from the vicinity of Ulu Endau have been described by Singh *et al* [1]. The study has provided a glimpse of the park's diverse wild rat and rat endoparasite populations. However, since then there have been no records of similar studies being carried out within the park.

In view of the increasing human activities in recent years, present study seeks to detect and highlight the changes that have occurred within the wild rat and related helminth endoparasite communities of the park. The objective of this study is to identify and catalogue the current population distribution and biodiversity of wild terrestrial rats and rat endoparasites from the Endau Rompin National Park. Present study aims to update and provide additional data on the parks' various rat and rat endoparasite species for future studies in environmental monitoring and biomedical research, essential for sustainable development in the country.

METHODOLOGY

Rat traps were placed within the vicinity of Lubuk Tapah. The present study categorizes the site as a disturbed primary lowland forest area, due to its high human activity. Trappings were concentrated around the base camp and the surrounding jungle. Logistical complications prevented larger and more varied trapping locations.

Trappings were divided into two phases. The first phase was conducted between September 2002 and October 2002, while the second phase was carried out from August 2004 to June 2005.

A total of 30 steel wire cage traps baited with oil palm fruits were set. Trappings were carried out in the span of four days and three nights. The traps were checked every morning and captured rats were collected.

The captured rats were then euthanized with chloroform and morphometric measurements of the head-body, tail, ear, hind foot and weight

were recorded. Each rat's age, sex and species were determined. Species identification was based on descriptions by Medway [15] and Payne and Francis [16].

Rats were sacrificed and selected organs, namely heart and lungs, stomach, small intestines, caecum and liver, were examined for endoparasites under a dissecting microscope. Endoparasites were collected, counted and preserved in 70% ethanol. Nematode specimens were examined in lactophenol in temporary mount. Trematode, cestode and pentastomid specimens were stained in paracarmine and mounted in Canada balsam. The microhabitat and intensity of each endoparasite species was recorded. The prevalence and mean abundance, as defined by Bush *et al*, were calculated and assessed [17].

RESULTS

A total of 128 wild terrestrial rats, consisting of four genus with eight different species, were successfully trapped, namely *Leopoldamys sabanus*, *Maxomys rajah*, *Maxomys surifer*, *Maxomys whiteheadii*, *Rattus exulans*, *Rattus rattus diardii*, *Rattus tiomanicus* and *Sundamys muelleri* (Figure 1). *Rattus tiomanicus* was the dominant rat species (42.19%), followed by *Maxomys rajah* (28.13%) and *Maxomys surifer* (8.59%).

The wild rat community was made up of commensal rats and forest rats. The commensal rats were *Rattus exulans, Rattus rattus diardii* and *Rattus tiomanicus* and the forest rats were *Leopoldamys sabanus, Maxomys rajah, Maxomys surifer, Maxomys whiteheadii* and *Sundamys muelleri*. The number of forest rats trapped (50.78%) was slightly higher than the commensal rats (49.22%).

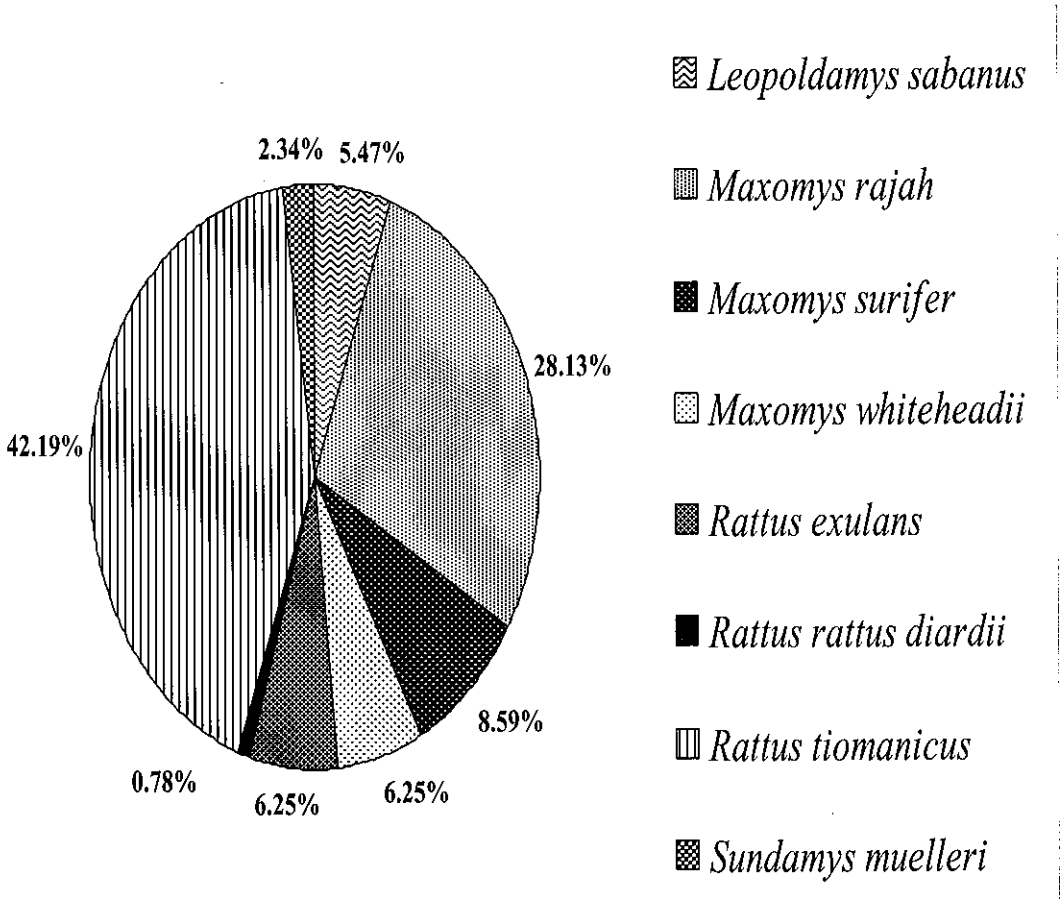

Figure 1. Wild Rat Population Distribution from the Endau Rompin National Park, Johor

