พลวัตรประชากรและสถานภาพสุขภาพของสัตว์เลี้ยงลูกด้วยน้ำนม ขนาดเล็กที่สถานีวิจัยสิ่งแวดล้อมสะแกราช นครราชสีมา

นายสิทธิศักดิ์ ปิ่นมงคลกุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาชีววิทยาสิ่งแวดล้อม
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POPULATION DYNAMICS AND HEALTH STATUS OF SMALL MAMMALS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA

Sitthisak Pinmongkholgul

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Environmental Biology

Suranaree University of Technology

Academic Year 2008

POPULATION DYNAMICS AND HEALTH STATUS OF SMALL MAMMALS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

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สิทธิศักดิ์ ปิ่นมงคลกุล : พลวัตรประชากรและสถานภาพสุขภาพของสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็กที่สถานีวิจัยสิ่งแวดล้อมสะแกราช นครราชสีมา (POPULATION DYNAMICS AND HEALTH STATUS OF SMALL MAMMALS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร. ณัฐวุฒิ ธานี, 313 หน้า.

การศึกษาพลวัติประชากรและสถานภาพของสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็กในพื้นที่ป่าของสถานีวิจัยสิ่งแวดล้อมสะแกราช นครราชสีมา ดำเนินการในช่วง มกราคม 2550 – ธันวาคม 2550 โดยแบ่งการศึกษา เป็น 4 ช่วงคือ ต้นฤดูฝน (พฤษภาคม – กรกฎาคม) ปลายฤดูฝน (สิงหาคม – ตุลาคม) ฤดูหนาว (พฤศจิกายน – มกราคม) และฤดูร้อน (กุมภาพันธ์ – เมษายน) โดยวิธี จับซ้ำ เพื่อประเมินการกระจายตัวของประชากรและความสัมพันธ์ระหว่างปรสิตที่พบเพื่อประเมินถึงสภาวะของของสุขภาพสัตว์ พบว่า จาก 3,528 กรงดัก สามารถจับสัตว์ได้ 1,047 ครั้ง พบจำนวนของสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็กจำนวนทั้งสิ้น 371 ตัว จากการจำแนกได้ 9 ชนิด 9 สกุล 4 วงศ์ ชนิดที่พบบ่อยมากที่สุด 4 ชนิด คือ หนูฟานเหลือง (*Maxomys surifer*) รองลงมาคือ กระแต (*Tupaia glis*) หนูท้องขาว (*Rattus rattus*) และ หนูหวาย (*Leopoldamys sabanus*) การศึกษาความหลากหลายของสิ่งมีชีวิตพบว่า หนูฟานเหลือง (*M. surifer*) เป็นชนิดเด่น โครงสร้างและอัตราส่วนเพศของสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็กไม่มีความแตกต่าง ในขณะที่โครงสร้างอายุ ความหนาแน่น และมวลชีวภาพมีความผันผวนตามประเภทของป่าและฤดูกาล พื้นที่ในการเคลื่อนที่หากินของสัตว์แต่ละชนิดพบว่า สัตว์จะมีพื้นที่ในการหากินมากที่สุดในฤดูหนาวและฤดูแล้งในทุกประเภทของป่า ความหนาแน่นของสัตว์พบว่าหนูฟานเหลือง (*M. surifer*) มีความหนาแน่นมากที่สุดของทุกป่าในแต่ละฤดู การวิเคราะห์ความสัมพันธ์ระหว่างปัจจัยทางนิเวศกับสังคมสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็กพบว่า มีความสัมพันธ์กันสูงมาก โดยปัจจัยที่มีความสัมพันธ์ในเชิงบวกกับความหนาแน่นของหนูฟานเหลือง (*M. surifer*) และ หนูหวาย (*L. sabanus*) ได้แก่ ชนิดของพรรณไม้ ความหนาแน่นของพรรณไม้ พื้นที่ของต้นไม้ เส้นผ่านศูนย์กลางต้นไม้ ความสูง ความหนาแน่นของชั้นเรือนยอด และความหนาแน่นของพืชคลุมดิน ในขณะที่กระแต (*T. glis*)และหนูท้องขาว (*R. rattus*) ที่พบในป่าเต็งรังและบริเวณรอยต่อของป่า (Ecotone) มีความสัมพันธ์ในเชิงลบกับปัจจัยดังกล่าว

การศึกษาปรสิตภายนอกและปรสิตภายในเลือดของสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็กที่พบในพื้นที่ป่าเต็งรัง ป่า Ecotone และ ป่าดิบแล้งพบปรสิตในสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็ก 4 ชนิด คือ หนูฟานเหลือง (*M. surifer*) รองลงมาคือ หนูท้องขาว (*R. rattus*) หนูหวาย (*L. sabanus*) และกระแต (*T. glis*) ปรสิตภายนอกที่พบคือ ไร (*Lealaps echidinus*) เห็บแข็ง (*Ixodes* sp.)

หมัด (*Xenopsylla cheopsis*) และ แมงป่องเทียม (*Chelifer cancroides*) ปรสิตที่พบในเลือด ได้แก่ *Microfilaria* sp. *Trypanosoma* sp. *Anaplasma* sp. และ *Grahamella* sp. ซึ่งไรและ *Anaplasma* sp. คือปรสิตภายนอกและภายในเลือดที่พบมากที่สุดในสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็กทั้ง 4 ชนิด โดยหนูฟานเหลือง (*M. surifer*) คือชนิดที่พบปรสิตภายนอกและภายในเลือดมากที่สุด ความสัมพันธ์ระหว่างสัตว์เลี้ยงลูกด้วยน้ำนมขนาดเล็กแต่ละชนิดกับความชุกของปรสิตภายนอกและภายในเลือดมีความสัมพันธ์กันอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) อายุของสัตว์มีความสัมพันธ์แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) กับจำนวนของ *Trypanosama* sp. ที่พบในหนูฟานเหลือง (*M. surifer*) ประเภทของป่า ฤดูกาล เพศ และอายุมีความสัมพันธ์แตกต่างกันอย่างมีนัยสำคัญ ($P < 0.05$) กับค่าเคมีของเลือด จำนวน และคุณภาพของเม็ดเลือดที่พบในสัตว์เลี้ยงลูกด้วยน้ำนมทั้ง 4 ชนิด ในส่วนของชนิดและจำนวนปรสิตที่พบในเลือดไม่มีผลต่อค่าเคมีของเลือด จำนวน และคุณภาพของเม็ดเลือดที่พบในสัตว์เลี้ยงลูกด้วยน้ำนมทั้ง 4 ชนิด จากการศึกษาแสดงให้เห็นว่า สัตว์เลี้ยงลูกด้วยน้ำนมทั้ง 4 ชนิดอาจเป็นโฮสท์ที่มีปรสิตอาศัยอยู่เป็นรังโรคของปรสิตดังกล่าว

สาขาวิชาชีววิทยา	ลายมือชื่อนักศึกษา________
ปีการศึกษา 2551	ลายมือชื่ออาจารย์ที่ปรึกษา________
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม________
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม________

SITTHISAK PINMONGKHOLGUL : POPULATION DYNAMICS AND HEALTH STATUS OF SMALL MAMMALS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA THESIS ADVISOR : ASST. PROF. NATHAWUT THANEE, Ph.D. 313 PP.

SMALL MAMMAL/ POPULATION DYNAMIC/ ECTOPARASITE/ PSEUDOSCORPION/BLOOD PARASITE

Small mammal communities were studied over 12 months since January 2007- December 2007 in three dry tropical habitats; dry dipterocarp (DD), ecotone (ECO) and dry evergreen (DE) forest, in Sakaerat Environmental Research Station, North-eastern Thailand. Mark-recapture grids were used to catch animals, and data were collected on age structure, population dynamics, diversity indices, biomass and minimum home-range size. The year was divided into four seasons; early rainy (May-July), late rainy (August-October), winter (November-January) and summer (February-April). From a total of 3,528 trap nights, there were 1,047 captures of 371 individuals (29.68% capture rate), comprising six species of rodent and one species each of Scandentia, Lagomorpha and Carnivora. The four most common species caught at all sites were *Maxomys surifer*, *Tupaia glis*, *Rattus rattus* and *Leopoldamys sabanus*, with *M. surifer* being the most frequently caught species in all forest types. Population age structure, density and biomass, but not community structure or sex ratios, varied by forest type and season in these species. Minimum home range size was largest in the winter and summer in all forest types in all four species. *M. surifer* had the highest population densities in all forest types in all seasons. Density estimates for *M. surifer* and *L. sabanus* in all habitat types, and for *T. glis* and *R. rattus* in DE forest, correlated positively with a range of ecological factors including tree species, tree density, basal area, average diameter at breast height, average height, canopy cover, and ground cover. In the ECO and DD forests, the density estimates for *T. glis* and *R. rattus* were negatively correlated with these environmental factors. A concurrent study of ectoparasites and blood parasites was undertaken on these four species. The most prevalent ectoparasites found were a mite (*Lealaps echidinus*), a tick (*Ixodes* sp.), a flea (*Xenopsylla cheopsis*) and a pseudoscorpion (*Chelifer cancroides*), with *L. echidinus* and *Anaplasma* sp. being the two most frequently recorded. Blood parasites detected were identified as *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp.. *M. surifer* had the highest numbers of ectoparasites and blood parasites. The relationship between ectoparasites and blood parasites differed to the typical pattern reported in the literature, with the same ectoparasites and blood parasites occurring across a range of host species, and the relationship between ectoparasites and blood parasites showing different patterns across hosts. In *M. surifer*, the incidence of *Trypanosoma* sp. was positively correlated with age. Blood serum biochemistry varied significantly across habitat type, season, sex and age in all four host species. The incidence of blood parasites did not correlate with total serum biochemistry values, strongly suggesting that the four host species studied here may be acting as reservoirs for these parasites.

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Academic Year 2008

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Sitthisak Pinmongkholgul

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LIST OF ABBREVIATIONS

°C	=	Degree Celsius
DD	=	Dry diterocapus forest
Eco	=	Ecotone
DE	=	Dry evergreen forest
ha^{-1}	=	Hectare
Avg. DBH.(cm)	=	Average diameter at breast height
Avg. High (m)	=	High
MHRS	=	Minimum home range size
PCA	=	Principal Component Analysis
EDTA	=	Ethylenediaminetetraacetic acid
RBC	=	Red blood cell
WBC	=	White blood cell
PVC	=	Packed cell volume

CHAPTER I

INTRODUCTION

Ecosystems are composed of natural populations, which are controlled by species interactions such as predation, competition and parasitism. When ecosystems are disturbed, there will be changes in species interactions that will affect the dynamic regulation.

Small mammals are important groups of organisms in ecosystem conservation. They have short life cycles and respond rapidly to environmental changes. They are also important prey for the majority of the carnivores. In addition, they are of medical and veterinary importance for maintaining the sylvatic cycle of some important diseases including leishmaniasis and hantaviruses. For these reasons they are considered as good biological indicators for abundant forest. Monitoring small mammal populations is thus an important tool that can help in the development of management and conservation strategies.

Small mammal population dynamics can indicate the functional effects associated with forest change. Environmental changes in land use or the introduction of new pathogens can cause the emergence of enzootic diseases. There is a variety of ways that forest changes affect host parasitic systems, therefore parasite loads in wild mammals may indicate habitat health, with animal health status being correlated with ecological impact (Boelaert et al., 2000)

Wild rodents play an important role in nature as reservoir hosts for many pathogens, including some that can be transmitted to other animals including humans. Free-living animals are frequently infected with parasites that can be transmitted to domestic animals. Some examples are filariasis and trypanosomiasis, thus it is possible to determine the infection originated from the wild rodents.

The objectives of this study are to monitor parasites disease and health status in small mammal groups, specifically rat and insectivore species, at Sakaerat Environmental Research Station (SERS) (associated with the emergence of diseases) and to identify some host-parasite relationships that could be indicators of the health status of small mammals and the ecosystem, interaction to population ecology.

CHAPTER II

LITERATURE REVIEW

2.1 Small Mammals

Small mammals are classified by several different criteria, based on weight and size. Small mammals are non-flying mammals that weight between 2 grams and up to 5 kg when they are adult, and include species in the Orders Insectivora and Rodentia. This group includes insectivorous, omnivorous, and herbivorous animals and is a major food support for many predators in the food web (Stoddart, 1981). Small mammals have higher metabolic rates and shorter life spans than larger ones (Stearns, 1992), and are primarily nocturnal or crepuscular. This group of animals covers the largest proportion (>60%) of total terrestrial mammals (Barnett and Dutton, 1995; Bourliere, 1975). Small mammals are also considered as the ideal taxonomic group to be used as models for ecological indicators because small mammals have relatively small home ranges, are short-lived and disperse from their natal areas when they reach adulthood. Some small mammal populations can be monitored easily to determine their structure (proportion of age classes, sex ratio, etc.), reproductive activity, survivorship, home rang size, etc. These data from small mammals help to better understand processes such as rates of colonization, extinction, dispersal and persistence (Barrett and Peles, 1999).

2.1.1 Order Rodentia

Morphology

Rodents range in size from about 5 grams to 5 kilograms. The upper and lower jaws each bear a single pair of persistently growing incisors, a feature developed early in the evolution of rodents and one that committed them to an essentially herbivore mode of feeding, while still permitting the exploitation of such abundant foods as insects. Because only the anterior surface is covered with enamel, the incisors assume a characteristic beveled tip as a result of wear. The occlusal surfaces of the cheek teeth are often complex and allow for effective sectioning and grinding of plant material. In some rodents, the cheek teeth are ever-growing. The dental formula never exceeds 1/1, 0/0, 2/1, 3/3 = 22, and a diastema is always present between the incisors, and canines always 1/1, 0/0.

Uniquely derived characters used to diagnose a monophyletic rodentia (Hartenberger, 1985).

1) One pair of upper and lower incisors; each tooth is enlarged, sharply beveled, and ever-growing.
2) Broad diastema (space) between incisors and premolars of both upper and lower jaws resulting from the loss of canines and some cheek teeth.
3) Incisor enamel restricted to the outside surface only.
4) Paraconid lost on lower cheek teeth.
5) Orbital cavity lying just dorsal to cheek tooth.
6) Ramus of the zygoma lies anterior to the first cheek tooth.
7) Glenoid fossa is an anterior-posterior trough allowing fore and aft movement of the mandible.

Family Muridae

The family Muridae is huge, including some 66 percent of the living species of rodent (roughly 1325 species and 281 genera) and is worldwide in distribution; its members occupy environments ranging from high arctic tundra to tropical forests to desert sand dunes. The subfamilies, common manes and distribution of family Muridae are shown in Table 1.1.

Table 2.1 The subfamilies and distribution of the family Muridea.

Subfamily (no. of species)	Common name	Distribution
1. Arvicolinae (143)	voles, lemmings, muskrat	Holaarctic
2. Calomyscinae (6)	mouse hamsters	Middle East and SW Asia
3. Cricetinae (18)	hamsters	Palearctic
4. Cricetomynae (6)	pouched rats and mice	Africa, South of Sahara
5. Dendromurinae (23)	climbing rats, forest mice	Africa, South of Sahara
6. Gerbillinae (110)	gerbils, jirds, sand rat	Africa, Southern Asia
7. Lophiomyinae (1)	maned rat	Eastern Africa
8. Murinae (529)	old World rats and mice	Nearly worldwide
9. Myospalacinae (7)	zokors	Siberia, Northern China
10. Mystromyinae (1)	white-tailed rat	South Africa
11. Nesomyinae (14)	malagasy rats and mice	Madagascar
12. Otomyinae (12)	vlei rats, karroo rats	Parts of Africa
13. Petromyscinae (5)	rock mice, swamp mouse	Parts of Africa

Table 2.1 The subfamilies and distribution of the family Muridea (Continued).

Subfamily (no. of species)	Common name	Distribution
14. Platacanthomyinae(3)	spiny mouse, blind tree mouse	India, Southeastern Asia
15. Rhizomyinae (15)	mole rats, bamboo rats	East Africa, South Asia
16. Sigmodontinae (422)	NewWorld rats and mice	New World
17. Spalaccinae (8)	blind mole-rats	Mediterranean region

Notes From Mammalogy (p.293), by Musser and Carleton 1993, quoted Vaughan, Ryan and Czaplewski, 2000 The United States: Thomson Learning.

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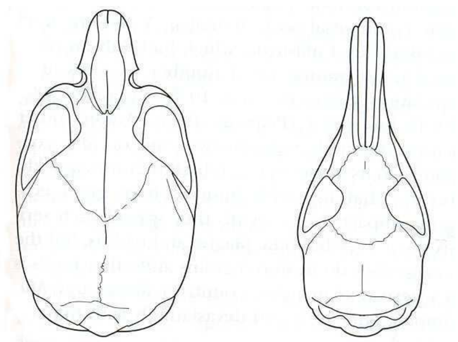
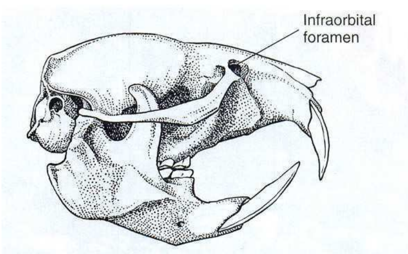
Most murids retain a "standard" mouselike form, with a long tail, generalized limb structure, and no loss of digits. Murids range in weight from about 10 grams, as in pygmy mouse (*Bariomys*), to two kilograms, as in the New Guinean rat (*Mallomys*). The skull varies widely in shape (Figures 2.1, 2.2), the infraorbital foramen is always above the zygomatic plate and is enlarged dorsally for the transmission of part of the medial massester, which originates on the side of the rostrum. Through the narrowed ventral part of this foramen pass blood vessels and a branch of the trigeminal nerve. The maxillary root of the zygomatic arch is platelike and provides surface for the origin of part of the lateral masseter. This myonorphous zygomasseteric arrangement was perhaps derived through a hystricomorphous ancestry. The dental formula is generally 1/1, 0/0, 0/0, 3/3 = 16; in some species the molars are reduced in number. Molars range from brachydont to hypsodont and ever-growing. The basic cusp pattern involves transverse crests (Figure 2.3) but crests are absent in some species and molar crown patterns vary widely (Musser and Carleton, 1993).



Rock mouse (*Delanymys brooks*)   Shrewlike rat (*Rhynchomys soricoides*)

Figure 2.1 Extremes in skull shape in rodents of the family Muridae The rock mouse is a rock-dwelling omnivore, while the shrewlike rat is a rare species that apparently feeds on invertebrates.

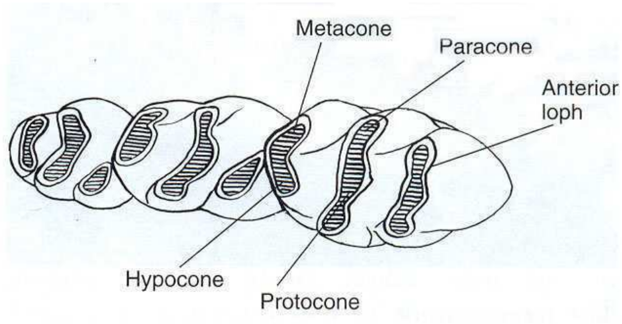
Notes From Mammalogy (p.293), by Vaughan, Ryan and Czaplewski, 2000, The United States : Thomson Learning.



Root rat (*Tachyoryctes splendens*)

Figure 2.2 Skull of an African root rat (Muridae, Rhizomyinae). Note the procumbent incisors, which are used for digging, and the dorsal position of the infraorbital foramen (length of skull 41 mm).

Notes From Mammalogy (p.293), by Vaughan, Ryan and Czaplewski, 2000, The United States : Thomson Learning.



Rattus sp.

Figure 2.3 Occlusal surfaces of the right upper molars of a murid rodent (*Rattus*).

With wear, the cross lophs become lakes of dentine (cross-hatched areas) rimmed with enamel.

Notes From Mammalogy (p.293), by Vaughan, Ryan and Czaplewski, 2000, The United States : Thomson Learning.

Subfamily Murinae

The Murinae is the largest murid subfamily (529 species), which occurs almost worldwide, and includes a wide diversity of types adapted to terrestrial, fossorial, largely aquatic, or arboreal life. Some murines live in close association with humans in situations ranging from isolated farms to the world's largest cities. As a result of introductions by humans, these animals have become very cosmopolitan in distribution and are probably the rodents most familiar to us. Murines that are not commensal with humans occur in much of southeastern Asia, Europe, Africa, Australia, Tasmania, and Micronesia. Tropical and subtropical areas are centers of murine abundance, and these animals have occupied a wide variety of habitats, and some genera are highly adapted to specialized modes of life. Murines range in weight from about 10 grams to 2 kilograms. Although the tail is usually more or less naked and scaly, it is occasionally heavily furred and bushy. The molars are rooted or ever-growing and usually have crowns with crests or chevrons; great simplification of crown pattern occasionally occurs. The dental formula is usually 1/1, 0/0, 0/0, 3/3 = 16. The feet retain all of the digits, but the pollex is rudimentary (Vaughan, Ryan and Czaplewski, 2000, Chap.18).

2.1.2 Small Mammal Physiology

Small species have higher metabolic rates and shorter life spans than larger ones. Fast metabolism and short life span is usually linked to high reproductive rates, giving rise to the so-called ‘r strategy’ so commonly found in small mammals (Stearns, 1992). Species that follow this strategy are able to respond quickly, with an higher number of descendents, to favorable environmental changes (mild climate, increased food availability, etc.). Their demographic are plasticity, along with their high turnover rate and adaptability. Rodents adapt to arid environments behaviourally as well as physiologically. Arid zone rodents generally display suites of specializations that allow them to exploit xeric environments. The most common are nocturnal habits, including a propensity towards being diurnally fossorial, decreased metabolic rates, and use of torpor as a physiological mechanism to conserve energy and water (Downs and Perrin, 1994).

2.1.3 Rat Species Groups in Thailand

Thailand has 36 species of terrestrial rats and mice (Lekagul and Mcneely, 1977).

Terrestrial Rats and Mice

The foot has five digits, each armed with a sharp claw. The hand's vestigial thumb is represented only by a flat nail, as in all Muridae, leaving four clawed fingers. The ground-based rodents grouped here have four interdigital and one or two plantar tubercles on the sole of the foot. In bandicoots, mice, and Rajah rats the foot is proportionately long; the paw-pads being grouped together distally.

The present grouping includes all the commensal rodents of Thailand, which were listed as having economic importance in the introduction.

Genus *Bandicota*

Bandicoots are robust, shaggy, blunt-nosed burrowing rats found in India and Southeast Asia. They are distinguished by the straight, cross-wise lamellae of worn molars. The upper incisors measure about 4 mm in combined width, whereas those of a large Norway rat are less than 3.5 mm. They have 44-46 chromosomes including 8 to 9 pairs of metacentrics. The lice effecting this genus are *Holopleura malabarica* and *Polyplax asiatica*. Bandicoots are vociferous in the trap, snarling and grunting like pigs. Thai species have a mammary formula of 3+3.

Genus *Mus*

The key trait is the large first molar contrasted with the diminutive third, such that the first is more than half the length of the toothrow. The pointed parietal bones and windows are at the side of the cranium where the bones do not meet. They consist of a prelambdoital fenestra divided by a slender bone, the paraoccipital process above the bulla. In older individuals of large species, such as *Mus shortridgei* and *M. cookii*, the openings become obliterated by union of the skull bones. Mice have six interdigital and plantar tubercles that are smooth, small, rounded, and grouped close together distally on the foot. None of the above traits is limited to *Mus*, but their association is coupled with the absence of a postero-internal cusp. All six species of Thailand have a mammary formula of 3+2 and three subgenera occur in Thailand.

Subgenus *Pyromys*, Spiny mice

These are *Rattus*-like in that they have chewing muscles. This perhaps implies a diet of hard seeds. *Pyromys* are spiny except for one Nepalese subspecies (*Mus saxicola gurkha*). *Mus shortridgei* is the only member of the subgenus which has gray bases to the white ventral fur. These mice are hosts of various lice, species of *Hoplopleura*, that are not the same as those from other mice. The karyotype in *Pyromys* contains metacentric chromosomes and a greater number of arms than the 40 found in the subgenus *Mus*. Spiny mice live exclusively in wild habitats.

Subgenus *Coelomys*, Shrew-mice

These shrew-like mice have broad frontal bones (exceeding 4 mm between the orbits), short and broad incisive foramina, no supraorbital ridges, small eyes, long nose, and dark colors. Their habitat is mountain rain forest. They also carry a unique species of lice found only on *Mus pahari*. The karyotype in *Coelomys*, also know only for *M. Pahari*, consists of 48 telocentrics.

Subgenus *Mus*, House mice and allies

These soft-furred mice lack spines and supraorbital ridges. They possess narrow frontal bones, long incisive foramina and notched incisors. The basic karyotype, found invariably in all four Thai species, consists of 40 telocentric chromosomes. Usually clean of ectoparasites, their particular lice, found so far on *Mus caroli* and *M. cervicolor*, is *Hoplopleura johnsonae*. *H. captiosa* and *Polyplax serrata* are found on *M. musculus*. All species in the subgenus *Mus* are able to live with man; all have been found in wild habitats as well. The six Asian forms occupy ricefields, whereas several dark-bellied subspecies of the Eurasian *Mus musculus* are specially adapted to live in houses.

Genus *Rattus*

This used to be called *Mus* and *Epimys*, before *Mus* became restricted to mice. The posterior internal cusp is absent, the worn molars show a chevron pattern of dentine and enamel, and the first molar is less than half the length of the tooth row. Six subgenera occur in Thailand.

Subgenus *Berylmys*, White-toothed rats

Of medium to large size, with a white front surface on the upper incisors, these rats have iron-gray dorsal color, pure white ventral color and crisp fur. Their slightly ridged skull, viewed from above, has a characteristic triangular outline that is shared with another white toothed genus, *Diomys* and subgenus *Coelomys*. They are naturally tame. They have 40 chromosomes that typically include 7 metacentric pairs, and they are hosts of the lice *Hoplopleura diaphora* (on *R. bowersi*) and the similar *H. kitti* (on *R. berdmorei*).

Subgenus *Maxomys*, Rajah rats

This group has been called *Lenothrix*, a name that seems inappropriate because *Lenothrix canus* is specialized for arboreal life. It has a broad foot and short, broad skull with supraorbital shelf over the eye. There are 46 chromosomes, including six small metacentrics, as in the Niviventer group, but the sex chromosome is a large subtelocentric. It ascends to the canopy of the Malayan rain forest. In contrast, the Rajah rat have a long, slender foot adapted for scampering over the ground, are never found in trees, have a normally elongate skull, have chromosomes of variable number depending on the species, and have a sex chromosome which is a large metacentric.

Subgenus *Niviventor*, White-bellied rats

The many species of the niviventor group occur in forests from the Himalayas and China to the Sunda Shelf. Most are small, long tailed, white bellied rats with spines and 2+2 mammae. The skull has relatively smaller bullae and shorter palate than *Rattus rattus*. The "short palate" figured as a percentage of total skull length, is an illusory consequence of the nasal bone projecting far ahead of the incisors with the niviventor group (to give a long skull) whereas the palate extends aft on the molars in the subgenus *Rattus* (to give a long palate). A characteristic, though rare, louse is *Hoplopleura sicata*. *Polyplax pricei* has also been described from this group. The 46 chromosomes are mostly telocentric, but the smallest six are invariably metacentric.

Subgenus *Rattus*, Roof rats and allies

The bullae are larger than in other forest-dwelling subgenera. Tails in Thai species are always unicolor blackish except

1. Pale underneath, not sharply demarcated in *R. norvegicus*.
2. Sometime minutely white tipped in *R. koratensis* from Prachinburi province.
3. Sharply bicolored in rare, partially albinistic mutants of *R. rattus*.

Mammae are various and subject to geographic variation in *Rattus rattus*.

Field identification, based on mammae, size, color and proportions, is complicated by the ubiquitous occurrence of the common, white bellied *Rattus rattus* in any trapline. The other species are restricted ecologically or geographically. It is usually necessary to examine the skull rostrum, ridge, and bullae to confirm an identification. Such identification features include short rostrum: losea; long rostrum: *nitidus* and *remotus*; small bullae: nitidus, remotus and koratensis; large bullae: *argentiventor* (and *annandalei* in Malaya peninsular); parietal ridges hight on top of the cranium and fairly close together: *norvegicus* and *losea*; parietal ridges low and bowed far apart: *nitidus* and *exulans*; *losea*, *koratensis-rattus-nitidus-argentiventer*, and *remotus-norvegicus*. Mammary formulae are 2+2 *exulans*, 2+3 *losea* and southern *rattus*, 3+3 in *koratensis*, *nitidus*, *argentiventer*, *remotus* and *norvegicus*, and some individuals of *rattus* in Trat. *Rattus rattus diardii* is a common in-house species in peninsular Thailand with dark brown belly the same color as the back. Those with the belly white are *rattus, koratensis* and *remotus*. *Argentiventor* has a silvery-gray belly, never cream-colored as in worn or soiled *rattus*. Both *exulans* and *norvegicus* have a pure black color phase in Thailand. *Exulans* and *Rattus* are found on island; on Koh Samui *remotus*, *norvegicus*, and *argentiventor* also occur. There are 42 chromosomes in the subgenus *Rattus*, including 7 pairs of small metacentrics, except for nitidus and koratensis, most individuals of which have 8 pairs. The lice affecting the Subgenus *Rattus* are *Hoplopleura pacifica* and *Polyplax spinulosa*.

Subgenus *Stenomys*, Aquatic giant rats

There are 42 chromosomes in *Stenomys*, including 6 metacentric pairs. The x-chromosome is a large submetacentric. The characteristic louse is *Hoplopleura dissicula*.

Subgenus *Leopoldamys*, Long-tailed giant rats

These are large, docil, semiarboreal rats with very long tails, sleek fur, sharply demarcated white or cream colored underparts, and 2+2 mammae. They have 42 or 44 chormodomes and the lice *Hoplopleura malaysiana* and *Polyplax insulsa*. The outline of the elongated version of *Rattus confucianus*. Turning to the photograph provided in the species accounts, the skulls of our three species of *Leopoldamys* have relatively even narrower cranium, larger teeth, and smaller bulla (Lekagul and Mcneely, 1977) compared to *R. confucianu*.

Most of small mammal species can be indentified mature or immature of sex and age criteria by use sex organ as shown in Figure 2.4 and 2.5.

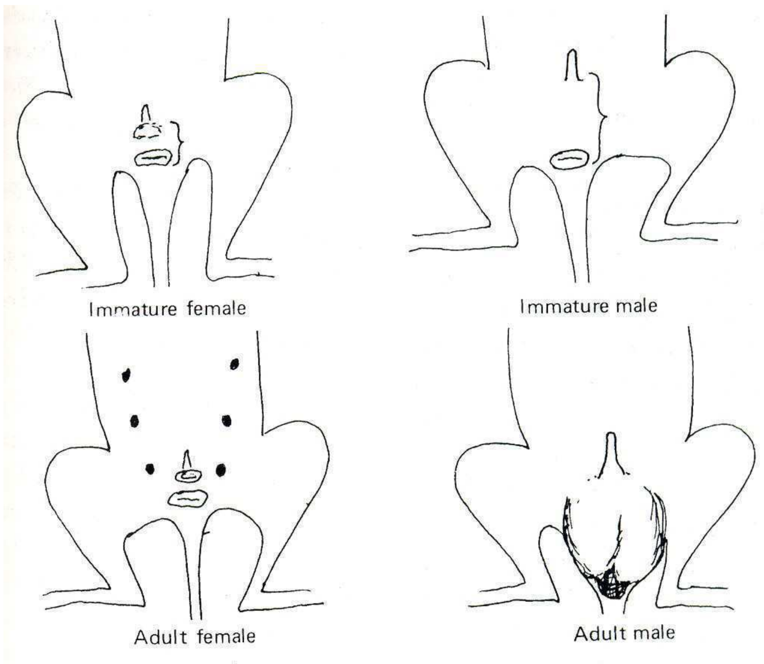


Figure 2.4 Sex and age criteria

__Notes__ From Mammals of Thailand (p.410), by Lekagul and Mcneely, 1977,

Bangkok : Kuruspha Press.

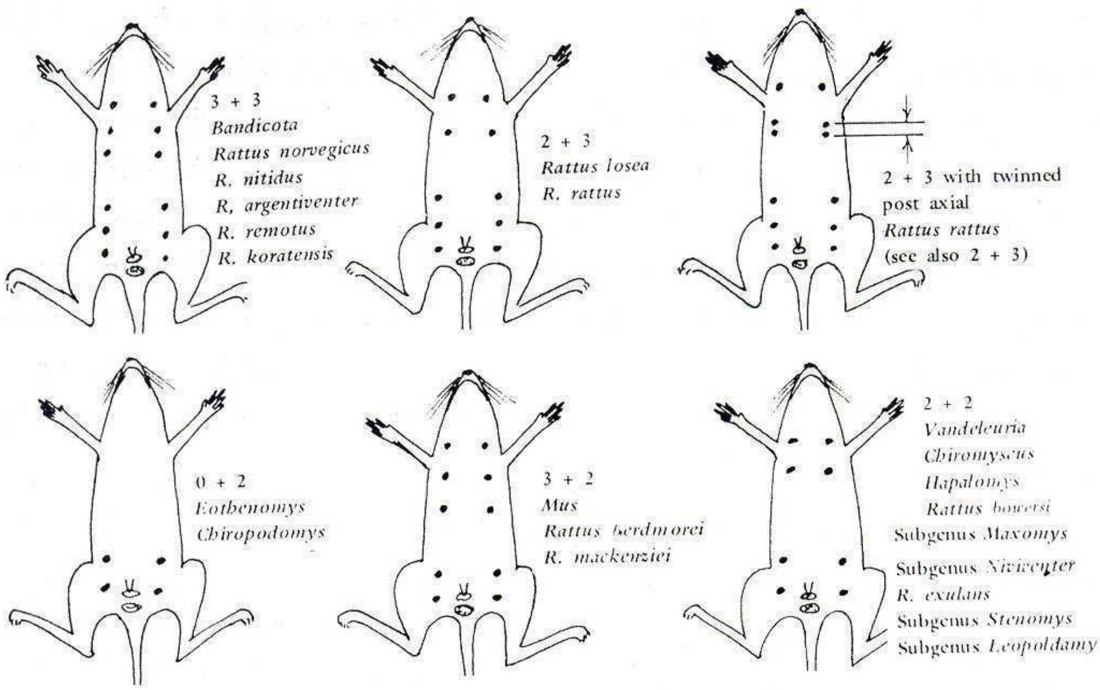


Figure 1.5 Mammary formulae of Muridea

<u>**Notes**</u> From Mammals of Thailand (p.410), by Lekagul and Mcneely,

1977, Bangkok : Kuruspha Press.

2.1.4 Small Mammal Abundance

The abundance of small mammals is mainly dependent on the forest seed production. Wiles (1981) studied the abundance of small mammals in three types of forest in western Thailand, and found higher abundance of small mammal in lowland bamboo forest than upper bamboo forest and dry dipterocarp forest (Wiles, 1981). He also mentioned that *Maxomys surifer* had the highest abundance both in lowland and plane bamboo forest (9.2% and 4.3%) while *Rattus rattus* was the most abundant species in dry dipterocarp forest (4.4%). Other studies in western Thailand have suggested that dry evergreen and mixed deciduous forest supported a greater abundance of small mammal and biomass of terrestrial small mammals than other forest types (Rabinowitz, 1989; Walker and Rabinowitz, 1992). In a second study, obtained by Walker and Rabinowitz (1992) revealed that *Maxomys surifer* showed greatest abundance in both habitats. Next was *Tupaia belangeri* and *Menetes bermorei* in mixed deciduous forest and dry dipterocarp forest plots and *Leopoldamys sabanus* and *Tupaia belangeri* in evergreen forest and mixed deciduous forest plots, respectively. Robinson, Smith and Bumrungsri (1995) studied the status and distribution of small mammal communities in Thung Yai Naresuan and Huai Kha Khaeng Wildlife Sanctuaries, including dry evergreen, dry dipterocarp, mixed deciduous and bamboo forest and found a total of 70 species of small mammals, three Insectivora, one Scandentia, 41 Chitoptera, 24 Rodentia and one Lagomorpha. Twenty-four of these were new records for the sanctuaries, bringing the total number of known small mammals species to 95, representing 47% of Thailand's small mammals. Wattanaratchakit (2005) studied abundance of small mammals around a Karen village in the Mae Hong Son province of Thailand, and found *Rattus rattus* had high abundance in paddy field, while the highest abundance of small mammals occurred in agricultural fields.

2.1.5 Small Mammal Population Density

Small mammal population densities are depended on characteristics of habitat. Elliott and his colleagues found different small mammal communities between deciduous and evergreen forest in Doi Suthep-Pui National park, Chiang Mai province (Elliott, Ua-Apisitwong and Bever, 1989). *Menetes berdmorei* and *Melogale personata* were common species in deciduous forest while the other five species of *Rattus rattus*, *Maxomys surifer*, *Niviventer bukit*, *Berylmys bowersi* and *Leopoldamys* *sabanus* were captured in evergreen forest. *Leopoldamys sabanus* was the only species found in both habitats. *Rattus rattus* was the dominant species in the evergreen forest, at about 23/ha, followed by *Maxomys surifer* and *Niviventer bukit*, at 11 and 10/ha, respectively.

Tropical evergreen forests show a great deal of variation, ranging from about 0.5 to 25 rodents/ha (Mares and Ernest, 1995). Other studies have found lower variation, but the range of densities was roughly the same, such as 4.1-4.9/ha in Malaysia (Harison, 1969) and 0.7-4.9/ha in Venezuela (August, 1983). High densities were found in the Brazilian gallery forest with densities ranging from 32-53/ha (Nitikman and Mares, 1987). In southern India, Rao and Sunquist (1996) reported mean density of rodents was 15 individual/ha. Other studies had showed much lower densities of rodents in mid- and low-elevation evergreen forests.

2.1.6 Food Resources of Small Mammals

Tropical forests are enormously diverse and complex habitats and harbor many species of mammals and birds, including small mammals (Robison, Smith and Bumrungsri, 1995). The species richness and abundance of small mammals in tropical forests can be attributed to affluent food resources, especially the abundant fruit crops (Wells, Pfeiffer, Lakim and Linsenmair, 2004). Terrestrial small mammals are considered to have effects on tropical forests ecosystems as seed and seedling predators and seed dispersers (Alder and Kestell, 1998). Suzuki and his colleagues studied fruit visitation patterns of small mammals on the forest floor in tropical seasonal forest of Thailand, and found 63 fruit plant species in 30 plant family were food resource for seven small mammal species. Family Anacardiaceae was the most number of visits of seven small mammals to each fruit species (Suzuki et al., 2007).

2.1.7 Small Mammals Community in Dry Tropical Forest

Seasonal dry tropical forest represents 42% of the tropical vegetation worldwide and is characterized by a relatively high number of tree species with small, dry wind-dispersed seeds and climate (Murphy and Lugo, 1995). Dry topical forest is dominant in the northeast of Thailand (Bunyavejchewin, 1999; Sukwong, 1982). Seasonal dry evergreen forest is widespread throughout Thailand, particularly in the northeast regions with 4-6 dry months and no more than 1,200 mm total annual rainfall (Ashton, 1990). It comprises two main representative types of forest: dry deciduous forest and dry evergreen forest (Stott, 1986)

Tropical dry forests are home to a wide variety of mammals. The animals survive in larger numbers in a seasonall dry forest, where food productivity may be very low during the dry season, are those that have larger home ranges and travel longer distance in search of food (Pontes, 2003), especially in Asian and African dry forests. Many of these species display extraordinary adaptations to the difficult climate (Prins and Reitsma, 1989).

Many tropical small mammal communities are richer in number of species and probably number of individuals than those in temperate regions (Golly et al., 1975). Small mammal communities are determined by heterogeneity of habitat (Eduardo and Grelle, 2003; Tews et al., 2004; Cramer and Willig, 2005). Community structure of small mammals is broadly determined by habitat structure, and abundance is positively correlated with habitat heterogeneity (Taraman et al., 2005). Habitat diversity is widely considered as an important determinant of local animal diversity, with more heterogeneous habitats generally having more animal species. In addition, habitat diversity is a function of both horizontal heterogeneity or patchiness and structural complexity or vertical stratification (August, 1983). Also, habitat patchiness and seasonality are major influences on structures and dynamics of the small mammal community in dry tropical forest (Walker and Rabinowitz, 1992). Several habitat variables including vegetation density, foliage height diversity, and soil structure significantly influence species distributions both between and within habitats including vegetative cover (which provides refugia) and abilities to escape from predators are keys in the spatial organization of the community (Taraborelli et al., 2003).

Small mammals are an integral component of forest animal communities, contributing to energy flow and nutrient cycling, and playing extremely important roles as seed predators, dispersal agents, and pollination agents in tropical forests (Fleming, 1975). They also form an important prey base for medium-sized carnivores and raptors (Hayward and Philipson, 1979).

2.2 Small Mammal As Reservoir Species

Trypanosomatids are important agents of parasitic diseases affecting human, domestic and wild animals. The pathogenic species include: *Trypanosoma cruzi*, responsible for Chagas' disease which infects a large number of animals, besides humans (Nunes et al., 1994), *Trypanosoma evansi*, agent of a severe disease in horses and dogs, which also parasites many other mammals (Franke, Greiner and Mehlitz, 1994) and *Trypanosoma vivax*, which infects cattle and others ruminants (Silva et al., 1996). Leishmaniasis, caused by *Leishmania chagasi*, is responsible for American visceral leishmaniasis (AVL) (Nunes et al., 1994), a chronic and wasting disease characterized by the infection of the mononuclear phagocytic system (Boelaert et al., 2000). AVL occurs in a zoonotic form in which dogs are considered to be the principal domestic reservoir of *L. chagasi*, while opossums and wild canids act as sylvatic reservoirs and humans are considered occasional hosts (Sherlock et al., 1984). Factors such as malnutrition, immunodeficiency, ecological and demographic changes are currently associated to the re-emergence of leishmaniasis as a public health problem (Cerf et al., 1987; Tesh, 1995).

2.2.1 Parasite and Disease Invasion of Wild Rats

Webster and MacDonald (1995) studied the parasite and disease load of wild rats on farms in England and concluded that;

Helminthes (worms) :

- The oxyuroid pinworm *Syphacia muris* in 67% of the rats
- The strongoloyd parasite *Nippostronglyus brasiliensis* found in 23%
- The liver worm *Capillaria* in 23%
- The cestode *Hymenolepsis diminuta* in 22%
- *Toxocara* cati cauasing Toxocariasis in 15%
- The oxyuroid pinworm *Heterakis* spp. in 14%
- The cestode *Hymenolepsis nana* in 11%
- The intestinal tapeworm *Taenia taeniaeformis* in 11%

Bacteria

- *Leptospira* spp. bacteria causing Weil's disease in 14%
- *Listeria* spp. bacteria cauasing listeriosis in 11%
- *Yersinia enterocolitica* bacteria causing yersiniosis in 11%
- *Pasturella* spp. bacteria causing Pasturellosis in 6%
- *Pseudomonas* spp. bacteria causing Meilioidosis in 4%

Protozoa

- *Cryptosporidium parvum* causing cryptosporidiosis in 63% of the rats
- *Toxoplasma gondii* causing toxoplasmosis 35%
- *Trypanosoma lewisi* in 29%
- *Eimeria separata* in 8%

Rickettsia

- *Coxiella burnetti* evidence of infection by Q fever in 34%

Viruses

- Hantavirus causing Hantaan-fever or hemorrhagic fever in 5%

Ectoparasite

- Fleas found on 100% of the rats
- Mites found on 67%
- Lice found on 38%

2.2.2 Small Mammals and Blood Parasites

Miyamata and Tsukamoto (1975) studied blood parasites detected in blood samples from small mammals such as rats, squirrels and fruit bats were taken in

Iwahig Penal Colonu, Palawan island of the Philippines, from 1970-1972. They found *Trypanosoma lewisi* (Kent) in 46% in the house rats in January, 1970, and 13% in the same season of 1971. *Trypanosoma palawanense* Miyata detected from 1 out of 20 *Rattus panglima* in 1971, and also 1 out of 19 of the same rat species in 1972. *Trypanosoma* sp., was also detected in 1 out of 46 squirrels (*Callosciurus juvencus*) from 1971 to 1972. Out of 46 squirrels examined, 4 cases of *H. vassali* were detected, *Hepatocystis pteropi* (Breinl). *H. pteropi* was also detected in all the six individuals of fruit bats (*Pteropus* spp.). Microfilaria was also detected in 2 out of the 5 rats of *Rattus mulleri balabagensis* and in 2 out of the 46 squirrels sampled. Nematode worms were detected from the peripheral blood of a squirrel. The other studies, by Manning, Harrison and Wooding (1972), on the filarial worm *Brugia tupaiae* in Thailand, the prevalence and definitive host of *B. tupaiae* in a selected area of Thailand. Tthey found microfilariae in tree shrews (*Tupaia glis*), rats, *Rattus rajah* and *Rattus rattus* and also in the ground squirrel, *Menestes berdmorei*.

Table 2.2 demonstrates blood parasites of small mammals and theirs vectors tranmission.

Table 2.2 Blood parasites of small mammals

Blood parasites	Small mammals	Transmission
Babesia microti	Wild rodents	Tick bites
Bartonella sp	Wild rodents and shrew	Tick bites and flea
Trypanosoma sp.	Wild small mammals	blood-sucking flies
Hepatozoon sp.	Wild small mammals	Tick bites
Leishmania sp.	Wild small mammals	Sand fly
Plasmodium sp.	Wild small mammals	Female *Anopheles* mosquitoes
Haemobartonella sp.	Wild small mammals	Tick bites
Anaplasma sp.	Wild small mammals	Tick bites
Ehrlichia sp.	Wild small mammals	Tick bites

2.2.3 Small Mammals and Ectoparasites

Many small mammals act as carriers and reservoirs and have a number of disease agents that infect humans and domestic animals. These disease agents, including bacteria, spirochetes, rickettsiae, viruses, protozoa and helminthes, are often transmitted by ectoparasites such as mites, fleas and lice (Soliman, Marzouk, Main and Montasser, 2001). The distribution of ectoparasites on their hosts is a result of an interaction between the parasites and the hosts and the co-existence among the parasites (Nilsson, 1981). Ectoparasites influence to small mammals not only by characters of the host, but also by characters of their off host environment, because their contact with the host is usually intermittent. The range of off-host: on host ratio of different ectoparasite taxa is very broad, varying from almost constant occurrence on the host lice, to sporadically attacking host tick and sand flies. Fleas take a median position in this range, alternating between periods when the occur on the body of their host and periods when they occur in its burrow or nest. Fleas are permanent satellites of higher vertebrates, being most abundant and diverse on small burrowing mammals (Krasnov, Khokhlova and Shenbrot, 2002).

Ectoparasite-Host Relationships

The host provides the important resources for the ectoparasite. Most vitally, the host supplies a source of food, which are blood, lymph, tear, sweat, the debris of skin, hair or feathers. The host's body also provides the environment in which many ectoparasite live, generating warmth, moisture and, within the skin or hair, a degree of protection from the external environment. The hosts, may also provide transportation from place to place for the parasite, a site at which to mate and, in many cases, the means of transmission from host to host (May and Anderson, 1990). Some ectoparasites, such as many species of lice for example, live in continuous association with their host throughout their life cycle and are therefore highly dependent on the host. The majority of ectoparasites have only intermittent contact with their hosts, and are free-living for the major portion of their life cycles. In some ectoparasites, such as many species of mites, are highly host specific; only one host species is exploited and the parasite can exist only on one defined of the host body. Other species are able to exploit a wider range of hosts (Waage, 1979).

Ectoparasite Damage

Ectoparasite activities may have a variety of direct and indirect effects on their hosts. Direct harm caused may be due to:

Blood loss: although each individual ectoparasite only removes a small volume of blood from a host, in large numbers the blood removed by feeding may be directly debilitating and anaemia is common in heavily infested hosts.

Myiasis: the infestation of the living tissue with fly larvae cause direct damage to carcasses or skin.

Skin inflammation and pruritus: various skin infestations caused by arthropod activity cause pruritus (itching) often accompanied by hair and wool loss (alopecia) and occasionally by skin thickening (lichenification). The presence of ectoparasites burrowing into the skin can stimulate keratinocytes to release cytokines (IL-1) which leads to epidermal hyperplasia and cutaneous inflammation. The antigens produced by ectoparasites can in some individuals stimulate an immune response leading to hypersensitivity.

Toxic and allergic responses: caused by antigens and anticoagulants in the saliva of blood-feeding arthopods.

Disturbance: the irritation caused, particularly by flies as they attempt to feed or oviposit, commonly result in a variety of behaviours such as head shaking, stamping, skin twitching, tail switching or scratching.

Self-wounding: the activity of particular ectoparasites, such as warble flies, may cause dramatic avoidance responses in the intended host, known as gadding. The madly panicking animal may cause serious self-injury following collision with fences and other objects (Wall and Shearer, 1997).

Ectoparasite of Wild Small Mammals

From the study by Bossi, Linhares and Bergallo (2002), on the associations between three species of rodents in Atlantic forest and their parasitic arthropod located in the Sao Paulo, Southern Brazil from March 1989 to February 1990 found that individuals of three species, *Oryzomys russatus*, *Proechimys iheringi* and *Nectomys squamipes* were infested with four species of insects and seven species of acari, and the most common parasite on it was the laelapid mite *Gigantolaelaps oudemansi*. Similarly to the result from the studies by Grassman, Sarataphan, Tewes, Silvy and Nakanakrat (2004), on ectoparasites of wild carnivores in Phu Khieo Wildlife Sanctuary, Thailand, which they found that four genera of ixodid ticks were collected from 8 wild carnivore species. Other study from Krasnov, Khokhlova and Shenbrot (2002), on the pattern of ectoparasite distribution of the desert rodent in Negev Highland, Israel found that the flea species, *Xenopsylla dipodilli* and *Nosopsyllus iranus theodori* were infested on the desert rodent species *Gerbillus dasyurus*. In addition, Clark and Durden (2002) state that twelve species of small mammals were livetrapped and examined for parasitic arthopods in 17 localities in Mississippi from June through November, 1998 were infested with 2 species of sucking lice (Order Anoplura), 4 species of mesostigmatid mites (Order Mesostigmata) and 3 species of hard ticks (Family Ixodidae), and they also found that the white-footed mouse (*Peromyscus leucopus*) was the most species of parasitic arthropods, followed by the cotton mouse (*Peromyscus gossypinus*) and the cotton rat (*Sigmodon hispidus*).

2.2.4 Parasites and Blood Chemistry

Blood characteristics and fat levels have been widely used to evaluate the condition of mammals. The presence of a large number of parasites may also indicate poor condition of the host individuals (Jacobson, Kirkpatrick and McGinness, 1978). The studies by Soveri, Arnio, Sankari and Haukisalmi (1992), on the endoparasites and blood chemistry of the mountain hare in high and low density population, found that high population density combined with a lack of suitable food leads to poor condition and high endoparasites abundance. Animals infected with *Protostrongylus pulmonalis* and *Trichostrongylus retortaeformis* had the highest Calcium, Magnesium, alkaline phosphatase, creatinine values, triglyceride and cholesterol values.

2.3 Aims

There are three main aims of this work, which are interconnected : 1) to determine the population dynamics of small mammals in three different habitat types; the dry dipterocarp forest, the dry evergreen forest and the ecotone area in Sakaerat Environmental Research Station, Nakhon Ratchasima. 2) to identify and to quantify blood parasites of small mammals and 3) to investigate the interaction between host-parasite and the effect of parasites have influence on their hosts, in term of hematology and some blood chemistry.

CHAPTER III

GENERAL MATERIALS AND METHODS

This chapter will give a general description of major materials and methods used in this research.

3.1 Study Area

The study area is situated at the Sakaerat Environmental Research Station (SERS), Thailand Institute of Scientific and Technological Research (TISTR). The station is located in Wang Num Kheaw district, Nakhon Ratchasima province. It is situated approximately at 14° 30′ N, 101° 55′ E, about 60 kilometers east of Nakhon Ratchasima and 300 kilometers northeast of Bangkok. The approximate area of the SERS is 81 km^2. The area is dedicated as a forest reserve for scientific purpose (Suriyapong, 2003) and the location of SERS is shown in Figure 2.1.

Figure 3.1 Location of Sakaerat Environmental Research Station (SERS)

(Adapted from UNESCO-MAB, Online, 2006).

3.2 Experimental Design

The main treatment comparison, in which the population dynamics and health status of small mammals will be measured are 3 different forest habitats viz.

The dry dipterocarp forest

The ecotone area

The dry evergreen forest

Site A; Dry dipterocarp forest (DDF)

The study plots are situated at approximately 14°30′ 29.50″ N, 101° 56 ′ 17.6″ E, and lie on the main road to the headquarters. The area includes good stands of DDF and dominated by the tree species of *Shorea obtusa* Wall., *Shorea siamensis* Mig., and *Arundinaria pusilla* Chevel A. camus (Suriyapong, 2003) (Figure 3.2).

Site B; The ecotone (ECO)

The study plots are situated at approximately 14° 30′ 08.2″ N, 101° 55′ 48.5″E, The area represents the transition zone from the dry dipterocarp forest to the dry evergreen. It consists of large trees (*Dipterocarpus*) sparingly distributed amongst small shrubs and short grasses (Suriyapong, 2003) (Figure 3.2).

Site C; Dry evergreen forest (DEF)

The study plots are situated at approximately 14° 30′ 08″ N, 101° 55′ 48.7″ E, and is about 1 kilometers from the head quarter. The area includes good stands of DEF and is dominated by tree species such as *Hopea ferrea* Pierre., *Hopea odorata* Roxb., and canopy trees attain 30 to 40 meters (Suriyapong, 2003)) (Figure 3.2).

Two sample sites, called “grid”, will be randomly located in each site (forest habitat), giving 6 grids in total.

i.e. Grid 1 and Grid 2 in the dry dipterocarp forest

Grid 3 and Grid 4 in the ecotone forest

Grid 5 and Grid 6 in the dry evergreen forest

The data on the distribution and abundance of small mammals were separated into four seasons including early rainy season (May-July), late rainy season (August-October), winter (November-January) and summer (February-April).

