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THESIS

GASTROINTESTINAL HELMINTHS OF MURID RODENTS IN BORDER PROVINCES OF NORTHERN AND NORTHEASTERN THAILAND

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A Thesis Submitted in Partial Fulfillment of
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The presence of gastrointestinal helminth (GI helminth) was investigated in 725 murid rodents, trapped in various habitats of Nan, Loei and Buriram province, in Thailand. The study revealed 17 species of rodents infected with 22 species or taxonomic groups of parasites (3 trematodes, 3 cestodes, 14 nematodes, 1 acanthocephalan and 1 pentastomid). Overall prevalence of infection was 57.7% (418 infected out of 725 rodents).

Among GI helminths, the dominant parasite was Trichostrongylidae (24.3%), followed by *Raillietina* sp. (17.1%), *Hymenolepis diminuta* (8.6%) and *Syphacia muris* (8.6%). The highest GI helminthic infection was found in *Mus caroli* (81.81%), followed by *Mus cervicolor* (76.5%), *Leopoldamys edwardsi* (75.0%), *Bandicota indica* (71.5%) and *Bandicota savilei* (71.4%). The highest total parasite species richness (totalPSR) was found in *Bandicota indica* with 14 parasite species, followed by *Rattus losea* (12), *Rattus tanezumi* (11), *Mus cervicolor* (10), and *Bandicota savilei* (9).

Statistical analysis of individual parasite species richness (individualPSR) with sex, maturity, locality and habitats showed that high individualPSR was possibly related to maturity (adult rodents) and also associated with living in wilder places. In contrast, individualPSR was not associated with host sex. The following parasites, *Raillietina* sp., *Rodentolepis nana* (syn. *Hymenolepis nana*), *Hymenolepis diminuta* and *Moniliformis moniliformis* were considered as cause of parasitic zoonoses of medical important linked with murid rodents.

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LIST OF ABBREVIATIONS

°C	=	Degree(s) Celsius
μm.	=	Micrometer(s)
AFA fixative	=	Alcohol-formal-acetic fixative
ANOVA	=	Analysis of variance
ANR CERoPath	=	Community Ecology of Rodents and their Pathogens in South-East Asia
DNA	=	Deoxyribonucleic acid
et al.	=	et alli (latin); and others
etc	=	et cetera (latin); and other things
g	=	Gram(s)
GI helminth	=	Gastrointestinal helminth(s)
GI tract	=	Gastrointestinal tract
GPS	=	Global Positioning System
i.e.	=	id est (latin); that is
individualPSR	=	Individual Parasite Species Richness
Log	=	Logarithm
mg.	=	Milligram(s)
ml.	=	Milliliter(s)
mm.	=	Millimeter(s)
No.	=	Number
SEA	=	Southeast Asia(n)
totalPSR	=	Total Parasite Species Richness

LIST OF ABBREVIATIONS (Continued)

UK	=	United Kingdom
USA	=	United States of America

GASTROINTESTINAL HELMINTHS OF MURID RODENTS IN BORDER PROVINCES OF NORTHERN AND NORTHEASTERN THAILAND

INTRODUCTION

Rats and mice (Murinae) belong to rodents, a key mammalian order (42% of all the mammal species) with more than 2,700 species (Wilson and Reeder, 2005). Within the order rodents, they represent two-thirds of living species. They are highly successful to most of environments throughout the world. They have learnt and adapted themselves in various conditions with a high potential in reproduction. They eat about 10% of their body weight each day and contaminate a great deal mainly with their feces and urine. They act as reservoir hosts for many zoonotic pathogens and can transmit several diseases to humans and animals, including leptospirosis, murine typhus, hantaviral diseases, plague and helminthic diseases.

Rodent characteristic and their biodiversity in Thailand

The main feature that rodent characterized is a pair of a big incisor teeth in upper and lower jaws which exist through the animal's life, so they can easily be differentiated from Lagomorphs which have two pairs of upper and one pair for lower gnawing teeth. Another characteristic is a long gap called “diastema” between the incisor and molar teeth. The cheek can be drawn into this gap to separate the anterior and posterior part of mouth, preventing the animals from swallowing a bit of soil or piece of wood while they are gnawing or digging a burrow (Marshall, 1988).

Two-thirds of living rodent species belong to the family Muridae. Asia is the center of murid diversification, all worldwide distributes species are from this region (Badenhorst *et al.*, 2009). In Thailand, rats and mice of this family are well represented by 40 species belonging to fourteen genuses as *Bandicota*, *Berylmys*, *Chiromyscus*, *Chiropodomys*, *Dacnomys*, *Hapalomys*, *Leopoldamys*, *Maxomys*, *Micromys*, *Mus*, *Niviventer*, *Rattus*, *Sundamys* and *Vandeleuria* (Marshall, 1988;

Corbet and Hill, 1992; Aplin *et al*., 2003 and Wilson and Reeder, 2005). Taxonomic classification of Murid rodent in Thailand as follow:

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Rodentia
Family: Muridae

Genus: *Bandicota*
Bandicota indica
Bandicota savilei

Genus: *Berylmys*
Berylmys berdmorei
Berylmys bowersi

Genus: *Chiromyscus*
Chiromyscus chiropus

Genus: *Chiropodomys*
Chiropodomys gliroides

Genus : *Dacnomys*
Dacnomys millardi

Genus: *Hapalomys*
Hapalomys delacouri
Hapalomys longicaudatus

Genus: *Leopoldamys*
Leopoldamys edwardsi
Leopoldamys neilli
Leopoldamys sabanus

Genus: *Maxomys*
Maxomys moi
Maxomys rajah
Maxomys surifer
Maxomys whiteheadi

Genus: *Micromys*

Micromys minutus

Genus: *Mus*

Mus caroli

Mus cervicolor

Mus cookii

Mus fragilicauda

Mus musculus

Mus pahari

Mus shortridgei

Genus: *Niviventer*

Niviventer confucianus

Niviventer cremoriventer

Niviventer fulvescens

Niviventer hinpoon

Niviventer langbianis

Niviventer tenaster

Genus: *Rattus*

Rattus andamanensis

Rattus argentiventer

Rattus exulans

Rattus losea

Rattus nitidus

Rattus norvegicus

Rattus tanezumi

Rattus tiomanicus

Genus: *Sundamys*

Sundamys muelleri

Genus: *Vandeleuria*

Vandeleuria oleracea

The difficulties in identifying rodents are probably occured, as attested by misnamed rodents. Rodent taxonomy is under revision with especially the *Rattus rattus* complex in which some species are hardly distinguishable. The problems of rodent taxonomy is occurred, cause from synonym names and species complex. Then, the updated name is redescribed following the Mammal Species of the World (Wilson and Reeder, 2005) as shown in Table 1.

Table 1 The synonyms of rodents taxonomy redescribed by Mammal Species of the World (Wilson and Reeder, 2005)

Lastest taxonomy (Updated name)	**Former taxonomy used in literature**
Berylmys berdmorei	*Rattus berdmorei*
Berylmys bowersi	*Rattus bowersi*
Leopoldamys edwardsi	*Rattus edwardsi*
Leopoldamys sabanus	*Rattus sabanus*
Maxomys surifer	*Rattus surifer*
Maxomys whiteheadi	*Rattus whiteheadi*
Niviventer cremoriventer	*Rattus cremoriventer*
Niviventer fulvescens	*Rattus bukit gracilis*
Rattus andamanensis	*Rattus koratensis*
	Rattus remotus
	Rattus sikkimensis
Rattus tanezumi	*Rattus rattus*
	Rattus rattus diardii
	Rattus rattus flavipectus
	Rattus rattus molliculus
	Rattus rattus sladeni
	Rattus rattus tanezumi

Impact of rodents to agriculture and public health

Murid rodents are highly successful to many environments. Their feeding are nocturnal omnivorous, mainly consume and spoil crops in the field and storage house. They eat about 10% of their body weight each day and contaminate a great deal with their feces and urine to environment. They have a large foraging range from their nest and highly learn to adapt themselves in various environments and high potential in reproduction. Typically, they have short gestation periods with high litter size. All of those information are much enough to conclude that rodents are important animal, can affect human in three main ways: (1) act as agricultural pest, (2) spoil and contaminate stored food and (3) carry diseases to human and livestock or companion pets (Aplin *et al*., 2003).

Rodents are reported as the cause of both preharvest and postharvest losses of crops. They are considered as the second most important pest after insects because they are the least controlled (Douangboupha *et al*., 2009). Especially, the most important crop is rice, produce 35-60% of the total food energy of human in Asia. The damage of rice production that caused from rodents had been recorded as 5-10% and some place increasing to 50% (Miller, 2007). A loss of 5% rice production in Asia accounts for approximately 30 million tons, sufficient to feed about 200 million people for a year (Singleton *et al*., 2003). The dominance murid rodent pest to rice crops in Southeast Asia is *Rattus argentiventer*, and the other pest species include *Rattus losea*, *Rattus rattus*, *Bandicota indica*, *Bandicota savilei*, *Mus caroli* and *Mus cervicolor* (Marshall, 1988; Aplin *et al*., 2003; Singleton *et al*., 2003 and Douangboupha *et al*., 2009).

Nowaday, rodents are reported to be important in transmitting diseases to human around the world. Because of they are very good to adapt themselves to variety habitats and then adapt to fast environmental changes, being able to breed rapidly and can eat many kind of food (Carleton, 1984). They eat every day and contaminate a great deal with their feces and urine in to environment. Rodent-borne diseases are numerous such as bacterial diseases (e.g. leptospirosis, plague, tularaemia, salmonellosis and rickettsioses as scrub typhus and murine typhus),

protozoal diseases (e.g. leishmaniosis, babesiosis and cryptosporidiosis), and viral diseases (e.g. hantaviral infections, arenaviral infections and ribies). In Southeast Asia, the most knowledge about rodent-borne disease relates to leptospirosis. This disease is reported from Indonesia, Vietnam, Malaysia to Australia and the Pacific Islands. In addition, Thailand also have reported to this disease, showed an increasing of the number of diagnosed cases of leptospirosis from 1995 to 2000 with a maximum of 14,608 cases and 365 deaths reported in hospitals in the year 2000 (Aplin *et al*., 2003). Macroparasites, helminths also play an important role in the zoonotic cycles of many diseases. Helminth infection in rodents that are a potential risk to humans in Southeast Asia and the Pacific region as follow: *Paragonimus* sp., *Schistosoma japonicum*, *Hymenolepis* sp., *Railletina* sp., *Angiostrongylus cantonensis*, *Capillaria hepatica*, *Gnathostoma spinigerum* and *Trichinella spiralis* (Maleewong *et al*., 1988 and Aplin *et al*., 2003).

Helminthiasis constitutes the most common parasitic infection in humans and animals throughout the world. They represent important public health problems with great economic impact in tropical and subtropical countries. The direct effects of helminths to their host or human are: robbing effects, direct injurious effects (i.e. blood suckling, lumen obstruction, ulceration, etc.), indirect injurious effect (secondary infection by microbes), allergic reaction and local reaction (cellular reaction as; phagocytosis, inflammatory reaction, fibrosis or calcification). Several species of murid helminths are zoonotic and difficult to control. Human can be infected directly by contact to infective stage larva or eggs. By the way, it also indirectly infected by various sources of environmental contamination: food, soil or water. Rates of transmission and exposure are dependent upon human behavior, occupation, social practices and cultural beliefs together with poor human hygiene, unsanitary animal husbandry and economic activities (Nithiuthai *et al*., 2004).

Gastrointestinal helminths of murid rodents also play an important role in the zoonotic cycles of many diseases and cause of mild enteric symptoms as; nausea, abdominal pain, diarrhea, vomit, malabsorption until severe signs as; enteritis, ulceration, intestinal block, edema, hemorrhagic anemia or irritate from parasite migration, eg. *Clonorchris sinensis* cause of clonorchiasis, *Echinostoma spp* cause of

echinostomiasis, *Echinococcus multilocularis* and *Echinococcus vogeli* cause of echinococcosis, *Hymenolepis diminuta*, *Capillaria hepatica* cause of capillariasis, *Gnathostoma spinigerum* cause of gnathostomiasis, *Trichinella spiralis* cause of trichinellosis, (McCarthy and Moore, 2000), *Gastrodiscoides hominis* (Scheller, 2006) *Taenia taeniaformis* (Paramasvaran *et al*., 2005), *Hymenolepis nana* (Cathy and Delaney, 1996), *Nippostrongylus brasiliensis* (Spatafora and Platt, 1982), *Syphacia muris* (Jueco and Zabala, 1990).

Although, there were several reports on helminth infection of rodent in other part of the world, studies in Southeast Asia (SEA) are still required. Thus, the present research focuses on GI helminths of rodent infections in Nan, Loei and Buriram, in order to check the prevalence and relation with their intrinsic factor (maturity, sex and bodymass) and extrinsic factor (habitat and locality). Finally, this will serve to determine the risk for humans to contract helminthiasis and may help to develop appropriate control programs.

OBJECTIVES

To investigate the rodent that can be found in northern and northeastern border provinces of Thailand, in order to see the prevalence of helminths that infect rodents in relation to their species, maturity, sex, body mass and habitats, and determine the risk for human to be in contact with helminth parasites from rodents as the following questions:

1. What is the GI helminth diversity of murid rodents in these regions?

2. Does the distribution of GI helminth species vary among localities?

3. Are sex, maturity, body mass and habitat related to GI helminth infection?

4. Which parasite in these regions might play an important role as a causative agent in parasitic zoonosis?

LITERATURE REVIEW

GI helminth infection in Southeast Asian murid rodents

Several studies have surveyed rodents and their endoparasites in Southeast Asia, concerning about twenty murid rodent species and more than fifty parasite species were reported to infect. The collection of literature review data was based on the presence of Southeast Asian helminths and acanthocephalan in GI tract. The number of helminth species and totalPSR from literature reviews are included, and new created as Table 2. Natural History Museum database from UK and the other concerned article that can not access the full paper were also used for data collection, as show in Table 3-6.

Table 2 The number of parasite species found in each rodent species.

Host	Number of GI-helminth species				
	Cestode	Trematode	Nematode	Acantho-cephala	TotalPSR
Bandicota bengalensis	2	0	0	0	2
Bandicota indica	4	2	3	1	10
Bandicota savilei	1	1	0	0	2
Berylmys bowersi	1	0	6	0	7
Leopoldamys edwardsi	1	0	1	0	2
Leopoldamys sabanus	0	0	8	0	8
Maxomys surifer	3	0	3	0	6
Maxomys whiteheadi	0	0	2	0	2
Mus caroli	2	0	0	0	2
Mus musculus	1	2	1	0	4
Niviventer cremoriventer	0	0	4	0	4
Niviventer fulvescens	1	0	1	0	2
Rattus andamanensis	4	0	0	0	4
Rattus argentiventer	2	2	10	1	15
Rattus exulans	6	2	4	1	13
Rattus losea	0	1	4	0	5
Rattus nitidus	1	1	5	0	7
Rattus norvegicus	8	4	9	1	22

Table 2 (Continued)

Host	Number of GI-helminth species				
	Cestode	Trematode	Nematode	Acantho-cephala	TotalPSR
Synnonym of *Rattus tanezumi*					
Rattus rattus	5	5	3	0	13
R. rattus diardii	3	4	9	1	17
R. rattus flavipectus	1	1	0	0	2
R.rattus molliculus	1	0	1	0	2
R.rattus sladeni	0	2	5	0	7
R.rattus tanezumi	1	0	3	1	5
Rattus hoffmanni	0	0	1	0	1
Rattus tiomanicus	3	0	7	1	12

Several literatures about the GI tract helminth infection on SEA murid rodents sort by the period as followed:

Tubangui (1931) examined the parasites infection from Brown rat (*Rattus norvegicus*) in Manila, Philippines. The results indicated that dominant species of parasites was *Taenia taeniaformis* (94%), commonly known as the cyst (Cysticercus fasciolaris) in rat's liver, follow by *Hepaticola hepatica* (90%), *Raillietina garrisoni* (86%), *Strongyloides ratti* (74%) and *Hymenolepis diminuta* (64%) respectively.

Miyazaki and Dunn (1965) found the new trematode species, *Gnathostoma malaysiae* in the stomach wall of *Rattus surifer* and *Rattus rattus tiomanicus* trapped in a mountain area of Tioman Island, Pahang State, Malaysia. In addition, the authors redescribed the morphological characteristic of *G. Malaysiae* collected from Phuket and Khao Yai National Park, Thailand from the survey by Kamiya *et al.* (1987). This survey was the first recorded of *G. malaysiae* found in stomach wall of *Maxomys (Rattus) surifer* in Thailand. They also discussed that *G. Malaysiae* may be distributed

widely in SEA, especially Indochina countries because the definitive hosts *Rattus rattus* and *Rattus surifer* also inhabit throughout mainland of SEA.

Areekul and Radomyos (1970) reported the infection of *Raillietina* sp. in man and rats in Thailand. Three species of rodents were found positive as *Rattus norvegicus, R. rattus* and *Bandicota indica.* Two human cases from hospital were also reported to infected by parasite with the sign of diarrhoea and found the gravid segment in the shape of cucumber seed liked from the both patient stools. However, the life cycle of *Raillietina* sp. has not been very well known but arthropods, especially cockroaches were suspected of being intermediate host.

Singh and Chee-Hock (1971) surveyed the nematode infection from Malayan rats in Malaysia. Sixteen species of nematodes were found as follow, *Angiostrongylus cantonensis, Breinlia* sp., *Capillaria hepatica, Cyclodontostomum pirvisi, Globocephalus connorfilii, Gongylonema neoplasticum, Hepatojarakus malayae, Heterakis spumosa*, *Nippostrongylus braziliensis*, *Physaloptera* sp., *Protospiura-Mastophorus* spp, *Rictularia tani, Strongyloides ratti, Subulara andersoni, Syphacia muris* and *Trichosomoides crassicauda*. The highest prevalence reported was the infection of *Protospiura-Mastophorus* spp (46.66%), follow by *Capillaria hepatica* (42.74%) and *Globocephalus connorfilii* (41.08%).

Varughese (1973) was redescribed the rat hookworm, *Cyclodontostomum purvisi,* Strongyloidea nematode from the large intestine of Malayan giant rats, *Sundamys mulleri, R. sabanus* and *R. whiteheadi*. The redescription was made on the life cycle and developmental morphology of the parasite. In the same way, Hasegawa and Syafruddin (1994) collected the *Cyclodontostomum purvisi,* nematode from the caecum of *Maxomys whiteheadi, Leopoldamys sabanus, Niviventer cremoniventer* and *Rattus hoffmani* of Kalimantan and Sulawesi, Indonesia. *C. purvisi* seems to have a wide host range in the Murinae, being distributed widely in the area from India to Australia.

Wiroreno (1978) surveyed for nematode parasite of rats in West Java, Indonesia. The results indicated that total of 217 rodents from nine species: *Rattus rattus diardii, R. exulans, R. tiomanicus, Niviventer niviventer, R. lepturus, R. bartelsii, R. cremoriventer, Leopoldamys sabanus* and *Pithecheir melanurus* were captured to recover the parasites. The prevalence of nematode infection was 21.7% (47 rodents were positively found). Eight nematode species were found as follow, *Angiostrongylus cantonensis, Capillaria hepatica, Cyclodontostomum purvisi, Hepatojarakus malayae, Rictularia tani, Mastophorus muris, Subulura andersoni* and *Physaloptera* sp.

Leong *et al*. (1979) reported the parasite fauna of House Rat, *Rattus rattus diardii* in Kuala Lumpur, Malaysia. Nineteen species of parasites were recovered including protozoa, helminths and acanthocephalans. *Hymenolepis diminuta* and *Nippostrongylus brasiliensis* are the predominant species. The other helminths that were found as follow, *Prosthodendrium* sp., *Echinostoma* sp., *Plagiorchis* sp., *Taenia taeniaformis, Raillietina tapeczoides, Aspicularis tetraptra, Heterakis muris, Gongylonema neoplasticum, Strongyloides ratti, Syphacia muris* and *Trichuris muris.*

Sinniah (1979) reported the prevalence of parasites in some rodents from Peninsular Malaysia. Nine species of rodents were found as *Rattus annandalei, R. argentiventer, R. r. diardii, R. exulans, R. tiomanicus, R. norvegicus, R. sabanus, R. mulleri* and *Bandicota indica.* Total prevalence of parasitic infection was 74.5%, predominated by *Angiostrongylus* sp. (43.2%), *Strongyloides ratti* (38.4%), *Taenia taeniformis* (20.3%) and *Capillaria hepatica* (15.4%) respectively. The other parasites infection found in this study as follow, *Hymenolepis diminuta, H. nana, Echinostoma malayanum, Hepatojarakus malayae, Syphacia muris, Rictularia tani, Cyclodontostomum purvisi, Nippostrongylus* sp. and *Moniliformis moniliformis*.

Krishnasamy *et al*. (1980) surveyed the prevalence of wood rat, *Rattus tiomanicus* in an oil-palm estate, Kuala Lumpur, Malaysia. They revealed 8 species of helminths; 5 nematodes, *Angiostrongylus malaysiensis* (54.2%), *Hepatojarakus malayae* (48.5%), *Nippostrongylus braziliensis* (48.0%), *Syphacia muris* (17.7%) and

Gongylonema neoplasticum (0.3%); 3 cestodes, *Hymenolepis nana* (7.6%), *H. diminuta* (6.0%) and *Hydatigera taeniaeformis* (cysticercus) (12.0%), respectively. Overall helminthic infection rates seemed to be higher than those previously reported in this host species.

Chenchittikul *et al.* (1983) examined the parasite of commensal rodents in the urban and rural area of Chanthaburi province, Thailand. The result showed that the infection rate in urban areas (36.6%) were higher than the rural areas (25.5%). Four helminth species were found as followed, *Angiostrongylus cantonensis, Hymenolepis diminuta, Hymenolepis nana* and *Raillietina siriraji*. All the reported helminths were showed as the medical and public health importance.

Roberts (1991) reported the review study of Polynesian rat (*Rattus exulans*) in Southeast Asia that infected by helminths. In Thailand, 1 nematode, *Angiostrongylus cantonensis* and 3 cestodes, *Hymenolepis diminuta, Hymenolepis nana* and *Raillietina siriraji* were found. In Malaysia, he reported 6 nematodes, *Angiostrongylus* sp., *Capillaria hepatica*, *Hepatojarkus malayae, Strongyloides ratti*, *Syphacia muris* and *Nippostrongylus* sp., 2 cestodes, *Taenia taeniaeformis and Hymenolepis diminuta and* 1 trematode, *Echinostoma malayanum.* Moreover, the acanthocephalan, *Moniliformis moniliformis* was found in this kind of rat.

Hasegawa *et al.* (1992) reported new genus in subfamily Seuratiinae of nematode, *Tikusnema javaense* from rice field rat, *Rattus argentiventer* from West Java, Indonesia. The result indicated that 23 *R. argentiventer* were captured and examined for the ailimentary parasite. In addition to *T. javaense* and then *Eucoleus bacillatus, Strongyloides ratti, Nippostrongylus brasiliensis, Syphacia muris,* and *Physaloptera* sp. were also detected.

Namue and Wongsawad (1997) reported the survey of helminths infection in *Rattus norvegicus* and *Rattus rattus* from Chiangmai, Thailand. The results showed that 100% of *R. norvegicus* and 77.27% of *R. rattus* were infected with 10 helminths species. Four trematodes: *Centrocestus* sp., *Echinostoma ilocanum, Echinostoma*

malayanum and *Quinqueseralis quinqueseralis*; 2 cestodes: *Raillietina* sp. and *Taenia* sp.; and 4 nematodes: *Angiostrongylus cantonensis*, *Nippostrongylus* sp., *Rictularia* sp. and egg of *Capillaria hepatica* were reported. The helminths were found in the small intestine, large intestine, lung, stomach, heart and liver respectively. The infected helminths showed no significant relationship between sexes and helminth infection

Pham *et al*. (2001) reported the helminth examination on *Rattus tanezumi, R. argentiventer* and *R. losea,* captured in 3 different habitats (residential, paddy field and hilly area) in Bac Ninh, Vietnam. One trematode, *Notocotylus* sp., two cestodes, *Raillietina celebensis* and *Hymenolepis diminuta,* six nematodes, *Strongyloides ratti, Strongyloides venezuelensis, Nippostrongylus brasiliensis, Orientostrongylus cf. tenorai, Syphacia muris* and *Gongylonema neoplasticum* and one acanthocephalan, *Moniliformis moniliformis* were collected. The species composition and prevalence of these helminths differed among the habitats, apparently because of biological characters of the parasites and environmental conditions of the localities.

Paramasvaran *et al*. (2005) reported the survey of helminths infection of small mammals in Selangor, Malaysia. The dominant rodents species examined were *Leopoldamys sabanus, Maxomys rajah, Sundamys muelleri* and *Berylmys bowersi* respectively. The overall infection rate is 41% prevalence (44% in males and 38% in females). Eight species of helminths were identified, as well as four species of nematodes (*Capillaria hepatica, Hepatojarakus malayae, Trichostrongylus* sp. and *Streptophagus* sp.) and three species of cestodes (*Taenia taeniaformis, Raillietina* sp. and *Hymenolopis* sp.). Only one trematode, *Zonorchis* sp. was found in *Tupaia glis*. The authors indicated that *C. hepatica,* and the cestodes, *T. taeniaformis, Hymenolepis* sp. and *Raillietina* sp. play an important role in zoonotic disease of medical importance.

Claveria *et al*. (2005) studied the biodiversity of parasite in *Rattus* sp. *(R. norvegicus* and *R. rattus*) caught in fresh market, Manila and Balayan, Philippines. The helminths found from the studied comprising with the acanthocephalan:

Moniliformis moniliformis, the cestodes: *Hymenolepis diminuta, Taenia taeniaeformis* and the nematodes: *Capillaria hepatica* in liver and *Trichosomoides crassicauda* of the urinary bladder. The results showed 100% infection with *C. hepatica* and *T. taeniaeformis*, exhibiting high parasitemia. Despite heavy infection with parasites, the authors notice that all rats appeared healthy and agile, suggestive of a well-established host-parasite relationship. In the view of public health and zoonotic disease, they can readily facilitate parasite transmission to humans and other susceptible animal hosts.

The result of helminth diversity in Southeast Asian rodents across six countries, Indonesia, Malaysia, Myanmar, the Philippines, Thailand, and Vietnam indicated that murid rodents infected with various helminth parasites. The highest number of helminth species was reported from Vietnam followed by Malaysia, Thailand, Indonesia, the Philippines and Myanmar as 28, 25, 17, 10, 9 and 1 species, respectively. Mainland countries, Vietnam, Malaysia and Thailand, seem to have a greater diversity of helminth species richness than insular countries, such as Indonesia and the Philippines. It might be due to habitat diversity, insular isolation or area size. However, the literature does not cover all Southeast Asian countries, since no rodent investigations could be found from Brunei, Cambodia, Lao PDR, Papua New Guinea, Singapore and Timor.