From the total number of rats examined, 90.63% rats were found to be infected with endoparasites. Infection among forest rats (93.85%) was higher than the commensal rats (87.30%). All specimens of *Leopoldamys sabanus*, *Maxomys rajah* and *Maxomys surifer* were found infected (100%), as was 94.44% of *Rattus tiomanicus*, 66.67% of *Sundamys muelleri*, 62.5% of *Maxomys whiteheadii* and 50% of *Rattus exulans*. A single specimen of *Rattus rattus diardii* was free from infection.

The helminth fauna comprised of Nematoda, Cestoda, Trematoda and Pentastomida parasites. The nematodes were the most common endoparasites, comprised of 99.68% of the total helminths recovered, followed by trematodes (0.23%), cestodes (0.08%) and pentastomides (0.01%). Nematodes also exhibited the most widespread infection among the rat endoparasite groups, with a prevalence of 90.63%, followed by cestode (14.06%), trematode (4.69%) and pentastomide infections (1.56%).

Nematodes were mostly intestinal parasites and consisted of two strongyloidae species, one rictulariid species and plural species of Trichostrongyloidea parasites. Single species of Chabertiidae, Oxyuridae, Heterakidae, Subuluridae and Ancyclostomatidae were found in the caecum. Other nematodes included filarial worms and a metastrongyloid from the heart and lungs, a gongylonematid and a spirocercid from the stomach, Physalopteridae parasites from body cavities and *Capillaria hepatica* from the liver. Cestode fauna included adult forms of Hymenolepididae and a Taenidae cysticercus. Digeneans were strictly of the intestinal variety. Pentastomide nymphs were recovered from body cavities.

A sum of 12 species of nematodes [*Angiostrongylus (Parastrongylus) malaysiensis*, *Capillaria hepatica*, *Cyclodonstomum purvisii*, *Globocephalus connorfilii*, *Gongylonema neoplasticum*, *Heterakis spumosa*, *Mastopharus muris*, *Reticularia tanii*, *Strongyloides ratti*, *Strongyloides venezuelensis*, *Subulara andersoni* and *Syphacia muris*]; three species of cestodes [*Hymenolepis diminuta*, *Rodentolepis (Hymenolepis) nana* and *Taenia taeniaformis*], two species of trematodes (*Fibricola ramachandrani* and *Zonorchis* sp.) and one species of pentastomide (*Armillifer moniliformis*) were successfully identified. Nematodes from the Filarioidea fam. gen. sp. and Physalopteridae gen. sp. were also reported.

In addition, nine plural species of minute coiled nematodes from the family Heligmonellidae, identified as *Heligmonoides bulbosus*, *Malaystrongylus odontospicularis*, *Macrostrongylus ratti*, *Maxomystrongylus* sp., *Nippostrongylus brasiliensis*, *Orientostrongylus* sp., *Paraheligmonelloides* sp., *Rattustrongylus odontoconus* and *Rattustrongylus rotundoconus*, were also recovered. The microhabitat, intensity, prevalence and mean abundance of each rat endoparasite are summarized in Table 1.

A total of 42,645 helminth parasites were recovered in this study. Among the rat hosts, *Maxomys rajah* harbored the highest number of helminths (20,631 worms). The maximum number of parasites found in any single rat was 5,186 worms from *Maxomys surifer*. The mean number of helminths was 333.16 worms per rat. Heligmonellidae parasites dominated the overall rat endoparasite fauna with the highest intensity value, 34,538 worms in total. *Syphacia muris* and *Strongyloides* sp. showed high intensity as well, with 4,776 and 2,944 worms respectively. Heligmonellidae parasites also displayed the highest mean abundance, with an average of 269.83 $\pm$ 50.54 worms in the current rat population, followed by *Syphacia muris* (37. 31 $\pm$ 14.15) and *Strongyloides* sp. (23.0 $\pm$ 14.45) (Table 1).

Infections by Heligmonellidae parasites were the most prevalent, parasitizing 84.38% rats, followed by *Capillaria hepatica* (35.16%), *Strongyloides* sp. (22.66%) and *Syphacia muris* (19.53%). The prevalence of all other remaining endoparasite species was less than 10% (Table 1).

Table 1. The Microhabitats, Intensity, Prevalence and Mean Abundance of Different Rat Endoparasite Species from the Endau Rompin National Park, Johor

ENDOPARASITES	MICROHABITAT	INTENSITY	PREVALENCE	MEAN ABUNDANCE ± SE	RANGE
Nematode:					
Angiostrongylus malaysiensis	Heart and Lungs	41	7.03%	0.32 ± 0.17	0 - 20
*Capillaria hepatica**	Liver	-	35.16%	-	-
Cyclodonstomum purvisii	Caecum	8	1.56%	0.06 ± 0.06	0 - 7
Filaroidea fam. gen. sp.	Heart and Lungs	54	0.78%	0.42 ± 0.42	0 - 54
Gongylonema neoplasticum	Stomach Wall	25	5.47%	0.2 ± 0.08	0 - 6
Globocephalus connorfilii	Caecum	15	1.56%	0.12 ± 0.08	0 - 9
Heterakis spumosa	Caecum	20	4.69%	0.16 ± 0.09	0 - 10
Mastophorus muris	Stomach	9	6.25%	0.07 ± 0.03	0 - 2
Heligmonellidae gen. sp.	Small Intestines	34538	84.38%	269.83 ± 50.54	0 - 5124
Physalopteridae gen. sp.	Body Cavities	14	3.91%	0.11 ± 0.05	0 - 4
Reticularia tanii	Small Intestines	14	7.03%	0.11 ± 0.04	0 - 3
Strongyloides sp.	Small Intestines	2944	22.66%	23.0 ± 14.45	0 - 1804
Subulura andersoni	Caecum	52	4.69%	0.41 ± 0.23	0 - 26
Syphacia muris	Caecum	4776	19.53%	37.31 ± 14.15	0 - 968