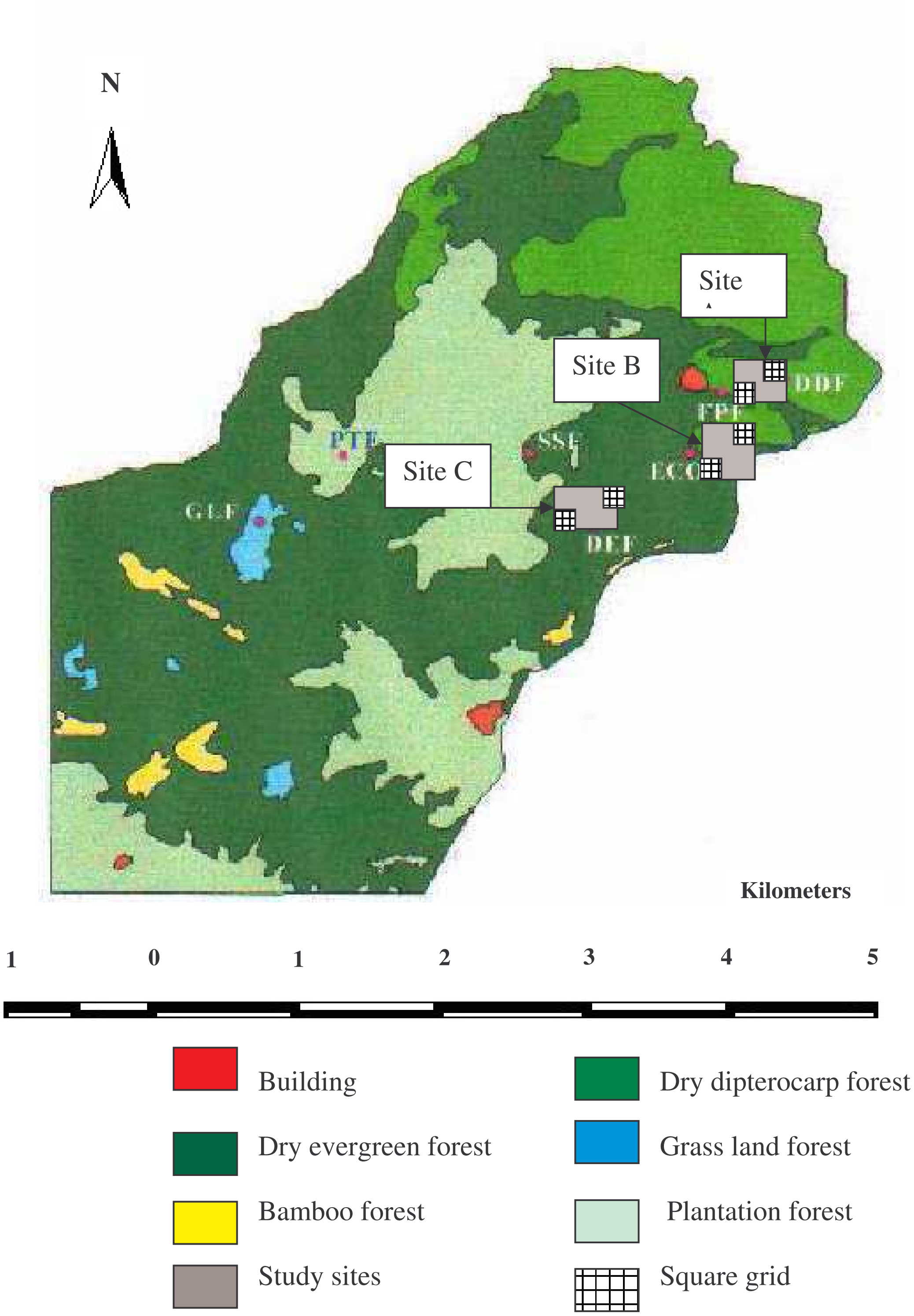


Figure 3.2 Location of the three trapping configurations in different forest types in Sakaerat Environmental Research Station (SERS).

Source : Adapted from a map of Sakaerat Environmental Research Station

3.3 Trapping Configuration

Each grid will comprised of 7 rows and 7 columns of live-wire traps (14 x 14 x 24 cm) placed at intervals of 15 m, giving a total of 49 marked trapping stations and covering an area of 0.81 ha. (Figure 3.3).

The traps were sampled over 3 consecutive nights for each month from January to December 2007.

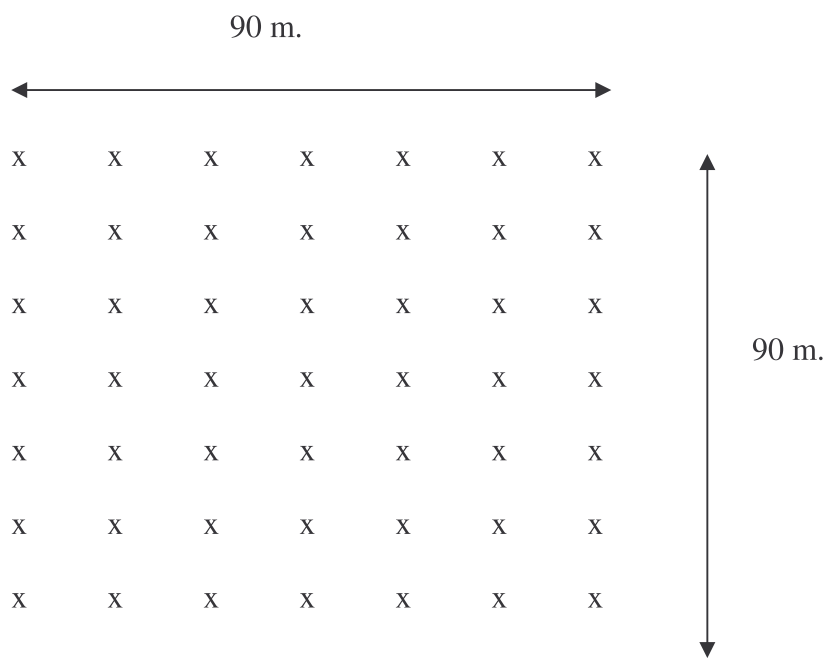


Figure 3.3 Configuration of square trapping grid consisting of seven rows and seven columns (x = trap station).

This represents a total of 98 trap stations between each site (forest habitat) and 49 trap station for each pair of 2 grids within each site (forest habitat). The data on the capture-recaptured of small mammals were obtained from 3,528 trap-nights over the twelve-month trapping period.

3.4 Baits

Live trapping, bait provides an attractant for the animals, thereby increasing the probability of capture. Coconuts are mixed with peanut butter as a bait during trapping periods.

3.5 Data Collection

3.5.1 Climatic Factors

Rainfall, temperature and relative humidity data were obtained from meteorological station in Sakaerat Environmental Research Station. The meteorological station located within one kilometer from each grid. The data were calculated into mean average by four seasons including early rainy season (May-July), late rainy season (August-October), winter (November-January) and summer (February-April).

3.5.2 Habitat Profiles

Each trapping site was described in term of habitat quality and environmental context. Habitat quality was estimated through various descriptive variables mainly based on vegetation characteristics. For each trapping site, the relative cover (%) of bare ground, grass, total shrub including species not exceeding 1.50 m, high and tree density (number of tree/m^2) were distinguished (Alain, Gilles and Yannicl, 2006).

3.5.3 Capture-Mark-Recapture, Trapping Success, Recapture Rate and Anatomical Measurement

In Sakaerat Environmental Research Station (SERS) areas, 98 live animal traps were placed in three different habitat types, dry dipterocarp, dry evergreen forest and ecotone. The live-wire traps baited with coconut mixed with peanut butter were set on the forest floor for three consecutive nights (Shanker and Sukumar, 1998). Each trap site was checked once daily in the morning between 08.00-12.00. Trapping was carried out monthly over a period of 12 months, from January to December 2007, for a total of 3,528 trap nights.

The trapped animals were taken to a nearby laboratory located in the laboratory building near the headquarter of SERS. The captured animals were anesthetized by Zoletil®100 (Virbac) (50 mg/kg bodyweight of Zoletil by intramuscular injection) then they were identified and marked by the ear-clipping method (Nietfeld, Barrett, and Silvy, 1994). They were weighed and body length was measured. The sexual condition was also observed and classified as adult, sub adult or juvenile according to body mass and sexual maturity. Before being released in the same trapping station, ectoparasites were collected and blood samples were taken from target species.

Each common species was calculated as total individuals captured per 100 trap-nights and assessed trap success (observed) against season and habitat type, the number of trap-nights (number of nights of trapping x number of traps) and the number of individuals captured (i.e. number of captures). The recaptured rate was calculated by the numbers of individuals recaptured at a trapping session per total number of individuals captured (Lathiya et al., 2003).

Captured small mammals were anaesthetized, measured weight (g), head and body length (HB) and tail length (T). The biometric measurement of small mammal species in all habitat types varied by seasons.

3.6 Data Analysis

3.6.1 Rodent Species

The total rodents collected from each habitat type were classified to subfamily, genus and species. The key for the identification based on Lekagul and McNeely (1977). The key was used to identify and name the animals. There were three key sets: a single key to identify subfamilies, a series of keys to identify genera within each subfamily and a key to identify species within a genera.

3.6.2 Population Characteristics

(1) Diversity index and evenness index were calculated by using the Shannon-Wiener index as follow :

$$H = -\sum_{i=1}^{s} (P_i) \ln * P_i$$

H = index of species diversity

S = number of species

P_i = Proportion of total sample belonging to i th species

Evenness index as follow:

$$E = \frac{H}{H_{\max}}$$

E = Equitability or evenness index

H = Shannon diversity index

$H_{\max} = \ln S$

Simpson's index

$$1 - D = 1 - \sum (P_i)^2$$

$1 - D$ = Simpson's index of diversity

P_i = Proportion of individuals of species i in the community

Species richness

$$\hat{S} = s\left(\frac{n-1}{n}\right)k$$

$\hat{S}$ = Jacknife estimate of species richness

s = Observed total number of species present in n quadrats

k = Number of unique species

(Krebs, 1999)

(2) Minimum Home Range Size (MHRS)

Minimum home-range sizes (MHRS) were estimated for animals with multiple captures by connecting the outermost capture sites (minimum convex polygon estimate). In many cases the number of re-captures was quite small, so these minimum home-range sizes should not be considered true estimates of home range, but are presented here as a minimum estimate of the size of the area used by each animal (Robinson et al., 1995).

(3) Population Density

The program DENSITY 4.1 (Efford et al., 2005) was used to estimate the population density. Twelve primary sessions with 3 secondary occasions, for a total 36 occasions, were also used as the sampling structure. Primary sessions were separated by unequal time intervals, with consecutive summer rainy and winter months separated by 1-month intervals. Encounter histories were generated for each individual and grouped by site for analysis (Wilson, Lochmiller and Janz, 2006)

(4) Biomass

Biomass was determined by multiplying the mean adult weight of each species in each habitat with their relative density estimate (individuals/ha), Mean adult weight was the mean peak biomass correlated to small mammals density (Decher and Bahian 1999). Seasonal biomass estimates were derived from the average monthly biomass of the population for each species during the early rainy season (May-July) late rainy season (August-October), winter (November-January) and summer (February-April).

(5) Sexes and Age Structures

Sexes and age structures were calculated including on the density of adult males and females; proportion of adults : number of adults / number of individual captured; proportion of sub-adults / number of individual captured; proportion of adult males and females / number of individual captured and sex ratio (all individuals, juveniles, sub-adults and adults) (Shanker and Sukumar, 1998)

3.7 Statistical Analysis

The ANOVA was used to check the possible effect of habitat on species abundance and used for detecting significance in the small mammals density among the different forest type. Then multivariate analysis using Principal Component Analysis (PCA) was used to calculate the relationship between small mammal species abundance and ecological factors. The PCA is used to identify which combination of variables could explain the largest amount of variation in the multivariate data set. Then, the correlation was determined using stepwise multiple regression by the simple Pearson correlation coefficient by SPSS program.

CHAPTER IV

SMALL MAMMALS POPULATION COMMUNITIES AND DYNAMICS

4.1 Abstract

Small mammal communities were studied over 12 months separated into four seasons including early rainy season (May-July), late rainy season (August-October), winter (November-January) and summer (February-April) in three dry tropical habitats; dry dipterocarp, ecotone and dry evergreen forests in Sakaerat Research Station, North- eastern Thailand. Data were collected from mark-recapture grid on age structure, population dynamics, diversity indices, biomass and minimum home-range size. Six species of rodent and one species of scandentia, lagomorph and carnivore were represented by 1,047 captures of 371 individuals out of a total of 3,528 trap nights (29.68% capture rate). Most common species caught in all sites including *Maxomys surifer*, *Tupia glis*, *Rattus rattus* and *Leopoldamys sabanus*. *Maxomys surifer* was dominant species in all forest types. Small mammal community structure and sex ratio were not significantly different, whereas age structure, density and biomass varied by forest types and seasons. The greatest minimum home range size (MHRS) was in the winter and summer in all forest types. The density estimates showed that estimate parameters model did not differ for analysis. These data suggests that dry dipterocarp forest supported the highest diversity of small mammals.

Small mammal communities was positively correlated to the heterogeneity of the forest type and their characteristics in each seasonal.

4.2 Result and Discussion

The results of this study are divided into five parts for ease of the interpretation. The first is the climatic factors. The second is habitat profiles which were measured in three different habitat types. The third is small mammal community and distribution. The forth are the principal component analysis and multiple regression analysis of small mammal community structure. The last is small mammal health status, host and parasites infection.

4.2.1 Climatic Factors

Climatic factors composed of air temperature, seasonal rainfall and relative humidity. The result indicated that mean of temperature was the highest (29.67°C) in the summer in DE forest, and the lowest (21.60°C) in the winter in ECO forest. Mean of seasonal rainfall was the highest (5.49 mm) in the early rainy season in DD forest, followed closely by the late rainy season in DD forest, the early and late rainy season in ECO forest, the late and early rainy season in DE forest had the mean of 5.07mm, 4.40 mm, 4.36mm, 3.91mm and 3.56mm respectively, and the lowest (0.19 mm) in the winter in DE forest. For the relative humidity, in the late rainy season in ECO forest had the highest of 94.64% while in the summer on DD forest had the lowest of 84.93%. The mean and standard error of the climatic factors in three habitat types are shown in Table 4.1 and Figures 4.1, 4.2 and 4.3.

The One-way ANOVA of climate factors of all habitat types were indicated significant differences at *P*<0.05 and the comparison among mean values of climate factors verified by Duncan's multiple range test were also shown in Table 4.1.

Table 4.1 Mean ± SE of climatic factors in the DD, ECO and DE forest varies by seasonal in Skaerat Research Station

Habitat type	Season	Temperature (°C)	Rainfall (mm)	Humidity (%)
DD forest	Early rainy	28.81 ± 0.34 [d]	5.49 ± 3.75[d]	92.59 ± 2.42 [bd]
	Late rainy	27.87 ± 0.82 [cd]	5.07 ± 2.08[cd]	93.50 ± 2.14[d]
	Winter	24.46 ± 0.66 [b]	0.21 ± 0.37 [a]	86.39 ± 2.13 [a]
	Summer	29.33 ± 1.99 [d]	1.95 ± 1.38 [abc]	84.93 ± 2.11[a]
ECO forest	Early rainy	27.80 ± 0.36[cd]	4.40 ± 2.70 [bcd]	93.69 ± 2.11 [d]
	Late rainy	26.00 ± 1.32 [bc]	4.36 ± 1.54 [bcd]	94.64 ± 2.40 [d]
	Winter	21.60 ± 0.35[a]	0.23 ± 0.39 [a]	88.95 ± 1.55[ab]
	Summer	28.16 ± 2.16 [cd]	1.61 ± 1.07[abc]	87.81 ± 1.78 [a]
DE forest	Early rainy	29.17 ± 0.38[d]	3.56 ± 2.63[abcd]	92.09 ± 2.63[bd]
	Late rainy	27.95 ± 1.13 [cd]	3.91 ± 1.42[bcd]	93.74 ± 2.44 [d]
	Winter	23.93 ± 0.23[b]	0.19 ± 0.32 [a]	87.47 ± 2.68 [a]
	Summer	29.67 ± 2.14 [d]	1.03 ± 0.74[ab]	85.21 ± 1.09 [a]

Remark: Significant difference are indicated by different small letter.

P<0.05 for One-way ANOVA

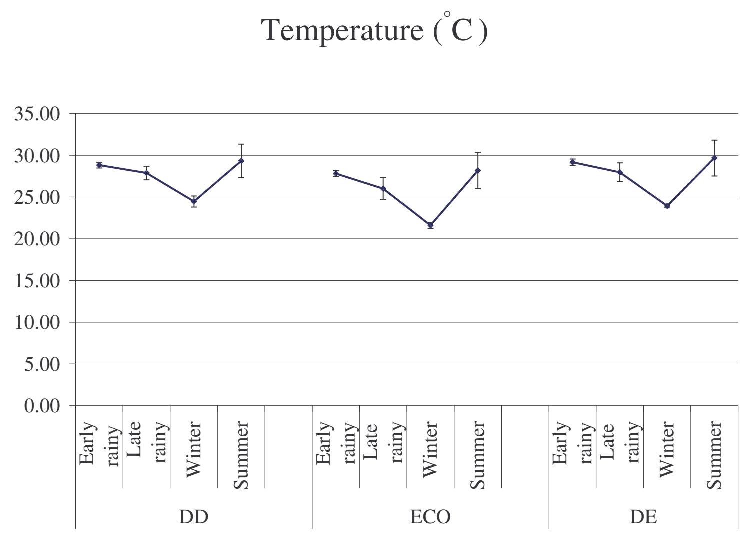


Figure 4.1 The mean ± SE of temperature (°C) in three habitat types.

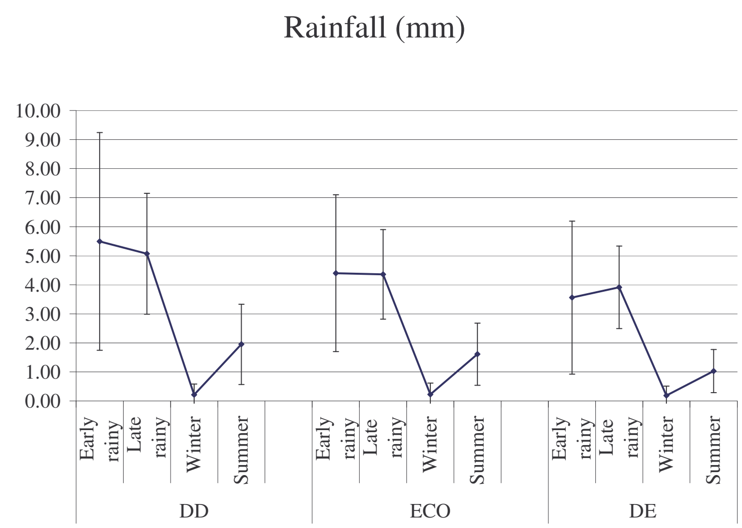


Figure 4.2 The mean ± SE of rainfall (mm) in three habitat types.

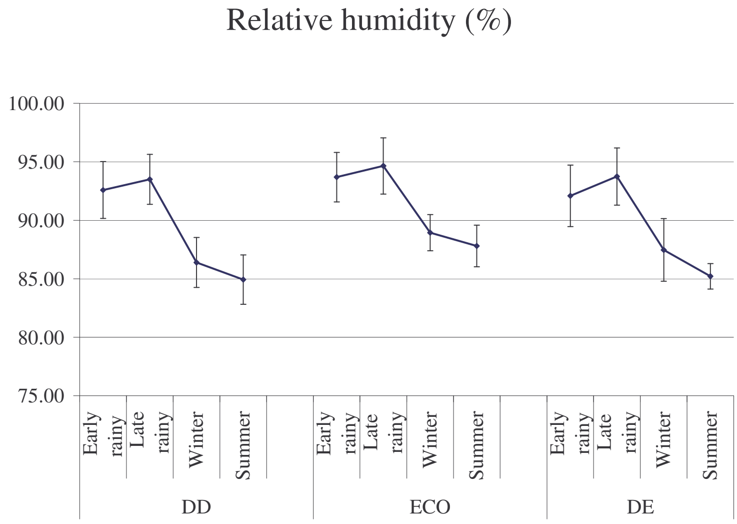


Figure 4.3 The mean ± SE of relative humidity (%) in three habitat types.

Generally, the temperature of all habitat types varied by places and times, and the significances of variation for plant cover. As shown in these results, the mean temperature of all habitat types were significantly different. The lowest recorded mean temperature was 21.60°C in ECO forest, while the highest was 29.67°C in DE forest. This might be caused by plant cover. Because of ECO forest was high density of canopy cover and moisture content, it could reduce sunlight. The modification of temperature by plant cover was both significant and complex. Shaded ground was cooler during the day than open area. Vegetation interrupts the laminar flow of air, impeding heat exchange by convection. This result is supported by the studies of Kimmins (1997) and Pitman (1996).

DE forest in the late rainy season had the highest relative humidity in all habitat types varied by seasons. For these results can be explained by temperature influences relative humidity (Pitman, 1996), relative humidity generally is higher at night and early morning when the air temperature are lower, so relative humidity lower by day when temperatures increasing.

4.2.2 Habitat Profiles

The three different habitats had different habitat profiles. Number of tree species was the highest value (23.00) in DD and ECO forest, and the lowest value (11.50) in the DE forest. Tree densities was the highest in DE forest, and followed by ECO and DD forests (1605.50 and 964.00 per ha), respectively. Mean of canopy cover was the highest (96.05) in DE forest, followed by ECO and DD (92.75% and 81.40%) respectively. Mean of average diameter at breast height (Avg. DBH) was the highest (15.80 cm) in DE forest, followed by ECO and DD forests (14.46 cm and 11.81 cm), respectively. Mean average high and basal area was the greatest (14.84m) (46.72 m^2/ha) and the lowest in DE forest ECO and DD forest respectively. The percent of ground cover was the highest (92.60%) in DD forest, followed by ECO and DE forests (47.50% and 27.15%), respectively. The mean and standard error the three habitat types are shown in Table 4.2.

The One-way ANOVA of climatic factors of all habitat types were indicated and showed the significant differences at $P<0.05$, whereas percent of canopy cover, average DBH and average hight of trees in each habitats were not different. The comparison among mean values of climatic factors verified by Duncan's multiple range test are also shown in Table 4.2.

Table 4.2 The values (mean ± SE) for habitat variables on three habitats in Sakearat Research Station, Thailand.

Variable	**Habitat**		
	DD	**ECO**	**DE**
No. of tree species	23.00 ± 1.41	23.00 ± 7.07	11.50 ± 0.71
Tree density (per ha)	964.00 ± 11.31[a]	1605.50 ± 369.82[ab]	2555.50 ± 471.64[b]
Canopy cover%	81.40 ± 3.68	92.75 ± 1.48	96.05 ± 2.47
Avg. DBH.(cm)	11.81 ± 2.76	14.46 ± 5.25	15.80 ± 0.64
Avg. High (m)	9.13 ± 3.39	12.69 ±1.93	14.84 ± 0.27
Basal area(m^2/ha)	12.51 ± 4.60[a]	38.15 ± 3.35[b]	46.72 ± 8.52[b]
Ground cover (%)	92.60 ± 8.34[b]	47.50 ± 17.11[a]	27.15 ± 4.74[a]

Remark: Significant difference are indicated by different small letter.

P<0.05 for One-way ANOVA

Avg. DBH = Average diameter at breast height

Avg. High = Average height

Among the three habitat profiles in this study found that the most habitat variables including tree density, canopy cover, average BDH, average height and basal area were higher value in DE forest than DD and ECO forests, whereas number of three species and percent of ground cover in DD and ECO forests were higher than DE forest. The results are similar to Lamotte, Gajaseni and Malaisse (1998), which found that in DD forest had the highest tree species richness, whereas tree density and basal area in DE forest were greater than DD and ECO forests. The presence of annual plant cover depended on a sufficient amount of rain and soil properties

(Kerley, 1992). Most vegetation types responsed to altitude and soil type distribution (Tongyai, 1980). From the study by Yothin (2003) on the soil texture in DD, ECO and DE forests in Skaerat Research Station found that the soil texture in DD forest was identified as sandy loam, in ECO was clay loam and sandy clay loam, and in DE forest was sandy clay loam and sandy loam. Therefore, these are major factors affect to forest community founded in Sakaerat Research Station, by the dry evergreen forest is a deciduous broad-leaved forest community type occurring on relative dry sites, and is mainly composed of trees belonging to the Dipterocapaceae family (Sahunalu and Dhanmanonda, 1995). Seasonal dry evergreen forest is closed canopy forest in which the main canopy is predomainantly evergreen forest trees with scattered individuals of deciduous trees. Dipterocarps form an important component of the canopy, although the diversity of dipterocarp species is less in seasonal dry evergreen forests than in the dry dipterocarp forest of peninsular Thailand. Mean canopy height is ca. 35-40 m. while these general descriptions are well documented, detailed data on the variation of stand structure and composition within seasonal dry evergreen forest is rare (Santisuk, 1988).

In addition, for the characteristic of habitat profiles in Sakaerat Research Station found that the ECO forest is characterized by tree species such as *Pteracarpus macrocarpus*, *Sindora siamensis*, *Shorea obtusa* and *Albizia odoratissima*, and very few bamboo-like grass (*Arundinaria pusilla*) grow under this forest canopy, but many seedlings of woody species and climber are present. The upper layer with tree are average height of 10-14 m.

Dry dipterocarp forest is characterized by the sparely distributed trees and the crown cover in more or less open on two layer. The upper layer is 11-15 m high,with the dominant species being *Shorea talura*, *Shorea obtusa* and *Dipterocarpus intricatus*. Generally, the forest floor in DD forest is more composed of tree sapling, dwarf bamboo-like grass (*Arundinaria pusilla*) and cycads (*Cycas siamensis*) (Lamotte,Gajaseni and Malaisa, 1998).

4.2.3 Small Mammal Community and Distribution

The data on the distribution and abundance of small mammals were obtained from 3,528 trap-nights over the twelve-month trapping period, and were separated into four seasons including early rainy season (May-July), late rainy season (August-October), winter (November-January) and summer (February-April).

4.2.3.1 Small Mammal Trapping

A total of 371 individuals, belonging to nine species in five families were captured (877 captures in 3,528 trap-nights or 24.86%), with six species in DD and ECO forest and seven species in DE forest. Species regularly captured included: *Maxomys surifer*, *Rattus rattus*, *Leopoldamys sabanus* and *Mus cervicolor* (Muridae); *Callosciurus finlaysoni* and *Callosciurus finlaysoni* (Sciuridae); *Tupaia glis* (Tupaidae); *Lepus peguensis* (Lepiridae); and *Herpestes javanicus* (Herpestidae). *M. surifer* was the most abundance small mammal trapped species representing 65.77% of total captures, and followed by *T. glis* (13.48%), *R. rattus* (11.32%), *L. sabanus* (3.77%), *C. finlaysoni* (2.43%), *C. finlaysoni* (1.89%), *H. javanicus* (0.81%), *M. cervicolor* (0.27%) and *L. peguensis* (0.27%). Numbers of the total individuals captured was the highest (37.20%) in DE forest, and closely followed by ECO forest (34.23%) and DD forest (28.57%), respectively (Table 4.3).

Four species i.e. *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* were caught in all habitat types and the most often caught was the rodent *M. surifer*., followed by *R. rattus*, *L. sabanus* and the Scandentia *T. gli*s. The four most frequently captured species in each habitat types accounted for over 90% of the total number of individuals captured. *M. surifer* was the highest (30.46%) abundance in DE forest, followed by ECO forest (21.02%) and DD forest (14.29%). *R. rattus* was the highest (7.55%) in DD forest, and followed by ECO forest (2.16%) and DE forest (1.62%). *L. sabanus* was the highest (2.16%) in ECO forest and closely followed by DE forest (1.62%). While *T. glis* was the highest (6.20%) in ECO forest, and followed by DD forest (5.39%) and DE forest (1.89%), respectively (Table 4.3).

Table 4.3 Number of different individuals and number of capture (% of total capture) obtained for nine small mammal species in different habitat types in Sakaerat Research Station, Thailand.

Species	Forest type			Total number of individuals
	DD	**ECO**	**DE**	
Trap-night		**3528**		
MURIDAE				
1) *Maxomys surifer*	53 (14.29%)	78 (21.02%)	113 (30.46%)	244 (65.77%)
2) *Rattus rattus*	28 (7.55%)	8 (2.16%)	6 (1.62%)	42 (11.32%)
3) *Leopoldamys sabanus*	-	8 (2.16%)	6 (1.62%)	14 (3.77%)
4) *Mus cervicolor*	-	-	1 (0.27%)	1 (0.27%)
TUPAIDAE				
5) *Tupaia glis*	20 (5.39%)	23 (6.20%)	7 (1.89%)	50 (13.48%)
SCIURIDAE				
6) *Callosciurus finlaysoni*	-	8 (2.06%)	1 (0.27%)	9 (2.43%)
7) *Callosciurus caniceps*	1 (0.27%)	2 (0.54%)	4 (1.08%)	7 (1.89%)
HERPESTIDAE				
8) *Herpestes javanicus*	3 (0.81%)	-	-	3 (0.81%)
LEPORIDAE				
9) *Lepus peguensis*	1 (0.27%)	-	-	1 (0.27%)
Total numbers (% of total captured)	**106 (28.57%)**	**127 (34.23%)**	**138 (37.20%)**	**371**
Total captures including recaptured		**877**		

For the small mammal trapped species abundance found that in the each seasons in DD forest was the highest (8.63%) in the late rainy season, and closely followed by the early rainy season (7.82%), the winter (6.20%) and the summer (5.93%), respectively. *M. surifer* was the greatest (14.29%) abundant species and was the highest in the early rainy season (5.12%), and the lowest (2.43%) in the late rainy. The next most commonly trapped species were *R. rattus* and *T. glis*. *R. rattus* was the highest (3.23%) abundant in the late rainy season and the lowest (1.08%) abundant in the summer. For *T. glis.* was the highest (2.96%) abundant in the late rainy season and the lowest (0.54%) abundant in the early rainy season and summer. Less frequently caught species were *H. javanicus* (0.81%), *C. caniceps* (0.27%) and *L. peguensis* (0.27%) (Table 4.4).

Table 4.4 Number of different individuals and numbers of capture (% of total capture) obtained for six small mammal species in DD forest in the each season in Sakaerat Research Station, Thailand.

Species	**DD**				**% of total captures (371)**
	Season				
	Early rainy	**Late rainy**	**Winter**	**Summer**	
MURIDAE					
Maxomys surifer	19 (5.12%)	9 (2.43%)	12 (3.23%)	13 (3.50%)	53 (14.29%)
Rattus rattus	7 (1..89%)	12 (3.23%)	5 (1.35%)	4 (1.08%)	28 (7.55%)
SCIURIDAE					
Callosciurus caniceps	-	-	-	1 (0.27%)	1 (0.27%)
TUPAIIDAE					
Tupaia glis	2 (0.54%)	11 (2.96%)	5 (1.35%)	2 (0.54%)	20 (5.39%)
LEPORIDAE					
Lepus peguensis	-	-	-	1 (0.27%)	1 (0.27%)
HERPESTIDAE					
Herpestes javanicus	1 (0.27%)	-	1 (0.27%)	1(0.27%)	3 (0.81%)
Total numbers of individuals (% of total captures)	**29 (7.82%)**	**32 (8.63%)**	**23 (6.20%)**	**22 (5.93%)**	**106 (28.57%)**

Small mammal abundance in each seasons in ECO forest was the highest (10.78%) in the late rainy season, and closely followed by early rainy season (10.24%), summer (7.01%) and winter (6.20%) respectively. *M. surifer* was the greatest (21.02%) abundant species, and was the highest in early rainy season (8.36%), and the lowest (2.70%) in winter. The next most commonly trapped species were *T. glis* (6.20%) and equally (2.16%) number individuals captured of *R. rattus*, *L. sabanus* and *C. finlaysoni*. *T. glis* was the highest (2.43%) abundance in late rainy season and the lowest (0.27%) abundant in early rainy season. *R. rattus* was the highest (1.08%) abundant in late rainy season. *L. sabanus* was the highest (0.81%) abundance in early rainy season and summer. For *C. finlaysoni* was the highest (0.81%) abundance in late rainy season. The least caught species was *C. caniceps* (0.54%) (Table 4.5).

Table 4.5 Number of different individuals and numbers of capture (% of total capture) obtained for six small mammal species in DE forest in the each seasons in Sakaerat Research Station, Thailand.

Species	ECO				% of total captures (371)
	Season				
	Early rainy	Late rainy	Winter	Summer	
MURIDAE					
Maxomy surifer	31 (8.36%)	23 (6.20%)	10 (2.70%)	14 (3.77%)	78 (21.02%)
Rattus rattus	2 (0.54%)	4 (1.08%)	2 (0.54%)	-	8 (2.16%)
Leopoldamys sabanus	3 (0.81%)	-	2 (0.54%)	3 (0.81%)	8 (2.16%)
SCIURIDAE					
Callosciurus finlaysoni	1 (0.27%)	3 (0.81%)	2 (0.54%)	2 (0.54%)	8 (2.16%)
Callosciurus caniceps	-	1 (0.27%)	-	1 (0.27%)	2 (0.54%)
TUPAIIDAE					
Tupaia glis	1 (0.27%)	9 (2.43%)	7 (1.89%)	6 (1.62%)	23 (6.20%)
Total numbers of individuals (%of total captures (371))	**38 (10.24%)**	**40 (10.78%)**	**23 (6.20%)**	**26 (7.01%)**	**127 (34.23%)**

For small mammal abundance in the each seasons in DE forest was the highest (12.67%) in late rainy season, and closely followed by winter (9.16%), early rainy season (8.89%) and the summer (6.47%), respectively. *M. surifer* was the greatest (30.46%) abundant species, and was the highest in late rainy season (10.78%), and the lowest (4.58%) in summer. The next most commonly trapped species were *T. glis* (1.89%) and equally (1.62%) number individuals captured of *R. rattus* and *L. sabanus*. *T. glis* was the equally (0.54%) abundant in early rainy season, late rainy season and summer. *R. rattus* was the highest (0.81%) abundant in late rainy season. *L. sabanus* was the highest (0.81%) abundant in the summer. For *C. canuceps* was the highest (0.54%) abundant in the summer. The least (0.54%) caught species was *M. cervicolor* and *C. finlaysoni* (Table 4.6).

Table 4.6 Number of different individuals and numbers of capture (% of total capture) obtained for six small mammal species in DE forest in the each seasons in Sakaerat Research Station, Thailand.

Species	**DE**				**% of total captures (371)**
	Season				
	Early rainy	**Late rainy**	**Winter**	**Summer**	
MURIDAE					
Maxomys surifer	26 (7.01%)	40 (10.78%)	30 (8.09%)	17 (4.58%)	113 (30.46%)
Rattus rattus	1 (0.27%)	3 (0.81%)	2 (0.54%)	-	6 (1.62%)
Leopoldamys sabanus	2 (0.54%)	1 (0.27%)	-	3 (0.81%)	6 (1.62%)
Mus cervicolor	1 (0.27)	-	-	-	1 (0.27%)
SCIURIDAE					
Callosciurus finlaysoni	-	1 (0.27%)	-	-	1 (0.27%)
Callosciurus caniceps	1 (0.27%)	-	1 (0.27%)	2 (0.54%)	4 (1.08%)
TUPAIIDAE					
Tupia glis	2 (0.54%)	2 (0.54%)	1 (0.27%)	2 (0.54%)	7 (1.89%)
Total numbers of individuals (%of total captures)	**33 (8.89%)**	**47 (12.67%)**	**34 (9.16%)**	**24 (6.47%)**	**138 (37.20%)**

The dry tropical forest, studies areas of small mammals communities contained a rarely small mammal fauna with 9 species, 6 species in the dry dipterocarp forest and ecotone forest and 7 in the dry evergreen forest. *M. surifer*, *R. rattus*, *L. sabanus* and the Scandentia *T. glis*. are the most common species were most frequently captured. Similar result was obtained by Walker and Rabiznovits (1992), they found that *M. surifer*, *T. glis* M. berdmorei and *L. sabanus* were the most common captured in their study. For example, the murid rodents *M. surifer* and *L. sabanus* are very abundant (Langham 1983; Kemper and Bell, 1985; Walker and Rabinowitz, 1992) and wide- spread in continuous forest. Especially, *M. surifer* is dominated the terrestrial community in South-east Asia. (Wells et al., 2004).

L. sabanus was only found in ECO forest and DE forest may be due to food abundance for ground-dwelling species would probably be reduced in wet areas due to the litter and logs and the extensive areas of disturbance by pigs. For the medium species, *L. peguensis* and *H. javanicus* were found in DD forest, indicated they were relatively common in the study area but, because of their restricted habitat preference, probably did not contribute to the other forest (Rabiznowits and Walker, 1991). In contrast. the study obtained by Kemper and Bell (1985) founded that *L. sabanus* was confined to forest habitats where, at lower altitudes, it is often the most common small mammal trapped in lowland forest in Malaysia. Harrison (1957) concluded that *L. sabanus* utilized high, well-drain habitat.

4.2.3.2 Small Mammals Trapping Success

As the resulted in Tables 4.7, 4.8 and 4.9, the overall trapping success in DD, ECO and DE forest was 42.04 small mammals for every 100 trap night.

In DD forest (Table 4.7), *M. surifer* was the highest trapped 2.15 individuals for every 100 trap night in early rainy season, and followed by summer (1.47), winter (1.36) and late rainy season (1.02) respectively. *R. rattus* was the highest trapped 1.36 individuals for every 100 trap night in late rainy season, and followed by early rainy season (0.79), winter (0.57) and summer (0.45), respectively. For the *T. glis* was the highest trapped 1.25 individuals for every 100 trap night in late rainy season, and followed by winter (0.57) and early rainy season and summer (0.23), respectively.

Table 4.7 Totals numbers of trapping success of all species trapped in the various study areas per 100 trap nights by season in the DD forest.

Species	Number of individuals	DD			
		Early rainy	Late rainy	Winter	Summer
Trap night		0882	0882	0882	0882
MURIDAE					
Maxomys surifer	53	2.15	1.02	1.36	1.47
Rattus rattus	28	0.79	1.36	0.57	0.45
SCIURIDAE					
Callosciurus Caniceps	1	-	-	-	0.11
TUPAIDAE					
Tupia glis	20	0.23	1.25	0.57	0.23
LEPORIDAE					
Lepus peguensis	1	-	-	-	0.11
HERPESTIDAE					
Herpestes javanicus	3	0.11	-	0.11	0.11
Total of trapping success	**106**	**3.28**	**3.63**	**2.61**	**2.48**
		12.00			

In ECO forest (Table 4.8), *M. surifer* was the highest trapped 3.51 individuals for every 100 trap night in early rainy season, and followed by late rainy season (2.61) and winter and summer (1.36), respectively. *R. rattus* was the highest trapped 0.45 individuals for every 100 trap night in late rainy season, and followed by early rainy season and winter (0.23). *L. sabanus* was equally greatest trapped 0.34 individuals for every 100 trap night in early rainy season and summer, and followed by winter (0.23). *C. finlaysoni* was greatest trapped 0.34 individuals for every 100 trap night in late rainy season and summer, and followed by winter and summer (0.23) and the lowest in early rainy season (0.11). For the *T. glis* was the greatest trapped 1.02 individuals for every 100 trap night in late rainy season, and followed by winter (0.79) and followed by summer (0.68) and early rainy season (0.11), respectively.

Table 4.8 Totals numbers of trapping success of all species trapped in the various study areas per 100 trap nights by season in the ECO forest.

Species	Number of individuals	ECO			
		Early rainy	Late rainy	Winter	Summer
Trap night		0882	0882	0882	0882
MURIDAE					
Maxomys surifer	78	3.51	2.61	1.36	1.36
Rattus rattus	8	0.23	0.45	0.23	-
Leopoldamys sabanus	8	0.34	-	0.23	0.34
SCIURIDAE					
Callosciurus finlaysoni	8	0.11	0.34	0.23	0.23
Callosciurus caniceps	2	-	0.11	-	0.11
TUPAIDAE					
Tupaia glis	23	0.11	1.02	0.79	0.68
Total of trapping success	**127**	**4.30**	**4.53**	**2.84**	**2.72**
		14.39			

In DE forest (Table 4.9), *M. surifer* was the highest trapped 4.54 individuals for every 100 trap night in late rainy season, and followed by late rainy season (3.40), early rainy season (2.95) and summer (1.93), respectively. *R. rattus* was the highest trapped 0.34 individuals for every 100 trap night in late rainy season, and followed by winter (0.23) and early rainy season (0.11). *L. sabanus* was equally greatest trapped 0.34 individuals for every 100 trap night in summer, and followed by early rainy season (0.23) and late rainy season (0.11). *C. caniceps* was greatest trapped 0.23 individuals for every 100 trap night in summer, and followed by early rainy season and summer (0.11). For the *T. glis* was equally the greatest trapped 0.23 individuals for every 100 trap night in early rainy season, late rainy season and summer, and followed by winter (0.11), respectively.

Table 4.9 Totals numbers of trapping success of all species trapped in the various study areas per 100 trap nights by season in the DE forest.

Species	Number of individuals	DE			
		Early rainy	Late rainy	Winter	Summer
Trap night		0882	0882	0882	0882
MURIDAE					
Maxomys surifer	113	2.95	4.54	3.40	1.93
Rattus rattus	6	0.11	0.34	0.23	0.00
Leopoldamys sabanus	6	0.23	0.11	0	0.34
Mus cervicolor	1	0.11	-	0	0
SCIURIDAE					
Callosciurus finlaysoni	1	-	0.11	0	0
Callosciurus caniceps	4	0.11	-	0.11	0.23
TUPAIDAE					
Tupaia glis	7	0.23	0.23	0.11	0.23
Total of trapping success	**138**	**3.74**	**5.33**	**3.85**	**2.73**
		15.65			

Trapping success varied greatly between and within habitats on a daily and seasonal basis. The number of small mammal species trapped in DD forest was greatest trapping success rate at 3.66 individuals for every 100 trap night in DE forest in the late rainy, similarly to in the ECO and DE it was greatest in the late rainy season had the trapping success rate at 4.53 and 5.33 individuals for every 100 trap night respectively. Whereas the lowest small mammal species trapped in DD, ECO and DE forest was in the summer, and had trapping success rate at 2.48, 2.72 and 2.73 individuals for every 100 trap night, respectively.

Trapping success varied over the study period, the DE forest had the greatest trapping success rate at 15.65 for every 100 trap night; the ECO forest had the second highest trapping success rate at 14.39 for every 100 trap night, and the DD forest was third at 12.00 for every 100 trap night. Trapping success rates were highest during the late rainy season in all three habitats. For the four most frequently captured species, *M. surifer* was captured most often during the rainy season in DE forest, *R. rattus* was captured most often during the rainy season in DD forest, *Leopoldamys sabanus* was captured most often in the hot season both in ECO and DE forest, and *T. glis* was captured most often in the cold season in the ECO forest.

Small mammals trapping has been especially problematic. Particular type of traps favor different species. Large wire mesh traps, for example, may be unreliable for species weighing <40 g (Emmons,1984), there for only captures one individual of *Mus cervicolor* . This study, the traps were placed only on the ground in this study, not many arboreal species were captured, the few numbers of *C. finlaysoni* and *C. caniceps* (Sciuridae) were captured (Walker and Rabiznovits, 1992). These traps were not suitable for these species.

The differences in trapping rates were observed among species and sampling habitat types, which may be due to differences in delectability, total trapping rate for all small mammals were high in the late rainy season (mean rate 4.50 of individuals per 100 trap nights) and low in the summer (mean rate of 2.64 individuals per 100 trap nights), and total capture rates for all habitat types were low (mean rate of 14.01 individuals per 100 trap nights). Therefore, trapping in the summer more rare number individuals than the rainy, it is likely that other environmental factors were responsible for the low number of small mammals observed in this study. Similarly, the study by Stephenson (1994) on seasonality effects on small mammal trap success in Madagascar, and he founded that the mean total number of small mammals captures was greatest between rainy season (April-November) and was the lowest in the dry season (winter and summer).

Relative abundance of small mammals is an extremely difficult task and one that is fraught with a multitude of potential sampling errors. As should be clear from other contributions in the volume, many variables can influence trapping results and recapture rates; these include the kind of the traps and baits used, size limitations of the traps, placement of the traps (on the ground or in the trees), species-specific behavior toward traps, and many other. The operation of one or more of theses biased during a trapping study will undoubtedly obscure to some extent the ecological situation that is being investigated (Golley, Petruswicz and Ryszkowski, 1975).

Factors affecting trap results have been noted by many authors (Adler and Lambert, 1997; Laurance, 1992; Voss and Emmons, 1996), They state that inventory methods are biased. In this study, the location of the traps influenced capture of some species such as arboreal species including *C. finlaysoni* and *C. caniceps*. These result can partly be explained by the locomotion and foraging habitats of the small mammals, hence their probability of coming across the traps. Some species of small mammals have short movement, walking around in a small area, and probably do not often use pathways, and morphologically typically a runner, so avoided tree falls and logs, whereas, most of rodents uses the ground to middle vegetation levels, winding along fallen brush or logs, and is most common around tree-falls (Emmons and Feer, 1990).

Effect of the water and fragmentation on the trapping success were different according the seasons. The number of captures increased with the number of trap night during the rainy season in Panama (Mcclearn et al., 1994). During the rainy, trap ability and trap success are generally increased because of the maximum fruit fall during this season (Guillotin, 1982). In this study, greatest success during this period resulted from increasing in density due to small mammals moving in from flooded area, reduced food viability, decrease in the number of potential resting places and shelters.

4.2.3.3 Small Mammal Recapture Rate

In all habitat topes, the percentage of recaptured rate was greatest in ECO forest (61.15%), and closely followed by DE forest (55.63%) and DD forest, respectively. As the result are showed in Table 4.10.

Table 4.10 Numbers of captures (recaptured) and percentage of recaptured for total number of small mammals in the various study habitat types of three seasons.

Seasons	No. Captured (recaptured) and % of recaptured					
	DD		ECO		DE	
	Captured (recaptured)	% Recaptured	Captured (recaptured)	% Recaptured	Captured (recaptured)	% Recaptured
Early rainy	53 (24)	45.28	70 (32)	45.71	64 (31)	48.44
Late rainy	78 (46)	58.97	129 (87)	67.44	104 (57)	54.81
Winter	71 (49)	69.01	90 (67)	74.44	91 (57)	62.64
Summer	32 (9)	28.13	43 (19)	44.19	52 (28)	53.85
Total	**234 (128)**	**54.70**	**332 (205)**	**61.75**	**311 (173)**	**55.63**

In DD forest, recapture rate was greatest in the winter. Considering the respective numbers of captures and recaptures, *M. surifer* was the highest (74.07%) recapture rate in winter, followed by late rainy season (65.71%), early rainy season (58.54%) and the lowest (29.17%) recapture rate in summer, respectively. *R. rattus* was the highest (93.75%) recapture rate in winter, followed by late rainy season (57.58%), summer (50.00%) and the lowest (0.00%) recapture rate in early rainy season, respectively. While *T. glis* was the highest (56.00%) recapture rate in winter, followed by late rainy season (40%), and equally the lowest (0.00%) recapture rate in early rainy season and summer. As the results are shown in Table 4.11.

Table 4.11 Numbers of captures (recaptured) for nine small mammal species in different area as functions of habitat and seasons in the DD forest.

Species	DD forest			
	Seasons			
	Early rainy	Late rainy	Winter	Summer
MURIDAE				
Maxomys surifer	41 (24)	35 (23)	27 (20)	24 (7)
	58.54%	65.71%	74.07%	29.17%
Rattus rattus	11 (0)	33 (19)	16 (15)	4 (2)
	0.00%	57.58%	93.75%	50.00%
SCIURIDAE				
Callosciurus	-	-	-	1 (0)
caniceps				0.00%
TUPAIIDAE				
Tupaia Glis	1 (0)	10 (4)	25 (14)	2 (0)
	0.00%	40.00%	56.00%	0.00%
LEPORIDAE				
Lepus peguensis	-	-	-	1 (0)
				0.00 %
HERPESTIDAE				
Herpestes	-	-	3 (0)	-
javanicus			0.00%	
Total	**53 (24)**	**78 (46)**	**71 (49)**	**32 (9)**
	45.28%	**58.97%**	**69.01%**	**28.13%**

In ECO forest, recapture rate was greatest (74.44%) in winter. Considering the respective numbers of captures and recaptures, *M. surifer* was the highest (85.07%) recapture rate in winter, followed by late rainy season (74.23%), summer (50.00%) and the lowest (46.55%) recapture rate in early rainy season, respectively. *R.rattus* was the highest (60.00%) recapture rate in winter, and they were no recaptured in early rainy season and winter. *L. sabanus* was the highest (100%) recapture rate in late rainy, followed by early rainy season (57.14%), summer (50.00%) and they were no recaptured in winter. For *T.glis* was equally the greatest (50.00%) recapture rate in early rainy season and winter, closely followed by late rainy season (47.06%), and the lowest (40.00%) recapture rate in summer. *C. finlaysoni* and *C. caniceps* were no recaptured in each seasons was founded. As the results are shown in Table 4.12.

Table 4.12 Numbers of captures (recaptured) for nine small mammal species in different area as functions of habitat and seasons in the ECO forest.

Species	**ECO forest**			
	Seasons			
	Early rainy	**Late rainy**	**Winter**	**Summer**
MURIDAE				
Maxomys surifer	58 (27)	97 (72)	67 (57)	24 (12)
	46.55%	74.23%	85.07%	50.00%
Rattus rattus	2 (0)	4 (0)	5 (3)	-
	0.00%	0.00%	60%	
Leopoldamys	7 (4)	7 (7)	2 (0)	6 (3)
sabanus	57.14%	100%	0.00%	50.00%
SCIURIDAE				
Callosciurus	-	3 (0)	2 (0)	2 (0)
finlaysoni		0.00%	0.00%	0.00%
Callosciurus	-	1 (0)	-	1 (0)
caniceps		0.00%		0.00%
TUPAIIDAE				
Tupaia glis	2 (1)	17 (8)	14 (7)	10 (4)
	50.00%	47.06%	50.00%	40.00%
Total	**70 (32)**	**129 (87)**	**90 (67)**	**43 (19)**
	45.71%	**67.44%**	**74.44%**	**44.19%**

In DE forest, recapture rate was greatest (62.64%) in winter Considering the respective numbers of captures and recaptures, *M. surifer* was the highest (62.92%) recapture rate in winter, followed by summer (60.47%), late rainy season (56.04%) and the lowest (46.94%) recapture rate in early rainy season, respectively. *R. rattus* was the highest (66.67%) recapture rate in winter, followed by late rainy season (40.00%) and they were no recaptured in early rainy season. *L. sabanus* was the highest (80.00%) recapture rate in late rainy season, followed by early rainy season (77.78%), winter (50.00%) and the lowest (40.00%) recapture rate in summer. *T. glis* were no recaptured in each seasons. *M. cervicolor* and *C. finlaysoni* was no recaptured in the this habitat. *C. caniceps* was greatest (50.00%) recapture rate in early rainy season, and they were no recaptured in winter and summer. As the results are shown in Table 4.13.

Table 4.13 Numbers of captures (recaptured) for nine small mammal species in different area as functions of habitat and seasons in the DE forest.

Species	**DE forest**			
	Seasons			
	Early rainy	**Late rainy**	**Winter**	**Summer**
MURIDAE				
Maxomys surifer	49 (23)	91 (51)	81 (51)	43 (26)
	46.94%	56.04%	62.92%	60.47%
Rattus rattus	1 (0)	5 (2)	6 (4)	-
	0.00%	40.00%	66.67%	
Leopoldamys	9 (7)	5 (4)	2 (2)	5 (2)
sabanus	77.78%	80.00%	50.00%	40.00%
Mus cervicolor	1 (0)	-	-	-
	0.00%			
SCIURIDAE				
Callosciurus	-	1 (0)	-	-
finlaysoni		0.00%		
Callosciurus	2 (1)	-	1 (0)	2 (0)
caniceps	50.00%		0.00%	0.00%
TUPAIIDAE				
Tupaia glis	2 (0)	2 (0)	1 (0)	2 (0)
	0.00%	0.00%	0.00%	0.00%
Total	**64 (31)**	**104 (57)**	**91 (57)**	**52 (28)**
	48.44%	**54.81%**	**62.64%**	**53.85%**

M. surifer was the most abundant species captured in all the seasons in each habitat type. The next most commonly trapped species were *T. glis* and *R. rattus* in

DD forest, and *T. glis* and *R. rattus* , *L. sabanus* both in ECO and DE forest. *M. surifer, T. glis* and *R. rattus* accounted for over 90% of the total number of animals caught. Two species of sciurid squirrel (*C. finlaysoni* and *C. caniceps*) were captured during the study. Especially, *C. finlaysoni* was only captured in ECO and DE forests.

All of habitat types was the greatest high recapture rates in winter, and closely followed by late rainy season, early rainy season in DD and ECO forest and summer in DE forest. Most of the lowest recapture rates founded in summer of all habitat types, except in DE forest was the lowest recapture rates in early rainy season.

The recapture rates showed a strong seasonal pattern and was linked to small mammals density and habitat types. The factors that promote recapture rates of small mammals cannot be specified precisely, but several observations suggest that rainfall may be important. Firstly, movements tended to increase after rain, and were directed toward areas where rain had fallen, Secondly, populations of small mammals increased locally in all habitat types after rainy, suggesting that immigrants had moved from surrounding areas. In Australia at Bungalbin Hill, numbers of small rodent (*P. albocinereus*) were 82 % higher in November and December 1988 less than six weeks after rain had fallen, than during the same period in 1987 when condition were dry. The increase in 1988 was due entirely to immigration because the time from conception to weaning in small rodent (*P. albocinereus*) was too long (73-74 days) to have allowed population increase after rainy season (Dickman et al., 1995).

Rain may be used most obviously as a source of free water by small mammals, but it is probably still more important in increasing food resources. For rodents, rain may produce an immediate increase in food by enhancing the accessibility of tree seeds and increase recapture rates after rainy season (Johnson and Jorgensen, 1981).

4.2.3.4 Small Mammals Anatomical Measurement

Captured animals were anaesthetized, measured weight (g), head and body length (HB) and tail length (T).The biometric measurement of small mammal species in all habitat types varied by seasons.

1) DD Forest

M. surifer; the mean of body weight, head and body length and tail length in male were 153.77 g, 16.97 mm and 17.26 mm, respectively, and the mean of body weight, head and body length and tail length in female were 125.44 g, 16.60 mm and 16.20 mm, respectively. *R. rattus*; the mean of body weight, head and body length and tail length in male were 125.52 g, 16.54 mm and 17.26 mm, respectively, and the mean of body weight, head and body length and tail length in female were 126.25 g, 16.06 mm and 17.13 mm, respectively. *T. glis*; the mean of body weight, head and body length and tail length in male were 151.77 g, 17.96 mm and 18.26 mm, respectively, and the mean of body weight, head and body length and tail length in female were 143.22 g, 17.95 mm and 18.09 mm, respectively. *H. javanicus*; the mean of body weight, head and body length and tail length in male were 877.50 g, 36.75 mm and 28.25 mm, respectively, and very low number of female, the body weight, head and body length and tail length were 510.00 g, 30.50 mm and 26.50 mm, respectively. Only one female of *C. caniceps* had body weight was 405.00 g, head and body length was 24.00 mm and tail length was 27.00 mm. For *L. peguensis,* only one female was measured, and had body weight was 905.00 g, head and body length was 32.50 mm and tail length was 6.50 mm. As the results are shown in Table 4.14.

