THE ROLE OF PERI-DOMESTIC RATS AS POTENTIAL RESERVOIR FOR ZOONOTIC PARASITES IN BANGLADESH

A Thesis

By

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*This is to certify that the thesis entitled "**THE ROLE OF PERI-DOMESTIC RATS AS POTENTIAL RESERVOIR FOR ZOONOTIC PARASITES IN BANGLADESH**" submitted to the Faculty of Animal Science &Veterinary Medicine, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science inMicrobiology and Parasitology**,embodies the result of a piece of bona fideresearch work carried out by **ANUP KUMAR ADHIKARY** Registration No. **13-05277** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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Dedicated To
The Soul of Captured
Rodents

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ACRONYMS AND ABBREVIATIONS

Abbreviation		Full Meaning
cm	=	**Centimeter**
CONT'D	=	**Continued**
Dr.	=	**Doctor**
e.g.	=	**For example**
etc.	=	**Et cetera**
et al.	=	**And others/Associates**
HCl	=	**Hydrochloric acid**
hrs.	=	**Hours**
i.e.	=	**That is**
M.S.	=	**Master of Science**
n	=	**Sample number**
No	=	**Number**
Sp.	=	**Single species**
spp.	=	**Plural species**

LIST OF SYMBOLS

Symbols	Full meaning
+	Plus
±	Plus or minus
<	Less than
>	Greater than
%	Percentage
&	And

THE ROLE OF PERI-DOMESTIC RATS AS POTENTIAL RESERVOIR FOR ZOONOTIC PARASITES IN BANGLADESH

ABSTRACT

Rats live around human habitat and they play as reservoirs and spread of many zoonotic parasites, responsible for public health problems. Total 87 (Male=58, Female=29) rats of 4 different species were captured live namely; *Rattus norvegicus* (24), *R. rattus* (5), *Bandicota bengalensis* (25), *Mus musculus* (33) from Dhaka (27), Bandarban (25), Naogaon (10), Meherpur (10), Thakurgaon (08) and Sylhet (07) districts of Bangladesh. All the rats were trapped alive by using ten (10) wire box bait traps with front spring door. Then, all the captured rats were put into a trolly bag and bought to the laboratory for enlisted the data, ectoparasites collection and dissection of rats for endoparasites collection. The overall prevalence of parasitic infection was 62.08%, in which 63.79% prevalence was found in male rats, and 58.62% was female rats. All the recovered parasites except the species *Heterakis spumosa* has public health significance. The prevalence of *M. monliformis* was the highest (21.11%), followed by *G. neoplasticum* (17.77%), *T. taeniformis* (12.22%) and *H. diminuta* (10%) and a single ectoparasite species *Xenopsylla cheopis* (31.03%). Thirty three out of 54 infected rats (61.11%) had mixed endoparasitic and ectoparasitic infection, and only 21 (38.89%) had single infection. The species *Bandicota bengalensis* (80%) had the highest infection followed by *Rattus norvrgicus* (79.17%), *R. rattus* (60%), *Mus musculus* (36.36%). In this study, the highest prevalence of parasites (endoparasites and ectoparasite) found of the examined rats in Naogaon were 90% followed by 71.43 % in Sylhet, 70.37% in Dhaka, 60% in Meherpur, 50% in Thakurgaon, 44% in the Bandarban The highest number of infected rats came from the houses in the slum areas, contributing to (75%), followed by local rent houses (72.22%), rice mill godwon (66.67%), stationary shops (62.50%), and paddy fields (33.33) and poultry shed (0%). Therefore, proper attention needs to be paid for the prevention of rat borne zoonosis through the control of rats.

Keywords: Rats, Prevalence, Endoparasites, Ectoparasite, Zoonosis.

CHAPTER 1

INTRODUCTION

Rats are the largest and most successful group of mammals in the world. Rats comprise many families, of which Muridae represents all the small rats such as rats, mice and rat-like rats. They are cosmopolitan in distribution and have a high rate of reproduction (Parshad, 1999). The diversity of rats is high in Bangladesh. Ahmed *et al.* (2009) listed 20 rat species under four families from Bangladesh. These include Sciuridae (9 species), Muridae (8 species), Spalacidae (1 species) and Hystricidae (2 species). Indur (Indian Mole Rat/Lesser Bandicoot Rat, *Bandicota bengalensis*); Dhadi Indur (Bandicoot Rat/Large Bandicoot Rat/Greater Bandicoot Rat, *Bandicota indica*); Metad Rat/Soft-furred Rat/Soft-furred Field Rat (*Millardia meltada*); Metho Indur (Indian Field Mouse/Little Indian Field Mouse, *Mus booduga*); Nengti Indur (House Mouse, *Mus musculus*); Short-tailed Bandicoot Rat/Short-tailed Mole Rat (*Nesokia indica*); Bram Rat (*Rattus norvegicus*); Indur (Common House Rat/Black Rat, *Rattus rattus*). They are abundant and live in close association with humans in order to obtain their basic survival needs such as food and shelter. Their predatory and depredatory habits have pronounced impact on human health as they are major vectors of human and domestic animal diseases worldwide (Anantharaman 1966; Huq *et al.* 1985).

Rats live around human habitat (commensal ratia). Some naturally occurring rat parasites are epidemiologically important and harbor parasites of humans and domestic animals. Besides various devastating activities to man, they play as reservoirs and spread many zoonotic diseases responsible for public health problems. The eggs of parasites are passed out in rat droppings in fields, grain stores and amongst foodstuffs in shops, houses and are responsible for spreading the diseases (Khatoon *et al*., 2004). Studies on the parasites of rats in most countries reported that they harbor a number of helminth parasites, such as cestodes (*Taenia taeniformis, Hymenolepis diminuta, Hymenolepis nana, Raillietina celebensis, Oochoristica symmetrica* etc.), nematodes (*Heterakis spumosa, Gongylonema neoplasticum, Mastophorus muris, Syphacia muris, Citellina dispar, Trichuris spp., Aspiculuris tetraptera, Syphacia obvelata* etc.) and acanthocephala, *Moniliformis moniliformis* (Singh, 1962; Gupta & Trivedi, 1985; Singla *et al*., 2008; Khanum *et al*., 2009) . The rat-borne endoparasites such as, *T. taeniformis, H. nana, H. diminuta, G. neoplasticum, M. moniliformis* etc. are reported as transmissible to human and constitute public health problem (Marangi *et al.,* 2003). Generally, urban rats inhabit in human altered habitats and therefore, trigger the possibility of transmitting rat-borne

