Prevalence of Ectoparasites and Blood Parasites in Small Mammals at Sakaerat Environmental Research Station, Thailand

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Abstract

A study of ectoparasites and blood parasites in small mammals was undertaken in three habitat types at Sakaerat Research Station, Thailand; dry dipterocarp forest, ecotone forest, and dry evergreen forest in four different seasons; early rainy season (May-July), late rainy season (August-October), winter (November-December), and summer (February-April) during 2007-2008. A total of 371 small mammals (9 species) were captured in traps. Four most common species included *Maxomys surifer*, *Rattus rattus*, *Leopoldamys sabanus* and *Tupaia glis*. Ectoparasites recorded include a mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroides*). Blood parasites such as *Microfilaria* spp., *Trypanosoma* spp., *Anaplasma* spp. and *Grahamella* spp. were identified. *Lealaps echidinus* (mite) and *Anaplasma* spp. were the most frequently observed in the four most common species captured. In this study the prevalence of ectoparasites and blood parasites was highest in *M. surifer* among small mammal communities.

Keywords: *Maxomys surifer, Leopoldamys sabanus*, *Rattus rattus*, *Tupaia glis*

Introduction

Small mammals are one of the most successful and diverse groups of mammals, and found in a wide variety of habitats (Fleming, 1975). Most of small mammals are rodents. Though, they help to maintain the ecosystem, they also are the important sources of infection for various viral, rickettsial and bacterial pathogens that cause diseases in humans. These rodent-borne diseases in human include plague, typhus, spotted fever, Hantavirus and Lyme disease. Many of such diseases are transmitted by arthropod vectors infesting rodent reservoirs (Woodhouse et al., 2001).

The distribution pattern of ectoparasites on their hosts is a result of an interaction between the parasites and the host and co-existence among the parasites. The ectoparasites relate with small mammals such as ticks, chiggers, gamasid mites, fleas and lice. Lice and certain gamasid mites are permanent parasites while fleas and certain mite species are nest-dwellers, which use the host for feeding and copulation. Among the last mentioned species, oviposition, development and molting may occur in the nest. Ticks, such as *Ixodes ricinus* and *Neotrombicula* spp. develop in the vegetation but feed on the host once in each developmental stage (Nilson, 1981).The species of ectoparasites may also be related to habitat selection by the host, and as a result, when habitats are disturbed and the composition of the small mammal community changes, ectoparasites may encounter different hosts near their nest microhabitat, and transfer may occur (Gettinger and Ernest, 1995). The occurrence of a particular ectoparasite species living on more than one host species may be related to the behavior, intra and interspecific relationship of

hosts, and with the microhabitats utilized by the host (Barker, 1994).

Small mammals are also vector – transmitted blood parasites. Blood parasites are closely related to ectoparasites in small mammals. Some small mammals investigated have been mix-infected with two parasite species. However, the number of mixed infections is relativly low in comparison to the whole number of infected rodents. For example, the most common co-infected is Hepatozoon and Batonela in bank vole (Turner, 1986). Other combinations, as well as co-infections in other host species, are seldom observed. Consistently with Karbowiak et al. (2005), the prediction shows the prevalence and diversity of blood parasites are higher in rodents than shrews.

The current prevalence of ectoparasites and blood parasites in small mammals in different habitat types at Sakaerat Research Station, Thailand, has not been studied Therefore, the objectives of this study were to determine the prevalence of ectoparasites and blood parasites founded in small mammals at the research station and to identify some host-parasite relationships that could be indicators of the reservoir species.

Materials and Methods

Study Site

Sakaerat is one of the five UNESCO-designated biosphere reserves in Thailand. The Sakaerat reserve was established in September 1967 by the applied Scientific Research Corporation of Thailand to use as a national forest reserve for scientific research by the Royal Forest Department, Ministry of Agriculture and Cooperative. In 1976, the Sakaerat Environmental Research Station was delegated by UNESCO to be a world biosphere reserve. The Sakaerat Biosphere Reserve is located in the south of Nakhon Ratchasima Province, Northeast Thailand. This forested reserve covers approximately 78.08 square km and ranges in altitude from 280-762 m above sea level. Rainfall averages 1260 mm per year and the annual mean temperature is 26°C. Dry evergreen forest and dry dipterocarp forest are the dominant forest types, representing 70% of the vegetation cover, and are located in the north and northeast of the reserve (Figure 1).