Table 3 Literature review of cestodes from murid rodents in Southeast Asia

Parasites (Cestodes)	Hosts	Countries	References
Bertiella anapolitica (Baylis, 1934)	*Rattus exulans* *R. tanezumi*	Vietnam	Krivolutsky *et al*., 1991
Diphyllobothrium sp.	*R. andamanensis*	Vietnam	Nguyen, 1986
Hymenolepis diminuta (Rudolphi, 1819)	*Bandicota indica* *Maxomys surifer* *Mus caroli* *R. annandalei* *R. andamanensis* *R. argentiventer* *R. exulans* *R. norvegicus* *R. tanezumi* *R. tiomanicus*	Malaysia Philippines Thailand Vietnam	Chenchittikul *et al*.,1983 Krishnasamy *et al.*, 1980; Leong *et al*., 1979; Nguyen, 1986; Pham *et al*., 2001; Roberts, 1991; Sinniah, 1979; Tubangui, 1931
Hymenolepis longior (Baylis, 1922)	*R. norvegicus* *R. tanezumi*	Myanmar	Nama, 1990
Mathevotaenia symmetrica (Baylis, 1927)	*Mus musculus*	Thailand	Coombs & Crompton, 1991
Rodentolepis sp.	*Maxomys surifer* *Mus caroli* *R. andamanensis*	Vietnam	Nguyen, 1986
Raillietina sp.	*Bandicota indica* *R. exulans* *R. norvegicus* *R. tanezumi*	Thailand	Areekul and Radomyos, 1970; Namue and Wongsawad, 1997
Raillietina celebensis (Janicki, 1902)	*Bandicota indica* *Berylmys bowersi* *Leopoldamys edwardsi* *Maxomys surifer* *R. andamanensis* *R. nitidus* *R. tanezumi*	Vietnam	Nguyen, 1986; Pham *et al.*, 2001

Table 3 (Continued)

Parasites (Cestodes)	Hosts	Countries	References
Raillietina siriraji (Robert, 1991)	*Bandicota savilei* *R. exulans* *R. norvegicus* *R. tanezumi*	Thailand	Chenchittikul *et al*.,1983; Roberts, 1991
Rodentolepis (Hymenolepis) nana (Siebold, 1852**)**	*R. annandalei* *R. exulans* *R. norvegicus* *R. tanezumi* *R. tiomanicus*	Malaysia Philippines Thailand	Chenchittikul *et al*.,1983; Krishnasamy *et al*., 1980; Roberts, 1991; Sinniah, 1979; Tubangui, 1931
Rodentolepis straminea (Goeze, 1782**)**	*Niviventer fulvescens*	Vietnam	Nguyen, 1986
Taenia sp.	*R. norvegicus* *R. tanezumi*	Thailand	Namue and Wongsawad, 1997
Taenia taeniaformis	*Bandicota indica* *R. annandalei* *R. argentiventer* *R. exulans* *R. norvegicus* *R. tanezumi* *R. tiomanicus*	Malaysia Philippines	Claveria *et al*., 2005; Krishnasamy *et al*., 1980; Sinniah, 1979; Tubangui, 1931
Rodentolepis straminea (Goeze, 1782)	*Niviventer fulvescens*	Vietnam	Nguyen, 1986
Taenia sp.	*R. norvegicus* *R. tanezumi*	Thailand	Namue and Wongsawad, 1997
Taenia taeniaformis	*Bandicota indica* *R. annandalei* *R. argentiventer* *R. exulans* *R. norvegicus* *R. tanezumi* *R. tiomanicus*	Malaysia Philippines	Claveria *et al*., 2005; Krishnasamy *et al*., 1980; Sinniah, 1979; Tubangui, 1931

Table 4 Literature review of trematodes from murid rodents in Southeast Asia

Parasites (Trematodes)	Hosts	Countries	References
Centrocestus sp	*R. norvegicus* *R. tanezumi*	Thailand	Namue and Wongsawad, 1997
Dictyonograptus babeensis (Nguyen, 1977)	*R. tanezumi*	Vietnam	Nguyen, 1991
Echinostoma sp.	*R. tanezumi*	Malaysia	Leong *et al*., 1979
Echinostoma cinetorchis (Ando & Ozaki, 1923)	*Bandicota indica* *R. tanezumi*	Vietnam	Nguyen, 1991
Echinostoma ilocanum (Garrison, 1908)	*R. norvegicus* *R. tanezumi*	Philippines Thailand	Cross and Basaca, 1986; Namue and Wongsawad, 1997
Echinostoma malayanum (Leiper, 1911**)**	*R. exulans* *R. norvegicus* *R. tanezumi*	Malaysia Philippines Thailand	Monzon and Kitikoon, 1989; Namue and Wongsawad, 1997; Sinniah, 1979
Gastrodiscoides hominis (Lewis & McConnall, 1876**)**	*Bandicota indica* *Bandicota savilei* *R. argentiventer* *R. tanezumi*	Thailand	Sey, 2001
Haplorchis taichui (Nishigori, 1926)	*Mus musculus*	Thailand	Sukontason *et al*., 1999
Notocotylus sp	*R. argentiventer* *R. losea*	Vietnam	Pham *et al*., 2001
Plagiorchis sp.	*R. tanezumi*	Malaysia	Leong *et al*., 1979
Plagiorchis muris (Tanabe, 1922)	*R. tanezumi*	Vietnam	Nguyen, 1991
Platynosomoides muris (Stscherbakova, 1942)	*R. nitidus*	Vietnam	Nguyen, 1991

Table 4 (Continued)

Parasites (Trematodes)	**Hosts**	**Countries**	**References**
Prosthodendrium sp.	*R. tanezumi*	Malaysia	Leong *et al*., 1979
Quinqueseralis quinqueseralis	*R. norvegicus* *R. tanezumi*	Thailand	Namue and Wongsawad, 1997
Stellantchasmus falcatus (Onji & Nishio, 1915)	*Mus musculus*	Thailand	Wongaswad *et al*., 1998

Table 5 Literature review of nematodes from murid rodents in Southeast Asia

Parasites (Nematodes)	Hosts	Countries	References
Ancylostoma gilsoni (Gedoelst, 1917)	*R. nitidus*	Vietnam	Phan, 1984
Ascaris sp.	*Berylmys bowersi* *R. nitidus*	Vietnam	Phan, 1984
Brevistriata skrjabini (Schulz & Lubimov, 1932)	*R. tanezumi*	Vietnam	Phan, 1984
Citellina levini (Li, 1933)	*Bandicota indica* *Berylmys bowersi* *R. nitidus* *Rattus* sp.	Vietnam	Phan, 1984
Cyclodontostomum purvisi (Adams, 1933)	*Bandicota indica* *Berylmys bowersi* *L. sabanus* *Maxomys bartelsii* *Maxomys rajah* *Maxomys surifer* *Maxomys whiteheadi* *N. cremoriventer* *R. annandalei* *R. argentiventer* *R. nitidus* *R. hoffmanni* *R. tanezumi* *R. tiomanicus* *Sundamys muelleri*	Indonesia Malaysia Vietnam	Hasegawa & Syafruddin, 1994; Phan, 1984; Singh and Chee-Hock, 1971; Sinniah, 1979; Varughese, 1973; Wiroreno, 1978
Eucoleus bacillatus (Eberth, 1863)	*R. argentiventer*	Indonesia	Hasegawa *et al*., 1992
Ganguleterakis spumosa (Schneider, 1866)	*Bandicota* sp. *Berylmys bowersi* *R. norvegicus* *Rattus* sp.	Malaysia Philippines Vietnam	Leong *et al*., 1979; Phan, 1984; Singh and Chee-Hock, 1971; Tubangui, 1931
Globocephalus connorfilii (Lane, 1992)	*L. sabanus*	Malaysia	Singh and Chee-Hock, 1971
Gnathostoma spinigerum (Owen, 1836)	*Mus musculus*	Thailand	Maleewong *et al*., 1988

Table 5 (Continued)

Parasites (Nematodes)	Hosts	Countries	References
Gnathostoma malaysiae (Miyazaki & Dunn, 1965)	*Maxomys surifer* *R. tiomanicus*	Malaysia Thailand	Kamiya *et al*., 1987; Miyazaki and Dunn, 1965
Gongylonema neoplasticum (Fibiger & Ditlevsen, 1914)	*R. norvegicus* *R. tanezumi* *R. tiomanicus*	Philippines Malaysia Vietnam	Krishnasamy *et al*., 1980; Leong *et al*., 1979; Pham *et al*., 2001; Singh and Chee-Hock, 1971; Tubangui, 1931
Mastophorus muris (Gmelin, 1790)	*Maxomys bartelsii* *N. lepturus* *R. exulans* *R. rattus*	Indonesia Malaysia	Hasegawa & Syafruddin, 1995; Wiroreno, 1978
Nippostrongylus sp.	*L. edwardsi* *Maxomys surifer* *R. exulans* *R. norvegicus* *R. tanezumi*	Malaysia Thailand Vietnam	Namue and Wongsawad, 1997; Phan, 1984; Sinniah, 1979
Nippostrongylus brasillensis (Travassos, 1914)	*L. sabanus* *Maxomys rajah* *N. cremoriventer* *N. fulvescens* *R. argentiventer* *R. losea* *R. nitidus* *R. tanezumi* *R. tiomanicus* *S. muelleri*	Indonesia Malaysia Vietnam	Hasegawa *et al*., 1992; Krishnasamy, 1980; Leong *et al*., 1979; Pham *et al*., 2001; Phan, 1984; Singh and Chee-Hock, 1971
Orientostrongylus tenorai (Durette-Desset, 1970)	*R. argentiventer* *R. losea*	Vietnam	Pham *et al*., 2001
Physaloptera sp.	*Berylmys bowersi* *L. sabanus* *Maxomys bartelsii* *Maxomys rajah* *N. lepturus*	Indonesia Malaysia	Hasegawa *et al*., 1992; Singh and Chee-Hock, 1971; Wiroreno, 1978

Table 5 (Continued)

Parasites (Nematodes)	Hosts	Countries	References
Physaloptera sp.	*R. argentiventer* *R. tiomanicus* *S. muelleri*	Indonesia Malaysia	Hasegawa *et al*., 1992 Singh and Chee-Hock, 1971 Wiroreno, 1978
Physaloptera ngoci (Le Van Hoa, 1961)	*Mus* sp. *Rattus* sp.	Vietnam	Phan, 1984
Protospiura-Mastophorus sp.	*Berylmys bowersi* *L. sabanus* *Maxomys rajah* *Maxomys whiteheadi* *N. cremoriventer* *R. argentiventer* *R. tiomanicus* *S. muelleri*	Malaysia	Singh and Chee-Hock, 1971
Rictularia sp.	*R. norvegicus* *R. tanezumi*	Thailand	Namue and Wongsawad, 1997
Rictularia tani (Hoeppli, 1929)	*L. sabanus* *Maxomys bartelsii* *Maxomys rajah* *N. cremoriventer* *R. tanezumi* *R. tiomanicus* *S. muelleri*	Indonesia Malaysia	Singh and Chee-Hock, 1971 Sinniah, 1979 Wiroreno, 1978
Streptophagus sp.	No information	Malaysia	Paramasvaran *et al*., 2005
Strongyloides sp.	*R. argentiventer* *R. losea*	Vietnam	Pham *et al*., 2001
Strongyloides ratti (Sandground, 1925)	*Bandicota indica* *L. sabanus* *R. annandalei* *R. argentiventer* *R. exulans* *R. norvegicus* *R. tanezumi* *R. tiomanicus*	Indonesia Malaysia Philippines Vietnam	Hasegawa *et al*., 1992; Hasegawa & Syafruddin, 1995 Leong *et al*., 1979 Pham *et al*., 2001 Roberts, 1991 Singh and Chee-Hock, 1971 Tubangui, 1931

Table 5 (Continued)

Parasites (Nematodes)	Hosts	Countries	References
Strongyloides venezuelensis (Brumpt, 1934)	*Rattus* sp.	Indonesia Malaysia	Hasegawa & Syafruddin, 1995
Syphacia obvelata (Rudolphi, 1802)	*Mus* sp. *Rattus* sp.	Vietnam	Phan, 1984
Syphacia muris (Yamaguti, 1935)	*L. sabanus* *R. annandalei* *R. argentiventer* *R. exulans* *R. losea* *R. norvegicus* *R. tanezumi* *R. tiomanicus*	Indonesia Malaysia Vietnam	Hasegawa *et al*., 1992; Krishnasamy *et al*., 1980; Leong *et al*., 1979; Pham *et al*., 2001; Singh and Chee-Hock, 1971; Sinniah, 1979
Tikusnema javaense (Hasegawa *et al*., 1992)	*R. argentiventer*	Indonesia	Hasegawa *et al*., 1992
Trichostrongylus sp.	No information	Malaysia	Paramasvaran *et al*., 2005
Trichuris muris (Schrank, 1788)	*R. tanezumi*	Malaysia Vietnam	Leong *et al*., 1979; Phan, 1984

Table 6 Literature review of acanthocephalan from murid rodents in Southeast Asia

Parasite (Acanthocephala)	**Hosts**	**Countries**	**References**
Moniliformis moniliformis (Bremser, 1811)	*Bandicota indica* *R. annandalei* *R. argentiventer* *R. exulans* *R. norvegicus* *R. tanezumi* *R. tiomanicus*	Malaysia Philippines Vietnam	Leong *et al*., 1979; Pham *et al*., 2001; Sinniah, 1979; Tubangui, 1931

The studies concerned about 20 rodent species and 58 parasite species, including 13 cestodes, 15 trematodes, 29 nematodes and 1 acanthocephalan. Averagely, individual rodent species can be multiple infected by nearly to 3 helminth species. Despite, heavy infection or multiple infection of helminth but rodent seem to be healthy and active, reflected to a well-developed and successful host-parasite interrelationship (Claveria *et al*., 2005 and Morand *et al*., 2006). The pre-dominant species of rodent that seem highly reported for total parasite species richness (totalPSR) were *Rattus norvegicus*, *Rattus rattus diardii* and *Rattus argentiventer*. In the same way, the overall helminth infection**:** cestodes (8 species or taxonomic groups), trematodes (5) and nematodes (10) were found as high diversity in *Rattus norvegicus*, *Rattus rattus* and *Rattus argentiventer*, respectively.

Many of the reported helminths are transmissible to humans and constitute a problem for public health especially cestodes and trematodes such as *Raillietina celebensis* (Rougier *et al*., 1981) *Hymenolepis nana* (Faust *et al*., 1970 and Keittivuti *et al.*, 1987), *Hymenolepis diminuta* (Sinniah *et al*., 1978 and Chenchittikul *et al*., 1983), *Raillietina Siriraji* (Pradatsundarsar, 1968 and Chenchittikul *et al*., 1983), *Echinostoma ilocanum* (Radomyos and Bunnag, 1982 and Cross and Basaca-Sevilla, 1986), *E. malayanum* (Sornmani, 1969), *Haplorchis taichui* (Pearson, 1964 and Manning and Lertprasert, 1971), *Stellntchamus falcatus* (Pearson, 1964 and Klicks and Tantachumrun, 1974), *Gastrodiscoides hominis* (Murty and Reddy, 1980) Some nematodes and acanthocephala can also infect humans, such as *Gnathostoma*

spinigerum (Nitidandhaprabhas *et al.* 1975; Kawamura *et al*., 1983 and Ménard *et al*., 2003) and *Moniliformis moniliformis* (Walter Beck, 1959; Moayedi *et a*l., 1971 and Sinniah *et al*., 1979).

MATERIALS AND METHODS

The work was organized into 2 parts: field work and laboratory work. The field work was followed by a protocol of ANR CERoPath (Community Ecology of Rodents and their Pathogens in South-East Asia; ANR CERoPath fieldwork protocol, unpublished data).

1. Field work

Sample localities

Three sampling locations were selected on the one northern and two northeastern province of Thailand: Nan, Loei and Burirum, followed to a part of ANR CERoPath program from France. These locations were highly represented from forest areas with low human density to poor forest areas with high human density follow the index of anthropization. The index of anthropization was a transformation of the habitat variable into a semi-quantitative variable following Jittapalapong *et al*. (2008) with the index varying from forests: 1; upland agricultural areas: 2; lowland agricultural area: 3 to domestic habitat: 4. Rodents were trapped either from city or rural areas, and habitats details were classified as:

1. Forests: Including primary or secondary forests, orchards/plantations (bamboo, teak, rubber tree, eucalyptus, etc.)
2. Upland agricultural area: Dry areas including maize, hop, cassava, dry rice or pineapple fields.
3. Lowland agricultural area: Humid or irrigated areas, especially rice fields but also soybean fields or maize fields.
4. Domestic habitat: Build-up areas, villages and isolated house.

Rodent trapping

Trap: Live-traps were used for trapping rodents. Locally made cage-traps available in each sampling location site have proven correct efficiency in preliminary sampling of medium-size and large-size rodents. The smallest mammals, like *Mus* sp., might escape from these cages built from perforated sheet metal. Therefore we used Ugland traps and Sherman traps. However an attempt to increase the trapping success, we used snap traps. In that case, animals were kept rapidly after they had been killed.

Baits: Different baits were used and mixed in a same trap to show more appealing, depend on the rodent species and their habitats:

- Smelly baits for rodents in rice fields as the piece of fishes, crabs can used or mixed with sticky rice
- Sticky rice (eventually a little bit grilled) for domestic rodents.
- Cassava and/or maize for rodents in dry crop fields.
- Banana and/or pineapple for rodents in forest areas. (Banana has the advantage of being less attractive to ants)

However, nothing impeded the combined use of these different baits in all habitats.

Trap lines: In each sampling locality, 10 trap lines (composed of 10 traps) were set during 12 days. Trap lines were moved every 4 days (3 moves). Each trap line was located for sampling a specific landscape category. The duration of 4 days was a compromise between too much mobility that can't lure careful animals and too much stability that can induce a decrease in the trapping success. These trapping systems provided a good diversity of rodent representative of the community structures and take into account the diversity within our landscape categories. The trapped rodents were collected in each morning and brought to laboratory. Trap lines were set in different habitats (or sub-categories) in proportion to their relative abundance in the landscape. To be accepted by local populations (and in order to limit trap removal or displacement), we contacted to the owner of the field before setting the traps. One simple way was to set the trap in a field where people are actually

working on. In order to facilitate daily control and trap recovery, each trap was marked by a piece of “plastic tape” (a fluorescent tag) attached at proximity (ie. 1-2 m) in the vegetation. Each trap line was referenced by a code and localized with its geographical coordinates taken in its center.

Figure 1 View of sampling localities in 3 provinces of Thailand.

Help of local hunters: In Thailand country side, rats can be hunted for food. Hunters have a great knowledge of rat's ecology and can catch several animals per night. Also, farmers may be a great help to catch rodents while they observe the displacements of rats through the state of their holes in the edge of fields. Usually farmers can inform if rodents are present or not in their field. However they may not know about small-size rodents and may directly give a negative answer if they are against any intrusion in their fields. Therefore, hunters were informed of the objectives of the study. Animals were preferably needed alive, with a little information about the place of capture (land use, and location). Then, the GPS location was later taken nearly the place of capture. Sometimes if a species cannot be caught alive (such as the biggest rats, i.e. *Bandicota indica*), kill-traps (locally-made snares or snap traps) or shooting were done. Such animals were kept rapidly or disposed in a fridge and placed in a plastic bag to avoid any contact with blood. Every day during the trapping session, one had to collect rodents and release empty traps directly at the hunter's house. These conditions are meant to prevent a long storage of rodents.

Trap handling: Traps containing rodents were carefully labelled to indicate the place of capture (capture code) and the date of capture (if the animal is kept alive). The label must be out of reach from the animal which can destroy it (avoid putting it directly on the cage). Animals were also protected from the sun, heat and have good ventilation.

Rodent euthanasia

Euthanasia was defined as the painless and stress-free killing of the animal. For security reasons, recommended methods without any handling of living animals to avoid bites. Cotton wool soaked in chloroform was used for induction of anesthesia followed by death of rodents in side a plastic box. These methods were used in open-air places, far from the other animals captured. The rodents only were handled out of the trap after been deeply anesthetized, as soon as breathing and heart beating have stopped.

Rodent morphological description

Weight: The animals were weighted (in grams) by used a digital balance for accuracy within one decigram. Calibrated balance to zero before measurement, and make sure that animal shouldn't be wet before weighting.

Measurement: Used a polystyrene board covered by a thinner plastic board to pin animals for a proper dissection. Such dissection board was easily disinfected and replaced regularly. The vernier caliper and a ruler with the extremity starting at "0" were used for take measuring of rodents parts (head to body, tail, hind foot, ear and skull). Take time to read twice by the measurements in order to reach the extremely accurate.

1. Head to body length: Placed the animal lying on its back, in a straight position without stretching the body. The distance between the tip of the nose and the middle of the anus were measured. For males, lift the scrotum up if the anus is not visible. Pins were used for marked the extremities and took measuring on the dissection board (the tip of the nose and the anus). Then removed the animal and precisely measured with a ruler.

2. Tail length: Placed the animal lying on its back and the tail in a straight position. The distance between the middle of the anus and the tip of the tail were measured. Do not include terminal hairs, if presents, but measured their length separately. Also used pins to mark the extremities before removing the animal and precisely measuring the distance with a ruler. If the tail was cut or damaged, indicate "cut", and eventually added in brackets the length of the cut tail (it can be useful to later identify quickly the animal in the collection). Verified that the tail has not been cut at its extremity: in such case, the tail looks like intact but its extremity is square (the tail length would be a little shorter and it may induce a wrong identification).

3. Hind foot length: Position the ruler on the dissection board and flattened the hind-foot on it. The distance between the back of the heel and the tip of the central toe were measured without the claw.

4. Ear length: The ruler (with the extremity starting at “0”) or internal jaws of vernier caliper was introduced into the ear and measured the distance between the notch (at the base of the ear) and the extremity of the ear. Verified that the ear is not cut or damaged at the extremity.

5. Skull length: Used the external jaws of vernier caliper measured the length between the extremity of nasal and the notch of lambdoid crest over the occipital condyle.

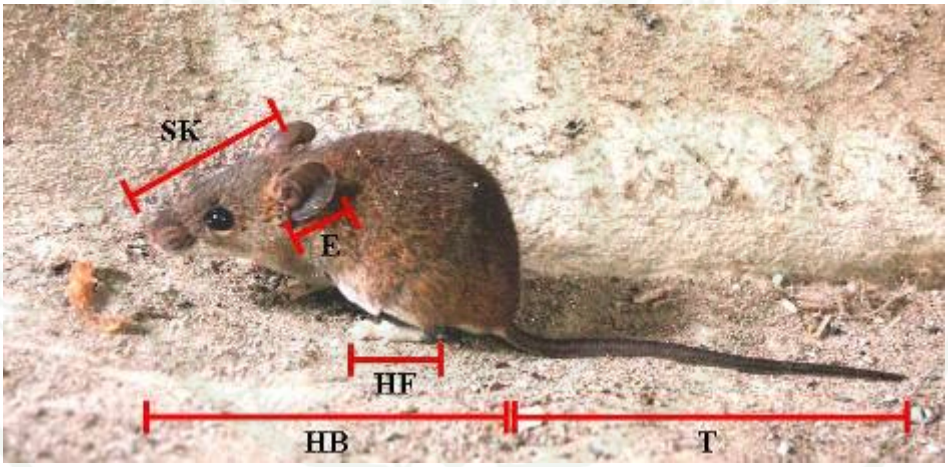


Figure 2 Measurements of head to body (HB), tail (T), hind foot (HF), ear (E) and skull (SK)

Sex and sexual maturity

While it is not possible to determine the age of an animal, the observation of the sexual organs is highly informative to assess its maturity (juvenile and adult) and behavior. A few criteria are considered as follow:

Female

Vagina: divided into 2 types: not perforated (juvenile) and perforated (adult).

Teats: divided into 3 types:

1 = barely visible (juvenile, hardly distinguished and enumerated)

2 = prominent but not lactating (adult)

3 = prominent and lactating (adult, large teats with no hair around)

Mammary formula: (divided in three parts from the top to the bottom) pectoral + post-axillary + inguinal. The mammary formula can be helpful to distinguish different species.

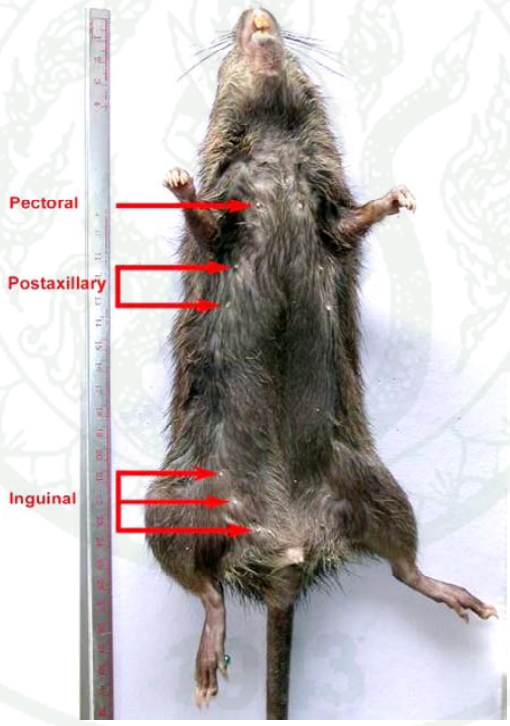


Figure 3 Position of teats, example of female *Bandicota indica* (1+2+3)

Male

Indicated if the testis is inside the body (juvenile), or descended into the scrotum, outside the body (adult). In rare cases, testis can be in the body even if the scrotum is developed: indicated these observations in the dissection sheet and validate

as an adult. It informs on the age of males. And also indicate if the seminal vesicles are developed or visible (adult) or undeveloped (juvenile). It informs on the activity of males.

Juvenile females and males might be difficult to distinguish (notice that both sexes have the urethral opening on a small protrusion). Nevertheless the distance between the anus and the urethral opening is larger for juvenile males than for juvenile females. The vaginal opening covered by a translucent skin might be observed for juvenile females. If the identification cannot be done morphologically or even to confirm the external identification, observed the sexual organs at the end of the dissection.

Rodent dissection and GI tract isolation

Open the animal:

- The euthanized rodents were pined ventral side up on the dissection board.
- Pinched and raised the skin with dissecting forceps and cut through the body wall muscles just anterior to the genital opening and continue just to one side of the midline on the ventral side until the thoracic cavity. Blunt-end scissors (either of double blunt-end scissors or single blunt, one sharp point scissors) was used for avoided the damage any organ.

GI tract isolation:

- The end of rectum was cut before anus and lifted the GI tract, and then carefully separated it from the body without opening the tract. Separated it from the liver and finally cut it from the esophageal sphincter of stomach.
- The whole GI tract was preserved in a plastic box, tube or even plastic bag, filled with 70% alcohol as a fixative agent. Carefully closed the container to avoided evaporation and put an identification tag in it.

2. Laboratory work

Helminths collection

- A gut sample was brought out from the container and spreaded it out in a Petri dish. Individually number of each animal was recorded.

- Poured some 70% alcohol (not too much) into the Petri dish to facilitated the dissection and examined under the stereomicroscope. The gut was stretched out from mesentery that attaches intestine and stomach together.