zoonoses. About 40 diseases are known to be spread by rats, including plague, arena and hanta viruses, rat typhus and helminthasis. Among different helminthiasis, hymenolepiasis, schistosomiasis and lung worm are common (Singleton *et al*., 2003). A survey of a wide range of parasites of brown rats on United Kingdom farms reported that they were infected with 13 zoonotic species with a range of 2-9 simultaneously per rat (Webster and MacDonald, 1995). According to Nowak (1991), more people have died in the last ten centuries due to rat borne diseases than war. The main reason for this accelerating health risk can be due to increasing human population density and rapid clearance of natural habitats, enhancing rat human contact (Singleton *et al*., 2003). Further, the high rat reproduction frequency worsens the situation. The rats borne zoonotic endoparasites such as *Taenia taeniformis, Hymenolepis dimunuata*, *Gongylonema neoplasticum, Heterakis spumosa*, *Moniliformis moniliformis* cause pernicious pneumonia, abdominal pain, diaarhoea, nausea, vomition, chronic headache, behavioral abnormalities and discomfort in human. Moreover, tissue reaction to the nematode infection has been rarely documented and most studies described little pathogenic effects (Villafane *et al*., 2008). Plague is caused by *Yersinia pestis*, a gram-negative coccobacillus that are harbored by the oriental rat flea *Xenopsylla cheopis*. According to United States Department of Agriculture (USDA), today plague occurs in some countries in Central and Far East Asia, Africa and the Americas. Plague started in China, where it killed half the population of about 120 million. Plague was brought to Europe from Asia by ships in 1347. In the early 1350s, it had killed 20 to 50 million people or 30% to 60% of the population of Europe according to different accounts. It killed not only people but also cows, sheep and other domesticated animals (kang *et al*., 1994).

Therefore, the presence of rats infected with zoonotic parasites is alarming and matter of great concern. Unfortunately, the rats are available in different part of Bangladesh are highly infected with this zoonotic parasites. The presence of rats, therefore, represent a potential epizootiological problem (Spatafora and Platt, 1982). Although emerging rat-borne diseases have been captured worldwide attention, but little has been documented on this aspect in Asia. The endoparasitic infections that rats harbor and transfer to human and animal populations have not been as thoroughly investigated as the microbial infections, especially in Bangladesh. In Bangladesh, very few studies (Huq, 1969; Shaha, 1974; Bhuiyan *et al*., 1996; Khanum *et al*., 2001; Alam *et al*., 2003; Khanum and Arefin, 2003; Muznebin *et al*., 2009; Khanum *et al*., 2009 and Gofur *et al.,* 2010) have been carried out only on the prevalence of the parasites and worm burden of rats in laboratory, Dhaka city and some specific areas. Howeverly, none of

these studies included detail morphological identification and geographical distribution of rat borne zoonotic parasites throughout Bangladesh.

Objectives of the study

The objectives of this present study was to carry out the prevalence and detail morphological identification of parasites of peri-domestic rats, to access the load of rat-borne parasitic infections and to elucidate the prevalence of zoonotic parasitic infection in Bangladesh. The findings of this study may assist in determining the risk of parasitic infection for public health, and thereby, will contribute to the development of awareness among the people in Bangladesh.

CHAPTER 2

REVIEW OF LITERATURE

Rats are worldwide distributed and are the most commonly rats found in the city and its surrounding areas. Four species of rats namely black rats (*R. rattus*), brown rats *(R. norvegicus*), lesser bandicoot rat (*B. bengalensis*) and house mouse (*M. musculus*) are very popular around human habitats in tropical and sub-tropical regions. Their origin from the far east and distributed around the world through ship trades. The breeding of rats has been increased rapidly in the recent years because of the abundance of food resources and lack of environmental hygiene in urban areas (Arfa, 1987; Abdel and Eisha, 1997). Rats impose economic damages, and involve significant cost on public health system. They can cause destruction of food stuffs, electrical equipment and buildings by contamination or gnawing with excreta resulting in significant economic losses (Coomansingh *et al.*, 2009).

Fourteen different species were found in Chittagong hilly tract. The most dominant small mammal species was Rattus rattus (54.06%) and the least was Tupaia glis (0.04%) and Callosciurus pygerythrus (0.04%). Out of the 14 small mammals, 12 were rodent species and two shrew (Family Soricidae) species. Six of 12 rodent species are new records for Bangladesh. The new species are *Mus cookii nagarum, Leopoldamys edwardsi, Rattus nitidus, Rattus andamanensis, Berylmys bowersi* and *Vernaya fulva*. *R. rattus* and *M. musculus* were found in all trapping habitats (Chakma *et al*., 2018).

Helminth parasites in small mammals comprise four major taxonomic groups. The cestodes or tapeworms, the flukes, the nematodes or roundworms, and the acanthocephalans or spiny-headed worms. Almost all of the cestodes, flukes, and acanthocephala, as well as many of the nematodes, require one or more invertebrate intermediate hosts for the development of their larval stages to complete their life cycles (Gibson *et al.,* 2014) The vertebrate's definitive host becomes infected either as a result of direct penetration of their tegument by larval stages or by ingestion of infective stages, the latter being the more usual route, especially in the case of helminths of terrestrial vertebrates (Zain *et al*., 2012).

Rats are hosts to a number of endoparasites (Khalid *et al*., 1992; Mafiana *et al*., 1997; Milaazzo *et al*., 2010; Zain *et al*., 2012; Hindi and Haddaf, 2013). Many parasites of rats are common with human too and some parasites can be transferred from rats to human, for example *H. nana, C. hepatica, H. diminuta, T. taeniaeformis, Diphyllobothrium* sp. *M. moniliformis, G.*

neoplasticum etc. (Beaver *et al*., 1984). These authors have recorded different species with different prevalence of endoparasites depending on the geographical distribution.