Table 4.14 Studies species in DD forest, their anatomical measurement, mean ± SD of weight (g), head and body length (HB) and tail length (T).

Species	**Biometric measurements of adults**				
	Sex	**N**	**Weight (g)**	**HB (mm)**	**T (mm)**
M. surifer	M	23	153.77 ± 21.06	16.97 ± 1.36	17.26 ± 1.01
	F	16	125.44 ± 7.39	16.60 ± 0.07	16.20 ± 0.56
R. rattus	M	13	125.52 12.49	16.54 ± 1.00	17.26 ± 0.77
	F	6	126.25 ± 16.39	16.06 ± 0.97	17.13 ± 3.09
T. glis	M	9	151.77 ± 14.96	17.96 ± 0.95	18.26 ± 0.30
	F	10	143.22 ± 4.72	17.95 1.04	18.09 ± 1.62
C. caniceps	F	1	405.00	24.00	27.00
H. javanicus	M	2	877.50 ± 137.89	36.75 ± 2.47	28.25 ± 1.77
	F	1	510.00	30.50	26.50
L. peguensis	F	1	905.00	32.50	6.50

2) ECO Forest

M. surifer; the mean of body weight, head and body length and tail length in male were 137.39 g, 17.37 mm and 17.35 mm, respectively, and the mean of body weight, head and body length and tail length in female were 128.70 g, 16.59 mm and 16.70 mm, respectively. *R. rattus*; the mean of body weight, head and body length and tail length in male were 121.67 g, 16.00 mm and 17.67 mm, respectively, and the body weight, head and body length and tail length in female were 125.00 g, 16.50 mm and 19.50 mm, respectively. *L. sabanus*; the mean of body weight, head and body length and tail length in male were 264.17 g, 21.25 mm and 32.67 mm, respectively, and the mean of body weight, head and body length and tail length in female were

335.00 g, 22.00 mm and 30.00 mm, respectively. *T. glis*; the mean of body weight, head and body length and tail length in male were 156.39 g, 17.97 mm and 17.58 mm, respectively, and the mean of body weight, head and body length and tail length in female were 143.22 g, 17.95 mm and 18.09 mm, respectively. *C. finlaysoni*; the mean of body weight, head and body length and tail length in male were 323.88 g, 22.00 mm and 21.75 mm, respectively, and the mean of body weight, head and body length and tail length in female were 313.75 g, 22.50 mm and 23.13 mm, respectively. For *C. canicapes,* only one female was measured, and had body weight was 905.00 g, head and body length was 32.50 mm and tail length was 6.50 mm. As the results are shown in Table 4.15.

Table 4.15 Studies species in ECO forest, their anatomical measurement, mean ± SD of weight (g), head and body length (HB) and tail length (T).

Species	Biometric measurements of adults				
	Sex	N	Weight (g)	HB (mm)	T (mm)
M. surifer	M	26	137.39 ± 6.68	17.37 ± 0.61	17.35 ± 0.50
	F	19	128.70 ± 10.89	16.59 ± 0.21	16.70 ± 1.49
R. rattus	M	3	121.67 ± 30.14	16.00 ± 1.50	17.67 ± 2.47
	F	1	125.00	16.50	19.50
L. sabanus	M	4	264.17 ± 39.24	21.25 ± 1.25	32.67 ± 1.53
	F	4	335.00 ± 35.00	22.00 ± 1.32	30.00 ± 3.28
T. glis	M	6	156.39 ± 21.74	17.97 ± 0.21	17.58 ± 0.88
	F	16	146.67 ± 12.60	18.06 ± 0.38	17.38 ± 0.84
C. finlaysoni	M	4	323.88 ± 24.80	22.00 ± 1.08	21.75 ± 3.66
	F	3	313.75 ± 15.91	22.50 ± 0.71	23.13 ± 1.24
C. caniceps	F	2	350.00 ± 28.28	23.50 ± 0.71	25.00 ± 1.41

3) DE Forest

M. surifer; the mean of body weight, head and body length and tail length in male were 136.59 g, 13.18 mm and 17.01 mm, respectively, and the mean of body weight, head and body length and tail length in female were 127.23 g, 16.18 mm and 16.26 mm, respectively. *R. rattus*; the mean of body weight, head and body length and tail length in female were 137.50 g, 17.75 mm and 19.50 mm, respectively. *L. sabanus*; the mean of body weight, head and body length and tail length in male were 298.33 g, 21.50 mm and 29.33 mm, respectively, and the mean of body weight, head and body length and tail length in female were 280.55 g, 22.00 mm and 27.00 mm, respectively. *T. glis*; the mean of body weight, head and body length and tail length in male were 166.25 g, 18.88 mm and 18.50 mm, respectively, and the mean of body weight, head and body length and tail length in female were 152.50 g, 17.75 mm and 17.25 mm, respectively. *C. caniceps*; the mean of body weight, head and body length and tail length in male were 372.50 g, 25.00 mm and 22.50 mm, respectively, and the mean of body weight, head and body length and tail length in female were 372.50 g, 23.00 mm and 28.00 mm, respectively. For *M. cervicolor,* only one female was measured, and had body weight was 35.00 g, head and body length was 10.00 mm and tail length was 13.00 mm. As the results are shown in Table 4.16.

Table 4.16 Studies species in DE forest, their anatomical measurement, mean ± SD of weight (g), head and body length (HB) and tail length (T).

Species	**Biometric measurements of adults**				
	Sex	**N**	**Weight (g)**	**HB (mm)**	**T (mm)**
M. surifer	M	35	136.59 ± 5.30	13.18 ± 7.51	17.01 ± 0.77
	F	21	127.23 ± 4.83	16.18 ± 0.29	16.26 ± 0.75
R. rattus	F	2	137.50 ± 17.68	17.75 ± 0.35	19.50 ± 1.41
L. sabanus	M	3	298.33 ± 28.43	21.50 ± 0.50	29.33 ± 5.11
	F	2	280.35 ± 25.42	22.00 ± 1.40	27.00 ± 7.07
T. glis	M	5	166.25 ± 7.50	18.88 ± 0.95	18.50 ± 1.47
	F	2	152.50 ± 10.61	17.75 ± 1.06	17.25 ± 0.35
C. caniceps	M	2	372.50 ± 31.82	25.00 ± 0.00	22.50 ± 4.95
	F	2	372.50 ± 10.61	23.00 ± 1.41	28.00 ± 2.83
M. cervicolor	F	1	35.00	10.00	13.00

The anatomical measurement of male and female of four most common species including *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* in DD, ECO and DE forest revealed that there were no significant difference in the weight, head and body length and tail length between habitat types. The mean weight of *M. surifer* in male was the highest in DD forest, followed by ECO and DE forest, and in female was the highest in ECO forest, followed by DE and DD forest. Male *R. rattus* had the mean weight highest in DD forest, followed by ECO forest, and in female was the highest in DE forest, followed by DD and ECO forest. The mean weight of male and female *L. sabanus* was the highest in DE forest, followed by ECO forest. For *T. glis*, in male and female had the mean weight highest in DE forest, followed by ECO and DD forest.

The anatomical measurement of of male and female of four most common species including *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* from this area are similar to those recorded in previous studies (Musser et al., 1979; Wilson et al., 2006).

4.2.3.5 Small Mammal Diversity Index

Species diversity index, Shannon's diversity and Simpson's diversity, evenness and species richness were calculated for the three habitat types varied by four season including early rainy season, late rainy season, winter and summer.

As the Table 4.4, 4.5, 4.6 were showed the numbers of small mammal species in the each seasons in all habitat types. The result indicated that in DD forest; four species, including *M. surifer*, *R. rattus*, *T. glis* and *H. javanicus* were captured in the early rainy. Three species, including *M. surifer*, *R. rattus* and *T. glis* were captured in the late rainy. Four species, including *M. surifer*, *R. rattus*, *T. glis* and *H. javanicus* were captured in the winter. Six species, including *M. surifer*, *R. rattus*, *C. caniceps*, *T. glis*, *L. peguensis* and *H. javanicus* were captured in the summer. In ECO forest; Five species, including *M. surifer*, *R. rattus*, *L. sabanus*, *C. finlasoni* and *T. glis* were captured in early rainy season. Five species, including *M. surifer*, *R. rattus*, *C. finlasoni*, *C. canice*ps and *T. glis* were captured in late rainy season. Five species, including *M. surifer*, *R. rattus*, *L. sabanus*, *C. finlasoni* and *T. glis* were captured in winter. Five species, including *M. surifer*, *L. sabanus*, *C. finlasoni*, *C. caniceps* and *T. glis* were captured in summer. In DE forest; Six species, including *M. surifer*, *R. rattus*, *L. sabanus*, *M. cervicolor*, *C. caniceps* and *T. glis* were captured in early rainy season. Five species, including *M. surifer*, *R. rattus*, *L. sabanus*, *C. finlaysoni* and *T. glis* were captured in late rainy season. Four species, including *M. surifer*, *R. rattus*, *C. caniceps* and *T. glis* were captured in winter. Four species, including *M. surifer*, *L. sabanus*, *C. caniceps* and *T. glis* were captured in summer.

Considering Shannon's diversity index, Simpson's diversity index, species evenness and species richness in each habitat types in each season was indicated that mean of Shannon's diversity index in DD forest was the highest (1.77) in winter, followed by summer (1.57), late rainy season (1.45) and early rainy season (1.24), respectively. For ECO forest was the highest (1.52) in winter, followed by summer (1.40), late rainy season (1.28) and early rainy season (0.89), respectively. For DE forest was the highest (1.01) in early rainy season, followed by summer (0.90), late rainy season (0.76) and winter (0.67), respectively.

The mean of Simpson's diversity index in DD forest was the highest (0.72) in winter, followed by late rainy season (0.64), summer (0.63) and early rainy season (0.51), respectively. For ECO forest was the highest (0.66) in winter, followed by summer (0.62), late rainy season (0.55) and early rainy season (0.33), respectively. For DE forest was the highest (0.38) in early rainy season, followed by summer (0.36), late rainy season (0.28) and winter (0.24), respectively.

The mean of species evenness in DD forest was the highest (0.91) in late rainy season, followed by winter (0.90), the summer (0.79) and early rainy season (0.69), respectively. For ECO forest was the highest (0.94) in winter, followed by summer (0.83), late rainy season (0.80) and early rainy season (0.50) respectively. For DE forest was the highest (0.79) in summer, followed by early rainy season (0.56), late rainy season (0.48) and the winter (0.41), respectively.

The mean of species richness in DD forest was equally the highest (1.25) both in winter and summer, followed by early rainy season (0.93), and late rainy season (0.73), respectively. For ECO forest was the highest (1.03) in summer, followed by winter (0.96), early rainy season (0.86) and late rainy season (0.70), respectively. For DE forest was the highest (0.89) in early rainy season, followed by summer (0.82), winter (0.72) and late rainy season (0.65), respectively.

As the result indicated that mean of The Shanon's diversity index for DD forest in winter was the great highest (1.77) and was the lowest (0.67) in DE forest in winter. The results was similar to the Simson's diversity index and found that mean of diversity for DD forest in winter was the great highest (0.72) and was the lowest (0.24) in DE forest in the winter. Species evenness was the great highest (0.94) in ECO forest in winter and was the lowest (0.41) in DE forest in winter. For species richness found that was equally the great highest (1.25) both in DD forest in winter and summer, and was the lowest (0.65) in DE forest in late rainy season.

The One-way ANOVA of small mammals diversity index of all habitat types by seasonal were indicated significant differences at $P<0.05$ and the comparison among mean values of climate factors verified by Duncan's multiple range test were also shown in Table 4.17.

Table 4.17 Containing four different of species diversity (mean ± SE) in all habitat types by seasonal in Sakaerat Research Station.

Site	Season	Shannon Diversity Index (H')	Evenness (J)	Simpson' s Diversity Index (1-D)	Species Richness
		($\bar{x}$ ± SE)			
DD	Early rainy	1.24 ± 0.35 [cd]	0.69 ± 0.09 [ab]	0.51 ± 0.15 [abc]	0.93 ± 0.21
	Late rainy	1.45 ± 0.04 [d]	0.91 ± 0.02 [abc]	0.64 ± 0.00 [bcde]	0.73 ± 0.07
	Winter	1.77 ± 0.50 [abc]	0.90 ± 0.02 [d]	0.72 ± 0.14 [ef]	1.25 ± 0.69
	Summer	1.57 ± 0.66 [ab]	0.79 ± 0.13 [cd]	0.63 ± 0.22 [cdef]	1.25 ± 0.59
ECO	Early rainy	0.89 ± 0.11 [bc]	0.50 ± 0.02 [ab]	0.33 ± 0.02 [a]	0.86 ± 0.08
	Late rainy	1.28 ± 0.09 [cd]	0.80 ± 0.06 [abc]	0.55 ± 0.05 [abcd]	0.70 ±0.06
	Winter	1.52 ± 0.76 [ab]	0.94 ± 0.07 [abc]	0.66 ± 0.13 [f]	0.96 ± 0.60
	Summer	1.40 ± 0.83 [ab]	0.83 ± 0.03 [abc]	0.62 ± 0.17 [def]	1.03 ± 0.43

Table 4.17 Containing four different of species diversity (mean ± SE) in all habitat types by seasonal in Sakaerat Research Station (Continued).

Site	Season	Shannon Diversity Index (H')	Evenness (J)	Simpson' s Diversity Index (1-D)	Species Richness
		($\bar{x}$ ± SE)			
DE	Early rainy	1.01 ± 0.25 [bcd]	0.56 ± 0.05 [ab]	0.38 ± 0.08 [ab]	0.89 ± 0.27
	Late rainy	0.76 ± 0.52 [bc]	0.48 ± 0.12 [a]	0.28 ± 0.19 [a]	0.65 ± 0.48
	Winter	0.67 ± 0.53 [a]	0.41 ± 0.16 [ab]	0.24 ± 0.19 [ab]	0.72 ± 0.54
	Summer	0.90 ± 0.34 [b]	0.79 ± 0.25 [abc]	0.36 ± 0.10 [cdef]	0.82 ± 0.28

Indices of small mammal community structure vary significantly between habitat types and season for any of the calculated indices (Table 4.17) (P>0.05 for all ANOVA). While not statistically significant, the diversity indices were consistently lowest in DE forest and highest in winter in DD forest. Evenness was highest in winter in ECO forest and lowest in DE forest. Species richness was equally high in DD forest both in winter and summer and lowest in DE forest in late rainy season.

As the result revealed that small mammals diversity, evenness and species richness were most the highest in winter both in DD and ECO forest and were the lowest in early rainy season. However, these results were opposite in DE forest. The reason may be due to in winter in DD and ECO forest had very dens bamboo-like grass (*Arundinaria pusilla*) were growing under this forest canopy, this is suitable to hide from predators, whereas generally the forest floor in DE forest were rarely dens plant cover.

DD forest habitats supported the greatest species diversity, and species richness, especially in the winter. However, species diversity index were generally higher in the wetter semi-evergreen and the moist deciduous forests (Chandrasekhar-Rao and Sunquist, 1996) In comparison revealed that small mammal composition within each habitat type generally clustered together, though the moist and dry deciduous habitats could not be distinguished (Venkataraman et al., 2005). The dry evergreen forest has low species diversity index despite having a complex vegetation structure, because low small mammals species are an extremely adaptable and aggressive rodent and may exclude other species from the area. Competitive interactions between the species may be one of the factors excluding other species from the dry evergreen forest habitats (Chandrasekhar-Rao and Sunquist, 1996).

Similar results were obtained by Kemper and Bell (1985) in lowland rain forest of Peninsular Malaysia founded that small mammal capture and diversity were more likely in drier sites and sub sites than forest sites, and greater numbers of species were captured in sites containing a variety of habitats, a discrete layering of vegetation and extensive under storey. In addition, they founded small mammal species captures were positive associated with five habitat variables including emergent, litter, rotting logs, seedling and rough bark and negatively associated with five other including layers, bertam, sedges, pig damage and flooding, so the well drain habitat is suitable for small mammals community.

Seasonality also probably plays a role in the level of diversity and relative abundance of the species present, as different species were captured within each habitat type in different seasons. For species found in more than one habitat type, the more productive habitats might be important sources of immigrants into areas with higher mortality rates (Rabinowitz and Nottingham, 1989). For rodents, rain may produce an immediate increase in food by enhancing the accessibility of tree seed, also rain have long term effects by promoting plant growth (Dickman et al., 1995). Similar results obtained by Murray and Dickman (1994) suggesting that the rodents are omnivorous and eat the green stem, leaf material and fungi, as well as seeds, that become more abundant and species diversity after rain.

4.2.3.6 Small Mammal Density, Biomass and Minimum Home Range Size

Minimum home-range sizes (MHRS) were estimated for animals with multiple captures by connecting the outermost capture sites (minimum convex polygon estimate). In many cases the number of re-captures was quite small, so these minimum home-range sizes should not be considered true estimates of home range, but are presented here as a minimum estimate of the size of the area used by each small mammals.

This study estimated small mammals density for the most common species by simulation and inverse prediction from the capture-recapture data for each habitat in each season using version 4.1 of the programme DENSITY (Efford et al., 2005), and used the maximum likelihood estimator for the null model (M_0), which assumes that the probability of capturing an animal is constant between different trap-nights (Otis et al., 1978)

Biomass was determined by multiplying the mean adult weight of each species in each habitat with their relative density estimate (individuals/ha), for the mean adult weight is the mean peak biomass correlated to small mammals density (Decher and Bahian, 1999). Seasonal biomass estimates were derived from the average monthly biomass of the population for each species during early rainy season (May-July), late rainy season (August-October), winter (November-January) and summer (February-April) seasons.

DD Forest

1) Minimum Home Range Size (MHRS)

MHRS of three common species in DD forest revealed that *M. surifer* had the largest (0.11 ha^{-1}) MHRS in late rainy season, followed by winter (0.08 ha^{-1}), early rainy season (0.06 ha^{-1}) and had the smallest MHRS in summer (0.03 ha^{-1}), respectively. *R. rattus* had the largest (0.08 ha^{-1}) in early rainy, followed by winter (0.03 ha^{-1}) and had the smallest MHRS in late rainy. MHRS could calculated for *T. glis* only in winter (0.09 ha^{-1}). The results are shown in the Table 4.18.

2) Small Mammal Density

The mean densities of three common species in DD forest revealed that *M. surifer* had the highest (7.15 ha^{-1}) density in early rainy season, followed by winter (6.41 ha^{-1}), summer (5.66 ha^{-1}), and had the lowest (2.95 ha^{-1}) density in late rainy season, respectively. *R. rattus* had the highest (9.36 ha^{-1}) density in late rainy season, followed by winter (4.80 ha^{-1}), and had the lowest (3.49 ha^{-1}) density in late rainy season. For *T. glis* had the highest (14.46 ha^{-1}) density in late rainy season, followed by winter (3.18 ha^{-1}) and had the lowest (1.09 ha^{-1}) density in summer, respectively. The results are shown in the Table 4.18.

3) Biomass

The mean biomass of three common species in DD forest revealed that *M. surifer* had the highest (1035 g ha^{-1}) biomass in early rainy season, followed by winter (870 g ha^{-1}), summer (794 g ha^{-1}), and had the lowest (381 g ha^{-1}) in late rainy season.

R. rattus had the highest (1189 g ha^{-1}) biomass in late rainy season, followed by winter (641 g ha^{-1}), and had the lowest (481 g ha^{-1}) biomass in late rainy season. For *T. glis* had the highest (2069 g ha^{-1}) biomass in late rainy season, followed by winter (501 g ha^{-1}) and had the lowest (171 g ha^{-1}) biomass in summer, respectively. The total biomass was 8137 (g ha^{-}1). Total biomass of three common small mammal species was the highest (3639 g ha^{-1}) in late rainy season, followed by winter (2012 g ha^{-1}), early rainy season (1521 g ha^{-1}) and was the lowest (965 g ha^{-1}) in summer. The results are shown in the Table 4.18.

Table 4.18 Minimum home-range size (ha^{-1}), density (ha^{-1}) and biomass ($g\ ha^{-1}$) for the three most abundance species in the DD forest.

		DD			
		Season			
Species	**Parameter**	**Early rainy**	**Late rainy**	**Winter**	**Summer**
	Length of study (months)	3	3	3	3
Maxomys surifer	MHR (ha^{-1})	0.06	0.11	0.08	0.03
	Density (animals ha^{-1})	7.15 (2.30)	2.95 (1.04)	6.41 (1.73)	5.66 (2.35)
	Biomass ($g\ ha^{-1}$)	1035 (137)	381 (18)	870 (66)	794 (63)
Rattus rattus	MHR (ha^{-1})	0.08	0.01	0.03	NA
	Density (animals ha^{-1})	3.49 (1.60)	9.36 (4.07)	4.80 (2.32)	NA
	Biomass ($g\ ha^{-1}$)	486 (27)	1189 (51)	641 (48)	NA
Tupaia glis	MHR (ha^{-1})	NA	NA	0.09	NA
	Density (animals ha^{-1})	NA	14.46 (8.35)	3.18 (1.81)	1.09 (1.04)
	Biomass ($g\ ha^{-1}$)	NA	2069 (118)	501 (38)	171 (8)
Total biomass		**1521**	**3639**	**2012**	**965**
		8137			

NA = Non Analysis

ECO Forest

1) Minimum Home Range Size (MHRS)

MHRS of four common species in ECO forest revealed that *M. surifer* had the largest (0.11 ha^{-1}) MHRS in summer, followed by early rainy season (0.06 ha^{-1}), late rainy season (0.04 ha^{-1}) and had the smallest MHRS in winter (0.03 ha^{-1}), respectively. *T. glis*, MHRS could not calculated for *T. glis* in early rainy, had the largest (0.39 ha^{-1}) MHRS in summer, followed by late rainy season (0.28 ha^{-1}) and had the smallest MHRS in winter (0.08 ha^{-1}). *L. sabanus*, MHRS could not calculated for *L. sabanus* in early rainy season and winter, had the largest (0.26 ha^{-1}) MHRS in summer, and had the smallest (0.08 ha^{-1}) MHRS in late rainy season. For *R. rattus*, MHRS could not calculated for *R. rattus* in each season. The results are shown in the Table 4.19.

2) Small Mammal Density

The mean densities of four common species in ECO forest revealed that *M. surifer* had the highest (15.51 ha^{-1}) density in winter, followed by late rainy season (11.50 ha^{-1}), early rainy season (10.81 ha^{-1}), and had the lowest (1.76 ha^{-1}) density in summer, respectively. *T. glis*, density could not calculated for *T. glis* in early rainy season, had the highest (5.62 ha^{-1}) density in winter, followed by late rainy season (1.37 ha^{-1}) and had the lowest density in summer (1.13 ha^{-1}). *L. sabanus*, density could not calculated for *L. sabanus* in early rainy season and winter, had the highest (1.65 ha^{-1}) density in late rainy season, and had the lowest (1.46 ha^{-1}) density in summer. For *R. rattus*, density could not calculated for *R. rattus* in each season. The results are shown in the Table 4.19.

3) Biomass

The mean biomass of four common species in ECO forest revealed that *M. surifer* had the highest (2114 g ha^{-1}) biomass in winter, followed by early rainy season (1642 g ha^{-1}), late rainy season (1621 g ha^{-1}), and had the lowest (254 g ha^{-1}) biomass in summer, respectively. *T. glis*, biomass could not calculated for *T. glis* in early rainy season, had the highest (821 g ha^{-1}) biomass in winter, followed by late rainy season (209 g ha^{-1}) and had the lowest biomass in summer (172 g ha^{-1}). *L. sabanus*, biomass could not calculated for *L. sabanus* in early rainy season and winter, had the highest (543 g ha^{-1}) biomass in late rainy season, and had the lowest (408 g ha^{-1}) biomass in summer. For *R. rattus*, biomass could not calculated for *R. rattus* in each season. Total biomass of four common small mammal species was the highest (2935 g ha^{-1}) in winter, followed by late rainy season (2373 g ha^{-1}), early rainy season (1642 g ha^{-1}) and was the lowest (834 g ha^{-1}) in summer. The results are shown in the Table 4.19.

Table 4.19 Minimum home-range size (ha^{-1}), density (ha^{-1}) and biomass (g ha^{-1}) for the four most abundance species in the ECO forest.

		ECO			
		Season			
Species	**Parameter**	**Early rainy**	**Late rainy**	**Winter**	**Summer**
	Length of study (months)	3	3	3	3
Maxomys surifer	MHR (ha^{-1})	0.06	0.04	0.03	0.11
	Density (animals ha^{-1})	10.81 (2.36)	11.50 (2.06)	15.51 (2.86)	1.76 (0.97)
	Biomass (g ha^{-1})	1642 (158)	1621 (83)	2114 (58)	254 (42)
Rattus rattus	MHR (ha^{-1})	NA	NA	NA	NA
	Density (animals ha^{-1})	NA	NA	NA	NA
	Biomass (g ha^{-1})	NA	NA	NA	NA
Tupaia glis	MHR (ha^{-1})	NA	0.28	0.08	0.39
	Density (animals ha^{-1})	NA	1.37 (0.16)	5.62 (4.11)	1.13 (0.12)
	Biomass (g ha^{-1})	NA	209 (21)	821 (41)	172 (13)
Leopoldamys sabanus	MHR (ha^{-1})	NA	0.07	NA	0.26
	Density (animals ha^{-1})	NA	1.65 (0.48)	NA	1.46 (0.36)
	Biomass (g ha^{-1})	NA	543 (19)	NA	408 (29)
Total biomass		**1642**	**2373**	**2935**	**834**
		7784			

NA = Non Analysis

DE Forest

1) Minimum Home Range Size (MHRS)

MHRS of four common species in DE forest revealed that *M. surifer* had the largest (0.10 ha^{-1}) MHRS in summer, followed by winter (0.07 ha^{-1}), late rainy season (0.05 ha^{-1}) and had the smallest MHRS in early rainy season (0.04 ha^{-1}) respectively. *L. sabanus*, MHRS could not calculated for *L. sabanus* in late rainy season and winter, had equally the largest (0.13 ha^{-1}) MHRS in early rainy season and summer. For *R. rattus* and *T. glis*, MHRS could not calculated for *R. rattus* and *T. glis* in each season. The results are shown in the Table 4.20.

2) Small Mammal Density

The mean densities of four common species in DE forest revealed that *M. surifer* had the highest (19.58 ha^{-1}) density in winter, followed by late rainy season (16.69 ha^{-1}), early rainy season (13.20 ha^{-1}) and had the lowest density in summer (4.78 ha^{-1}), respectively. *L. sabanus*, density could not calculated for *L. sabanus* in late rainy season and winter, had the highest (1.85 ha^{-1}) density in early rainy season and had the lowest (1.50 ha^{-1}) in summer. For *R. rattus* and *T. glis*, density could not calculated for *R. rattus* and *T. glis* in each season. The results are shown in the Table 4.20.

3) Biomass

The mean biomass of four common species in DE forest revealed that *M. surifer* had the highest (2559 g ha^{-1}) biomass in winter, followed by late rainy season (2199 g ha^{-1}), early rainy season (1981 g ha^{-1}), and had the lowest (664 g ha^{-1}) biomass in summer, respectively. *L. sabanus*, biomass could not calculated for *L. sabanus* in late rainy season and winter, had the highest (593 g ha^{-1}) biomass in eary rainy season, and had the lowest (518 g ha^{-1}) biomass in summer. For *R. rattus* and *T. glis*, biomass could not calculated in each season. Total biomass of four common small mammal species was the highest (2559 g ha^{-1}) in winter, followed by early rainy season (2574 g ha^{-1}), late rainy season (2199 g ha^{-1}) and was the lowest (1182 g ha^{-1}) in summer. The results are shown in the Table 4.20.

Table 4.20 Minimum home-range size (ha^{-1}), density (ha^{-1}) and biomass ($g\ ha^{-1}$) for the four most abundance species in the DE forest.

Species	Parameter	DE Season Early rainy	Late rainy	Winter	Summer
	Length of study (months)	3	3	3	3
Maxomys surifer	MHR (ha^{-1})	0.04	0.05	0.07	0.10
	Density (animals ha^{-1})	13.20 (3.56)	16.69 (2.92)	19.58 (3.79)	4.78 (1.38)
	Biomass ($g\ ha^{-1}$)	1981 (197)	2199 (58)	2559 (66)	664 (16)
Rattus rattus	MHR (ha^{-1})	NA	NA	NA	NA
	Density (animals ha^{-1})	NA	NA	NA	NA
	Biomass ($g\ ha^{-1}$)	NA	NA	NA	NA
Tupaia glis	MHR (ha^{-1})	NA	NA	NA	NA
	Density (animals ha^{-1})	NA	NA	NA	NA
	Biomass ($g\ ha^{-1}$)	NA	NA	NA	NA
Leopoldamys sabanus	MHR (ha^{-1})	0.13	NA	NA	0.13
	Density (animals ha^{-1})	1.85 (0.65)	NA	NA	1.50 (0.85)
	Biomass ($g\ ha^{-1}$)	593 (24)	NA	NA	518 (6)
Total biomass		**2574**	**2199**	**2559**	**1182**
		8514			

NA = Non Analysis

For most commons species of small mammals, the minimum home range estimates were largest during dry season, including winter and summer. The only exception to this was *M. surifer* in DD forest, which showed the largest minimum home-range size in rainy seasons (early rainy season, mean = 0.06 ha, late rainy season, mean = 0.11 ha^{-1}) and the smallest MHRS in summer (mean = 0.03 ha^{-1}). The largest MHRS recorded for the four most commonly caught species was 0.39 ha^{-1} for *T. glis* in ECO forest.

Density and biomass of the four most frequently captured species varied seasonally in each site. The density of *M. surifer* ranged from 2.95-19.58 individuals/ ha^{-1} across habitats and seasons. Their density was greatest in winter season in the DE forest and lowest during late rainy season in the DD site. *T. glis* density ranged from 0.37-14.46 individuals/ ha^{-1}; it was greatest during late rainy season in DD forest and the lowest during late rainy season in ECO forest. *R. rattus* ranged from 3.49-9.36 individuals/ha^{-1} but density was calculated only in rainy seasons and winter. *L. sabanus* was captured infrequently so it was excluded from density analysis.

Biomass of the four most frequently captured species range from 171-2559 g/ ha^{-1} across seasons and habitat types. The biomass of both *M. surifer* and *R. rattus* was greatest during rainy seasons and lowest during winter and summer for all habitat types, whereas the biomass of *T. glis* and *L. sabanus* varied by season and habitat.

Although some sub-adult and juvenile were capture during the study, these individuals were not included in biomass estimates and would not have contributed substantially to overall biomass. The biomass values we report under estimate true biomass for adults of the four most frequently recaptured because the proportion of adults of them in each sampling was uniformly high in all habitats.

Small mammal diversity index steadily declined across the transition from dry dipterocarpus forest into dry evergreen forest, whereas biomass underwent a steady rise in ecotone forest. The productivity theory of diversity suggest that diversity should increase with productivity (Cornell and Orians, 1964). However, many recent studies have found that diversity is highest at intermediate levels of productivity (Rosenzweig and Abramasky, 1993). This study, it seems likely that the assume higher productivity of the ecotone forest is correlated with a higher small mammal biomass. Small mammal species assemblage structure at the ecotone highlights the close relationship between species and the vegetation structure (Williams and Marsh, 1998).

In terms of density, the dry evergreen forest supported the highest small mammal densities. Unfortunately, be obtained sufficient recapture data for one species only (*M. surifer*) to allow density to be calculated in each habitat, This may well have been influenced by differences in diet specificity and food availability for the other less widely captured species (Shanker, 2001). There was also a considerable difference in terms of biomass and density in dry dipterocarpus forest. Lower densities and biomass of small mammals for *M. surifer* in dry dipterocarpus forest compared with dry evergreen and ecotone forest could be a product of seasonal perturbations creating a relatively resource-poor habitat (Walker and Rabiznovits, 1992). Moreover, variations in soil fertility has been reported as a factor in the lower productivity of dry dipterocarpus forest and correlated with density of small mammals in the Amazon (Emmons, 1984).

Most species of small mammals showed the largest minimum home range size in the dry season in each habitats. The home range size of *M. surifer* found here is smaller and differ form reported by Walker and Rabiznovits (1992), their data showed that *M. surifer* has the largest minimum home range size was 0.8 ha^{-1} in the rainy season and 0.6 ha^{-1} in the hot season. Most of home range size in small rodents are usually has a relationship between spacing patterns and social structure especially during the breeding season (Priotto et al., 2002). In addition, another study suggested that food abundance and population density could be influence home range size (Taitt and Krebs, 1981). In this study areas was less in food supplies in dry season, therefore small mammals expand their home range size to seek abundant food supplies, normally in the dry season, small mammals usually move from one area to search for food. In addition, migratory animals have different in summer and winter, and the size of home range may vary with sex, possibly age and season (Burt, 1943).

Ripley (1979) has suggested that a high biomass of primate folivores is associated with a lack of synchrony in deciduous behavior of trees, a situation leading to the constant availability of edible foliage. Ripley predicts a low biomass of folivores in an ecosystem like dry tropical forest, during which has a single, relative long dry season which leaf shedding by canopy trees is concentrated.

4.2.3.7 Sex and Age Structure of Small mammals

Determination of population sex and age structure for the four most common species including *M. surifer*, *R. rattus*, *T. glis* and *L. sabanus* were based on the actual number of individuals captured during each trapping period. Sex ratios were examined using Chi-square goodness-of-fit tests.

Maxomys surifer

1) DD Forest

The ratio of adult, sub adult and juvenile males of *M. surifer* in DD forest revealed that in early rainy season, more adult (N=6) than sub adult (N=4) and juvenile (N=1). In late rainy season, more sub adult (N=2) than adult (N=1). In winter, more adult (N=7) than sub adult (N=2). In summer, most of animals captured were adults (N=9) and no sub adult and juvenile were captured. For the ratio of adult, sub adult and juvenile females of *M. surifer* in DD forest revealed that in early rainy season, more adult (N=5) than sub adult (N=2) and juvenile (N=1). In late rainy season, more adult (N=4) than sub adult and juvenile (N=1). In winter and summer, most of animals captured were adult (N=3) (N=4) and no sub adult and juvenile were captured.

2) ECO Forest

The ratio of adult, sub adult and juvenile males of *M. surifer* in ECO forest revealed that in early rainy season, more adult (N=9) than sub adult (N=4) and juvenile (N=1). In late rainy season, more sub adult (N=5) than adult and juvenile (N=3). In winter, more adult (N=7) than sub adult (N=3). In summer, most of animals captured were adults (N=7) and no sub adult and juvenile were captured. For the ratio of adult, sub adult and juvenile females of *M. surifer* in ECO forest revealed that in early rainy season, more sub adult (N=10) than adult (N=5) and juvenile (N=2). In late rainy season, more adult (N=8) than sub adult (N=4) and no juvenile was captured. In winter, equally numbers of animal captured were adult and juvenile (N=1) and no sub adult was captured. In summer, most of animals captured were adult (N=5) and no sub adult and juvenile were captured.

2) DE Forest

The ratio of adult, sub adult and juvenile males of *M. surifer* in DE forest revealed that in early rainy season, more sub adult (N=7) than adult (N=5) and no juvenile was captured. In late rainy season, more sub adult (N=15) than adult and juvenile (N=9)(N=3) respectively. In winter, more adult (N=12) than sub adult (N=4) and no juvenile was captured. In summer, most of animals captured were adults (N=9) and no sub adult and juvenile were captured. For the ratio of adult, sub adult and juvenile females of *M. surifer* in DE forest revealed that in early rainy season, more sub adult (N=8) than adult (N=4) and juvenile (N=2). In late rainy season, more sub adult (N=7) than adult (N=6) and juvenile (N=1) respectively. In winter, most of animals captured were sub adult (N=6) than adult (N=5) and juvenile (N=3), respectively. In summer, most of animals captured were adult (N=5) than sub adult (N=2) and no juvenile were captured.

Sex ratios did not differ significantly from 1:1 for *M. surifer* in all habitat types (P>0.1), the percentage proportion of sex and age structure of *M. surifer* are showed in the Figure 4.4.

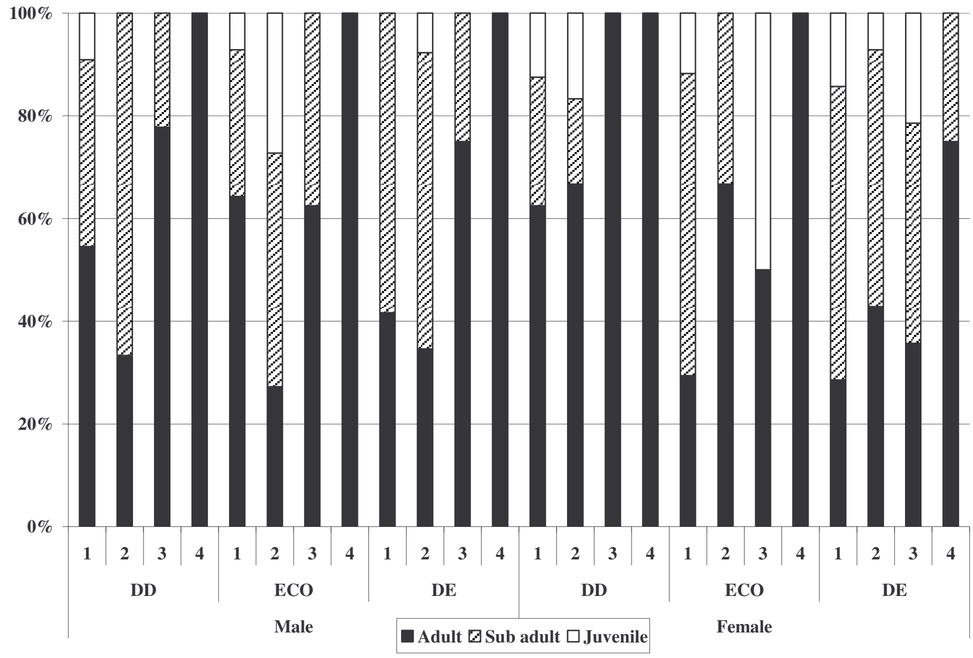


Figure 4.4 Proportion of adult sub adult and juvenile *Maxomys surifer* captured in each seasons in each habitat types. DD = dry dipterocarp forest; ECO = ecotone forest; DD = dry evergreen forest. 1 = Early rainy season; 2 = Late rainy season; 3 = Winter; 4 = Summer.

Rattus rattus

1) DD Forest

The ratio of adult, sub adult and juvenile males of *R. rattus* in DD forest revealed that in early rainy season, more adult (N=4) than sub adult (N=1) and no juvenile were captured. In late rainy season, more adult (N=4) than juvenile (N=2) and no sub adult were captured. In winter, equally numbers captured of adult and sub adult (N=2) were captured and no juvenile were captured. In summer, animals captured were only adults (N=3) and no sub adult and juvenile were captured. For the ratio of adult, sub adult and juvenile females of *R. rattus* in DD forest revealed that in early rainy season, animals captured were only adult (N=2) and no sub adult and juvenile were captured. In late rainy season, equally numbers captured of adult, sub adult and juvenile (N=2). In winter and summer, animals captured were adult (N=1) and no sub adult and juvenile were captured.

2) ECO forest

The ratio of adult, sub adult and juvenile males of *R. rattus* in ECO forest revealed that in early rainy season, equally numbers captured of adult and sub adult (N=1) and no juvenile were captured. In the late rainy, more juvenile (N=2) than adult (N=1) and no sub adult were captured. In winter, equally numbers captured of adult and sub adult (N=1) were captured and no juvenile were captured. In summer, no adult, sub adult and juvenile were captured. For the ratio of adult, sub adult and juvenile females of *R. rattus* in ECO forest revealed that only one adult (N=1) in late rainy season was captured and no adult, sub adult and juvenile were captured in other seasons.

3) DE Forest

The ratio of adult, sub adult and juvenile males of *R. rattus* in DE forest revealed that only one juvenile (N=1) in late rainy season was captured and no adult, sub adult and juvenile were captured in other seasons. For the ratio of adult, sub adult and juvenile females of *R. rattus* in DE forest revealed that in early rainy season and late rainy season, only juvenile (N=1, N=2) were captured and no adult, sub adult were captured. In winter, animals captured were only adults (N=2) and no sub adult and juvenile were captured. In the summer, no adult, sub adult and juvenile were captured.

CHAPTER V

PREVALENCE OF ECTOPARASITES, BLOOD PARASITES IN SMALL MAMMALS AND HEALTH STATUS

5.1 Abstract

A study of ectoparasites and blood parasites in small mammals was undertaken in three habitat types of Sakaerat Environmental Research Station, dry dipterocarp forest, ecotone forest and dry evergreen forest in early rainy season (May-July), late rainy season (August-October), winter (November-December) and summer (February-April). A total of 371 small mammals (9 species) were captured in traps. Four most common species included *Maxomys surifer*, *Rattus rattus*, *Leopoldamys sabanus* and *Tupaia glis* were observed. Ectoparasites presenting were mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroides*). Blood parasites such as *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. Mite (*Lealaps echidinus*) and *Anaplasma* sp. were most frequently observed in four most common species captured. *M. surifer*, was most common species observed with abundant ectoparasites and blood parasites. There was a great relationship between ectoparasites and blood parasites found among species. Habitat types, season, sex and age significantly influenced the prevalence infection, intensity of blood parasites and hematological values. However, parasites found did

not cause any abnormal change of hematological values and serum biochemistry values. This strongly suggests that small mammals might be only parasite reservoirs.

5.2 Introduction

Of the widely recognized threats to global biodiversity and ecosystem functioning, infectious diseases of wildlife play an important role (Daszak et al., 2000). Diseases have long been recognized as one of the potential limiting factors of wildlife populations and pose a serious threat to the persistence of endangered species (McCallum and Dobson, 1995). Of particular interests are introduced pathogens that can cause high mortality in many native animal species. Wildlife diseases also have a potential risk of spillover or crossover infection in domestic animal and human populations. Understanding the dynamic of disease and its ecology is imperative and has implications for management of species of conservation concern. Epidemics of infections diseases may be an important population regulator in mammals (Elton, 1925) and the occurrence and localization of disease are determined by a variety of factors relating to the host, vectors and pathogens (Wobeser, 1994). For vector-born disease, interactions between populations of host species are important for distribution of the vectors and transmission of the pathogens.

Small mammals are one of the most successful and diverse groups of mammals, being found in a wide variety of habitats. Most of small mammals are rodent, also important sources of infection for various viral, rickettsial and bacterial pathogens that cause diseases in humans. Rodent-borne diseases in human include plague, typhus, spotted fever, Hantavirus and Lyme disease. Many of these diseases are transmitted by arthropod vectors infesting rodent reservoirs. At present, our lack of understanding about the ecology of these diseases limits our ability to prevent them in humans and limit their impacts on wildlife populations (Woodhouse et al., 2001).

The distribution pattern of ectoparasites on their hosts is a result of an interaction between the parasites and the host and co-existence among the parasites. The ectoparasites deal with small mammals are tick, chiggers, gamasid mites, fleas and lice. Lice and certain gamasid mites are permanent parasites while fleas and certain mite species are nest-dwellers, which use the host for feeding and/or copulation. Among the last mentioned species, oviposition, development and moulting may occur in the nest. Others, such as *Ixodes ricinus* and *Neotrombicula* spp. develop in the vegetation but feed on the host once in each developmental stage (Nilsson, 1981).

The specify of ectoparasites may also be related to microhabitat selection by the host, and as a result, when habitats are disturbed and the composition of the small mammal community changes, ectoparasites may encounter different host near their nest microhabitat, and transfer may occur (Gettinger and Ernest, 1995). Barker (1994) suggested that occurrence of a particular ectoparasite species living on more than one host species may be related to the behavior, intra and interspecifc relationship, and with the microhabitats utilized by the host.

Small mammals are vector-transmitted blood parasites. Blood parasites are closely related to ectoparasites in small mammals. Some small mammals investigated have been mix-infected with two parasite species. However, the number of mixed infections is relative low in comparison to the whole number of infected rodents. The most common co-infected was Hepatozoon and Batonela in bank vole (Turner, 1986). Other combinations, as well as co-infections in other host species, were seldom.

Consistently, the prediction showed the prevalence and diversity of blood parasites were higher in rodents than shrews (Karbowaiak et al., 2005).

5.3 Materials and Methods

5.3.1 Animal Experiments

The experiments performed on small mammal were conducted in accordance with the advice of the Institutional Animal Care and Use Committee, SUT.

5.3.2 Collection of Ectoparasite

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

5.3.3 Blood Collection

Each anesthetized rat was placed in a restrainer. Blood was collected from the vein of rat tail using a 23-25 gauge needle. A drop of blood was collected into vacutainer tubes contain ethylenediaminetetraacetic acid (EDTA) as an anticoagulant (depending on the size of animal).

5.3.3.1 Examination of Microparasites

***Microfilaria* sp. and *Trypanosoma* sp.**

A measure volume of 50 μl of blood was placed into capillary tubes (35 x 1.5 mm). The capillary tubes were be sealed with plasticine and centrifuged at 12000 g for 5 min for the micro-hematocrit centrifuge technique. A capillary of the micro-hematocrit centrifuge was scratched, broken 1 mm below the buffy-coat layer (top layer of red blood cells, white blood cells and plasma), expelled onto a slide, Giemsa stained thin smear and examined under microscope at x 400 magnification and identified following the method of Urquhart, Armour, Duncan, Dunn and Jennings (1996).

Heamoparasites

Blood from the rat tail was used for the thin blood smears. Blood smears were then air-dried, fixed in absolute methanol, and stained with Giemsa at pH 7.1. Smears were viewed at x 1000 magnification. Approximately 200 fields of vision were inspected and the number of red blood cells (RBC) infected with blood parasite was recorded and expressed as number of infected cells/100 RBC (Sinski, Bajer, Welc, Pawelczyk, Ogrzewalska and Behnke, 2006) and identified following the protocol of Urquhart, Armour, Duncan, Dunn and Jennings (1996).

5.3.4 Prevalence of Parasites and Infection

The prevalence of ectoparasite and blood parasite species of small mammals in three habitat types, DD forest; ECO forest and DE forest were observed in 4 seasons. These seasons were the early rainy season, May-July; the late rainy season, August-October; winter, November-December; summer, February-April. Infected individuals were classified into 3 maturity classes for each sex, males: juvenile, sub adult, adult; females: juvenile, sub adult, adult.

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

The intensity of infections of blood parasites was recorded as type of blood parasites per 100 RBC.

5.3.5 Heamatology

Five hours after sampling, the packed cell volume (PVC) was measured using the micro-hematocrit centrifuge technique and total RBC and total white blood cell (WBC) were counted in Neubauer chamber (hemacytometer) (Figure 5.1). The differential leukocyte counting was performed on blood smears stained with giemsa and methanol. Differential WBC counts were based on counting of 100 leucocytes.

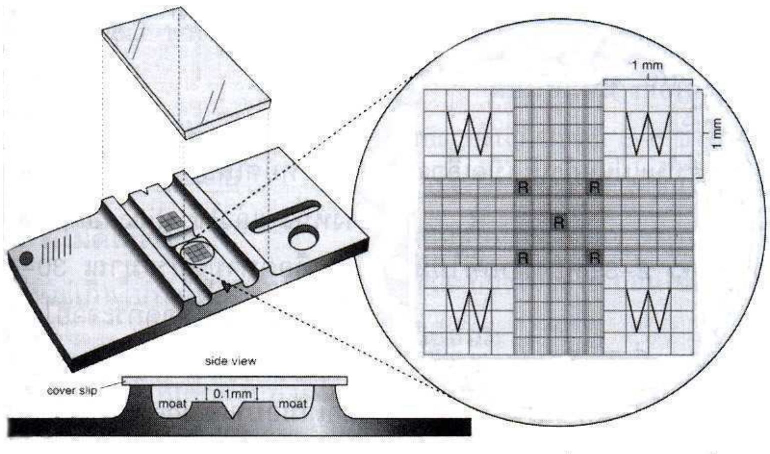


Figure 5.1 A chamber for red blood cells and white blood cells count, on "W" area for white blood cells count and on "R" area for red blood cells counts.

Notes From the laboratory in clinical medicine: interpretation and application (p.575), by Halsted and Halsted (2002).

Formula : WBC count

Average of WBC x Dilution factor multiplied by Area factor x Depth factor x 10^6 = 10^9 WBC/L

Formula : RBC count

Average of RBC x Dilution factor multiplied by Area factor x Depth factor x 10^6 = 10^{12} RBC/L

5.3.6 Plasma Glucose and Triglyceride Concentration

Plasma glucose and triglyceride concentrations were estimated using an Accutrend® GCT (Roche Diagnostics, Mannheim, Germany) from blood samples taken from the tail vein. A drop of blood (30 µl) was collected, and applied to the Accutrend glucose test strip and Accutrend triglyceride test strip (Roche). The concentration of glucose and triglyceride was measured by a process of dry chemistry and colorimetry. The measurement range standard for glucose and triglyceride concentrations was at 20 to 600 mg/dL and 70 to 600 mg/dL respectively (Gur, Karahan, Ozturk and Badilli, 2005).

5.3.7 Data Analysis

5.3.7.1 Statistic Analysis for the Prevalence of Infection

Data were evaluated with the SPSS 16. Descriptive statistic for all data were then presented as mean ± S.E. and "n" represents the number of individuals, each one from a different animal. The results of prevalence of infection expressed as percentages of infested small mammals. Chi-square tests and P values <0.05 was used to analyses significant of the prevalence in different habitat types, seasons, sexes and broad age group (immature or adult) (Laakkonen, Lehtonen, Ramiarinjanahary and Wright, 2003).

5.3.7.2 Statistic Analysis for the Relationship between Ectoparasite Species and Blood Parasites Species

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

5.3.7.3 Statistic Analysis for the Correlation between Habitat Types, Seasons, Sexes and Age with Intensity of Parasites and hematological Values.

Pearson correlation was considered significant at *P*<0.05 to test the correlation between habitat types, seasons, sexes and age with intensity of parasites and bood values. Then multivariate analysis of variance was considered statistically significant at *P*<0.05. The detectable variation was observed between groups (particularly by habitat types, seasond, sex and age), group were combined when making comparisons.

5.4 Results

5.4.1 Prevalence and Infection of Parasites in Small Mammals

5.4.1.1 Prevalence of Ectoparasites in Small Mammals in All Habitat types

A total of 371 small mammals (including 244 individuals of *Maxomys surifer*, 42 *Rattus rattus*, 14 *Leopoldamys sabanus*, 50 *Tupaia glis*, 9 *Callosciurus finlaysoni*, 7 *Callosciurus caniceps*, 3 *Herpestes javanicus*, 1 *Lepus peguensis* and 1 *Mus cervicolor*) were examined (Table 5.1).

Table 5.1 Numbers of small mammal examination and numbers of ectoparasite species and pseudoscorpion in Sakearat Environmental Research Station.

Host species	Location	No.	Ectoparasite species			Pseudoscorpion
			Mite	Tick	Flea	
			Lealaps echidinus	***Ixodes* sp.**	***Xenopsylla cheopsis***	***Chelifer cancroides***
			Numbers of prevalence (%)			
Maxomys surifer	DD,ECO,DE	244	188 (77.05)	25 (10.25)	76 (31.15)	36 (14.75)
Rattus rattus	DD, CO,DE	42	19 (45.24)	4 (9.52)	6 (14.29)	5 (11.90)
Leopoldamys sabanus	ECO, DE	14	3 (21.43)	-	-	-
Tupaia glis	DD,ECO,DE	50	8 (16.00)	11 (22.00)	8 (16.00)	6 (12.00)
Callosciurus finlaysoni	ECO, DE	9	-	-	-	-
Callosciurus erythraeus	DD,ECO,DE	7	-	-	-	-
Herpestes javanicus	DD	3	-	-	-	-
Lepus peguensis	DD	1	-	-	-	-
Mus cervicolor	DE	1	-	-	-	-
Total		**371**	**218 (58.76)**	**40 (10.78)**	**90 (24.56)**	**47 (12.67)**

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

M. surifer; in DD forest, a total of 53 individuals was collected. The prevalence of mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroides*) found were 84.91% (N=45), 5.66% (N=3), 24.53% (N=13) and 3.77% (N=2), respectively. In ECO forest, a total of 78 individuals was collected. The prevalence of mite (*Lealaps echidinus*), tick

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

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

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

For *T. glis*; in DD forest, a total of 20 individuals was collected. The prevalence of mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroides*) found were 10.00% (N=2), 20.00% (N=4), 20% (N=4) and 5% (N=1), respectively. In ECO forest, a total of 23 individuals was collected. The prevalence of mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroides*) found were 37.50%

(N=6), 30.43% (N=7), 17.39% (N=4) and 21.74% (N=5), respectively. For DE forest a total of 7 individuals were collected. The prevalence of ectoparasites was not found.

The prevalence rates and percentage of ectoparasites and pseudoscorpion founded in four most common species are shown in Table 5.2

Table 5.2 Prevalence of ectoparasites and pseudoscorpion found in four most common species captured in Sakearat Environmental Research Station with varied by habitat types.