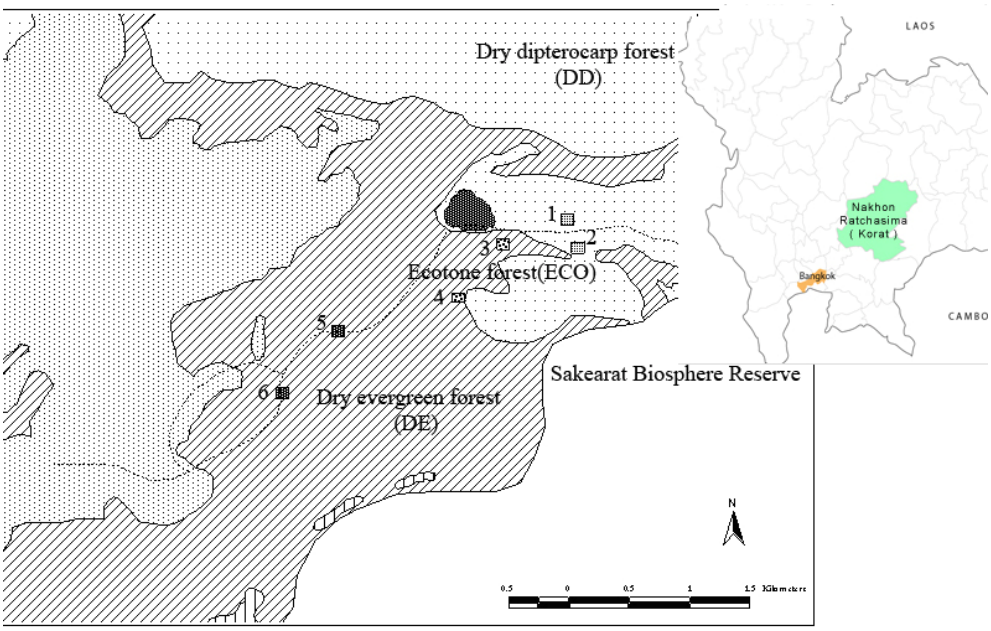

Figure 1 Map of Sakaerat Biosphere Reserve in Northeastern Thailand and the location of the trapping sites in each forest type; a little square is a permanent plot; plots 1-2 are in dry dipterocarp (DD) forest, plots 3-4 are in ecotone (ECO) forest and plots 5-6 are in dry evergreen (DE) forest. The dotted white area indicates DD forest, the crosshatched area indicates DE forest, and the boundary between DD forest and DE forest indicates ECO forest. The dotted dense white area to the left of the map is plantation forest.

Sampling

Trapping grids were positioned randomly within each forest type. Each grid comprised 49 traps set along seven lines each with seven traps spaced at 15-m intervals, covering an area of 0.81 ha[10]. A live-wire trap measuring 32 × 18 × 20 cm was placed at each trapping point (Vieira et al., 2004). The traps were set for three consecutive nights each month from January to December 2007, giving a total of 3,528 trap-nights.

Collection of Ectoparasites

Each anesthetized rat was placed in a restrainer during handling. Larger ectoparasites were removed from fur, ears and tail with a fine comb, toothbrushes or tweezers and stored in 70% alcohol. Ectoparasites that dropped from the animals during anesthesia in a plastic bag were also stored in 70% alcohol for identification as previously described (Wall and Shearer, 1997).

Identification of Ectoparasites

Ectoparasites specimens were mounted using different stages of clearing, dehydration and mounting procedures. Finally specimens were fixed in between microscope slides and cover glass using Canadabalzam. Different criteria of morphology of rodents were used for species identification. Wherever possible, ectoparasites were identified to the species level.

Collection of Blood Parasites

Blood was collected from the vein of rat tail using a 23-25 gauge needle. . Blood smears were then air-dried, fixed in absolute methanol, and stained with Giemsa at pH 7.1. Smears were viewed at x 1000 magnification. Approximately 200 fields of vision were inspected (Sinski et al., 2006) and identified following the protocol as previously described (Urquhart et al., 1996).