Rats play an important role in the zoonotic cycle of many parasitic diseases (Okoye and Obiezue, 2008; Onyenwe *et al*., 2009 and Sumangali *et al*., 2012). Some of which are more important than the others such as schistosomiasis, hymenolepiasis and angiostrongliosis. Several studies on the endoparasites of rats have been conducted in different parts of the world (Seong *et al*.,1995; Mafiana *et al*.,1997; Wahed *et al*.,1999; Kassa and Assefa, 2000; Milazzo *et al*., 2003; Stojcevic *et al*., 2004; Claveria *et al*., 2005; Zihiry, 2006; Waugh *et al*., 2006; Zain *et al*., 2012; Coomansingh *et al*., 2009; Milaazzo *et al*., 2010; Madi *et al.,* 2001; Gaherwal *et al*., 2011; Kataranovski *et al*., 2011; Bashan and Sabra, 2012; Shafiyyah *et al*., 2012; Kiran *et al*., 2013; Amarasingh and Premathilake, 2014; Araujo *et al*., 2014; Guimarães *et al*., 2014; Ogunniyi *et al*., 2014 and Priyanto *et al*., 2014). Many endoparasites include cestodes, trematodes and nematodes have been identified and reported from *R. rattus, R. norvegicus, B. bengalensis and M. musculus* in cities and villages from developed and developing countries. In Egypt, Wahed *et al*., (1999) identified many endoparasites in wild rats from Qalyobia Governorate. The species and their infection rates were *H. diminuta* (23.8%), *C. fasciolaris* (7%), *M. moniliformis* and *Strongyloides* sp. While Elkady *et al.,* (2008) recorded 10 species trematodes, 4 species cestodes and 10 species nematodes in rats collected from Dakahlia Governorate. On other hand, Madi *et al.*, (2001), found only one species of cestode in brown rats from urban area of Doha, Qatar. Zihiry (2006) recovered *H. diminuta* and two species of nematodes Protospirura magna and Pterygodermatites tani from R. norvegicus in Basrah, Iraq. Kassa and Assefa, (2000) recorded *H. diminuta* (30.7%) and *H. nana* (12.9%) among household rats in Addis Ababa. Seven helminthes species were recovered from *R. norvegicus* in Belgrade area (Serbia) of which five were nematode (*H. spumosa*, *Nippostrongylus brasiliensis, Capillaria* sp*., Trichuris muris and Syphacia muris*) and two cestode species *H. diminuta* and, *Ratolepis fraternall* (Kataranovski *et al.,* 2010).

In Nigeria, many parasitic species were recovered from *R. rattus* collected from different regions, which include *Capillaria hepatica, Hymenolepis* sp*, Raillietina* sp*, Trichuris muris, Ascaris* sp*, Cyathostomum* sp*, M. moniliformis, Taenia* sp*, Trichuris and Trichinella* (Okoye and Obiezue, 2008, Onyenwe *et al.,* 2009 and Ogunniyi *et al.,* 2014). Milazzo *et al.,* (2003) and Milaazzo *et al*., (2010) studied helminth fauna of commensal rats, *M. musculus* and *R. rattus* in Sicily, Italy. Parasites recovered from black rat, *R. rattus* were one species of digenea (*Brachylaima* sp.), two species of cestode (*H. diminuta, H. nana*) seven species of nematode

(*S. muris, A. tetraptera, M. muris, H. spumosa, C. hepatica, Eucoleus gastricus* and *N. brasiliensis*) and one unidentified species of acanthocephala. Katranovski *et al*., (2010) showed helminth fauna of *R. norvegicus* from the Belgrade, Serbia. They recovered *H. diminuta* (30.46%) and *Ratolepis fraternal* (12.5%), *H. spumosa* (36.75%), *N. brasiliensis* (16.22%), *Capillaria* sp. (5.96%), *T. muris* (5.96%), *S. muris* (4.30%) and *Strongylus* sp. larvae (0.33%).

Many reports on rats endoparasites come from the Far East, Zain *et al*., (2012) identified several species of parasites from urban rat population in Kuala lumpur, Malaysia. Eleven species of endoparasites comprising seven nematodes (*H. spumosa, M. muris, N. brasiliensis, S. muris, Pterygodermatites tani, G. neoplasticum, Angiostrongylus malaysiensis*), three platyhelminthes (*H. nana, H. diminuta and T. taeniaeformis*) and one Acanthocephala *(M. moniliformis*).On other study from Malaysia, Sitishafiyyah *et al*., (2012) identified *N. brasiliensis* (80.3%), *H. nana* (23.4%), *C. hepatica* (13.9%) and *H. diminuta* (2.9%) in wild rats.

Claveria *et al*., (2005) were reported in Philippines, parasite biodiversity in *Rattus* spp. captured in wet markets. They detected *H. diminuta, M. moniliformis, T. taeniaformis* strobilocercus larvae and *C. hepatica* in liver, Trichosomoides crassicauda of the urinary bladder, *Sarcocystis* sp. in muscle tissue, and two different species of Stronglyloid looking intestinal nematodes.

Amarasingh and Premathilake, (2014) observed that *R. rattus* captured from the western province of Srilanka harbored liver cysts of *C. fasciolaris* and acanthocephalan, *M. moniliformis*. On other hand, Seong *et al.,* (1995) recovered *C. hepatica* (11.6%), *H. diminuta* (16.3%), *T. taeniaformis* metacestde (51.2%) from *R. norvegicus* in Korea. Recent studies in rats from Brazil showed occurrence of *M. musculus* and *R. rattus* (Guimarães *et al*., 2014 and Araujo *et al*., 2014). The parasites found in these studies were, *A. tetraptera* and *S. obvelata, H. diminuta, Strongyloides* sp. and *H. diminuta*. Meanwhile, Waugh *et al.,* (2006) recorded nine species of gastrointestinal helminths from wild rats, *R. rattus* and *R. norvegicus* in Jamaica. The detected endoparasites were *Raillietina* sp. (0.2%), *Trichuris* sp. (0.2%), *Rictularia* sp (0.7%), *Syphacia obvelata* (1.1%), *Strongyloides ratti* (1.4%), *H. diminuta* (3.8%), *P. muricola* (4.3%), *M. moniliformis* (11.2%) and *N. brasiliensis* (14.2%).

Gofur *et al*., (2010) reported that 23 out of 30 rats were infected with endoparasites, two species of helminth parasites, *H. nana* and nematode *S. muris*. The prevalence of parasites was quite different in different groups of helminth parasites in hosts. The prevalence of cestodes infection was 26.67% while, higher prevalence was found in of nematodes (66.67%) in the Long-Evans

respectively. *H. nana* was observed in small intestine and *S. muris* in all parts of the alimentary tract. The prevalence of infestation was 36.67% in small intestine. The prevalence of infection was similar both in caecum (63.33%) and rectum (63.33%). Muznebin, (2009) with other researchers found five helminth parasite species from two taxonomic groups from *R. norvegicus*. The cestodes were *Vampirolepis nana, H. diminuta* and nematodes were *C. dispar, H. spumosa* and *S. muris*. They found the highest prevalence in *H. diminuta* but the highest intensity was recorded in *V. nana*. The prevalence and intensity of *V. nana, H. diminuta, C. dispar, H. spumosa* and *S. muris* were 56.25% (65.11±13.23), 72.92% (4.37±0.89), 62.50% (19.63 ±2.10), 66.67% (9.06±1.85) and 64.58% (24.65±2.60), respectively. Sumangali *et al*., (2012) showed that urban rats played important role in public health through being reservoirs of many zoonotic diseases. Screening of rats for endoparasites from Peradeniya and Pilimathalawe in Kandy district was carried out to assess their potential as reservoirs of zoonoses. They caught live rats by using single catch rat traps from July 2006 to February 2007. Three rat species, *R. rattus* (n = 17), *M. musculus* (n = 2) and *B. indica* (n = 2) were examined. Five zoonotic endoparasites were identified, namely, *H. diminuta, M. moniliformis, Raillietina sp*. and *C. fasciolaris*. Cestodes were the predominant parasitic group (52.4%), of which *C. fasciolaris* (42.7%) was the most common type followed by Strongyloides type eggs (19.0%). Among the infected rats, 23.8% had mixed infections with *H. diminuta* and *M. moniliformis* and *H. diminuta, Raillietina* sp. and *C. fasciolaris*. Although *R. madagascariensis* was recorded in *R. rattus* in 1954, none of the rats examined in their study was infected with Raillietina. However, one bandicoot was infected with *Raillietina* sp. in their study. They identified that urban rats carried zoonotic infections, and in developing countries where the communities are socio-economically challenged, urbanization is in favours the spread of these infections to humans.