Host species	Habitats	No.	Mite	Tick	Flea	Pseudoscorpion
			Lealaps Echidinus	***Ixodes* sp.**	***Xenopsylla cheopsis***	***Pseudochiridium* sp.**
			Numbers of prevalence (%)			
Maxomys surifer	DD	53	45 (84.91)	3 (5.66)	13 (24.53)	2 (3.77)
	ECO	78	70 (89.74)	4 (5.13)	34 (43.59)	11 (14.10)
	DE	113	73 (64.60)	18 (15.93)	29 (25.66)	23 (20.35)
Rattus rattus	DD	28	14 (50.00)	4 (14.29)	2 (7.14)	2 (7.14)
	ECO	8	3 (37.50)	-	4 (50.00)	3 (37.50)
	DE	6	2 (33.33)	-	-	-
Leopoldamys sabanus	ECO	8	1 (12.50)	-	-	-
	DE	6	1 (16.67)	-	-	-
Tupia glis	DD	20	2 (10.00)	4 (20.00)	4 (20.00)	1 (5.00)
	ECO	23	6 (26.09)	7 (30.43)	4 (17.39)	5 (21.74)
	DE	7	-	-	-	-
Total		**350**	**217 (62.00)**	**40 (11.43)**	**90 (25.71)**	**47 (13.43)**

As shown, the results revealed that mite (*L. echidinus)* was the highest (N= 217, 62.00%) species found in four most common species of small mammals, followed by flea (*X. cheopsis* N=90, 25.71%), pseudoscorpion (*Chelifer cancroides* sp. N=47, 13.43%) and tick (*Ixodes* sp. N=40, 11.3%). Total prevalence of ectoparasites in all habitat types, *M. surifer* was the most highest with mite (*L. echidinus)* found, followed by flea (*X. cheopsis*), tick (*Ixodes* sp.) and pseudoscorpions (*Chelifer cancroides*), respectively. While *R. rattus*, *L. sabanus and*

T. glis, whereas in *L. sabanus* was not found of tick (*Ixodes* sp.), flea (*X. cheopsis*) and pseudoscorpions (*Chelifer cancroides*)

5.4.1.2 Prevalence of Blood Parasites in Small Mammals in All Habitat Types

A total of 371 small mammals (including 244 individuals of *Maxomys surifer*, 42 *Rattus rattus*, 14 *Leopoldamys sabanus*, 50 *Tupia glis*, 9 *Callosciurus finlaysoni*, 7 *Callosciurus caniceps*, 3 *Herpestes javanicus*, 1 *Lepus peguensis* and 1 *Mus cervicolor*) were examined (Table 5.3). The following blood parasites species were found: *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. in *M. surifer* (N=181, 74.18%) and *R. rattus* (N=14, 33.33%); *Microfilaria* sp. and *Trypanosoma* sp. in *L. sabanus* (N=14, 100.00%); *Microfilaria* sp., *Trypanosoma* sp. and *Anaplasma* sp. in *T. glis* (N=18, 36.00%).

Table 5.3 Summary of blood parasites found in small mammal species examined in Sakearat Environmental Research Station.

Host species	Location	Prevalence examination/infection (% infection)	Parasite
Maxomys surifer	DD, ECO,DE	244 / 181 (74.18)	*Microfilaria* sp. *Trypanosoma* sp. *Anaplasma* sp. *Grahamella* sp.
Rattus rattus	DD, ECO,DE	42 / 14 (33.33)	*Microfilaria* sp. *Trypanosoma* sp. *Anaplasma* sp. *Grahamella* sp.
Leopoldamys sabanus	ECO, DE	14 / 14 (100.00)	*Microfilaria* sp. *Trypanosoma* sp.
Tupia glis	DD, ECO,DE	50 / 18 (36.00)	*Microfilaria* sp. *Anaplasma* sp. *Grahamella* sp.
Callosciurus finlaysoni	ECO, DE	9 / 0	-
Callosciurus erythraeus	DD, ECO,DE	7 / 0	-
Herpestes javanicus	DD	3 / 0	-
Lepus peguensis	DD	1 / 0	-
Mus cervicolor	DE	1/ 0	-
Total		**371 /227 (61.19)**	

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

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

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

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

The prevalence of blood parasites founded in four most common species of small mammals is shown in Table 5.4.

Table 5.4 Prevalence of blood parasites found in four most common species of small mammals captured in Sakearat Environmental Research Station varied by habitats.

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

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

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

5.4.2 Prevalence of Parasitics found in Yellow Rajah Rat (*Maxomys surifer*)

5.4.2.1 Prevalence of Ectoparasites and Pseudoscorpion of Yellow Rajah Rat (*Maxomys surifer*)

The prevalence of mite (*Laelaps echidinus*) found in *M. surifer* was not different among seasons in each habitat types. The mean prevalence of mite was not different (50.00 ± 10.87%) in the late rainy season between DD and ECO forest. The lowest (21.67 ± 15.00%) was found in winter in DE forest (Figure 5.2).

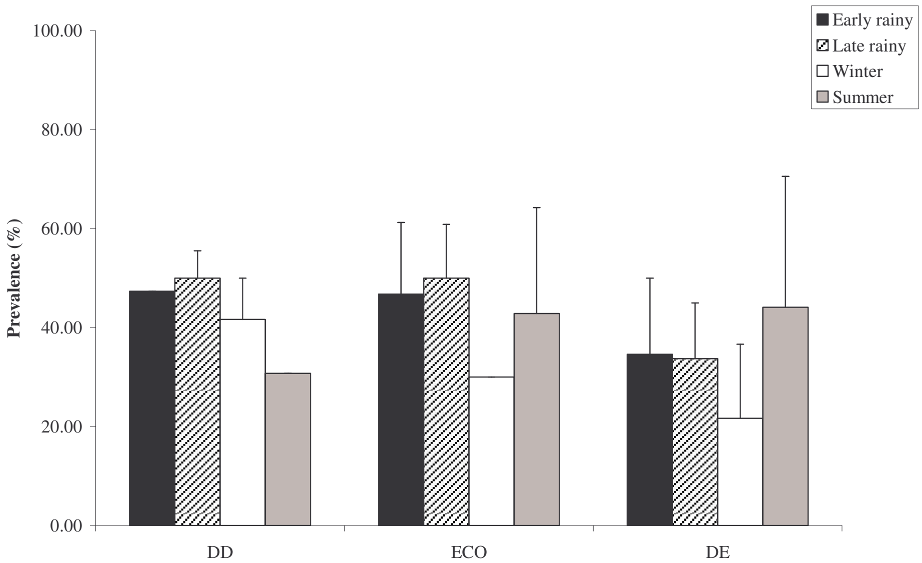


Figure 5.2 Mean prevalence of mite (*Laelaps echidinus*) found in *M. surifer* in different seasons and habitat types.

The prevalence of flea (*Xenopsylla cheopsis*) found in *M. surifer* varied among seasons in each habitat types. The mean prevalence of flea was the highest (35.71 ± 28.57) in the summer in ECO forest, and was lowest (6.67%) in winter in DE forest (Figure 5.3).

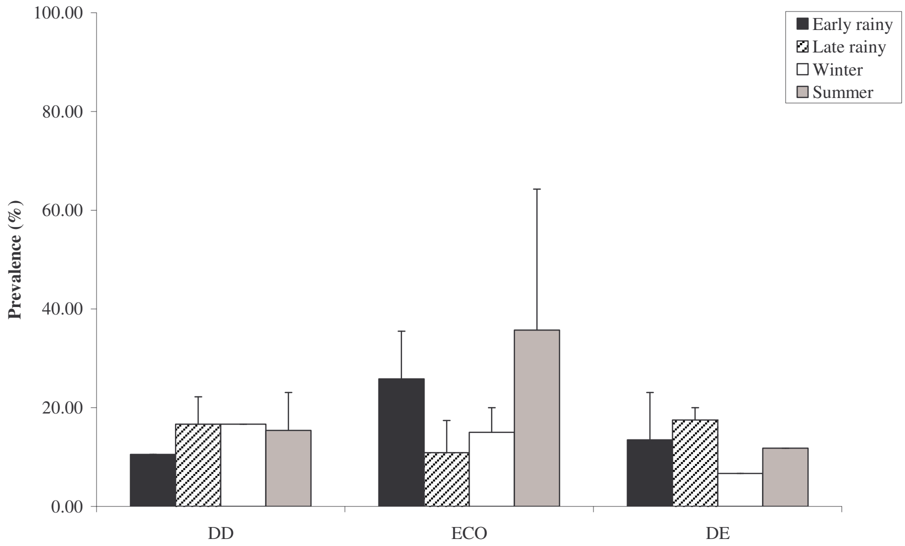


Figure 5.3 Mean prevalence of flea (*Xenopsylla cheopsis*) found in *M. surifer* in different seasons and habitat types.

The prevalence of tick (*Ixodes* sp.) found in *M. surifer* varied among seasons in each habitat types. The mean prevalence of tick was highest (11.11%) in the late rainy season in DD forest, and was lowest (4.35%) in the late rainy season in ECO forest (Figure 5.4).

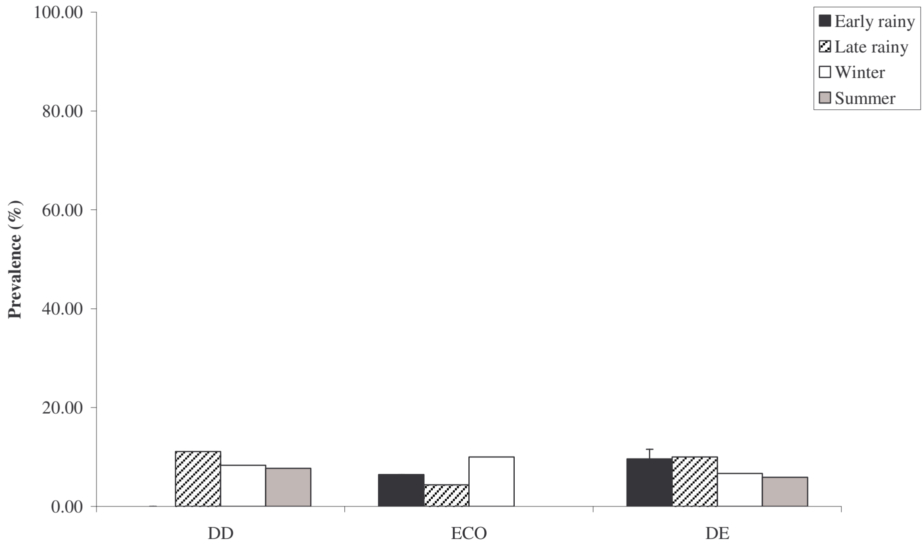


Figure 5.4 Mean prevalence of tick (*Ixodes* sp.) found in *M. surifer* in different seasons and habitat types.

The prevalence of pseudoscorpion (*Chelifer cancroides*) found in *M. surifer* varied among seasons in each habitat types. The mean prevalence of pseudoscorpion was highest (20.00%) in winter in ECO forest, and was lowest (7.14%) in summer in ECO forest (Figure 5.5).

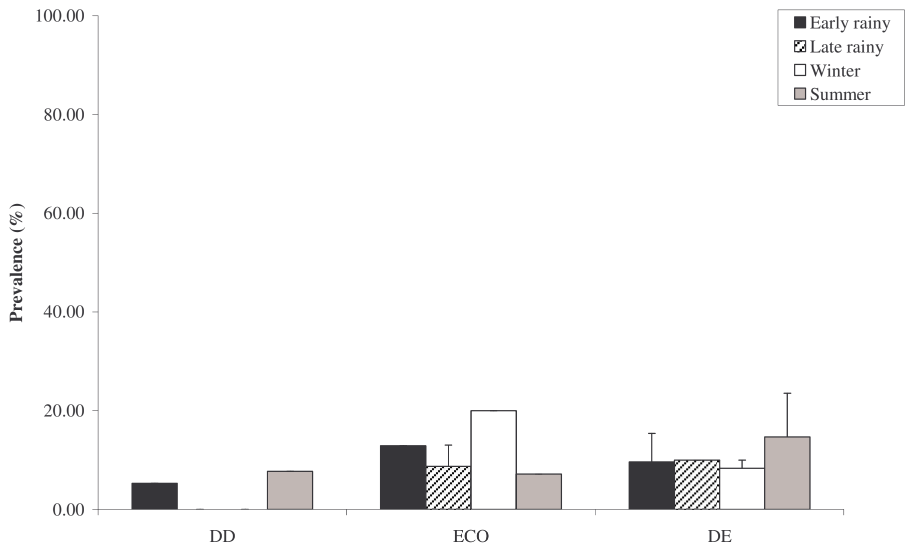


Figure 5.5 Mean prevalence of pseudoscorpion (*Chelifer cancroides*) found in *M. surifer* in different seasons and habitat types.

The relationship between seasons and the prevalence of ectoparasite species and pseudoscorpion: mite (*Laelaps echidinus*), flea (*Xenopsylla cheopsis*), tick (*Ixodes* sp.) and pseudoscorpion (*Chelifer cancroides*) revealed that the prevalence of mite (*Laelaps echidinus*) was significantly different (χ^2 = 17.535, df = 3, P<0.01). For other ectoparaqsite species and pseudoscorpion, there were not significant different (P>0.05).

5.4.2.2 Prevalence of Ectoparasites and Pseudoscorpion of Yellow Rajah Rat (*Maxomys surifer*) Varied by Sex, Age and Habitat Types.

Mite (*Laelaps echidinus*)

In DD forest, the prevalence of mite (*Laelaps echidinus*) found in adult males was greater (41.30 ± 2.17%) than in adult females (37.50 ± 6.25%), but equally in sub adult and juvenile (50.00 ± 12.50%, 100.00%) both males and females. In ECO forest, the prevalence of mite (*Laelaps echidinus*) found in females was greater than in adult males (50.00 ± 15.13% and 40.38 ± 11.54%). This was also the case for sub adult females (46.43 ± 16.96%) and male (41.67 ± 14.58%). However, there was no different in juvenile males and females (50.00 ± 14.81, 9.38%). For DE forest, the prevalence of mite (*Laelaps echidinus*) found in adult male was greater (34.29 ± 2.86%) than in adult females (33.33 ± 0.00, whereas in sub adult the prevalence in females was greater (36.96 ± 2.17%) than in males (25.00 ± 1.92%). However, the prevalence in juvenile was equally in both sexes (50.00%) (Figure 5.6).

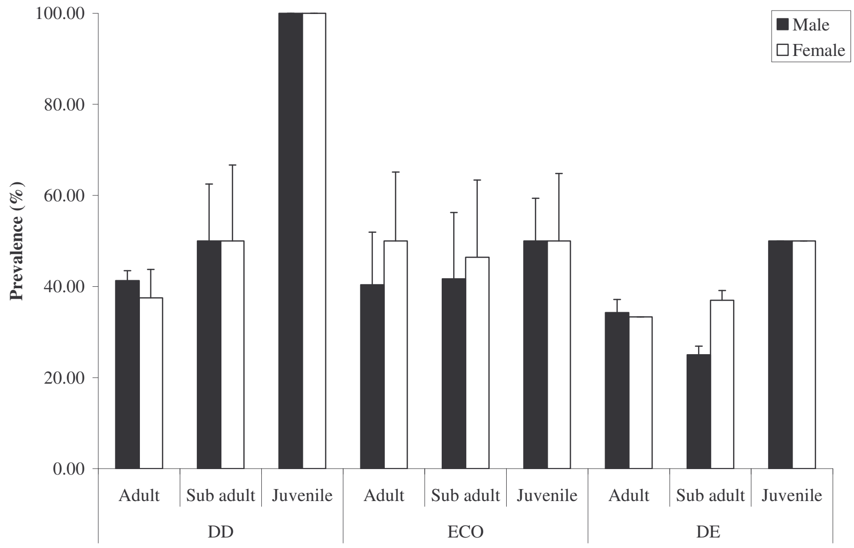


Figure 5.6 Mean prevalence of mite (*Laelaps echidinus*) found in *M. surifer* in different sex, age and habitat types.

Flea (*Xenopsylla cheopsis*)

In DD forest, the prevalence of flea (*Xenopsylla cheopsis*) found in adult males (17.39 ± 4.35%) was greater than in adult females (12.50%), whereas the prevalence found in sub adult females was greater (33.33%) than in sub adult males (25.00%). In ECO forest, the prevalence of flea (*Xenopsylla cheopsis*) found in adult males (28.85 ± 8.65%) was greater than in adult females (21.05 ± 9.21%), whereas the prevalence found in sub adult and juvenile females (25.00 ± 11.11% and 33.33%) were greater than in sub adult and juvenile males (8.33 ± 11.46% and 25.00%). For DE forest, the prevalence of flea (*Xenopsylla cheopsis*) found in adult females (11.90 ± 2.38%) was greater than in adult males (10.00 ± 4.29%), whereas the prevalence found in sub adult and juvenile males (19.23 ± 3.85 and 50.00%) were greater than in sub adult and juvenile females (10.87 ± 6.52 and 16.67%) (Figure 5.7).

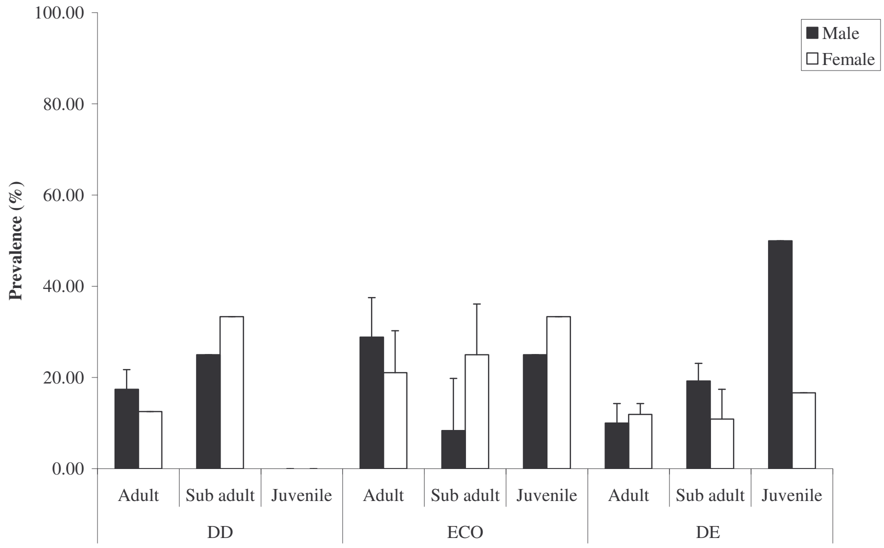


Figure 5.7 Mean prevalence of flea (*Xenopsylla cheopsis*) found in *M. surifer* in different sex, age and habitat types.

Tick (*Ixodes* sp.)

In DD forest, the prevalence of tick (*Ixodes* sp.) found in adult females (12.50%) was greater than in adult males (4.35%). In ECO forest, the prevalence of tick (*Ixodes* sp.) was only found in adult males (3.85%), whereas the prevalence found in sub adult males (8.33%) was greater than in sub adult females (7.14%). For DE forest, the prevalence of tick (*Ixodes* sp.) found in adult and sub adult males (11.43 and 11.54%) was greater than in adult and sub adult females (Figure 5.8).

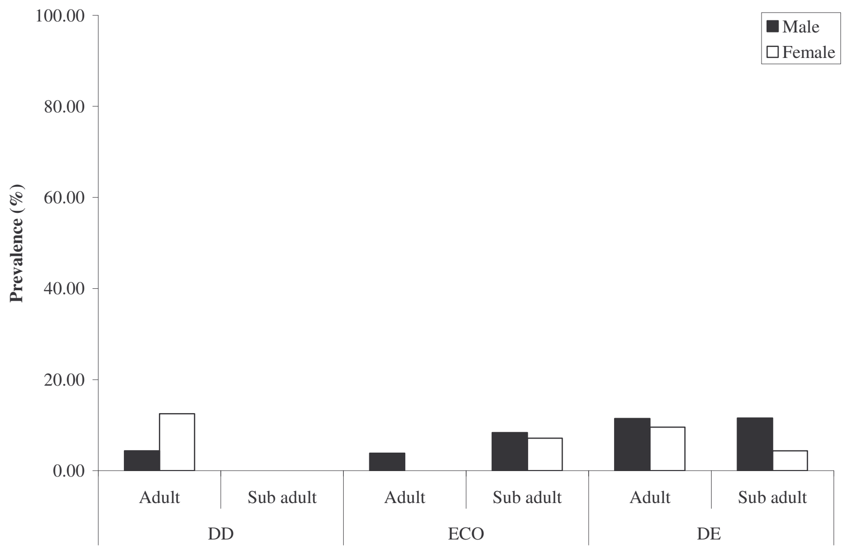


Figure 5.8 Mean prevalence of tick (*Ixodes* sp.) found in *M. surifer* in different sex, age and habitat types.

Pseudoscorpion (*Chelifer cancroides*)

In DD forest, the prevalence of pseudoscorpion (*Chelifer cancroides*) was only found in adult females (6.25%) and in sub adult males (12.50%). In ECO forest, the prevalence of pseudoscorpion (*Chelifer cancroides*) found in adult females (13.16 ± 11.16%) was greater than in adult males (11.54%), whereas the prevalence found in sub adult males (16.67%) was greater than in sub adult females (7.14%). For DE forest, the prevalence of pseudoscorpion (*Chelifer cancroides*) found in adult and sub adult males (12.86 and 11.54%) was greater than in adult and sub adult females (9.52 and 4.35%), However, the prevalence in (50.00%) was equally in both sexes (Figure 5.9).

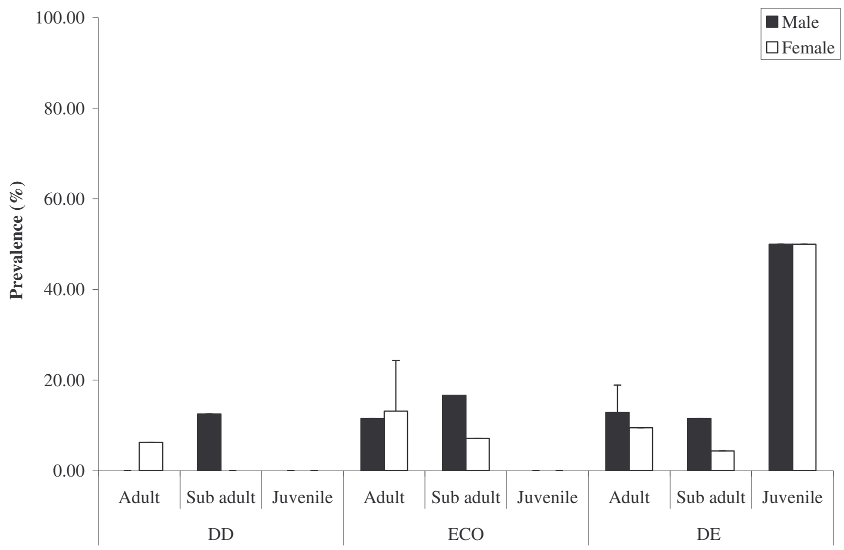


Figure 5.9 Mean prevalence of pseudoscorpion (*Chelifer cancroides*) found in *M. surifer* in different sex, age and habitat types.

The relationship between sex and age of *M. surifer* and the prevalence with ectoparasite species and pseudoscorpion found that the prevalence of mite was only significant different in adult of females (χ^2 = 8.817, df = 3, $P<0.05$), while other species were not significant different ($P>0.05$).

5.4.2.3 Prevalence of Blood Parasites of Yellow Rajah Rat (*Maxomys surifer*)

***Microfilaria* sp.**

The peak of *Microfilaria* sp. prevalence in *M. surifer* occurred in the early rainy season in ECO forest. The highest prevalence of *Microfilaria* sp. (22.58%) was found in the early rainy season in ECO forest, whereas the lowest prevalence (2.50%) was found in the late rainy season in DE forest (Figure 5.10).

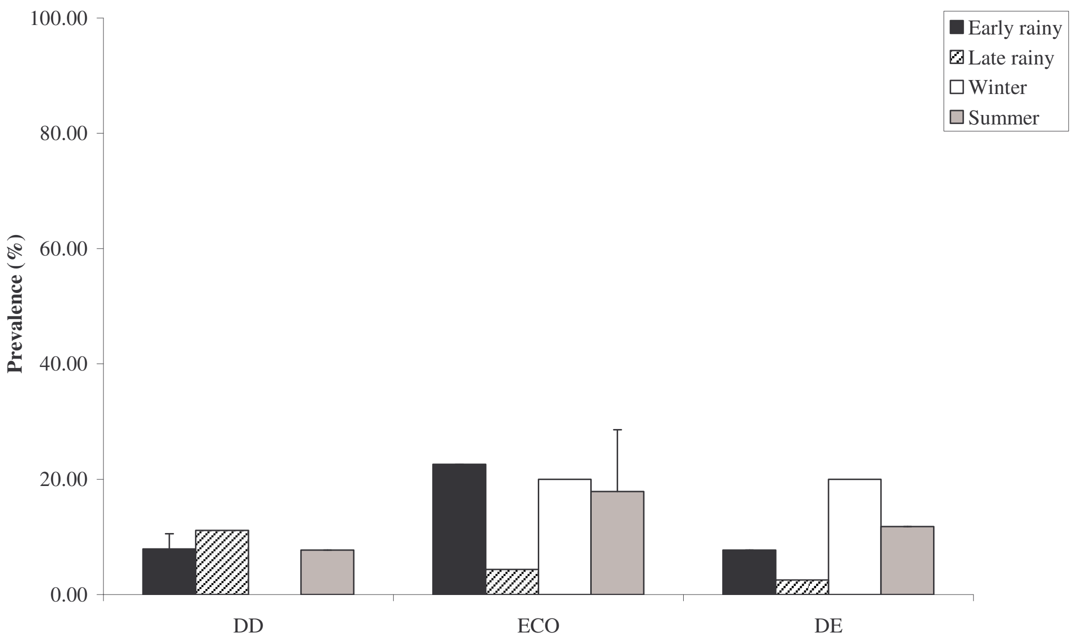


Figure 5.10 Mean prevalence of *Microfilaria* sp. found in *M. surifer* in different seasons and habitat types.

***Trypanosoma* sp.**

The peak of *Trypanosoma* sp. prevalence in *M. surifer* occurred in the late rainy season in DD forest. The highest prevalence of *Trypanosoma* sp. (22.22%) was found in the late rainy season in DD forest, whereas the lowest prevalence (5.77 ± 1.92%) was found in the early rainy season in DE forest (Figure 5.11).

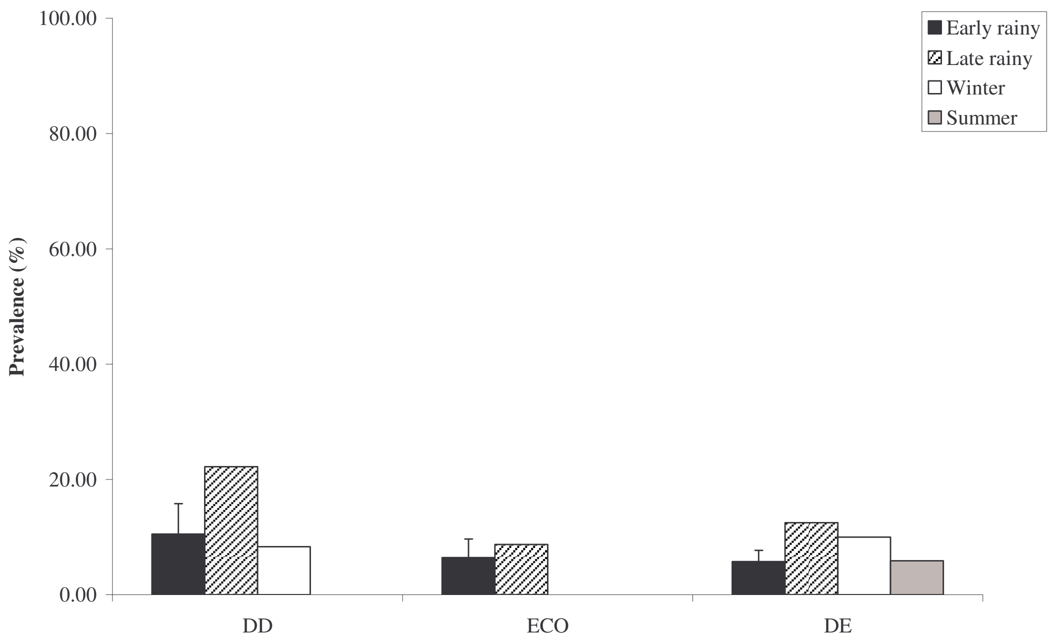


Figure 5.11 Mean prevalence of *Trypanosoma* sp. found in *M. surifer* in different seasons and habitat types.

***Anaplasma* sp.**

The peak of *Anaplasma* sp. prevalence in *M. surifer* occurred in the early rainy season in DD forest. The highest prevalence of *Anaplasma* sp. (36.84 ± 10.53%) was found in the early rainy season in DD forest, whereas the lowest prevalence (17.86 ± 10.71%) was found in the early rainy season in ECO forest (Figure 5.12).

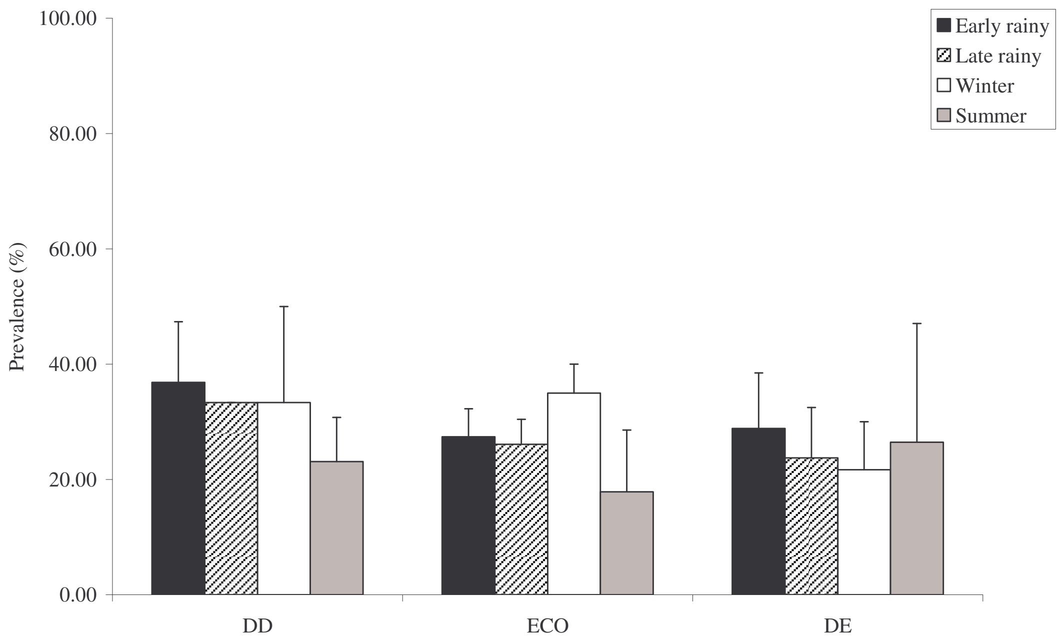


Figure 5.12 Mean prevalence *Anaplasma* sp. found in *M. surifer* in different seasons and habitat types.

***Grahamella* sp.**

The peak of *Grahamella* sp. prevalence in *M. surifer* occurred in the summer in DE forest. The highest prevalence of *Grahamella* sp. (47.06 ± 29.41%) was found in the summer in DD forest, whereas the lowest prevalence (18.75 ± 4.35%) was found in the late rainy season in ECO forest (Figure 5.13).

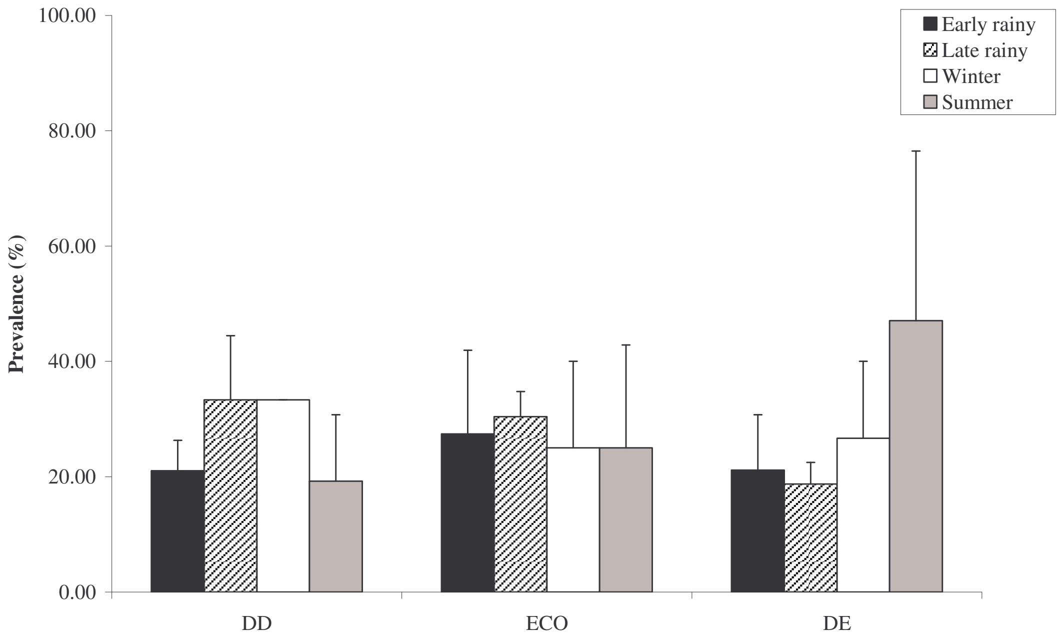


Figure 5.13 Mean prevalence of *Grahamella* sp. found in *M. surifer* in different seasons and habitat types.

The relationship between seasons and the prevalence infection with blood parasite species: *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. revealed *Microfilaria* sp. was significant different (χ^2 = 8.768, df = 3, P<0.05). For other blood parasite species, there were not significant different (P>0.05).

5.4.2.4 Prevalence of Blood Parasites of Yellow Rajah Rat (*Maxomys surifer*) Varied by Sex, Age and Habitat Types.

***Microfilaria* sp.**

In DD forest, the prevalence of *Microfilaria* sp. was greater in adult females (12.50%) than in adult males (8.70%). In ECO forest, the prevalence of *Microfilaria* sp. was greater in adult males than adult females (26.92 ± 5.77% and 5.26%). This was also the case for animals sub adult (25.00 ± 4.17% and 21.43%) whereas it was only found in juvenile females (33.33%). For DE forest, the prevalence of *Microfilaria* sp. was greater in adult females (14.29%) than in adult males (11.43 ± 5.71%), whereas it was only found in sub adult females (6.52 ± 2.17%) (Figure 5.14).

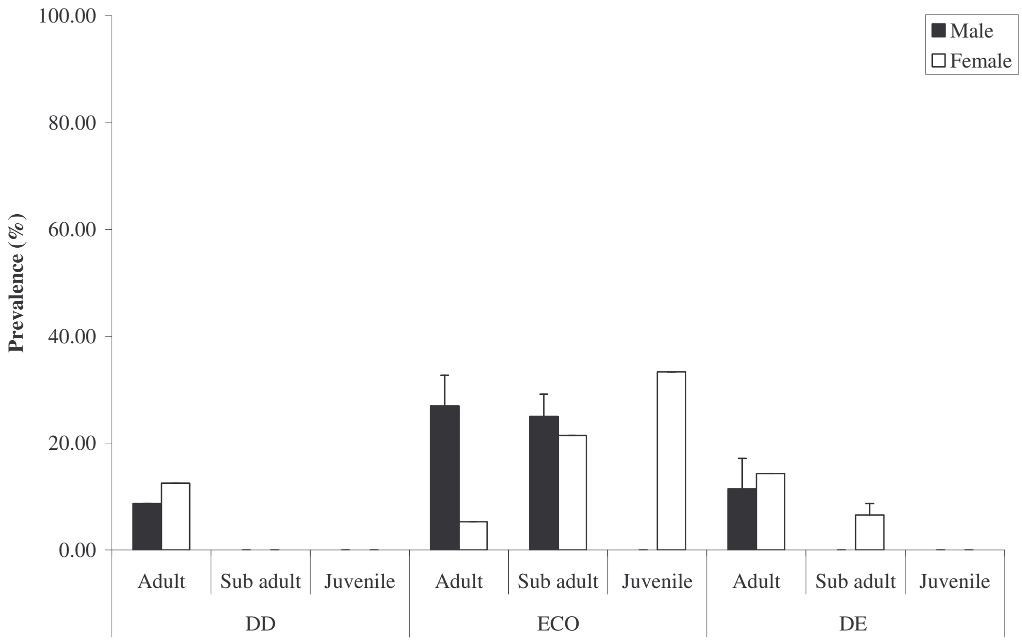


Figure 5.14 Mean prevalence of *Microfilaria* sp. found in *M. surifer* in different sex, age and habitat types.

***Trypanosama* sp.**

In DD forest, the prevalence of *Trypanosama* sp. was greater in adult males (8.70%) than in adult females (6.25%), whereas it was greater in sub adult females (33.33%) than sub adult males (25.00%). In ECO forest, the prevalence of *Trypanosama* sp. was greater in adult females (10.53%) than in adult males (3.85%), whereas it was greater in sub adult males (25.00%) than in sub adult females (14.29%). For DE forest, the prevalence of *Trypanosama* sp. was greater in adult females than in adult males (9.52 and 4.29%), it was also the case for sub adult animals (10.87 and 3.85%) (Figure 5.15).

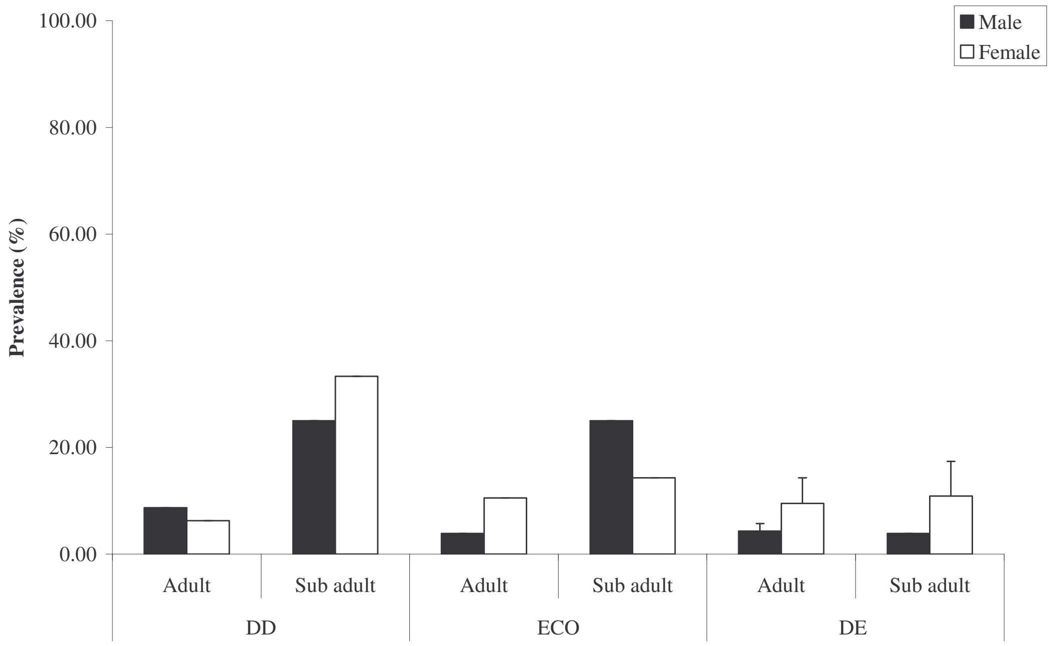


Figure 5.15 Mean prevalence of *Trypanosama* sp. found in *M. surifer* in different seasons and habitat types.

***Anaplasma* sp.**

In DD forest, the prevalence of *Anaplasma* sp. was greater in adult females (34.38 ± 3.13%) than in adult males (23.91 ± 2.17%), whereas it was greater in sub adult males (43.75 ± 6.25%) than in sub adult females (33.33%), and it was also the case for juvenile animals (100.00%). In ECO forest, the prevalence of *Anaplasma* sp. was greater in adult males (65.38 ± 5.77%) than in adult females (47.37 ± 2.63%), whereas it was greater in sub adult females than in sub adult males (42.86 ± 14.29% and 33.33 ± 8.66%) and was greater in juvenile females than in juvenile males (100.00 ± 16.67% and 50.00%). For DE forest, the prevalence of *Anaplasma* sp. was greater in adult males (30.00 ± 1.43%) than in adult females (26.19 ± 2.38%), whereas it was greater in sub adult females (21.74%) than sub adult males (19.23%), whereas it was only found in juvenile females (33.33 ± 16.67%) (Figure 5.16).

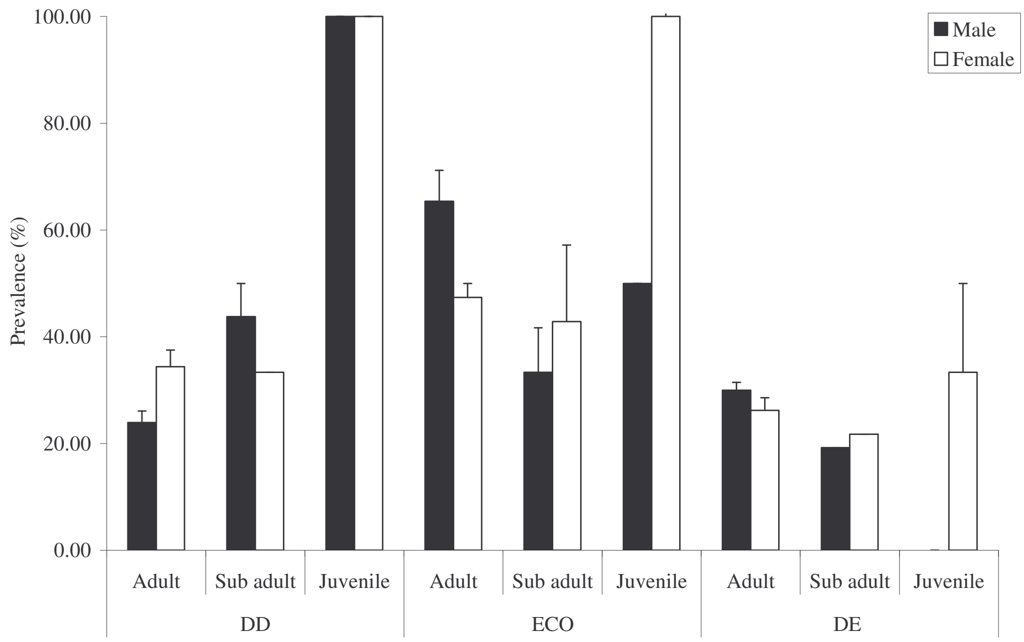


Figure 5.16 Mean prevalence of *Anaplasma* sp. found in *M. surifer* in different by seasons and habitat types.

***Grahamella* sp.**

In DD forest, the prevalence of *Grahamella* sp. was greater in adult females than in adult males (28.13 ± 3.13% and 23.91 ± 6.52%), also was in sub adult in both sexes (33.33 and 31.25 ± 6.25%). In ECO forest, the prevalence of *Grahamella* sp. was greater in in adult males than in adult females (64.54 ± 3.85% and 52.63 ± 10.53%), also was in sub adult in both sexes (75.00 ± 12.50% and 57.14 ± 14.29%). For DE forest, the prevalence of *Grahamella* sp. was greater in in adult females than in adult males (35.71 ± 34.29% and 34.29 ± 2.86%), also was in sub adult in both sexes (19.57 ± 6.52% and 17.31 ± 1.92%), whereas it was only found in juvenile males (50.00%) (Figure 5.17).

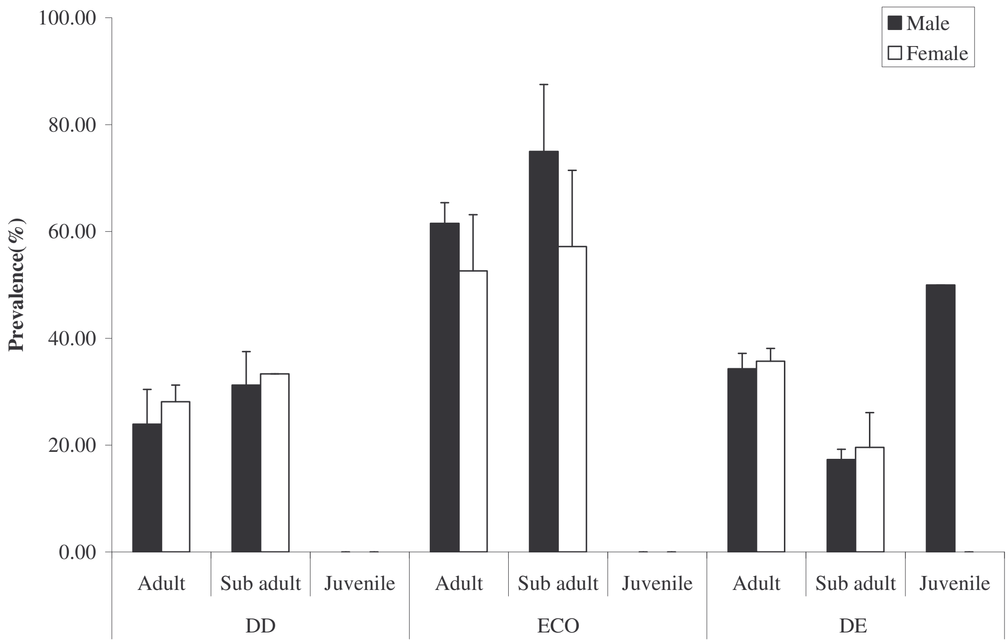


Figure 5.17 Mean prevalence of *Grahamella* sp. found in *M. surifer* in different seasons and habitat types.

The relationship between sex and age of *M. surifer* and the infection of *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. were not reach statistic differences (*P*>0.05). The relationship between mixed infection with *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. revealed that *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. was significantly correlated with *Grahamella* sp. (r^2 = 0.179, r^2 = 0.188 and r^2 = 0.317).

5.4.2.5 Relationship of The Prevalence between Ectoparasites Species, Pseudoscorpion and Blood Parasite Species of *Maxomys surifer*

The prevalence relationship between ectoparasite species, pseudoscorpion and blood parasite species was significant greatest between tick (*Ixodes* sp.) and *microfilaria* sp. (χ^2 = 4.665, df = 1, *P*<0.05), followed by between flea (*Xenopsylla cheopsis*) and *microfilaria* sp. (χ^2 = 4.043, df = 1, *P*<0.05) found in *M. surifer*. For the relationship of other ectoparasite species and blood parasite species infected in *M. surifer* did not significant different (*P*>0.05). The chi-square test relationship between ectoparasite species and blood parasite species are shown in Table 5.5.

Table 5.5 Test statistic and associated *P* values for the relationship between ectoparasite species, pseudoscorpion and blood parasite species in *M. surifer*.

Ectoparasite species	**Blood parasite species**	χ^2	**df**	***P***
Mite (*Laelaps echidinus*)	*Microfilaria* sp.	0.779	1	0.377
	Trypanosoma sp.	0.041	1	0.839
	Anaplasma sp.	3.429	1	0.064
	Grahamella sp.	1.060	1	0.303
Flea (*Xenopsylla cheopsis*)	*Microfilaria* sp.	4.043	1	0.044
	Trypanosoma sp.	0.308	1	0.579
	Anaplasma sp.	0.003	1	0.957
	Grahamella sp.	0.058	1	0.810
Tick (*Ixodes* sp.)	*Microfilaria* sp.	4.665	1	0.031
	Trypanosoma sp.	0.008	1	0.931
	Anaplasma sp.	3.756	1	0.053
	Grahamella sp.	0.002	1	0.961
Pseudoscorpion (*Chelifer cancroides.*)	*Microfilaria* sp.	1.242	1	0.265
	Trypanosoma sp.	1.457	1	0.227
	Anaplasma sp.	0.014	1	0.906
	Grahamella sp.	0.102	1	0.749

5.4.2.6 Intensity of Blood Parasites of Yellow Rajah Rat (*Maxomys surifer*) Varied by Habitat Types, Seasonal, Sex and Age

Intensity of blood parasites infected per 100 erythrocyte of *M. surifer* in all habitat types varied by seasonal, sex and age were described as follow;

DD forest

Microfilaria sp., mean intensity ranged from 1.00-2.50 infected per 100 erythrocytes. *Trypanosoma* sp., mean intensity ranged from 1.00-3.00 infected erythrocytes per 100 erythrocytes. *Anaplasma* sp., mean intensity ranged from 2.25-16.00 infected erythrocytes per 100 erythrocytes. For *Grahamella* sp., mean intensity ranged from 2.33-23.80 infected erythrocytes per 100 erythrocytes (Table 5.6).

ECO forest

Microfilaria sp., mean intensity ranged from 1.00-10.00 infected per 100 erythrocytes. *Trypanosoma* sp., mean intensity ranged from 1.00-12.00 infected erythrocytes per 100 erythrocytes. *Anaplasma* sp., mean intensity ranged from 3.00-18.50 infected erythrocytes per 100 erythrocytes. For *Grahamella* sp., mean intensity ranged from 5.00-41.00 infected erythrocytes per 100 erythrocytes (Table 5.7).

DE forest

Microfilaria sp., mean intensity ranged from 1.00-15.00 infected per 100 erythrocytes. *Trypanosoma* sp., mean intensity ranged from 1.00-24.25 infected erythrocytes per 100 erythrocytes. *Anaplasma* sp., mean intensity ranged from 1.00-28.00 infected erythrocytes per 100 erythrocytes. For *Grahamella* sp., mean intensity ranged from 4.50-30.00 infected erythrocytes per 100 erythrocytes (Table 5.8).

The correlation between habitat types, seasonal, sex and age with intensity infected with blood parasite species revealed that age was significant correlated with intensity infected with *Trypanosoma* sp. ($r^2 = 0.321$). Intensity of infection with all blood parasite species did not vary significant through combined for habitat types, seasonal, sex and age (*Microfilaria* sp., $F = 0.781$, df=1, $P = 0.391$; *Trypanosoma* sp., $F = 0.207$, df=1, $P = 0.654$; *Anaplasma* sp., $F = 0.003$, df=1, $P = 0.957$; *Grahamella* sp., $F = 1.307$, df=1, $P = 0.257$).

Table 5.6 Intensity of blood parasite infected of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean intensity ± SE							
				No.	*Microfilaria* sp. (N)	No.	*Trypanosoma* sp. (N)	No.	*Anaplasma* sp. (N)	No.	*Grahamella* sp. (N)
DD	Early rainy season	M	Adult	2	1.00 ± 0.00	-	-	3	7.00 ± 1.00	2	12.50 ± 7.78
			Sub adult	-	-	1	1.00	3	9.33 ± 1.15	1	7.00
			Juvenile	-	-	-	-	1	4.00	-	-
		F	Adult	1	2.00	2	3.00 ± 2.83	4	6.25 ± 2.87	3	7.33 ± 5.51
			Sub adult	-	-	1	1.00	2	7.50 ± 0.71	2	3.00 ± 2.83
			Juvenile	-	-	-	-	1	10.00	-	
	Late rainy season	M	Adult	-	-	1	1.00	1	16.00	1	19.00
			Sub adult	-	-	1	3.00	2	7.50 ± 3.54	2	13.00 ± 2.83
		F	Adult	1	2.00	-	-	2	3.00 ± 0.00	3	10.00 ± 0.00
			Juvenile	-	-	-	-	1	4.00	-	-
	Winter	M	Adult	-	-	1	1.00	4	2.25 ± 1.26	5	23.80 ± 12.77
			Sub adult	-	-	-	-	2	5.00 ± 2.66	2	6.00 ± 5.66
		F	Adult	-	-	-	-	2	6.00 ± 1.41	1	7.00
	Summer	M	Adult	2	2.5 ± 0.71	-	-	3	13.00 ± 4.00	3	2.33 ± 1.31
		F	Adult	-	-	-	-	3	10.00 ± 4.36	2	18.50 ± 7.78

Table 5.7 Intensity of blood parasite infected of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean intensity ± SE							
				No.	*Microfilaria* sp. (N)	No.	*Trypanosoma* sp. (N)	No.	*Anaplasma* sp. (N)	No.	*Grahamella* sp. (N)
ECO	Early rainy season	M	Adult	2	2.50 ± 0.71	-	-	8	8.75 ± 4.62	7	9.14 ± 8.25
			Sub adult	2	1.50 ± 0.71	1	1.00	1	3.00	2	5.00 ± 1.41
			Juvenile	-	-	-	-	1	5.00		
		F	Adult	-	-	1	4.00	2	4.50 ± 1.54	2	26.00 ± 13.94
			Sub adult	2	1.50 ± 0.71	2	4.00 ± 2.83	3	8.33 ± 2.52	6	22.67 ± 9.95
			Juvenile	1	1.00	-	-	2	4.00 ± 1.24		
	Late rainy season	M	Adult	1	9.00	1	12.00	1	6.00	1	16.00
			Sub adult	-	-	3	2.33 ± 1.53	2	4.50 ± 1.95	4	8.00 ± 4.97
			Juvenile	-	-	1	10.00	1	7.00		
		F	Adult	-	-	1	17.00	4	12.50 ± 9.57	4	11.25 ± 6.50
			Sub adult	1	1.00	-	-	3	3.67 ± 2.52	2	41.00 ± 25.15
			Juvenile	-	-	-	-	-			
	Winter	M	Adult	1	2.00	-	-	2	4.50 ± 1.95	2	5.50 ± 2.95
			Sub adult	2	10.00 ± 5.31	2	2.50 ± 0.71	-	-	1	5.00
			Juvenile	1	3.00	-	-	-	-	-	-
	Summer	M	Adult	4	1.25 ± 0.50	-	-	3	10.00 ± 6.24	5	8.20 ± 3.01
		F	Adult	1	2.00	-	-	2	18.50 ± 4.85	2	13.00 ± 9.90

Table 5.8 Intensity of blood parasite infected of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean intensity ± SE							
				No.	*Microfilaria* sp. (N)	No.	*Trypanosoma* sp. (N)	No.	*Anaplasma* sp. (N)	No.	*Grahamella* sp. (N)
DE	Early rainy season	M	Adult	1	4.00	1	3.00	2	4.50 ± 1.95	2	4.50 ± 0.71
			Sub adult	2	15.00 ± 6.73	1	3.00	2	8.50 ± 2.12	1	5.00
		F	Adult	2	4.00 ± 2.24	1	7.00	3	6.67 ± 3.06	3	10.33 ± 8.50
			Sub adult	1	8.00	2	2.00 ± 0.00	3	7.33 ± 2.31	2	22.00 ± 15.46
			Juvenile	-	-	-	-	1	1.00	-	-
	Late rainy season	M	Adult	1	5.00	5	3.00 ± 1.41	2	4.00 ± 2.24	1	8.00
			Sub adult	1	5.00	4	24.25 ± 19.27	7	28.00 ± 6.30	5	15.20 ± 11.95
			Juvenile	-	-	-	-	-	-	1	8.00
		F	Adult	-	-	2	2.00 ± 0.00	2	5.00	3	27.67 ± 12.68
			Sub adult	-	-	4	3.50 ± 3.00	2	7.00 ± 3.49	2	30.00 ± 11.11
	Winter	M	Adult	3	2.00 ± 1.00	2	3.00 ± 2.83	7	7.43 ± 5.80	9	16.11 ± 10.16
			Sub adult	-	-	1	3.00	1	5.00	-	-
		F	Adult	1	1.00	-	-	1	16.00	2	20.00 ± 14.14
			Sub adult	2	1.50 ± 0.71	2	2.50 ± 0.71	2	8.50 ± 4.95	3	12.33 ± 2.66
			Juvenile	-	-	2	9.50 ± 2.12	1	20.00	-	-
	Summer	M	Adult	2	1.50 ± 0.71	-	-	4	10.25 ± 5.44	9	15.56 ± 9.81
		F	Adult	1	2.00	2	1.00 ± 0.00	3	15.00 ± 6.24	5	13.20 ± 5.93
			Sub adult	1	5.00	-	-	2	11.50 ± 4.95	2	17.50 ± 6.36

5.4.2.7 Blood Values of Yellow Rajah Rat (*Maxomys surifer*) Varied by Habitat Types, Seasonal, Sex and Age

Blood values obtained from *M. surifer* in three habitat types. Sex and age classes were combine for habitat types and seasonal comparison. Significant of habitat types and seasonal difference were detected for RBC, Hct, glucose, triglycerides, WBC and differential count of leucocytes (nuetrophil, lymphocyte, monocyte and eosinophil) (Table 5.9-5.16). The results were described as follow;

DD forest

Mean of RBC was the highest (6.69 ± 0.80 10^6/µl) in adult females in the winter, and was the lowest (2.80 ± 0.00 10^6/µl) in juvenile females in the late rainy season. Mean of Hct was the highest (50.67 ± 2.66%) in adult male in the summer, and was the lowest (38.75 ± 4.50%) in sub adult females in the late rainy season. Mean of glucose was the highest (166.33 ± 7.77 mg/dl) in sub adults males in the early rainy season, and was the lowest (79.50 ± 23.57 mg/dl) in sub adult females in the winter. For the mean of triglyceride was the highest (147.20 ± 66.04 mg/dl) in adult females in the winter, and was the lowest (85.00 ± 0.00 mg/dl) in adult females in the summer (Table 5.9).