SE = Standard error

* No intact worms were retrieved

Table 1. The Microhabitats, Intensity, Prevalence and Mean Abundance of Different Rat Endoparasite Species from the Endau Rompin National Park, Johor (continued)

ENDOPARASITES	MICROHABITAT	INTENSITY	PREVALENCE	MEAN ABUNDANCE ± SE	RANGE
Cestode:					
Hymenolepis dimunita	Small Intestines	8	3.13%	0.06 ± 0.03	0 - 3
Rodentolepis nana	Small Intestines	14	3.91%	0.11 ± 0.06	0 - 5
Taenia taeniaformis	Liver	14	7.81%	0.11 ± 0.04	0 - 2
Trematode:					
Fibricola ramachandrani	Small Intestines	92	3.13%	0.72 ± 0.47	0 - 56
Zonorchis sp.	Small Intestines	5	1.56%	0.04 ± 0.03	0 - 4
Pentastomide					
Armillifer moniliformis	Body Cavities	2	1.56%	0.02 ± 0.01	0 - 1

SE = Standard error

* No intact worms were retrieved

Table 2 encapsulates the prevalence and distribution of each endoparasite infection in different rat species. The rats had a mean number of 2.26 ± 0.14 different endoparasites per rat and a range of 0 - 8 species. More than 60% of rat hosts harboured 2 - 8 species. *Rattus tiomanicus* showed the greatest endoparasite diversity, harbouring 13 different endoparasites from all four helminth groups, while *Sundamys muelleri* harboured the least (Table 2). However, collectively, forest rats showed greater endoparasitic diversity with 17 different helminth communities.

Maxomys surifer harbored the highest nematode diversity while *Leopoldamys sabanus* showed the least (Table 2). All three cestode species were found in *Rattus tiomanicus* but were absent in *Maxomys whiteheadii* and *Sundamys muelleri.* Digeneans were found in three rat species while the pentastomide *Armillifer moniliformis* was observed in only two host species.

A total of 10 endoparasites were recovered in both forest and commensal hosts: *Capillaria hepatica*, *Heterakis spumosa*, *Mastophorus muris*, Heligmonellidae parasites, *Strongyloides* sp., *Syphacia muris, Hymenolepis dimunita*, *Rodentolepis nana*, *Taenia taeniaformis* and *Armillifer moniliformis* (Table 2). On the other hand, six species (*Cyclodonstomum purvisii*, *Globocephalus connorfillii*, Physalopteridae parasites, *Reticularia tanii, Subulura andersoni* and *Zonorchis* species) were found exclusively in forest rats. *Angiostrongylus malaysiensis*, *Gongylonema neoplasticum*, Filarioidea parasites and *Fibricola ramachandrani* were restricted to commensal rats.

Heligmonellidae parasites were found to be present in all infected rats. All *Leopoldamys sabanus*, *Maxomys rajah* and *Maxomys surifer* were found infected, followed by 83.33% of *Rattus tiomanicus*, 62.5% of *Maxomys whiteheadii*, 62.5% of *Sundamys muelleri* and 25.0% of *Rattus exulans* (Table 2). *Capillaria hepatica*, *Strongyloides* sp., *Syphacia muris* and *Taenia taeniaformis* were not specific in host selection. In contrast, the intestinal helminths *Globocephalus connorfilii* and *Fibricola ramachandrani* were only recorded in one host species, *Leopoldamys sabanus* and *Rattus tiomanicus* respectively.

The commensal rats of *Rattus exulans* and *Rattus tiomanicus* had similar endoparasite distribution patterns. Several endoparasite infections were common in both rats (*Angiostrongylus malaysiensis*, *Capillaria hepatica*, *Gongylonema neoplasticum, Mastophorus muris,* Heligmonellidae parasites, *Strongyloides* sp. and *Taenia taeniaformis*) (Table 2). Similarly, the forest rat species of *Maxomys rajah* and *Maxomys surifer* also showed corresponding endoparasite infections such as *Capillaria hepatica*, *Heterakis spumosa,* Heligmonellidae parasites, Physalopteridae parasites, *Reticularia tanii, Strongyloides* sp., *Subulura andersoni, Syphacia muris* and *Taenia taeniaformis.* Two parasite species, *Capillaria hepatica* and *Strongyloides* sp., were seen parasitizing all forest rats with the exception of *Leopoldamys sabanus*.