Kiran *et al*., (2013) reported that the prevalence of cestodes in three species of rats, *R. rattus, R. norvegicus* and *M. musculus*, revealed 36% (n=50) of infection in four cities of Dehradun, from April 2011 to December 2011. Three species, *H. diminuta, T. taeniaeformis* and *Diphyllobothrium* sp, were recorded from each infected rat. *R. norvegicus* were highly infected with cestodes (46.1%) followed by *R. rattus* (37.5%). They found the association between rat species and cestodes was significant (P>0.05). Mean worm burden of *T. taeniaeformis* was high 3.3 and 2.8, respectively in both the rat species, *R. rattus* and *R. norvegicus*. In their study, they found mixed infection of nematodes and cestodes in 58% of captured rats.

Coomansingh, (2009) and other team members reported that recent significant increases in the population of rats in Grenada warranted a study to determine the prevalence of helminth endoparasites in 242 *R. norvegicus* rats (Norwegian rats) captured from all six parishes. They observed overall prevalence of helminth parasites as 90.9%. Three nematodes, two cestodes and one acanthocephalan were identified. The prevalences of *N. brasiliensis, S. muris, H. diminuta, T. taeniaeformis, M. morniliformis* and *T. crassicauda* were 76.8%, 28.1%, 16.1%, 23.1%, 3.7% and 1.2%, respectively. Significant parasite burdens were identified in the captured rats, some of which are of public health significance due to their zoonotic potentiality.

Singla *et al.* monitored the prevalence of endoparasitic infections of rats in Punjab State, India, between January 2004 and December 2005. Three species of wild rats, namely, *R. rattus* (n = 42), *B. bengalensis* (n = 34) and *T. indica* (n = 15), were live captured from houses and crop fields. Various organs examined revealed that the highest rate of helminth parasites infection occurred in *R. rattus* (40.5%), followed by *B. bengalensis* (35.3 %) and *T. indica* (20.0%), with an overall infection rate of 35.2%. Metacestodes (1–6) of *C. fasciolaris* (larvae of *T. taeniaeformis*) were observed in all three rat species (in the liver).

Paul *et al.,* (2016) surveyed in domestic rats investigated the prevalence of gastrointestinal helminths in Maiduguri municipal between February and June 2015. They collected rats randomly from residential sites within Maiduguri metropolis by trapping, using mechanical and glue board traps. Out of 85 rats sampled in the study, a total of 7 (8.2%) were positive for gastrointestinal helminths. The only species of endoparasite identified was *H. diminuta*. There was no significant difference in prevalence of intestinal helminths among different sexes and age groups ($P>0.05$).

CHAPTER 3

MATERIALS AND METHODS

3.1. Sampling area and rats trapping

In this present study, a total of 87 rats were trapped from different urban and rural areas of Dhaka (n=27), Sylhet (n=07), Naogaon (n=10), Meherpur (n=10), Thakurgaon (n=08) and Bandarban (n=25). The sampling procedure were conducted from September, 2018 to August, 2019. The rats were collected from houses in the slum areas (n=20), local rent houses (n=18), different stationary shops (n=16), rice fields (n=12), poultry shed (n=12) and rice mill godwon (n=09). All the rats were trapped alive by using ten (10) wire box bait traps with front spring door. Baits included meat, parts of fishes, biscuits, potatoes, breads, tomato, cucumber and cheese were used. Traps were set just before sunset, and were collected in the next morning. The rats captured from Dhaka, were brought to the laboratory of Microbiology & Parasitology, Faculty of Animal Science and Veterinary Medicine, Sher-e-Bangla Agricultural University, Dhaka. The samples rather than Dhaka were stored on that collecting wire box bait traps and the empty bait traps were used to capture the rats on the next night. Then, all the captured rats were put into a trolly bag and bought to the laboratory for enlisted the data, ectoparasites collection and dissection of rats for endoparasites collection. The data includes the date of captured, captured area and nitches, rat species, weight, length, sex of the rats were recorded in the record book.

Figure 1: Rat traps and anaesthetized rat.

3.2. Rat species identification

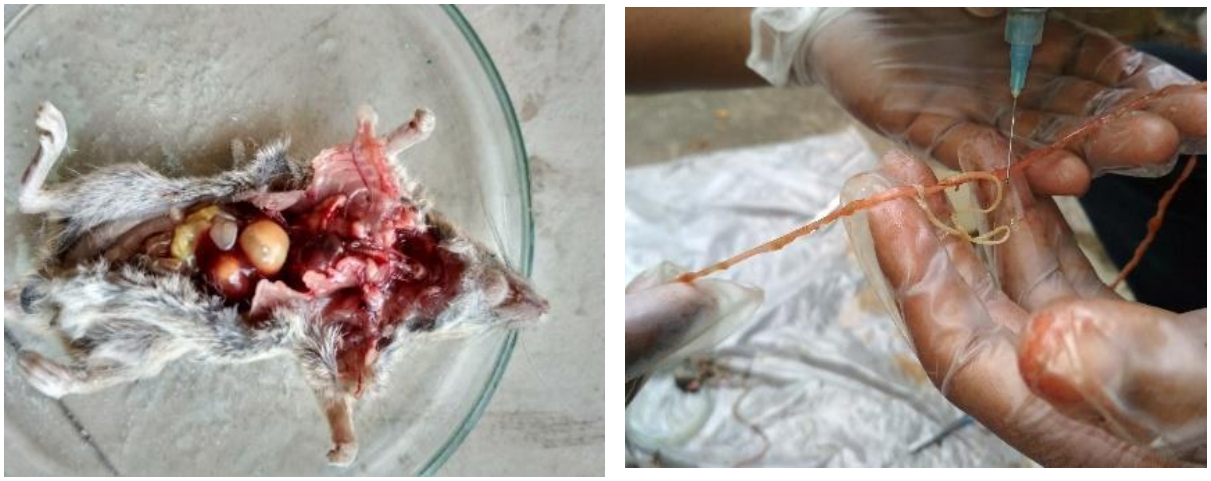
Characteristic		*Bandicota bengalensis*	*Rattus rattus*	*Rattus norvrgicus*	*Mus musculus*
Coat color	(Body)	Blackish	Light blackish	Blackish to greyish	Blackish
	(Abdomen)	Greyish	Whitish	Light greyish	Greyish
Fur structure		Dense and coarse	Dense and smooth	Thin and very smooth	Thin and smooth
Tail structure		Short, hairy blackish	Narrow, longer than body length	Reddish to whitish hairy tail	Blackish hairy long tail
Mammae (pair)		8	5-6	4	5
Body structure		Strong and stout	Elongated	Elongated	Moderately strong
Behavior		Ferocious	Ferocious	Docile	Docile