Mean WBC was the highest (10.59 ± 2.64 10^3/µl) in adult females in the early rainy season, and was the lowest (3.40 ± 0.00 10^3/µl) in juvenile females in the early rainy season (Table 5.12). Differential count of leucocytes, mean of neutrophil was the highest (48.50 ± 4.95%) in adult females in the winter, and was the lowest (8.00%) only one detected in juvenile female in the late rainy season. Lymphocyte was the highest (92.00%) only one detected in juvenile female in the late rainy season, and was the lowest (37.00%) only one detected in juvenile male in the early rainy season. Monocytes was the highest (2.00%) only one detected in adult female in the late rainy season. For mean of eosinophil was the highest (5.67 ± 3.21%) in adult females in the early rainy season, and was the lowest (1.00%) only one detected in adult male in the early rainy season (Table 5.14).

ECO forest

Mean of RBC was the highest (7.00 ± 0.72 10^6/µl) in adult females in the winter, and was the lowest (5.04 ± 0.62 10^6/µl) in adult females in the early rainy season. Mean of Hct was the highest (50.86 ± 3.48%) in adult male in the summer, and was the lowest (40.42 ± 1.53%) in adult females in the summer. Mean of glucose was the highest (139.00 ± 31.20 mg/dl) in juvenile females in the late rainy season, and was the lowest (69.62 ± 28.09 mg/dl) in adult males in the winter. For the mean of triglyceride was the highest (171.25 ± 69.88 mg/dl) in sub adult males in the winter, and was the lowest (71.67 ± 1.15 mg/dl) in adult females in the summer (Table 5.10).

Mean WBC was the highest (7.76 ± 2.63 10^3/µl) in adult females in the late rainy season, and was the lowest (4.30 10^3/µl) only one detected adult males in the summer (Table 5.12). Differential count of leucocytes, neutrophil was the highest (68.00%) only one detected juvenile males in the early rainy season, and was the lowest (14.00%) only one detected in juvenile female in the winter. Lymphocyte was the highest (86.00%) only one detected in juvenile female in the winter, and was the lowest (32.00%) only one detected in juvenile male in the early rainy season. Monocytes ranged from 1.00-2.00%. For eosinophil was the highest (8.00%) in adult males in the late rainy season, and was the lowest (1.00%) only one detected in sub adult female in the late rainy season (Table 5.15).

DE forest

Mean of RBC was the highest (7.58 ± 0.99 10^6/µl) in sub adult males in the winter, and was the lowest (4.84 10^6/µl) only one detected juvenile females in the late rainy season. Mean of Hct was the highest (49.64 ± 6.79%) in sub adult female in the early rainy season, and was the lowest (41.50 ± 3.85%) in adult females in the summer. Mean of glucose was the highest (181.67 ± 11.22 mg/dl) in juvenile females in the early rainy season, and was the lowest (87.27 ± 31.59 mg/dl) in sub adult females in the late rainy season. For the mean of triglyceride was the highest (149.00 ± 75.07 mg/dl) in sub adult males in the late rainy season, and was the lowest (80.33 ± 0.58 mg/dl) in sub adult males in the early rainy season (Table 5.11).

WBC was the highest (8.10 10^3/µl) in only one detected sub adult females in the summer, and the mean was the lowest (3.91 ± 2.29 10^3/µl) in sub adult males in the winter (Table 5.13). Differential count of leucocytes, mean of neutrophil was the highest (56.00 ± 16.33%) in sub adult males in the winter, and was the lowest (9.50 ± 7.78%) in sub adult females in the summer. Mean of lymphocyte was the highest (87.50 ± 6.36%) in sub adult females in the summer, and was the lowest (40.50 ± 21.48%) in sub adult males in the winter. Mean of monocytes was the highest (3.00 ± 1.41%) in sub adult females in the summer, and was the lowest (1.00 ± 0.00%) in sub adult males in the early rainy season. Eosinophil was the highest (6.00%) only one detected sub adult females in the late rainy season, and was the lowest (1.00%) only one detected adult male in the summer. For basophile was only one detected adult female (1.00%) in the summer (Table 5.16).

The correlation between habitat types, seasonal, sex and age with blood values revealed that habitat types was significant correlated with RBC (r^2 = 0.190). Seasonal was significantly correlated with RBC (r^2 = 0.306), Hct (r^2 = 0.219) and glucose (r^2 = -0.323). Sex was significantly correlated with RBC (r^2 = -0.278) and WBC (r^2 = 0.241). For age was significant correlated with glucose (r^2 = 0.232), triglycerides (r^2 = 0.316) and WBC (r^2 = -0.173) respectively. Blood values did not vary significant through combined for habitat types, seasonal, sex and age (P>0.05).

The correlation between blood parasite species found in *M.surifer* with blood values revealed that *Anaplasma* sp. was significant correlated with RBC (r^2 = -0.174). The correlation between intensity of blood parasite species with blood values revealed that intensity infected of *Microfilaria* sp. was significantly correlated with eosiniphil (r^2 = 0.691). *Trypanosoma* sp. was significantly correlated with monocyte (r^2 = 0.989). *Anaplasma* sp. was significant correlated with triglycerides (r^2 = 0.456). For *Grahamella* sp. was significant correlated with RBC (r^2 = 0.269).

Table 5.9 Blood values of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	No.	RBC (10^6/μl)	No.	Hct (%)	No.	Glucose (mg/dl)	No.	Triglycerides (mg/dl)
				Mean blood value ± SE							
DD	Early rainy season	Male	Adult	12	6.56 ± 0.61	19	49.42 ± 4.35	10	148.70 ± 18.37	5	107.00 ± 40.30
			Sub adult	3	5.78 ± 0.86	5	47.04 ± 4.24	3	166.33 ± 7.77	1	96.00
			Juvenile	4	5.62 ± 0.43	4	49.50 ± 3.00	4	162.25 ± 9.50	1	96.00
		Female	Adult	7	5.26 ± 0.31	14	45.50 ± 6.56	11	123.00 ± 21.50	6	110.67 ± 32.07
			Sub adult	1	6.27	4	41.00 ± 2.71	2	161.00 ± 0.00	-	-
			Juvenile	2	4.83 ± 0.00	2	50.00 ± 0.00	2	82.00 ± 0.00	-	-
	Late rainy season	Male	Adult	7	6.10 ± 1.85	13	45.15 ± 5.10	8	97.00 ± 26.65	4	104.75 ± 29.07
			Sub adult	5	5.77 ± 0.92	6	44.50 ± 0.77	4	145.00 ± 6.93	4	85.75 ± 8.38
			Juvenile	1	4.47	1	46.00	2	132.50 ± 53.03	-	-
		Female	Adult	7	6.06 ± 0.45	17	40.12 ± 6.66	8	99.00 ± 46.71	5	111.80 ± 50.68
			Sub adult	3	6.24 ± 0.75	4	38.75 ± 4.50	1	86.00	3	111.00 ± 36.37
			Juvenile	2	2.80 ± 0.00	3	44.33 ± 2.31	3	139.67 ± 26.56	-	-
	Winter	Male	Adult	13	6.28 ± 0.71	17	43.98 ± 3.97	21	132.14 ± 41.02	9	109.33 ± 29.98
			Sub adult	4	6.44 ± 0.17	6	43.33 ± 3.44	7	138.00 ± 35.92	2	87.00 ± 0.00
		Female	Adult	10	6.69 ± 0.80	10	43.75 ± 4.67	14	117.43 ± 42.29	5	147.20 ± 66.04
			Sub adult	3	6.52 ± 0.70	3	44.33 ± 3.79	4	79.50 ± 23.57	-	-
	Summer	Male	Adult	8	5.71 ± 0.64	6	50.67 ± 2.66	4	124.25 ± 2.87	1	96.00
		Female	Adult	3	6.08 ± 2.01	4	41.25 ± 8.02	3	115.00 ± 12.12	2	85.00 ± 0.00

Table 5.10 Blood values of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value ± SE							
				No.	RBC ($10^6/\mu l$)	No.	Hct (%)	No.	Glucose (mg/dl)	No.	Triglycerides (mg/dl)
ECO	Early rainy season	Male	Adult	16	5.84 ± 0.95	24	46.69 ± 3.60	15	129.47 ± 31.45	8	114.00 ± 44.85
			Sub adult	3	6.18 ± 0.22	6	42.28 ± 2.43	3	136.00 ± 6.93	-	-
			Juvenile	5	5.10 ± 0.26	5	46.80 ± 2.17	5	119.60 ± 44.75	3	152.33 ± 14.43
		Female	Adult	9	5.04 ± 0.62	16	43.88 ± 5.20	7	118.00 ± 30.87	3	151.67 ± 37.83
			Sub adult	10	5.54 ± 0.78	14	42.11 ± 4.86	6	116.83 ± 36.60	3	86.00 ± 19.08
			Juvenile	11	5.19 ± 0.53	11	45.36 ± 3.32	7	127.14 ± 52.48	7	102.43 ± 51.02
	Late rainy season	Male	Adult	16	5.86 ± 1.12	28	45.27 ± 3.40	18	100.06 ± 37.70	10	142.70 ± 96.32
			Sub adult	9	6.20 ± 0.67	19	44.71 ± 3.37	7	104.71 ± 34.33	3	79.33 ± 8.74
			Juvenile	2	6.94 ± 0.47	6	46.00 ± 2.61	1	102.00	3	87.67 ± 10.97
		Female	Adult	16	5.72 ± 0.65	28	43.50 ± 4.64	15	121.80 ± 29.25	12	104.75 ± 43.68
			Sub adult	15	6.25 ± 0.58	18	43.22 ± 6.50	8	128.38 ± 34.66	5	118.80 ± 25.86
			Juvenile	5	5.21 ± 1.71	11	43.68 ± 3.29	8	139.00 ± 31.20	5	83.00 ± 10.97
	Winter	Male	Adult	22	6.81± 0.85	22	44.75 ± 4.12	29	69.62 ± 28.09	8	156.63 ± 38.79
			Sub adult	7	6.80 ± 0.69	7	45.79 ± 3.53	9	86.22 ± 27.50	4	171.25 ± 89.88
		Female	Adult	9	7.00 ± 0.72	14	44.93 ± 2.97	17	103.94 ± 46.32	7	91.86 ± 50.90
			Sub adult	4	6.99 ± 0.56	8	45.94 ± 2.21	11	81.64 ± 34.74	3	161.67 ± 51.60
			Juvenile	2	6.72 0.00	2	41.50 ± 0.00	2	83.00 ± 0.00	2	122.00 ± 0.00
	Summer	Male	Adult	1	5.30	7	50.86 ± 3.48	4	119.25 ± 9.84	2	113.00 ± 28.28
		Female	Adult	2	5.50 ± 0.39	6	40.42 ± 1.53	4	105.25 ± 20.43	3	71.67 ± 1.15
			Sub adult	2	5.65 ± 1.48	3	42.80 ± 4.94	3	124.33 ± 13.61	1	136.00

Table 5.11 Blood values of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value ± SE							
				No.	RBC (10^6/µl)	No.	Hct (%)	No.	Glucose (mg/dl)	No.	Triglycerides (mg/dl)
DE	Early rainy season	Male	Adult	11	5.82 ± 1.54	15	43.63 ± 8.23	8	141.50 ± 49.25	1	86.00
			Sub adult	11	6.59 ± 0.62	13	46.50 ± 4.36	9	150.22 ± 17.58	3	80.33 ± 0.58
			Juvenile	1	7.12	1	49.00	1	156.00	-	-
		Female	Adult	12	5.29 ± 0.67	19	43.68 ± 7.20	9	114.67 ± 32.24	8	114.75 ± 33.26
			Sub adult	10	5.74 ± 0.47	14	49.64 ± 6.79	9	147.44 ± 21.59	5	87.40 ± 9.10
			Juvenile	5	5.77 ± 0.76	7	45.86 ± 5.18	6	181.67 ± 11.22	4	132.25 ± 91.22
	Late rainy season	Male	Adult	9	6.56 ± 0.88	26	43.58 ± 4.15	16	110.06 ± 29.34	2	83.50 ± 12.02
			Sub adult	15	6.38 ± 1.08	30	43.77 ± 3.52	11	125.36 ± 42.59	5	149.00 ± 75.07
			Juvenile	3	6.17 ± 0.73	9	45.06 ± 3.18	4	151.25 ± 21.70	2	90.50 ± 0.71
		Female	Adult	10	5.43 ± 1.08	23	43.37 ± 2.70	15	105.33 ± 31.75	12	121.17 ± 77.90
			Sub adult	16	5.14 ± 0.89	26	43.15 ± 4.27	11	87.27 ± 31.59	9	120.00 ± 52.61
			Juvenile	1	4.84	7	43.79 ± 1.29	3	97.67 ± 41.43	3	145.00 ± 70.67
	Winter	Male	Adult	20	6.54 ± 0.74	34	43.82 ± 3.73	27	107.33 ± 34.69	11	137.18 ± 42.62
			Sub adult	7	7.58 ± 0.99	13	43.88 ± 2.92	10	130.50 ± 29.39	3	107.33 ± 1.15
		Female	Adult	9	6.91 ± 0.28	20	44.20 ± 2.83	17	107.41 ± 33.83	6	108.67 ± 39.81
			Sub adult	4	7.12 ± 0.98	11	42.55 ± 1.56	6	113.83 ± 46.13	5	119.00 ± 39.03
			Juvenile	7	7.06 ± 0.39	8	41.88 ± 2.79	1	100.00	-	-
	Summer	Male	Adult	7	5.58 ± 0.66	12	44.71 ± 4.06	10	114.00 ± 27.66	1	115.00
		Female	Adult	4	5.62 ± 0.28	12	41.50 ± 3.85	4	101.00 ± 12.94	-	-
			Sub adult	1	6.13	3	42.17 ± 5.58	-	-	-	-

Table 5.12 White blood cell count of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	No.	WBC (10^3/µl)
DD	Early rainy season	M	Adult	12	5.64 ± 1.54
			Sub adult	3	5.03 ± 1.97
			Juvenile	4	7.00 ± 2.27
		F	Adult	7	10.59 ± 2.64
			Sub adult	1	4.20
			Juvenile	2	3.40 ± 0.00
	Late rainy season	M	Adult	7	4.81 ± 1.73
			Sub adult	5	7.94 ± 5.14
			Juvenile	1	5.70
		F	Adult	7	7.07
			Sub adult	3	5.17 ± 2.02
			Juvenile	2	4.10 ± 0.00
	Winter	M	Adult	13	5.55 ± 1.25
			Sub adult	4	5.30 ± 2.34
		F	Adult	10	6.70 ± 1.59
			Sub adult	3	5.00 ± 1.70
	Summer	M	Adult	8	5.07 ± 2.26
		F	Adult	3	4.97 ± 1.17
ECO	Early rainy season	M	Adult	16	6.24 ± 2.18
			Sub adult	3	5.23 ± 0.61
			Juvenile	5	6.50 ± 2.83
		F	Adult	9	6.21 ± 1.19
			Sub adult	10	5.73 ± 1.58
			Juvenile	11	6.75 ± 0.77
	Late rainy season	M	Adult	16	4.34 ± 1.50
			Sub adult	9	5.92 ± 1.39
			Juvenile	2	6.15 ± 1.20
		F	Adult	16	7.76 ± 2.63
			Sub adult	15	6.99 ± 3.63
			Juvenile	5	5.68 ± 2.56
	Winter	M	Adult	22	5.52 ± 1.89
			Sub adult	7	5.03 ± 1.81
		F	Adult	9	7.03 ± 2.27
			Sub adult	4	6.53 ± 1.40
			Juvenile	2	4.50 ± 0.00
	Summer	M	Adult	1	4.30
		F	Adult	2	6.45 ± 1.48
			Sub adult	2	6.53 ± 1.42

Table 5.12 White blood cell count of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station (Continued).

Habitat	**Season**	**Sex**	**Age**	**No.**	**WBC (10^3/µl)**
DE	Early rainy season	M	Adult	11	6.45 ± 2.70
			Sub adult	11	7.28 ± 1.36
			Juvenile	1	5.80
		F	Adult	12	5.98 ± 0.73
			Sub adult	10	6.22 ± 1.99
			Juvenile	5	5.98 2.33
	Late rainy season	M	Adult	9	4.72 ± 1.98
			Sub adult	15	4.33 ± 2.17
			Juvenile	3	6.53 ± 1.02
		F	Adult	10	7.49 ± 2.78
			Sub adult	16	7.58 ± 4.18
			Juvenile	1	7.50
	Winter	M	Adult	20	4.94 ± 2.01
			Sub adult	7	3.91 ± 2.29
		F	Adult	9	5.99 ± 3.41
			Sub adult	4	7.30 ± 3.23
			Juvenile	7	7.16 ± 4.11
	Summer	M	Adult	7	6.50 ± 1.11
		F	Adult	4	5.92 ± 1.78
			Sub adult	1	8.10

Table 5.13 Differential counts of leucocytes in percentage of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value							
				No.	Nuetrophil (%)	No.	Lymphocytes (%)	No.	Monocytes (%)	No.	Eosinophil (%)
DD	Early rainy season	M	Adult	4	46.50 ± 19.49	4	52.75 ± 18.75	1	2.00	1	1.00
			Sub adult	3	27.00 ± 3.00	3	73.00 ± 3.00	-	-	-	-
			Juvenile	1	63.00	1	37.00	-	-	-	-
		F	Adult	3	40.00 ± 28.00	3	54.33 ± 24.95	-	-	3	5.67 ± 3.21
			Sub adult	1	30.00	1	66.00	-	-	1	4.00
			Juvenile	1	30.00	1	70.00	-	-	-	-
	Late rainy season	M	Adult	1	33.00	1	65.00	-	-	1	2.00
			Sub adult	2	45.50 ± 16.26	2	53.00 ± 15.56	1	1.00	1	2.00
			Juvenile	-	-	-	-	-	-	-	-
		F	Adult	3	30.33 ± 11.15	3	68.67 ± 10.12	1	2.00	1	1.00
			Sub adult	1	35.00	1	65.00	-	-	-	-
			Juvenile	1	8.00	1	92.00	-	-	-	-
	Winter	M	Adult	4	52.75 ± 11.87	4	46.75 ± 11.64	-	-	1	2.00
			Sub adult	1	41.00	1	59.00	-	-	-	-
		F	Adult	2	48.50 ± 4.95	2	56.50 ± 12.02	-	-	-	-
			Sub adult	-	-	-		-	-	-	-
	Summer	M	Adult	4	47.00 ± 16.99	4	52.00 ± 17.80	2	1.00 ± 000	2	1.00 ± 0.00
		F	Adult	1	32.00	1	63.00	1	1.00	1	4.00

Table 5.14 Differential counts of leucocytes in percentage of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value							
				No.	Nuetrophil (%)	No.	Lymphocytes (%)	No.	Monocytes (%)	No.	Eosinophil (%)
ECO	Early rainy season	M	Adult	8	48.75 ± 16.76	8	50.13 ± 17.03	1	2.00	5	1.40 ± 0.55
			Sub adult	4	39.25 ± 14.17	4	57.25 ± 13.60	2	1.00 ± 0.00	4	3.00 ± 2.16
			Juvenile	1	68.00	1	32.00	-	-	1	4.00
		F	Adult	4	59.50 ± 14.62	4	39.50 ± 13.96	-	-	2	2.00 ± 0.00
			Sub adult	8	42.50 ± 15.43	8	56.25 ± 14.88	2	2.00 ± 0.00	4	2.75 ± 2.22
			Juvenile	2	40.50 ± 12.02	2	58.00 ± 11.31	-	-	2	1.50 ± 0.71
	Late rainy season	M	Adult	1	30.00	1	62.00	-	-	1	8.00
			Sub adult	4	44.25 ± 14.24	4	54.75 ± 16.11	-	-	1	4.00
			Juvenile	1	60.00	1	40.00	-	-	-	-
		F	Adult	6	35.67 ± 12.53	6	62.17 ± 13.50	1	2.00	3	3.33 ± 2.31
			Sub adult	3	18.00 ± 17.78	3	81.67 ± 17.39	-	-	1	1.00
			Juvenile	-	-	-		-	-	-	-
	Winter	M	Adult	4	52.50 ± 10.97	4	47.00 ± 10.42	-	-	-	-
			Sub adult	2	57.00 ± 9.90	2	40.00 ± 5.66	-	-	1	6.00
		F	Adult	1	44.00	1	56.00	-	-	-	-
			Sub adult	-	-	-	-	-	-	-	-
			Juvenile	1	14.00	1	86.00	-	-	-	-
	Summer	M	Adult	-	-	4	67.75 ± 22.62	-	-	3	4.00 ± 3.46
		F	Adult	4	29.25 ± 11.79	4	63.75 ± 31.48	1	1.00	3	1.33 ± 0.58
			Sub adult	4	35.00 ± 10.99	-	-	-	-	-	-

Table 5.15 Differential counts of leucocytes in percentage of *M. surifer* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value									
				No.	Nuetrophil (%)	No.	Lymphocytes (%)	No.	Monocytes (%)	No.	Eosinophil (%)	No.	Basophile (%)
DE	Early rainy season	M	Adult	5	42.20 ± 13.08	5	55.40 ± 14.67	3	1.67 ± 1.15	4	1.75 ± 0.96	-	-
			Sub adult	6	30.83 ± 14.08	6	67.67 ± 13.72	2	1.00 ± 0.00	4	1.75 ± 0.96	-	-
			Juvenile	-	-	-	-	-	-	-	-	-	-
		F	Adult	4	51.75 ± 13.65	4	44.75 ± 12.69	-	-	3	4.67 ± 2.08	-	-
			Sub adult	5	39.80 ± 11.48	5	60.00 ± 11.62	-	-	2	1.50 ± 0.71	-	-
			Juvenile	2	41.50 ± 19.09	2	58.50 ± 19.09	-	-	-	-	-	-
	Late rainy season	M	Adult	4	35.75 ± 12.82	4	60.00 ± 30.87	-	-	3	5.67 ± 1.53	-	-
			Sub adult	8	34.00 ± 23.24	8	64.75 ± 22.83	-	-	2	5.00 ± 2.83	-	-
			Juvenile	-	-	-	-	-	-	-	-	-	-
		F	Adult	4	51.50 ± 23.23	4	47.50 ± 21.56	-	-	1	4.00	-	-
			Sub adult	4	26.00 ± 13.19	4	72.00 ± 14.07	1	2.00	1	6.00	-	-
			Juvenile	-	-	-	-	-	-	-	-	-	-
	Winter	M	Adult	9	48.67 ± 21.84	9	49.78 ± 20.63	-	-	2	7.00 ± 4.24	-	-
			Sub adult	4	56.00 ± 16.33	4	40.50 ± 12.48	-	-	2	7.00 ± 4.24	-	-
		F	Adult	3	26.67 ± 9.24	3	73.33 ± 9.24	-	-	-	-	-	-
			Sub adult	3	51.00 ± 30.54	3	48.33 ± 29.57	1	2.00	-	-	-	-
			Juvenile	3	48.33 ± 21.73	3	51.67 ± 21.73	-	-	-	-	-	-
	Summer	M	Adult	2	21.00 ± 5.66	2	78.00 ± 4.24	1	1.00	1	1.00	-	-
		F	Adult	3	54.00 ± 20.07	3	43.00 ± 18.36	1	1.00	2	2.00 ± 0.00	1	1.00
			Sub adult	2	9.50 ± 7.78	2	87.50 ± 6.36	2	3.00 ± 1.41	-		-	-

5.4.3 Prevalence of Parasitics found in Roof Rat (*Rattus rattus*)

5.4.3.1 Prevalence of Ectoparasites and Pseudoscorpion of Roof Rat (*Rattus rattus*)

The prevalence of mite (*Laelaps echidinus*) found in *R. rattus* was not different among seasons in each habitat types. The highest (66.68%) prevalence of mite was in the late rainy season in DE forest, and was lowest (20.00 ± 15.00%) in the winter in DE forest (Figure 5.18).

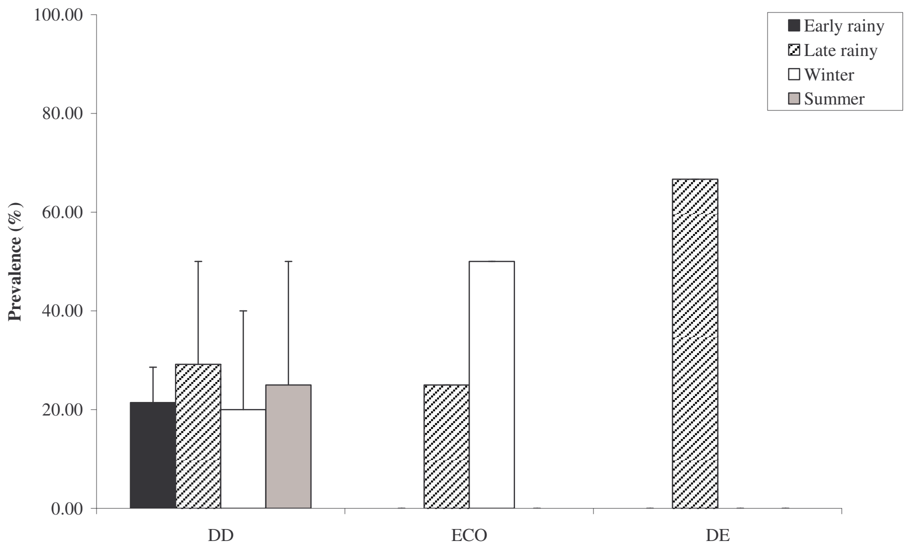


Figure 5.18 Mean prevalence of mite (*Laelaps echidinus*) found in *R. rattus* in different seasons and habitat types.

The prevalence of flea (*Xenopsylla cheopsis*) found in *R. rattus* varied among seasons in each habitat types. The prevalence of flea was the highest (100%) in the winter in ECO forest, and was lowest (8.33%) in the late rainy season in DD forest (Figure 5.19).

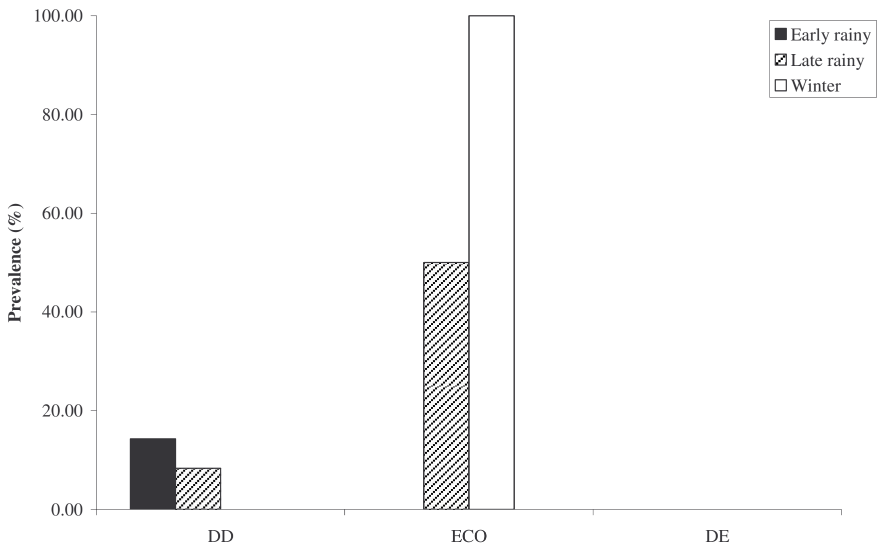


Figure 5.19 Mean prevalence of flea (*Xenopsylla cheopsis*) found in *R. rattus* in different seasons and habitat types.

The prevalence of tick (*Ixodes* sp.) was only found in *R. rattus* in DD forest. The prevalence of tick was the highest (25.00%) in the summer in DD forest, and was lowest (16.67%) in the late rainy season in DD forest (Figure 5.20).

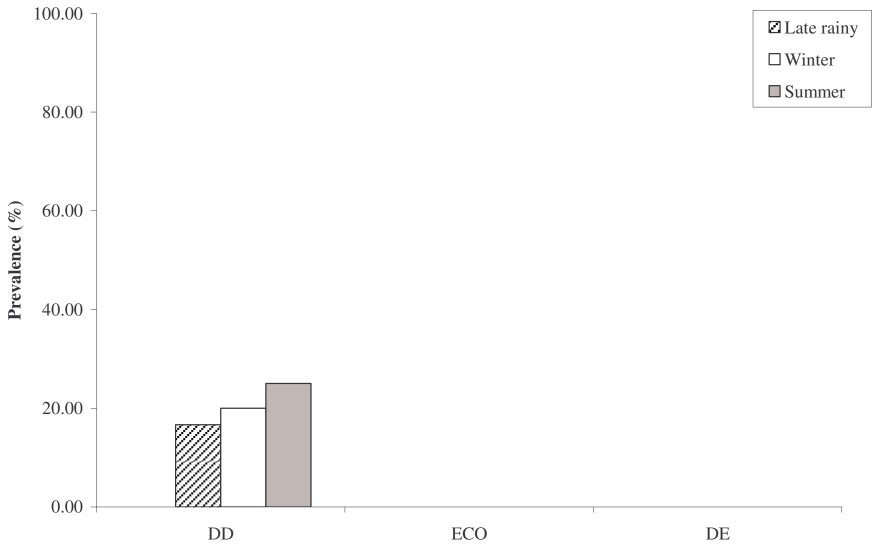


Figure 5.20 Mean prevalence of tick (*Ixodes* sp.) found in *R. rattus* in different seasons and habitat types.

The prevalence of pseudoscorpion (*Chelifer cancroides*) found in *R. rattus* both in DD and ECO forest. Whereas in case was equally the highest (50.00%) both in the late rainy season and winter in ECO forest, and was lowest (16.67%) in the late rainy season in DD forest (Figure 5.21).

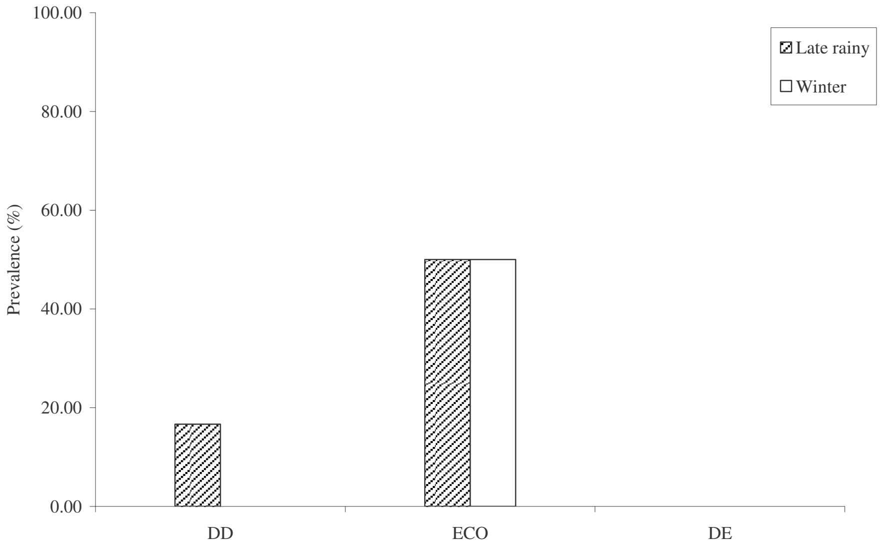


Figure 5.21 Mean prevalence of pseudoscorpion (*Chelifer cancroides*) found in *R. rattus* in different seasons and habitat types.

The relationship between seasons and the prevalence of ectoparasite species and pseudoscorpion: mite (*Laelaps echidinus*), Flea (*Xenopsylla cheopsis*), Tick (*Ixodes* sp.) and pseudoscorpion (*Chelifer cancroides*), there were not significant different (P>0.05).

5.4.3.2 Prevalence of Ectoparasites and Pseudoscorpion of Roof Rat (*Rattus rattus*) Varied by Sex, Age and Habitat Types.

Mite (*Laelaps echidinus*)

In DD forest, the prevalence of mite (*Laelaps echidinus*) found in adult females was greater than in adult males (83.33% and 19.23 ± 11.54%).This was also in sub adult females and males (100 % and 33.33%), whereas it was only found in juvenile male (50.00%). In ECO forest, the prevalence of mite (*Laelaps echidinus*) found in adult males (33.33%), sub adult and juvenile males (50.00%). For DE forest, the prevalence of mite (*Laelaps echidinus*), it was only found in juvenile females (66.67%) (Figure 5.22).

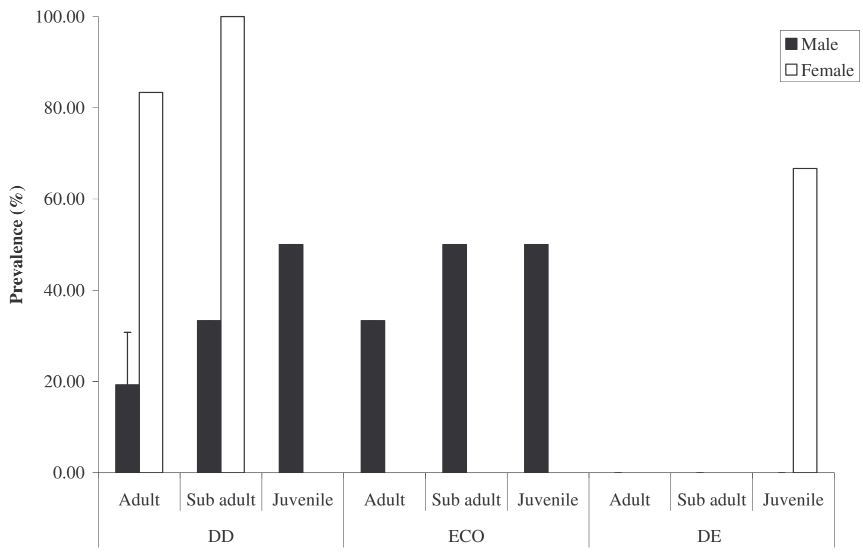


Figure 5.22 Mean prevalence of mite (*Laelaps echidinus*) found in *R. rattus* in different sex, age and habitat types.

Flea (*Xenopsylla cheopsis*)

The prevalence of flea (*Xenopsylla cheopsis*) found in both DD and ECO forest. In DD forest, the prevalence of flea (*Xenopsylla cheopsis*), it was only found in adult females (16.67%) and adults males (33.33%). In ECO forest, the prevalence of flea (*Xenopsylla cheopsis*), it was only found in adult (33.33%), sub adult (50.00 ± 25.00%) and juvenile (100.00 ± 22.22%) males (Figure 5.23).

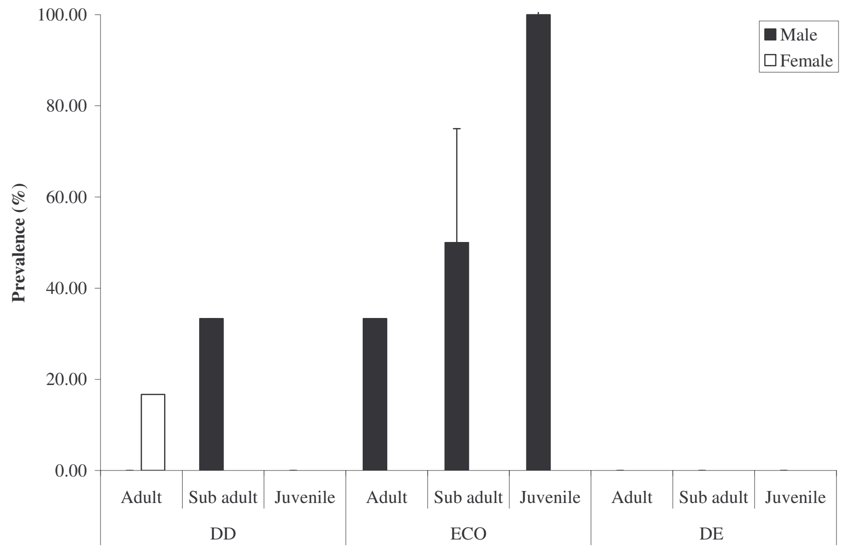


Figure 5.23 Mean prevalence of flea (*Xenopsylla cheopsis*) found in *R. rattus* in different sex, age and habitat types.

Tick (*Ixodes* sp.)

The prevalence of tick (*Ixodes* sp.), it was only found in DD forest. In DD forest, the prevalence of tick (*Ixodes* sp.), it was only found in adult (23.08%) and sub adult (33.33%) males (Figure 5.24).

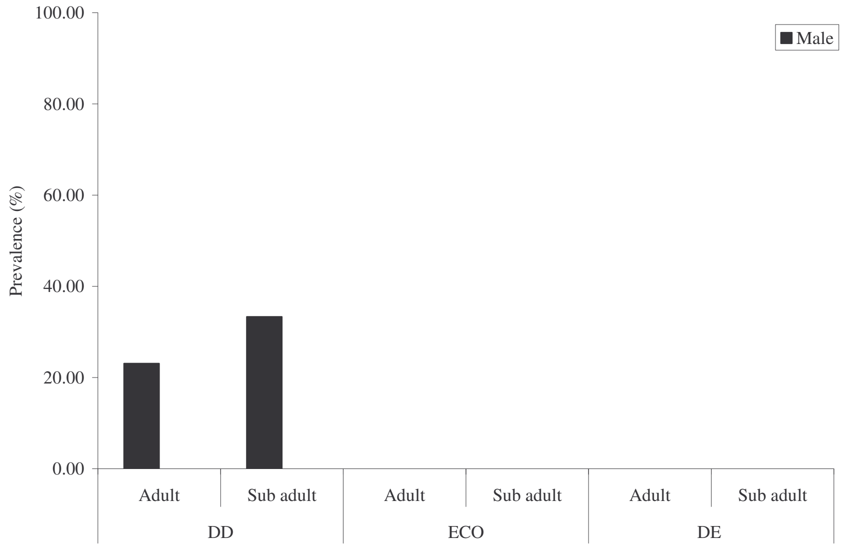


Figure 5.24 Mean prevalence of tick (*Ixodes* sp.) found in *R. rattus* in different sex, age and habitat types.

Pseudoscorpion (*Chelifer cancroides*)

The prevalence of pseudoscorpion (*Chelifer cancroides*), it was only found in DD and ECO forest. In DD forest, the prevalence of pseudoscorpion (*Chelifer cancroides*), it was only found in juvenile males (100.00%). For ECO forest, the prevalence of pseudoscorpion (*Chelifer cancroides*) found in adult males (66.67%) was greater than in adult females (7.69%) (Figure 5.25).

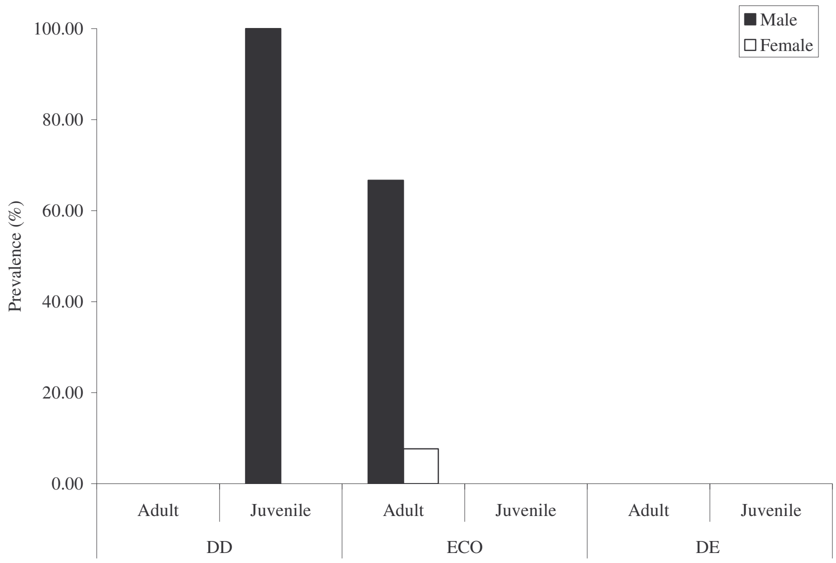


Figure 5.25 Mean prevalence of pseudoscorpion (*Chelifer cancroides*) found in *R. rattus* in different sex, age and habitat types.

The relationship between sex and age of *R. rattus* and the prevalence of ectoparasite species: mite (*Laelaps echidinus*), Flea (*Xenopsylla cheopsis*), Tick (*Ixodes* sp.) and pseudoscorpion (*Chelifer cancroides*) revealed that was not significant different (P>0.05).

5.4.3.3 Prevalence of Blood Parasites of Roof Rat (*Rattus rattus*)

***Microfilaria* sp.**

The peak of *Microfilaria* sp. prevalence in *R. rattus* occurred in the winter in ECO forest. The highest prevalence of *Microfilaria* sp. (100.00%) was found in the winter in ECO forest, whereas lowest prevalence (16.67%) was found in the late rainy season in DD forest (Figure 5.26).

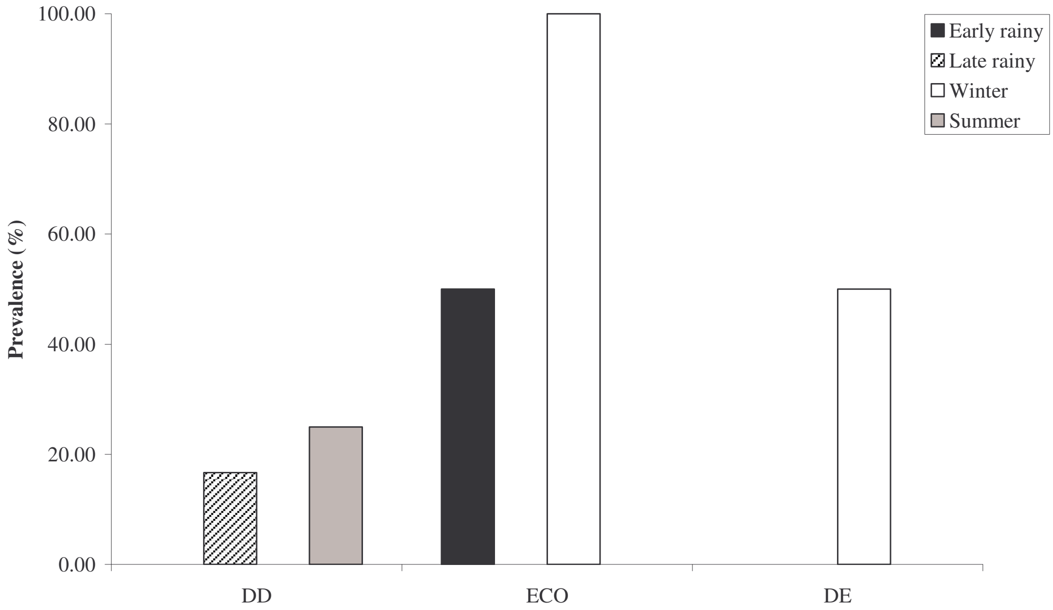


Figure 5.26 Mean prevalence of *Microfilaria* sp. found in *R. rattus* in different seasons and habitat types.

***Trypanosoma* sp.**

The peak of *Trypanosoma* sp. prevalence in *R. rattus* was only occurred in the summer in DD forest. The prevalence of *Trypanosoma* sp., it was only found in the summer (25%) in DD forest (Figure 5.27).

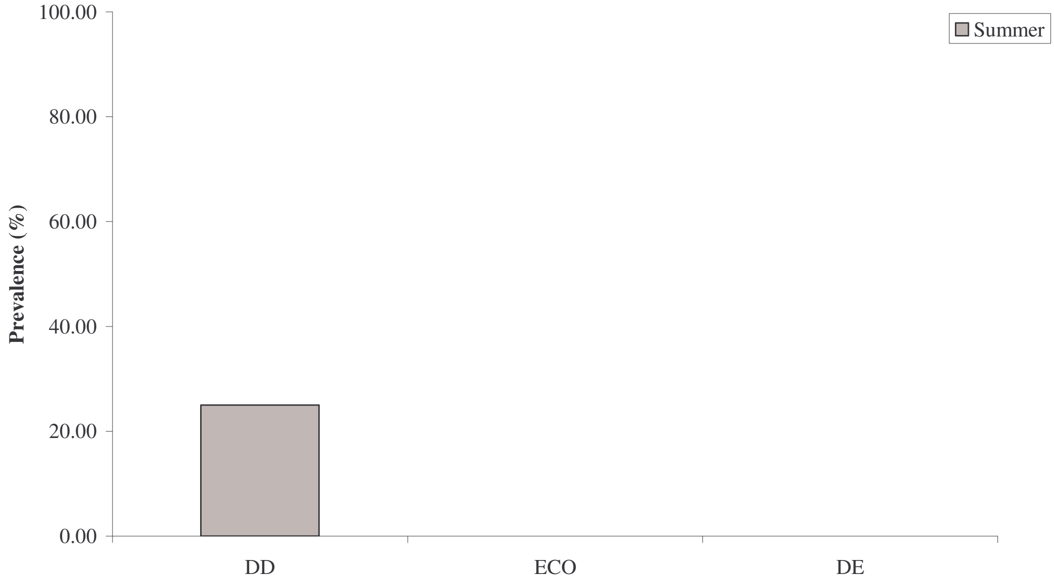


Figure 5.27 Mean infection of *R. rattus* infected with *Trypanosoma* sp. in different seasons and habitat types.

***Anaplasma* sp.**

The prevalence of *Anaplasma* sp. found in *R. rattus* was in DD and DE forest. The prevalence of *Anaplasma* sp. in DD forest, it was only found in the early rainy season (14.29%). For DE forest, the prevalence of *Anaplasma* sp., it was only found in late rainy season (Figure 5.28).

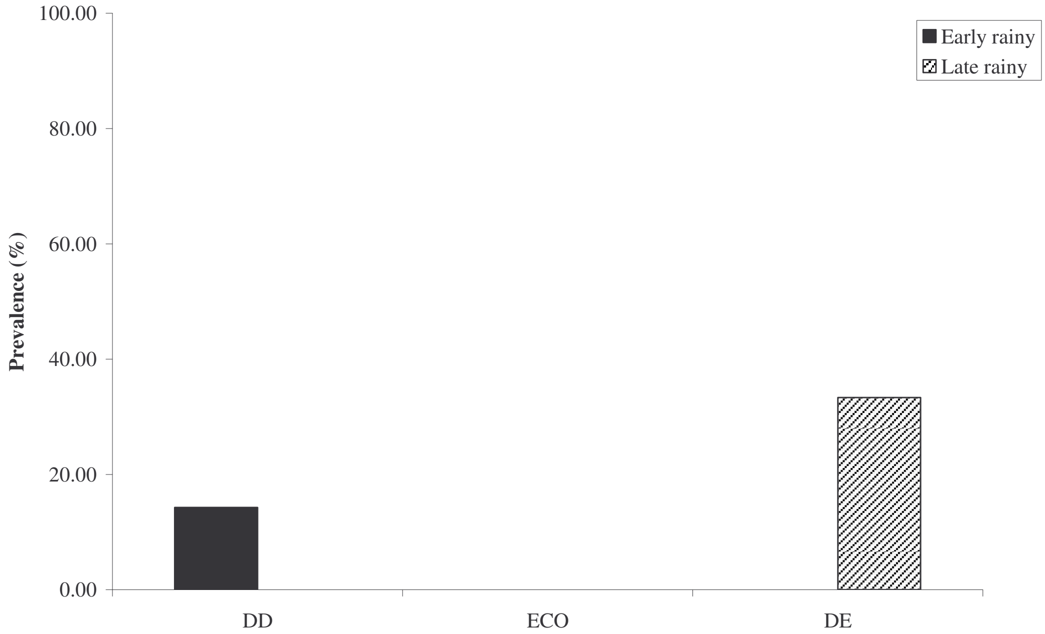


Figure 5.28 Mean prevalence of *Anaplasma* sp. found in *R. rattus* in different seasons and habitat types.

***Grahamella* sp.**

The prevalence of *Grahamella* sp. found in *R. rattus* was only in DD. The prevalence of *Grahamella* sp. in DD forest, it was only found in the summer (50.00%) (Figure 5.29).

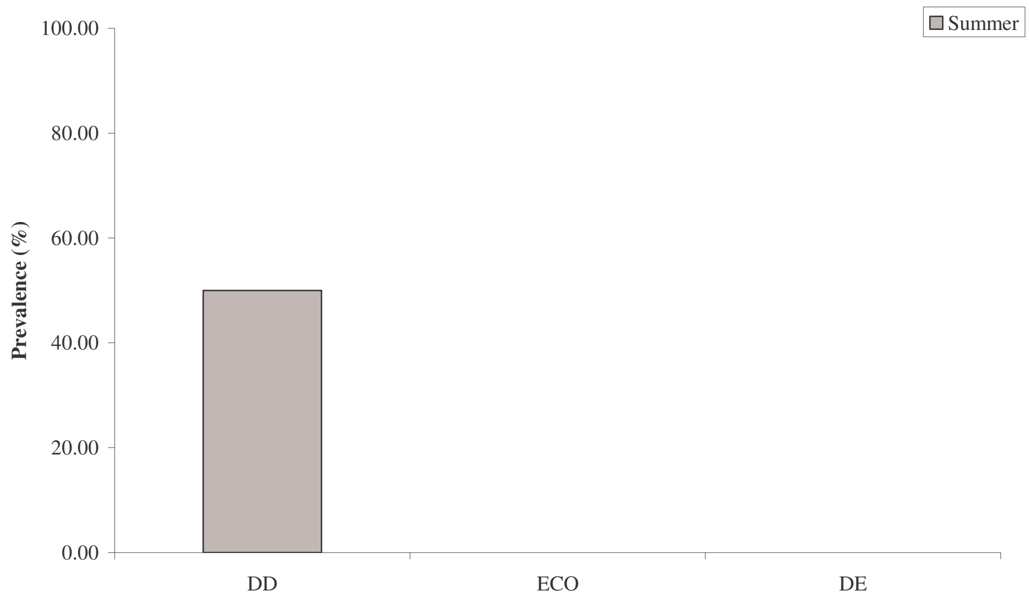


Figure 5.29 Mean prevalence of *Grahamella* sp. found in *R. rattus* in different seasons and habitat types.

The relationship between seasons and the prevalence infection with blood parasite species: *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. revealed *Trypanosoma* sp. was significant different (χ^2 = 9.732, df=3, P<0.05) and *Grahamella* sp. was significantly different (χ^2 = 19.950, df=3, P<0.01). For other blood parasite species, there were not significant different (P>0.05).

5.4.3.4 Prevalence of Blood Parasites of Roof Rat (*Rattus rattus*) Varied by Sex, Age and Habitat Types.

***Microfilaria* sp.**

In DD forest, the prevalence of *Microfilaria* sp. was greater in adult females (33.33%) than in adult males (7.69%). In ECO forest, the prevalence of *Microfilaria* sp., it was only found in adult (33.33%) and sub adult (100.00%) males. Whereas it was only found in adult females in DE forest (50.00%) (Figure 5.30).

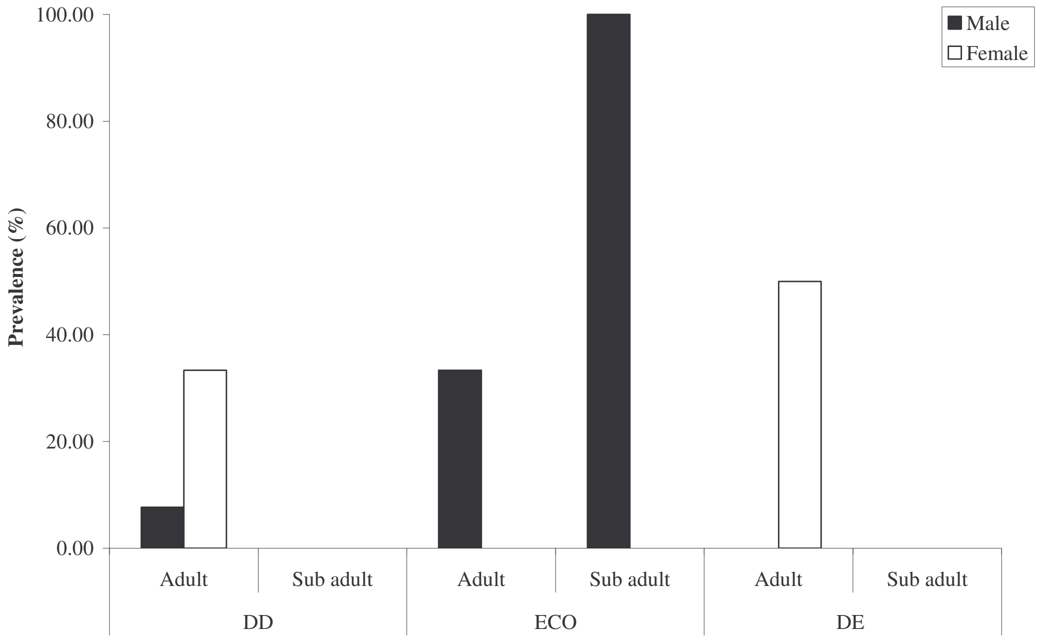


Figure 5.30 Mean prevalence of *Microfilaria* sp. found in *R. rattus* in different sex, age and habitat types.