Table 2. Rat Endoparasite Prevalence, Mean Abundance, Standard Error and Distribution of Each Wild Rats Species from the Endau Rompin National Park, Johor

NO	ENDOPARASITES		FOREST RATS					COMMENSAL RATS		
			Leopoldamys sabanus	*Maxomys rajah*	*Maxomys surifer*	*Maxomys whiteheadii*	*Sundamys muelleri*	*Rattus exulans*	*Rattus rattus diardii*	*Rattus tiomanicus*
	Nematode:									
1	*Angiostrongylus malaysiensis*	P	-	-	-	-	-	25.00	-	12.96
		MA ± SE						0.25 ± 0.16		0.72 ± 0.40
2	*Capillaria hepatica**	P	-	30.56	36.36	25.00	33.33	37.50	-	44.44
		MA ± SE		-	-	-	-	-		-
3	*Cyclodonstomum purvisii*	P	-	-	-	12.50	33.33	-	-	-
		MA ± SE				0.13 ± 0.13	2.33 ± 2.33			
4	Filarioidea fam. gen. sp.	P	-	-	0.78	-	-	-	-	-
		MA ± SE			4.91 ± 4.91					
5	*Gongylonema neoplasticum*	P	-	-	-	-	-	12.50	-	11.11
		MA ± SE						0.13 ± 0.13		0.44 ± 0.18
6	*Globocephalus connorfilii*	P	28.57	-	-	-	-	-	-	-
		MA ± SE	2.14 + 1.42							

P = Prevalence, MA = Mean Abundance, SE = Standard Error * No intact worms were retrieved

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Table 2. Rat Endoparasite Prevalence, Mean Abundance, Standard Error and Distribution of Each Wild Rats Species from the Endau Rompin National Park (continued)

NO	ENDOPARASITES		FOREST RATS					COMMENSAL RATS		
			Leopoldamys sabanus	*Maxomys rajah*	*Maxomys surifer*	*Maxomys whiteheadii*	*Sundamys muelleri*	*Rattus exulans*	*Rattus rattus diardii*	*Rattus tiomanicus*
7	Heligmonellidae gen. sp.	P	100.00	100.00	100.00	62.50	66.67	25.00	-	83.33
		MA ± SE	147.86 ± 41.56	499.83 ± 91.20	803.27 ± 438.24	173.88 ± 94.31	26.33 ± 18.91	22.88 ± 16.57		92.96 ± 24.27
8	*Heterakis spumosa*	P	-	2.78	18.18	12.50	-	-	-	3.70
		MA ± SE		0.28 ± 0.28	0.36 ± 0.27	0.13 ± 0.13				0.09 ± 0.07
9	*Mastophorus muris*	P	14.29	-	-	-	-	25.00	-	9.26
		MA ± SE	0.14 ± 0.14					0.25 ± 0.16		0.11 ± 0.05
10	Physalopteridae gen. sp.	P	-	11.11	9.09	-	-	-	-	-
		MA ± SE		0.31 ± 0.16	0.27 ± 0.27					
11	*Reticularia tanii*	P	-	16.67	27.27	-	-	-	-	-
		MA ± SE		0.25 ± 0.11	0.45 ± 0.28					
12	*Strongyloides* sp.	P	-	2.78	9.09	12.50	33.33	25.00	-	40.74
		MA ± SE		7.56 ± 7.56	0.09 ± 0.09	1.63 ± 1.63	1.0 ± 1.0	0.25 ± 0.16		50.67 ± 33.73
13	*Subulura andersoni*	P	-	11.11	18.18	-	-	-	-	-
		MA ± SE		1.0 ± 1.21	1.45 ± 0.98					

P = Prevalence, MA = Mean Abundance, SE = Standard Error * No intact worms were retrieved

Table 2. Rat Endoparasite Prevalence, Mean Abundance, Standard Error and Distribution of Each Wild Rats Species from the Endau Rompin National Park (continued)

NO	ENDOPARASITES		FOREST RATS					COMMENSAL RATS		
			Leopoldamys sabanus	*Maxomys rajah*	*Maxomys surifer*	*Maxomys whiteheadii*	*Sundamys muelleri*	*Rattus exulans*	*Rattus rattus diardii*	*Rattus tiomanicus*
14	*Syphacia muris*	P	-	25.00	36.36	-	33.33	-	-	20.37
		MA ± SE		63.50 ± 35.51	75.18 ± 69.0		5.33 ± 5.33			30.5 ± 19.29
	Cestode:									
15	*Hymenolepis dimunita*	P	28.57	2.78	-	-	-	-	-	1.85
		MA ± SE	0.71 ± 0.47	0.28 + 0.28						0.04 ± 0.04
16	*Rodentolepis nana*	P	14.29	-	9.09	-	-	-	-	5.56
		MA + SE	0.71 + 0.71		0.09 + 0.09					0.15 + 0.1
17	*Taenia taeniaformis*	P	-	13.89	18.18	-	-	12.50	-	3.70
		MA + SE		0.22 + 0.1	0.18 + 0.12			0.13 + 0.13		0.56 + 0.04
	Trematode:									
18	*Fibricola ramachandrani*	P	-	-	-	-	-	-	-	7.41
		MA + SE								1.7 + 1.11
19	*Zonorchis sp.*	P	14.29	2.78	-	-	-	-	-	-
		MA + SE	0.14 + 0.14	0.11 + 0.11						

P = Prevalence, MA = Mean Abundance, SE = Standard Error * No intact worms were retrieved

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Table 2. Rat Endoparasite Prevalence, Mean Abundance, Standard Error and Distribution of Each Wild Rats Species from the Endau Rompin National Park (continued)

NO	ENDOPARASITES		FOREST RATS					COMMENSAL RATS		
			Leopoldamys sabanus	*Maxomys rajah*	*Maxomys surifer*	*Maxomys whiteheadii*	*Sundamys muelleri*	*Rattus exulans*	*Rattus rattus diardii*	*Rattus tiomanicus*
	Pentastomide:									
20	*Armillifer moniliformis*	P	-	-	-	12.50	-	-	-	1.85
		MA + SE				0.13 + 0.13				0.02 + 0.02

P = Prevalence, MA = Mean Abundance, SE = Standard Error * No intact worms were retrieved

DISCUSSIONS

An in-depth review of available reports on wild rats and their endoparasites from lowland primary forest habitats in Peninsular Malaysia was conducted and findings of each study were compared [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14]. Table 3 summarizes the results of the present study and of related surveys. Special attention was given to an earlier survey of small vertebrates and their endoparasites from the rainforests of Endau by Singh *et al.* (1987) [1]. The wild terrestrial rat and rat endoparasite population from the Endau Rompin National Park in 2002 - 2005 was found to be higher and more diverse compared to the prior observation.