3.3. Sexing of rats

Sexing of rats usually relies on differences in the genitalia between sexes. Male possess testes and a penis, while females possess mammary glands with visible nipples and a vaginal opening with a noticeable clitoris. Non-reproductively active females without prominent nipples can be difficult to sex, especially because their clitoris superficially resembles a penis. When nipples or testes are not prominent and there is no sexual difference in color or size, the anogenital distance can be used to sex animals. The anogenital distance is the distance between the base of the penis and the anus (male) or between the clitoris and the anus (female). The anogenital distance is shorter in females than in males.

3.4. Animal dissection for endoparasites collection

Each of the rats was put separately in a glass flask and anesthetized with a cotton plug soaked in chloroform until it dies. The body cavity of individual rat was slit open from throat to anus revealing the esophagus, lungs, stomach, heart, small intestine, large intestine, liver and urinary bladder. The viscera were removed without damaging, and dissected separately under the dissecting microscope and examined for helminthes. The contents of the intestine were also examined carefully for parasites. The length of the recovered parasites were measured with scale, washed the parasites with normal saline and fixed in 70% alcohol.



(A) **(B)**

Figure 2: Internal organs infected with parasites. **A**. Liver having cyst containing *T. taeniaformis*. **B**. Small intestine infected with acanthocephalan parasites.

3.5. Processing of cestodes, acanthocephala and nematodes

Cestodes and acanthocephala were collected in a separate glass petri dishes, containing normal saline and washed three times to remove any debris. The flatworms were then flattened between two glass slides with slight pressure and fixed in 70% alcohol until future works. For staining, specimens were transferred to 50% alcohol and washed in distilled water. Then specimens put in hematoxylin solution for 24hrs. The excessive stain was removed by 3% Hydrochloric acid (HCl). The stained specimen was dehydrated with ascending grades of alcohol (from 70% to 100%), cleared by xylene and mounted with Canada balsam. Then examined under microscope (4X, 10X and 40X) for morphological identification of parasites.

The nematodes were washed well in saline water to remove the preservative, and examined under microscope using lactophenol.

3.6. Processing of ectoparasites

Before dissecting the rats, the body coat was thoroughly examined for any external lesion or ectoparasite. Only the fleas were found. Fleas were cleared by dissolving in 10% Potassium Hydroxide (KOH) solution at room temperature for overnight to allow transmitted light to pass through them. After clearing with KOH, for staining, specimens were transferred to 50% alcohol and washed in distilled water. Then specimens put in hematoxylin solution for 24hrs. The excessive stain was removed by 3% Hydrochloric acid (HCl). The stained specimens were dehydrated with ascending grades of alcohol (from 70% to 100%), cleared by xylene and mounted with Canada balsam. Fine forceps, needles and insect pins were used to handle the specimens during the mounting process. Then examined under microscope (4X, 10X and 40X) for morphological identification of parasites

CHAPTER 4

RESULTS AND DISCUSSION

RESULTS

Through examination of 87 different types of rats *(Bandicota bengalensis, Rattus norvrgicus, Rattus. rattus* and *Mus musculus*), many different parasites were recovered. The endoparasites includes two species of cestodes (*Hymenolepis diminuta* and larvae of *Taenia taeniaeformis*), one species of acanthocephala (*Moniliformis moniliformis*) and two species of nematodes (*Heterakis spumosa* and *Gongylonema neoplasticum*) and single ectoparasite species, *Xenopsylla cheopis.*

4.1. Morphological observation

4.1.1. *Cysticercus fasciolaris* (Larva of *T. taeniaeformis*)

Zoological classification

Kingdom: Animalia

Phylum: Platyhelminthes

Class: Cestoda

Order: Cyclophyllidae

Family: Taeniidae

Genus: *Taenia*

Species: *Taenia taeniaeformis*

Morphological features

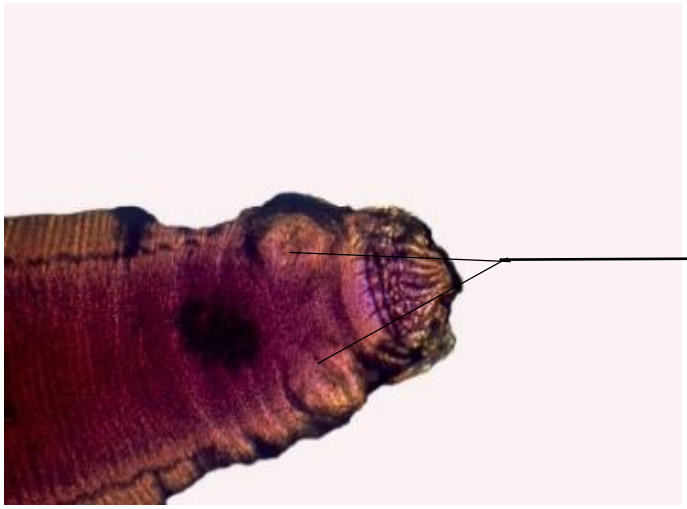
Cysticercus fasciolaris is a larval stage (Metacestode) of *T. taeniaeformis*, feline tapeworm, which is commonly found in liver of intermediate hosts, such as mice, rats, cats, muskrats, squirrels, rabbits, other rats, bats and human. The larvae were 4-15 cm in length with a scolex bearing four large suckers and a rostellum containing two rows of large and small hooks attached to a long neck. There were 34-42 small and large hooks (Hamid *et al*., 2017). The results of this study showed the rat livers infected with single and multiple hepatic cysts (Figure A). Some of these cystic structures were found less than 5mm in diameter. Liver with this size of cyst was suspected to be less than one month of infection, where the larval scolex did not develop yet. In cases of more than one month of infection, the cysts were biggest and clearest, adults reach maximum length of about 60 cm (Figure B). These findings are supported by the previous report (Karim, 2010). The tapeworms beared double rows of hooks with distinctly large four lateral suckers on the scolex. These morphological properties match with those in the Order Cyclophyllidea (Figure C, D). At the anterior end of the strobilocerci, the protoescolex consisting of an envaginated rostellum armed with a double and alternating ring of large and small hooks, which are the morphological traits of the family Taeniidae. The hooks were arranged in a circular pattern with a large double circlet of 30 to 48 hooks belonging to the Genus *Taenia* and Species *T. taeniaeformis* (Figure C). Behind the scolex, there was the neck region. The third region was the strobilus which have pseudosegmentation throughout the whole body (Figure E), and there was a bulged terminal portion at the posterior end of the parasites (Figure F) which are the characteristic features of the metacestode of *T. taeniaeformis.*