Identification of Blood Parasites

Identification of blood parasites species using morphology of blood stages and based on parasite morphology. The parasite identification was based on Urquhart et al. (1996).

Prevalence of Parasites

The prevalence of ectoparasite and blood parasite species of small mammals in three habitat types, Dry Dipterocarp (DD) forest; Ecotone (ECO) forest and Dry Evergreen (DE) forest were observed during four seasons during 2007-2008. The seasonal classifications were early rainy season, May-July; late rainy season, August-October; winter, November-December; summer, February-April. Infected individuals were classified into 6 maturity classes, males: juvenile, sub-adult and adult; females: juvenile, sub-adult and adult.

The prevalence of ectoparasites and blood parasites of small mammals captured were analyzed and expressed as a percentage of infection per small mammal species captured.

Statistical Analysis

Chi–square tests and P-values < 0.05 were used to test significant of the relationship between ectoparasite species and blood parasite species.

Results

Prevalence of Ectoparasites in Small Mammals

A total of 371 small mammals (including 244 individuals of *Maxomys surifer*, 42 *Rattus rattus*, 14 *Leopoldamys sabanus*, 50 *Tupaia glis*, 9 *Callosciurus finlaysoni*, 7 *Callosciurus caniceps*, 3 *Herpestes javanicus*, 1 *Lepus peguensis* and 1 *Mus cervicolor*) were examined.

During the study period, ectoparsites and pseudoscorpion were found on four small mammal species (*M. surifer*, *R. rattus*, *L. sabanus* and *T. glis*) in each habitat type. The ectoparasites found were mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroides*).

A total of 53 *M. surifer* individuals were collected from the DD forest. The prevalence of a mite (*L. echidinus*), tick (*Ixodes* sp.), flea (*X. cheopsis*) and pseudoscorpion (*C. cancroides*) found were 84.91% (n=45), 5.66% (n=3), 24.53% (n=13), and 3.77% (n=2) respectively. In ECO forest, a total of 78 individuals were collected. The prevalence of mite (*L. echidinus*), tick (*Ixodes* sp.),

flea (*X. cheopsis*) and pseudoscorpion (*C. cancroides*) found were 89.74% (n= 70), 5.13% (n= 4), 43.59% (n= 34), and 14.10% (n=11) respectively. For DE forest, a total of 113 individuals were collected. The prevalence of mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroides*) found were 64.60% (n= 73), 15.93% (n= 18), 25.66% (n= 29), and 20.23% (n= 23) respectively.

R. rattus; from DD forest, a total of 28 individuals was collected. The prevalence of mite (*L. echidinus*), tick (*Ixodes* sp.), flea (*X. cheopsis*) and pseudoscorpion (*C. cancroides*) found were 50% (n= 14), 14.29% (n= 4), 7.14% (n= 2) and 7.14% (n= 2) respectively. In ECO forest, a total of 8 individuals was collected. The prevalence of mite (*L. echidinus*), flea (*X. cheopsis*) and pseudoscorpion (*C. cancroides*) found were 37.50% (n= 3), 50.00% (n= 4), and 37.50% (n= 3) respectively. For DE forest a total of 6 individuals was collected. The prevalence of mite (*L. echidinus*) found were 33.33% (n= 2).

L. sabanus; from ECO forest, a total of 8 individuals was collected. The prevalence of mite (*L. echidinus*) found were 12.50% (n= 2). For DE forest a total of 6 individuals was collected. The prevalence of mite (*L. echidinus*) was 33.33% (n= 2).

For *T. glis*; from DD forest, a total of 20 individuals was collected. The prevalence of mite (*L. echidinus*), tick (*Ixodes* sp.), flea (*X. cheopsis*) and pseudoscorpion (*C. cancroides*) found were 10.00% (n= 2), 20.00% (n= 4), 20% (n= 4), and 5% (n= 1) respectively. In ECO forest, a total of 23 individuals was collected. The prevalence of mite (*L. echidinus*), tick (*Ixodes* sp.), flea (*X. cheopsis*) and pseudoscorpion (*C. cancroides*) found were 37.50% (n= 6), 30.43% (n= 7), 17.39% (n= 4), and 21.74% (n= 5) respectively. For DE forest, a total of 7 individuals was collected. The prevalence of ectoparasites was not found.