- Separated into 3 parts: stomach, small intestine and large intestine. Each part was put in individual Petri dish and dissection was done one by one. Opened each part by forceps or needles to ripe along its entire length and examined by visible eyes for the presence of mature and immature helminths, both in the contents inside and in scraping from the mucosa (do not use the scissors or razors to open the gut because it can damage parasites samples).

- Carefully collected and counted helminths under the stereomicroscope. All obtained helminths parasites were collected and relaxed in water, then fixed in 70% alcohol.

- A score was given to quantified parasites infection by counting or estimating the number of each genus and report as: not found, 1, 2, 3, 4, 5, 10, 30, 50, 100 and more than 100 parasites.

- A paint brush or needle was used for carefully picked the parasites and collected them in a tube with cap that contains 70% glycerine alcohol (70% alcohol / 5% glycerine). Parasites were separated by genus for each individual animal. Labeled (by pencil) the details of collection on drawing paper and put it into the tube (for example: identifiant number of rodent, group or genus of parasite, date, and name of collector in order to identify the species of parasites by properly methods and identification key).

Helminth identification

The collected nematodes (roundworms) were preserved in a 70% glycerine alcohol prior to the morphological observations the parasites were immersed in lacto-phenol solution. The specimens were mounted temporarily in the solution on the glass slides.

The cestodes (tapeworms) that fixed in the same preservative, the specimens were lightly pressed between two glass slides and keep in AFA (Alcohol-formal-acetic) fixative for 24 hours. Soon after, they were processed in a graded series of alcohol, stained with Semichon's carmine and mounted in temporary mounting agents.

The trematodes (flukes) were used as the same methods with tapeworms, pressed and fixed in AFA fixative for 24 hours, dehydrated under the graded series of alcohol and then stained with Semichon's carmine and mounted in temporary mounting agents.

3. Statistical analysis

This study aims to assess the possible relations between ecological traits of rodent hosts and helminths prevalence. Individual parasitological status (positive or negative) was considered as a dependent variable for each genus or species of helminth during their isolation was used for further analyses.

The significance of each host individual factors as species, sex, maturity, body mass, spleen weight, locality and anthropization index were used for determine the parasite infection as individualPSR. The analysis was investigated by univariate statistical analysis to evaluate the relations between individualPSR and each host factor by using multiple logistic regression model, student's t-test and analysis of variance (ANOVA) as well. The critical probability was set at $P = 0.05$. Statistical analysis was performed by using computer softwares (Statistica).

RESULTS

Diversity of GI helminths

A total of 725 murid rodents including 17 species as *Bandicota indica, Bandicota savilei, Berylmys berdmorei, Berylmys bowersi, Chiropodomys gliroides, Hapalomys delacouri, Leopoldamys edwardsi, Leopoldamys neilli, Maxomys surifer, Mus caroli, Mus cervicolor, Mus cookii, Mus fragilicauda, Niviventer fulvescens, Rattus exulans, Rattus losea* and *Rattus tanezumi* were trapped from forest areas, upland agricultural areas; lowland agricultural area:and domestic habitat of Nan, Loei and Burirum provinces. The GI helminthes were examined only from gastrointestinal tract as stomach, small intestine and large intestine of murid rodents. Four hundread and eighteen animals (57.66%) were infected with GI helminths including acanthocephalan and pentastomida. Twenty-two parasites species or taxonomic grouping were identified from all infected rodents. Three species of cestodes (30.48%): *Raillietina* sp., *Hymenolepis diminuta* and *Rodentolepis nana*; 3 species of trematodes (3.45%): *Notocotylus* sp., Lecithodendriidae and *Echinostoma* sp.; 14 species of nematodes (41.79%): *Trichuris muris, Eucoleus* sp., *Aonchotheca* sp., *Ganguleterakis spumosa, Syphacia obvelata, Syphacia muris, Physaloptera* sp., *Protospiura* sp., *Mastophorus* sp., *Pterygodermatites* sp., *Gongylonema neoplasticum, Cyclodontostomum purvisi*, Trichostrongylidae and Filariidae; 1 species of acanthocephalan (0.41%): *Moniliformis moniliformis* and 1 sample of pentastomid larva (0.14%) were identified.

The highest prevalence of helminth infection was *Mus caroli* (81.81%), followed by the other rodents were *M. cervicolor* (76.47%), *Leopoldamys edwardsi* (75.00%), *Bandicota indica* (71.54%) and *Bandicota savilei* (71.43%). The highest totalPSR was shown in *B. indica* follwed by *Rattus losea, Rattus tanezumi, M. cervicolor* and *B. savilei* as 14, 12, 11, 10 and 9 parasite species respectively. *Hapalomys delacouri, L. neilli* and *M. fragilicauda* were the 3 rodent species that not found to be infected with any parasite (Table 7).

Table 7 Prevalence of GI helminthic infection in murid rodents from Nan, Loei and Buriram provinces (Thailand)

Murid rodents	Total	Examined		TotalPSR	Type of parasite							
					Cestode		Trematode		Nematode		Acanthocephala	
		+	(%)		+	(%)	+	(%)	+	(%)	+	(%)
Bandicota indica	123	88	(71.54)	14	75	(60.98)	1	(0.81)	51	(41.46)	-	-
Bandicota savilei	21	15	(71.43)	9	5	(23.81)	1	(4.76)	13	(61.91)	-	-
Berylmys berdmorei	19	12	(63.16)	7	7	(36.84)	-	-	10	(52.63)	-	-
Berylmys bowersi	25	9	(36.00)	5	3	(12.00)	-	-	8	(32.00)	-	-
Chiropodomys gliroides	2	1	(50.00)	1	1	(50.00)	-	-	-	-	-	-
Hapalomys delacouri	1	-	-	-	-	-	-	-	-	-	-	-
Leopoldamys edwardsi	12	9	(75.00)	4	8	(66.66)	-	-	3	(25.00)	-	-
Leopoldamys neilli	1	-	-	-	-	-	-	-	-	-	-	-
Maxomys surifer	21	5	(23.81)	5	3	(14.29)	-	-	4	(19.05)	-	-
Mus caroli	33	27	(81.81)	5	6	(18.18)	-	-	26	(78.79)	-	-
Mus cervicolor	51	39	(76.47)	10	14	(27.45)	-	-	36	(70.59)	-	-
Mus cookii	69	49	(71.01)	7	16	(23.19)	1	(1.45)	43	(62.32)	-	-
Mus fragilicauda	1	-	-	-	-	-	-	-	-	-	-	-

Table 7 (Continued)

Murid rodents	Total	Examined		TotalPSR	Type of parasite							
					Cestode		Trematode		Nematode		Acanthocephala	
		+	(%)		+	(%)	+	(%)	+	(%)	+	(%)
Niviventer fulvescens	66	42	(63.64)	8	31	(46.97)	-	-	21	(31.82)	-	-
Rattus exulans	124	23	(18.55)	8	17	(13.71)	-	-	8	(6.45)	2	(1.61)
Rattus losea	88	54	(61.36)	12	13	(14.77)	22	(25.00)	46	(52.27)	-	-
Rattus tanezumi	68	45	(66.18)	11	22	(32.35)	-	-	34	(50.00)	1	(1.47)
Total	**725**	**418**	**(57.66)**	**22**	**221**	**(30.48)**	**25**	**(3.45)**	**303**	**(41.79)**	**3**	**(0.41)**

The nematode in family Trichostrongylidae (24.28%), cestode *Raillietina* sp. (17.10%), cestode *Hymenolepis diminuta* (8.55%), nematode *Syphacia muris* (8.55%) and cestode *Rodentolepis nana* (4.97%) were the most prevalent parasites. The *H. diminuta* and Trichostrongylidae were the most wide host range, 11 rodent species found to infect with those parasites (Table 8-9).

Table 8 Prevalence of cestodes, trematodes acanthocephalan and pentastomida in different species of murid rodents from Nan, Loei and Buriram (Thailand)

Murid rodents	**Trematodes**			**Cestodes**			
	***Notocotylus* sp.**	**Lecithodendriidae**	***Echinostoma* sp.**	***Raillietina* sp.**	***H. diminuta***	***R. nana***	***M. moniliformis***
Bandicota indica (n=123)	0.81	-	-	60.98	0.81	-	-
Bandicota savilei (n=21)	-	-	4.76	19.05	4.76	-	-
Berylmys berdmorei (n=19)	-	-	-	21.05	15.79	-	-
Berylmys bowersi (n=25)	-	-	-	-	12.00	-	-
Chiropodomys gliroides (n=2)	-	-	-	-	-	50.00	-
Hapalomys delacouri (n=1)	-	-	-	-	-	-	-
Leopoldamys edwardsi (n=12)	-	-	-	25.00	41.67	-	-
Leopoldamys neilli (n=1)	-	-	-	-	-	-	-
Maxomys surifer (n=21)	-	-	-	9.52	4.76	-	-
Mus caroli (n=33)	-	-	-	-	-	18.18	-
Mus cervicolor (n=51)	-	-	-	3.92	-	23.53	-
Mus cookii (n=69)	-	1.45	-	-	2.89	20.29	-
Mus fragilicauda (n=1)	-	-	-	-	-	-	-
Niviventer fulvescens (n=66)	-	-	-	12.12	33.33	1.52	-
Rattus exulans (n=124)	-	-	-	1.61	12.09	-	1.61
Rattus losea (n=88)	9.09	19.32	1.14	11.36	1.14	2.27	-
Rattus tanezumi (n=68)	-	-	-	20.59	11.76	-	1.47
Total (N=725)	**1.24**	**2.48**	**0.28**	**17.10**	**8.55**	**4.97**	**0.41**

Table 9 Prevalence of nematode in different species of murid rodents from Nan, Loei and Buriram provinces (Thailand)

Murid rodents	Nematodes													
	T. muris	***Eucoleus* sp.**	***Aonchotheca* sp.**	***G. spumosa***	***S. obvelata***	***S. muris***	***Physaloptera* sp.**	***Protospiura* sp.**	***Mastophorus* sp.**	***Pterygodermatites* sp.**	***G. neoplasticum***	***C. purvisi***	**Trichostrongylidae**	**Filariidae**
Bandicota indica (n=123)	7.32	0.81	2.44	15.45	-	8.94	7.32	2.44	2.44	-	-	0.81	12.19	-
Bandicota savilei (n=21)	4.76	-	-	9.53	-	42.86	9.52	-	-	-	4.76	-	14.29	-
Berylmys berdmorei (n=19)	-	-	-	36.84	-	10.53	5.26	10.53	5.26	-	-	-	-	-
Berylmys bowersi (n=25)	-	-	-	20.00	-	16.00	-	4.00	4.00	-	-	-	-	-
Chiropodomys gliroides (n=2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hapalomys delacouri (n=1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leopoldamys edwardsi (n=12)	-	-	-	-	-	8.33	-	-	-	-	-	-	25.00	-
Leopoldamys neilli (n=1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maxomys surifer (n=21)	-	-	-	-	-	4.76	-	-	-	-	4.76	-	9.53	-
Mus caroli (n=33)	-	-	-	-	18.18	-	3.03	12.12	-	-	-	-	72.72	-

Table 9 (Continued)

Murid rodents	Nematodes													
	T. muris	***Eucoleus* sp.**	***Aonchotheca* sp.**	***G. spumosa***	***S. obvelata***	***S. muris***	***Physaloptera* sp.**	***Protospiura* sp.**	***Mastophorus* sp.**	***Pterygodermatites* sp.**	***G. neoplasticum***	***C. purvisi***	**Trichostrongylidae**	**Filariidae**
Mus cervicolor (n=51)	-	5.88	1.96	-	11.76	-	1.96	13.73	-	-	3.92	-	52.94	-
Mus cookii (n=69)	-	-	-	-	26.09	-	-	11.59	-	-	1.45	-	43.48	-
Mus fragilicauda (n=1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Niviventer fulvescens (n=66)	-	-	-	-	-	1.52	-	-	-	4.55	1.52	-	27.27	1.52
Rattus exulans (n=124)	-	-	-	-	-	2.42	-	1.61	0.81	-	0.81	-	1.61	-
Rattus losea (n=88)	1.14	-	-	-	-	22.73	11.36	2.27	-	-	1.14	-	32.95	-
Rattus tanezumi (n=68)	1.47	-	-	-	-	14.71	-	1.47	1.47	5.88	7.35	-	33.82	2.94
Total (N=725)	**1.66**	**0.55**	**0.55**	**4.55**	**4.14**	**8.55**	**3.31**	**4.14**	**0.97**	**0.97**	**1.79**	**0.14**	**24.28**	**0.41**

Distribution of GI helminths

The sample of murid rodents from 3 provinces as Nan, Loei and Buriram showed the distribution of parasites species differed in the totalPSR and prevalence of infection on each location. We found 33.7% infection in Loei, 18.5% in Nan and 5.5% in Buriram. The difference of totalPSR within 3 localities was examined by ANOVA, and significantly showed the independence among each other ($F_{(2, 722)}$ = 3.2482, p-value = 0.03941). Although the number of parasite species was highest in Loei followed by Nan and Buriram as 19, 16 and 12 respectively, but the statistical analysis result showed the mean of totalPSR was highest in Nan followed by Buriram and Loei. The prevalence of helminth infection among the habitats of each rodent also reported (see more details in Table 10-15 and Figure 4).

In Loei, 14 murid rodent species were infected by 19 species of GI helminths: 3 cestodes, 3 trematodes, 12 nematodes and 1 acanthocephalan. The hishest prevalence parasite was Trichostrongylidae (25.45%) followed by *Hymenolepis diminuta* (12.39%) and *Syphacia muris* (9.23%). Two trematodes: Lecithodendriidae and *Echinostoma* sp. and one nematode: Filariidae were found only in this locality.

In Nan, 8 murid rodent species were infected by 16 species of GI helminths: 3 cestodes, 11 nematodes, 1 acanthocephalan and 1 pentastomida. The highest prevalence parasite was *Raillietina* sp. (37.06%) followed by Trichostrongylidae (21.32%) and *Ganguleterakis spumosa* (12.18%). One pentastomida was accidentally found only one specimen in small intestine of *Bandicota indica.* The nematode *Mastophorus* sp. was found only in this locality.

In Buriram, only 4 murid rodent species were infected by 12 species of GI helminths: 1 Trematode, 3 cestodes and 8 nematodes. The highest prevalence parasite was Trichostrongylidae (25%) followed by *Raillietina* sp. (17.86%) and *Syphacia muris* (14.29%). The nematode *Cyclodontostomum purvisi* were found only in this locality.

Nine GI helminths species that found in all of the 3 localities in this study were cestodes: *Raillietina* sp., *Hymenolepis diminuta* and *Rodentolepis nana*; and nematodes: *Aonchotheca* sp., *Syphacia muris, Physaloptera* sp., *Protospiura* sp., *Gongylonema neoplasticum* and Trichostrongylidae.

Table 10 Statistical analysis (ANOVA) of independent test between individualPSR and sample localities ($p < 0.05$)

Dependent variable		
IndividualPSR	$F_{(2,722)} = 3.2482$	p-value = 0.04
Categorical variable	**Number examined**	**IndividualPSR Mean±SD**
Loei	444	0.8513±0.047
Nan	197	1.0659±0.070
Buriram	84	0.8690±0.118

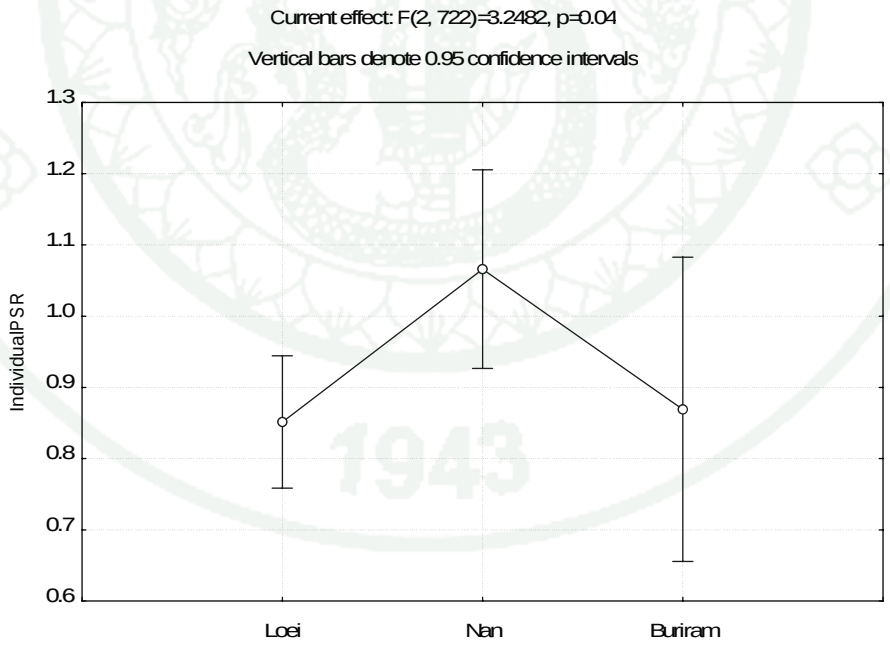


Figure 4 Significant variation of mean individualPSR among sampling localities using ANOVA

Table 11 Data on murid rodents captured among habitats from Nan, Loei and Buriram provinces (Thailand)

Murid Rodents	Habitats							
	Forest		Upland		Lowland		Domestic	
	+	(%)	+	(%)	+	(%)	+	(%)
Bandicota indica (n=123)	6	(4.9)	10	(8.1)	104	(84.6)	3	(2.4)
Bandicota savilei (n=21)	5	(23.8)	1	(4.8)	15	(71.4)	-	-
Berylmys berdmorei (n=19)	4	(21.1)	9	(47.4)	1	(5.3)	5	(26.3)
Berylmys bowersi (n=25)	7	(28)	17	(68)	-	-	1	(4)
Chiropodomys gliroides (n=2)	1	(50)	1	(50)	-	-	-	-
Hapalomys delacouri (n=1)	1	(100)	-	-	-	-	-	-
Leopoldamys edwardsi (n=12)	4	(33.3)	8	(66.7)	-	-	-	-
Leopoldamys neilli (n=1)	1	(100)	-	-	-	-	-	-
Maxomys surifer (n=21)	11	(52.4)	8	(38.1)	2	(9.5)	-	-
Mus caroli (n=33)	-	-	12	(36.4)	21	(63.6)	-	-
Mus cervicolor (n=51)	2	(3.9)	26	(51)	23	(45.1)	-	-
Mus cookii (n=69)	6	(8.7)	51	(73.9)	11	(15.9)	1	(1.4)
Mus fragilicauda (n=1)	1	(100)	-	-	-	-	-	-
Niviventer fulvescens (n=66)	15	(22.7)	41	(62.1)	10	(15.2)	-	-
Rattus exulans (n=124)	2	(1.6)	5	(4)	5	(4)	112	(90.3)
Rattus losea (n=88)	12	(13.6)	16	(18.2)	60	(68.2)	-	-
Rattus tanezumi (n=68)	6	(8.8)	17	(25)	25	(36.8)	20	(29.4)
Total (N=725)	**84**	**(11.6)**	**222**	**(30.6)**	**277**	**(38.2)**	**142**	**(19.6)**

Table 12 Murid rodent infection with GI helminths in different locations and habitats

Murid rodents	Location			Habitat			
	Loei	Nan	Buriram	Forest	Upland	Lowland	Domestic
	+ (%)	+ (%)	+ (%)	+ (%)	+ (%)	+ (%)	+ (%)
Bandicota indica (n=123)	3 (2.4)	66 (53.7)	19 (15.4)	6 (4.9)	6 (4.9)	73 (59.3)	3 (2.4)
Bandicota savilei (n=21)	15 (71.4)	-	-	4 (19)	1 (4.8)	10 (47.6)	-
Berylmys berdmorei (n=19)	3 (15.8)	9 (47.4)	-	3 (15.8)	4 (21.1)	1 (5.3)	4 (21.1)
Berylmys bowersi (n=25)	7 (28)	2 (8)	-	2 (8)	6 (24)	-	1 (4)
Chiropodomys gliroides (n=2)	1 (50)	-	-	-	1 (50)	-	-
Hapalomys delacouri (n=1)	-	-	-	-	-	-	-
Leopoldamys edwardsi (n=12)	9 (75)	-	-	4 (33.3)	5 (41.7)	-	-
Leopoldamys neilli (n=1)	-	-	-	-	-	-	-
Maxomys surifer (n=21)	5 (23.8)	-	-	3 (14.3)	1 (4.8)	1 (4.8)	-
Mus caroli (n=33)	22 (66.7)	5 (15.2)	-	-	9 (27.3)	18 (54.5)	-
Mus cervicolor (n=51)	19 (37.3)	12 (23.5)	8 (15.7)	1 (2)	19 (37.3)	19 (37.3)	-
Mus cookii (n=69)	33 (47.8)	16 (23.2)	-	3 (4.3)	36 (52.2)	9 (13)	1 (1.4)
Mus fragilicauda (n=1)	-	-	-	-	-	-	-
Niviventer fulvescens (n=66)	42 (63.6)	-	-	8 (12.1)	29 (43.9)	5 (7.6)	-
Rattus exulans (n=124)	12 (9.7)	5 (4)	6 (4.8)	-	1 (0.8)	-	20 (16.1)

Table 12 (Continued)

Murid rodents	Location			Habitat			
	Loei	**Nan**	**Buriram**	**Forest**	**Upland**	**Lowland**	**Domestic**
	+ (%)	**+ (%)**	**+ (%)**	**+ (%)**	**+ (%)**	**+ (%)**	**+ (%)**
Rattus losea (n=88)	53 (60.2)	-	-	5 (5.7)	9 (10.2)	36 (40.9)	-
Rattus tanezumi (n=68)	19 (27.9)	19 (27.9)	7 (10.3)	6 (8.8)	12 (17.6)	11 (16.2)	16 (23.5)
Total (N=725)	**244 (33.7)**	**134 (18.5)**	**40 (5.5)**	**49 (6.8)**	**139 (19.2)**	**183 (25.2)**	**47 (6.5)**

Table 13 Murid rodent infection with GI helminths among habitats in Nan province (Thailand) classified by rodent species.

Murid Rodents	Habitat							
	Forest		Upland		Lowland		Domestic	
	+	(%)	+	(%)	+	(%)	+	(%)
Bandicota indica (n=84)	6	(7.1)	6	(7.1)	51	(60.7)	3	(3.6)
Berylmys berdmorei (n=10)	2	(20)	2	(20)	1	(10)	4	(40)
Berylmys bowersi (n=3)	1	(33.3)	-	-	-	-	1	(33.3)
Mus caroli (n=6)	-	-	3	(50)	2	(33.3)		
Mus cervicolor (n=14)	1	(7.1)	9	(64.3)	2	(14.3)		
Mus cookii (n=22)	-	-	13	(59.1)	3	(13.6)		
Rattus exulans (n=38)	-	-	1	(2.6)	-	-	4	(10.5)
Rattus tanezumi (n=20)	2	(10)	6	(30)	1	(5)	10	(50)
Total (N=197)	**12**	**(6.1)**	**40**	**(20.3)**	**60**	**(30.5)**	**22**	**(11.2)**

Table 14 Murid rodent infection with GI helminths among habitats in Buriram province (Thailand) classified by rodent species.

Murid Rodents	Habitat							
	Forest		Upland		Lowland		Domestic	
	+	(%)	+	(%)	+	(%)	+	(%)
Bandicota indica (n=23)	-	-	-	-	19	(82.6)		
Mus cervicolor (n=9)	-	-	-	-	8	(88.9)		
Rattus exulans (n=39)	-	-	-	-	-	-	6	(15.4)
Rattus tanezumi (n=13)	1	(7.7)	-	-	4	(30.8)	2	(15.4)
Total (N=84)	**1**	**(1.2)**	**-**	**-**	**31**	**(36.9)**	**8**	**(9.5)**

Table 15 Murid rodent infection with GI helminths among habitats in Loei province (Thailand) classified by rodent species.

Murid Rodents	Habitat							
	Forest		Upland		Lowland		Domestic	
	+	(%)	+	(%)	+	(%)	+	(%)
Bandicota indica (n=16)	-	-	-	-	3	(18.8)	-	-
Bandicota savilei (n=21)	4	(19)	1	(4.8)	10	(47.6)	-	-
Berylmys berdmorei (n=9)	1	(11.1)	2	(22.2)	-	-	-	-
Berylmys bowersi (n=22)	1	(4.5)	6	(27.3)	-	-	-	-
Chiropodomys gliroides (n=2)	-	-	1	(50)	-	-	-	-
Hapalomys delacouri (n=1)	-	-	-	-	-	-	-	-
Leopoldamys edwardsi (n=12)	4	(33.3)	5	(41.7)	-	-	-	-
Leopoldamys neilli (n=1)	-	-	-	-	-	-	-	-
Maxomys surifer (n=21)	3	(14.3)	1	(4.8)	1	(4.8)	-	-
Mus caroli (n=27)	-	-	6	(22.2)	16	(59.3)	-	-
Mus cervicolor (n=28)	-	-	10	(35.7)	9	(32.1)	-	-
Mus cookii (n=47)	3	(6.4)	23	(48.9)	6	(12.8)	1	(21.3)
Mus fragilicauda (n=1)	-	-	-	-	-	-	-	-
Niviventer fulvescens (n=66)	8	(12.1)	29	(43.9)	5	(7.6)	-	-
Rattus exulans (n=47)	-	-	-	-	-	-	12	(25.5)
Rattus losea (n=88)	9	(10.2)	9	(10.2)	36	(41)	-	-
Rattus tanezumi (n=35)	3	(8.6)	6	(17.1)	6	(17.1)	4	(11.4)
Total (N=444)	**36**	**(8.1)**	**99**	**(22.3)**	**92**	**(20.7)**	**17**	**(3.8)**

The influence of host sex, maturity, body mass and habitat to GI helminth infection and individualPSR

Totally murid rodent examined, showed the prevalence of parasite infection was closely found in male (59.03%) and female (56.57%) rodents. The number of parasite species that found is 14 and 13 in male and female rodents respectively. Statistical analysis, student's t-test showed that presence of individualPSR was not different among host sex (t = 0.2695, p-value = 0.79), see Table 16 and Figure 5.

Host maturity did not seem to play a role in GI helminth infection. We found the prevalence of infection was 54.87% in juvenile and 59.07% in adult rodents. The number of parasite species that closely found is 13 and 14 in juvenile and adult rodents respectively. However, the statistical analysis, student's t-test showed that individualPSR was significantly differed by age maturity (t = 2.2925, p-value = 0.02), see Table 17 and Figure 6.