A total of 8 rat species were trapped, with 5 new species recorded (*Maxomys surifer, Maxomys whiteheadii, Rattus exulans, Rattus rattus diardii* and *Rattus tiomanicus*). Present study also notes 20 new records of rat endoparasites from the site, namely 17 nematodes species (*Angiostrongylus malaysiensis*, *Capillaria hepatica*, *Cyclodonstomum purvisii*, *Globocephalus connorfilii*, *Gongylonema neoplasticum*, *Heterakis spumosa*, *Macrostrongylus ratti*, *Maxomystrongylus* sp., *Nippostrongylus brasiliensis*, *Orientostrongylus* sp., *Paraheligmonelloides* sp., Physalopteridae parasites, *Rattustrongylus odontoconus*, *Rattustrongylus rotundoconus*, *Reticularia tanii*, *Strongyloides ratti*, *Strongyloides venezuelensis* and *Syphacia muris*) one cestode species (*Rodentolepis nana*) and one trematode species (*Fibricola ramachandrani*). The emergence of commensal rats and cosmopolitan endoparasites in the park suggests that significant changes had occurred in the time between prior and present study.

Results of the earlier survey did not detect the presence of commensal rats [1]. However, present study found a significant number of commensal rats, particularly *Rattus tiomanicus* (42.19%), living in the area. These rats may have originated from the nearby Orang Asli village and/or the oil palm and rubber plantations. The invasion and dispersion of commensal rats were likely to have been facilitated and maintained by the ongoing human activities in the park.

Preceding survey reported the infections of *Breinlia* sp., *Heligmonoides* sp., *Hepatojarakus malayae*, *Malaistrongylus* sp., *Mastophorus* sp., *Subulura* sp., *Zonorchis* sp. and *Hymenolepis dimunita* from three forest rat species [1]. The sudden emergence of endoparasites previously not observed in the area appears to have coincided with the abrupt arrival of commensal rats into the forest reserve. The rapid transmission rate of some of these endoparasites seemed to indicate their high adaptability. The notable absence of *Hepatojarakus malayae* in present study was attributed to its low occurrence in the area, as shown from the previous survey [1].

Infections of *Angiostrongylus malaysiensis*, *Capillaria hepatica*, *Gongylonema neoplasticum*, *Heterakis spumosa*, *Strongyloides* sp., *Syphacia muris* and *Rodentolepis nana* in commensal rats have been well recorded in other habitats from Peninsular Malaysia [13, 18, 19, 20, 21]. It seemed very likely that these parasites were brought into the park together with the invading commensal rats. Several studies have suggested that certain widespread cosmopolitan parasites species such as *Capillaria hepatica*, *Heterakis spumosa* and *Hymenolepis dimunita* are flexible enough to persist in their original hosts whilst moving with them into new localities [22, 23, 24].

Rattus tiomanicus was the dominant rat species and exhibited the greatest endoparasite diversity, as well as a relatively high prevalence and overall worm burden (Figure 1 and Table 2). It is highly probable that *Rattus tiomanicus* was primarily responsible for influencing and altering the diversity and incidence of the natural rat endoparasite community. The flexible lifestyle of these rats would have enabled them to thrive in the area, while at the same time maintaining and transmitting a distinct and highly adaptive cosmopolitan endoparasites community. The gregarious nesting habits of *Rattus tiomanicus* may have resulted in the contamination of soil and water with eggs/ infective stage helminths and transmission were thought to have mainly occurred through ingestion.

There have been indications that endoparasites originally found in forest rats are also capable of infecting the newly arrived commensal rats. Such a case was seen in the trematode *Fibricola ramachandrani*, previously recorded only in forest rats [11, 12], presently found parasitizing *Rattus tiomanicus* (Table 2). The omnivorous diet and foraging behavior of commensal rats may have exposed them to a variety of endoparasites

and consequently account for the high prevalence and great diversity presently observed.

Half of the total endoparasites species encountered in the present study were retrieved from both commensal and forest rats (Table 2). These observations suggest that a degree of interaction may exist between the two groups and may have further facilitated endoparasite transmissions. Similar widespread infections in other habitats [13, 18, 19, 20, 21] seemed to substantiate indications that some these helminths are highly adaptable and their transmission can occur easily.

Angiostrongylus malaysiensis, *Cyclodonstomum purvisii*, *Fibricola ramachandrani*, Filaroidea parasites, *Gongylonema neoplasticum*, Physalopteridae parasites, *Reticularia tanii*, *Subulura andersoni* and *Zonorchis* species were found in only one of the two rat groups (Table 2). Despite indications of active endoparasitic transmission between forest and commensal rats, these parasites appear to maintain a certain degree of host specificity. Filaroidea parasites and *Fibricola ramachandrani*, in particular, was presently observed in only one rat species. The presence of helminths in specific rat hosts implicitly reflects the differences in the diet and behavior of individual rat species [25, 26].