The prevalence and percentage of ectoparasites and pseudoscorpion found in four most common species are shown in Table 1.

As shown, the results revealed that a mite (*L. echidinus)* was the most prevalent species (n = 217, 62%) found, followed by a flea (*X. cheopsis* n=90, 25.71%), pseudoscorpion (*C. cancroides* sp. n=47, 13.43%) and a tick (*Ixodes* sp. n= 40, 11.3%). From all ectoparasites, the most prevalent species was *M. surifer* irrespective of habitat type. No ectoparasites or pseudoscorpion were recorded on *R. rattus*, *L. sabanus and T. glis*, as well as *L. sabanus*.

Table 1 Prevalence of ectoparasites and pseudoscorpion found in four most common species captured at Sakearat Environment Research Station with varied by habitat types.

Host species	Habitat	No.	Mite *Lealaps echidinus*	Tick *Ixodes* sp.	Flea *Xenopsylla cheopsis*	Pseudoscorpion *Chelifer cancroides*
			(---------- Numbers of prevalence (%) ----------			----------)
Maxomys surifer	DD	53	45 (84.91)	3 (5.66)	13 (24.53)	2 (3.77)
	ECO	78	70 (89.74)	4 (5.13)	34 (43.59)	11 (14.10)
	DE	113	73 (64.60)	18 (15.93)	29 (25.66)	23 (20.35)
	Total	244	188 (77.05)	25 (10.25)	76 (31.15)	36 (14.75)
Rattus rattus	DD	28	14 (50.00)	4 (14.29)	2 (7.14)	2 (7.14)
	ECO	8	3 (37.50)	-	4 (50.00)	3 (37.50)
	DE	6	2 (33.33)	-	-	-
	Total	42	19 (45.24)	4 (9.53)	6 (14.29)	5 (11.90)
Leopoldamys sabanus	ECO	8	1 (12.50)	-	-	-
	DE	6	1 (16.67)	-	-	-
	Total	14	2 (14.29)	-	-	-
Tupia glis	DD	20	2 (10.00)	4 (20.00)	4 (20.00)	1 (5.00)
	ECO	23	6 (26.09)	7 (30.43)	4 (17.39)	5 (21.74)
	DE	7	-	-	-	-
	Total	50	8 (16)	11 (22)	8 (16)	6 (12)
Total		350	217 (62.00)	40 (11.43)	90 (25.71)	47 (13.43)

Prevalence of Blood Parasites in Small Mammals

The following blood parasites species were found; *Microfilaria* spp., *Trypanosoma* spp., *Anaplasma* spp. and *Grahamella* spp. in *M. surifer* (n=181, 74.18%) and *R. rattus* (n=14, 33.33%); *Microfilaria* spp. and *Trypanosoma* spp. in *L. sabanus* (n=14, 100%); *Microfilaria* spp., *Trypanosoma* spp. and *Anaplasma* spp. in *T. glis* (n=18, 36%) (Table 2).

Microfilaria spp. were found in all four of the most common small mammal species. The prevalence of *Microfilaria* spp. in *M. surifer* was the highest (n= 15, 19.23%) in ECO forest, followed by DE forest (n=14, 12.39%) and DD forest (n=6, 11.32%). A similar pattern was found in *R. rattus* with the highest prevalence in the ECO forest (n= 3, 37.50%), followed by DE forest (n=2, 33.33%) and DD forest (n=3, 10.71%). The prevalence of *Microfilaria* spp. in *T. glis* with was the highest (n= 6, 26.09%) in ECO forest, followed by DD forest (n=4, 26.09%) and DE forest (n=1, 14.49%). For *L. sabanus*, the prevalence of *Microfilaria* sp. was the highest (n= 4, 66.67%) in DE forest, followed by ECO forest (n=1, 12.50%).