Table 16 Student's t-test analysis for independent sample between individualPSR and host sexes ($p < 0.05$)

Dependent variable	Host sex			t-value	p-value
	Number examined	Male Mean±SD	Female Mean±SD		
IndividualPSR	718	0.90±0.98	0.92±1.02	0.2695	0.79

Table 17 Student's t-test analysis for independent sample between individualPSR and host maturity ($p < 0.05$)

Dependent variable	Host maturity			t-value	p-value
	Number examined	Juvenile Mean±SD	Adult Mean±SD		
IndividualPSR	719	0.78±0.88	0.97±1.04	2.2925	0.02

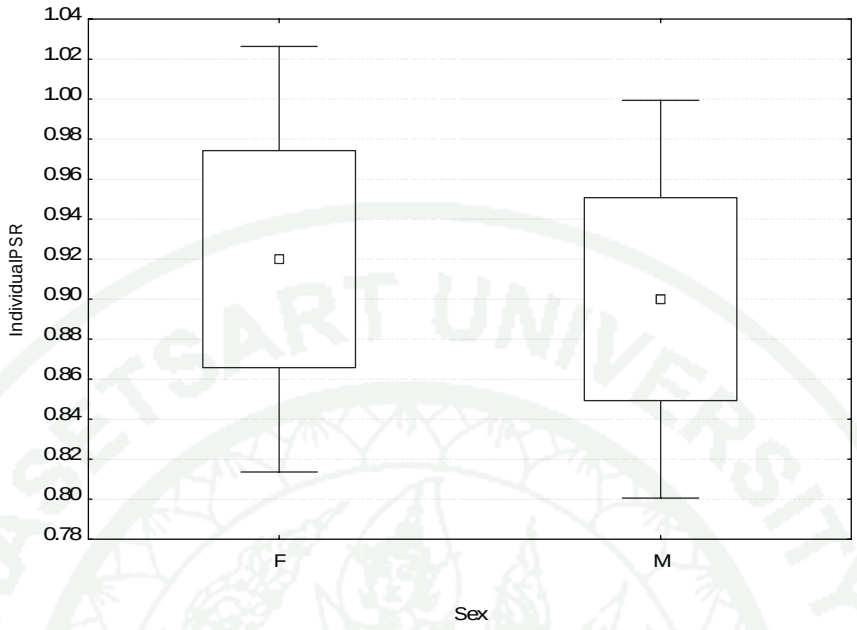


Figure 5 No significant difference of individualPSR between female and male rodents

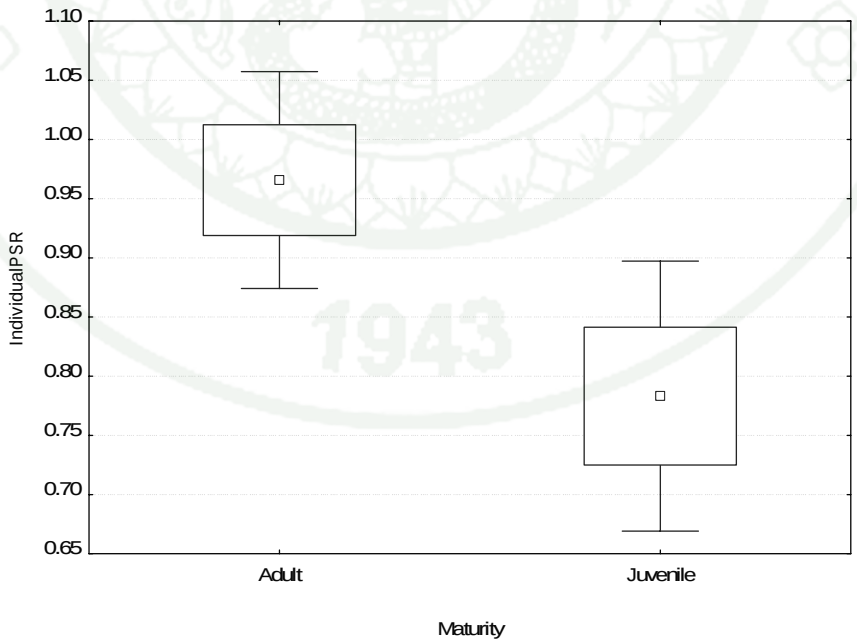


Figure 6 Significant difference of individualPSR between adult and juvenile rodents

The prevalence of parasite infection in each habitat was showed by anthropization index as 6.8% in forest, 19.2% in upland agricultural area, 25.2% in lowland agricultural area and 6.5% in domestic place (see Table 12). In addition, we performed the multiple regression analysis to find the relationship between dependent variable, individualPSR and independent variable as anthropization index and log body mass. The result showed that individualPSR was slightly related to anthropization index (p-value = 0.02) but not significantly related to log body mass (p-value = 0.96) as showed in Table 18.

Table 18 Multiple regression analysis of relationship between individualPSR and host factors ($p < 0.05$)

Dependent variable		
IndividualPSR	N = 725 F (3.694) = 11.999 p-value < 0.001 R= 0.22 R^2= 0.05	
Independent variable	**b slope**	**p-value**
Log body mass	-0.008	0.96
Anthropization index	-0.097	0.02

Table 19 The data of murid rodent infection with GI helminths on different individual factor as sex and maturity

Murid rodents	GI helminth infection (%)	TotalPSR	Sex (%)		Maturity (%)	
			Male	Female	Juvenile	Adult
Bandicota indica (n=123)	71.54	14	74.58	68.75	58.86	81.94
Bandicota savilei (n=21)	71.43	9	71.43	71.42	55.56	83.33
Berylmys berdmorei (n=19)	63.16	7	66.67	60.00	44.44	80.00
Berylmys bowersi (n=25)	36.00	5	33.33	38.46	41.67	80.00
Chiropodomys gliroides (n=2)	50.00	1	100.00	-	-	50.00
Hapalomys delacouri (n=1)	-	-	-	-	-	-
Leopoldamys edwardsi (n=12)	75.00	4	75.00	75.00	83.33	66.67
Leopoldamys neilli (n=1)	-	-	-	-	-	-
Maxomys surifer (n=21)	23.81	5	23.08	25.00	25.00	23.53
Mus caroli (n=33)	81.81	5	77.78	85.71	83.33	80.00
Mus cervicolor (n=51)	76.47	10	78.57	77.27	55.56	82.93
Mus cookii (n=69)	71.01	7	73.53	68.57	66.67	73.33
Mus fragilicauda (n=1)	-	-	-	-	-	-
Niviventer fulvescens (n=66)	63.64	8	65.00	61.54	68.75	62.00
Rattus exulans (n=124)	18.55	8	10.91	25.00	14.29	19.27

Table 19 (Continued)

Murid rodents	GI helminth infection (%)	TotalPSR	Sex (%)		Maturity (%)	
			Male	Female	Juvenile	Adult
Rattus losea (n=88)	61.36	12	60.42	62.50	52.38	69.56
Rattus tanezumi (n=68)	66.18	11	73.68	56.67	52.94	70.59
Total (N=725)	**57.66**	**22**	**59.03**	**56.57**	**54.87**	**59.07**

DISCUSSION

Rodents have been the representative animal of several studies on the survey of GI helminth parasites in Europe, America, Australia and many country in Africa or Asia including Southeast Asia (Feliu *et al*., 1997; Pulido-Flores *et al*., 2005; Warner, 1998; Behnke *et al*., 2000; Singla *et al*., 2008 and Paramasvaran *et al*., 2005) but surprisingly not so much work has been done in Thailand. In this study, we collected murid rodents from 3 border provinces from Northern and Northeastern Thailand, according to the protocol of ANR Ceropath project from France. Then, the GI helminths diversity of rodents was informed. Mean while some statistical analysis was used to test the relative importance of two extrinsic factors (locality and habitats) and three intrinsic factors (sex, maturity and body mass) in order to determine the individualPSR.

Trapped rodents in this study belonged to 17 species from 4 types of habitats, both of urban and rural area. The overall prevalence of infection is 57.66% with 22 species or taxonomic group of GI helminths indicated that murid rodents in these 3 localities were highly infected with various parasites. Nematode was the dominant parasite highly found on prevalence of infection (41.79%) and also high totalPSR with 14 species. The nematode in family Trichostrongylidae appeared to be the dominant parasite with 24.28% prevalence infection. The specimens from this study difficult to determined to genus or species. They seem to comprise with 4 or 5 species, so the further identification on molecular technique are still required. However, nematode in family *Trichostronngylidae* that have been reported in SEA possibly be the *Trichostrongylus* sp., *Nippostrongylus brasiliensis, Brevistriata skrjabini* and *Orientostrongylus tenorai* (Singh and Chee-Hock, 1971; Sinniah, 1979; Leong *et al*., 1979; Phan, 1984; Namue and Wongsawad, 1997; Pham *et al*., 2001 and Paramasvaran *et al*., 2005).

Two genuses of capillarid nematode, *Eucoleus* sp. and *Aonchotheca* sp. were found only in stomach from two species of field rodents as *Bandicota indica* and *Mus cervicolor*. One possible species of *Eucoleus* that has been reported in Indonesia was

Eucoleus bacillatus (Hasegawa *et al*., 1992). This study also shows the first report of *Aonchotheca* sp. infection in murid rodents in Thailand.

The nematode in family Rictulariidae*: Pterygodermatites* sp. (syn. *Rictularia* sp.) was infected only in duodenum of *Niviventer fulvescens* and *Rattus tanezumi.* The possible species of Rictulariidae has been reported in SEA was *Rictularia tani*, found in Indonesia and Malaysia (Singh and Chee-Hock, 1971; Wiroreno, 1978 and Sinniah, 1979).

The Filariidae in this study was found in the GI tract of two species of murid rodent as *Niviventer fulvescens* and *Rattus tanezumi.* The review study of nematode parasites in Malaysian rodents, Singh and Chee-Hock (1971) was reported one species of Filariidae: *Breinlia* sp. from abdominal cavity and lung. However, our filarid specimens still required the molecular identification in further study.

Only one of all rodents (0.14%) was infected with *Cyclodontostomum purvisi*. This is the first report of *Cyclodontostomum purvisi* has been found in Thailand. The worm was found in caecum of *Bandicota indica* from Buriram. In contrast, many species of rodents from Indonesia, Malaysia and Vietnam were found to be infected with this nematode (Singh and Chee-Hock, 1971; Varughese, 1973; Wiroreno, 1978; Sinniah, 1979; Phan, 1984 and Hasegawa and Syafruddin, 1994).

Three cestodes species were infected with 30.48% of overall prevalence infection, comprising of *Raillietina* sp. (17.10%), *Hymenolepis diminuta* (8.55%) and *Rodentolepis nana* (4.97%). All of these cestodes were found only in small intestine. The *Raillietina* sp. is commonly found in birds (Yamaguti, 1959) while rodents in SEA were reported to be infected by *Raillietina celebensis* and *Raillietina siriraji* from Thailand and Vietnam (Chenchittikul *et al*., 1983; Nguyen, 1986; Roberts, 1991 and Pham *et al.*, 2001). The other two cestodes in family *Hymenolepididae*, *Hymenolepis diminuta* and *Rodentolepis nana* (syn. *Hemenolepis nana*) were found in small intestine of many murid rodent species.

Interestingly, all of these three cestodes have been reported in human as the zoonotic disease (Areekul and Radomyos, 1970; Sinniah, 1979 and Chenchittikul *et al*., 1983). Therefore, the murid rodents from these 3 localities were realized as the possible reservoirs for cestodes transmitted to human.

The prevalence infection of overall trematodes from this study is 3.45% by 3 trematodes family or genus as *Notocotylus* sp. (1.24%), Lecithodendriidae (2.48%) and *Echinostoma* sp. (0.28%). All of these flukes were found only in 4 species of field rodents as *Bandicota indica*, *B. savilei, Rattus losea* and *Mus cookii*. The result of these trematodes found in field rodents was similar to the previous study reported by Artchawakom (1981) that found the trematode of family Notocotylidae: *Quinqueserialis quinqueserialis* and *Echinostoma* sp. from rice field rats, *Rattus argentiventer* and *Bandicota indica* in Nakhon Prathom, Thailand.

The acanthocephalans: *Moniliformis moniliformis* were also found in this study. Three rodents (0.41%), 2 *Rattus exulans* and 1 *Rattus tanezumi* from domestic habitat were infected with *Moniliformis moniliformis*. This parasite often found in township or near human living place because their life cycle must be completed by cockroach as intermediate host (Skrjabin, 1958). For this reason, the *Moniliformis moniliformis* was also realized as the zoonotic parasite that might be affected to the human public health.

Moreover, we accidentally found the toungue worm, worm-liked arthropod parasite in the subclass Pentastomida of Maxillopoda class. According to our specimen, only one individual nymphal stage (0.81%) was found in small intestine of *Bandicota indica* from Nan province. This worm has been reported as the parasite of the respiratory system of vertebrates especially reptiles, and occasionally found in nasopharynx of canine and feline even in human (Self, 2009). In this specimen, this bandicoot rat might be act as the intermediate host to complete the life cycle of parasite. In addition, more data have to be collected and paralelly sampled some reptile or possible definitive host from this area to examine the parasite in further study. However, the previous study in SEA, Krishnasamy *et al* (1980) reported one

genus of Pentastomida: *Armillifer* sp. was found in *Rattus tiomanicus* from West Malaysia.

The results in present study indicated that murid rodents are highly infected with various GI-helminth parasites. From our data, the highest multiple infections are 5 helminths species, individually found in *Rattus losea* from Loei with Lecithodendriidae, *Raillietina* sp., *Syphacia muris, Physaloptera* sp. and Trichostrongylidae. Despite heavy infection or multiple infection by helminths, rodents seem to remain healthy and actives, reflecting a well-developed and successful host-parasite interrelationship (Claveria *et al*., 2005; Morand *et al*., 2006).

According to the statistical analysis, some patterns seem to emerge in relationship between individualPSR and host factors. Multiple regression analysis on the dependent variable (individualPSR) and independent variable (anthropization index) was slightly significant while host body mass was showed non-significant related to individualPSR. Student's t-test analysis for independent sample between individualPSR and host maturity (adult and juvenile) was significantly differed while host sex (male and female) was showed non-significant difference for individualPSR. Summary that increasing of individualPSR was possibly found more in adult rodents and also associated with living in more wild places. In contrast, individualPSR was not any associated with host body mass and sex. Some previous studies in Europe about the infection with GI helminths were in agreement with significantly correlated by age maturity (Webster and Macdonald, 1995 and Stojcevic *et al*., 2004).

Four of the parasites in present study have been reported as transmissible to humans and constitute a problem for public health especially cestodes such as *Raillietina* sp. (Pradatsundarsar, 1968 and Areekul and Radomyos, 1970), *Rodentolepis* (*Hymenolepis*) *nana* (Faust *et al*., 1970 and Keittivuti *et al*., 1987), *Hymenolepis diminuta* (Sinniah *et al*., 1978 and Chenchittikul *et al*., 1983). Moreover, the acanthocephalan: *Moniliformis moniliformis* can also found to infect in humans (Walter Beck, 1959; Moayedi *et al*., 1971 and Sinniah, 1978).

This study provides some information on GI-helminth of murid rodents in some part of Thailand. However, the helminths infection was reported only from gastrointestinal tract, while parasites of other organs should also be studied, such as ectoparasites or endoparasites in blood circulation, lung, liver, peritoneum cavity and reproductive organ. Further study should be done on the other parts of Thailand and also determine the rodent-parasite relationships such as host sex, maturity, body mass, habitat and so on. The analysis might be useful to find out the possible routes of its zoonotic potential to human and domestic animal health in Thailand or even in SEA.

CONCLUSION

A total of 725 murid rodents were examined in 3 border provinces in Northern and Northeastern Thailand: Nan, Loei and Buriram. The prevalence of infection was 57.66% (418 rodents) from 17 species of murid rodents were infected with helminths including acanthocephalan and pentastomida. Twenty-two parasites species or taxonomic groups were identified from all infected rodents. Four parasites species of medical importance as zoonotic parasite were *Raillietina* sp., *Hymenolepis diminuta, Rodentolepis nana* and *Moniliformis moniliformis*. According to statistical analysis showed some pattern of relationship between individualPSR and host intrinsic or extrinsic factors. Increasing of individualPSR was possibly found more in adult rodents and also associated with living in more wild places. In contrast, individualPSR was not any associated with host body mass and sex. The difference of individualPSR within 3 localities was examined, and significantly showed the independence among each other. The prevalence of infection and diversity of parasites are also discussed.

LITERATURE CITED

Alley, J., J. Moore and N. Gotelli. 1992. *Moniliformis moniliformis* Infection has no Effect on Some Behaviors of the Cockroach *Diploptera punctata*. **J Parasitol**. 78: 524-526.

Anderson, R.C. 2000. **Nematode Parasites of Vertebrates: Their Development and Transmission**. 2nd edition. CABI Publishing, New York.

Andreassen, J., E. Bennet-Jenkins and C. Bryant. 1999. Immunology and biochemistry of *Hymenolepis diminuta*. **Adv Parasitol**. 42: 223-275.

Aplin, K.P., P.R. Brown, J. Jacob, C. Krebs and G.R. Singleton. 2003. **Field Methods for Rodent Studies in Asia and the Indo-Pacific**. ACIAR Monograph No.100, Canberra, Australia.

Areekul, S. and P. Radomyos. 1970. Preliminary report of *Raillietina* sp. infection in man and rats in Thailand. **Southeast Asian J Trop Med Public Health**. 1: 559.

Artchawakom, T. 1981. **A study on parasites in the rice field rat (*R.argentiventer*) and the great bandicoot (*Bandicota indica*)**. M.Sc. Thesis, Kasetsart University.

Auffray, J.C., A. Orth, J. Catalan, J.P. Gonzalez, E. Desmarais and F. Bonhomme. 2002. Phylogenetic position and description of a new species of subgenus *Mus* (Rodentia, Mammalia) from Thailand. **Zool Scr**. 32: 119–127.

Badenhorst, D., V. Herbreteau, Y. Chaval, M. Page` s, T. J. Robinson, W. Rerkamnuaychoke, S. Morand, J.P. Hugot and G. Dobigny. 2009. New karyotypic data for Asian rodents (Rodentia, Muridae) with the first report of B-chromosomes in the genus *Mus*. **J Zool**. 279: 1-13.

Baylis, H.A., 1922. Observation on certain cestodes of rats, with an account of a new species of *Hymenolepis.* **Parasitol.** 14: 1-8.

Behnke, J.M., C.J. Barnard, N. Mason, P.D. Harris, N.E. Sherif, S. Zalat and F.S. Gilbert. 2000. Intestinal helminths of spiny mice (*Acomys cahirinus dimidiatus*) from St Katherine's Protectorate in the Sinai, Egypt. **J Helminthol**. 74: 31-43.

Carleton, M.D. 1984. Introduction to rodents, pp. 255–265. *In* S. Anderson and J.K. Jones, Jr., eds. **Orders and Families of Recent Mammals of the World**, Wiley -Inter science Publication, New York.

Cathy, A. and J. Delaney. 1996. Zoonotic parasites of selected exotic animals. **Semin Avian Exot Pet**. 5: 115-124.

Chenchittikul, M., S. Daengpium, M. Hasegawa, T. Itoh and B. Phanthumachinda. 1983. A study of commensal rodents and shrews with reference to the parasites of medical importance in Chanthaburi Province, Thailand. **Southeast Asian J Trop Med Public Health.** 14: 255-259.

Claveria, F.G., J. Causapin, M.A. Guzman, M.G. Toledo and C. Salibay. 2005. Parasite biodiversity in Rattus spp. caught in wet markets. **Southeast Asian J Trop Med Public Health**. 36: 146-148.

Colin, G. and Ogden. 1916. **Observations on the systematics of nematodes belonging to the genus Syphacia**. Bulletin of the British Museum (Natural History), London.

Coombs, I. and D.W.T. Crompton. 1991. **A Guide to Human Helminths**. Taylor & Francis, London, UK.

Corbet, G. and J. Hill. 1992. **The Mammals of the Indomalayan Region: A Systematic Review**. Oxford University Press, USA.

Cross, J.H. and V. Basaca-Sevilla. 1986. Studies on *Echinostoma ilocanum* in the Philippines. **Southeast Asian J Trop Med Public Health.** 17: 23-27.

Dawes, B. 1968. **The Trematoda with Special Reference to British and Other European Forms**. The syndics of the Cambridge University Press. Bently House, Euston Road, London.

Douangboupha, B., P.R. Brown, K. Khamphoukeo, K.P. Aplin and G.R. Singleton. 2009. Population Dynamics of Rodent Pest Species in Upland Farming Systems of Lao PDR. **Kasetsart J. (Nat. Sci.)**. 43: 125 – 131.

Faust, E.C., P.F. Russell and R.C. Jung. 1970. Cyclophyllidean Tapeworm of man, pp. 522-529. *In* C.C. Fraklin, eds. **Craig and Faust's Clinical Parasitology**. 8th edition. Lea and Febiger, Philadelphia.

Feliu, C., F. Renaud, F. Catzeflis, J.P. Hugot, P. Durand and S. Morand. 1997. A comparative analysis of parasite species richness of Iberian rodents. **Parasitol.** 115: 453-466.

Hasegawa, H., S. Shiraishi and Rochman. 1992. *Tikusnema javaense* n. gen., n. sp. (Nematoda: Acuarioidea) and other nematodes from *Rattus argentiventer* collected in west Java, Indonesia. **J Parasitol**. 78: 800-804.

Hasegawa, H. and Syafruddin. 1994. *Cyclodontostomum purvisi* (syn. *Ancistronema coronatum*) (Nematoda: Strongyloidea: Chabertiidae) from rats of Kalimantan and Sulawesi, Indonesia. **J Parasitol.** 80: 657-660.

Hasegawa, H. and Syafruddin. 1995. Nematode fauna of the two sympatric rats *Rattus rattus* and *R. exulans*, in Kao District, Halmahera Island, Indonesia. **J Helm Soc Wash.** 62: 27-31.

Hussey, K.L. 1957. *Syphacia muris* vs. *Syphacia obvelata* in laboratory rats and mice. **J Parasitol**. 43: 555-559.

Jittapalapong, S., T. Inpankaew, N. Sarataphan, V. Herbreteau, J.P. Hugot, S. Morand, and R.W. Stich. 2008. Molecular detection of divergent trypanosomes among rodents of Thailand. **Infect Gent Evol.** 8: 445-449.

Jueco, N.L. and Z.R. Zabala. 1990. The nematodes of *Rattus norvegicus* and *Rattus rattus mindanensis*. **Phil Vet Med**. 27: 39-46.

Kamiya, H., M. Kamiya, M. Ohbayashi, K. Klongkamnuankarn and S. Vajrasthira. 1987. *Gnathostoma malaysiae* Miyazaki and Dunn, 1965 from *Rattus surifer* in Thailand. **Southeast Asian J Trop Med Public Health.** 18: 121-126.

Kawamura, J., Y. Kohri and N. Oka. 1983. Eosinophilic Meningoradiculomyelitis caused by *Gnathostoma spinigerum*. **Arch Neurol**. 40: 583-585.

Khalil, L.F., A. Jones and R.A. Bray. 1994. **Keys to the cestode parasites of vertebrates**. CAB International, United Kingdom.

Kiettivuti, A., B. Kiettivuti and P. Vongleang. 1987. Control of *Hymenolepis nana* and other parasitic infections at babies, home in Bangkok. **J Parasitol Trop Med Assoc Thai**. 10: 51-56.

Klicks, M. and T. Tantachamrun. 1974. Heterophyid (Trematoda) parasites of cats in north Thailand, with notes on a human case found at necropsy. **Southeast Asian J Trop Med Public Health**. 5: 547-550.

Krishnasamy, M., K.I. Singh, S. Ambu and P. Ramachandran. 1980. Seasonal prevalence of the helminth fauna of the wood rat *Rattus tiomanicus* (Miller) in West Malaysia. **Folia Parasitol.** 27: 231-235.

Krivolutsky, D.A., N.T. Ki and F.T. Viet. 1991. On the fauna of orbatid mites and anoplocephalats, helminths of domestic and wild animals in Vietnam. **Parazitologiya.** 25: 468-469.

Leong, T.S., B.L. Lim, L.F. Yap and M. Krishnasamy. 1979. Parasite fauna of the house rat *Rattus rattus diardii* in Kuala Lumpur and nearby villages. **Southeast Asian J Trop Med Public Health**. 10: 122-126.

Liat, L.B., Y.L. Fong and M. Krishnasamy. 1977. *Capillaria hepatica* infection of wild rodents in Peninsular Malaysia. **Southeast Asian J Trop Med Public Health**. 8: 354-358.

Maleewong, W., P. Sitthithaworn, S. Tesana and N. Morakote. 1988. Scanning electron microscopy of the early third-stage larvae of *Gnathostoma spinigerum*. **Southeast Asian J Trop Med Public Health.** 19: 643-647.

Manning, G.S. and P. Lertprasert. 1971. Four new nematode of man from Thailand. **Trans R Soc Trop Med Hyg**. 65: 101-102.

Marshall, J.T. 1988. Family Muridae: Rats and mice, pp. 397-487. *In* B. Lekagul and J.A. Mc Neely, eds. **Mammals of Thailand**. Association for the Conservation of Wildlife, Bangkok.

McCarthy, J. and T.A. Moore. 2000. Emerging helminth zoonoses. **Int J Parasitol.** 30: 1351-1360.

Ménard, A., G. Dos Santos, P. Dekumyoy, S. Ranque, J. Delmont, M. Danis, F. Bricaire and E. Caumes. 2003. Imported cutaneous gnathostomiasis: report of five cases. **Trans R Soc Trop Med Hyg**. 97: 200-202.

Miller, R.W. 2007. ***Rattus tanezumi* in the Upland Rice Terraces of Banaue, Philippines: Demography, Habitat Use, Crop Damage and Yield Assessment**. M.Sc, Thesis, The University of New South Wales, Sydney.

Miyazaki, I. and F.L. Dunn. 1965. *Gnathostoma malaysiae* sp. n. from rats on Tioman Island, Malaysia (Nematoda: Gnathostomatidae). **J Parasitol**. 51: 382.

Moayedi, B., M. Izadi, M. Maleki and E. Ghadirian. 1971. Human Infection with *Moniliformis Moniliformis* (Bremser, 1811) Travassos, 1915 (Syn. *Moniliformis Dubius*), Report of A Case in Isfahan, Iran. **Am J Trop Med Hyg.** 20: 445-448.

Monzon, R.B. and V. Kitikoon. 1989. *Lymnaea* (*Bullastra*) *cumingiana Pfeiffer* (Pulmonata: Lymnaeidae): second intermediate host of *Echinostoma malayanum* in the Philippines. **Southeast Asian J Trop Med Public Health**. 20: 453-460.

Morand, S., B.R. Krasnov and R. Poulin. 2006. **Micromammals and macroparasites; From Evolutionary Ecology to Management**. Springer-Verlag Kato Bunmeisha, Tokyo.

Murty, C.V. and C.R. Reddy. 1980. A case report of *Gastrodiscoides hominis* infestation. **Indian J Pathol Microbiol**. 23: 303-304.

Musser, G.G. 1972. The Species of *Hapalomys* (Rodentia, Muridae). **Am Mus Novit**. 2503: 1-27.

Musser, G.G. and C. Newcomb. 1985. Definitions of Indochinese *Rattus losea* and a New Species from Vietnam. **Am Mus Novit**. 2814: 1-32.

Nama, H.S. 1990. An overview of the tapeworm genus *Hymenolepis* Weinland, 1958 sensu lato from arid and non-arid regions. **Sci Rev Arid Zone Res.** 7: 1-80.