The cyst of *C. fasciolaris*, a larval form in the liver of rats.

Figure : 3 (A)

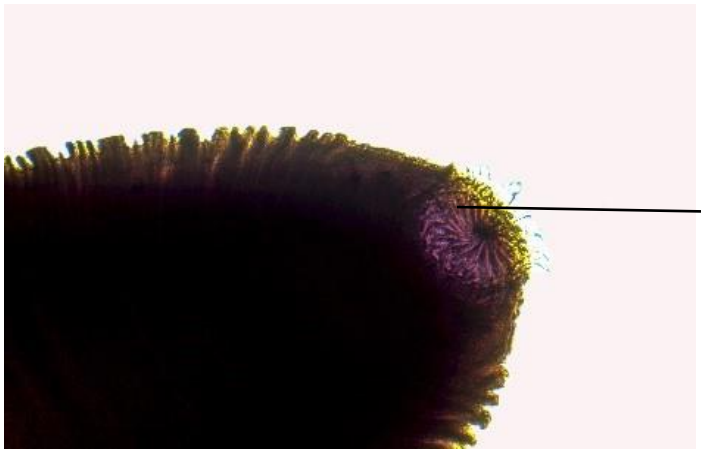
Larval stage (Gross) of *T. taeniformis*, *C. fasciolaris*, found after the rupture of the cyst.

Figure : 3 (B)



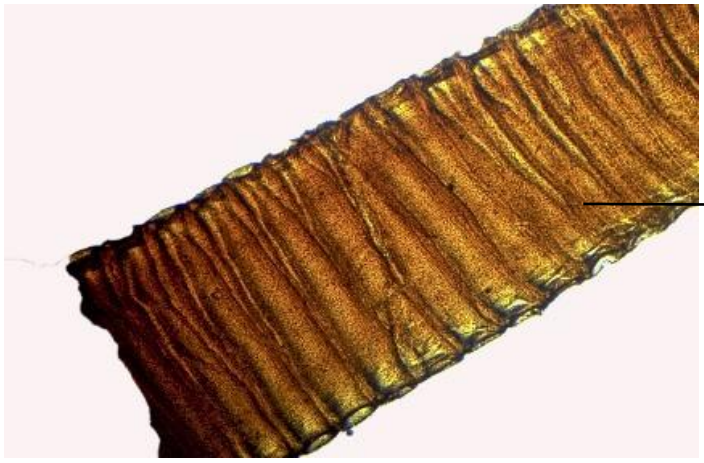
Scolex region with suckers (X4).

Figure : 3 (C)



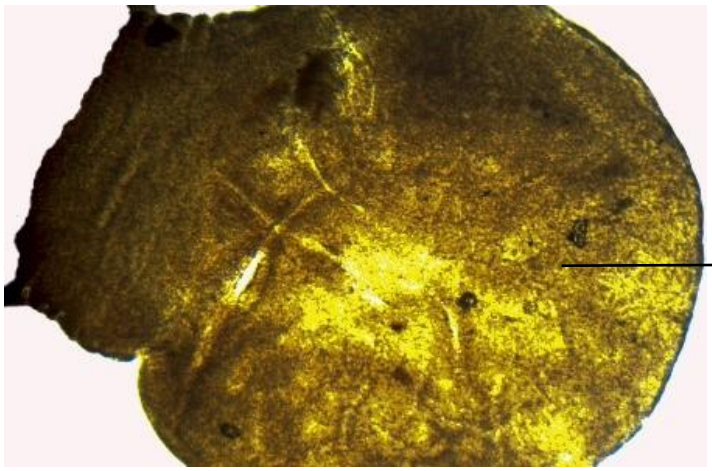
Protoscolex region with rostellum with hooks. (X4)

Figure : 3 (D)



Strobilocercus without internal organ. (X4)

Figure : 3 (E)



Bulged posterior portion (Terminal bladder) (X4).

Figure : 3 (F)

Figure 3: Different body parts of larval stage of *Taenia taeniaeformis*

4.1.2. ***Hymenolepis diminuta*** **(rat tapeworm)**: This worm was recovered from the intestinal tract of rats.