Trypanosoma spp. were found in *M. surifer*, *R. rattus* and *L. sabanus*. *Trypanosoma* spp. Was the highest in *M. surifer* (n= 7, 13.21%) in DD forest, followed by DE forest (n=13, 11.50%) and ECO forest (n=8, 10.26%). *R. rattus* with prevalence of *Trypanosoma* spp. was detected only in DD forest (n=1, 3.57%). The prevalence of *L. sabanus* with *Trypanosoma* spp. was the highest (n= 3, 50.00%) in DE forest, followed by ECO forest (n=1, 12.50%).

Anaplasma spp. were found in all four most common species of small mammals. The prevalence of *M. surifer* with *Anaplasma* spp. was the highest (n= 34, 64.15%) in DD forest, followed by ECO forest (n=41, 52.56%) and DE forest (n=56, 49.66%). The prevalence of *R. rattus* with *Anaplasma* spp. were detected in DD and DE forest, and was the highest (n= 1, 16.67%) in DE forest, followed by DD forest (n=1, 3.57%). *L. sabanus*, was detected only in ECO forest (n=4, 50.00%). For *T. glis*, the prevalence with *Anaplasma* spp. in DE forest, followed by DD forest (n=3, 15.00%).

Table2 Blood parasites found in small mammal species examined at Sakearat Research Station.

Host species	Location	Prevalence examination/infection (% infection)	Parasite
Maxomys surifer	DD, ECO,DE	244 / 181 (74.18)	*Microfilaria* spp. *Trypanosoma* spp. *Anaplasma* spp. *Grahamella* spp.
Rattus rattus	DD, ECO,DE	42 / 14 (33.33)	*Microfilaria* spp. *Trypanosoma* spp. *Anaplasma* spp. *Grahamella* spp.
Leopoldamys sabanus	ECO, DE	14 / 14 (100)	*Microfilaria* spp. *Trypanosoma* spp.
Tupia glis	DD, ECO,DE	50 / 18 (36)	*Microfilaria* spp. *Anaplasma* spp. *Grahamella* spp.
Callosciurus finlaysoni	ECO, DE	9 / 0	
Callosciurus erythraeus	DD, ECO,DE	7 / 0	
Herpestes javanicus	DD	3 / 0	
Lepus peguensis	DD	1 / 0	
Mus cervicolor	DE	1/ 0	
Total		371 /227 (61.19)	

Grahamell spp. were found in all four most common species of small mammals. The prevalence of *M. surifer* with *Grahamell* spp. was the highest (n= 43, 55.33%) in ECO forest, followed by DE forest (n=58, 51.33%) and DD forest (n=27, 50.94%). The prevalence of *R. rattus* with *Grahamella* spp. was detected only in DD forest (n=2, 7.14%). *L. sabanus*, was detected only in ECO forest (n=3, 37.50%). For *T. glis*, the prevalence of *Anaplasma* spp. were detected in DD and ECO forest, and was the highest (n= 8, 34.78%) in ECO forest, followed by DD forest (n=3, 15.00%).

The prevalence of blood parasites founded in four most common species of small mammals are shown in Table 3.

As shown, the results revealed that *Anaplasma* spp. was the highest (n=148, 42.29%) prevalence in four most common species, followed by *Grahamella* spp. (n=144, 41.14%), *Microfilaria* spp. n=59, 16.86%) and *Trypanosama* spp. (n= 33, 9.43%). Total prevalence of *Microfilaria* sp. of *M. surifer* ranged from 11.32% to 19.23%; *R. rattus* ranged from 10.71% to 37.50%; *L. sabanus* ranged from 12.50% to 66.67% and *T. glis* ranged from 10.71% to 37.50%. Total prevalence of *Trypanosoma* spp. of *M. surifer* ranged from 10.26% to 13.21%. Total prevalence of *Anaplasma* spp. of *M. surifer* ranged from 49.66% to 64.15%. For total prevalence of *Grahamella* spp. of *M. surifer* ranged from 50.94% to 55.13%.

Mixed parasitic manifestation, with four parasites species, were observed in *M. surifer*. *R. rattus* and *L. sabanus*. There were the following combinations of these parasitics; *Microfilaria* spp., *Trypanosama* spp., *Anaplasma* spp. and *Grahamella* spp., whereas three parasites species, were observed in *T.glis.* There were also the combinations of these parasites; *Microfilaria* spp., *Anaplasma* spp. and *Grahamella* spp.