Namue, C. and C. Wongsawad. 1997. Survey of helminth infection in rats (*Rattus* spp) from Chiang Mai Moat. **Southeast Asian J Trop Med Public Health.** 28: 179-183.

Nithiuthai, S., M.T. Anantaphrutib, J. Waikagul and A. Gajadhar. 2004. Waterborne zoonotic helminthiases. **Vet Parasitol**. 126: 167–193.

Nitidandhaprabhas, P., A. Sirikarna, K. Harnsomburana and P. Thepsitthar. 1975. Human Urinary Gnathostomiasis: A Case Report from Thailand. **Am J Trop Med Hyg**. 24: 49-51.

Nguyen, T. K. 1986. **Cestode fauna in Tay Nguyen Region**. Tap Chi Sinh Hoc, Vietnam.

Nguyen, T. L. 1991. **The trematode of birds and mammals in South Vietnam**. Tap Chi Sinh Hoc, Vietnam.

Paramasvaran, S., M. Krishnasamy, H.L. Lee, J. John, H. Lokman, B.M. Naseem, A.S. Rehana and R.L. Santhana. 2005. Helminth infections in small mammals from Ulu Gombak Forest Reserve and the risk to human health. **Trop Biomed.** 22: 191–194.

Pasuralertsakul, S., R. Yaicharoen and S. Sripochang. 2008. Spurious human infection with *Gongylonema*: nine cases reported from Thailand. **Ann Trop Med Parasitol.** 102: 455-457.

Payne, J., C.M. Francis and K. Phillipps. 1985. **A Field Guide to The Mammals of Borneo**. The Sabah Society with WWF Malaysia. Setiakawan Printer Sdn. Bhd, Petaling Jaya, Malaysia.

Pearson, J.C. 1964. A revision of the family Haplorchinae Looss, 1899 (Trematoda: Heterophyidae). **Parasitol.** 54: 601-676.

Pham X.D., C.L. Tran and H. Hasegawa. 2001. Helminths collected from *Rattus* spp. in Bac Ninh Province, Vietnam. **Comp Parasitol**. 68: 261-264.

Phan, T.V. 1984. **The nematodes parasitizing on animals in Taynguyen Plateau**. Tap Chi Sinh Hoc, Vietnam.

Pradatsundarsar, A. 1968. Nine cases of *Raillietina* sp. in Bangkok. **J Med Assoc Thai**. 43: 56.

Pulido-Flores, G., S. Moreno-Flores and S. Monks. 2005. Helminths of Rodents (Rodentia: Muridae) from Metztitlan, San Cristobal, and Rancho Santa Elena, Hidalgo, Mexico. **Comp Parasitol**. 72: 186–192.

Radomyos, P. and D. Bunnag. 1982. *Echinostoma ilocanum* (Garrison, 1908) Odner, 1911, infection in man in Thailand. **Southeast Asian J Trop Med Public Health.** 13: 265-269.

Roberts, M. 1991. The parasites of the Polynesian rat within and beyond New Zealand. **Int J Parasitol**. 21: 777-783.

Rougier, Y., F. Legros, J.P. Durand and Y. Cordoliani. 1981. Four cases of parasitic infection by *Raillietina* (*R.*) *celebensis* (Kanicki, 1902) in French Polynesia. **Trans R Soc Trop Med Hyg**. 75: 121.

Rojas, M.C. and M.C. Digiani. 2003. First record of *Mastophorus muris* (Gmelin, 1790) (Nematoda: Spiruroidea) from a wild host in South America. **Parasite**. 10: 375-378.

Scheller, S. 2006. **Gastrodiscoidiasis, Parasites and Pestilence: Infectious Public Health Challenges.** Available Source: http://www.stanford.edu/class/humbio 103/ParaSites2006/Gastrodiscoidiasis/gastro.htm, January 17, 2010.

Schmidt, G.D. 1986. **Handbook of Tapeworm Identification**. CRC Press Inc., Boca Raton, Florida.

Self, J.T. 2009. Pentastomida: Tongue Worms, pp. 561-567. *In* L.S. Roberts and J.Jr. Janovy, eds. **Foundations of Parasitology**. 8th edition. The McGraw-Hill Companies, Inc., New York.

Sey, O. 2001. **Amphistomes of the world: A check-list of the amphistomes of vertebrates**. Hungarian Natural History Museum, University of Pécs, Budapest.

Singh, M. and C. Chee-Hock. 1971. On a collection of nematode parasites from Malayan rats. **Southeast Asian J of Trop Med Public Health**. 2: 516-522.

Singla, L.D., N. Singla, V.R. Parshad, P.D. Juyal and N.K. Sood. 2008. Rodents as reservoirs of parasites in India. **Integrative Zool.** 3: 21-26.

Singleton, G.R., L.A. Hinds, C. J. Krebs and D.M. Spratt. 2003**. Rats, mice and people: rodent biology and management**. ACIAR Monograph, Canberra, Australia.

Sinniah, B. 1979. Parasites of some rodents in Malaysia. **Southeast Asian J of Trop Med Public Health.** 10: 115-121.

Skrjabin, K.I. 1958. **Acanthocephala of Domestic and Wild Animals**. All-Union Society of Helminyhologists, Academy of Sciences of the USSR, Moscow.

Skrjabin, K.I., N.P. Shikhobalova and E.A. Lagodovskaya. 1974. **Oxyuroidea of Animals and Man Part Two**. Helminthological Laboratory, Academy of sciences of the USSR, Keter Publishing House Jerusalem Ltd., Jerusalem.

Skrjabin, K.I., N.P. Shikhobalova and I.V. Orlov. 1970. **Trichocephalidae and Capillariidae of Animals and Man and the Diseases Caused by Them**. Helminthological Laboratory, Academy of sciences of the USSR, Keter Press Binding; Weiner Bindery Ltd., Jerusalem.

Sood, M.L. 2006. **Nematode Parasites of Birds (Including Poultry) from South Asia**. Department of Zoology Punjab Agricultural University. International Book Distributing Co., Punjab.

Sornmani, S. 1969. Echinostomiasis in Thailand, pp. 171-175. *In* **Proceeding of 4th Southeast Asian Seminar on Parasitology and Tropical Medicine**, **Schistosomiasis and other snails-transmitted helminthiasis, Manila.** 24-27 February 1969, Thai Wattana Panich Press. Bangkok, Thailand.

Spatafora, G.A. and T.R. Platt. 1982. Survey of the helminth parasites of the rat, *Rattus norvegicus*, from Maymont Park, Richmond, Virginia. **Virg J Sci.** 32: 3-6.

Stojcevic, D., Z. Mihaljevic and A. Marinculic. 2004. Parasitological survey of rats in rural regions of Croatia. **Vet Med Czech.** 49: 70-74.

Sukontason, K., S. Piangjai, K. Sukontason and U. Chaithong. 1999. Potassium permanganate staining for differentiation the surface morphology of *Opisthorchis viverrini*, *Haplorchis taichui* and *Phaneropsolus bonnei* eggs. **Southeast Asian J of Trop Med Public Health**. 30: 371-374.

Tenora, F. and E. Murai. 1972. Recent data on five species of the genus *Hymenolepis* (Weinland, 1958) (Cestoidea, Hymenolepididae) parasitizing rodents in Hungary. **Acta Zool Hung**. 18:129–145.

Tubangui, M.A. 1931. Trematode parasites of Philippine vertebrates, II: Two echinostome flukes from rats. **Phil. J. Sci.** 44: 273.

Varughese, G. 1973. Studies on the life cycle and developmental morphology of *Cyclodontostomum purvisi* (Adam, 1933), a hookworm parasite of Malayan giant rats. **Southeast Asian J Trop Med Public Health**. 4: 78-95.

Waengsothorn, S., A. Kenthao, A. Latinne and J.P. Hugot. 2009. Rodents within the Centre for Thai National Reference Collections (CTNRC), Past, Present and Future. **Kasetsart J. (Nat. Sci.).** 43: 118 – 124.

Walter Beck, J. 1959. Report of a Possible Human Infection with the Acanthocephalan *Moniliformis moniliformis* (Syn. *M. dubius*). **J Parasitol.** 45: 510.

Warner, L.R. 1998. Australian helminths in Australian rodents: an issue of biodiversity. **Int J Parasitol**. 28: 839-846.

Webster, J.P. and D.W. Macdonald. 1995. Parasites of wild brown rats (*Rattus norvegicus*) on UK farms. **Parasitol**. 111: 247-255.

Wilson, D.E. and D.M. Reeder, 2005. **Mammal Species of the World**. 3rd edition. Johns Hopkins University Press, USA.

Wiroreno, W. 1978. Nematode parasites of rats in West Java, Indonesia. **Southeast Asian J Trop Med Public Health**. 9: 520-525.

Wongaswad, C., P. Chariyahpongun and C. Namue. 1998. Experimental host of *Stellantchasmus falcatus*. **Southeast Asian J Trop Med Public Health**. 29: 406-409.

Yamaguti, S. 1958. The Digenetic Trematodes of Vertebrates part I: Volume I, pp. 800-972. *In* **Systema Helminthum**. Interscience publishers, Inc., New York.

Yamaguti, S. 1959. The Cestodes of Vertebrates: Volume II, pp. 212-213. *In* **Systema Helminthum**. Interscience publishers, Inc., New York.

Yamaguti, S. 1961. The Nematodes of Vertebrates part I: Volume III, pp. 331-638. *In* **Systema Helminthum**. Interscience publishers, Inc., New York.

Yorke, W. and P.A. Maplestone. 1969. **The Nematode Parasites of Vertebrates**. Hafner Publishing Company, New York and London.

APPENDICES

Appendix A

The discussion of murid rodent species

Bandicota indica Bechstein, 1800

Common name: Great Bandicoot

Synonyms: *Bandicota bandicota* (Bechstein, 1800), *B. elliotanus* (Anderson, 1878), *B. eloquens* (Kishida, 1926), *B. gigantea* (Hardwicke, 1804), *B. jabouillei* (Thomas, 1927), *B. macropus* (Hodgson, 1845), *B. malabarica* (Shaw, 1801), *B. maxima* (Pradhan, Mondal, Bhagwat, and Agrawal, 1993), *B. mordax* (Thomas, 1916), *B. nemorivaga* (Hodgson, 1836), *B. perchal* (Shaw, 1801), *B. setifera* (Horsfield, 1824), *B. siamensis* (Kloss, 1919), *B. sonlaensis* (Dao, 1975), and *B. taiwanus* (Tokuda, 1939)

Distribution in SEA: Cambodia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam

Population trend: Increasing

Locality in this study: Loei (13.01%), Nan (68.29%) and Buriram (18.70%)

Habitat: Domestic (2.44%), Lowland (84.55%), Upland (8.13%) and Forest (4.88%)

Feeding behavior: Omnivorous

Number of examined host: 123

Number of infected host: 88

Prevalence (%): 71.54

Helminth infection: *Notocotylus* sp., *Raillietina* sp., *Hymenolepis diminuta, Trichuris muris, Eucoleus* sp., *Aonchotheca* sp., *Ganguleterakis spumosa, Syphacia muris, Physaloptera* sp., *Protospiura* sp., *Mastophorus* sp., *Cyclodontostomum purvisi,* Trichostrongylidae *and Pentastomida*

Discussion for species:

Morphological features are large and energetic rodent with robust, big head and blunt-nosed. The dorsal fur is distinctly shaggy and blackish-brown with the spiny-shaped. The belly fur is usually dark grey. The tail is unicolor black, usually shorter than the head to body range. The feet are dark with strong claws adapted for digging. Big pairs of orange-yellowish incisor teeth with powerful cheek muscle of mandible. The mammary formation in adult female is 1+2+3 (pectoral + postaxillary + inguinal). In our captured adult animals were aggressive and highly vocal, make a noise to warn off their enemy. Their feeding behavior are omnivorous, highly damage to rice crop, potato and soy bean field. In addition, they also feed on invertebrates as mollusks and arthropods.

Measurement: 71 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	400.02	241.60	209.67	46.83	27.78	56.91
Min	91.20	157.00	117.50	31.50	20.50	41.70
Max	740.00	303.00	270.00	58.00	32.50	69.80

Bandicota savilei Thomas, 1961

Common name:	Lesser Bandicoot
Synonyms:	*Bandicota bangchakensis* (Boonsong and Felten, 1989), *B. curtata* (Thomas, 1929), *B. giaraiensis* (Dao and Cao, 1990) and *B. hichensis* (Dao, 1961)
Distribution in SEA:	Cambodia, Lao PDR, Myanmar, Thailand and Vietnam
Population trend:	Stable
Locality in this study:	Loei (100%)
Habitat:	Lowland (71.43%), Upland (4.76%) and Forest (23.81%)
Feeding behavior:	Omnivorous
Number of examined host:	21
Number of infected host:	15
Prevalence (%):	71.43
Helminth infection:	*Echinostoma* sp., *Raillietina* sp., *Hymenolepis diminuta*, *Trichuris muris*, *Ganguleterakis spumosa*, *Syphacia muris*, *Physaloptera* sp., *Gongylonema neoplasticum* and Trichostrongylidae

Discussion for species:

The medium-sized rat with shaggy fur, brownish grey on their back and grey at the belly similarly like *Bandicota indica* but they can be distinguished by its overall smaller size (Aplin *et al*., 2003). Lower back fur is spiny, contains numerous long guard hairs. The tail is unicolored, uniformly dark grey or black above and below, normally shorter than head and body length. The ears are relative large and well furred. The hind feet are dark on the dorsal, shorter and narrower compared with *B. indica*. The incisors are orange-yellowish color, broad and strong with powerful mandible. The mammary formation in adult female is 1+2+3 (pectoral + postaxillary + inguinal). They are bit aggressive compared with *Rattus* or *Mus* but less than *B.indica*. Their habitat are apparently restricted to agricultural area especially crops or paddy field in lowland area. They can also occur together with *B. indica* in dry field, so both of them are realized as the important pest for agricultural products.

Measurement: 12 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	183.87	189.75	158.41	35.04	24.13	47.14
Min	60.00	139.00	109.00	26.00	17.50	35.40
Max	348.10	230.50	332.00	47.50	30.80	60.50

Berylmys berdmorei Blyth, 1851

Common name:	Lesser White-toothed Rat
Synonyms:	*Rattus berdmorei* (Blyth, 1851), *R. magnus* (Kloss, 1916) and *R. mullulus* (Thomas, 1916)
Distribution in SEA:	Cambodia, Lao PDR, Myanmar, Thailand and Vietnam
Population trend:	Unknown
Locality in this study:	Loei (47.37%) and Nan (52.63%)
Habitat:	Domestic (26.32%), Lowland (5.26%), Upland (47.37%) and Forest (21.05%)
Feeding behavior:	Omnivorous
Number of examined host:	19
Number of infected host:	12
Prevalence (%):	63.16
Helminth infection:	*Raillietina* sp., *Hymenolepis diminuta*, *Ganguleterakis spumosa*, *Syphacia muris*, *Physaloptera* sp., *Protospiura* sp. and *Mastophorus* sp.

Discussion for species:

The medium-sized rat with soft and crisp fur in iron-grey color on the back and sides while the belly fur is purely white, sharply demarcated between dorsal and ventral of body. Tail is dorsum dark and paler on the undersurface, normally shorter than head and body length. Feet are clothed in pure white or grey hairs. The *Berylmys* genus can be recognized or distinguished from *Bandicota* by their pale-cream or white incisors enamel and also by the mammary formation in adult female as 1+2+2. They are most commonly found in upland region and also forest habitat. They are omnivorous by a diet of fruits and vegetable with occasional insects and mollusks. Thai farmer usually call them as the handsome rat according to their cute appearance and behavioral character that very calm and gentle. However, they are realized as the occasional upland agricultural pest and responsible for many kind of crops damage.

Measurement: 10 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	221.42	208.90	165.50	38.10	24.60	48.92
Min	195.10	191.00	147.00	35.50	22.50	45.80
Max	269.50	233.00	187.00	41.00	27.00	52.40

Berylmys bowersi Anderson, 1879

Common name:	Great White-toothed Rat and Bowers' Rat
Synonyms:	*Rattus bowersi* (Anderson, 1879), *R. latouchei* (Thomas, 1897), *R. ferreocanus* (Miller, 1900), *R. kennethi* (Kloss, 1919) and *R. wellsi* (Thomas, 1921)
Distribution in SEA:	Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam
Population trend:	Decreasing
Locality in this study:	Loei (88%) and Nan (12%)
Habitat:	Domestic (4%), Upland (68%) and Forest (28%)
Feeding behavior:	Omnivorous
Number of examined host:	25
Number of infected host:	9
Prevalence (%):	36.00
Helminth infection:	*Hymenolepis diminuta, Ganguleterakis spumosa, Syphacia muris, Protospiura* sp. and *Mastophorus* sp.

Discussion for species:

Large-sized rat, look similarly to *Berylmys berdmorei* but bigger in size. The dorsal fur is brownish-grey to dull-tan while the belly is white showed clearly demarcated between dorsal and ventral of body. Tail length is slightly longer than head and body, so they are capable to climb. The tail usually darker above than below, sometimes possibly found the white tip at the end of tail. The ears are moderately large and thinly furred. The teeth are pale cream to white colored, recurved incisors. Mammary formation in adult female is different from *B. berdmorei* as 1+1+2, so it could be the other criteria to distinguish them. Their habitats are most commonly found in upland region and also act as an occasional pest in gardens and orchards. Although the longer-tailed *B. bowersi* is a capable climber, they spends most of time foraging on the ground within the upland forest, where it make burrow and eat a fallen fruits (Aplin *et al*., 2003).

Measurement: 13 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	340.32	241.84	256.36	50.84	30.27	56.82
Min	100.40	163.00	171.50	37.50	24.50	46.90
Max	482.00	270.50	293.00	56.00	33.00	63.10

Chiropodomys gliroides Blyth, 1855

Common name: Pencil-tailed Tree Mouse

Synonyms: *Mus gliroides (Blyth, 1855), M. peguensis* (Blyth, 1859), *Chiropodomys penicillatus* (Peters, 1868), *C. niadis* (Miller, 1903), *C. anna* (Thomas and Wroughton, 1909) and *C. jingdongensis* (Wu and Deng, 1984)

Distribution in SEA: Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam

Population trend: Stable

Locality in this study: Loei (100%)

Habitat: Upland (50%) and Forest (50%)

Feeding behavior: Herbivorous

Number of examined host: 2

Number of infected host: 1

Prevalence (%): 50.00

Helminth infection: *Rodentolepis nana*

Discussion for species:

They are small mouse with relatively long tail generally hairy, ending in a brush-liked tip. A wooly soft fur on the dorsal parts of body are smoky-brown, and the ventral parts are white. The head with short snout, large eyes, rounded ear and long whiskers. The feet are short and adapted for climbing with opposable thumbs. The mammary formation in adult female found only at the inguinal area as 0+0+2. They are herbivorous, live in the bamboo and rarely come to ground (Marshall, 1988; Payne *et al.*, 1998). Our two specimens were captured by the help of local hunter in Loei province. They caught one from the forest area and another from banana plantation in upland agricultural area.

Measurement: 2 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	25.45	90.50	118.50	18.50	16.5	27.45
Min	25.40	90.50	116.00	16.00	15.00	26.80
Max	25.50	90.50	121.00	21.00	18.00	28.10

Hapalomys delacouri Thomas, 1927

Common name: Lesser Marmoset Mouse

Synonyms: *Hapalomys pasquieri* (Thomas, 1927) and *H. marmosa* (Allen, 1927)

Distribution in SEA: Lao PDR and Vietnam

Population trend: Decreasing

Locality in this study: Loei (100%)

Habitat: Forest (100%)

Feeding behavior: Herbivorous

Number of examined host: 1

Number of infected host: -

Prevalence (%): 0

Helminth infection: -

Discussion for species:

Medium-sized rat with soft silky fur, brown color on the dorsal parts of body while the ventral parts are white. The head compound with big eyes and ears, blunt-nosed with long whiskers extending from ear and face. Tail length is longer than the head and body, with the hair tufts along the distal third of tail. The feet are short with

long and widely space between digits. The hallux is wide, fully opposable, and bears a nail rather than a claw, so they are excellent climber (Musser, 1972). The mammary formation in adult female is 1+1+2. They are herbivore; eat on the flowers and fruits. They live inside the internodes of bamboo as the same with *Chiropodomys* (Marshall, 1988). There are two species of *Hapalomys* in Southeast Asia, only one species of *Hapalomys* reported in Thailand was *Hapalomys longicaudatus* (Marshall, 1988) while the another is *H. delacouri*, the smaller species, as identified here. The measurement of one adult male specimen in this study showed the relation with *H.delacouri.* In addition, the molecular technique, cytochrome *b* mitochondrial DNA gene was done and showed the same result as in morphological measurement. The distribution of this species was reported only in Lao PDR and Vietnam, then the present study are realized as the first report of the species found in Thailand.

Measurement: 1 specimen (adult)

Measurement	**Weight (g)**	**Head-Body (mm)**	**Tail (mm)**	**Hind foot (mm)**	**Ear (mm)**	**Skull (mm)**
Average	55.30	132.50	144.00	23.50	12.00	36.80

Leopoldamys edwardsi Thomas, 1882

Common name:	Edwards's Long-tailed Giant Rat
Synonyms:	*Rattus edwardsi* (Thomas, 1882), *R. garonum* (Thomas, 1921), *R. gigas* (Satunin, 1903), *R. melli* (Matschie, 1922), *R. hainanensis* (Xu and Yu, 1985), *Epimys listeri* (Thomas, 1916)
Distribution in SEA:	Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam
Population trend:	Unknown
Locality in this study:	Loei (100%)
Habitat:	Forest (66.67%) and Upland (33.33%)
Feeding behavior:	Herbivorous
Number of examined host:	12
Number of infected host:	9
Prevalence (%):	75.00
Helminth infection:	*Raillietina* sp., *Hymenolepis diminuta*, *Syphacia muris* and Trichostrongylidae

Discussion for species:

They are the large-sized rat with plain brown color on dorsal part and darker down to middle of back than on the flank. The tail is dark, longer than head and body, however it shorter than *Leopoldamys sabanus*, which species that the longest tail of any rat in Thailand (Marshall, 1988). The skull is point-shaped, big ears, large eyes and long whiskers on the cheek. The mammary formation in adult female is 1+1+2. They are herbivorous, mainly found in both primary and secondary evergreen forest, possibly found more in upland or mountainous area.

Measurement: 6 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	229.15	212.75	296.00	41.75	29.58	55.06
Min	121.40	173.50	183.00	28.50	26.00	46.30
Max	361.00	245.00	361.50	48.00	31.50	61.90

Leopoldamys neilli Marshall, 1976

Common name: Neill's Rat

Synonyms: *Rattus neilli* (Marshall, 1976)

Distribution in SEA: Thailand

Population trend: Endangered

Locality in this study: Loei (100%)

Habitat: Forest (100%)

Feeding behavior: Herbivorous

Number of examined host: 1

Number of infected host: -

Prevalence (%): 0

Helminth infection: -

Discussion for species:

They are large-sized rat with dusky face and red-brown fur on the dorsal parts of body while the ventral parts are pure white. The appearance is look similarly to *Leopoldamys edwardsi* in the shape of smaller, as the dwarf version of them (Marshall, 1988). The tail length is longer than head and body with dark color along the dorsal surface except for the distal third, which is white on both dorsal and ventral

tail area. The feet are long, with the dark line along the dorsal part of each hind foot. They are the arboreal species, good climber, quiet and gentle behavior. This species has just reported only 2 places endemic to Thailand, Kanchanaburi and Saraburi province within the habitat of lowland bamboo forest and limestone area (Marshall, 1988 and Waengsothorn *et al*., 2009). The molecular technique by using of cytochrome *b* mitochondrial DNA gene was done together with morphological measurement, and the results were showed as *L. neilli*. Only one specimen was captured in the present study that came from Loei province. For the reason, this study is could be the first report for the expanding area of *L. neilli* to the northeastern area in Thailand.

Maxomys surifer Miller, 1900

Common name:	Yellow Rajah Rat or Spiny-backed Rat
Synonyms:	*Rattus surifer* (Miller, 1900), *R. anambae* (Miller, 1900), *R. bandahara* (Robinson, 1921), *R. finis* (Kloss, 1916), *R. grandis* (Kloss, 1911), *R. koratis* (Kloss, 1919), *R. luteolus* (Miller, 1903), *R. mabalus* (Lyon, 1916), *R. natunae* (Chasen, 1940), *R. ravus* (Robinson and Kloss, 1916), *R. saturatus* (Lyon, 1911), *R. telibon* (Chasen, 1940), *R. umbridorsum* (Miller, 1903) and *R. verbeeki* (Sody, 1930)
Distribution in SEA:	Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam
Population trend:	Decreasing
Locality in this study:	Loei (100%)
Habitat:	Forest (52.38%), Upland (38.10%) and Lowland (9.52%)
Feeding behavior:	Herbivorous
Number of examined host:	21
Number of infected host:	5
Prevalence (%):	23.81
Helminth infection:	*Raillietina* sp., *Hymenolepis diminuta, Syphacia*

muris, Gongylonema neoplasticum and
Trichostrongylidae

Discussion for species:

The medium-sized rat, bright yellowish-brown color mixed with black long pile hairs on the dorsal parts of body. The ventral parts are white-cream, sharply dermacated between dorsal and ventral area. The skull is medium-sized with long nose and big eyes, including large pairs of ears, which well moveable in order to tune in the sound while exciting. The tail is slightly longer but nearly equal to the head and body length. The tail is dark-colored on the dorsal surface which is white at ventral and the third extremity of tail. The feet are long, especially hind foot with purely white color on dorsal part. The mammary formation in adult female is 1+1+2. They are herbivorous, gentle and cute, widely distributed rat of wild habitats throughout Thailand (Marshall, 1988). Most of specimens in the present study were found numerous of ectoparasites as ticks, fleas, mites and chiggers, making *Maxomys spp.* well distinguishable from the other rat species.

Measurement: 15 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	93.08	162.26	166.68	34.90	22.17	42.64
Min	17.00	103.00	126.00	25.00	19.50	31.50
Max	156.90	194.00	196.00	42.00	25.50	49.10

Mus caroli Bonhote, 1902

Common name:	Ryukyu Mouse
Synonyms:	*Mus boninensis* (Kuroda, 1930), *M. formosanus* (Kuroda, 1925), *M. kurilensis* (Kuroda, 1924) and *M. ouwensi* (Kloss, 1921)
Distribution in SEA:	Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam
Population trend:	Stable
Locality in this study:	Loei (81.82%) and Nan (18.18%)
Habitat:	Upland (36.36%) and Lowland (63.64%)
Feeding behavior:	Omnivorous
Number of examined host:	33
Number of infected host:	27
Prevalence (%):	81.81
Helminth infection:	*Rodentolepis nana*, *Syphacia obvelata*, *Physaloptera* sp., *Protospiura* sp. and Trichostrongylidae

Discussion for species:

The small mouse with brownish-grey fur on the dorsal parts of body, and the belly is white. Tail is slightly longer than head and body length with sharply bicolored, almost darker on the upper surface than below. Small skull with short snout and contain the large eyes, big ears and white lips with dark-orange upper incisors. The hind foot is relatively large with white fur on the dorsal surface. The mammary formation in adult female is 1+2+2. They are omnivorous; eat on crops, grains and also some small invertebrate. The habitat use is commonly found in low land rice field and agricultural grassy area and possibly causes some damage to crops. In addition, they are often found together with *Mus cervicolor* in the same field (Aplin *et al*., 2003).