***Trypanosama* sp.**

The prevalence of *Trypanosama* sp. found in *R. rattus*, it was only found in adult males (7.69%) in DD forest (Figure 5.31).

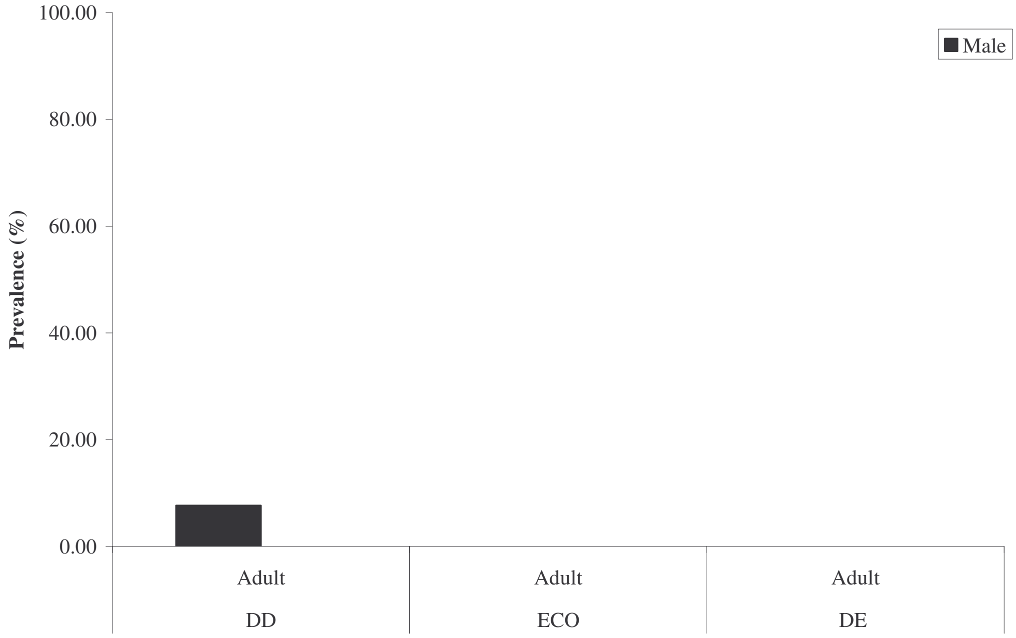


Figure 5.31 Mean prevalence of *Trypanosama* sp. found in *R. rattus* in different seasons and habitat types.

***Anaplasma* sp.**

The prevalence of *Anaplasma* sp. found in *R. rattus*, it was only found in adult females (16.67%) in DD forest and juvenile females (33.33%) in DE forest (Figure 5.32).

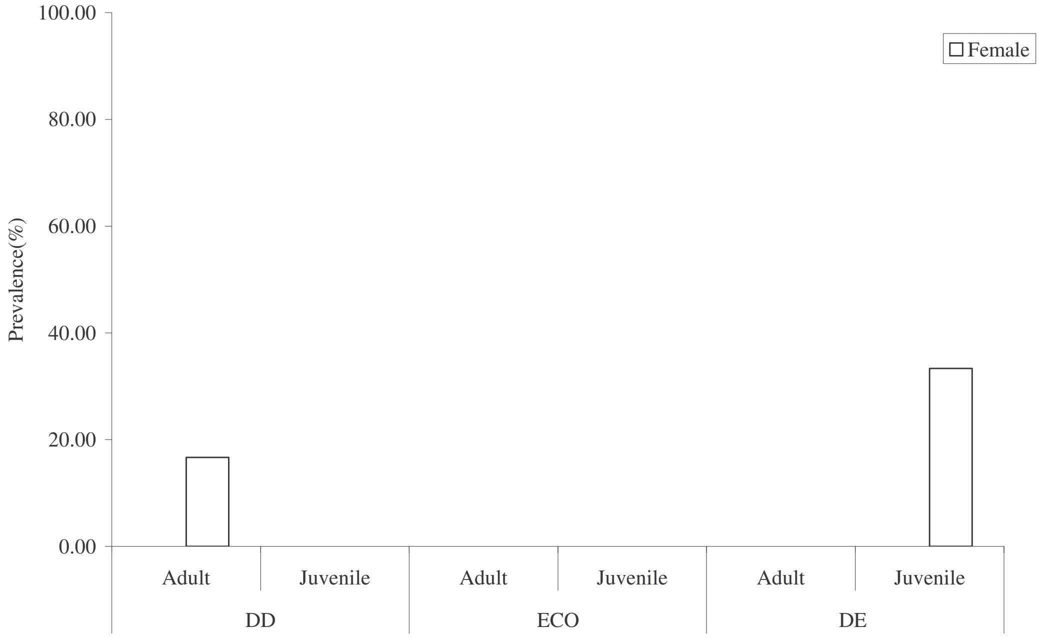


Figure 5.32 Mean prevalence of *Anaplasma* sp. found in *R. rattus* in different seasons and habitat types.

***Grahamella* sp.**

The prevalence of *Grahamella* sp. found in *R. rattus*, it was only found in adult males (15.38%) in DD forest (Figure 5.33).

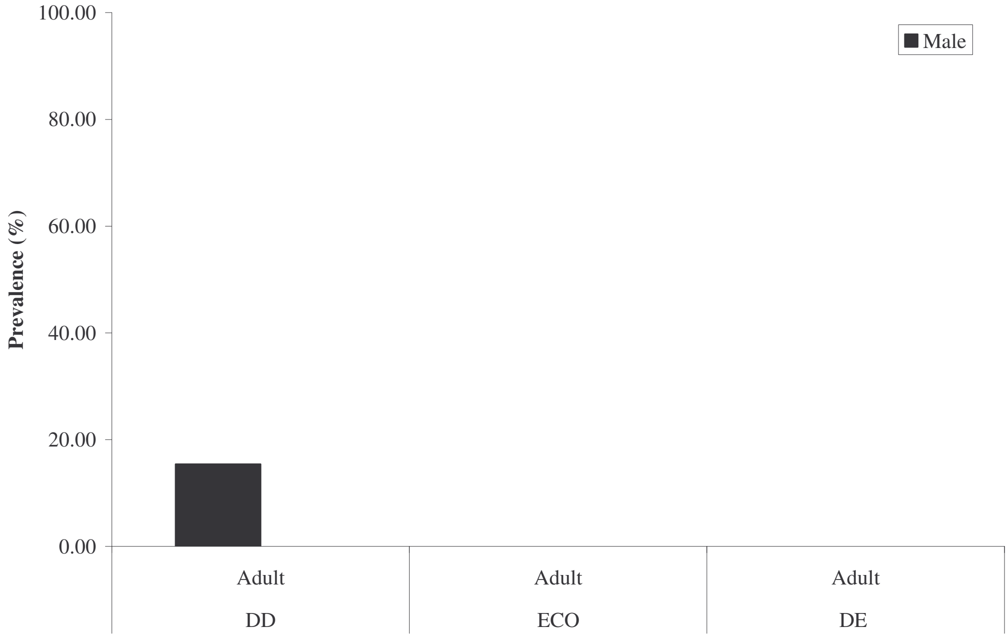


Figure 5.33 Mean prevalence of *Grahamella* sp. found in *R. rattus* in different seasons and habitat types.

The relationship between sex and age of *R. rattus* and the infection of *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. were not reach statistic differences (P>0.05). The relationship between mixed infection with *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. revealed that *Trypanosoma* sp. was significantly correlated with *Grahamella* sp. (r^2 = 0.706).

5.4.3.5 Relationship of The Prevalence between Ectoparasites Species, Pseudoscorpion and Blood Parasite Species of *Rattus rattus*

The prevalence relationship between ectoparasite species, pseudoscorpion and blood parasite species was significantly between mite (*Laelaps echidinus*) and *microfilaria* sp. (χ^2 = 25.317, df = 1, P<0.001) and *Anaplasma* sp. (χ^2 = 50.940, df=1, P<0.001); flea (*Xenopsylla cheopsis*) and *microfilaria* sp. (χ^2 = 90.546 df=1, P<0.001); pseudoscorpion (*Chelifer cancroides*) and *microfilaria* sp. (χ^2 = 10.886 df=1, P<0.01). For the relationship of other ectoparasite species, pseudoscorpion and blood parasite species infected in *R. rattus* did not significant different (P>0.05). The chi-square test relationship between ectoparasite species, pseudoscorpion and blood parasite species are shown in Table 5.17.

Table 5.16 Test statistic and associated *P* values for the relationship between ectoparasite species, pseudoscorpion and blood parasite species in *R. rattus*.

Ectoparasite species	**Blood parasite species**	χ^2	**df**	***P***
Mite (*Laelaps echidinus*)	*Microfilaria* sp.	25.317	1	0.000
	Trypanosoma sp.	0.039	1	0.842
	Anaplasma sp.	50.940	1	0.000
	Grahamella sp.	0.079	1	0.778
Flea (*Xenopsylla cheopsis*)	*Microfilaria* sp.	90.546	1	0.000
	Trypanosoma sp.	0.012	1	0.912
	Anaplasma sp.	0.024	1	0.876
	Grahamella sp.	0.024	1	0.876

Table 5.16 Test statistics and associated *P* values for the relationship between ectoparasite species, pseudoscorpion and blood parasite species in *R. rattus* (Continued).

Ectoparasite species	Blood parasite species	χ^2	df	*P*
Tick (*Ixodes* sp.)	*Microfilaria* sp.	0.065	1	0.798
	Trypanosoma sp.	0.008	1	0.928
	Anaplasma sp.	0.016	1	0.899
	Grahamella sp.	0.016	1	0.899
Pseudoscorpion (*Chelifer cancroides*)	*Microfilaria* sp.	10.886	1	0.001
	Trypanosoma sp.	0.010	1	0.920
	Anaplasma sp.	0.020	1	0.887
	Grahamella sp.	0.020	1	0.887

5.4.3.6 Intensity of Blood Parasites of Roof Rat (*Rattus rattus*) Varied by Habitat Types, Seasonal, Sex and Age

Intensity of blood parasites infected per 100 erythrocyte of *R. rattus* in all habitat types varied by seasonal, sex and age were described as follow;

DD forest

Microfilaria sp., the intensity ranged from 3.00-17.00 infected per 100 erythrocytes. *Trypanosoma* sp., the intensity was only one detected *R. rattus*, was 2.00 infected erythrocytes per 100 erythrocytes. *Anaplasma* sp., was only one detected *R. rattus*, was 5.00 infected erythrocytes per 100 erythrocytes. For *Grahamella* sp., mean intensity ranged from 3.00-5.00 infected erythrocytes per 100 erythrocytes (Table 5.18).

ECO forest

The numbers blood parasites infected per 100 erythrocytes was detected *Trypanosoma* sp. and *Anaplasma* sp.. *Trypanosoma* sp., the intensity ranged from 3.00-6.00 infected erythrocytes per 100 erythrocytes. For *Anaplasma* sp., the intensity was 5.00 infected erythrocytes per 100 erythrocytes (Table 5.18).

DE forest

The numbers blood parasites infected per 100 erythrocytes was only detected of *Anaplasma* sp. of one *R. rattus* in the late rainy season (5.00 infected per 100 erythrocytes) (Table 5.18).

The correlation between habitat types, seasonal, sex and age with intensity infection revealed that age was significantly correlated with intensity infected with *Microfilaria* sp. (r^2 = 0.998). Intensity of infection with all blood parasite species were not vary significant (P>0.05) through combined for habitat types, seasonal, sex and age.

Table 5.17 Intensity of blood parasite infected of *R. rattus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood parasites count							
				No.	*Microfilaria* sp. (N)	No.	*Trypanosoma* sp. (N)	No.	*Anaplasma* sp. (N)	No.	*Grahamella* sp. (N)
DD	Early rainy season	F	Adult	-	-	-	-	1	5.00	-	-
	Late rainy season	M	Adult	1	4.00	-	-	-	-	-	-
		F	Adult	1	3.00	-	-	-	-	-	-
	Winter		Sub adult	-	-	-	-	-	-	1	5.00
		F	Adult	1	17.00	-	-	-	-	-	-
	Summer	M	Adult	-	-	1	2.00	-	-	2	3.00 ± 2.83
		F	Adult	1	3.00	-	-	-	-	-	-
ECO	Late rainy season	M	Adult	-	-	-	-	1	5.00	-	-
		F	Adult	-	-	1	3.00	-	-	-	-
	Winter	M	Sub adult	-	-	1	6.00	1	5.00	-	-
DE	Late rainy season	F	Juvenile	-	-	-	-	1	5.00	-	-

5.4.3.7 Blood Values of Roof Rat (*Rattus rattus*) Varied by Habitat Types, Seasonal, Sex and Age

Blood values obtained from *R. rattus* in three habitat types. Sex and age classes were combine for habitat types and seasonal comparison. Significant of habitat types and seasonal difference were detected for RBC, Hct, glucose, triglycerides, WBC and differential count of leucocytes (nuetrophil, lymphocyte, monocyte and eosinophil) (Table 5.19-5.21). The results were described as follow;

DD forest

Mean of RBC was the highest (6.26 ± 5.14 10^6/µl) in adult males in the late rainy season, and was the lowest (5.14 ± 0.28 10^6/µl) in adult males in the early rainy season. Mean of Hct was the highest (50.00 ± 0.00%) in juvenile males in the late rainy season, and was the lowest (39.25 ± 1.71%) in adult females in the winter. Mean of glucose was the highest (131.50 ± 5.20 mg/dl) in adult males in the summer, and was the lowest (76.00 ± 39.60 mg/dl) in adult females in the late rainy season. For the triglyceride was the highest (153.00mg/dl) in only one detected adult females in the late rainy season, and was the lowest (75.50 ± 3.79 mg/dl) in adult males in the early rainy (Table 5.19).

Mean WBC was the highest (7.76 ± 2.63 10^3/µl) in adult females in the late rainy season, and was the lowest (4.30 10^3/µl) only one detected adult males in the summer (Table 5.20). Differential count of leucocytes, neutrophil was the highest (54.00%) only one detected in sub adult male in the early rainy season, and was the lowest (11.00%) in only one detected in sub adult female in the late rainy season. Lymphocyte was the highest (89.00%) only one detected in sub adult female in the late rainy season, and was the lowest (34.50 ± 10.61%) in adult females in the late rainy season. The values of monocytes was 2.00%. For the mean of eosinophil was the highest (10.00 ± 4.49%) in adult males in the late rainy season, and was the lowest (2.00%) in only one detected in sub adult male in the winter (Table 5.21).

ECO forest

RBC was the highest (6.95 10^6/µl) in sub adult males in the early rainy season, and was the lowest (5.28 ± 1.45 10^6/µl) in adult males in the early rainy season. Hct was the highest (45.00%) only one detected sub adult male in the early rainy season, and was the lowest (39.25 ± 4.92%) in adult males in the winter. Mean of glucose was the highest (141.00 ± 0.00 mg/dl) in adult males in the late rainy season, and was the lowest (63.00 ± 0.00 mg/dl) in juvenile males in the late rainy season. For the mean of triglyceride was the highest (216.00 mg/dl) only one detected adult male in the winter, and was the lowest (108.00 ± 0.00 mg/dl) in adult males in the late rainy season (Table 5.19).

Mean WBC was the highest (6.80 ± 1.87 10^3/µl) in adult males in the winter, and was the lowest (3.60 10^3/µl) only one detected sub adult male in the early rainy season (Table 5.20). Differential count of leucocytes, neutrophil was the highest (70.00%) only one detected in juvenile male in the late rainy season, and was the lowest (28.00%) only one detected in sub adult male in the winter. Lymphocyte was the highest (72.00%) only one detected in sub adult male in the winter, and was the lowest (30.00%) only one detected in juvenile males in the late rainy season. The values of monocytes did not detected. For eosinophil was only one detected in sub adult male (8.00%) in the early rainy season (Table 5.21).

DE forest

Mean of RBC was the highest (6.67 ± 0.29 10^6/µl) in adult females in the winter, and was the lowest (3.25 10^6/µl) in only one detected sub adult male in the winter. Mean of Hct was the highest (44.20 ± 2.54%) in adult females in the winter, and was the lowest (37.50 ± 3.54%) in juvenile females in the late rainy season. Glucose was the highest (117.00 mg/dl) only one detected sub adult males in the winter, and was the lowest (69.00 ± 16.89 mg/dl) in juvenile females in the late rainy season. For triglyceride was the highest (163.00 mg/dl) only one detected adult female in the early rainy season, and was the lowest (131.00 mg/dl) only one detected sub adult female in the winter (Table 5.19).

WBC was the highest (7.50 10^3/µl) only one detected sub adult female in the winter, and the mean was the lowest (2.60 10^3/µl) only one detected sub adult male in the winter (Table 5.20). Differential count of leucocytes, neutrophil was the highest (64.00%) only one detected adult female in the winter, and was the lowest (13.00%) only one detected in juvenile female in the late rainy season. lymphocyte was the highest (85.00%) only one detected juvenile female in the late rainy season, and was the lowest (36.00%) only one detected in adult female in the winter. The values of monocytes did not detected. For eosinophil was 2.00% only one detected juvenile females in the late rainy season (Table 5.21).

The correlation between habitat types, seasonal, sex and age with blood values revealed that seasonal was significant correlated with triglycerides (r^2 = 0.723). Blood values did not vary significant through combined for habitat types, seasonal, sex and age (*P*>0.05).

The correlation between blood parasite species found in *R. rattus* with blood values were not significant different (*P*>0.05). The correlation between intensity of blood parasite species with blood values revealed that intensity infected of *Grahamella* sp. was significantly correlated with neutrophil and lymphocyte (r^2 = -1.000 and r^2 = 1.000) respectively.

Table 5.18 Blood values of *R. rattus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value: No.	RBC ($10^6/\mu l$)	No.	Hct (%)	No.	Glucose (mg/dl)	No.	Triglycerides (mg/dl)
DD	Early rainy season	Male	Adult	4	5.14 ± 0.28	12	45.25 ± 2.80	4	94.25 ± 13.30	4	75.50 ± 3.79
			Sub adult	1	5.55	1	49.00	-	-	-	-
		Female	Adult	2	6.13 ± 0.00	4	42.00 ± 2.31	-	-	-	-
	Late rainy season	Male	Adult	5	6.26 ± 0.50	14	44.00 ± 3.96	6	106.00 ± 29.82	7	83.29 ± 13.02
			Juvenile	-	-	2	50.00 ± 0.00			-	-
		Female	Adult	2	5.23 ± 0.21	8	43.13 ± 2.10	2	76.00 ± 39.60	1	153.00
			Sub adult	1	5.38	2	43.50 ± 0.71	-	-	-	-
			Juvenile	-	-	2	41.00 ± 0.00	-	-	-	-
	Winter	Male	Adult	8	5.99 ± 0.68	7	41.50 ± 3.01	8	94.75 ± 34.83	3	116.33 ± 15.01
			Sub adult	4	6.15 ± 0.35	4	41.50 ± 2.89	4	109.00 ± 24.25	2	100.00 ± 0.00
		Female	Adult	4	6.20 ± 0.09	4	39.25 ± 1.71	4	83.75 ± 29.87	3	139.33 ± 61.24
	Summer	Male	Adult	1	5.49	6	46.25 ± 7.15	4	131.50 ± 5.20	-	-
ECO	Early rainy season	Male	Adult	3	5.28 ± 1.45	3	41.67 ± 2.89	3	121.67 ± 14.43	-	-
			Sub adult	1	6.95	1	45.00	1	105.00	-	-
	Late rainy season	Male	Adult	2	5.41 ± 0.00	2	42.00 ± 0.00	2	141.00 ± 0.00	2	108.00 ± 0.00
			Juvenile	-	-	4	41.00 ± 1.15	2	63.00 ± 0.00	-	-
		Female	Adult	-	-	2	43.50 ± 0.00	2	80.00 ± 0.00	2	116.50 ± 52.03
	Winter	Male	Adult	4	5.91± 0.95	4	39.25 ± 4.92	4	86.00 ± 13.21	1	216.00
			Sub adult	2	6.75	2	44.00 ± 0.00	2	76.00	-	-

Table 5.18 Blood values of *R. rattus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station (Continued).

Habitat	Season	Sex	Age	Mean blood value							
				No.	RBC ($10^6/\mu l$)	No.	Hct (%)	No.	Glucose (mg/dl)	No.	Triglycerides (mg/dl)
DE	Early rainy season	Male	Adult	-	-	3	40.67 ± 7.37	-	-	-	-
			Juvenile	-	-	2	41.00 ± 0.00	-	-	-	-
		Female	Adult	1	3.64	-	-	1	90.00	1	163.00
	Late rainy season	Male	Sub adult	-	-	1	43.00	-	-	-	-
			Juvenile	1	6.25	2	41.50 ± 0.00	-	-	-	-
		Female	Juvenile	-	-	2	37.50 ± 3.54	3	69.00 ± 16.89	-	-
	Winter	Male	Sub adult	1	3.25	1	41.00	1	117.00	-	-
		Female	Adult	3	6.67 ± 0.29	5	44.20 ± 2.54	1	103.00	-	-
			Sub adult	1	6.25	-	-	1	92.00	1	131.00

Table 5.19 White blood cell count of *R. rattus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	No.	WBC ($10^3/\mu l$)
DD	Early rainy season	M	Adult	4	8.83 ± 6.53
			Sub adult	1	7.00
		F	Adult	2	6.30 ± 0.00
	Late rainy season	M	Adult	5	9.00 ± 5.68
		F	Adult	2	6.65 ± 3.18
			Sub adult	1	4.40
	Winter	M	Adult	8	7.50 ± 4.76
			Sub adult	4	6.00 ± 0.00
		F	Adult	4	7.08 ± 4.36
	Summer	M	Adult	1	7.90
ECO	Early rainy season	M	Adult	3	5.07 ± 1.27
			Sub adult	1	3.60
	Late rainy season	M	Adult	2	4.40 ± 0.00
	Winter	M	Adult	4	6.80 ± 1.87
			Sub adult	2	3.50 ± 0.00
DE	Early rainy season	M	Adult	1	3.90
	Late rainy season	F	Juvenile	1	7.50
	Winter	M	Sub adult	1	2.60
		F	Adult	3	4.47 ± 0.81
			Sub adult	1	7.50

Table 5.20 Differential counts of leucocytes in percentage of *R. rattus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value							
				No.	Nuetrophil (%)	No.	Lymphocytes (%)	No.	Monocytes (%)	No.	Eosinophil (%)
DD	Early rainy	M	Adult								
	season			2	27.50 ± 11.82	2	72.50 ± 31.82	-	-	-	-
			Sub adult	1	54.00	1	46.00	-	-	-	-
		F	Adult	1	49.00	1	48.00	-	-	1	3.00
	Late rainy	M	Adult					-	-		
	season			2	32.00 ± 14.14	2	58.00 ± 22.63			2	10.00 ± 4.49
		F	Adult	2	62.50 12.02	2	34.50 ± 10.61	-	-	2	3.00 ± 1.41
			Sub adult	1	11.00	1	89.00	-	-	-	-
	Winter	M	Adult	1	39.00	1	61.00	-	-	-	-
			Sub adult	2	29.00 ± 4.24	2	69.00 ± 4.24	1	2	1	2.00
		F	Adult	1	24.00	1	72.00	-		1	4.00
	Summer	M	Adult	2	35.50 ± 2.12	2	61.50 ± 4.95	2	2.00 ± 0.00	1	3.00
		F	Adult	1	37.00	1	59.00	-	-	1	4.00
ECO	Early rainy	M	Adult					-	-		
	season			1	35.00	1	65.00			-	-
			Sub adult	1	56.00	1	36.00	-	-	1	8.00
	Late rainy	M	Adult					-	-		
	season			1	42.00	1	58.00			-	-
			Juvenile	1	70.00	1	30.00	-	-	-	-
	Winter	M	Adult	1	64.00	1	36.00	-	-	-	-
			Sub adult	1	28.00	1	72.00	-	-	-	-
DE	Late rainy	M	Juvenile					-	-		
	season			1	32.00	1	64.00			-	-
		F	Juvenile	1	13.00	1	85.00	-	-	1	2.00
	Winter	F	Adult	1	64.00	1	36.00	-	-	-	-

5.4.4 Prevalence of Parasitics found in Noisy Rat (*Leopoldamys sabanus*)

5.4.4.1 Prevalence of Ectoparasites of Noisy Rat (*Leopoldamys sabanus*)

The prevalence of ectoparsite species found in *L. sabanus*, it was only found mite (*Laelaps echidinus*) in the early rainy season and summer in ECO and DE forest. The prevalence of mite (*Laelaps echidinus*) found in *L. sabanus* was not different among seasons in each habitat types. The highest (50.00%) prevalence of mite was in the early rainy season in DE forest, and was lowest (33.33%) in the summer in ECO and DE forest (Figure 5.34).

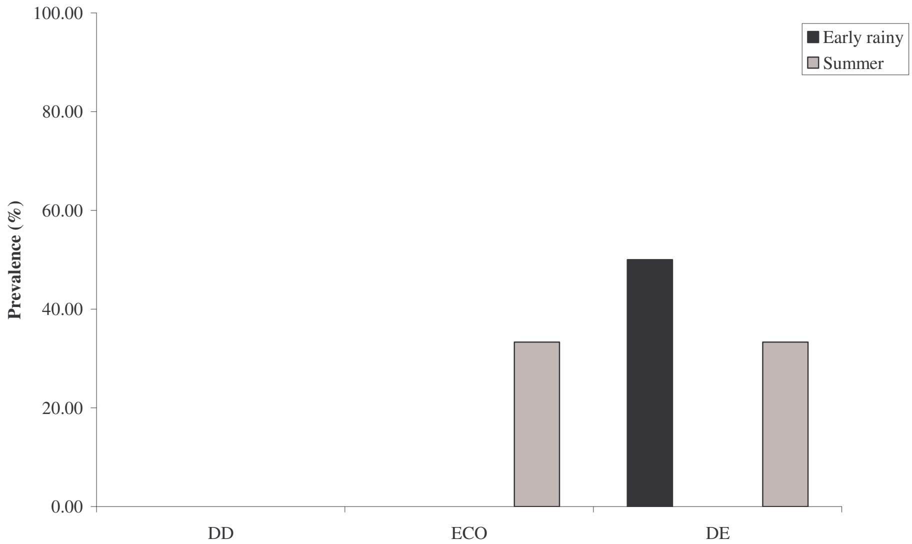


Figure 5.34 Mean prevalence of mite (*Laelaps echidinus*) found in *L. sabanus* in different seasons and habitat types.

The relationship between seasons and the prevalence of ectoparasite species: mite (*Laelaps echidinus*) was not significant different (*P*>0.05).

5.4.4.2 Prevalence of Ectoparasites of Noisy Rat (*Leopoldamys sabanus*) Varied by Sex, Age and Habitat Types.

Mite (*Laelaps echidinus*)

In ECO forest, the prevalence of mite (*Laelaps echidinus*), it was only found in adult male (25.00%). For DE forest, the prevalence of mite (*Laelaps echidinus*) found in adult females (50.00%) was greater than adult males (33.33%) (Figure 5.35).

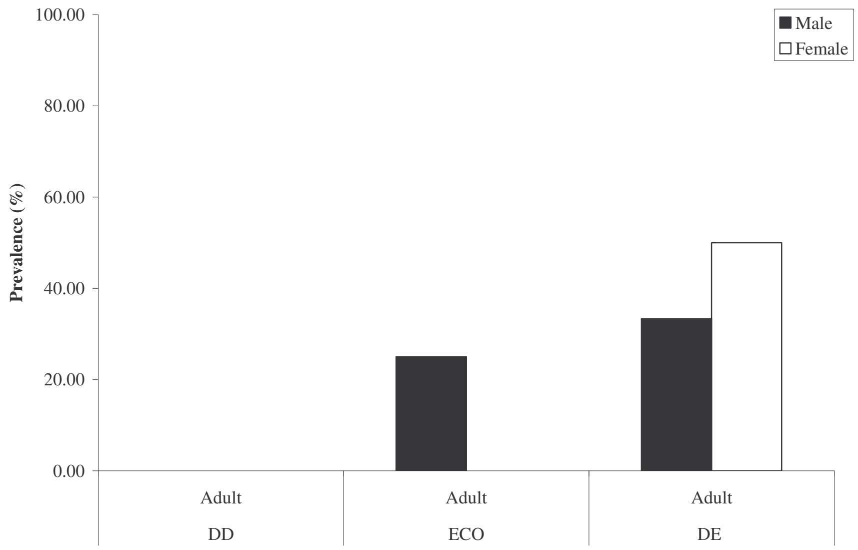


Figure 5.35 Mean prevalence of mite (*Laelaps echidinus*) found in *L. sabanus* in different sex, age and habitat types.

The relationship between sex and age of *R. rattus* and the prevalence of ectoparasite species: mite (*Laelaps echidinus*) was not significant different (P>0.05).

5.4.4.3 Prevalence of Blood Parasites of Noisy Rat (*Leopoldamys sabanus*)

***Microfilaria* sp.**

The peak of *Microfilaria* sp. prevalence in *L. sabanus*, it was equally occurred in the winter in ECO forest (50.00%), the early rainy season and the summer (50.00%) in DE forest (50.00 ± 16.67%). (Figure 5.36).

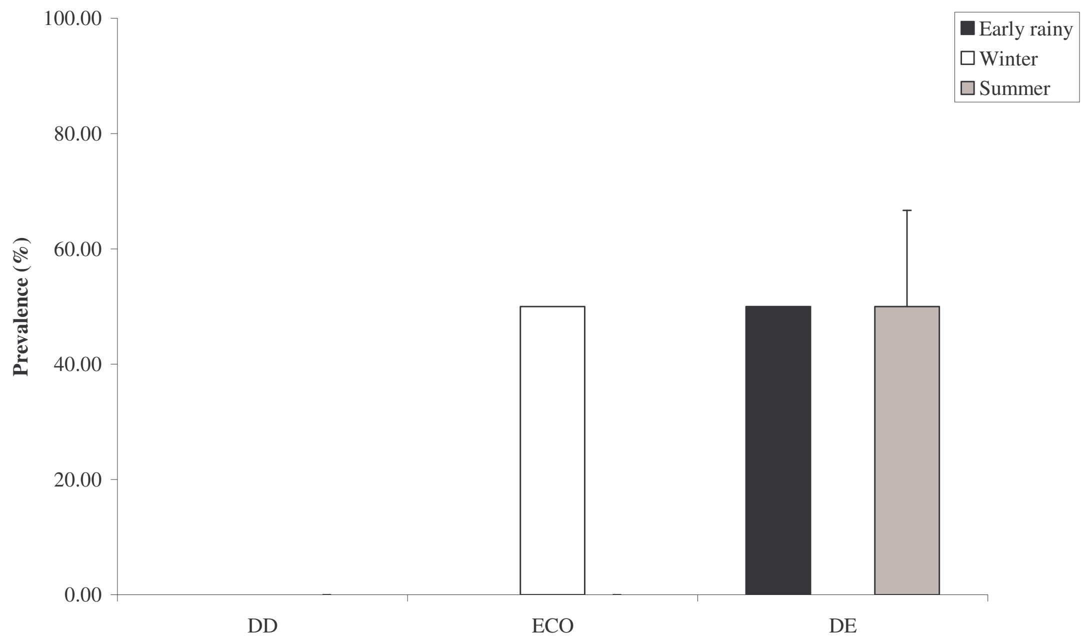


Figure 5.36 Mean prevalence of *Microfilaria* sp. found in *L. sabanus* in different seasons and habitat types.

***Trypanosoma* sp.**

The peak of *Trypanosoma* sp. prevalence in *L. sabanus* occurred in the late rainy season in DE forest. The highest prevalence of of *Trypanosoma* sp. (100.00%) was found in the late rainy season in DE forest, followed by the early rainy season (50.00%) in DE forest, whereas equally the lowest prevalence (33.33%) was found in in the early rainy season in ECO forest and the summer in DE forest.(Figure 5.37).

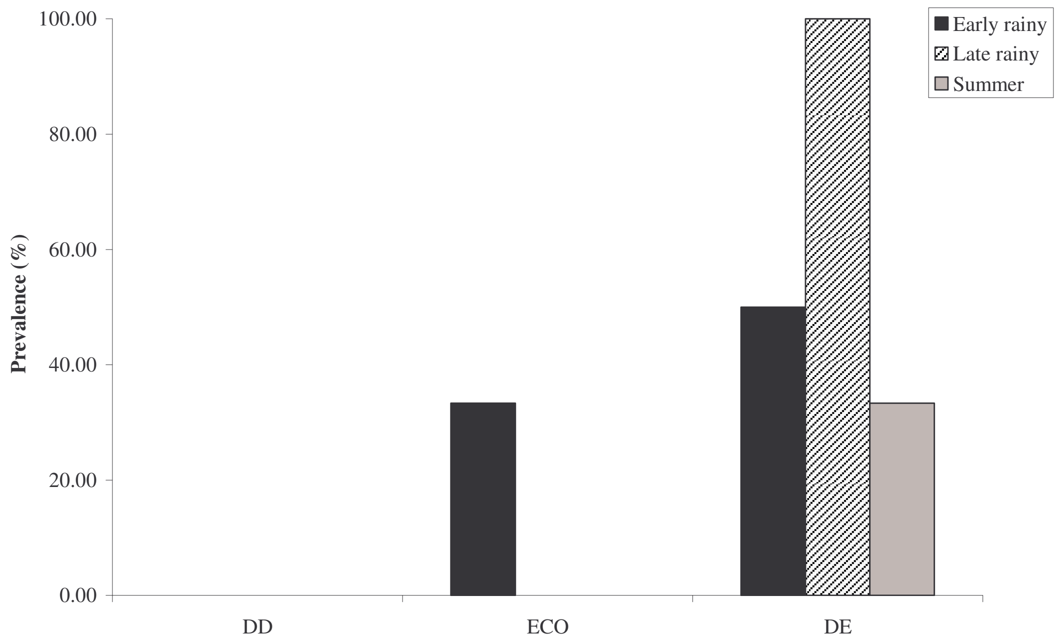


Figure 5.37 Mean prevalence *Trypanosoma* sp. found in *L. sabanus* in different seasons and habitat types.

***Anaplasma* sp.**

Anaplasma sp. was only found in ECO forest. The peak of *Anaplasma* sp. prevalence in *L. sabanus* occurred in the winter in ECO forest. The highest prevalence of *Anaplasma* sp. (100.00%) was found in the winter in ECO forest, followed by in the early rainy season (66.67%) in ECO forest (Figure 5.38).

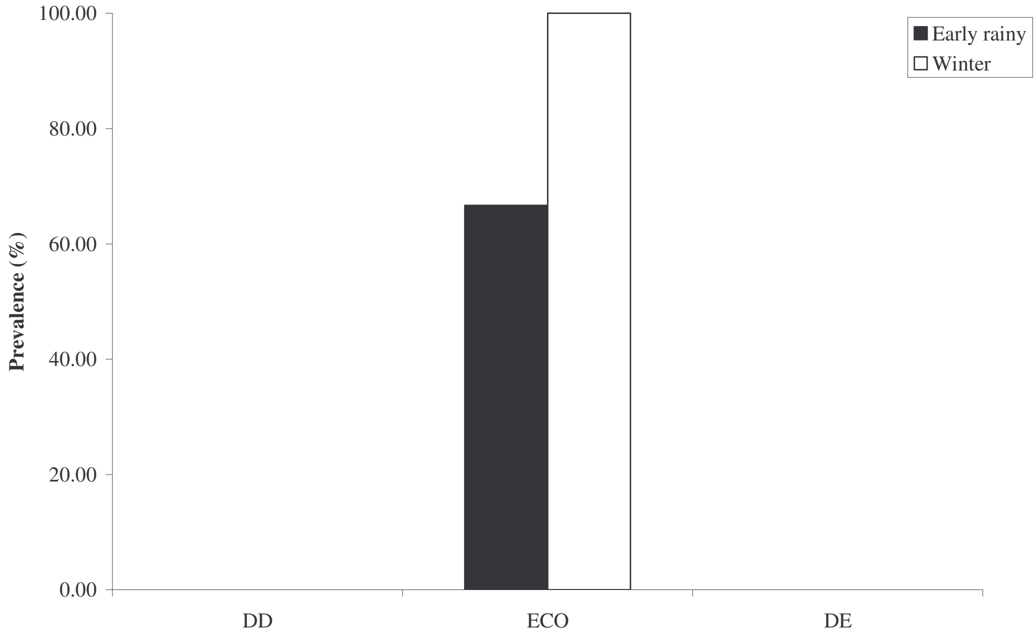


Figure 5.38 Mean prevalence of *Anaplasma* sp. found in *L. sabanus* in different seasons and habitat types.

***Grahamella* sp.**

Grahamella sp. was only found in ECO forest. The peak of *Grahamella* sp. prevalence in *L. sabanus* occurred in the early rainy season in ECO forest. The highest prevalence of *Grahamella* sp. (66.67%) was found in the early rainy season in ECO forest, followed by in the winter (50.00%) in ECO forest (Figure 5.39).

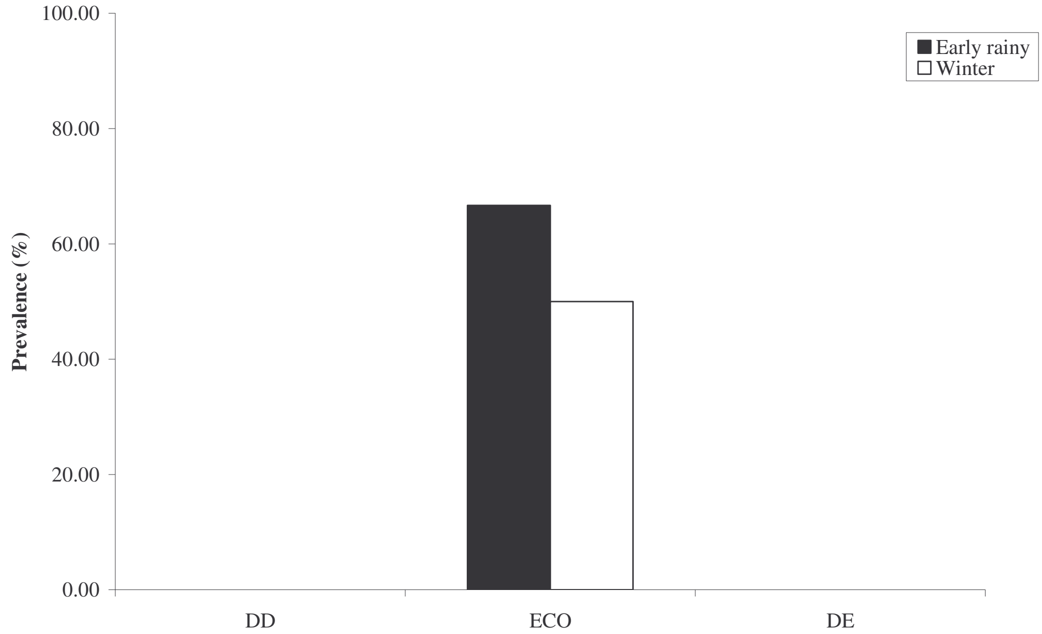


Figure 5.39 Mean prevalence of *Grahamella* sp. found in *L. sabanus* in different seasons and habitat types.

The relationship between seasons and the prevalence infection with blood parasite species: *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. revealed that *Anaplasma* sp. was significant different (χ^2 = 8.120, df=3, P<0.05) For other blood paraqsite species, there were not significant different (P>0.05).

5.4.4.4 Prevalence of Blood Parasites of Noisy Rat (*Leopoldamys sabanus*) Varied by Sex, Age and Habitat Types.

***Microfilaria* sp.**

In ECO forest, the prevalence n of *Microfilaria* sp. was only found in adult males (25.00%). For DE forest, the prevalence of *Microfilaria* sp. was greater in adult males (66.67%) than in adult females (50.00%) (Figure 5.40).

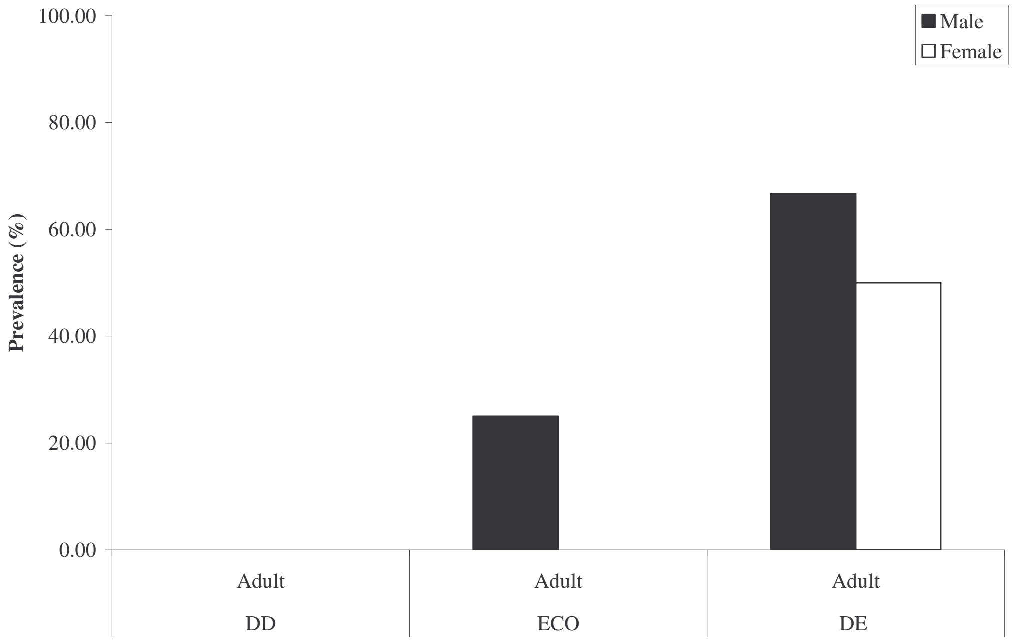


Figure 5.40 Mean prevalence *Microfilaria* sp. found in *L. sabanus* in different sex, age and habitat types.

***Trypanosoma* sp.**

In ECO forest, the prevalence of *Trypanosoma* sp. was only found in adult females (25.00%). Whereas the prevalence of *Trypanosoma* sp. was greater in adult females (50.00 %) than in adult males (33.33%) in DE forest (Figure 5.41).

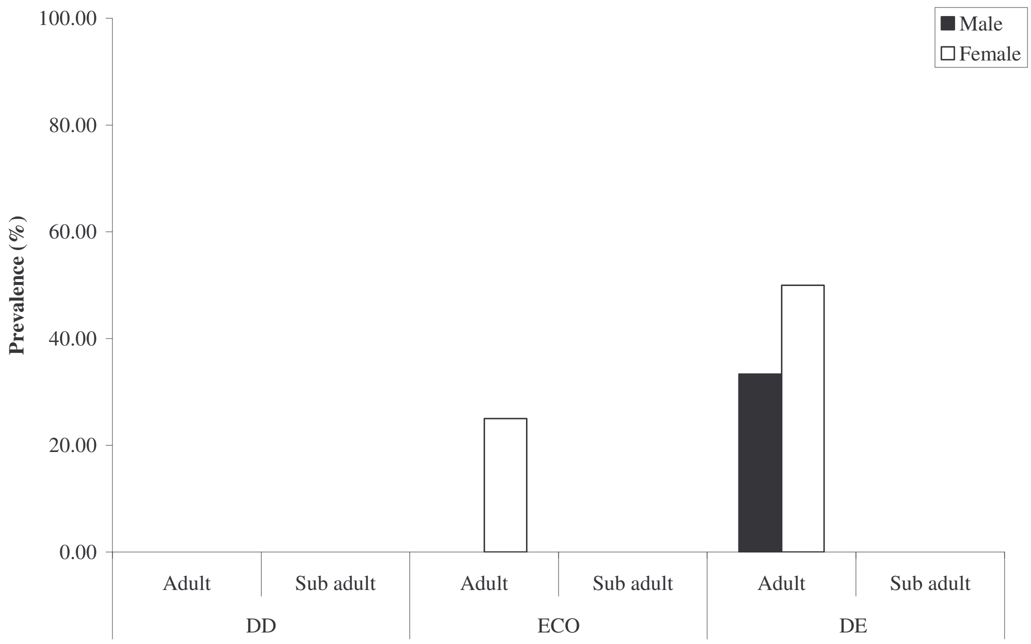


Figure 5.41 Mean prevalence of *Trypanosoma* sp. found in *L. sabanus* in different sex, age and habitat types.

***Anaplasma* sp.**

In ECO forest, the prevalence of *Anaplasma* sp. was greater in adult females (75.00 %) than in adult males (25.00%) (Figure 5.42).

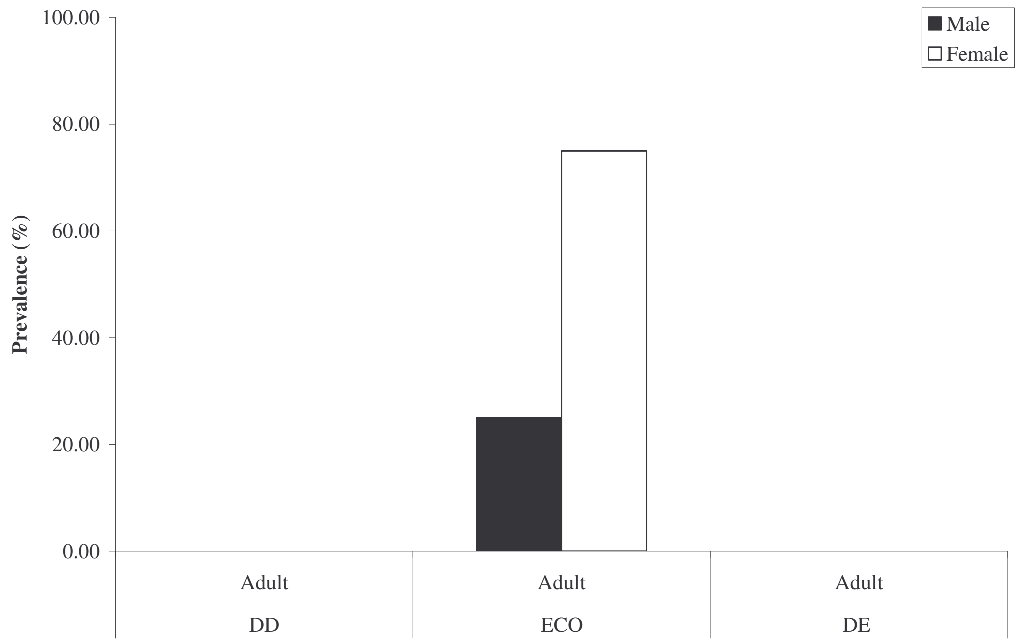


Figure 5.42 Mean prevalence of *Anaplasma* sp. found in *L. sabanus* in different seasons and habitat types.

Grahamella sp.

In ECO forest, the mean prevalence of *Grahamella* sp. was greater in adult females (50.00%) than in adult males (25.00%) (Figure 5.43).

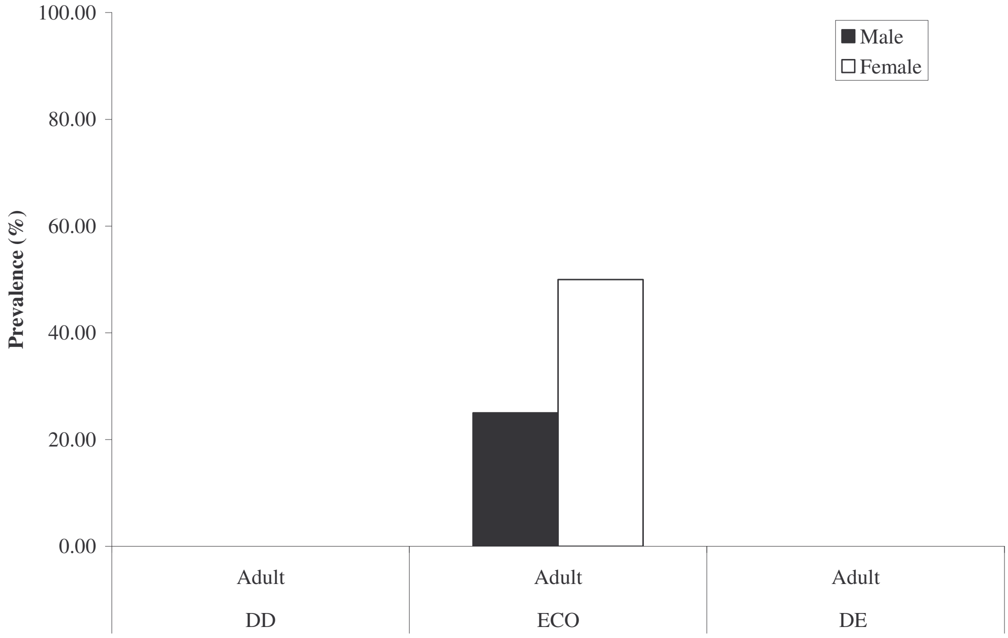


Figure 5.43 Mean prevalence of *Grahamella* sp. found in *L. sabanus* in different seasons and habitat types.

The relationship between sex and age of *L. sabanus* and the infection of *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. were not reach statistic differences (P>0.05). The relationship between mixed infection with *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. revealed that *Anaplasma* sp. was significantly correlated with *Grahamella* sp. (r^2 = 0.826).

5.4.4.5 Relationship of The Prevalence between Ectoparasites Species and Blood Parasite Species of *Leopoldamys sabanus*

The prevalence relationship between ectoparasite species: mite (*Laelaps echidinus*) and blood parasite species did not significant different (*P*>0.05) Table 5.22.

Table 5.21 Test statistic and associated *P* values for the relationship between ectoparasite species and blood parasite species in *L. sabanus*.

Ectoparasite species	Blood parasite species	χ^2	df	*P*
Mite (*Laelaps echidinus*)	*Microfilaria* sp.	1.593	1	0.207
	Trypanosoma sp.	0.042	1	0.837
	Anaplasma sp.	1.527	1	0.217
	Grahamella sp.	1.041	1	0.308

5.4.4.6 Intensity of Blood Parasites of Noisy Rat (*Leopoldamys sabanus*) Varied by Habitat Types, Seasonal, Sex and Age

Intensity of blood parasites infected per 100 erythrocyte of *R. rattus* in all habitat types varied by seasonal, sex and age were described as follow;

ECO forest

The numbers blood parasites infected per 100 erythrocytes was detected in *Microfaria* sp., *Anaplasma* sp. and *Grahamella* sp.. *Microfaria* sp., the intensity was only detected in adult males in the summer, and was 2.50 ± 0.71 infected erythrocytes per 100 erythrocytes. *Anaplasma* sp., the intensity ranged from 5.50-8.80 infected erythrocytes per 100 erythrocytes. For *Grahamella* sp., the intensity ranged from 7.50 -10.00 infected erythrocytes per 100 erythrocytes (Table 5.23).

DE forest

The numbers blood parasites infected per 100 erythrocytes was detected in *Microfaria* sp.and *Trypanosoma* sp.. *Microfaria* sp., the intensity was only detected in adult males in the summer, and was 8.00 infected erythrocytes per 100 erythrocytes. For *Trypanosoma* sp., the intensity ranged from 1.00-3.00 infected erythrocytes per 100 erythrocytes (Table 5.23).

The correlation between habitat types, seasonal, sex and age with intensity infection did not different (P>0.05). Intensity of infection with all blood parasite species did not vary significant (P>0.05) through combined for habitat types, seasonal, sex and age.

Table 5.22 Intensity of blood parasite infected of *L. sabanus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood parasites count per 100 erythrocytes							
				No.	*Microfilaria* sp. (N)	No.	*Trypanosoma* sp. (N)	No.	*Anaplasma* sp. (N)	No.	*Grahamella* sp. (N)
ECO	Early rainy season	F	Adult	-	-	-	-	2	5.50 ± 0.70	2	7.50 ± 0.70
	Winter	M	Adult	-	-	-	-	1	8.00	1	10.00
	Summer	M	Adult	2	2.50 ± 0.71	-	-	-	-	-	-
DE	Early rainy season	M	Adult	1	3.00	-	-	-	-	-	-
		F	Sub adult	-	-	1	2.00	-	-	-	-
	Late rainy season	M	Adult	-	-	1	3.00	-	-	-	-
	Summer	M	Adult	1	8.00	-	-	-	-	-	-
		F	Adult	-	-	1	1.00	-	-	-	-

5.4.4.7 Blood Values of Noisy Rat (*Leopoldamys sabanus*) Varied by Habitat Types, Seasonal, Sex and Age

Blood values obtained from *L. sabanus* in ECO and DE forest. Sex and age classes were combine for habitat types and seasonal comparison. Significant of habitat types and seasonal difference were detected for RBC, Hct, glucose, triglycerides, WBC and differential count of leucocytes (nuetrophil, lymphocyte, monocyte and eosinophil) (Table 5.24-5.26). The results were described as follow;

ECO forest

The mean of RBC was the highest (6.62 ± 0.20 10^6/µl) in adult females in the winter, and was the lowest (4.33 ± 0.00 10^6/µl) in adult males in the early rainy season. Mean of Hct was the highest (43.00 ± 0.00 %) in adult males in the early rainy season, and was the lowest (37.86 ± 2.67%) in adult females in the late rainy season. Mean of glucose was the highest (142.83 ± 38.78 mg/dl) in adult females in the early rainy season, and was the lowest (80.00 mg/dl) only one detected adult males in the winter. For the mean of triglyceride was the highest (188.50 ± 47.38 mg/dl) in sub adult females in the summer, and was the lowest (89.00 ± 0.00 mg/dl) in adult males in the early rainy season (Table 5.24).

Mean WBC was the highest (8.00 ± 4.10 10^3/µl) in adult females in the late rainy season, and was the lowest (4.03 ± 0.40 10^3/µl) in adult female in the winter (Table 5.25). Differential count of leucocytes, neutrophil was the highest (78.00%) only one detected adult female in the winter, and was the lowest (24.00%) only one detected in adult male in the summer. lymphocyte was the highest (75.00%) only one detected adult male in the summer, and was the lowest (20.00%) only one detected in adult female in the winter. For eosinophil was the highest (12.00%) only one detected adult male in the winter, and was equally the lowest (1.00%) only one detected adult male both in the early rainy season and summer. The values of monocytes and basophil did not detected (Table 5.26).