The Prevalence Relationship of Ectoparasites Species, Pseudoscorpion and Blood Parasite Species

The prevalence relationship of ectoparasite species, pseudoscorpion and blood parasite species was significantly greatest between tick (*Ixodes* sp.) and *mMicrofilaria* spp. (χ^2 = 4.665, df = 1, P < 0.05), followed by the prevalence relationship between flea (*X. cheopsis*) and *Microfilaria* spp. (χ^2 = 4.043, df = 1, P < 0.05) found in *M. surifer*. In *R. rattus*, there was a significant relationship between mite (*L. echidinus*) and *Microfilaria* spp. (χ^2 = 25.317, df = 1, P < 0.001) including *Anaplasma* spp. (χ^2 = 50.940, df = 1, P < 0.001); flea (*X. cheopsis*) and *Microfilaria* sp. (χ^2 = 90.546 df = 1, P < 0.001); pseudoscorpion (*C. cancroides*) and

Table 3 Prevalence of blood parasites found in four common small mammal species captured at Sakearat Environment Research Station varied by habitats.

Host species	Habitat	No.	*Microfilaria* spp.	*Trypanosoma* spp.	*Anaplasma* spp.	*Grahamella* spp.
			(---------- Number of animals infected (%) ----------)			
M. surifer	DD	53	6 (11.32)	7 (13.21)	34 (64.15)	27 (50.94)
	ECO	78	15 (19.23)	8 (10.26)	41 (52.56)	43 (55.13)
	DE	113	14 (12.39)	13 (11.50)	56 (49.66)	58 (51.33)
R. rattus	DD	28	3 (10.71)	1 (3.57)	1 (3.57)	2 (7.14)
	ECO	8	3 (37.50)	-	-	-
	DE	6	2 (33.33)	-	1 (16.67)	-
L. sabanus	ECO	8	1 (12.50)	1 (12.50)	4 (50.00)	3 (37.50)
	DE	6	4 (66.67)	3 (50.00)	-	-
T. glis	DD	20	4 (20.00)	-	3 (15.00)	3 (15.00)
	ECO	23	6 (26.09)	-	8 (34.78)	8 (34.78)
	DE	7	1 (14.49)	-	-	-
Total		350	59 (16.86)	33 (9.43)	148 (42.29)	144 (41.14)

mMicrofilaria spp. (χ^2 = 10.886 df = 1, P < 0.01). In *T. glis* it was found that there was the prevalence relationship between tick (*Ixodes* sp.) and *Grahamella* sp. (χ^2 = 4.521, df = 1, P < 0.05). For *L. sabanus* there was not significantly different (P>0.05) in the prevalence relationship between species.

Discussion

During the study period, *M. surifer*, showed the most prevalence parasites with 77.05 % of total mite (*L. echidinus*), 31.15 % of total flea (*X. cheopsis*) and 14.75 % of total pseudoscorpion (*C. cancroides*), followed by *R. rattus*. *T. glis*, the most prevalence parasites with 22% of the total of tick (*Ixodes* sp.). Except for *L. sabanus*, they were only infested of mite (*L. echidinus*). When the data were compared with studies at Huay Khum Nature and Wildlife Education Centre part of Phu Khieaw Sanctuary in Chaiyaphum Province, they revealed that four species of 1,609 ectoparasites were found on 85 mammals; namely, mites (*L. echidninus*), hard ticks (*Ixodes* sp.), oriental rat fleas (*X. cheopis*), and northern rat fleas (*Nosopsyllus fasciatus*) (Tinarat, 1996). The diversity of ectoparasites on roof rats, yellow rajah rats, common tree shrew, ground squirrels and lesser bandicoots was 1.147, 1.013, 1.000, 1.990, and 1.000, respectively. This is consistent with a study done in the topic of survey of Scrub and Murine typhus vectors, infection rate at 6 international seaports founded that all infected rats were chigger mite and flea (*X. cheopis*) (Cheewakriengkrai and Prasartwit, 1994).