Measurement: 20 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	16.28	84.20	78.97	17.25	13.58	22.83
Min	10.90	75.00	71.50	12.00	12.50	20.30
Max	23.00	95.50	85.00	19.00	18.00	25.20

Mus cervicolor Hodgson, 1845

Common name:	Fawn-colored Mouse
Synonyms:	*Mus annamensis* (Robinson and Kloss, 1922), *M. cunicularis* (Blyth, 1855), *M. imphalensis* (Roonwal, 1948), *M. nitidulus* (Blyth, 1859), *M. popaeus* (Thomas, 1919) and *M. strophiatus* (Hodgson, 1845)
Distribution in SEA:	Cambodia, Indonesia, Lao PDR, Myanmar, Thailand and Vietnam
Population trend:	Stable
Locality in this study:	Loei (81.82%) and Nan (18.18%)
Habitat:	Forest (3.92%), Upland (50.98%) and Lowland (45.10%)
Feeding behavior:	Omnivorous
Number of examined host:	51
Number of infected host:	39
Prevalence (%):	76.47
Helminth infection:	*Raillietina* sp., *Rodentolepis nana*, *Eucoleus* sp., *Aonchotheca* sp., *Syphacia obvelata*, *Physaloptera* sp., *Protospiura* sp., *Mastophorus* sp., *Gongylonema neoplasticum* and Trichostrongylidae

Discussion for species:

The small, soft-furred mouse with orange-brown to brownish-grey on the dorsal parts of body, and the belly fur is white-cream with pale-grey bases. Numerous very fine and soft spines are present in the dorsal fur. The tail is usually shorter than head and body length, distinctly bicolored that darker above than below. The skull is small, contain with the longer nasal bone than *Mus caroli*, and upper incisors are orange or pale-brown in color. The dorsal surface of feet is white with occasional dark hairs on the hind foot. The mammary formation in adult female is 1+2+2. They are omnivorous, found mainly in rice field and grass land. They are widely distributed species often found together with *M. caroli* in rice fields. They can be distinguished from *M. caroli* by their shorter tail and softer fur (Aplin *et al*., 2003).

Measurement: 20 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	21.63	90.91	68.66	16.90	14.27	24.44
Min	9.60	70.50	46.50	13.50	11.00	20.20
Max	102.70	163.00	91.50	27.50	19.00	39.00

Mus cookii Ryley, 1914

Common name:	Cook's Mouse or Ryley's Spiny Mouse
Synonyms:	*Mus darjilingensis* (Hodgson, 1849), *M. nagarum* (Thomas, 1921), *M. palnica* (Thomas, 1923), *M. rahengis* (Kloss, 1920) and *M. thai* (Kloss, 1917)
Distribution in SEA:	Lao PDR, Myanmar, Thailand and Vietnam
Population trend:	Stable
Locality in this study:	Loei (68.12%) and Nan (31.88%)
Habitat:	Forest (8.70%), Upland (73.91%), Lowland (15.94%) and Domestic (1.45%)
Feeding behavior:	Herbivorous
Number of examined host:	69
Number of infected host:	49
Prevalence (%):	71.01
Helminth infection:	*Lecithodendridae*, *Hymenolepis diminuta*, *Rodentolepis nana*, *Syphacia obvelata*, *Protospiura* sp., *Gongylonema neoplasticum* and Trichostrongylidae

Discussion for species:

The large-sized of mouse species, look similarly to large edition of *Mus caroli* but the fur is denser and longer. In addition, they are more elongated skull with long snout, recurved incisors and bigger molar teeth (Marshall, 1988). The ears are large compared with the animal size. The dark brown dorsal fur and contain numerous spine hairs on upper parts of body while the ventral parts are white or pale grey. The tail is shorter than head and body length. The hind foot is large and hairy, usually with a mixture of white and dark hairs (Aplin *et al*., 2003). The mammary formation in adult female is 1+2+2. Their habitat are restricted to mountain, upland rice field and possibly found in orchard. However, nothing reported on the damage to crops, they are probably regarded as an occasional or minor pest species.

Measurement: 45 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	21.10	90.10	78.84	18.55	14.92	25.03
Min	12.90	76.50	70.00	17.00	12.50	21.30
Max	35.20	105.00	86.50	20.00	20.70	29.20

Mus fragilicauda Auffray, 2003

Common name: Sheath-tailed Mouse

Synonyms: -

Distribution in SEA: Thailand

Population trend: Unknown

Locality in this study: Loei (100%)

Habitat: Forest (100%)

Feeding behavior: Herbivorous

Number of examined host: 1

Number of infected host: -

Prevalence (%): 0

Helminth infection: -

Discussion for species:

Mus fragilicauda is the new species of subgenus *Mus* in Southeast Asia, discovered by Auffray *et al*. (2002) in Thailand. They are very similar to *Mus cervicolor*, brown fur on the dorsal parts and whitish-grey below at the belly. However, the fur of *M. fragilicauda* is softer than *M. cervicolor*, and easy to tear off. The mammary formation in adult female is 1+2+2. The tail is slightly shorter than

head and body length with bicolored, usually darker above than below. On the basis of external morphology, the species is distinguished by its aptitude to loose its tail integument naturally or when handled. This character is the most reliable way to distinguish the *M. fragilicauda* and *M. cervicolor* on living specimens. Only one animal was captured in the present study that came from Loei province. The identification of this specimen was confirmed by morphological measurement and molecular technique, cytochrome *b* mitochondrial DNA gene, together with the other *Mus* specimens.

Measurement: 1 specimen (adult)

Measurement	**Weight (g)**	**Head-Body (mm)**	**Tail (mm)**	**Hind foot (mm)**	**Ear (mm)**	**Skull (mm)**
Average	13.40	76.50	57.00	16.00	12.50	20.20

Niviventer fulvescens Gray, 1847

Common name: Chestnut Rat or Bonhote's Rat

Synonyms: *Mus cinnamomeus* (Blyth, 1859), *M. octomammis* (Gray, 1863), *Rattus bukit* (Bonhote, 1903), *R. blythi* (Kloss, 1917), *R. flavipilis* (Shih, 1930), *R. wongi* (Shih, 1931), *Epimys lepidus* (Miller, 1913), *E. gracilis* (Miller, 1913) *and E. orbus* (Robinson and Kloss, 1914)

Distribution in SEA: Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam

Population trend: Decreasing

Locality in this study: Loei (100%)

Habitat: Forest (22.73%), Upland (62.12%) and Lowland (15.15%)

Feeding behavior: Herbivorous

Number of examined host: 66

Number of infected host: 42

Prevalence (%): 63.64

Helminth infection: *Raillietina* sp., *Hymenolepis diminuta, Rodentolepis nana, Syphacia muris, Pterygodermatites* sp., *Gongylonema neoplasticum*, Trichostrongylidae and

Helminth infection: Filariidae

Discussion for species:

The medium-sized rat with bright reddish-brown color on the dorsal parts of body and white-cream, soft fur at the ventral part, sharply demarcated between dorsum and ventrum side. On the back is mixed with black spiny hairs along the back ridge. The tail is longer than head and body length, sharply bicolored with dark on above and pale beneath. The skull is medium-sized with small bullae and long whiskers on the cheeks. The mammary formation in adult female is 1+1+2. They are herbivorous, usually found in subtropical evergreen forest, also in grass and bushy land along the edge between forest and agricultural field.

Measurement: 50 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	70.96	140.57	158.49	27.55	20.59	37.78
Min	34.50	106.00	133.00	15.00	16.20	33.90
Max	122.90	168.00	188.00	38.00	22.50	42.20

Rattus exulans Peal, 1848

Common name: Polynesian Rat

Synonyms: *Rattus aemuli* (Thomas, 1896), *R. aitape* (Troughton, 1937), *R. bocourti* (Milne-Edwards, 1872), *R. browni* (Alston, 1877), *R. concolor* (Blyth, 1859), *R. ephippium* (Jentink, 1880), *R. gawae (Troughton, 1845)* *R. hawaiiensis (Stone, 1917), R. jessook* (Jentink, 1879), *R. lassacquerei* (Sody, 1933), *R. micronesiensis* (Tokuda, 1933), *R. obscurus* (Miller, 1900), *R. pullus* (Miller, 1901), *R. querceti* (Hollister, 1911), *R. raveni* (Miller and Hollister, 1921), *R. surdus* (Miller, 1903), *R. tibicen* (Troughton, 1937), *R. vulcani* (Mearns, 1905) and *R. wichmanni* (Jentink, 1890)

Distribution in SEA: Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Vietnam

Population trend: Stable

Locality in this study: Loei (37.90%), Nan (30.65%) and Buriram (31.45%)

Habitat: Forest (1.61%), Upland (4.03%), Lowland (4.03%) and Domestic (90.32%)

Feeding behavior: Omnivorous

Number of examined host: 124

Number of infected host: 23

Prevalence (%): 18.54

Helminth infection: *Raillietina* sp., *Hymenolepis diminuta, Syphacia muris, Protospiura* sp., *Mastophorus* sp., *Gongylonema neoplasticum,* Trichostrongylidae and *Moniliformis moniliformis*

Discussion for species:

The smallest rat in *Rattus* spp sometimes could be misidentified as mouse. The fur is pale grey at the belly while the dorsal parts of body are grey-brown with dark spiny hairs. The tail is longer than head and boy length, uniformly dark colored. The skull ridge curve widely contain with walleyed, large ears and small incisors. The whiskers are very long and typically reach beyond the ears when folded back. The hind foot is white with a small dark strip on the dorsal part of foot along the outer edge. The mammary formation in adult female is 1+1+2. They are one of the major species found in the field and domestic area, generally confined to houses and gardens. They can move very quick and also very good climber with a long tail and energetic muscle. Because of their habitat live nearly human, they are realized as the pest that seriously damage and contaminate stored food, moreover they are possibly transmit several disease to human and the other animal.

Measurement: 109 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	34.37	112.22	121.56	22.62	15.69	30.27
Min	7.40	67.00	74.00	18.00	12.00	13.10
Max	58.30	132.00	147.00	28.00	18.50	38.00

Rattus losea Swinhoe, 1870

Common name:	Lesser Ricefield Rat
Synonyms:	*Rattus exiguous* (Howell, 1927) and *R. sakeratensis* (Gyldenstolpe, 1917)
Distribution in SEA:	Cambodia, Lao PDR, Malaysia, Thailand and Vietnam
Population trend:	Increasing
Locality in this study:	Loei (100%)
Habitat:	Forest (13.64%), Upland (18.18%) and Lowland (68.18%)
Feeding behavior:	Omnivorous
Number of examined host:	88
Number of infected host:	54
Prevalence (%):	61.36
Helminth infection:	*Notocotylus* sp., *Lecithodendridae, Echinostoma* sp., *Raillietina* sp., *Hymenolepis diminuta, Rodentolepis nana, Trichuris muris, Syphacia muris, Physaloptera* sp., *Protospiura* sp., *Gongylonema neoplasticum* and Trichostrongylidae

Discussion for species:

The medium, dark and wooly furred rat with brownish grey colored on the dorsal parts of body, the belly is white grey. Tail is shorter than head and body length, uniformly dark with finely scales. The skull is medium-sized contain with blunt nose, small ears and large orange incisors. The hind foot is usually white-grey, but sometimes with a narrow dark band of hairs along the outer side. The mammary formation in adult female is 1+1+3. They are omnivorous; eat on crops, rice, vegetable and also some invertebrates as insects and mollusks. The habitat mainly occurring in low land rice fields, possibly found in orchards, garden and mangrove forest (Musser and Newcomb, 1985).

Measurement: 44 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	75.19	148.91	129.57	28.60	17.36	36.88
Min	21.90	103.50	85.00	17.00	12.50	20.70
Max	172.30	186.00	223.00	39.50	26.90	44.60

Rattus tanezumi Temminck, 1844

Common name:	Asian House Rat, Roof Rat, Black Rat and Ship Rat
Synonyms:	Asian *Rattus rattus*
Distribution in SEA:	Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Vietnam
Population trend:	Increasing
Locality in this study:	Loei (61.24%), Nan (27.17%) and Buriram (11.59%)
Habitat:	Forest (11.59%), Upland (30.62%), Lowland (38.21%) and Domestic (19.59%)
Feeding behavior:	Omnivorous
Number of examined host:	68
Number of infected host:	45
Prevalence (%):	66.18
Helminth infection:	*Raillietina* sp., *Hymenolepis diminuta*, *Trichuris muris*, *Syphacia muris*, *Protospiura* sp., *Mastophorus* sp., *Pterygodermatites* sp., *Gongylonema neoplasticum*, Trichostrongylidae, Filariidae and *Moniliformis moniliformis*

Discussion for species:

The medium-sized rat clothed with reddish brown on the dorsal parts of body and the ventral parts are white. The tail is uniformly dark, slightly longer or some specimen nearly equal to head and body length. The skull is medium-sized, contain with pointed snout, big ears with thinly fur and large bullae. The hind foot is white with a small dark strip on the dorsal part of foot along the outer edge. The hind foot is white; probably show a small dark strip on the dorsal part of foot. The mammary formation in adult female is 1+1+3. They are omnivorous, commonly found throughout mainland of Southeast and South Asia, including all large and small islands. They are also widely distributed through the Pacific region (Aplin *et al*., 2003). Habitat mainly found in urban area, village, garden and agricultural field. They are the cause of seriously damage to food stores and also act as the important vector of many rodent-borne diseases. Formerly, *R. tanezumi* was included in the *Rattus rattus* group, recent molecular studies suggested to consider *R. tanezumi* as a different species (Wilson and Reeder, 2005). Some specimen was confirmed by molecular technique, cytochrome *b* mitochondrial DNA gene to identify the species together with morphological measurement data.

Measurement: 49 specimens (adult)

Measurement	Weight (g)	Head-Body (mm)	Tail (mm)	Hind foot (mm)	Ear (mm)	Skull (mm)
Average	105.03	164.68	165.89	31.01	21.46	41.42
Min	22.20	98.50	98.00	21.20	14.40	29.60
Max	181.90	202.00	224.00	38.00	24.50	48.40

Appendix Table A1 The murid rodent profiles of habitats and feeding behaviors

Murid rodents	Normal habitats	Feeding
Bandicota indica	Agricultural area (lowland or upland)	Omnivorous
Bandicota savilei	Agricultural area (upland or lowland)	Omnivorous
Berylmys berdmorei	Agricultural area (upland) or forest edge	Omnivorous
Berylmys bowersi	Agricultural area (upland) or forest	Omnivorous
Chiropodomys gliroides	Forest	Herbivorous
Hapalomys delacouri	Forest	Herbivorous
Leopoldamys edwardsi	Forest	Herbivorous
Leopoldamys neilli	Forest (karst and cave)	Herbivorous
Maxomys surifer	Forest and agricultural area (upland)	Herbivorous
Mus caroli	Agricultural area (lowland)	Omnivorous
Mus cervicolor	Agricultural area (lowland)	Omnivorous
Mus cookii	Forest and agricultural area (upland)	Omnivorous
Mus fragilicauda	Agricultural area (lowland or upland)	Herbivorous
Niviventer fulvescens	Forest and agricultural area (upland)	Herbivorous
Rattus exulans	Domestic	Omnivorous
Rattus losea	Agricultural area (lowland)	Omnivorous
Rattus tanezumi	Ubiquitous from domestic to forest edge	Omnivorous

Appendix Figure A1 *Bandicota indica*

Appendix Figure A2 *Bandicota savilei*

Appendix Figure A3 *Berylmys berdmorei*

Appendix Figure A4 *Berylmys bowersi*

Appendix Figure A5 *Chiropodomys gliroides*

Appendix Figure A6 *Hapalomys delacouri*

Appendix Figure A7 *Leopoldamys edwardsi*

Appendix Figure A8 *Leopoldamys neilli*

Appendix Figure A9 *Mus cervicolor*

Appendix Figure A10 *Mus cookii*

Appendix Figure A11 *Maxomys surifer*

Appendix Figure A12 *Niviventer fulvescens*

Appendix Figure A13 *Rattus exulans*

Appendix Figure A14 *Rattus tanezumi*

Appendix B

The discussion of parasite species

Notocotylus sp. Diesing, 1839

Synonyms: -

Classification:
Phylum: Platyhelminthes
Order: Digenea
Family: Notocotylidae
Genus: Notocotylus
Species: *Notocotylus* sp.

Distribution in SEA: Thailand and Vietnam

Locality in this study: Loei (88.89%) and Buriram (11.11%)

Habitat: Lowland (55.56%) and Upland (44.44%)

Number of examined host: 725

Number of infected host : 9

Prevalence (%): 1.24

Host in this study: *Bandicota indica* and *Rattus losea*

Possible host: *Bandicota indica, Rattus argentiventer* and *Rattus losea,*

Target organ: Large intestine

Discussion to the parasite:

The trematode in the family *Notocotylidae*, description from Yamaguti (1958), Dawes (1968) and Pham, *et al.* (2001): The monostome of fairly small size, leaf-shaped body with 1.39-2.64 mm. long and 0.57-0.91 mm. width. Cuticle covered with spinelets, especially on the ventral surface and in the anterior region. The main characteristic is the 3 longitudinal rows of prominent ventral gland present on ventral surface, composed of 8 to11 glands in each row. Oral sucker placed on the terminal of anterior end, pharynx absent, short esophagus (0.144-0.267 mm. long) and diverticulated intestinal caeca ending just posterior to ovary. The acetabulum is absent. Testes are lobe-shaped, 0.261-0.494x 0.113-0.267 mm, located lateral to terminal portion of caeca. Genital pore opened anterior of body at the posterior to oral sucker. Ovary is lobe-shaped, 0.123-0.236x0.061-0.164 mm. placed on the middle between testes. Vitelline glands are in lateral fields, extending from middle of body to anterior margin of testis. Oval-shaped eggs, 0.022-0.024x0.011-0.012 mm. large with polar filaments.

Lecithodendriidae Odhner, 1910

Synonyms: -

Classification:
Phylum: Platyhelminthes
Order: Digenea
Family: Lecithodendriidae
Genus: -
Species: -

Distribution in SEA: Thailand

Locality in this study: Loei (100%)

Habitat: Lowland (72.22%), Upland (11.11%) and Forest (16.67%)

Number of examined host: 725

Number of infected host : 18

Prevalence (%): 2.48

Host in this study: *Mus cookii* and *Rattus losea*

Possible host: *Mus cookii* and *Rattus losea*

Target organ: Small intestine

Discussion to the parasite:

The description from Yamaguti (1958) and Dawes (1968) as follow: the small spherical distomes without any spine covered on the body. Oral sucker is subterminal and ventral sucker located near the middle of body. Pharynx present while esophagus and caeca are barely visible. Testes are located side by side at the middle part of body. Cirrus pouch is present. Ovary is at the submedian of body, separated testes in to two sides. Vitelline glands are forming small clusters of follicles at the anterior region between oral and ventral sucker. The uterus is much folded in the posterior region. Eggs are small oval shaped, usually grouped in small numerous masses.

Generally, the definitive hosts of this minus intestinal flukes are insectivores but also well represented in the gut of amphibians, reptiles, birds and mammals. In present study, more information still required to understanding the life cycle of parasite. Moreover, the molecular technique for genus or species identification is still need for further study.

Echinostoma sp. Rudolphi, 1809

Synonyms: -

Classification:
Phylum: Platyhelminthes
Order: Digenea
Family: Echinostomatidae
Genus: Echinostoma
Species: *Echinostoma* sp.

Distribution in SEA: Malaysia, Philippines, Thailand and Vietnam

Locality in this study: Loei (100%)

Habitat: Lowland (50%) and Forest (50%)

Number of examined host: 725

Number of infected host : 2

Prevalence (%): 0.28

Host in this study: *Bandicota savilei* and *Rattus losea*

Possible host: *Bandicota indica, Bandicota savilei, Rattus exulans, Rattus losea, Rattus norvegicus, Rattus rattus diardii, Rattus rattus sladeni* and *Rattus rattus*

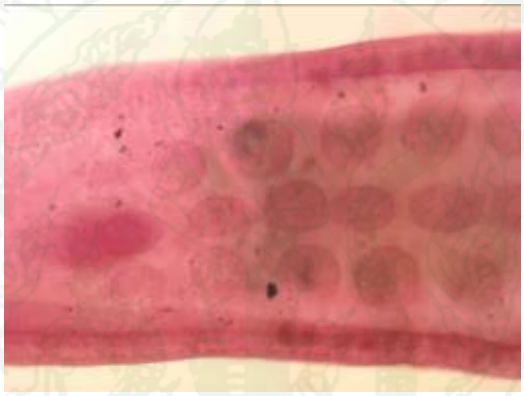
Target organ: Small intestine

Discussion to the parasite:

The description from Yamaguti (1958) and Dawes (1968): the parasite attached to the small intestine. The elongated slender distomes, body enlarged at the middle while both end sides are attenuated. Anterior end is provided with head bearing with a collar of 42 spines. The cuticle is covered with small spines over anterior part of body. The anterior sucker placed at the center of oral disk, and the ventral sucker is at the anterior fifth of the body. Cirrus pouch is present, extending behind the ventral sucker. Testes are slightly lobed and ovary is round, placed in the middle part of body. Vitelline glands are in the lateral region of the body, well developed in numerous follicle shaped. The uterus is much folded between ovary and the ventral sucker. The eggs are yellow-brown colored, oval shaped with operculum on the anterior pole, 0.080-0.116x0.058-0.069 mm. in size.

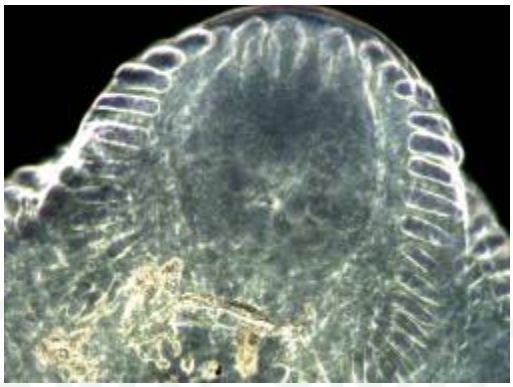
The parasites located in small intestine of birds and mammals. The snails and freshwater mollusks are act as the 1st and 2nd intermediate host respectively. There are some reported of echinostomiasis, the *Echinostoma* sp. infection in human caused from eating uncooked snails (Cross and Basaca-Sevilla, 1986 and McCarthy and Moore, 2000). *Rattus* species are reported as important natural reservoir hosts while dogs and cats may also be important host.

Appendix Figure B1 *Notocotylus* sp. in large intestine of *Rattus losea* from Loei (5x)



Appendix Figure B2 The 3 longitudinal rows of ventral glands on ventral surface (10x)

Appendix Figure B3 Licithodendriidae in small intestine of *Rattus losea* (10x)



Appendix Figure B4 Anterior end of *Echinostoma* sp. bear with a collar spines (20x)

Raillietina sp. Fuhrmann, 1920

Synonyms: *Johnstonia Fuhrmann, 1920;*
Meggittia Lopez-Neyra, 1929;
Idiogenoides Lopez-Neyra, 1929;
Brumptiella Lopez-Neyra, 1929

Classification:
Phylum: Platyhelminthes
Order: Cyclophyllidae
Family: Davaineidae
Genus: Raillietina
Species: *Raillietina* sp.

Distribution in SEA: Thailand and Vietnam

Locality in this study: Loei (29.03%), Nan (58.87%) and Buriram (12.10%)

Habitat: Domestic (5.65%), Lowland (62.10%), Upland (22.58%) and Forest (9.68%)

Number of examined host: 725

Number of infected host : 124

Prevalence (%): 17.10

Host in this study: *Bandicota indica, Bandicota savilei, Berylmys berdmorei, Leopoldamys edwardsi, Maxomys surifer, Mus cervicolor, Niviventer fulvescens, Rattus exulans, Rattus losea and Rattus tanezumi*

Possible host: *Bandicota indica, Bandicota savilei, Berylmys berdmorei, Leopoldamys edwardsi, Maxomys surifer, Mus cervicolor, Niviventer fulvescens, Rattus exulans, Rattus losea, Rattus norvegicus, Rattus rattus* and *Rattus tanezumi*

Target organ: Small intestine

Discussion to the parasite:

The description from Yamaguti (1959): The tapeworm in subfamily Davaineinae with numerous segments and small round scolex. Rostellum comprising with 2 rows of hammer-shaped hooks, arranged in double circle pattern and four suckers armed with several circles of minute hooks. In mature segment, numerous testes are spread inside, lobe-shaped ovary placed on the median of segment. Small cirrus pouch is not reaching excretory stems. Genital pores arranged in unilateral pattern of all segments and seminal receptacle is present. Egg capsule containing several eggs, capsules usually grouped or surrounded by modified parenchyma.

There were reported as parasite of wide host range: Aves, Rodentia, Carnivora, Primates, Chiroptera and Lagomorpha. Distribution reported as worldwide cosmopolitan (Schmidt, 1986). The larval stage found in insects, house flies and ants as intermediate host.

Hymenolepis diminuta Rudolphi, 1819

Synonyms: *Taenia varesina* Parona, 1884;
Taenia minima Grassi, 1886;
Hymenolepis anomala Splendore, 1920;
Hymenolepis megaloon Linstow, 1901;
Hymenolepis diminutoides Cholodk, 1912

Classification:
Phylum: Platyhelminthes
Order: Cyclophyllidae
Family: Hymenolepididae
Genus: Hymenolepis
Species: *Hymenolepis diminuta*

Distribution in SEA: Malaysia, Philippines, Thailand and Vietnam

Locality in this study: Loei (88.71%), Nan (4.84%) and Buriram (6.45%)

Habitat: Domestic (27.42%), Lowland (14.52%), Upland (45.16%) and Forest (12.90%)

Number of examined host: 725

Number of infected host : 62

Prevalence (%): 8.55

Host in this study: *Bandicota indica, Bandicota savilei, Berylmys berdmorei, Berylmys bowersi, Leopoldamys edwardsi, Maxomys surifer, Mus cookii, Niviventer fulvescens, Rattus exulans, Rattus losea* and *Rattus tanezumi*

Possible host: *Bandicota bengalensis, Bandicota indica, Bandicota savilei, , Berylmys berdmorei, Berylmys bowersi, Leopoldamys edwardsi, Maxomys surifer, Mus caroli, Mus cookii, Niviventer fulvescens, Rattus annandalei, Rattus andamanensis, Rattus argentiventer, Rattus exulans, Rattus losea, Rattus norvegicus, Rattus rattus, Rattus rattus diardii, Rattus rattus molliculus, Rattus tanezumi* and *Rattus tiomanicus*

Target organ: Small intestine

Discussion to the parasite:

The description from Baylis (1922); Yamaguti (1959); Tenora and Murai (1972): A medium sized tapeworm with 1.4-4.0 mm. in width of mature segment length, usually broader than long. Scolex diameter 0.15-0.27x0.13-0.22 mm, provided with unarmed rostellum and bearing with 4 suckers, 0.08-0.125 mm. Rostellar sack measuring was 0.080-0.123x0.025-0.067 mm. The male sexual organ consist of 3 testis arranged in a line. Ovary in lobe shaped, placed in the median or submedian and separated testis in to two groups. Testis diameter is 0.1-0.13 mm. while ovary sized is 0.25-0.37x0.12-0.80 mm. Uterus with eggs, filled entire of gravid segment. Eggs are globular in shape with 0.05-0.076 mm. in diameter. Onchosphere inside the eggs is 0.03-0.041 mm. length of diameter.