DE forest

RBC was the highest (6.77 10^6/µl) only one detected adult males in the late rainy season, and was the lowest (4.83 ± 1.11 10^6/µl) in adult males in the summer. Mean of Hct was the highest (50.00 ± 0.00 %) in sub adult females in the early rainy season, and was the lowest (36.00%) only one detected adult male in the winter. Mean of glucose was the highest (115.00 ± 3.46 mg/dl) in adult males in the summer, and was the lowest (91.00 ± 34.50 mg/dl) in adult females in the late rainy season. For the mean of triglyceride was the highest (213.00 ± 54.15 mg/dl) in sub adult females in the early rainy season, and was the lowest (108.00mg/dl) in adult female in the late rainy season (Table 5.24).

Mean WBC was the highest (7.00 ± 0.00 10^3/µl) in sub adult females in the early rainy season, and was the lowest (4.33 ± 2.78 10^3/µl) in adult male in the summer (Table 5.25). Differential count of leucocytes, neutrophil was the highest (61.00%) only one detected adult male in the early rainy season, and was the lowest (11.00%) only one detected in adult male in the late rainy season. lymphocyte was the highest (89.00%) only one detected adult male in the late rainy season, and was the lowest (37.00%) only one detected in adult male in the early rainy season. For eosinophil was the highest (13.00%) only one detected adult female in the summer, and was the lowest (2.00%) only one detected adult male in the early rainy season. The values of monocytes and basophil did not detected (Table 5.26).

The correlation between habitat types, seasonal, sex and age with blood values revealed that seasonal was significantly correlated with RBC (r^2 = 0.845). Age was significant correlated with Hct (r^2 = 0.681). Blood values did not vary significant through combined for habitat types, seasonal, sex and age (P>0.05).

The correlation between blood parasite species found in *L. sabanus* with blood values revealed that *Trypanosoma* sp. was significant correlated with Hct and WBC (r^2 = 0.639 and 0.677). *Anaplasma* sp. was significant correlated with neutrophil and lymphocytes (r^2 = 0.567 and 0.605).The correlation between intensity of blood parasite species with blood values did not significant different (P>0.05).

Table 5.23 Blood values of *L. sabanus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value							
				No.	RBC (10^6/µl)	No.	Hct (%)	No.	Glucose (mg/dl)	No.	Triglycerides (mg/dl)
ECO	Early rainy	Male	Adult	2	4.33 ± 0.00	2	43.00 ± 0.00	2	111.00 ± 0.00	2	89.00 ± 0.00
		Female	Adult	6	5.01± 0.69	8	40.00 ± 4.60	6	142.83 ± 38.78	3	103.67 ± 18.48
	Late rainy	Female	Adult	2	5.52 ± 0.19	7	37.86 ± 2.67	6	110.50 ± 37.04	3	131.33 ± 70.57
	Winter	Male	Adult	1	6.85	-	-	1	80.00	-	-
		Female	Adult	3	6.62 ± 0.20	2	39.00 ± 0.00	3	103.33 ± 20.82	-	-
	Summer	Female	Adult	3	6.02 ± 1.74	3	39.33 ± 2.08	2	116.50 ± 10.61	1	155.00
			Sub adult	2	5.28 ± 0.88	2	39.00 ± 2.83	2	124.50 ± 21.92	2	188.50 ± 47.38
DE	Early rainy	Male	Adult	3	4.88 ± 0.32	4	40.75 ± 0.96	3	98.33 ± 37.53	3	122.67 ± 4.04
		Female	Adult	4	6.10 ± 0.93	6	39.67 ± 3.14	3	98.00 ± 31.43	1	175.00
			Sub adult	2	5.41 ± 0.00	2	50.00 ± 0.00	2	109.00 ± 0.00	2	213.00 ± 54.15
	Late rainy	Male	Adult	1	6.77	1	42.00	-	-	-	-
		Female	Adult	-	-	3	48.00 ± 7.00	4	91.00 ± 34.50	1	108.00
	Winter	Male	Adult	1	6.77	1	36.00	1	150.00	-	-
	Summer	Male	Adult	3	4.83 ± 1.11	3	43.33 ± 4.91	3	115.00 ± 3.46	-	-
		Female	Adult	3	5.43 ± 1.43	3	44.50 ± 2.60	2	98.00 ± 0.00	-	-

Table 5.24 White blood cell count of *L. sabanus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	No.	WBC (10^3/µl)
ECO	Early rainy	M	Adult	2	5.70 ± 0.00
		F	Adult	6	4.48 ± 2.52
	Late rainy	F	Adult	2	8.00 ± 4.10
	Winter	M	Adult	1	4.50
		F	Adult	3	4.03 ± 0.40
	Summer	F	Adult	3	5.23 ± 1.25
			Sub adult	2	4.45 ± 0.21
DE	Early rainy	M	Adult	3	5.57 ± 1.85
		F	Adult	4	4.90 ± 2.11
			Sub adult	2	7.00 ± 0.00
	Late rainy	M	Adult	1	6.20
	Winter	M	Adult	1	6.20
	Summer	M	Adult	3	4.33 ± 2.78
		F	Adult	3	4.77 ± 0.81

Table 5.25 Differential counts of leucocytes in percentage of *L. sabanus* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value					
				No.	Nuetrophil (%)	No.	Lymphocytes (%)	No.	Eosinophil (%)
ECO	Early rainy	M	Adult	1	61.00	1	38.00	1	1.00
		F	Adult	2	69.00 ± 18.38	2	28.50 ± 16.26	2	2.50 ± 1.22
	Winter	M	Adult	1	60.00	1	28.00	1	12.00
		F	Adult	1	78.00	1	20.00	1	2.00
	Summer	M	Adult	1	24.00	1	75.00	1	1.00
		F	Adult	1	46.00	1	50.00	1	4.00
DE	Early rainy	M	Adult	1	61.00	1	37.00	1	2.00
			Sub adult	1	49.00	1	44.00	1	7.00
	Late rainy	M	Adult	1	11.00	1	89.00	1	3.00
	Summer	M	Adult	1	32.00	1	65.00	1	3.00
		F	Adult	2	50.00 ± 15.36	2	43.50 ± 26.16	1	13.00

5.4.5 Prevalence of of Parasitics found in Common Treeshrew (*Tupaia glis*)

5.4.5.1 Prevalence of Ectoparasites and Pseudoscorpion of Common Treeshrew (*Tupaia glis*)

The prevalence of mite (*Laelaps echidinus*) found in *T. glis* in DD and ECO forest. The highest (28.57 ± 14.29%) prevalence of mite was in the winter in ECO forest, and was lowest (11.11 ± 0.00%) in the late rainy season in ECO forest (Figure 5.44).

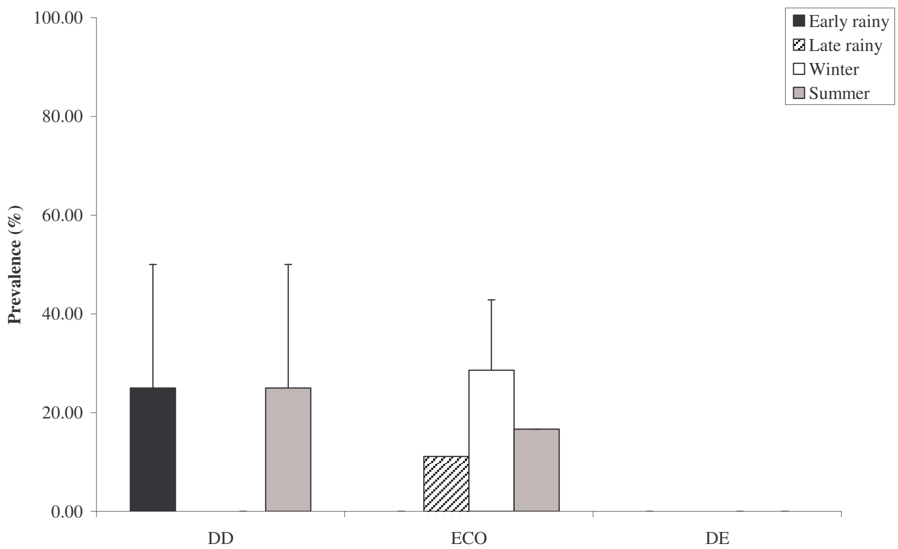


Figure 5.44 Mean prevalence of mite (*Laelaps echidinus*) found in *T. glis* in different seasons and habitat types.

The prevalence of flea (*Xenopsylla cheopsis*) found in *T. glis* in DD and ECO forest. The highest (18.18%) prevalence of flea was in the late rainy season in DD forest, and was lowest (16.67%) in the late rainy season and summer in ECO forest (Figure 5.45).

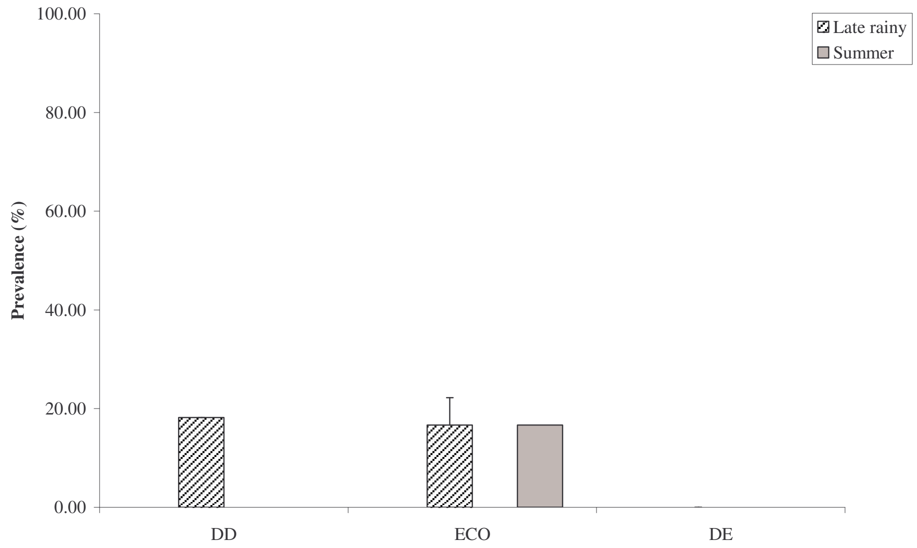


Figure 5.45 Mean prevalence of flea (*Xenopsylla cheopsis*) found in *T. glis* in different seasons and habitat types.

The prevalence of tick (*Ixodes* sp.) found in *T. glis* in DD and ECO forest. The highest (50.00%) prevalence of tick was in the summer in DD forest, and was lowest (14.29 %) in the winter in ECO forest (Figure 5.46).

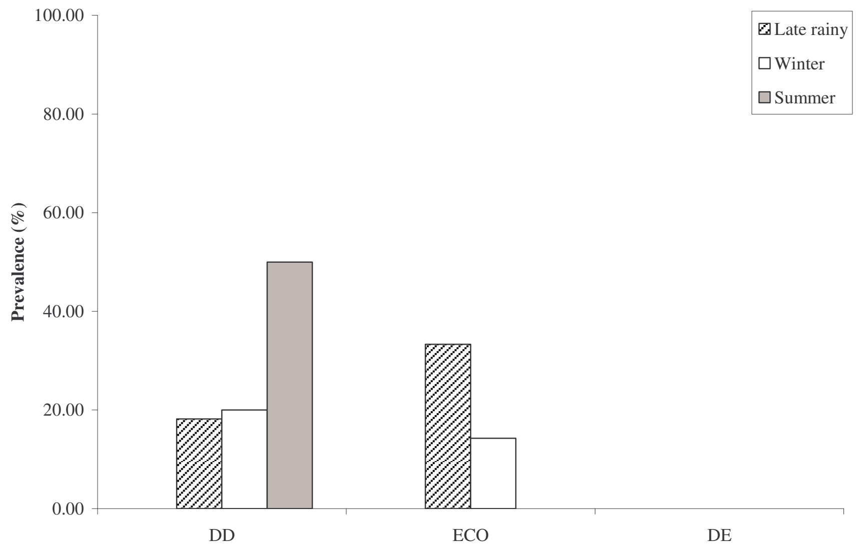


Figure 5.46 Mean prevalence of tick (*Ixodes* sp.) found in *T. glis* in different seasons and habitat types.

The prevalence of pseudoscorpion (*Chelifer cancroides*) found in *T. glis* in DD and ECO forest. The highest (16.67%) prevalence of pseudoscorpion was both in the late rainy season and summer in ECO forest, and was lowest (9.09%) in the late rainy season in DD forest (Figure 5.47).

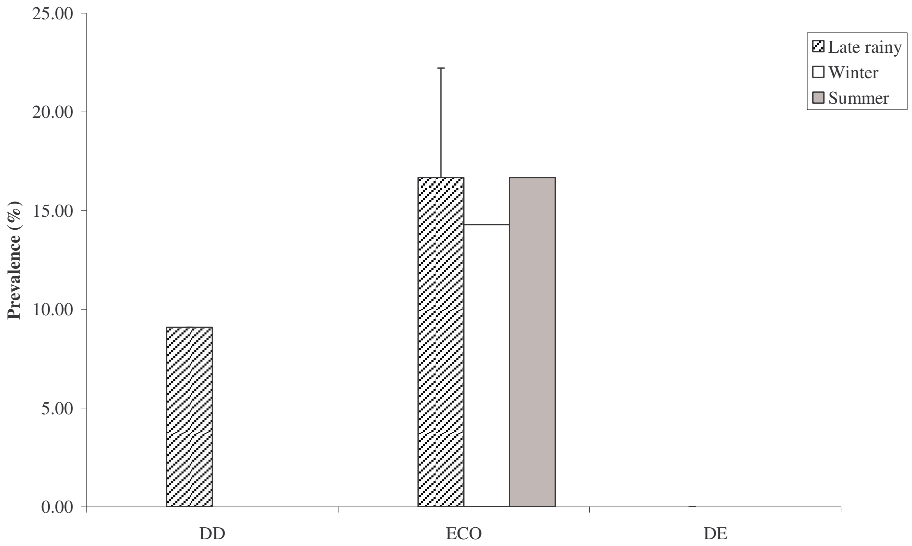


Figure 5.47 Mean prevalence of pseudoscorpion (*Chelifer cancroides*) found in *T. glis* in different seasons and habitat types.

The relationship between seasons and the prevalence of ectoparasite species and pseudoscorpion: mite (*Laelaps echidinus*), Flea (*Xenopsylla cheopsis*), Tick (*Ixodes* sp.) and pseudoscorpion (*Chelifer cancroides*), there were not significant different (P>0.05).

5.4.5.2 Prevalence of Ectoparasites and Pseudoscorpion of Common Treeshrew (*Tupaia glis*) Varied by Sex, Age and Habitat Types.

Mite (*Laelaps echidinus*)

In DD forest, the prevalence of mite (*Laelaps echidinus*) found in adult males (11.11%) was greater than in adult females (10.00%). For ECO forest, the prevalence of mite (*Laelaps echidinus*) found in adult females (18.18 ± 9.09%) was greater than in adult males (36.36 ± 13.64%) (Figure 5.48).

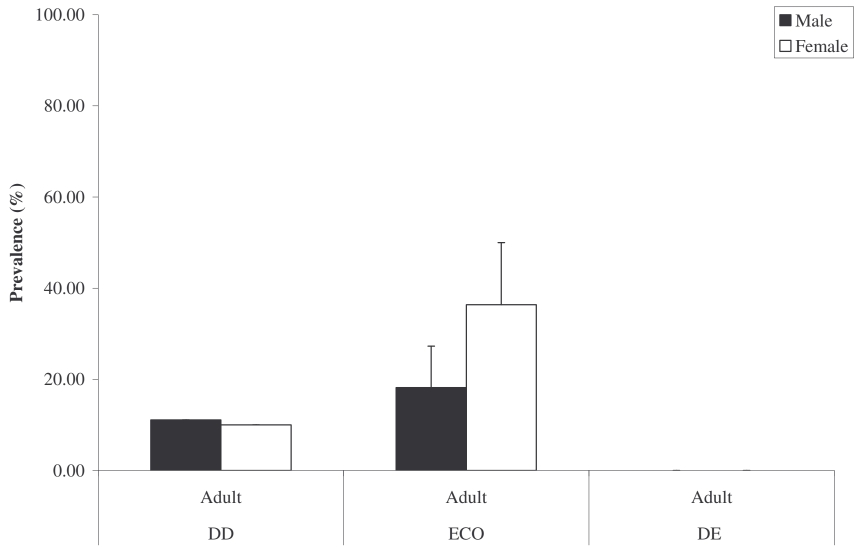


Figure 5.48 Mean prevalence of mite (*Laelaps echidinus*) found in *T. glis* in different sex, age and habitat types.

Flea (*Xenopsylla cheopsis*)

In DD forest, the prevalence of flea (*Xenopsylla cheopsis*) found in adult females (20.00%). For ECO forest, the prevalence of flea (*Xenopsylla cheopsis*) found in adult males (13.64 ± 4.04%) was greater than adult females (9.09%) (Figure 5.49).

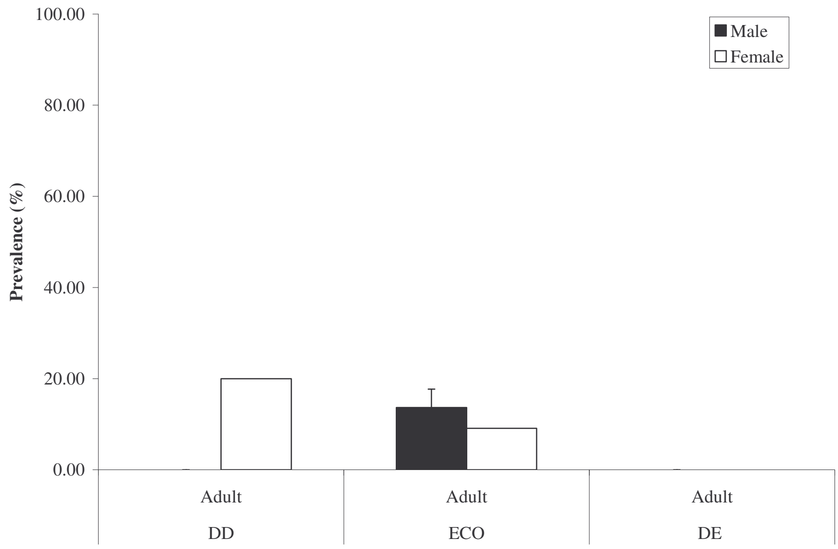


Figure 5.49 Mean prevalence of flea (*Xenopsylla cheopsis*) found in *T. glis* in different sex, age and habitat types.

Tick (*Ixodes* sp.)

In DD forest, the prevalence of tick (*Ixodes* sp.) found in adult females (30.00%) was greater than in adult males (11.11%). For ECO forest, the prevalence of tick (*Ixodes* sp.) found in adult females (27.27 ± 9.09%) was greater than in adult males (13.64 ± 6.06%), whereas it was only found in sub adult females (100.00%) (Figure 5.50).

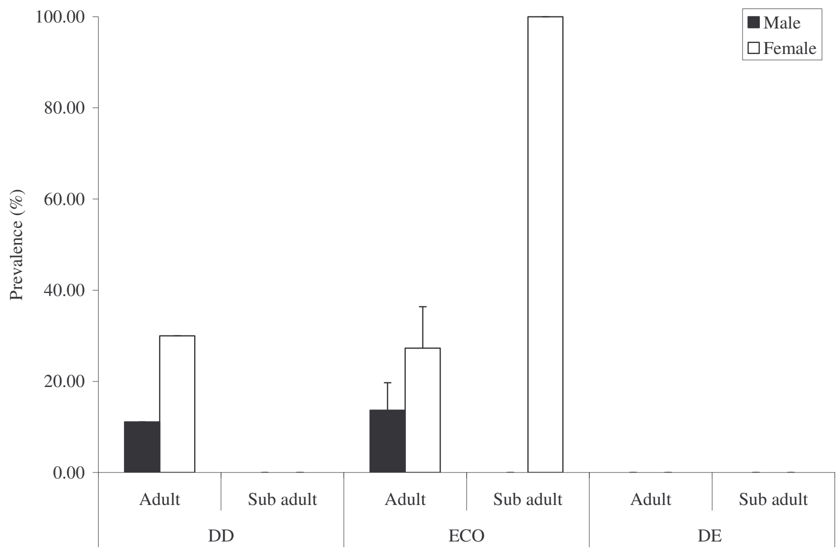


Figure 5.50 Mean prevalence of tick (*Ixodes* sp.) found in *T. glis* in different sex, age and habitat types.

Pseudoscorpion (*Chelifer cancroides*)

In DD forest, the prevalence of pseudoscorpion (*Chelifer cancroides*), it was only found in adult males (11.11%). For ECO forest, the prevalence of pseudoscorpion (*Chelifer cancroides*) found in adult males (18.18%) was greater than in adult females (9.09%) (Figure 5.51).

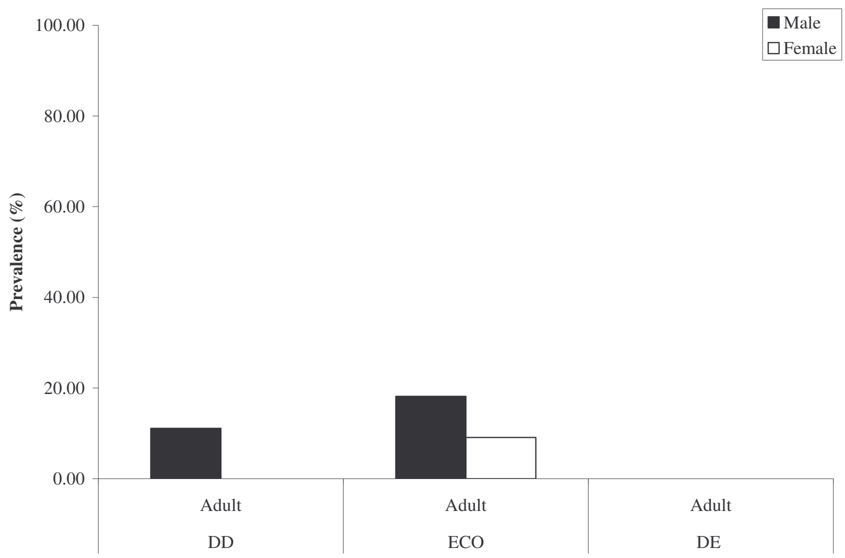


Figure 5.51 Mean prevalence of pseudoscorpion (*Chelifer cancroides*) found in *T. glis* in different sex, age and habitat types.

The relationship between sex and age of *T. glis* and the prevalence of ectoparasite species and pseudoscorpion was not significant different (P>0.05).

5.4.5.3 Prevalence of Blood Parasites of Common Treeshrew (*Tupaia glis*)

***Microfilaria* sp.**

The peak of *Microfilaria* sp. prevalence in *T. glis* occurred in the winter in DE forest. The highest prevalence of *Microfilaria* sp. (100.00%) was found in the winter in DE forest, whereas the lowest prevalence (14.29%) was found in the winter in ECO forest (Figure 5.52).

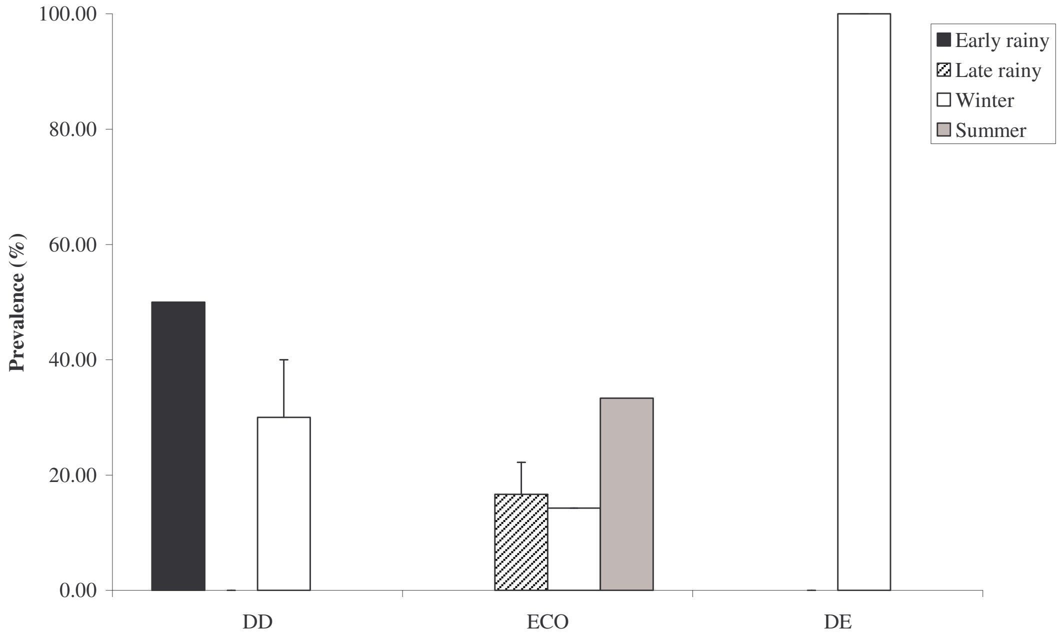


Figure 5.52 Mean prevalence of *Microfilaria* sp. found in *T. glis* in different seasons and habitat types.

***Anaplasma* sp.**

The peak of *Anaplasma* sp. prevalence in *T. glis* occurred in the early rainy season in DD forest. The highest prevalence of *Anaplasma* sp. (50.00%) was found in the early rainy season in DD forest, whereas the lowest prevalence (9.09%) was found in the late rainy season in DD forest (Figure 5.53).

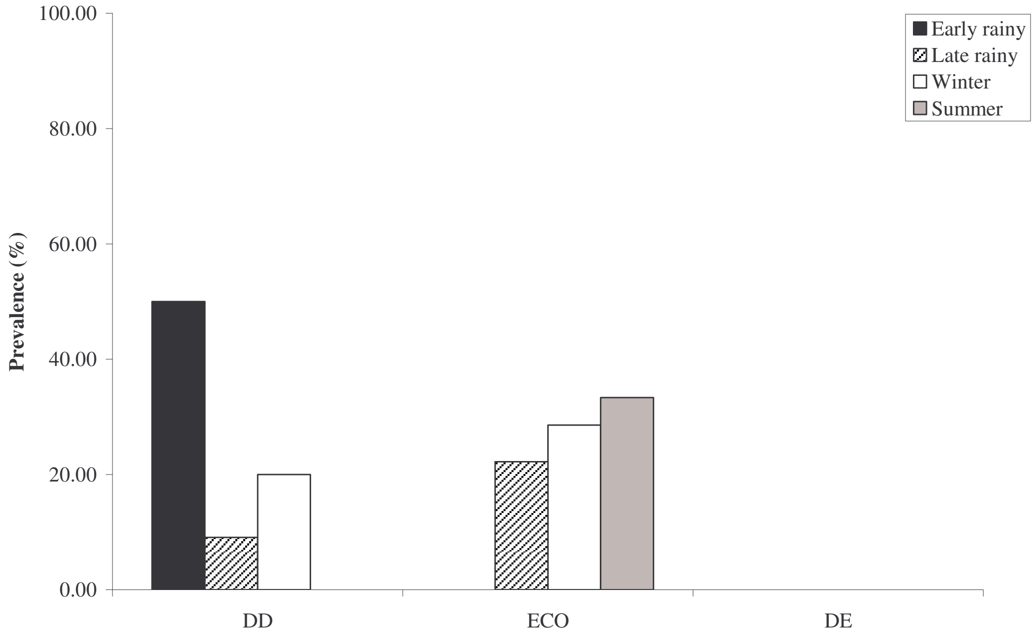


Figure 5.53 Mean prevalence of *Anaplasma* sp. found in *T. glis* in different seasons and habitat types.

***Grahamella* sp.**

The peak of *Grahamella* sp. prevalence in *T. glis* equally occurred in the summer in DD and ECO forest. The highest prevalence of *Grahamella* sp. (50.00%) was found in the summer in DD and ECO forest, whereas the lowest prevalence (9.09 %) was found in the late rainy season in DD forest (Figure 5.54).

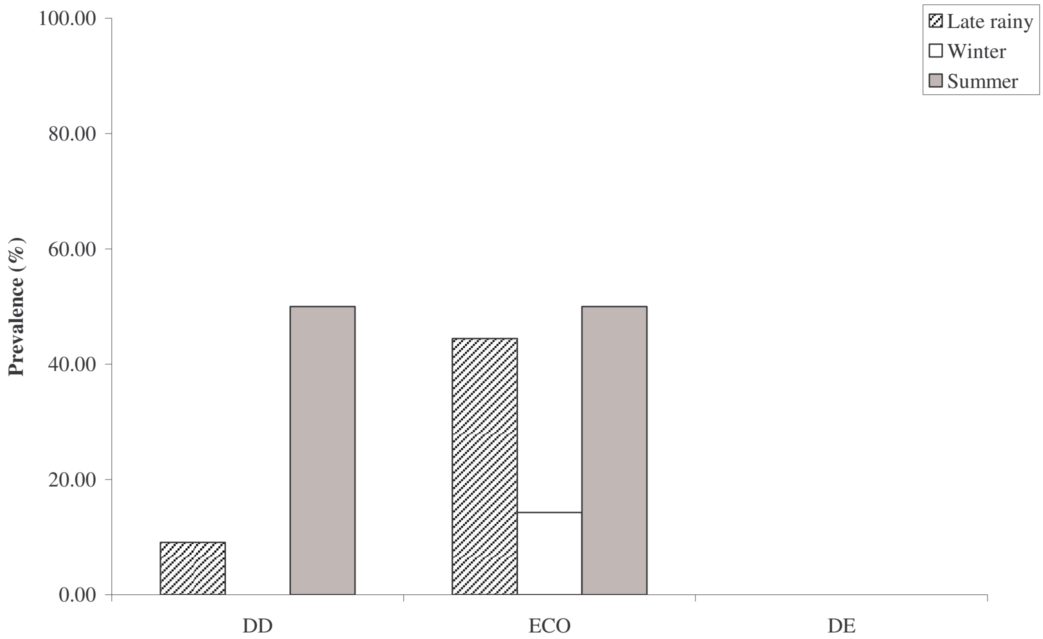


Figure 5.54 Mean prevalence of *Grahamella* sp. found in *T. glis* in different seasons and habitat types.

The relationship between seasons and the prevalence of blood parasite species were not significant different (*P*>0.05).

5.4.5.4 Prevalence of Blood Parasites of Common Treeshrew (*Tupaia glis*) Varied by Sex, Age and Habitat Types.

***Microfilaria* sp.**

In DD forest, the prevalence of *Microfilaria* sp. was greater in adult males (16.67%) than in adult females (10.00%). In ECO forest, the prevalence of *Microfilaria* sp., it was equally in adult males and adult females (50.00%). For DE forest, the infection of *Microfilaria* sp., it was only found in adult males (50.00%) (Figure 5.55).

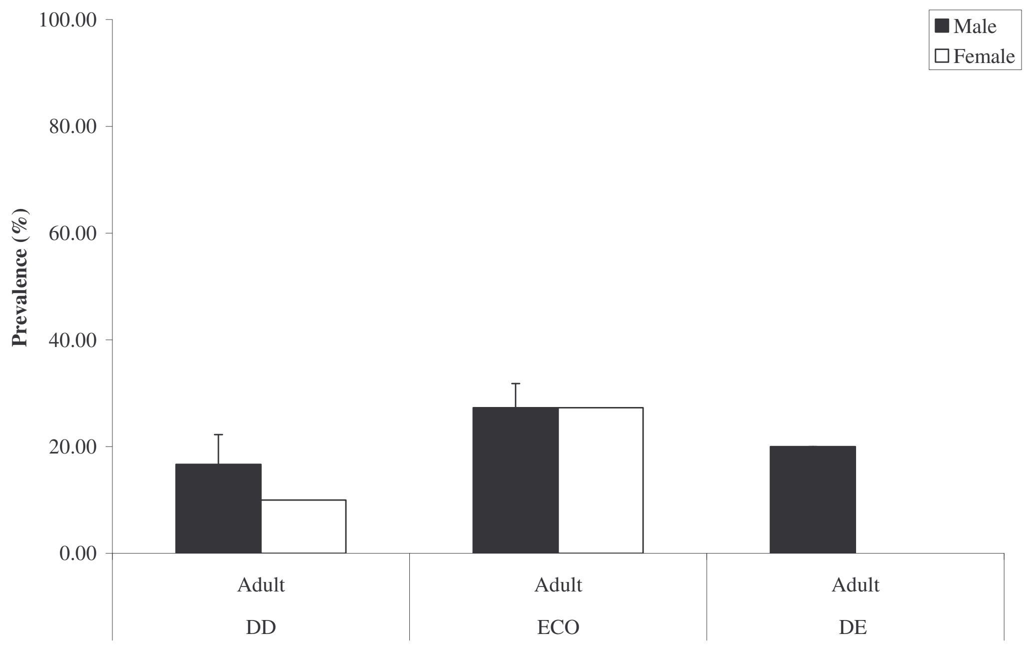


Figure 5.55 Mean prevalence of *Microfilaria* sp. found in *T. glis* in different sex, age and habitat types.

***Anaplasma* sp.**

In DD forest, the prevalence of *Anaplasma* sp. was greater in adult males (22.22%) than in females (10.00%). For ECO forest, the prevalenc of *Anaplasma* sp. was greater in adult males (36.36 ± 9.09%) than I adult females (27.27 ± 4.55%), Where as it was only found in sub adult females (100.00%) (Figure 5.56).

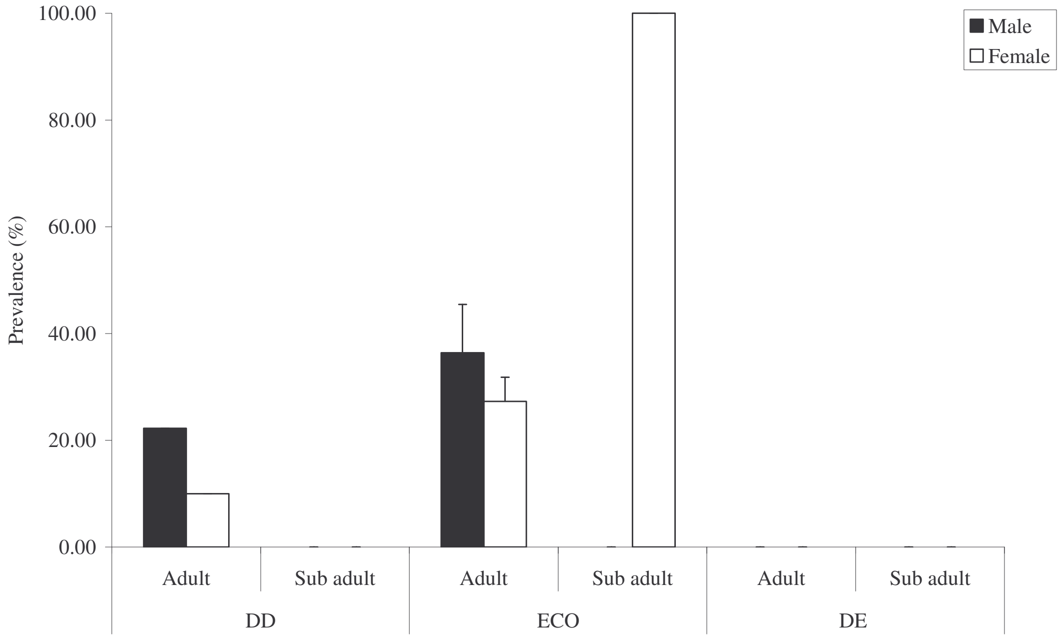


Figure 5.56 Mean prevalence of *Anaplasma* sp. found in *T. glis* in different seasons and habitat types.

***Grahamella* sp.**

In DD forest, the prevalence of *Grahamella* sp., it was only found in adult males (16.67 ± 5.56%). For ECO forest, the prevalence of *Grahamella* sp. was greater in adult males (36.36%) than in adult females (27.27%), Where as it was only found in sub adult females (100.00%) (Figure 5.57).

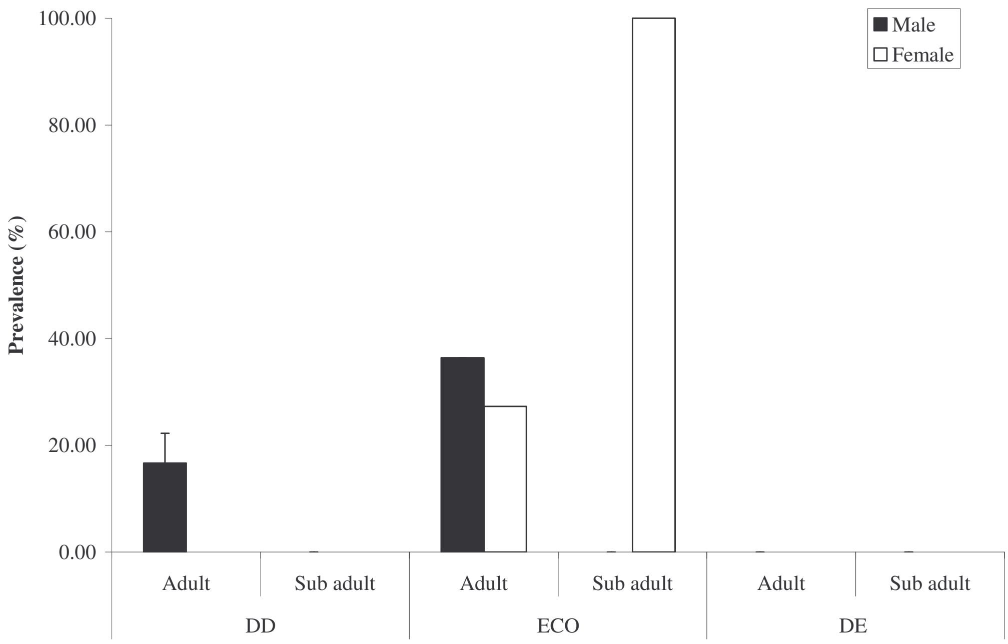


Figure 5.57 Mean prevalence of *Grahamella* sp. found in *T. glis* in different seasons and habitat types.

The relationship between sex and age of *T. glis* and the prevalence of *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. was were not reach statistic differences (P>0.05). The relationship between mixed infection with *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. revealed that *Anaplasma* sp. was significantly correlated with *Grahamella* sp. ($r^2 = 0.301$).

5.4.5.5 Relationship of The Prevalence between Ectoparasites Species, Pseudoscorpion and Blood Parasite Species of *Tupaia glis*

The prevalence relationship between ectoparasite species, pseudoscorpion and blood parasite species was significant greatest between tick (*Ixodes* sp.) and *Grahamella* sp. (χ^2 = 4.521, df=1, P<0.05). For the relationship of the prevalence between other ectoparasite species, pseudoscorpion and blood parasite species did not significant different (P>0.05).

Table 5.26 Test statistic and associated *P* values for the relationship between ectoparasite species, pseudoscorpion and blood parasite species in *T. glis*.

Ectoparasite species	Blood parasite species	χ^2	df	*P*
Mite (*Laelaps echidinus*)	*Microfilaria* sp.	0.050	1	0.823
	Anaplasma sp.	1.333	1	0.248
	Grahamella sp.	0.050	1	0.823
Flea (*Xenopsylla cheopsis*)	*Microfilaria* sp.	2.686	1	0.101
	Anaplasma sp.	0.050	1	0.823
	Grahamella sp.	0.050	1	0.823
Tick (*Ixodes* sp.)	*Microfilaria* sp.	0.228	1	0.633
	Anaplasma sp.	1.696	1	0.193
	Grahamella sp.	4.521	1	0.033

Table 5.26 Test statistic and associated *P* values for the relationship between ectoparasite species, pseudoscorpion and blood parasite species in *T. glis* (Continued).

Ectoparasite species	Blood parasite species	χ^2	df	*P*
Pseudoscorpion	*Microfilaria* sp.	0.510	1	0.475
	Anaplasma sp.	0.510	1	0.475
	Grahamella sp.	0.510	1	0.475

5.4.5.6 Intensity of Blood Parasites of Common Treeshrew (*Tupaia glis*) Varied by Habitat Types, Seasonal, Sex and Age

Intensity of blood parasites infected per 100 erythrocyte of *T. glis* in all habitat types varied by seasonal, sex and age were described as follow;

DD forest

Microfilaria sp., the intensity ranged from 1.00-3.00 infected per 100 erythrocytes. *Trypanosoma* sp., intensity was only found in adult female, and was 2.00 infected erythrocytes per 100 erythrocytes. *Anaplasma* sp., the intensity ranged from 1.00-6.00 infected erythrocytes per 100 erythrocytes. For *Grahamella* sp., mean intensity ranged from 1.50-6.00 infected erythrocytes per 100 erythrocytes (Table 5.28).

ECO forest

Microfilaria sp., mean intensity ranged from 4.00-8.00 infected per 100 erythrocytes. *Trypanosoma* sp., mean intensity ranged from 2.00-4.00 infected erythrocytes per 100 erythrocytes. *Anaplasma* sp., mean intensity ranged from 1.00-3.00 infected erythrocytes per 100 erythrocytes. For *Grahamella* sp., mean intensity was only found in adult females, and was 2.00 infected erythrocytes per 100 erythrocytes (Table 5.28).

DE forest

Microfilaria sp., the intensity was only found in one male adult, and was 3.00 infected erythrocytes per 100 erythrocytes (Table 5.28).

The correlation between habitat types, seasonal, sex and age with intensity infection did not significant different (*P*>0.05).

Table 5.27 Intensity of blood parasite infected of *T. glis* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood parasites count per 100 erythrocytes							
				No.	*Microfilaria* sp. (N)	No.	*Trypanosoma* sp. (N)	No.	*Anaplasma* sp. (N)	No.	*Grahamella* sp. (N)
DD	Early rainy	M	Adult	-	-	-	-	1	1.00	-	-
	Late rainy	M	Adult	-	-	-	-	-	-	2	1.50 ± 0.71
		F	Adult	-	-	1	2.00	1	6.00	1	2.00
	Winter	M	Adult	1	1.00	-	-	-	-	1	6.00
	Summer	M	Adult	1	3.00	-	-	-	-	-	-
ECO	Late rainy	M	Adult	-	-	1	4.00 ± 1.41	-	-	-	-
		F	Adult	1	4.00	1	3.00	1	3.00	-	-
	Winter	F	Adult	1	5.00	1	2.00	-	-	2	2.00 ± 0.00
	Summer	M	Adult	1	8.00	-	-	-	-	-	-
		F	Adult	-	-	-	-	1	1.00	-	-
DE	Winter	M	Adult	1	3.00	-	-	-	-	-	-

5.4.5.7 Blood Values of Common Treeshrew (*Tupaia glis*) Varied by Habitat Types, Seasonal, Sex and Age

Blood values obtained from *T. glis* in three habitat types. Sex and age classes were combine for habitat types and seasonal comparison. Significant of habitat types and seasonal difference were detected for RBC, Hct, glucose, triglycerides, WBC and differential count of leucocytes (nuetrophil, lymphocyte, monocyte and eosinophil) (Table 5.29-5.31). The results were described as follow;

DD forest

Mean of RBC was the highest (7.00 ± 1.89 10^6/µl) in adult males in the winter, and was the lowest (5.93 10^6/µl) only one detected adult female in the late rainy season. Mean of Hct was the highest (48.25 ± 2.72%) in adult males in the winter, and was the lowest (38.50%) only one detected adult female in the winter. Mean of glucose was the highest (186.00 ± 70.71 mg/dl) in adult males in the early rainy season, and was the lowest (60.00 ± 0.00 mg/dl) in adult females in the winter. For the triglyceride was the highest (203.17 ± 90.35 mg/dl) in adult females in the late rainy season, and was the lowest (72.00 mg/dl) only one detected adult females in the winter (Table 5.19).

Mean WBC was the highest (6.20 10^3/µl) only one detected adult female in the late rainy season, and was the lowest (3.70 ± 1.20 10^3/µl) in adult females in the summer (Table 5.30). Differential count of leucocytes, neutrophil was the highest (84.00%) only one detected in adult male in the late rainy season, and was the lowest (20.00%) in only one detected in adult female in the late rainy season. Lymphocyte was the highest (80.00%) only one detected adult female in the late rainy season, and was the lowest (16.00%) only one detected adult male in the late rainy season. For the eosinophil was only one detected adult male in the winter (8.00%). For monicyte did not detected (Table 5.31).

ECO forest

RBC was the highest (7.95 10^6/µl) only one detected sub adult female in the late rainy season, and was the lowest (5.59 ± 1.63 10^6/µl) in adult females in the late rainy season. Mean of Hct was the highest (52.63 ± 7.42%) in adult males in the summer, and was the lowest (42.35 ± 0.50%) in adult males in the winter. Glucose was equally the highest (162.00 mg/dl) only one detected both in adult male and female in the late rainy season, and was the lowest (110.88 ± 31.63 mg/dl) in adult females in the winter. For the mean of triglyceride was the highest (143.00 ± 46.38 mg/dl) in adult females in the late rainy season, and was the lowest (80.00 ± 0.00 mg/dl) in adult males in the winter (Table 5.29).

Mean WBC was the highest (6.08 ± 0.59 10^3/µl) in adult females in the winter, and was the lowest (3.00 ± 1.83 10^3/µl) in adult males in the winter (Table 5.30). Differential count of leucocytes, mean of neutrophil was the highest (77.67 ± 10.97%) in adult male in the late rainy season, and was the lowest (13.00%) only one detected in adult female in the late rainy season. Lymphocyte was the highest (87.00%) only one detected in adult female in the late rainy season, and was the lowest (22.00 ± 11.27%) in adult males in the late rainy season. Monocytes was only detected adult male in the summer (3.00%). For eosinophil was only one detected in adult male (1.00%) in the late rainy season (Table 5.31).

DE forest

Mean of RBC was the highest (7.59 ± 0.00 10^6/µl) in adult males in the winter, and was the lowest (5.40 ± 0.00 10^6/µl) in adult males in the early rainy season. Mean of Hct was the highest (51.00 ± 0.00%) in adult females in the early rainy, and was the lowest (30.00%) only one detected adult male in the early rainy season. Glucose was the highest (199.00 ± 0.00% mg/dl) in adult males in the winter, and was the lowest (137.00 mg/dl) only one detected adult males in the early rainy season. For triglyceride was the highest (208.00 mg/dl) only one detected adult male in the late rainy season, and was the lowest (84.00 mg/dl) only one detected adult male in the early rainy season (Table 5.29).

Mean of WBC was the highest (66.60 ± 0.00 10^3/µl) in adult females in the early rainy season, and was the lowest (4.70 ± 0.71 10^3/µl) in adult males in the winter (Table 5.30). Differential count of leucocytes, neutrophil was the highest (88.00%) only one detected adult male in the early rainy season, and was equally the lowest (60.00%) only one detected both in adult female in the late rainy season and adult male in the winter. lymphocyte was equally the highest (40.00%) only one detected both in adult female in the late rainy season and adult male in the winter, and was the lowest (12.00%) only one detected adult male in the early rainy season. The values of monocytes and eosinophil did not detected.

The correlation between habitat types, seasonal, sex and age with blood values revealed that seasonal was significantly correlated with Hct (r^2 = 0.536); sex was significantly correlated with glucose (r^2 = -0.717), and was significant correlated with neutriphil (r^2 = -0.538) and lymphocyte (r^2 = 0.545). Blood values did not vary significant through combined for habitat types, seasonal, sex and age (P>0.05).

The correlation between blood parasite species found in *T. glis* with blood values revealed that *Microfilaria* sp. was significant correlated with lymphocyte (r^2 = -0.615). The correlation between intensity of blood parasite species with blood values did not significant different (P>0.05).

Table 5.28 Blood values of *T. glis* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value							
				No.	RBC (10^6/µl)	No.	Hct (%)	No.	Glucose (mg/dl)	No.	Triglycerides (mg/dl)
DD	Early rainy	Male	Adult	-	-	2	45.00 ± 0.00	2	186.00 ± 70.71	2	90.00 ± 0.00
	Late rainy	Male	Adult	2	6.33 ± 0.00	5	44.20 ± 4.09	-	-	-	-
		Female	Adult	1	5.93	12	44.88 ± 5.94	2	86.00 ± 70.71	6	203.17 ± 90.35
			Sub adult	-	-	2	47.00 ± 0.00	-	-	-	-
	Winter	Male	Adult	5	7.00 ± 1.89	4	48.25 ± 2.72	8	134.13 ± 26.92	2	112.00 ± 0.00
		Female	Adult	-	-	4	44.00 ± 2.83	2	115.00 ± 21.21	1	72.00
		Female	Adult	3	6.20 ± 1.11	1	38.50	2	60.00 ± 0.00	-	-
ECO	Late rainy	Male	Adult	4	5.91 ± 0.87	9	47.67 ± 6.72	1	162.00	1	112.00
		Female	Adult	4	5.59 ± 1.63	7	46.29 ± 6.50	1	162.00	3	143.00 ±46.38
			Sub adult	1	7.95	1	52.00	-	-	-	-
	Winter	Male	Adult	2	5.27 ± 2.45	4	43.25 ± 0.50	5	144.60 ± 65.27	2	80.00 ± 0.00
		Female	Adult	4	6.96 ± 0.40	6	48.25 ± 2.52	8	110.88 ± 31.63	2	95.00 ± 0.00
	Summer	Male	Adult	3	6.79 ± 1.36	8	52.63 7.42	3	152.00 ± 1.73	-	-
DE	Early rainy	Male	Adult	2	6.79 ± 0.00	1	51.00	1	137.00	1	84.00
		Female	Adult	2	5.40 ± 0.00	2	30.00 ± 0.00	-	-	-	-
	Late rainy	Male	Adult	-	-	2	44.50 ± 0.00	-	-	1	208.00
		Female	Adult	-	-	2	43.00 ± 0.00	-	-	-	-
	Winter	Male	Adult	2	7.59 ± 0.00	2	50.00 ± 0.00	2	199.00 ± 0.00	-	-

Table 5.29 White blood cell count of *T. glis* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	**Season**	**Sex**	**Age**	**No.**	**WBC (10^3/µl)**
DD	Late rainy	M	Adult	2	5.10 ± 0.00
		F	Adult	1	6.20
	Winter	M	Adult	5	3.42 ±1.23
	Summer	F	Adult	3	3.70 ± 1.20
ECO	Late rainy	M	Adult	4	4.10 ± 1.25
		F	Adult	4	4.40 ± 0.47
			Sub adult	1	4.60
	Winter	M	Adult	2	3.00 ± 1.83
		F	Adult	4	6.08 ± 0.59
	Summer	M	Adult	3	5.46 ± 0.17
DE	Early rainy	M	Adult	2	4.80 ± 2.40
		F	Adult	2	6.60 ± 0.00
	Winter	M	Adult	2	4.70 ± 0.71

Table 5.30 Differential counts of leucocytes in percentage of *T. glis* in different habitat types varies by seasons, sex and age in Sakearat Environmental Research Station.

Habitat	Season	Sex	Age	Mean blood value							
				No.	Nuetrophil (%)	No.	Lymphocytes (%)	No.	Monocytes (%)	No.	Eosinophil (%)
DD	Late rainy	M	Adult	1	84.00	1	16.00	-	-	-	-
		F	Adult	1	20.00	1	80.00	-	-	-	-
	Winter	M	Adult	2	48.00 ± 19.80	2	48.00 ± 25.46	-	-	1	8.00
ECO	Late rainy	M	Adult	3	77.67 ± 10.97	3	22.00 ± 11.27	-	-	1	1.00
		F	Adult	1	13.00	1	87.00	-	-	-	-
			Sub adult	1	41.00	1	53.00	-	-	-	-
	Winter	F	Adult	2	69.00 ± 5.66	2	31.00 ± 5.66	-	-	-	-
	Summer	M	Adult	1	71.00	1	26.00	1	3.00	-	-
DE	Early rainy	M	Adult	1	88.00	1	12.00	-	-	-	-
		F	Adult	1	60.00	1	40.00	-	-	-	-
	Winter	M	Adult	1	60.00	1	40.00	-	-	-	-

5.5 Discussion

5.5.1 The prevalence and infection of ectoparasites and blood parasites

5.5.1.1 The prevalence of ectoparasites species and pseudoscorpion in small mammals

During the study period, 350 small mammals represented ectoparsites. The four most common small mammal species captured including *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* in all habitat types. The ectoparasites mainly found were from different species including mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroide*).

M. surifer, had the most abundant parasites with 77.05% of total mite (*L. echidinus*), 31.15% of total flea (*X. cheopsis*) and 14.75% of total pseudoscorpion (*Chelifer cancroide*) followed by *R. rattus*. *T. glis*, the most abundant, with 22.00% of the total of tick (*Ixodes* sp.). Except for *L. sabanus*, was only found infested of mite (*L. echidinus*).

Tinarat (1996) studied at Huay Khum Nature and Wildlife Education Centre part of phu Khieaw Sanctuary in Chaiyaphum Province, revealed that four species of 1,609 ectoparasites found on 85 mammals; namely, mites (*Laelaps echidninus*), hard ticks (*Ixodes* sp.), Oriental rat fleas (*Xenopsylla cheopis*), and Northern rat fleas (*Nosopsyllus fasciatus*). The diversity of ectoparasites on roof rats, yellow rajah rats, common tree shrew, ground squirrels and lesser bandicoots was 1.147, 1.013, 1.000, 1.990 and 1.000 respectively.

According to the study by Cheewakrienkrai and Parsartwit (2004) in the topic of survey of Scrub and Murine typhus vectors and infection rate at 6 international seaports founded that all infected rats were found to have chigger mite was 93% and 7% was flea *Xenopsylla cheopis*.

This study presences pesudoscorpion in *M. surifer*, *R. rattus* and *T. glis*. From the study by Weygoldt (1969) revealed that the presence of pseudoscorpions in rodent nest has been know for along time. Symbiosis has been defined by Wilson (1975) as the intimate, relatively protracted, and dependent relationship of members of members of one species with those of another. He further recognized three kinds of such interaction including parasitism, commensalism and mutualism. The study obtained by Francke and Guzman (2006) revealed that thirty-two species of pseudoscorpion have been found co-existing with nine packrat or wood rat species of the genus *Neotoma*, and this association has been referred to as phoresy. Phoresy is a term for passive dispersal when and animal literally hitches as a ride on another to reach a new habitat. The psedoscorpions reported above live in or on the nest of the packrat and do not ride on the rats them selves, elimating a truly phoretic association, and indicating at least a communalistic relationship exists, whereby the pseudoscorpion benefits from shelter and food found in the nest by feeding on rodent ectoparasites, specifically larval and adult fleas.