This study presents pesudoscorpion in *M. surifer*, *R. rattus* and *T. glis*. The study of pseudoscorpions in rodent nest has been know for along time (Weygoldt 1969). Thirty-two species of pseudoscorpion have been found co-existing with nine packrat or wood rat species of the genus *Neotoma*, and this association has been referred to as phoresy (Francke and Gusman, 2006). Phoresy is a term for passive dispersal when and animal literally hitches as a ride on another to reach a new habitat. The psedoscorpions reported above live in or on the nest of the packrat and do not ride on the rats them selves, eliminating a truly phoretic association, and indicating at least a communalistic relationship exists, whereby the pseudoscorpion benefits from shelter and food found in the nest by feeding on rodent ectoparasites, specifically larval and adult fleas.

The occurrence of animal infectioned with blood parasites found in four most common species captured including *M. surifer*, *R. rattus* , *L. sabanus* and *T. glis* in all habitat types. One genus of protozoa and microfilariae, and two genera of Rickettsia were detected in this study. The hemaoprotozoa was *Trypanosoma* spp., which was found in plasma. The Microfilariae was *Microfilaria* spp. The Rickettsia were represented by *Anaplasma* spp. and *Grahamella* spp. In general, among the hosts, *M. surifer* showed the highest overall infection rate with *Microfilaria* spp., *Trypanosoma* spp., *Anaplasma* spp. and *Grahamella* spp. whereas *Anaplasma* spp. was most frequently observed in four most common species captured, followed by *Grahamella* spp., *Microfilaria* spp. and *Trypanosoma* spp. The study by Dunn et al. (1968) on endoparasite patterns in mammals of the Malayan rain forest, where they founded that host species such as *M. surifer* was low infected with red cell protozoa, microfilariae and trypanosomes, *Rattus sabanus* was high infected with microfilariae and low infected with red cell protozoa and trypanosomes. For *T. glis* was medium infected with microfilariae and trypanosomes. Recently, a study on zeroprevalence of *Toxoplasma gondii* revealed that *Trypanosoma lewisi*, like trypanosomes, were present among *Rattus* and *Bandicota* rodent species and salivarian trypanosomes closely related to *T. evansi* were detected in *Leopoldamys* and *Rattus* species (Jittapalapong, 2005). In New Jersey, United State, detected *Anaplasma phagocytophilum* in wild rodent was transmitted by ticks (Adelson et al., 2004).

The prevalence and infection of ectoparasites and blood parasites in small mammals varied by habitat types. The prevalence of all ectoparasite species in small mammals was most frequently founded in ECO forest while blood parasite species were most frequently found in DD and ECO forest. DD and ECO forest were the optimal habitats for *M. surifer*, *R. rattus*, and *T. glis*, whereas DE forest and ECO forest were optimal for *L. sabanus*. The results shown is consistent with the habitat profiles in DD forest and ECO forest were contribute of

ground cover with few bamboo-like grass (*Arundinaria pusilla*). The study is consistent with the study by Nava et al. (2003) on the interrelationship between ectoparasite and wild rodent in Argentina. They found that infestation parameters and indices of mite, tick and fleas associated with wild rodent, and was mostly associated with grassland from northeastern of Argentina. The differences in infection rates observed between the three habitat types could result, for example, from local environmental conditions that may influence the dominance structure, prevalence of infestation and seasonal dynamics of ectoparasites and, in turn, the blood parasites (Haitlinger, 1981). Certain physical qualities, habitats and habitat preferences were related to infestation with ectoparasites. The small mammals most likely to be infested were those that ran on the surface of the soil, and the tree-top squirrels carried no parasites (Pearse, 1929).

The study in the topic of natural infections of small mammals with blood parasites on the borderland of boreal and temperate forest zones revealed that infection rates of rodent species seem to be higher in their typical habitats: for bank vole it was the highest in mixed forest, whereas for root vole in sedge swamp (Karbowiak et al., 2005). They results suggest that Arvicolidae play a greater role than Muridae or Soricidae in maintenance of Babesia and Hepatozoon foci in natural environments of central Europe. This study found that in four most common species captured in all habitat type were infested with different prevalence number of ectoparasites and blood parasites; showing that the prevalence of many species differed with habitat, both within and between seasons. Generally, reasons for these differences may be due to the prevalence and intensity of parasitism was independent of small mammal population density.