The life cycle of *H. diminuta* involves rodents as the definitive host and beetles or other arthropods as the intermediate host. They are sometimes causes infection in humans, results from eating such foods as dried fruits and precooked breakfast cereals in which the infected grain insects. The other possibility is infected from eating rat or mouse droppings, was also reported (Andreassen *et al*., 1999).

Rodentolepis nana Spasskii, 1954

Synonyms: *Taenia nana* Siebold, 1852;
Hymenolepis nana fraternal Stiles, 1906

Classification:
Phylum: Platyhelminthes
Order: Cyclophyllidae
Family: Hymenolepididae
Genus: Rodentolepis
Species: *Rodentolepis nana*

Distribution in SEA: Malaysia, Philippines and Thailand

Locality in this study: Loei (66.67%), Nan (19.44%) and Buriram (13.89%)

Habitat: Domestic (2.78%), Lowland (44.44%), Upland (47.22%) and Forest (5.56%)

Number of examined host: 725

Number of infected host : 36

Prevalence (%): 4.97

Host in this study: *Chiropodomys gliroides, Mus caroli, Mus cervicolor, Mus cookii, Niviventer fulvescens* and *Rattus losea*

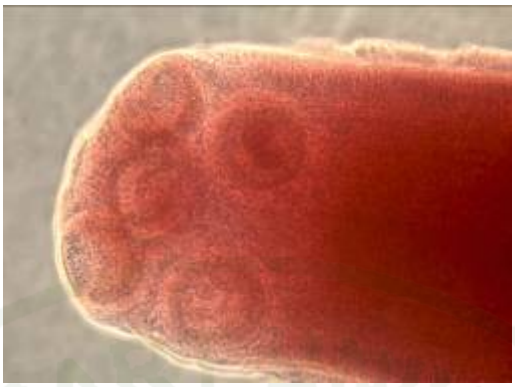
Possible host: *Chiropodomys gliroides, Mus caroli, Mus cervicolor, Mus cookii, Niviventer fulvescens, Rattus annandalei, Rattus exulans, Rattus losea, Rattus norvegicus, Rattus rattus diardii* and *Rattus tiomanicus*

Target organ: Small intestine

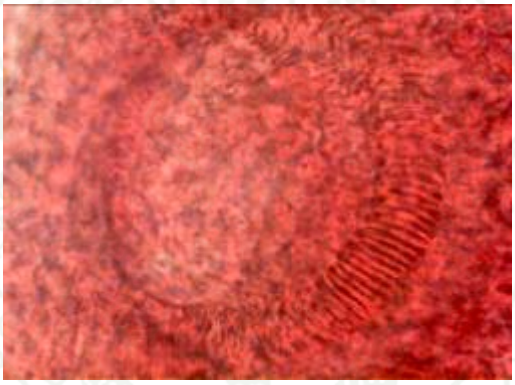
Discussion to the parasite:

Genus *Rodentolepis* Spasskii, 1954 according to Khalil *et al.* (1994): several to numerous hooks of various shapes, often fraternoid. In mature segment, testis arranged in transverse line or in elongated triangle, separated into two groups by female gonads. The adult worm is feature with a scolex, a neck region and a strobila (body) which consisted of numerous segmentss approximately 3-4 cm. The anterior tip of scolex consisted of 4 muscular sucker 0.05-0.07 mm. long for outside diameter. There is a well-developed rostellum armed with a single row of hooks, approximately 22-26 (usually 22-23) in number, and 0.016-0.018 mm. in length. Eggs in spherical or oval shaped 0.067-0.090x0.066-0.087 mm. in size, thin shell and discontinuous embryophore layer. Furthermore, eggs possess a polar filament layer between the oncosphere and oncospheral membrane. Onchosphere embryo consisted of 6 hooks in approximately 0.015 mm. long for hook length. They are parasite in various mammals (rodents, marsupials, chiropterans, primates).

Rodentolepis (*Hymenolepis*) *nana* was also known as the dwarf sister species very closely related to *Hymenolepis diminuta*, sometimes also the causes of infection to humans. Then, “Hymenolepiasis” is the term for human to be infected with either *Hymenolepis diminuta* or *Rodentolepis* (*Hymenolepis*) *nana*.



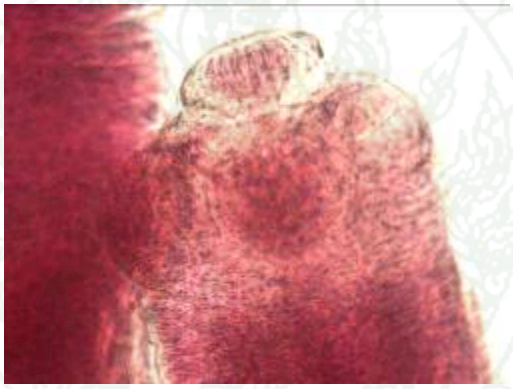
Appendix Figure B5 Scolex of *Raillietina* sp. with 4 suckers and armed rostellum (20x)



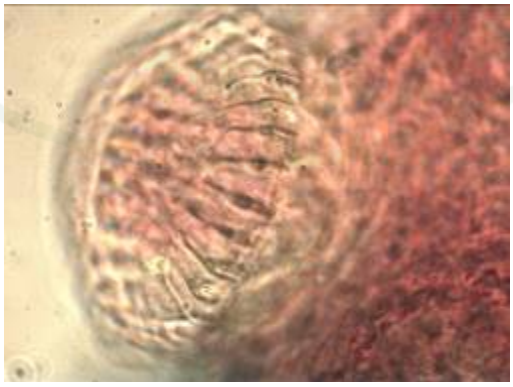
Appendix Figure B6 The hooks characteristic on rostellum of *Raillietina* sp. (100x)

Appendix Figure B7 Scolex with 4 suckers and unarmed rostellum of *Hymenolepis diminuta* (20x)

Appendix Figure B8 Reproductive organs from mature segments of *Hymenolepis diminuta* (10x)



Appendix Figure B9 *Rodentolepis nana* scolex with armed rostellum of (20x)



Appendix Figure B10 Reproductive organs from mature segments of *Rodentolepis nana* (10x)

Appendix Figure B11 Reproductive organs from mature segments of *Rodentolepis nana* (10x)

Appendix Figure B12 Hymenolepididae eggs with onchosphere (100x)

Trichuris muris Hall, 1916

Synonyms: *Trichocephalus nodosus* Schrank, 1761; *Mastigodes muris* Zeder, 1800

Classification:
Phylum: Nematoda
Order: Trichuridea
Family: Trichuridae
Genus: Trichuris
Species: *Trichuris muris*

Distribution in SEA: Malaysia, Thailand and Vietnam

Locality in this study: Loei (33.33%) and Nan (66.67%)

Habitat: Lowland (83.34%), Upland (8.33%) and Forest (8.33%)

Number of examined host: 725

Number of infected host : 12

Prevalence (%): 1.66

Host in this study: *Bandicota indica, Bandicota savilei, Rattus losea* and *Rattus tanezumi*

Possible host: *Bandicota indica, Bandicota savilei, Rattus losea, Rattus rattus diardii, Rattus rattus sladeni and Rattus tanezumi*

Target organ: Large intestine

Discussion to the parasite:

From the description of Skrjabin *et al* (1970) and Anderson (2000): the anterior end of the parasite is filiform and the posterior thick. The cuticle is finely, transversely striated. The caudal end of male is spirally curved, and in the female only slightly bent ventrally. The mouth is simple without lips. The esophagus is narrow and long, surrounded by a row of stichocyte, sub-esophageal cells.

Male, the body length is 15.6-22.2 mm. long, with a maximum width of 0.256-0.518 mm. The width of the end of esophagus is 0.207-0.473 mm. The cloaca lies almost terminal. The spicule is thin and long, 0.571-0.732 mm. long. The spicular sheath is covered by delicate conical spines. The configuration of spicular sheath changes depending on the length of the protruding part of spicule. Usually a spicule which is retracted is covered by spicular sheath, which does not protrude beyond the body of the parasite. A single papilla structure is present on either side of the cloacal aperture.

Female, the body is 14.64-28.6 mm. long, with a maximum width of 0.4-0.6 mm. The width at the end of esophagus is 0.198-0.251 mm. Vagina with muscular walls is directed posterior to the tail. Uterus is unpaired. The caudal end of body is rounded with a knob-shaped tip. The tip of tail bears a single papilla. The eggs are barrel-shaped as in characteristic for the genus, and have operculum on the poles. The average size of egg is 0.0594-0.0806x0.032-0.039 mm.

This whipworm usually found in the large intestine of rodents. Their direct life cycle showed that eggs developed outside the body of host and directly infected to the definitive host. Eggs hatched in the small intestine and larvae migrate rapidly to the large intestine.

Eucoleus sp. Dujardin, 1845

Synonyms: -

Classification:
Phylum: Nematoda
Order: Trichuridea
Family: Trichuridae
Genus: Eucoleus
Species: *Eucoleus* sp.

Distribution in SEA: Indonesia and Thailand

Locality in this study: Loei (25%) and Buriram (75%)

Habitat: Lowland (75%) and Upland (25%)

Number of examined host: 725

Number of infected host : 4

Prevalence (%): 0.55

Host in this study: *Bandicota indica and Mus cervicolor*

Possible host: *Bandicota indica, Mus cervicolor* and *Rattus argentiventer*

Target organ: Stomach

Discussion to the parasite:

From the description of Skrjabin *et al.* (1970) and Yorke and Maplestone (1969) as follow: the filiform shaped parasite which anterior part of body much shorter than the posterior. The dorsal and ventral bacillary bands are present. The mouth is round and unarmed. The nerve ring is on the sub-terminal of anterior end.

Male, The caudal end is consisting of two short cuticular lobes, each bearing one post-cloacal papillae. The cloacal opening is on sub-terminal of posterior end. The spicular sheath is protrusible and thickly armed with fine spines.

Female, The body is longer and bigger than male. The tail is blunt and slightly curved at the posterior extremity. Vulva is not projecting and opening at the end of esophagus. The eggs are whitish with a thick granular shell, and have small opercular plug on each pole as the characteristic for the genus.

Aonchotheca sp.

Synonyms: -

Classification:
Phylum: Nematoda
Order: Trichuridea
Family: Trichuridae
Genus: Aonchotheca
Species: *Aonchotheca* sp.

Distribution in SEA: Thailand

Locality in this study: Loei (25%), Nan (50%) and Buriram (25%)

Habitat: Domestic (100%)

Number of examined host: 725

Number of infected host : 4

Prevalence (%): 0.55

Host in this study: *Bandicota indica and Mus cervicolor*

Possible host: *Bandicota indica* and *Mus cervicolor*

Target organ: Stomach

Discussion to the parasite:

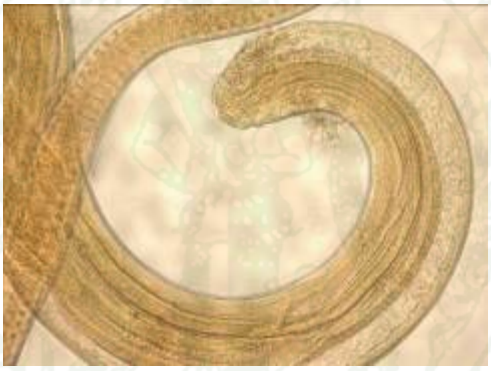
The description of parasite from Skrjabin *et al.* (1970) as follow: the filiform nematode that similar shape with *Eucoleus* sp. but different in some sex characteristic. The anterior esophageal region is shorter than posterior region which the stichocyte cells are slightly thicker. The mouth is round and unarmed. The nerve ring is on the sub-terminal of anterior end.

Male, The body is shorter and smaller than female. The caudal is slightly tilted end, consisting of caudal lateral papillae and caudal extremity papillae at the end. The spicule is represented by unsheathed long and thin without any spine.

Female, The tail is blunt and slightly curved at the posterior extremity. The vulva opening has a funnel-shaped protruding ovijector at the end of esophagus region. The eggs in uterus have arranged in a row as one by one, before releasing to the environment at the vulva opening. The eggs are whitish with a thick granular shell, and have small opercular plug on each pole as the characteristic for the genus.

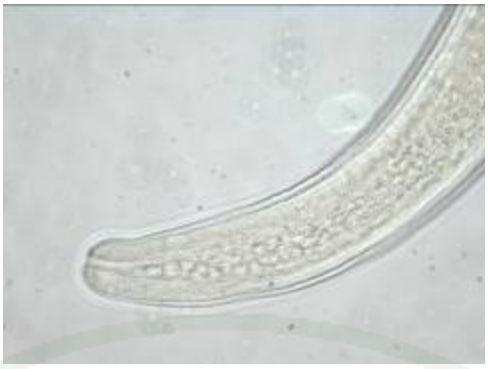
The parasite is normally found in chickens, grouse, pheasants, turkeys, pigeons, ducks, and the mammals such as martens, minks or cats, not any reported in murid rodents. Therefore, this study is seemed to be the first reported of this parasite infection in stomach of murid rodents.

Appendix Figure B13 The esophagus of *Trichuris muris*, showed the characteristic of stichocytes (20x)



Appendix Figure B14 The caudal end of male *Trichuris muris* (20x)

Appendix Figure B15 The *Eucoleus* sp. male caudal end with cuticular lobes and spicular sheath armed with fine spines (40x)



Appendix Figure B16 The *Eucoleus* sp. female caudal end (40x)

Appendix Figure B17 The vulva opening and the capillarid typed eggs of *Eucoleus* sp. (40x)

Appendix Figure B18 The *Aonchotheca* sp. male caudal end with caudal papillae and very long spicule (40x)

Appendix Figure B19 The vulva opening with the funnel-shaped protruding ovijector of *Aonchotheca* sp. (40x)

Cyclodontostomum purvisi Adam, 1933

Synonyms: *Ancistronema coronatum* Smales, 1992

Classification:
Phylum: Nematoda
Order: Strongyloidea
Family: Chabertiidae
Genus: Cyclodontostomum
Species: *Cyclodontostomum purvisi*

Distribution in SEA: Indonesia, Malaysia, Thailand and Vietnam

Locality in this study: Buriram (100%)

Habitat: Lowland (100%)

Number of examined host: 725

Number of infected host : 1

Prevalence (%): 0.14

Host in this study: *Bandicota indica*

Possible host: *Bandicota indica, Berylmys bowersi, Leopoldamys sabanus, Maxomys surifer, Maxomys rajah, Maxomys whiteheadi, Niviventer cremoniventer, Rattus annandalei, Rattus argentiventer, Rattus bartelsii Rattus mulleri, Rattus nitidus, Rattus rattus diardii Rattus rattus hoffmanni, Rattus rattus molliculus Rattus rattus sladeni* and *Rattus tiomanicus*

Target organ: Large intestine

Discussion to the parasite:

This hookworm parasite was re-described by Varughese (1973); Hasegawa and Syafruddin (1994) as follow. The cephalic end was bended dorsally, comprised with 8 bifid elements of external corona radiate on the extremity. The cephalic collar diameter is 0.109-0.176 mm. and esophagus is 0.475-0.632 mm. long. The female parasites with 5.7-12.2 mm. in length are larger and longer than males, 4.4-9.7 mm. long.

In male, gubernaculum length is 0.09-0.102 mm. not clearly visible. The thin spicules in long rod shaped with 0.560-0.658 mm. in length, clearly distinguishable striated sheaths. The bursal lobes are broad and deep with prebursal papillae also present.

The female parasite vulva opened at posterior part of body, 4.976-10.704 mm. length from cephalic end. Tail is point-shaped, 0.430-0.573 mm. in length. The eggs are oval shaped and thin shelled with characteristic of strongylid typed, 0.068-0.084x0.034-0.048 mm. in size.

The direct life cycle of parasite is similar to the other strongylid nematodes with free living and parasitic stages. Infection is occurred by ingesting the 3rd stage larva, and developed to adult worm in large intestine. Although, many species of murid rodents host in SEA were reported the infection of this parasite but only 1 *Bandicota indica* from the present study was positively found.

Ganguleterakis spumosa Schneider, 1866

Synonyms: *Heterakis spumosa* Schneider, 1866;
Ganguleterakis gangula Lane, 1914;
Heterakis (Ganguleterakis) dahomensis Gendre, 1911

Classification:
Phylum: Nematoda
Order: Ascaridida
Family: Heterakidae
Genus: Ganguleterakis
Species: *Ganguleterakis spumosa*

Distribution in SEA: Malaysia, Philippines, Thailand and Vietnam

Locality in this study: Loei (27.27%) and Nan (72.73%)

Habitat: Domestic (15.15%), Lowland (36.36%), Upland (24.24%) and Forest (24.24%)

Number of examined host: 725

Number of infected host : 33

Prevalence (%): 4.55

Host in this study: *Bandicota indica, Bandicota savilei, Berylmys berdmorei* and *Berymys bowersi*

Possible host: *Bandicota indica, Bandicota savilei, Berylmys berdmorei, Berylmys bowersi, Rattus* sp., *Rattus norvegicus* and *Rattus rattus diardii*

Target organ: Large intestine

Discussion to the parasite:

They are the intestinal parasites of mammals and birds. Cuticle transversely striated. Lateral wings often present. Mouth with 3 distinct lips each with 2 papillae. Esophagus consisting of 3 parts: a reduced pharynx, an elongated cylindrical part and a well developed bulb with a valvular apparatus. The preanal sucker of male has a chitinized rim, two equal or nearly equal spicules. Gubernaculum absent and caudal wings (pseudobursa) well developed. Vulva situated in middle of body or before it. Vagina is divided into two uteri diverging in opposite directions. Oviparous, eggs with thick shell and light granulation at one pole.

Measurement from Skrjabin *et al*., 1974 as followed: cuticle finely and transversely striated. Head is 0.007-0.105 mm. wide. Lateral wings beginning 0.12-0.18 mm. behind the cephalic end. Nerve ring, excretory pore and cervical papillae situated 0.3-0.38 mm, 0.3-0.41 mm. and 0.32-0.43 mm. respectively from the cephalic end. Mouth is compound with 3 lips, each with 2 papillae. Pharynx 0.045-0.069x0.036-0.051 mm. with 3 pyramidal chitinized teeth at the anterior end. The cylindrical muscular part of the esophagus passes into the bulb, which has a valvular apparatus.

Male length 6.2-8.6 mm. and width 0.22-0.3 mm. Anterior part of esophagus 0.41-0.58 mm. long, bulb 0.2-0.26x0.14-0.18 mm. Ten pairs of caudal papillae. Longitudinal diameter of preanal sucker 0.066-0.087 mm., a median incision at its posterior margin. Two equal spicules, 0.27-0.315 mm. long.

Female length 8.5-11.9 mm. and width 0.28 – 0.38 mm. Anterior part of esophagus 0.46-0.63 mm. long, bulb 0.25-0.3x0.15-0.21 mm. Vulva with thick lips, situated in middle of body. Eggs are 0.063-0.07 mm. long, 0.045-0.05 mm. wide, with thick shell and reticulate surface.

Syphacia muris Yamaguti, 1935

Synonyms: *Enterobius muris* Yamuguti, 1935

Classification:
Phylum: Nematoda
Order: Oxyurida
Family: Oxyuridae
Genus: Syphacia
Species: *Syphacia muris*

Distribution in SEA: Indonesia, Malaysia, Thailand and Vietnam

Locality in this study: Loei (66.13%), Nan (14.52%) and Buriram (19.35%)

Habitat: Domestic (11.29%), Lowland (51.61%), Upland (17.74%) and Forest (19.35%)

Number of examined host: 725

Number of infected host : 62

Prevalence (%): 8.55

Host in this study: *Bandicota indica, Bandicota savilei, Berylmys berdmorei, Berylmys bowersi, Leopoldamys edwardsi, Maxomys surifer, Niviventer fulvescens, Rattus exulans, Rattus losea* and *Rattus tanezumi*

Possible host: *Bandicota indica, Bandicota savilei, Berylmys berdmorei, Berylmys bowersi, Leopoldamys edwardsi, Leopoldamys sabanus, Maxomys surifer, Niviventer fulvescens, Rattus annandalei, Rattus argentiventer,*

Rattus exulans, Rattus losea, Rattus norvegicus, Rattus rattus diardii, Rattus tanezumi and *Rattus tiomanicus*

Target organ: Large intestine

Discussion to the parasite:

The parasites are small, thick worm and white when alive with cephalic inflation conspicuous. They have a great sexual dimorphism. Description from Colin and Ogden (1916) and Yamaguti (1961) as:

Male length 1.2-1.3 mm, width 0.1 mm. Lateral wings indistinct. Esophagus is compound with pharynx and bulb 0.27 mm. long, esophageal bulb spherical, 0.08 mm. wide. There are three transversely striated, semispherical combs on the ventral of body, called mamelons. Three pairs of caudal papillae: 2 adanal, close together and 1 postanal on the outer side of symmetrical processes directed posterolaterally from base of caudal filament. Spicule thin, with pointed end, 0.056 mm. long. Gubernaculum 0.036 mm. long, with a small denticle at the distal end.

Female cuticle finely transversely striated, cephalic end with a cuticular vesicle, lateral wing absent. Body length is 2.2-3.4 mm. width at the middle of body 0.18-0.25 mm. Mouth with three lips, two subventral lips with a characteristic papilliform formation, not protruding above the surface, dorsal lip with two such formations. Esophagus is nearly cylindrical, flask-shaped, esophagus with bulb 0.29-0.35 mm. long, bulb 0.08-0.09 mm. wide. There are bulb with valvular apparatus and three rudimentary lobes at the posterior end. Vulva not protruding situated 0.75-0.88 mm. from cephalic end. A group of gland cells are present before and behind the vulva. Vagina and long ovejector directed posteriorly. Uterus extending anteriorly to the esophageal bulb and ending posteriorly near the anus. Eggs 0.072-0.082x0.025-0.036 mm. large, oval asymmetrical, with thin shell, containing not fully developed larvae

Syphacia obvelata Rudolphi, 1802

Synonyms: *Ascaris obvelata* Rudolphi, 1802;
Fusaria obvelata Rudolphi, 1802; Zeder, 1803;
Oxyuris obvelata Rudolphi, 1802; Bremser, 1819

Classification:
Phylum: Nematoda
Order: Oxyurida
Family: Oxyuridae
Genus: Syphacia
Species: *Syphacia obvelata*

Distribution in SEA: Thailand and Vietnam

Locality in this study: Loei (63.33%) and Nan (36.67%)

Habitat: Lowland (30.00%), Upland (66.67%) and Forest (3.33%)

Number of examined host: 725

Number of infected host : 30

Prevalence (%): 4.14

Host in this study: *Mus caroli*, *Mus cervicolor* and *Mus cookii*

Possible host: *Mus* sp., *Mus caroli*, *Mus cervicolor*,*Mus cookii* and *Rattus* sp.

Target organ: Large intestine

Discussion to the parasite:

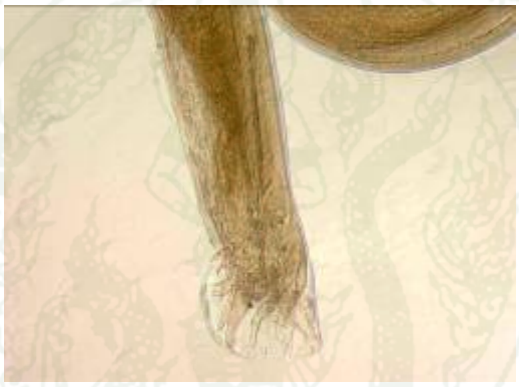
This species was confused for a long time with *Aspiculuris tetraptera* because both species were parasites of the same hosts in the same localities, and were externally similar. Small, thick worm, size are difference between males and females, great sexual dimorphism. Description from Colin and Ogden (1916) and Skrjabin *et al.* (1974):

Male length 1.3 mm, maximum width 0.122 mm. Esophagus with bulb 1/7 of body length (0.188-0.249 mm. long). Three cuticular, semi-spherical, transversely striated combs on the ventral surface called mamelons. Spicule is relatively long, 0.08 mm. Gubernaculum 0.035 mm. long, its free end in the form of a fishhook.

Female length 6 mm, much larger than the male, maximum width 0.275 mm., curved in a question mark shaped. Cuticle is forming a vesicular widening of head. Two very narrow lateral wings extend nearly along the entire body. The small, rounded excretory pore situated in the middle between esophageal bulb and vulva. Esophagus with bulb is 1/12 of length of body. Vulva situated in middle of a slightly convex cuticular thickening, 0.45-0.74 mm. from anterior end of body. Vagina very long, directed posteriorly, ovary club-shaped, parallel, blackish. Spindle-shaped eggs which are 0.115x0.035 mm. large, one side flattened, and adhering in pairs at the flat surface.

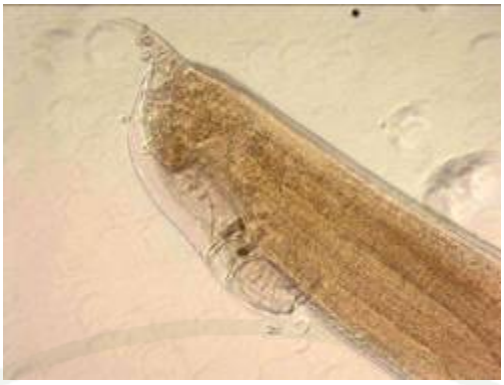
Hussey (1957) reported after a morphology study of *S. obvelata* and *S. muris*, from the literature and a study of parasites obtained by experimental infection of mice and rats with both species. She decided that these two species are often confused. , indicated that *S. muris* differs from *S. obvelata* in the size of eggs. *S. obvelata* eggs are twice as larger than *S. muris* eggs, but nearly the same width, and also concluded that *S.obvelata* is a parasite of white mice and *S. muris* of white rats.