5.5.1.2 The prevalence of blood parasite species in small mammals

The occurrence of patient infections with blood parasites found in four most common species captured including *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* in all habitat types. One genara of Protozoa and Microfilariae, and two genus of Rickettsia were detected in this study. The hemaoprotozoa was *Trypanosoma* sp., which was found in plasma. The Microfilariae was *Microfilaria* sp. The Rickettsia were represented by *Anaplasma* sp. and *Grahamella* sp.

In general, among the host, *M. surifer* showed the highest overall infection rate with *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. whereas *Anaplasma* sp. was most frequently observed in four most common species captured, followed by *Grahamella* sp., *Microfilaria* sp. and *Trypanosoma* sp.

Dunn et al. (1968) studied on endoparasite patterns in mammals of the Malayan rain forest, where they founded that host species such as *M. surifer* was low infected with red cell protozoa, microfilariae and trypanosomes, *Rattus sabanus* was high infected with microfilariae and low infected with red cell protozoa and trypanosomes. For *T. glis* was medium infected with microfilariae and trypanosomes. Recently, a study by Jittapalapong et al. (2005) revealed that *Trypanosoma lewisi* like trypanosomes were present among *Rattus* and *Bandicota* rodent species and salivarian trypanosomes closely related to *T. evansi* were detected in *Leopoldamys* and *Rattus* species. In New Jersey, United State, detected *Anaplasma phagocytophilum* in wild rodent was transmitted by ticks (Adelson et al., 2004).

5.5.1.3 The prevalence and infection of ectoparasites and blood parasites in small mammals varied by habitat types.

M. surifer was the most infested host for mite (*L. echidinus*), was the highest prevalence in the ECO forest; tick (*Ixodes* sp.), was the highest prevalence in DE forest; flea (*X. cheopsis*), was the highest prevalence in ECO forest; and pseudoscorpion (*Pseudochiridium* sp.) was the highest prevalence in DE forest. *R. rattus* was the highest infected with mite (*L. echidinus*) in DD forest; tick (*Ixodes* sp.)

was only found in DD forest; flea (*X. cheopsis*) and pseudoscorpion (*Pseudochiridium* sp.) found in DD and ECO forest, and was the highest prevalence in ECO forest. *L. sabanus* was infested with mite (*L. echidinus*) only found in ECO and DE forest, and was the highest prevalence in ECO forest. For *T. glis* was the infested host with mite (*L. echidinus*), tick (*Ixodes* sp.) flea (*X. cheopsis*) and pseudoscorpion (*Pseudochiridium* sp.), were found in DD and ECO forest.

The prevalence of all ectoparasite species in small mammals was most frequently founded in ecotone forest while blood parasite species were most frequent found in dry dipterocarp and ecotone forest. Dry dipterocarp and ecotone forest were the optimal habitats for *M. surifer*, *R. rattus*, and *T. glis*, whereas dry evergreen forest and ecotone forest were optimal for *L. sabanus.* Consistently the result of habitat profiles in dry dipterocarp forest and ecotone forest were contribute of ground cover with few bamboo-like grass (*Arundinaria pusilla*) founded in that habitats.

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

The study by Karbowiak et al. (2005) in the topic of natural infections of small mammals with blood parasites on the borderland of boreal and temperate forest zones revealed that infection rates of rodent species seem to be higher in their typical habitats: for bank vole it was the highest in mixed forest, whereas for root vole in sedge swamp. They results suggest that Arvicolidae play a greater role than Muridae or Soricidae in maintenance of Babesia ans Hepatozoon foci in natural environments of central Europe.

This study found that in four most common species captured in all habitat type were infested with different prevalence number of ectoparasites and blood parasites, these shown that the prevalence of many species differed with habitat, both within and between seasons. Generally, reasons for these differences may be due to the prevalence and intensity of parasitism was independent of small mammals population density.

5.5.1.4 The prevalence and infection of ectoparasites and blood parasites in small mammals varied by season.

As the results showed that the prevalence of ectoparasites and infection with blood parasites varied by seasonal. Ectoparasites and blood parasite were founded in *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* and were mostly highest during summer and rainy season. These seasons may be suitable for activity of ectoparasites and blood parasite.

The seasonal variation in the prevalence of ectoparasites was similar to the study of Soliman et al. (2001) on seasonal and ectoparasites in rats in Egypt which revealed that the prevalence and general indices of some ectoparasites including mite, flea and lice showed differences related to the locality of their rat hosts, and seasonal changes in the general indices of some ectoparasites paralleled seasonal change in the relative abundance of their rat hosts. They suggested that ectoparasites obtain some of their requirements, like oxygen, from the physical environment, and to some extent, are influenced by factors that affect their nonparasitic associates, and they are also dependent on their hosts for nutritional requirements and for developmental and maturation stimuli.

The study obtained by Pearse (1929) on the ecology of the ectoparasites of Nigerian rodents founded that the highest indices of infestation in the warm-rainy season, fleas, tick and mite live where the climate is dry. The result of these study suggested that fleas were most abundant on large animals living in dry climate and frequenting more or less permanent homes; tick were most prevalent among low scattered shrubs in dry climates, but were also numerous in wet climates; mites were abundant where there was ground cover of low vegetation and were infrequent in the steppe.

The study obtained by Randolph (1975) on seasonal dynamics of a host-parasite system of *Ixodes trianguliceps* and its small mammal host founded that tick have hatched from egg in the autumn, continue to feed until May, but mymphs and females are rarely found much beyond the predicted periods of their emergence. This data showed that the seasonal variation, humidity and temperature in the infestation levels of tick related to the seasonal variation in the population density of its small mammal host.

The prevalence of blood parasites in small mammals were similar to the study by Wiger (1979) on the seasonal and annual variation in the prevalence of blood parasites in cyclic species of small rodent in Norway, which revealed that the peak prevalence of *Grahamella* and *Hepatozoon* occurred in early summer whereas trypanosomes peaked near the end of summer. The increase in the spring and early summer are most likely related to the heightened activity of the host in connection with the initiation of breeding, increased activity and numbers of vector (ectoparasites) and the recruitment of young susceptible host into the population (Wiger, 1979). In addition, the study obtained by Linardi and Botelho (2002) showed data about monthly that *T. lewisi* infections throughout the year are presented for the first time in Brazil, with the highest prevalences observed in the warm-rainy season (October to March).

5.5.1.5 The prevalence and infection of ectoparasites and blood parasites in small mammals varied by sexes and age.

The result showed that total prevalence of ectoparasites among both sexes and age in small mammals was the highest among adult males than among females. These results were similar to the study by Soliman et al. (2001), demonstrated that the prevalence and general indices of many ectoparasites were significantly higher on males than on females of both rat host, and prevalences and general indices of most ectoparasites on rat species showed a tendency to increase with size and age of rat host.

The higher prevalences of most ectoparasite species for male compared with female rat host might be explained by the larger average movement and larger home range size of male rats (Stroud, 1982). Males, moreover, experience greater chance of contact with other males during competitive activities or fighting (Farhang-Azad and

Southwick, 1979). Ectoparasites may also have a higher reproductive activity on male hosts (Lehman, 1992).

Prevalences and general indices of ectoparasites on small mammal hosts showed a tendency to increase with increased age of rat hosts. This relationship could be explained on the basis of increased foraging activity and home range in older compared to younger individuals, which results in more chance of contact between rat hosts and ectoparasites. Older rats also have larger body surface areas. Similar relationship were recorded between other small mammal hosts and their ectoparasites (Main, 1983)

This results indicated that the infection with blood parasites of small mammal hosts showed greater in females than males. Comparable results with the study by Kartman (1954) on observations on *Trypanosoma lewisi* and *Grahamella* sp. in the blood of rats from the Hamakua district , Island of Hawai, as well as different results, was founded that sex of the host appeared was not a significant factor infected with *T. lewisi* and *Grahamella* sp.. On the other hand, the other study (Schalk and Forbes, 1997) revealed that differences in parasitism between the sexes are small, and the statistically significant male biases in parasitism are not a general rule, and parasitism in relation to host age and parasite taxon. This relationship could be explained on the basis of sexes and immune system because male and female sex hormones have different effect on immune system. Although the effect of hormones on the immune system are incompletely, evidence suggests that estrogens stimulate humoral and cell-mediated immunity, whereas androgens (testosterone) depress immunity (Schuurs and Verheul, 1990). Thus, parasites may become more readily established in male mammals, leading to higher levels of parasitism in males as to females.

5.5.2 Relationship between ectoparasites species and blood parasite species

The study of relationship between the prevalences of ectoparasites species and infection of blood parasites showed that in *M. surifer*, tick and flea was significantly correlated with *Microfilaria* sp.; *R. rattus*, mite was significantly correlated with all blood parasites, flea and pseudoscorpion was significantly correlated with *Microfilaria* sp.; *L. sabanus*, had no significant correlation; *T. glis*, tick was significantly correlated with *Grahamella* sp.

That showed different results of correlation between ectoparasites and *Microfilaria* sp., because generally, the important groups of the Filarioidea a wide range of hematophagous insect and acarines as intermediate host and vectors. The bloodsucking insects appear more frequently from before sunset to dark and the severest itchiness are observed in parallel to their appearance, blood-feeding flies are mosquitoes, black flies, biting midges, deer flies and horse flies and biting stable fly (Anderson, 1988).

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

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

5.5.3 Correlation of mixed infection of blood parasites

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

Some small mammals investigated have been mix-infected with two parasite species. However, the number of mixed infections is relatively low in comparison to the whole number of infected rodents. The most common co-infection was *Anaplasma* sp. + *Grahamella* sp. in *M. surifer*, *L. sabanus* and *T. glis*. Other combinations, as well as co-infections in other host species, were seldom. Consistently with our prediction, the prevalence and diversity of blood parasites were higher in rodents than shrews. Similar results were found by the other authors (Baker, 1974) This corresponds to higher infection rates and diversities of ectoparasites in rodents than shrews (Stanko et al., 2002).

5.5.4 Intensity of blood parasites

As the results of intensity infection of *Trypanosoma* sp. and *Microfilaria* sp. showed significant correlation with age of *M. surifer* and *R. rattus* respectively. This result was supported by the study obtained by Kartman (1954) which revealed that the higher infection rate, the greater intensity of infection were correlated between infection rate of *Trypanosoma lewisi* and *Grahamealla* sp. and age of rats. On the other hand, the study obtained by Laakkonan et al. (2003) revealed that age class of the host species had no significant correlation with endoparasites.

Age class and intensity of blood parasites could be explained by the basis of immune function, resulting increased susceptibility to infections and age related changes in the adaptive immune system, including a reduction in clonal expansion and function of antigen-specific T and B cells (Miller, 1996). Studies conducted on mice suggest that in aged individuals B cells undergo phenotypic and functional changes, and furthermore, bone narrow production of B cells declines sharply with age (Li et al., 2001; Weklser, 2000).

5.5.5 Blood values in small mammals

Hematologic profiles were performed for four most common captured small mammal species including *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis*. Normally distributed parameters included RBC count, Hct, glucose, triglycerides, WBC count, neutrophil numbers, lymphocyte numbers, monocyte numbers, eosinophil numbers and basophil numbers. Some parameter of some small mammal species were inadequate sample size because of the blood were collected from some small mammal species was inadequate to test blood parameters.

The present data documented similarity between captured small mammals in this study and wild rat species obtained by other studies (Clark, 2004; Old et al., 2005; Webb et al., 2000; Webb et al., 2003). However, most of small mammals tested in this study appeared healthily. In the serum part of biochemical analysis, most of animals had highest elevated glucose in the early rainy season and was slightly in winter. This results can be explained by availability of primary food (mature leaves, bamboo shoots and fruits) pecks in viability occurred during the rainy season, so, it can induce animals elevated glucose in rainy season. Plasma glucose levels have also been demonstrated to exhibit seasonal and daily rhythms, *Abrothrix andinus* shows a dramatic increase in intestinal uptake of glucose in winter as compared to summer seasons. These, winter glucose levels may be reduced because energy expenditures are at their yearly low (Bozinovic and Iturri, 1990)

For triglycerides, most of small mammals had the highest level of triglycerides in the winter because the higher relative body fat in winter is primarily due to a decrease in body mass from decreasing fat-free tissue, and not to a increase in lipid mass, The use of lipids to increases survival during an energy crisis does not support an energy-storing overwintering adaptation (Edward et al., 2003).

The numbers of monocytes in all three species studied were low and were similar to those reported for the house mouse (*Mus musculus*), black rat (*Rattus rattus*), dusky- footed wood-rat (Neotoma fuscipes) and cotton rat (Morowatii, 1998; LaBorde et al., 1999; Webb et al., 2003). Basophils are usually rare or absent in most animals. Clark (2004) did not observe any basophils in *Pseudomys* species.

Most of WBC count and neutrophil count were highest in rainy season, which consistently to the prevalence and infection of ectoparasites and blood parasites that were peaked in rainy season. For some individuals had a high WBC count and differences in neutrophil count can explained by generally wide range of neutrophil numbers in many mammalian species, which in often reported in free-ranging wildlife due to parasitic infestation (Feldman et al., 2000). Possible causes of relative neutrophilia include inflammation and stress with steroid response (Weber, 2002). In addition, seasonal change in mammalian immune function and disease prevalence have also been reported. For instance, circulating of immunoglobulin levels were elevated in common European voles (*Microtus arvalis*) that were trapped in the autumn and the late winter as compared to summer-trapped voles (Dobrowolska and Adamczewska-Andrzejewska, 1991).

Determination of packed cell volume (Hct) is important to determine anemia. In this study the animals that had blood parasites were not anemic, suggesting that the animals are reservoirs of those parasites both ectoparasites and blood parasites (Silva et al., 2007).

Clearly greater sampling numbers from captive and small mammals addressing issue of age, sex, reproductive status, lactation and season are required to clarify both the normal range of blood and serum biochemical parameters as well as the effects of these factors. Moreover, diet and the time at which blood samples were taken (diurnal variation) may also affect these parameters, This study provides preliminary information health assessment based on hematology and blood chemistry values for four most common species small mammals captured in Sakearat Research Station during January-December 2007.

5.6 References

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CHAPTER VI

CONCLUSION

The main aims of this thesis were to investigate small mammals community and their health status. The major findings are summarized as follows:

6.1 Climatic Factors

Climatic factors composed of air temperature, seasonal rainfall and relative humidity. Temperature was the highest in the summer in DE forest, and the lowest in the winter in ECO forest. Mean of seasonal rainfall was the highest in the early rainy season in DD forest, and the lowest in the winter in DE forest. For the relative humidity, in the late rainy season in ECO forest had the highest while in the summer on DD forest had the lowest.

6.2 Habitat Profiles

Number of tree species was the highest value in DD and ECO forest, and the lowest value in the DE forest. Tree densities was the highest in DE forest. Mean of canopy cover was the highest in DE forest, followed by ECO and DD, respectively. Mean of average diameter at breast height (Avg. DBH) was the highest in DE forest, followed by ECO and DD forests, respectively. Mean average high and basal area was the greatest in DE forest and ECO and the lowest in and DD forest, respectively. The percent of ground cover was the highest in DD forest, followed by ECO and DE forests, respectively.

6.3 Small Mammal Community and Distribution

6.3.1 Small Mammal Trapping

A total of 371 individuals, belonging to nine species in five families were captured (877 captures in 3,528 trap-nights or 24.86%), with six species in DD and ECO forest and seven species in DE forest. *M. surifer* was the most abundance small mammal trapped species representing of total captures, and followed by *T. glis*, *R. rattus*, *L. sabanus*, *C. finlaysoni*, *C. finlaysoni*, *H. javanicus*, *M. cervicolor* and *L. peguensis*. Four species i.e. *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* were caught in all habitat types and the most often caught was the rodent**.**

6.3.2 Small Mammals Trapping Success

M. surifer was the highest trapped in DD forest for every 100 trap night in early rainy season. Trapping success varied over the study period, the DE forest had the greatest trapping success rate. Trapping success rates were highest during the late rainy season in all three habitats.

6.3.3 Small Mammal Recapture Rate

M. surifer was the most abundant species captured in all the seasons in each habitat type. All of habitat types was the greatest high recapture rates in winter, and closely followed by late rainy season, early rainy season in DD and ECO forest and summer in DE forest. Most of the lowest recapture rates founded in summer of all habitat types, except in DE forest was the lowest recapture rates in early rainy season.

6.3.4 Small Mammals Anatomical Measurement

The anatomical measurement of male and female of four most common species including *M. surifer*, *R. rattus, L. sabanus* and *T. glis* in DD, ECO and DE forest revealed that there were no significant difference in the weight, head and body length and tail length between habitat types. The mean weight of *M. surifer* in male was the highest in DD forest, followed by ECO and DE forest, and in female was the highest in ECO forest, followed by DE and DD forest. Male *R. rattus* had the mean weight highest in DD forest, followed by ECO forest, and in female was the highest in DE forest, followed by DD and ECO forest. The mean weight of male and female *L. sabanus* was the highest in DE forest, followed by ECO forest. For *T. glis*, in male and female had the mean weight highest in DE forest, followed by ECO and DD forest.

6.3.5 Small Mammal Diversity Index

small mammals diversity, evenness and species richness were most the highest in winter both in DD and ECO forest and were the lowest in early rainy season. However, these results were opposite in DE forest.

6.3.6 Small Mammal Density, Biomass and Minimum Home Range Size

Density, biomass and minimum home range size of the four most frequently captured species varied seasonally in each site. The highest density, biomass and minimum home rage size was *M. surifer*. Density and biomass of four most common species were highest in winter and rainy season in DE forest and for minimum home range size was largest in dry seasons.

6.3.7 Sex and Age Structure of Small mammals

Sex ratios (sex ratio is the percent of male in the total sample of males and females) were not significantly different from 1:1 for the four most commonly caught species in each site, whereas age structure varied considerably across seasons and forest types.

6.3.8 Environmental Factor Analysis

Habitat profiles about tree factors including tree species, tree density, basal area, avg. DBH, avg. height, canopy cover and ground cover were positively correlated with *M. surifer* and *L. sabanus* and small mammal abundance in ECO and in all habitat types. Whereas these were negatively with *R. rattus* and *T. glis*, and small mammal abundance in DD and ECO forest. Humidity and rainfall were positively correlated with *R. rattus* and small mammal abundance in DD and DE forest. Where as these were negatively with *M. surifer*, *L. sabanus*, *T. glis*, and small mammal abundance in ECO forest and all habitat types. Temperature was positively correlated with *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis*.

6.4 Prevalence of Ectoparasites, Blood Parasites in Small Mammals and Health Status

6.4.1 The prevalence of ectoparasites species and pseudoscorpion in small mammals

During the study period, 350 small mammals represented ectoparsites. The four most common small mammal species captured including *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* in all habitat types. The ectoparasites mainly found were from different species including mite (*Lealaps echidinus*), tick (*Ixodes* sp.), flea (*Xenopsylla cheopsis*) and pseudoscorpion (*Chelifer cancroide*). *M. surifer*, had the most abundant parasites with 77.05% of total mite (*L. echidinus*), 31.15% of total flea (*X. cheopsis*) and 14.75% of total pseudoscorpion (*Chelifer cancroide*) followed by *R. rattus*. *T. glis*, the most abundant, with 22.00% of the total of tick (*Ixodes* sp.). Except for *L. sabanus*, was only found infested of mite (*L. echidinus*).

6.4.2 The prevalence of blood parasite species in small mammals

The occurrence of patient infections with blood parasites found in four most common species captured including *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* in all habitat types. One genara of Protozoa and Microfilariae, and two genus of Rickettsia were detected in this study. The hemaoprotozoa was *Trypanosoma* sp., which was found in plasma. The Microfilariae was *Microfilaria* sp.. The Rickettsia were represented by *Anaplasma* sp. and *Grahamella* sp. In general, among the host, *M. surifer* showed the highest overall infection rate with *Microfilaria* sp., *Trypanosoma* sp., *Anaplasma* sp. and *Grahamella* sp. whereas *Anaplasma* sp. was most frequently observed in four most common species captured, followed by *Grahamella* sp., *Microfilaria* sp. and *Trypanosoma* sp.

6.4.3 The prevalence and infection of ectoparasites and blood parasites in small mammals varied by habitat types.

The prevalence of all ectoparasite species in small mammals was most frequently founded in ecotone forest while blood parasite species were most frequent found in dry dipterocarp and ecotone forest. Dry dipterocarp and ecotone forest were the optimal habitats for *M. surifer*, *R. rattus* and *T. glis*, where as dry evergreen forest and ecotone forest were optimal for *L. sabanus*.

6.4.4 The prevalence and infection of ectoparasites and blood parasites in small mammals varied by season.

The prevalence of ectoparasites and infection with blood parasites varied by seasonal. Ectoparasites and blood parasite were founded in *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis* and were mostly highest during summer and rainy season.

6.4.5 Relationship between ectoparasites species and blood parasite species

The relationship between the prevalences of ectoparasites species and infection of blood parasites showed that in *M. surifer*, tick and flea was significantly correlated with *Microfilaria* sp.; *R. rattus*, mite was significantly correlated with all blood parasites, flea and pseudoscorpion was significantly correlated with *Microfilaria* sp.; *L. sabanus*, had no significant correlation; *T. glis*, tick was significantly correlated with *Grahamella* sp.

6.4.6 Correlation of mixed infection of blood parasites

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

6.4.7 Intensity of blood parasites

Intensity infection of *Trypanosoma* sp. and *Microfilaria* sp. showed significant correlation with age of *M. surifer* and *R. rattus*, respectively.

6.4.8 Blood values in small mammals

Hematologic profiles were performed for four most common captured small mammal species including *M. surifer*, *R. rattus*, *L. sabanus* and *T. glis*. Normally distributed parameters included RBC count, Hct, glucose, triglycerides, WBC count, neutrophil numbers, lymphocyte numbers, monocyte numbers, eosinophil numbers and basophil numbers.

Future Work

In future studies, it would be interesting to further investigate some possible future experiments, Long-term studies at Skaerat Research Station on small mammals population dynamic, as well as precise information on resource abundance and the ecology of tropical small mammals including microhabitat preferences, home-range size, and factors affecting community structure, are needed to clarify the drivers of small mammal community composition and structure in dry tropical forest.

Further studies, for ectoparasites and blood parasite prevalence should be focused on immunology of small mammals population and the relationship between mortality factors in the population ecology of a cyclic population of small mammals.

APPENDICES

APPENDIX A

FLORISTIC COMPOSITION

Table 1 Floristic composition in dry dipterocarp forest (DD) plot1 (100 m x 100 m plot), number, average DBH and basal area of trees at Sakaerat Research Station.

Vernacular name	Botanical name	numbers	avg. High (m)	avg. DBH (cm)	Basal area (m^2/ha)
Trees					
รัง	*Shorea siamensis*	8	9.76	17.95	2.25
เต็ง	*Shorea obtuse*	11	7.65	10.37	1.03
แดง	*Xylia xylocarpa*	7	6.57	8.23	0.41
ยางกราด	*Dipterocarpus intricatus*	3	9.47	17.30	0.78
กางขี้มอด	*Albizia odomatissima*	3	7.57	9.48	0.10
ซาด	*Erythrophleum succirubrum*	1	3.60	8.92	0.07
ประดู่	*Plerocarpus indicus*	6	10.00	13.09	0.90
มะกอกเกลื้อน	*Canariam subulatum*	8	7.90	9.43	0.62
มะค่าแต้	*Sindora siamensis*	3	7.83	17.44	0.80
คำมอกหลวง	*Gardenia sootepensis*	8	3.65	4.84	0.16
ยางแดง	*Dipterocarpus turbinatus*	2	5.14	7.64	0.10
ปอขาว	*Sterculia pexa*	2	6.53	7.48	0.10
มะม่วงหัวแมลงวัน	*Buchanania latifolia*	2	5.40	11.93	0.25
มะขามป้อม	*Phyllanthus emblica*	7	7.34	7.32	0.33
ติ้วขาว	*Cratoxylum formusum*	3	6.33	3.71	0.04
ยอป่า	*Morinda coreia*	3	7.17	10.83	0.31
มะกาเครือ	*Bridelia stipularis*	1	4.40	6.05	0.03
ฉนวน	*Dalbergia nigrescens*	2	4.60	4.46	0.03
ปอแดง	*Sterculia guttata*	1	4.90	5.41	0.03
ติ้วแดง	*Gratoxylum formusum*	2	2.80	2.87	0.01
พะยอม	*Shorea roxburghii*	1	15.00	31.53	0.87
เสี้ยวป่า	*Bauhinia vaiegata*	2	4.65	3.98	0.03

Table 2 Floristic composition in dry dipterocarp forest (DD) plot2 (100 m x 100 m plot), number, average DBH and basal area of trees at Sakaerat Research Station.

Vernacular name	Botanical name	Numbers	avg. High (m)	avg. DBH (cm)	Basal area (m^2/ha)
Trees					
รัง	*Shorea siamensis*	21	12.77	15.91	2.32
เต็ง	*Shorea obtuse*	4	25.00	21.97	0.84
แดง	*Xylia xylocarpa*	66	5.80	5.93	1.01
ยางกราด	*Dipterocarpus intricatus*	2	13.00	17.83	0.28
กางขี้มอด	*Albizia odomatissima*	2	4.10	4.88	0.02
ประดู่	*Plerocarpus indicus*	26	17.36	19.48	4.30
มะกอกป่า	*Spondias pinnata*	1	14.50	20.38	0.18
มะค่าแต้	*Sindora siamensis*	3	19.33	24.31	0.77
กระโดน	*Careya sphaericulatum*	1	12.00	27.07	0.32
คูณ	*Cassia fistula*	1	7.00	8.60	0.03
มะม่วงหัวแมลงวัน	*Buchanania latifolia*	1	21.00	28.03	0.34
ยอป่า	*Morinda coreia*	13	7.76	7.41	0.31
ฉนวน	*Dalbergia nigrescens*	15	15.00	25.16	4.14
กระดูกกบ	*Hymenopyramis brachiata*	1	5.00	3.03	0.01
งิ้วป่า	*Bombax valetorii*	1	13.00	7.01	0.02
เหมือดโลด	*Aporasa villosa*	1	14.75	15.45	0.10
พะยอม	*Shorea roxburghii*	2	3.20	3.50	0.01
ขันทองพยาบาท	*Suregada multiforum*	3	2.60	1.91	0.01
เปล้าใหญ่	*Croton oblongifolius*	1	9.80	8.92	0.03
กางสามปีก	*Vitex peduncularis*	3	1.95	2.23	0.01
หว้า	*Syzygium cacuminis*	1	21.00	28.03	0.34
กระทุ่มขี้หมู	*Mitragyna rofundifolia*	1	15.00	17.20	0.13
อีแป๊ะ	*Pyrrosia piloselloides*	4	10.63	10.87	0.21

Table 3 Floristic composition in ecotone forest (ECO) plot1 (100 m x 100 m plot), number, average DBH and basal area of trees at Sakaerat Research Station.

Vernacular name	Botanical name	numbers	avg. High (m)	avg. DBH (cm)	Basal area (m^2/ha)
Trees					
ไทร	*Ficus annlata*	1	32.00	70.06	17.14
เขลง	*Dialium cochinchinense*	5	16.22	20.89	7.62
ตะแบกเปลือกบาง	*Lagerstoemia duperreana*	3	14.33	5.92	0.83
พลับพลา	*Micrococ tomentosa*	11	8.98	8.28	2.63
มะนาวป่า	*Citus aurartifolia*	1	2.20	2.23	0.02
กระเบากลัก	*Hydnocarpus ilicifolia*	4	12.90	7.48	0.78
มะกอกป่า	*Spondias pinnata*	1	31.00	70.06	17.14
มะค่าแต้	*Sindora siamensis*	1	5.00	8.60	0.26
หนามกราย	*Terminalia tripteroides*	4	16.75	21.58	6.50
กระทุ่มขี้หมู	*Mitragyna rofundifolia*	1	3.10	3.82	0.05
งิ้วป่า	*Bombax valetorii*	1	26.00	3.66	0.05
ก่อแพะ	*Quercus kerrii*	3	7.83	5.94	0.37
ตะโกสวน	*Diospyros malabarica*	1	16.00	11.15	0.43
อินทนิล	*Lagerstroemia calyculeta*	1	37.00	55.73	10.84
ขันทองพยาบาท	*Suregada multiforum*	1	4.00	3.18	0.04
คอแลน	*Nephelium hypoleucum*	1	4.00	3.50	0.04
ปอกระเจา	*Cocchorus capsularis*	1	16.00	5.73	0.11
ยอป่า	*Morinda coreia*	1	10.20	16.24	0.92

Table 4 Floristic composition in ecotone forest (ECO) plot2 (100 m x 100 m plot), number, average DBH and basal area of trees at Sakaerat Research Station.

Vernacular name	Botanical name	numbers	avg. High (m)	avg. DBH (cm)	Basal area (m^2/ha)
Trees					
คำมอกน้อย	*Gardenia obtusifolia*	9	12.78	10.12	0.80
กระโดน	*Careya sphaericulatum*	2	26.00	46.63	3.32
โมกมัน	*Wrightia pubescens*	14	11.75	8.36	0.85
อีแป๊ะ	*Pyrrosia piloselloides*	5	11.86	7.29	0.23
เปล้าใหญ่	*Croton oblongifolius*	7	10.61	7.60	0.35
โมกน้อย	*Holarrhena cutisii*	4	10.95	8.44	0.25
เปล้าน้อย	*Croton sublyratus*	4	11.44	7.87	0.22
แคหางค่าง	*Fernandao adenophylla*	8	7.81	9.04	0.57
หนามกราย	*Terminalia tripteroides*	5	11.82	5.86	0.15
กางสามปีก	*Vitex peduncularis*	4	9.90	5.73	0.11
สาธร	*Millettia leucantha*	1	18.00	16.56	0.24
มะค่าแต้	*Sindora siamensis*	8	15.45	18.47	2.38
มะกอกป่า	*Spondias pinnata*	1	11.00	7.32	0.05
ตะแบกกราย	*Terminalia pierrei*	13	15.30	9.09	0.94
คำมอกหลวง	*Gardenia sootepensis*	6	11.58	8.01	0.34
มะยมป่า	*Ailanthus triphysa*	3	13.13	5.68	0.08
ฉนวน	*Dalbergia nigrescens*	7	10.79	4.57	0.13
มะนาวป่า	*Citus aurartifolia*	1	3.20	2.87	0.01
คนทา	*Harrisonia perforata*	7	5.56	5.69	0.20
เสี้ยวป่า	*Bauhinia vaiegata*	1	3.50	21.97	0.42
ชงโค	*Bauhinia purpurea*	3	7.67	4.46	0.05
มะค่าโมง	*Afzelia xylocarpa*	1	24.40	44.90	1.76
โมกหลวง	*Holarrhena pubessens*	1	3.45	4.46	0.02
งิ้วป่า	*Bombax valetorii*	1	8.60	8.28	0.06
กระทุ่มขี้หมู	*Mitragyna rofundifolia*	1	9.10	7.64	0.05
ขันทองพยาบาท	*Suregada multiforum*	1	3.10	7.96	0.06

Table 5 Floristic composition in dry evergreen forest (DE) plot1 (100 m x 100 m plot), number, average DBH and basal area of trees at Sakaerat Research Station.

Vernacular name	Botanical name	numbers	avg. High (m)	avg. DBH (cm)	Basal area (m^2/ha)
Trees					
ตะเคียนหิน	*Hopea ferrea*	14	13.50	13.69	9.17
พลองขี้ควาย	*Memecylon caeruleum*	5	10.42	6.69	0.78
พลองกินลูก	*Memecylon ovalum*	6	9.77	6.42	0.86
กะเบากลัก	*Hydrocarpus ilicifolia*	13	8.05	5.63	1.44
ข่อยหนาม	*Streblus ilicifolius*	4	3.80	4.62	0.30
เคี่ยมคะนอง	*Shorea henryana*	2	5.75	5.10	0.18
ตะโกสวน	*Diospyros malabarica*	1	13.00	50.96	9.06
กัดลิ้น	*Walsura trichostemon*	14	8.77	5.44	1.44
คอแลน	*Nephelium hypoleucum*	2	9.00	5.77	0.22
มะนาวป่า	*Citus aurartifolia*	1	6.00	5.10	0.09
มะกอกเกลื้อน	*Canariam subulatum*	2	18.50	28.50	5.67
มะค่าโมง	*Afzelia xylocarpa*	1	30.00	57.32	11.47

Table 6 Floristic composition in dry evergreen forest (DE) plot2 (100 m x 100 m plot), number, average DBH and basal area of trees at Sakaerat Research Station.

Vernacular name	Botanical name	numbers	avg. High (m)	avg. DBH (cm)	Basal area (m^2/ha)
Trees					
ตะเคียนหิน	*Hopea ferrea*	32	18.39	10.01	2.80
พลองขี้ควาย	*Memecylon caeruleum*	7	15.20	21.97	1.69
พลองกินลูก	*Memecylon ovalum*	9	8.73	3.82	1.15
กะเบากลัก	*Hydrocarpus ilicifolia*	10	12.04	9.36	3.06
ข่อยหนาม	*Streblus ilicifolius*	3	6.30	3.82	0.15
แคฝอย	*Stereospermum cylindricum*	1	4.00	3.18	0.04
กระบก	*Irvingia malayana*	4	28.25	45.06	28.36
กัดลิ้น	*Walsura trichostemon*	16	9.56	6.73	2.53
คอแลน	*Nephelium hypoleucum*	3	21.33	16.99	3.02
ลูกดิ่ง	*Parkia sumatrana*	3	25.12	32.48	11.05

APPENDIX B

POPULATION PARAMETER ESTIMATES

Table 7 Population parameter estimates of *Maxomys surifer* captured in each season in each habitat type. DD = dry dipterocarp forest; ECO = ecotone; DD = dry evergreen forest. *N* and *D* are based on the null model (N_0) and the heterogeneity model (M_h) (Chao, 1987). $\hat{N}_{th}$ = estimate of population size, $\hat{p}$ = estimate of capture probability, *RPSV* = root pooled spatial variance, a measure of animal movement used in the estimation of *D*, $\hat{g}_0$ = estimated probability of capture when trap is at the centre of home range, $\hat{\sigma}$ = a measure of home range width, $\hat{D}_{th}$ = estimated density of population (individuals ha^{-1}).

Species	**Habitat**	**Season**	**Model**	**Estimator**	$\hat{N}$	$\hat{p}$	***RPSV***	$\hat{D}$	$\hat{g}_0$	$\hat{\sigma}$
Maxomys surifer	DD	Early rainy	M_0	M_{t+1}	32 (4.7)	0.38	25.3	7.2 (2.3)	0.080 (0.028)	21.9 (4.7
		Late rainy			21 (0.9)	0.68	29.6	3.0 (1.0)	0.220 (0.084)	29.1 (5.3)
		Winter			28 (2.5)	0.51	26.4	6.4 (1.7)	0.096 (0.028)	22.5 (3.7)
		Summer			23 (6.4)	0.29	23.3	5.7 (2.3)	0.080 (0.043)	17.8 (5.1)
		Early rainy	M_h	Chao N_h	61.1 (25.9)	0.20	25.3	7.2 (2.3)	0.080 (0.028)	21.9 (4.7)
		Late rainy			23.3 (2.5	0.62	29.6	2.9 (1.4)	0.220 (0.084)	29.2 (5.3)
		Winter			26.4 (1.6)	0.54	26.4	6.4 (1.7)	0.096 (0.028)	22.5 (3.7)
		Summer			35.2 (17.4)	0.19	23.3	5.7 (2.3)	0.080 (0..043)	17.8 (5.0)
	ECO	Early rainy	M_0	M_{t+1}	45 (4.5)	0.43	22.0	10.8 (2.4)	0.124 (0.033)	18.6 (2.7)
		Late rainy			52 (2.2)	0.60	21.4	11.5 (2.1)	0.219 (0.041)	19.0 (2.0)
		Winter			49 (4.1)	0.46	17.0	15.5 (2.9)	0.163 (0.039)	13.6 (1.6)
		Summer			12 (0.8)	0.67	31.0	1.8 (1.0)	0.193 (0.090)	29.0 (8.7)
		Early rainy	M_h	Chao N_h	57 (11.5)	0.34	22.0	10.8 (2.4)	0.124 (0.033)	18.5 (2.7)
		Late rainy			55.1 (4.1)	0.57	21.4	11.5 (2.1)	0.219 (0.041)	19.0 (2.0)
		Winter			46.9 (3.5)	0.48	17.0	15.5 (2.9)	0.163 (0.039)	13.6 (1.6)

Table 7 Population parameter estimates of *Maxomys surifer* captured in each season in each habitat type. DD = dry dipterocarp forest; ECO = ecotone; DD = dry evergreen forest. *N* and *D* are based on the null model (N_0) and the heterogeneity model (M_h) (Chao, 1987). $\hat{N}_{th}$ = estimate of population size, $\hat{p}$ = estimate of capture probability, *RPSV* = root pooled spatial variance, a measure of animal movement used in the estimation of *D*, $\hat{g}_0$ = estimated probability of capture \when trap is at the centre of home range, $\hat{\sigma}$ = a measure of home range width, $\hat{D}_{th}$ = estimated density of population (individuals ha^{-1}). (Continued).

Species	Habitat	Season	Model	Estimator	$\hat{N}$	$\hat{p}$	*RPSV*	$\hat{D}$	$\hat{g}_0$	$\hat{\sigma}$
		Summer			14 (2.6)	0.57	31.0	1.8 (1.0)	0.193 (0.090)	29.0 (8.7)
	DE	Early rainy	M_0	M_{t+1}	54 (9.1)	0.30	24.9	13.2 (3.6)	0.065 (0.325)	19.8 (3.7)
		Late rainy			64 (4.6)	0.47	20.5	16.7 (2.9)	0.135 (0.028)	17.4 (2.0)
		Winter			76 (8.4)	0.36	24.2	19.6 (3.8)	0.072 (0.019)	19.7 (2.6)
		Summer			26 (2.0)	0.55	25.9	4.8 (1.4)	0.182 (0.059)	23.0 (3.8)
		Early rainy	M_h	Chao N_h	84.3 (27.2)	0.19	24.9	13.2 (3.6)	0.065 (0.325)	19.8 (3.7)
		Late rainy			85 (14.5)	0.35	20.5	16.7 (2.9)	0.135 (0.028)	17.4 (2.0)
		Winter			75.2 (9.0)	0.36	24.2	19.6 (3.8)	0.072 (0.019)	19.7 (2.6)
		Summer			32.6 (6.8)	0.44	25.9	4.8 (1.4)	0.182 (0.059)	23.0 (3.8)

Table 8 Population parameter estimates of *Rattus rattus* captured in each season in each habitat type. DD = dry dipterocarp forest; ECO = ecotone; DD = dry evergreen forest. *N* and *D* are based on the null model (N_0) and the heterogeneity model (M_h) (Chao, 1987). $\widehat{N}_{th}$ = estimate of population size, $\widehat{p}$ = estimate of capture probability, *RPSV* = root pooled spatial variance, a measure of animal movement used in the estimation of *D*, $\widehat{g}_0$ = estimated probability of capture when trap is at the centre of home range, $\widehat{\sigma}$ = a measure of home range width, $\widehat{D}_{th}$ = estimated density of population (individuals ha^{-1}).

Species	Habitat	Season	Model	Estimator	$\widehat{N}$	$\widehat{p}$	***RPSV***	$\widehat{D}$	$\widehat{g}_0$	$\widehat{\sigma}$
Rattus rattus	DD	Early rainy	M_0	M_{t+1}	11 (2.7)	0.39	19.4	3.5 (1.6)	0.118 (0.074)	14.9 (4.7)
		Late rainy			26 (8.7)	0.24	15.0	9.4 (4.1)	0.135 (0.085)	9.6 (2.9)
		Winter			12 (2.9)	0.55	23.7	4.8 (2.3)	0.186 (0.131)	12.2 (4.4)
		Summer			NA	NA	NA	NA	NA	NA
		Early rainy	M_h	Chao N_h	NA	NA	19.4	3.5 (1.6)	0.118 (0.074)	14.9 (4.7)
		Late rainy			30.1 (12.5)	0.21	15.0	9.4 (4.1)	0.135 (0.085)	9.6 (2.9)
		Winter			NA	NA	23.7	4.8 (2.3)	0.186 (0.131)	12.2 (4.4)
		Summer			NA	NA	NA	NA	NA	NA
	ECO	Early rainy	M_0	M_{t+1}	NA	NA	NA	NA	NA	NA
		Late rainy			NA	NA	NA	NA	NA	NA
		Winter			NA	NA	NA	NA	NA	NA
		Summer			NA	NA	NA	NA	NA	NA
		Early rainy	M_h	Chao N_h	NA	NA	NA	NA	NA	NA
		Late rainy			NA	NA	NA	NA	NA	NA
		Winter			NA	NA	NA	NA	NA	NA
		Summer			NA	NA	NA	NA	NA	NA
	DE	Early rainy	M_0	M_{t+1}	NA	NA	NA	NA	NA	NA

Table 8 Population parameter estimates of *Rattus rattus* captured in each season in each habitat type. DD = dry dipterocarp forest; ECO = ecotone; DD = dry evergreen forest. *N* and *D* are based on the null model (N_0) and the heterogeneity model (M_h) (Chao, 1987). $\widehat{N}_{th}$ = estimate of population size, $\widehat{p}$ = estimate of capture probability, *RPSV* = root pooled spatial variance, a measure of animal movement used in the estimation of *D*, $\widehat{g}_0$ = estimated probability of capture when trap is at the centre of home range, $\widehat{\sigma}$ = a measure of home range width, $\widehat{D}_{th}$ = estimated density of population (individuals ha^{-1}) (Continued).

Species	**Habitat**	**Season**	**Model**	**Estimator**	$\widehat{N}$	$\widehat{p}$	***RPSV***	$\widehat{D}$	$\widehat{g}_0$	$\widehat{\sigma}$
		Late rainy			NA	NA	NA	NA	NA	NA
		Winter			NA	NA	NA	NA	NA	NA
		Summer			NA	NA	NA	NA	NA	NA
		Early rainy	M_h	Chao N_h	NA	NA	NA	NA	NA	NA
		Late rainy			NA	NA	NA	NA	NA	NA
		Winter			NA	NA	NA	NA	NA	NA
		Summer			NA	NA	NA	NA	NA	NA

Table 9 Population parameter estimates of *Tupia glis* captured in each season in each habitat type. DD = dry dipterocarp forest; ECO = ecotone; DD = dry evergreen forest. *N* and *D* are based on the null model (N_0) and the heterogeneity model (M_h) (Chao, 1987). $\hat{N}_{th}$ = estimate of population size, $\hat{p}$ = estimate of capture probability, *RPSV* = root pooled spatial variance, a measure of animal movement used in the estimation of *D*, $\hat{g}_0$ = estimated probability of capture when trap is at the centre of home range, $\hat{\sigma}$ = a measure of home range width, $\hat{D}_{th}$ = estimated density of population (individuals ha^{-1}).

Species	Habitat	Season	Model	Estimator	$\hat{N}$	$\hat{p}$	***RPSV***	$\hat{D}$	$\hat{g}_0$	$\hat{\sigma}$
Tupia glis	DD	Early rainy	M_0	M_{t+1}	NA	NA	NA	NA	NA	NA
		Late rainy			57 (48.2)	0.08	NA	14.5 (18.3)	0.015 (0.020)	19.3 (13.2)
		Winter			13 (4.4)	0.31	31.8	3.2 (1.8)	0.057 (0.042)	21.4 (8.0)
		Summer			3 (1.1)	0.44	NA	1.1 (1.0)	0.154 (0.170)	14.2 (9.5)
		Early rainy	M_h	Chao N_h	NA	NA	NA	NA	NA	NA
		Late rainy			85 (83.6)	0.08	NA	14.5 (18.3)	0.015 (0.020)	19.3 (13.2)
		Winter			15 (6.5)	0.27	31.8	3.2 (1.8)	0.057 (0.042)	21.4 (8.0)
		Summer			5 (3.7)	0.27	NA	1.1 (1.0)	0.154 (0.169)	14.2 (9.5)
	ECO	Early rainy	M_0	M_{t+1}	NA	NA	NA	NA	NA	NA
		Late rainy			13 (2.4)	0.44	48.0	0.4 (0.6)	0.022 (0.011)	148.4 (158.2)
		Winter			22 (10.1)	0.32	35.2	5.6 (4.1)	0.053 (0.046)	21.6 (10.5)
		Summer			6.0 (1.0)	0.56	57.0	0.1 (0.1)	0.023 (0.013)	203.8 (121.5)
		Early rainy	M_h	Chao N_h	NA	NA	NA	NA	NA	NA
		Late rainy			15.5 (4.8)	0.37	48.0	0.4 (0.6)	0.022 (0.011)	148.4 (158.2)
		Winter			NA	NA	NA	NA	NA	NA
		Summer			8.3 (3.4)	0.40	57.0	0.13 (0.1)	0.023 (0.013)	203.8 (121.6)

Table 9 Population parameter estimates of *Tupia glis* captured in each season in each habitat type. DD = dry dipterocarp forest; ECO = ecotone; DD = dry evergreen forest. *N* and *D* are based on the null model (N_0) and the heterogeneity model (M_h) (Chao, 1987). $\widehat{N}_{th}$ = estimate of population size, $\widehat{p}$ = estimate of capture probability, *RPSV* = root pooled spatial variance, a measure of animal movement used in the estimation of *D*, $\widehat{g}_0$ = estimated probability of capture when trap is at the centre of home range, $\widehat{\sigma}$ = a measure of home range width, $\widehat{D}_{th}$ = estimated density of population (individuals ha^{-1}) (Continued).

Species	**Habitat**	**Season**	**Model**	**Estimator**	$\widehat{N}$	$\widehat{p}$	***RPSV***	$\widehat{D}$	$\widehat{g}_0$	$\widehat{\sigma}$
	DE	Early rainy	M_0	M_{t+1}	NA	NA	NA	NA	NA	NA
		Late rainy			NA	NA	NA	NA	NA	NA
		Winter			NA	NA	NA	NA	NA	NA
		Summer			NA	NA	NA	NA	NA	NA
		Early rainy	M_h	Chao N_h	NA	NA	NA	NA	NA	NA
		Late rainy			NA	NA	NA	NA	NA	NA
		Cold			NA	NA	NA	NA	NA	NA
		Hot			NA	NA	NA	NA	NA	NA

Table 10 Population parameter estimates of *Leopoldamys sabanus* captured in each season in each habitat type. DD = dry dipterocarp forest; ECO = ecotone; DD = dry evergreen forest. *N* and *D* are based on the null model (N_0) and the heterogeneity model (M_h) (Chao, 1987). $\hat{N}_{th}$ = estimate of population size, $\hat{p}$ = estimate of capture probability, *RPSV* = root pooled spatial variance, a measure of animal movement used in the estimation of *D*, $\hat{g}_0$ = estimated probability of capture when trap is at the centre of home range, $\hat{\sigma}$ = a measure of home range width, $\hat{D}_{th}$ = estimated density of population (individuals ha^{-1}).

Species	Habitat	Season	Model	Estimator	$\hat{N}$	$\hat{p}$	***RPSV***	$\hat{D}$	$\hat{g}_0$	$\hat{\sigma}$
Leoplodamys sabanus	ECO	Rainy 1	M_0	M_{t+1}	NA	NA	NA	NA	NA	NA
		Rainy 2			3 (0.2)	0.78	28.1	0.7 (0.5)	0.307 (0.199)	18.8 (5.9)
		Cold			NA	NA	NA	NA	NA	NA
		Hot			3 (0.4)	0.67	58.1	0.4 (0.5)	0.104 (0.092)	38.4 (22.7)
		Rainy 1	M_h	Chao N_h	NA	NA	NA	NA	NA	NA
		Rainy 2			3.0 (0.0)	0.78	28.1	0.7 (0.5)	0.307 (0.199)	18.8 (6.0)
		Cold			NA	NA	NA	NA	NA	NA
		Hot			3.5 (1.3)	0.57	58.1	0.4 (0.5)	0.104 (0.092)	38.4 (22.7)
	DE	Rainy 1	M_0	M_{t+1}	5.0 (0.7)	0.60	16.8	0.7 (0.8)	0.104 (0.076)	36.2 (23.5)
		Rainy 2			6 (3.5)	0.28	NA	NA	NA	NA
		Cold			NA	NA	NA	NA	NA	NA
		Hot			3.0 (0.7)	0.56	NA	0.5 (2.8)	0..046 (0.486)	38.1 (81.2)
		Rainy 1	M_h	Chao N_h	6.0 (1.9)	0.50	16.8	0.7 (0.8)	0.104 (0.076)	36.2 (23.5)
		Rainy 2			8.5 (7.2)	0.20	NA	NA	NA	NA
		Cold			NA	NA	NA	NA	NA	NA
		Hot			3.3 (0.7)	0.51	NA	0.5 (2.8)	0.046 (0.486)	38.1 (81.2)

APPENDIX C

FIGURE OF SMALL MAMMAL SPECIES

1a

1b

Figure 1a.-1d. Small mammal species in Muridae trapped in Sakaerat Reseach Station

1c

1d

Figure 1a.-1d. Small mammal species in Muridae trapped in Sakaerat Reseach Station. (Continued).

1a. *Maxomys surifer* 1b. *Rattus rattus*

1d. *Leopoldamys sabanus* 1d. *Mus cervicolor*

1f

Figure 1f. Small mammal specie in Tupaidae trapped in Sakaerat Reseach Station

1f. *Tupaia glis*

1g

1h

Figure 1g.-1h. Small mammal species in Sciuridae trapped in Sakaerat Reseach Station

1g. *Callosciurus finlaysoni* 1h. *Callosciurus caniceps*

1i

Figure 1i. Small mammal specie in Herpestidae trapped in Sakaerat Reseach Station

1i . *Herpestes javanicus*

1j

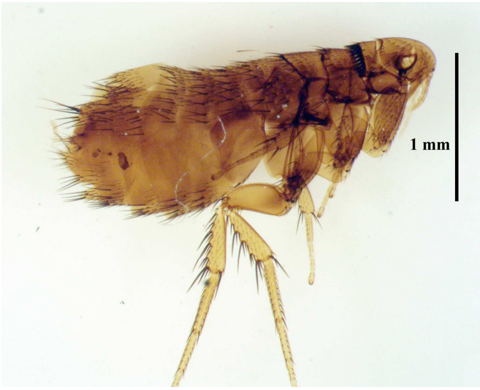
Figure 1j. Small mammal specie in Leporidae trapped in Sakaerat Reseach Station

1j. *Lepus peguensis*

APPENDIX D

FIGURE OF ECTOPARASITRE AND

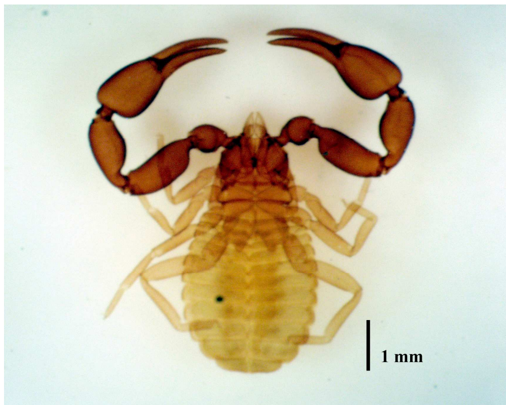
PSEUDOSCORPION OF SMALL MAMMALS



2a

2b

2c



2d

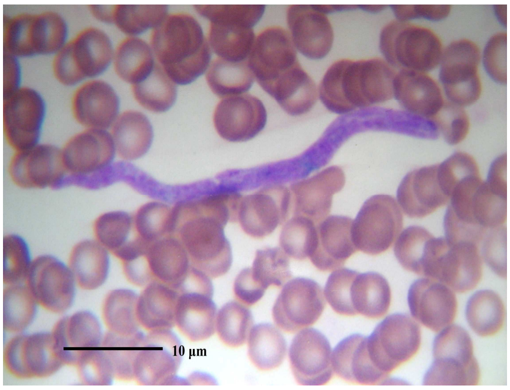
Figure 2a.-2d. Different ectoparasites and psedoscorpion collected from small mammals in Sakaerat Research Station

2a. *Xenopsylla cheopsis* 2b. *Laelaps echidinus*

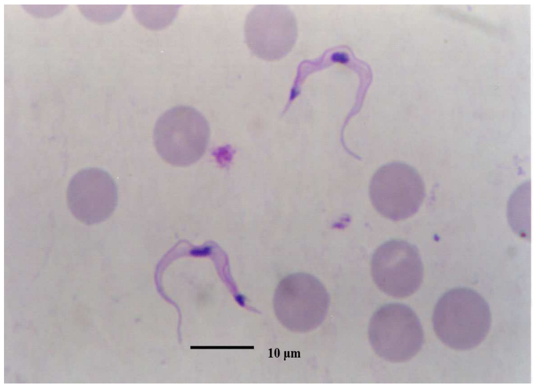
2c. *Ixodes* sp. 2d. Pseudoscorpion (*Chelifer cancroides*)

APPENDIX E

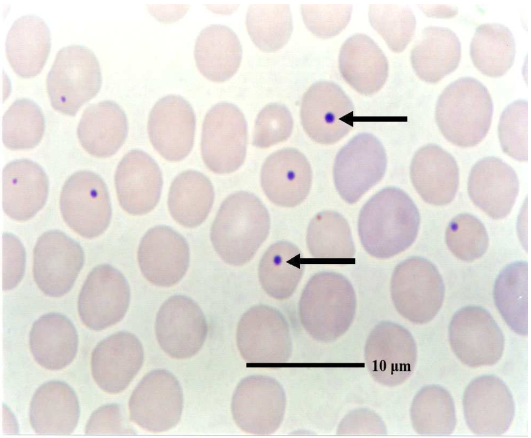
FIGURE OF BLOOD PARASITES OF SMALL MAMMALS



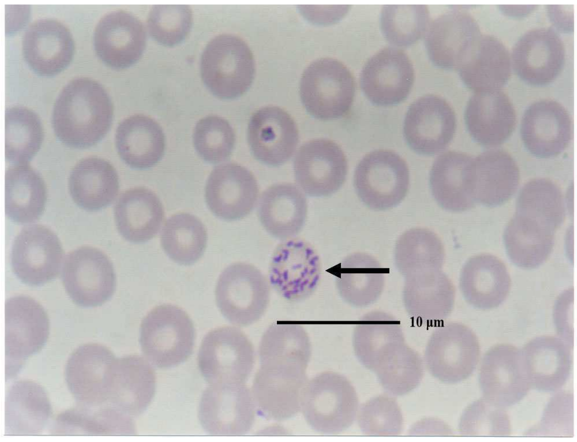
3a



3b



3c



3d

Figure 3a.-3d. Different blood parasites of small mammals in Sakaerat Research Station. Scale bars = 10 µm

3a. *Microfilaria* sp. 3b. *Trypanosoma* sp.

3c. *Anaplasma* sp. 3d. *Grahamella* sp.

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