The relationship study between the prevalences of ectoparasites species and infection of blood parasites showed that, in *M. surifer*, tick and flea was significantly correlated with *Microfilaria* spp.; in *R. rattus*, mite was significantly correlated with all blood parasites, flea and pseudoscorpion was significantly correlated with *Microfilaria* spp.; in *L. sabanus*, had no significant correlation; in *T. glis*, tick was significantly correlated with *Grahamella* spp. These showed different results of correlation between ectoparasites and *Microfilaria* spp., generally because the important groups of the Filarioidea, which a wide range of hematophagous insect and acarines as intermediate host and vectors. The bloodsucking insects appear more frequently from before sunset to dark and the severest itchiness are observed in parallel to their appearance, blood-feeding flies are mosquitoes, black flies, biting midges, deer flies and horse flies and biting stable fly (Anderson, 1988).

This study is different from the basis of ectoparasites correlated with *Trypanosama* spp. because this species parasitized synanthropic rodents of the genus *Rattus* and has rat-fleas as vectors. *X. cheopsis* is the principal vector in tropical and subtropical areas (Hoare, 1972). The finding is also consistent with other study that found that rats presented significantly higher infection of *Trypanosama* spp. with highest levels of infestation by *X. cheopsis* (Linardi and Batelho, 2002; Smith et al., 2006).

Furturemore, interaction of *Anaplasma* spp. and *Grahamella* spp. with ectoparasite was similar to other study revealed that most of infection of *Anaplasma* spp. and *Grahamella* spp. are transmitted by tick species (*Ixodes* spp.) and some species of mite and flea (Foley et al., 2008; Kosoy et al., 2000). Vector-mediated transmission is another common theme within the genus. *Grahamella* spp. are typically transmitted between mammalian hosts by arthropods, with each bacterial species transmitted by a particular insect vector (Minmick and Anderson, 2006).

For the mixed infections, two pasrasite species, were observed in *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis*. The parasites found were the following combinations of parasites: *Microfilaria* spp. and *Grahamella* spp., *Trypanosoma* spp. and *Grahamella* spp. and *Anaplasma* spp. and *Grahamella* spp. in *M. surifer*; *Trypanosoma* spp. and *Grahamella* spp. in *R. rattus*; *Anaplasma* spp. and *Grahamella* spp. in *L. sabanus* and *T. glis.*

Some small mammals investigated have been mix-infected with two parasite species. However, the number of mixed infections is relatively low in comparison to the whole number of infected rodents. The most common co-infection was *Anaplasma* spp. and *Grahamella* spp. in *M. surifer*,

L. sabanus and *T. glis*. Other combinations, as well as co-infections in other host species, were seldom. Consistently with our prediction, the prevalence and diversity of blood parasites were higher in rodents than shrews. Similar results were found by the other authors (Baker, 1974). This corresponds to higher infection rates and diversities of ectoparasites in rodents than in shrews (Stanko et al., 2002).

In conclusion, this study provides preliminary information prevalence assessment based on ectoparasites and blood parasites for small mammals captured at Sakearat Research Station during January-December 2008. Long-term studies at other locations, as well as precise information on parasites invasion and the health status of small mammals including blood and serum biochemical parameters at Sakaerat Research Statuon are also provided.

Conclusions

The ectoparasites mainly found from small mammals were mite (*L. echidinus*), tick (*Ixodes* sp.), flea (*X. cheopsis*) and pseudoscorpion (*C. cancroide*). The occurrence of patient infections with blood parasites were one genara of Protozoa and Microfilariae, and two genus of Rickettsia. The hemaoprotozoa was *Trypanosoma* spp., which was found in plasma. The Microfilariae was *Microfilaria* spp. The Rickettsia were represented by *Anaplasma* spp. and *Grahamella* spp. This study found that *M. surifer* had the most abundant parasites.

Acknowledgments

This work was supported by grants from Suranaree University of Technology, Thailand and National Research Council. We thank Taksin Artchawakom, head of Sakaerat Environment Research Station for permissions to undertake this study at Sakaerat Environment Research Station. The staff at Sakaerat Environment Research Station provided valuable assistance in the field. We also thank Seksan Sansorrapisut, Sarawee Aroon and Warin Boonreum for their excellent assistance with fieldwork.

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Manuscript received 12 May 2009, accepted 30 October 2009