Heligmonellidae parasites were observed to have a very broad host range (Table 2). This feature seemed to be a characteristic trait for these parasites as several studies have reported similar observations [1, 2, 4, 13, 18, 19, 20, 21]. In contrast, *Globocephalus connorfilli* have only been reported from *Leopoldamys sabanus*, suggesting a highly specific host-parasite relationship.

Present investigations have provided new insights into the host range of rat helminths from lowland primary forest habitats. *Maxomys surifer*, *Maxomys rajah*, *Maxomys whiteheadii*, *Leopoldamys sabanus* and *Rattus tiomanicus* were described as new hosts for several endoparasites (Table 3). Infections of other rat species by previously observed parasites from the area were also reported. Of particular interest were *Heterakis spumosa*, *Rodentolepis nana* and *Taenia taeniaformis* infections in forest rats. There have been no prior observations of *Heterakis spumosa* from forest habitats, while *Rodentolepis nana* and *Taenia taeniaformis* have only been reported in commensal rats from a developed rainforest area [4].

Significant patterns were detected in endoparasite distribution of commensal and forest rats. Parallel endoparasite infection was seen between the two infected commensal rats, whereby all helminths found in *Rattus exulans* were also observed in *Rattus tiomanicus* (Table 2). This indicates that these rats have similar food preferences and/or may share a common source of infection. Similar patterns were also seen between endoparasite communities of *Maxomys rajah* and *Maxomys surifer*. However, in general, the forest rats did not explicitly show any comparable trends within their endoparasitic fauna, implying different forest rat species have distinct and separate lifestyles.

The high overall prevalence of endoparasite infection among forest rats was unexpected. Prevalence of natural endoparasite infections among forest rats is usually found to be low due to the forest rats' wide home range, small population and solitary nesting habits [25, 27, 28]. Given that in the prior study of the area, the occurrence of rat endoparasites was relative low, it seemed clear that the high prevalence presently observed was caused by the invasion of cosmopolitan parasites. The possibility exists that with the influx of the cosmopolitan parasites, the general immunity among forest rats was compromised to a certain extent, enabling a rapid and widespread general parasitic infection across the rat population of the area.

High prevalence of Heligmonellidae parasites, *Capillaria hepatica*, *Stongyloides* sp. and *Syphacia muris* further substantiate their high adaptability and rapid transmission rate among the rat population (Table 1). Filaroidea parasites, *Cyclodonstomum purvisii*, *Globocephalus connorfilii*, and *Zonorchis* sp., on the other hand, had the lowest overall prevalence, indicating limited distribution and high host specificity. Low infection of *Armillifer moniliformis* among the rat population is not unusual as the pentastomide is capable of utilizing a wide range of animals as intermediate hosts.

The presence of several endoparasite species reflects the diet and food intake of their rat hosts [25, 26]. The occurrence of *Angiostrongylus malaysiensis* in commensal rats indicated a diet that includes snails [29, 30], while the presence

of *Gongylonema neoplasticum*, *Hymenolepis dimunita*, *Rodentolepis nana* and *Subulura andersoni* suggests the intake of intermediate insect hosts [1, 9, 10, 31]. The present study seemed to support the findings of Lim (1970) that *Sundamys muelleri* consumes relatively few insects, as shown by the absence of cestode infection, and that *Leopoldamys sabanus* included more fruits and vegetables in their diet, as indicated by the low endoparasite diversity [26].

Wild rats may also be a source of endoparasitic infection for other animals. Rats are known to function as intermediate hosts for *Taenia taeniaformis* and *Armillifer moniliformis* [1, 2, 13, 14] while *Capillaria hepatica* can be transmitted to other animals through consumption of infected liver [5, 32]. Future investigations into the endoparasite fauna of local animals such as wild cats, rodents, snakes and primates may reveal the intricate dispersal of rat parasites in various other hosts.

The earlier survey of the Endau Rompin National Park reported the occurrence of *Taenia taeniaformis* and *Armillifer moniliformis* in tree shrews, *Tupaia glis*, and *Brenlia* sp. and *Subulura* sp. in ground squirrels, *Rhinosciurus laticaudatus* (Table 3) [1]. These findings appeared to corroborate the involvement of other rodents in several rat endoparasites lifecycles. It also seemed likely that active interactions between the different rodent species may have further facilitated the transmission of rat endoparasites within the park. The presence of rat endoparasites in other animals also supports earlier indications of these parasites' high adaptability and broad host range.

The present study was unable to determine the exact population distribution and prevalence of each plural species of the Heligmonellidae family due to the various concurrent infections that occur between them. Similar difficulties were also encountered in distinguishing *Strongyloides ratti* and *Strongyloides venezuelensis*. The absence of intact specimens of *Capillaria hepatica* prevented further analysis. Future investigations must therefore give special attention in determining the presence of these endoparasites to avoid inaccurate identification.

More detailed investigations should be initiated in order to ascertain the changes in the park's rat and rat endoparasite populations, the possible role of commensal rats as the source of these changes and the effects of ongoing human activities in the area. The information from such studies may facilitate future efforts in protecting and maintaining the integrity of the park's unique ecosystem and animal diversity.