Zoological classification

Kingdom: Animalia

Phylum: Platyhelminthes

Class: Cestoda

Order: Cyclophyllidae

Family: Hymenolepididae

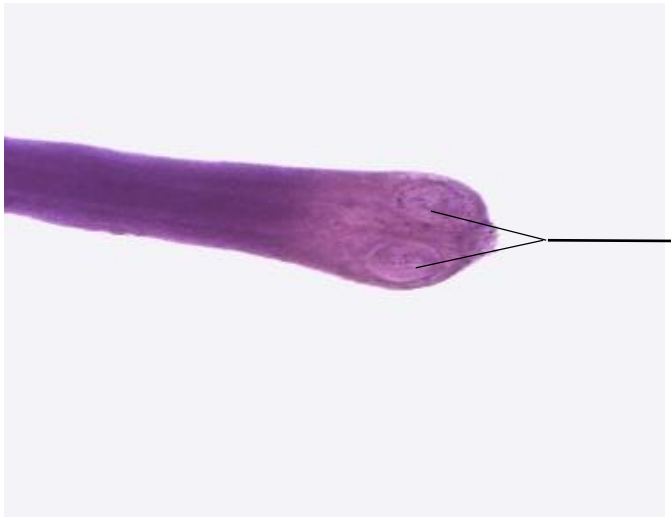
Subfamily: Hymenolepidinae

Genus: *Hymenolepis*

Species: *Hymenolepis diminuta*

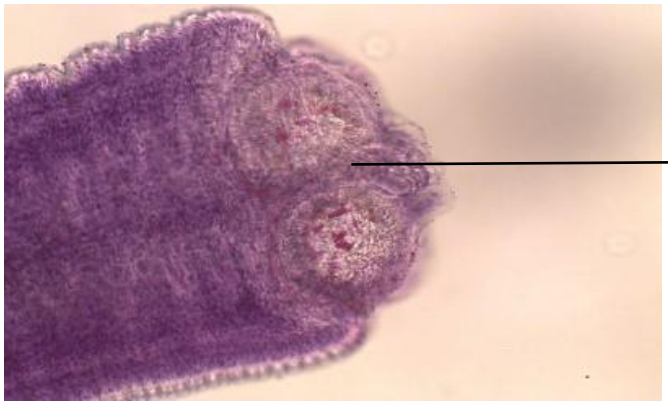
Morphological features

Hymenolepis diminuta has been indicated as the common cestodes of humans, domestic and wild rats. Adult *Hymenolepis diminuta* reach 20 to 60 cm, and up to 90 cm. The cestode has a long cylindrical body with 4 suckers and an apical organ at its scolex with no rostellar hooks. *Hymenolepis diminuta*, along with all cestodes, lacks any trace of a digestive tract. *Hymenolepis diminuta*, like all other cestodes, has three body sections, a scolex (head), neck, and a strobilus, which is the rest of the cestodes body. The strobilus is divided into many section called proglottids, each with male and female sexual organs. These are the defining characteristics of cestodes. (Arai, 1980; Deines, *et al*., 1999; Pappas, 2000; Roberts and Janovy, 2005).The results of this study showed that the rats small intestine was infected with single and multiple mature *H. diminuta*, measuring 15- 60 cm long. The scolex was spherical, and had four suckers located bilaterally on the dorsal and ventral surface (Figure A), which are the identifying characters of the Order Cyclophyllidae. The scolx had retractable rostellum without hooks (Figure A, B), which is the morphological feature of the Family Hymenolepididae. The strobila started with short and narrow proglottids, followed by mature ones (Figure C). These are the identifying traits of the Family Hymenolepididae. Each mature segment contained with three ball like testes and one ovary (Figure C), matching with the morphological characteristics of Genus *Hymenolepis* and Species *H. diminuta.*



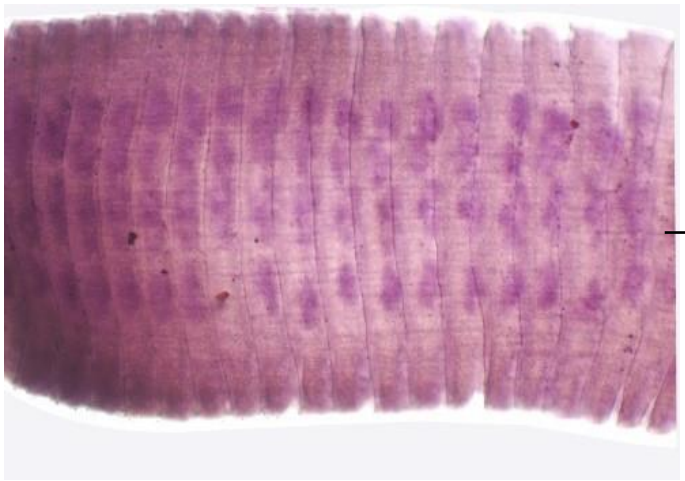
Scolex region. Black lines indicate armed suckers (X4).

Figure : 4 (A)



Suckers with retractable unarmed rostellum (X10).

Figure : 4 (B)



Mature proglottids with testes and ovary (X10).

Figure : 4 (C)

Figure 4: Different body parts of *Hymenolepis diminuta*

4.1.3. *Moniliformis moniliformis*:The worm was recovered from intestinal tract of examined Rats.

Zoological classification

Kingdom: Animalia

Phylum: Acanthocephala

Class: Archiacanthocephala

Order: Moniliformida

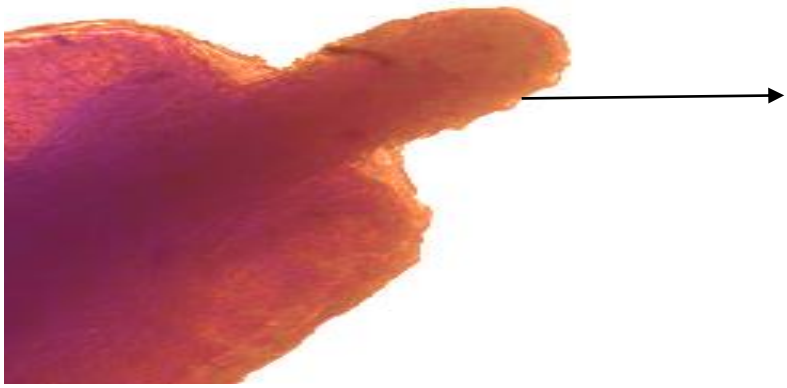
Family: Moniliformidae

Genus: *Moniliformis*

Species: *Moniliformis moniliformis*

Morphological features

Moniliformis moniliformis, acanthocephala, is pseudocoelomate animals. Adult worms are white, and because of pitted horizontal lines on the body surface, they appear to be segmented (Beaver *et al*., 1984; Roberts and Janovy, 2005). The body consists of a proboscis, located on the anterior end of the worm, a neck, and a trunk (Roberts and Janovy, 2005). The cylindrical proboscis is hollowed with a thin muscular wall, and armed with 12-15 rows of recurved hooks, 7-8 hooks to each row (Beaver *et al*., 1984; Roberts and Janovy, 2005). The adult male is generally 4 to 13 cm long, while female longer, ranging from 10 to 30 cm (Lawlor *et al.*, 1990). The results of this study showed that the proboscis is covered with hooks (Figure A), and is attached to the trunk by a neck. The proboscis retracts into a proboscis sheath which also known as receptacle (Figure B). The lemnisci, which arise near the point where the proboscis sheath attaches to the trunk, and float free within the body cavity (Figure C). These morphological features match with these in the Family Moniliformidae. In male, there are two testes arranged in tandem (Figure D). Male has copulatory bursa, used to hold the female during copulation, and has cement glands. At the posterior end of the female body cavity, there is a selector apparatus, and then there is a uterus, which connects via a short vagina to a vulva. Occasionally a cement cap can be seen over the vulva, which is deposited by the male after copulation, these are the morphological structures of Genus and Species *Moniliformis* and *M. moniliformis*, respectively.



Proboscis covered with hooks (X10).

Figure : 5 (A)

Proboscis sheath or receptacle (X4).

Figure : 5 (B)

Lemnisci near the point where the proboscis sheath attaches to the trunk (X4).

Figure : 5 (C)

Two testes arranged in tandem position (X4).