Appendix Figure B20 The cephalic end of *Cyclodontostomum purvisi* (20x)



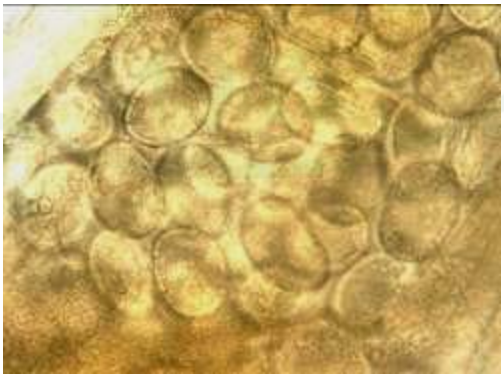
Appendix Figure B21 The busar copulatrix of male *Cyclodontostomum purvisi* with one pair of thin long spicules (10x)

Appendix Figure B22 The cephalic part of *Ganguleterakis spumosa* (10x)

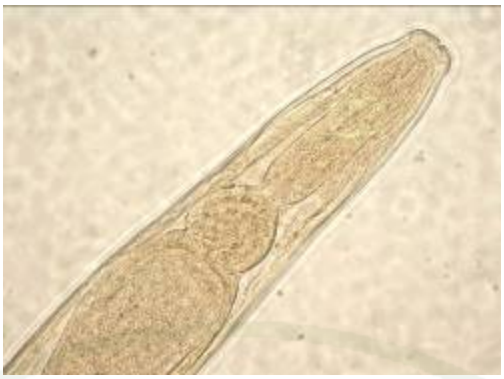


Appendix Figure B23 The male caudal part of *Ganguleterakis spumosa* (10x)

Appendix Figure B24 Vulva of *Ganguleterakis spumosa* female situated in middle of body (10x)

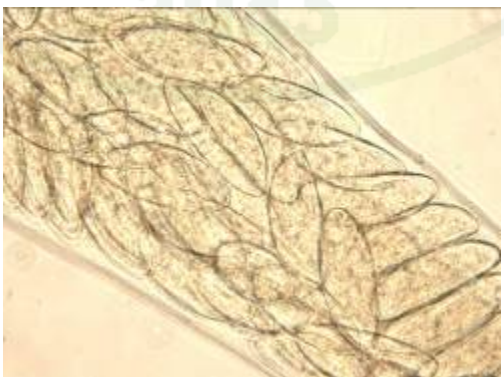


Appendix Figure B25 The eggs inside uterus of female *Ganguleterakis spumosa* (40x)



Appendix Figure B26 The cephalic end of *Syphacia obvelata* (40x)

Appendix Figure B27 The caudal part of male *Syphacia muris* with one pair of spicules and 3 mamelons (40x)



Appendix Figure B28 Asymmetrical eggs of *Syphacia muris* in female uterus (40x)

Physaloptera sp. Rudolphi, 1819

Synonyms: *Chlamydonema* Noordhoek, 1910; *Pentadentoptera* Shakhnazarova, 1949; *Skrjabinoptera* Schulz, 1927

Classification:
Phylum: Nematoda
Order: Spiruridae
Family: Physalopteridae
Genus: Physaloptera
Species: *Physaloptera* sp.

Distribution in SEA: Indonesia, Malaysia, Thailand and Vietnam

Locality in this study: Loei (58.33%), Nan (25%) and Buriram (16.67%)

Habitat: Lowland (70.83%), Upland (16.67%) and Forest (12.50%)

Number of examined host: 725

Number of infected host : 24

Prevalence (%): 3.31

Host in this study: *Bandicota indica, Bandicota savilei, Berylmys berdmorei, Mus caroli, Mus cervicolor* and *Rattus losea*

Possible host: *Bandicota indica, Bandicota savilei, Berylmys berdmorei Berylmys bowersi, Leopoldamys sabanus, Maxomys rajah, Mus caroli, Mus cervicolor, Rattus*

Possible host: *argentiventer, Rattus bartelsii, Rattus jalorensis, Rattus lepturus, Rattus losea, Rattus mulleri* and *Rattus rattus rumpia*

Target organ: Stomach

Discussion to the parasite:

The description of the parasite from Yamaguti (1961); Yorke and Maplestone (1969) and Sood (2006) as followed: the nematode with two large, simple triangular lateral lips, each provided apically and externally covered with papillae. The cuticle reflected over the lips to form a large cephalic collarette. Buccal cavity is absent and esophagus consisting of an anterior muscular, and posterior glandular part.

Male, caudal allae is wide, meeting ventrally in front of anus. At least four pairs of papillae, supporting the allae and surrounding the cloaca, and variable number of sessile papillae. Spicules are unequal placed in the posterior portion of body.

Female is bigger and longer than male. The vulva opened at the middle to posterior of body. One pair of uterus located inside and paralleled each other. Oviparous female with eggs in oval-shaped, thick-shelled and will develop when deposited.

The life cycle is indirect, when eggs deposited by female and hatched in the intermediate host as cockroaches or crickets that ingested the parasite eggs. The larva would develop to infective stage larva inside the gut of insect. The final host can acquire infections from ingesting insect containing infective larvae. The larvae would attach to the stomach wall of host and developed to adult inside the definitive host (Anderson, 2000). The previous studies reported this worm as the parasite in stomach of mammals, birds, reptiles, and rarely in amphibians (Yamaguti, 1961; Yorke and Maplestone, 1969 and Anderson, 2000).

Protospiura sp. Seurat, 1914

Synonyms: *Mastophorus* Dies., 1853

Classification:
Phylum: Nematoda
Order: Spiruridea
Family: Spiruridae
Genus: Protospiura
Species: *Protospiura* sp.

Distribution in SEA: Malaysia and Thailand

Locality in this study: Loei (66.67%), Nan (16.67%) and Buriram (16.67%)

Habitat: Domestic (13.33%), Lowland (40%), Upland (36.67%) and Forest (10%)

Number of examined host: 725

Number of infected host : 30

Prevalence (%): 4.14

Host in this study: *Bandicota indica, Berylmys berdmorei, Berylmys bowersi, Mus caroli, Mus cervicolor, Mus cookii, Rattus exulans, Rattus losea* and *Rattus tanezumi*

Possible host: *Bandicota indica, Berylmys berdmorei, Berylmys bowersi, Leopoldamys sabanus, Maxomys rajah, Maxomys whiteheadi, Mus caroli, Mus cervicolor, Mus cookii, Niviventer cremoniventer, Rattus argentiventer, Rattus canus, Rattus jalorensis, Rattus losea,*

Possible host: *Rattus mulleri*, *Rattus rattus rumpia* and *Rattus tanezumi*

Target organ: Stomach

Discussion to the parasite:

This nematode is similar appearance with *Mastophorus* sp., the nematode worm in rodent stomach. The description from Yamaguti (1961) as followed: the body of parasite is attenuated anteriorly, without lateral flanges. The mouth is consisted with 2 large trilobed lateral lips. In each lobe is bearing with papillae externally at base and 3 teeth on its inner surface. Buccal cavity is long, continued with esophagus that divided into 2 parts.

In male, the posterior extremity is spiral and caudal alae well developed. The tail is consisted with four pairs of preanal papillae, two pairs of large postanal papillae and a group of small papillae near the tip of tail. The spicules are unequal; one is longer and bigger than another. The gubernaculums is present. Female tail is short in conical shaped with the vulva opening in middle region of body. Uterus comprised with the oval shaped and thick-shelled eggs, containing embryo when deposited.

Mastophorus sp. Diesing, 1853

Synonyms: *Protospiura* Seurat, 1914

Classification:
Phylum: Nematoda
Order: Spiruridea
Family: Spirocercidae
Genus: Mastophorus
Species: *Mastophorus* sp.

Distribution in SEA: Indonesia, Malaysia and Thailand

Locality in this study: Nan (100%)

Habitat: Domestic (42.86%), Lowland (28.57%), Upland (14.29%) and Forest (14.29%)

Number of examined host: 725

Number of infected host : 7

Prevalence (%): 0.97

Host in this study: *Bandicota indica, Berylmys berdmorei, Berylmys bowersi, Rattus exulans* and *Rattus tanezumi*

Possible host: *Bandicota indica, Berylmys berdmorei, Berylmys bowersi, Rattus bartelsii, Rattus exulans, Rattus lepturus, Rattus rattus* and *Rattus tanezumi*

Target organ: Stomach

Discussion to the parasite:

This parasites species are parasites mainly of the stomach. Worms are medium to large in size which females are bigger than males. Buccal cavity is long, continued with esophagus that divided into 2 parts. The appearance is very similar to *Protospiura* sp. The distinct position of *Mastophorus sp.* (Spirocercidae: Mastophorinae) and *Protospirura* sp. (Spiruridae), sometimes still confused. However, these two species can be distinguished by the pattern of pseudolabial teeth, a large central tooth with smaller teeth on each side (Rojas and Digiani, 2003). That is the *Mastophorus* sp. teeth will show this characteristic while in *Protospiura* sp. is less.

Pterygodermatites sp. Weld, 1861

Synonyms: *Rictularia* Froelich, 1802;
Laphyctes Dujardin, 1845;
Ophiostoma Rudolphi, 1801;
Ophiostomum Creplin, 1839

Classification:
Phylum: Nematoda
Order: Spiruridea
Family: Rictulariidae
Genus: Pterygodermatites
Species: *Pterygodermatites* sp.

Distribution in SEA: Indonesia, Malaysia and Thailand

Locality in this study: Loei (71.43%) and Nan (28.57%)

Habitat: Domestic (42.86%), Lowland (14.29%), Upland (28.57%) and Forest (14.29%)

Number of examined host: 725

Number of infected host : 7

Prevalence (%): 0.97

Host in this study: *Niviventer fulvescens* and *Rattus tanezumi*

Possible host: *Leopoldamys sabanus, Maxomys rajah, Niviventer cremoniventer, Niviventer fulvescens, Rattus bartelsii, Rattus jalorensis, Rattus mulleri, Rattus rattus diardii, Rattus rattus jarak, Rattus norvegicus, Rattus rattus,*

Possible host: *Rattus tanezumi* and *Rattus tiomanicus*

Target organ: Small intestine

Discussion to the parasite:

The description from Yamaguti (1961); Yorke and Maplestone (1969) and Anderson (2000) as followed: the elongated nematode with two subventral rows of comblike spines extending almost entire length of body. This presence of numerous large body spines is the main characteristic of the species. The oral opening and the buccal cavity are generally displaced to the dorsal side of the cephalic extremity. The buccal cavity is well developed and armed with teeth and spines at its base.

The male tail is conical with small alae. There are several pairs of preanal and postanal papillae on the posterior part. The spicules are small unequal and gubernaculum is present.

The female tail is conical-shaped; vulva is opened anterior, near posterior end of esophagus. The oviparous female with eggs are containing embryo when deposited. Eggs are oval, with smooth, thick-shelled and each contains a fully developed 1st stage larva.

This parasite is found in lumen, attached to the mucosa of the small intestine. The previous studies have been reported as the parasitic intestine in small intestine of carnivore, insectivora, rodents, bats and lizards.

Gongylonema neoplasticum Fibiger and Ditlevsen, 1914

Synonyms: *G. neoplasticum orientale* Yokogawa, 1924;

Classification:
Phylum: Nematoda
Order: Spiruridea
Family: Spiruridae
Genus: Gongylonema
Species: *Gongylonema neoplasticum*

Distribution in SEA: Philippines, Malaysia, Thailand and Vietnam

Locality in this study: Loei (38.46%), Nan (53.85%) and Buriram (7.69%)

Habitat: Domestic (42.86%), Lowland (14.29%), Upland (28.57%) and Forest (14.29%)

Number of examined host: 725

Number of infected host : 13

Prevalence (%): 1.79

Host in this study: *Bandicota savilei, Maxomys surifer, Mus cervicolor, Mus cookii, Niviventer fulvescens, Rattus exulans, Rattus losea* and *Rattus tanezumi*

Possible host: *Bandicota savilei, Maxomys surifer, Mus cervicolor, Mus cookii, Niviventer fulvescens, Rattus exulans, Rattus losea, Rattus norvegicus, Rattus rattus diardii, Rattus rattus jarak, Rattus tanezumi* and *Rattus tiomanicus*

Target organ: Stomach

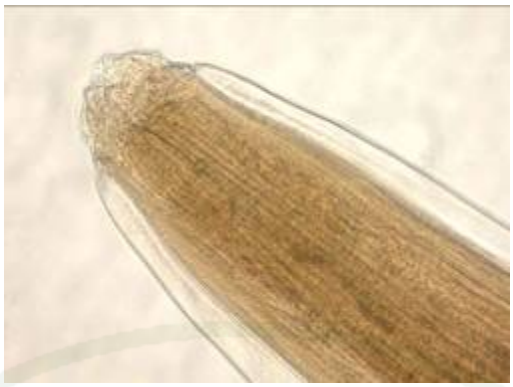
Discussion to the parasite:

The nematode, long slender shaped with small dorsal and ventral lips on the mouth. Each lips bearing a tooth on the inner surface. The cuticle is thick with transverse striations. Cephalic and esophageal region ornamented with cuticular plaques irregularly arranged in longitudinal rows on dorsal and ventral aspects. The buccal cavity is cylindrical, and esophagus is very long divided in to anterior and posterior part, anterior part much the shorter.

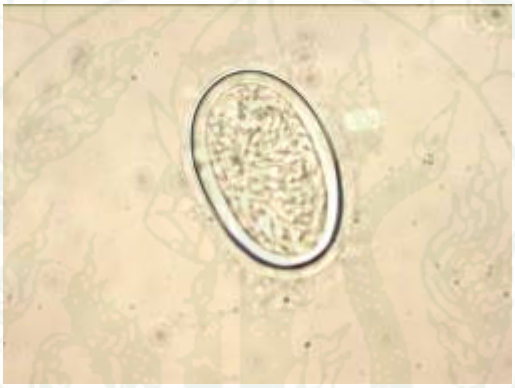
In male, tail is twisted slightly, very unequal spicules and gubernaculums present. One spicule measurement is 0.526-0.740 mm. long while another is shorter with 0.073-0.125 mm. in length. The gubernaculum measurement is 0.125-0.130 mm. long.

Female posterior extremity is bluntly rounded, vulva opened at the posterior part of body. The distance from vulva to the end of body is 0.773-0.826 mm. long. The parasite is oviparous with oval shaped and thick-shelled eggs containing a larva at deposition. The measurement of egg is 0.052-0.064x0.033-0.040 mm. in size.

This parasite is easy to recognize from the unique characteristic of irregular cuticle plaques on the cephalic and esophagus region. They were reported as the parasite of esophageal and stomach walls of mammals and birds. The intermediate host of parasite has been reported as dung beetles (Coleoptera) and cockroaches (Anderson, 2000). Interestingly, there were 9 cases reported of human infection with *Gongylonema* sp. from Thailand (Pasuralertsakul *et al*., 2008). Then, this parasite from murid rodent of present study might play the roll as transmitted to human.



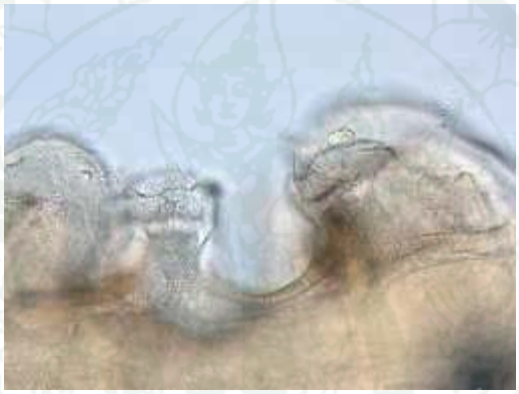
Appendix Figure B29 The cephalic end of *Physaloptera* sp. (20x)



Appendix Figure B30 The egg of *Physaloptera* sp. (100x)

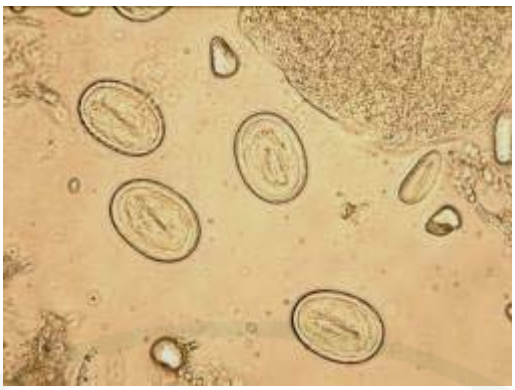
Appendix Figure B31 Frontal view of *Protuspiura* sp. lips (40x)

Appendix Figure B32 The pattern of pseudolabial teeth of *Protospiura* sp. (100x)



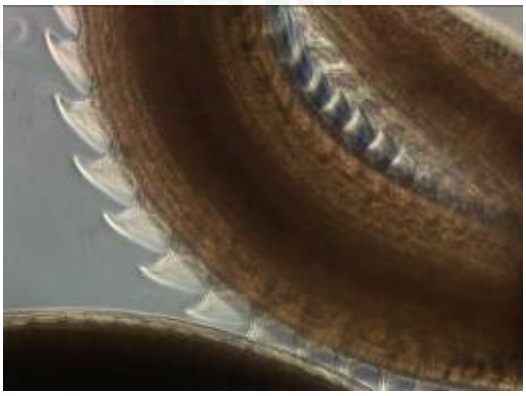
Appendix Figure B33 The pattern of pseudolabial teeth of *Mastophorus* sp. (100x)

Appendix Figure B34 The caudal end of *Protospiura* sp. (40x)

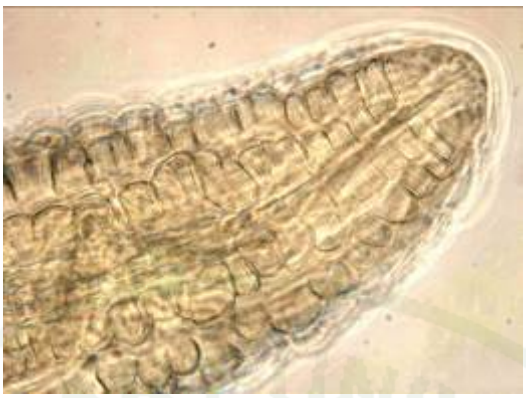


Appendix Figure B35 The eggs of *Protospiura* sp. (40x)

Appendix Figure B36 The cephalic part of *Pterygodermatites* sp. (20x)



Appendix Figure B37 Presence of numerous large cuticular spines along the body of



Appendix Figure B38 The cephalic part of *Gongylonema neoplasticum* with the irregular cuticle plaques (40x)

Appendix Figure B39 The caudal part of male *Gongylonema neoplasticum* (20x)

Appendix Figure B40 The caudal part of female *Gongylonema neoplasticum* (10x)

Trichostrongylidae Leiper, 1912

Synonyms: -

Classification:
Phylum: Nematoda
Order: Strongylidea
Family: Trichostrongylidae
Genus: -
Species: -

Distribution in SEA: Indonesia, Malaysia, Thailand and Vietnam

Locality in this study: Loei (64.20%), Nan (23.86%) and Buriram (11.93%)

Habitat: Domestic (5.11%), Lowland (47.73%), Upland (38.64%) and Forest (8.52%)

Number of examined host: 725

Number of infected host : 176

Prevalence (%): 24.28

Host in this study: *Bandicota indica, Bandicota savilei, Leopoldamys edwardsi, Maxomys surifer, Mus caroli, Mus cervicolor, Mus cookii, Niviventer fulvescens, Rattus exulans, Rattus losea* and *Rattus tanezumi*

Possible host: *Bandicota indica, Bandicota savilei, Leopoldamys edwardsi, Leopoldamys sabanus, Maxomys surifer, Maxomys rajah, Mus caroli, Mus cervicolor, Mus cookii, Niviventer cremoniventer, Niviventer fulvescens,*

Possible host: *Rattus argentiventer, Rattus canus, Rattus exulans, Rattus jalorensis, Rattus losea, Rattus mulleri, Rattus nitidus, Rattus norvegicus, Rattus rattus, Rattus rattus diardii, Rattus rattus sladeni, Rattus tanezumi* and *Rattus tiomanicus*

Target organ: Small intestine

Discussion to the parasite:

The Trichostrongylidae is the large family among the bursate nematode. The groups is distinguished from the hookworms and the strongyles by the absence of buccal cavity or greatly reduce, lips and corona radiata are vestigial or absent. The lateral lobes of bursa are highly developed although the dorsal lobe may be considerably reduced (Anderson, 2000).

The description from Yamaguti (1961) and Yorke and Maplestone (1969) as followed: the body is more filiform with simple mouth, directed straight forward. Bursa copulatrix of male is well developed in lateral lobes but dorsal lobe is very small or not differentiated. Female vulva is in the posterior part of body, exceptionally at extreme posterior end. Some species have the ovijector to release the eggs to environment.

The parasites are wide host range, found in all terrestrial mammals as bats, rodents and ruminants. They are much less common in amphibians, reptiles and birds. The herbivorous or omnivorous hosts usually acquire the parasite by ingesting infective stage larvae contaminating on food. The specimens from present study are reported in the family level. Because of this large group of nematode is complicate and difficult to identify. In the author opinion, the present specimens might comprise of more than 5 species of Trichostrongylids. However, the molecular technique for genus or species identification is still need for further study.

Filariidae Claus, 1864

Synonyms: Filaridae *Cobbold*, 1864

Classification:
Phylum: Nematoda
Order: Filariidea
Family: Filariidae
Genus: -
Species: -

Distribution in SEA: -

Locality in this study: Loei (100%)

Habitat: Domestic (33.33%) and Upland (66.67%)

Number of examined host: 725

Number of infected host : 3

Prevalence (%): 0.41

Host in this study: *Niviventer fulvescens* and *Rattus tanezumi*

Possible host: *Niviventer fulvescens* and *Rattus tanezumi*

Target organ: Stomach and small intestine

Discussion to the parasite:

The description from Yamaguti (1961) and Yorke and Maplestone (1969) as followed: the filiform worm paraite with simple mouth part without any lip and bounded by one pair of chitinous structures. The buccal cavity is very rudimentary and esophagus divided in to anterior muscular and posterior glandular portion. The intestine is simple and not clearly visible at the posterior portion. In male, the tail is coiled comprising of one pair of spicules, very unequal and dissimilar. Female is much longer than the male. The vulva is opened at the esophageal region. Regularly reports will be found in lymphatic, muscular, connective tissue or serous cavities of vertebrates.

In the present study, we found this filarid worm in stomach and small intestine of murid rodents. Then, we assumed that might be the accidental infection to the unreported target organ. Another assumption is might be the new genus or new species found from the study. However, more information still required and the molecular technique for genus or species identification is still need for further study.

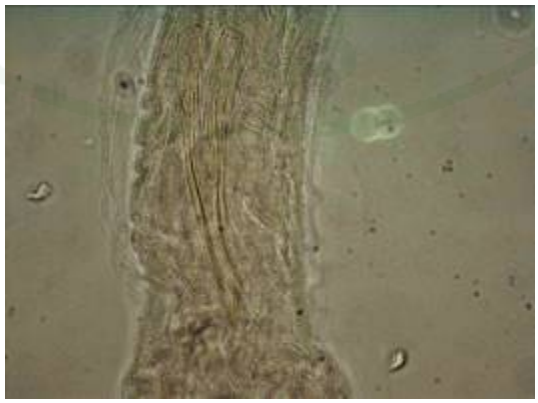
Appendix Figure B41 The adult female Trichostrongylidae (10x)

Appendix Figure B42 The cephalic end of Trichostrongylidae (40x)

Appendix Figure B43 Female caudal end with ovijector of Trichostrongylidae (40x)

Appendix Figure B44 The Trichostrongylidae female caudal end with ponted tail (20x)

Appendix Figure B45 The male Trichostrongylidae tail with asymmetrical bursa and long spicules (20x)



Appendix Figure B46 The spicules of the other male Trichostrongylidae (100x)

Appendix Figure B47 The cephalic part of Filariidae (4x)

Appendix Figure B48 The mouth part of Filariidae (40x)

Appendix Figure B49 The coiled caudal end with two unequal spicules of Filariidae male (10x)

Moniliformis moniliformis Bremser, 1811

Synonyms: *Echinorhynchus moniliformis* Bremser, 1811;
Echinorhynchus grassi Deffke, 1891;
Echinorhynchus canis Porta, 1914;
Echinorhynchus belgicus Railliet, 1919

Classification:
Phylum: Acanthocephala
Order: Moniliformida
Family: Moniliformidae
Genus: Moniliformis
Species: *Moniliformis moniliformis*

Distribution in SEA: Malaysia, Philippines, Thailand and Vietnam

Locality in this study: Loei (33.33%) and Nan (66.67%)

Habitat: Domestic (100%)

Number of examined host: 725

Number of infected host : 3

Prevalence (%): 0.41

Host in this study: *Rattus exulans* and *Rattus tanezumi*

Possible host: *Bandicota indica, Rattus annandalei, Rattus argentiventer, Rattus exulans, Rattus norvegicus, Rattus rattus diardii, Rattus tiomanicus* and *Rattus tanezumi*

Target organ: Small intestine

Discussion to the parasite:

The description of this parasite from Skrjabin (1958) as followed: the parasite consists of a proboscis, located on the anterior end of the worm, neck and trunk. Body is elongated with pseudosegmentation of body surface. The proboscis is cylindrical shaped with slight broadening of anterior end. The proboscis is consisted with twelve longitudinal rows of 7-8 hooks, which decrease in size from anterior to posterior. Hooks are small and numerous, arranged in a zigzag pattern along the longitudinal rows. Sheath attached at base of proboscis. The trunk is located posterior to the neck and contains the reproductive system. Both males and females have sacs that contain the gonads as well as several accessory organs in posterior end of body.

In male, body is about 80 mm. long and 2 mm. wide. Testes are large and elongated with 6-8 orbicular cement glands. Female is bigger and longer than male with 115-270 mm. long and maximum width in posterior third 1.5-2.0 mm. wide. Eggs are rather large with oval, concentric membrane without shells.

The life cycle of the parasites must have at least two hosts in order to complete its life cycle. Intermediate hosts must be either a beetle or a cockroach, which must be eaten by a definitive host. Common definitive hosts include rats, mice, hamsters, dogs and cats (Alley *et al*., 1992).

Appendix Figure B50 The cephalic end of *Moniliformis moniliformis* with armed proboscis (20x)

Appendix Figure B51 The pseudosegmentation of *Moniliformis moniliformis* body surface (4x)

Appendix C

Reagents and chemical solutions

1. Alcohol

Normally, ethyl-alcohol used in laboratory is in absolute form, which may be contained in the storage bottle. Alcohol is absorp moisture very quickly. After expose to moisture, concentration will be reduced to 95%. Therefore, the commercial alcohol is normally 95% concentration. The preparation of the alcohol concentration level from 95% alcohol as:

Prepared 70% alcohol by 95% alcohol.

95% Alcohol	70	portions
Distilled Water	25	portions
Total	95	portions

2. Glycerine Alcohol components:

70% Alcohol	90	portions
Glycerine (Glycerol)	10	portions

3. Alcohol-formal-acetic (AFA) fixative components:

Formalin (Formaldehyde)	10	portions
95% Alcohol	25	portions
Gracial Acetic Acid	5	portions
Glycerine	10	portions
Distilled Water	50	portions

4. Lactophenol components:

Glycerine	5	portions
Distilled Water	1	portion
Phenol	1	portion

Lactic Acid	1	portion

5. Semichon's Carmine

Preparing method: The Gracial acetic gradually added into a flask containing distilled water. Fill a volume of Gracial acetic equal to the volume of water. After that, the estimated of carmine powder added into the flask and heated to 95-100 °C approximately 15 minutes long. Leave the solution until cold and filtered several times with filter paper. To be used, dilute with 70% alcohol at least equal by volume of the stock solution.

CIRRICULUM VITAE

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