Table 3. Summary of Findings from Present and Prior Studies in Endoparsite Fauna of Wild Terrestrial Rats from Lowland Forest Habitats

NO	ENDOPARASITE	PRESENT STUDY HOSTS	PRIOR STUDY [1]	OTHER STUDIES FROM SIMILAR HABITATS	REMARKS
1	*Angiostrongylus malaysiensis*	*Rattus exulans* *Rattus tiomanicus*	Not present	1. *Rattus tiomanicus* and *Leopoldamys sabanus* [2] 2. *Maxomys surifer, Maxomys whiteheadii, Sundamys muelleri* [3] 3. *Rattus exulans* and *Rattus tiomanicus* [4]	New geographical distribution record
2	*Capillaria hepatica*	*Maxomys rajah* *Maxomys surifer* *Maxomys whiteheadii* *Rattus exulans* *Rattus tiomanicus* *Sundamys muelleri*	Not present	1. *Rattus tiomanicus, Sundamys muelleri, Maxomys rajah, Leopoldamys sabanus* and *Maxomys whiteadii* [2] 2. *Leopoldamys sabanus, Maxomys rajah, Maxomys surifer, Maxomys whiteheadii, Sundamys muelleri* [5]	New geographical distribution record
3	*Cyclodonstomum purvisii*	*Maxomys whiteheadii* *Sundamys muelleri*	Not present	1. *Leopoldamys sabanus* and *Sundamys muelleri* [6] 2. *Leopoldamys sabanus, Maxomys rajah, Maxomys whiteheadii* and *Sundamys muelleri* [2]	New geographical distribution record
4	Filarioidea fam. gen. sp.	*Maxomys surifer*	*Breinlia* sp. (Filaroidea: Onchocercidae) in *Leopoldamys sabanus, Rhinosciurus laticaudatus* and *Tupaia glis*	1. *Breinlia* sp. in *Leopoldamys sabanus, Rattus tiomanicus* and *Sundamys muelleri* [2] 2. *Breinlia* sp. in *Leopoldamys sabanus* [7] 3. *Dunnifilaria ramachandrani* in *Leopoldamys sabanus* [8]	Species presently undetermined

Table 3. Summary of Findings from Present and Prior Studies in Endoparsite Fauna of Wild Terrestrial Rats from Lowland Forest Habitats (continued)

NO	ENDOPARASITE	PRESENT STUDY HOSTS	PRIOR STUDY [1]	OTHER STUDIES FROM SIMILAR HABITATS	REMARKS
5	*Gongylonema neoplasticum*	*Rattus exulans* *Rattus tiomanicus*	Not present	1. *Rattus tiomanicus* [2] 2. *Rattus exulans* and *Rattus tiomanicus* [4]	New geographical distribution record
6	*Globocephalus connorfilii*	*Leopoldamys sabanus*	Not present	1. *Leopoldamys sabanus* [2]	New geographical distribution record
7	Heligmonellidae gen. sp.	*Leopoldamys sabanus* *Maxomys rajah* *Maxomys surifer* *Maxomys whiteheadii* *Rattus exulans* *Rattus tiomanicus* *Sundamys muelleri*	*Heligmonoides* sp. in *Leopoldamys sabanus* *Malaistrongylus* sp. in *Maxomys rajah*	1. *Nippostrongylus brasiliensis* in *Leopoldamys sabanus, Maxomys rajah, Maxomys whiteheadii, Rattus tiomanicus* and *Sundamys muelleri* [2] 2. *Nippostrongylus muris* in *Rattus tiomanicus* [4]	New geographical distribution record (*Macrostrongylus ratti, Maxomystrongylus sp., Nippostrongylus brasiliensis, Orientostrongylus sp., Paraheligmonelloides* sp., *Rattustrongylus odontoconus* and *Rattustrongylus rotundoconus*)
8	*Heterakis spumosa*	*Maxomys rajah* *Maxomys surifer* *Maxomys whiteheadii* *Rattus tiomanicus*	Not present	No records	New geographical distribution record New hosts record (*Maxomys surifer* and *Maxomys whiteheadii*)
9	*Mastophorus muris*	*Leopoldamys sabanus* *Rattus exulans* *Rattus tiomanicus*	*Mastophorus* sp. in *Leopoldamys sabanus*	1. *Leopoldamys sabanus, Maxomys rajah, Maxomys whiteheadii,* *Rattus tiomanicus* and *Sundamys muelleri* [2]	

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Table 3. Summary of Findings from Present and Prior Studies in Endoparsite Fauna of Wild Terrestrial Rats from Lowland Forest Habitats (continued)

NO	ENDOPARASITE	PRESENT STUDY HOSTS	PRIOR STUDY [1]	OTHER STUDIES FROM SIMILAR HABITATS	REMARKS
10	Physalopteridae gen. sp.	*Maxomys rajah* *Maxomys surifer*	Not present	1. *Leopoldamys sabanus, Maxomys rajah, Maxomys whiteheadii,* *Rattus tiomanicus* and *Sundamys muelleri* [2] 2. *Rattus rattus diardii* [9]	Species presently undetermined New geographical distribution record
11	*Reticularia tanii*	*Maxomys rajah* *Maxomys surifer*	Not present	1. *Leopoldamys sabanus, Maxomys rajah, Maxomys surifer,* *Rattus tiomanicus* and *Sundamys muelleri* [2]	New geographical distribution record
12	*Strongyloides* sp.	*Maxomys rajah* *Maxomys surifer* *Maxomys whiteheadii* *Rattus exulans* *Rattus tiomanicus* *Sundamys muelleri*	Not present	1. *Strongyloides ratti* in *Maxomys whiteheadii, Rattus tiomanicus* and *Sundamys muelleri* [10] 2. *Strongyloides ratti* in *Rattus tiomanicus* [2] 3. *Strongyloides ratti* in *Rattus exulans* [4]	New geographical distribution record New host record (*Strongyloides ratti* in *Maxomys rajah and Maxomys surifer*) New host record (*Strongyloides* sp. in *Maxomys rajah, Maxomys surifer, Maxomys whiteheadii. Rattus exulans, Rattus tiomanicus* and *Sundamys muelleri*).
13	*Subulura andersoni*	*Maxomys rajah* *Maxomys surifer*	*Subulura andersoni* in *Rhinosciurus insignis* *Subulura* sp. in *Sundamys muelleri*	1. *Leopoldamys sabanus* [10]	New hosts record (*Maxomys rajah* and *Maxomys surifer*)
14	*Syphacia muris*	*Maxomys rajah* *Maxomys surifer* *Sundamys muelleri* *Rattus tiomanicus*	Not present	1. *Sundamys muelleri* [10] 2. *Leopoldamys sabanus* [2] 3. *Rattus tiomanicus* [4] 4. *Rattus exulans* [9]	New geographical distribution record New hosts record (*Maxomys surifer*)

Table 3. Summary of Findings from Present and Prior Studies in Endoparsite Fauna of Wild Terrestrial Rats from Lowland Forest Habitats (continued)

NO	ENDOPARASITE	PRESENT STUDY HOSTS	PRIOR STUDY [1]	OTHER STUDIES FROM SIMILAR HABITATS	REMARKS
15	*Hymenolepis dimunita*	*Leopoldamys sabanus* *Maxomys rajah* *Rattus tiomanicus*	*Leopoldamys sabanus*	1. *Rattus tiomanicus* [4]	-
16	*Rodentolepis nana*	*Leopoldamys sabanus* *Maxomys surifer* *Rattus tiomanicus*	Not present	1. *Rattus tiomanicus* [9]	New geographical distribution record New hosts (*Leopoldamys sabanus* and *Maxomys surifer*)
17	*Taenia taeniaformis*	*Maxomys rajah* *Maxomys surifer* *Rattus exulans* *Rattus tiomanicus*	*Tupaia glis*	1. *Rattus tiomanicus* [4]	New hosts (*Maxomys rajah* and *Maxomys surifer*)
18	*Fibricola ramachandrani*	*Rattus tiomanicus*	Not present	1. *Sundamys muelleri* [11] 2. *Maxomys whiteheadii* and *Sundamys muelleri* [12]	New geographical distribution record New host (*Rattus tiomanicus*)
19	*Zonorchis* sp.	*Leopoldamys sabanus* *Maxomys rajah*	*Zonorchis* sp. in *Leopoldamys sabanus*	1. *Zonorchis* sp. in *Leopoldamys sabanus* [13]	New host (*Maxomys rajah*)
20	*Armillifer moniliformis*	*Maxomys whiteheadii* *Rattus tiomanicus*	*Tupaia glis*	1. *Leopoldamys sabanus, Maxomys rajah, Maxomys surifer, Maxomys whiteheadii* and *Rattus tiomanicus* [14]	-

CONCLUSION AND SUMMARY

A survey of the Endau Rompin National Park's wild terrestrial rats and rat helminths was carried out to determine the current population and biodiversity. The aim of the present study is to provide the baseline data that would be useful in designing appropriate programmes for environmental monitoring and biomedical research within the park.

The current wild terrestrial rat community consists of forest rats (*Leopoldamys sabanus, Maxomys rajah, Maxomys surifer, Maxomys whiteheadii,* and *Sundamys muelleri*) and commensal rats (*Rattus exulans, Rattus rattus diardii, Rattus tiomanicus*). 5 new species were recorded (*Maxomys surifer, Maxomys whiteheadii, Rattus exulans, Rattus rattus diardii* and *Rattus tiomanicus*). Forest rat population was higher than the commensal rat population.

Endoparasite fauna recovered from all rats consists of 23 nematode species (*Angiostrongylus malaysiensis, Capillaria hepatica, Cyclodonstomum purvisii*, Filarioidea fam. gen. sp., *Globocephalus connorfilii, Gongylonema neoplasticum, Heligmonoides bulbosus, Heterakis spumosa, Mastopharus muris, Macrostrongylus ratti, Malaystrongylus odontospicularis, Maxomystrongylus* sp., *Nippostrongylus brasiliensis, Orientostrongylus* sp., *Paraheligmonelloides* sp., Physalopteridae gen. sp., *Rattustrongylus odontoconus, Rattustrongylus rotundoconus, Reticularia tanii, Strongyloides ratti, Strongyloides* sp., *Subulara andersoni*, and *Syphacia muris*), three cestode species (*Hymenolepis diminuta, Rodentolepis nana* and *Taenia taeniaformis*), two trematode species (*Fibricola ramachandrani* and *Zonorchis* sp.) and one pentastomide species (*Armillifer moniliformis*).

Of these, 20 rat endoparasites were new records, namely 17 nematodes species (*Angiostrongylus malaysiensis, Capillaria hepatica, Cyclodonstomum purvisii, Globocephalus connorfilii, Gongylonema neoplasticum, Heterakis spumosa, Macrostrongylus* sp., *Maxomystrongylus* sp., *Nippostrongylus brasiliensis, Orientostrongylus* sp., *Paraheligmonelloides* sp., Physalopteridae parasites, *Rattustrongylus odontoconus, Rattustrongylus rotundoconus, Reticularia tanii, Strongyloides ratti, Strongyloides* sp. and *Syphacia muris*) one cestode species (*Rodentolepis nana*) and one trematode species (*Fibricola ramachandrani*).

The prevalence of endoparasite infection in forest rats was higher than commensal rats'. *Rattus tiomanicus* was the dominant rat species and exhibited the highest parasite diversity. The qualitative and quantitative composition of wild rat and rat helminth fauna may be explained by recent human dispersion in the park. The dissimilarities in results of an earlier survey and present study strongly suggest that the changes to the rat endoparasite population and epidemiology were caused by the recent emergence of commensal rats, particularly *Rattus tiomanicus*.

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