Figure : 5 (D)

Figure 5: Different body parts of *Moniliformis moniliformis*

4.1.4. Intestinal nematode, *Heterakis spumosa*

Zoological classification

Kingdom: Animalia

Phylum: Nematoda

Class: Secementea

Subclass: Rhabditia

Order: Ascaridida

Family: Heterakidae

Genus: *Heterakis*

Species: *Heterakis spumosa*

Morphological features

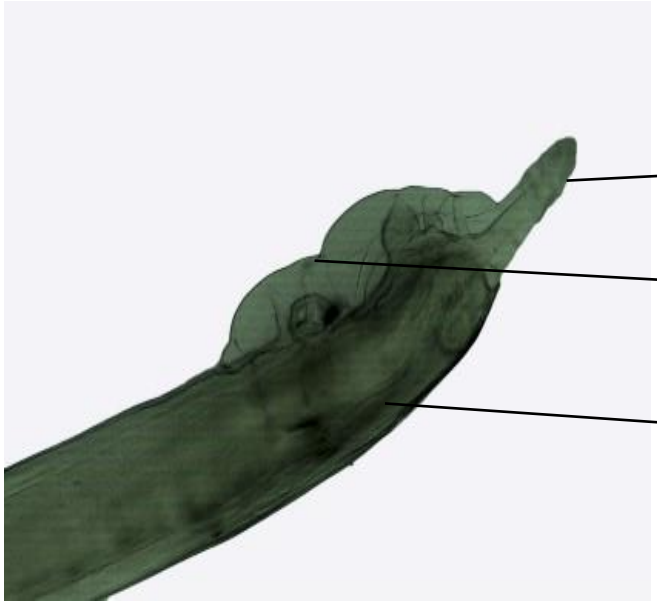
The specimens of *H. spumosa* were collected from the large intestine, specifically in the blind and initial portion of the colon. The adults *H. spumosa* were whitish in color, having 3 small unequal lips (Figure A) in the oral cavity, which are the special feature of Order Ascaridida. Oesophagus was cylindrical and long, ending in a distinct bulb with a "Y" shaped structure inside (Figure B). This morphological character match with the Family Heterakidae. In male, large pre-cloacal genital suction cup and spicule were present at the posterior end (Figure C). There were 3 pairs of lateral papillae (the proximal and distal papillae located dorsally, whereas the middle papilla is double and located ventrally) at the tip of the tail (Figure D). Females had 5 cuticular processes associated with vulva: first one anterior to the vulvar opening, second one posterior to it, and other three located posteriorly to the latter (Figure E). There was an elongated, sharp, pointed tail posteriorly (Figure F). Ovoid eggs with sharp shell were present. Eggs were slightly longer than they were wide and morulated (Figure G). Those special morphological features correspond to the Genus *Heterakis* and Species *H. spumosa*. This morphological features also previously describe by other author (Barman *et al*., 2020).

Mouthpart.with three unequal lips (X4).

Figure : 6 (A)

Oesophagus, bulb shaped at the end of the oesophagus (X4).

Figure : 6 (B)

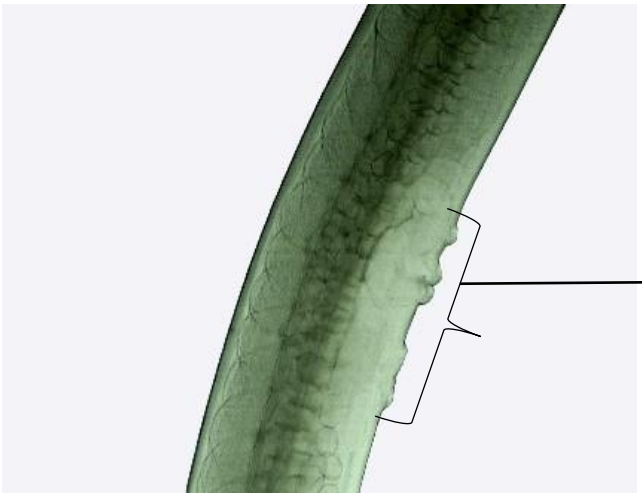


Three pairs of lateral papillae.

Posterior part of male.with procloacal genital suction.

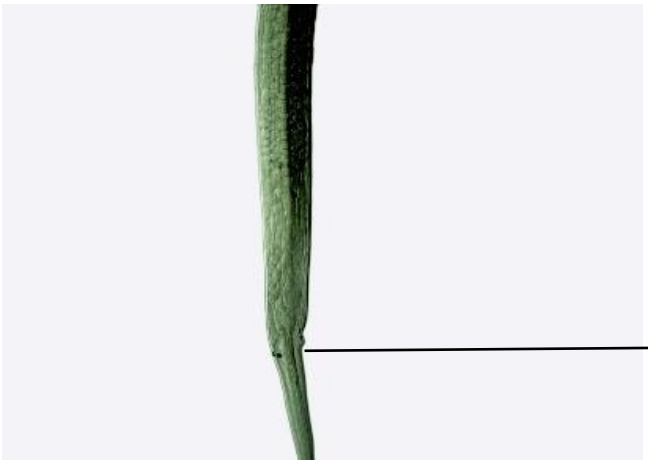
Spicule

Figure : 6 (C)



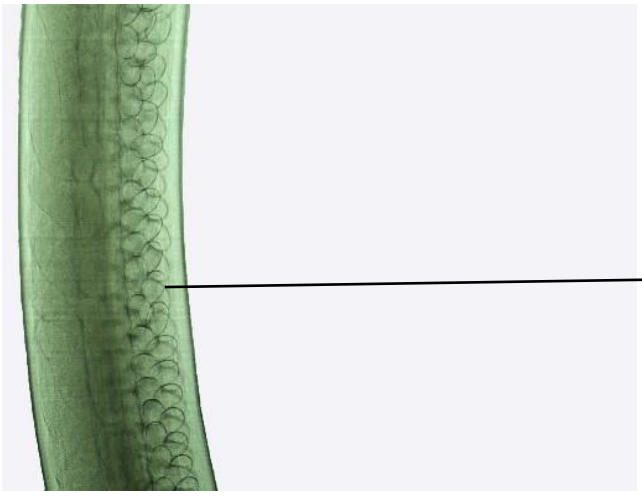
Posterior part of female. Five cuticular processes associated with vulva (X4).

Figure : 6 (D)



The elongated, sharp and pointed tail of female (X4).

Figure : 6 (E)



Eggs of parasite (X4).

Figure : 6 (F)

Figure 6: Different body parts of *Heterakis spumosa*

4.1.5. *Gongylonema neoplasticum*

Zoological classification

Kingdom: Animalia

Phylum: Nematoda

Class: Secementea

Order: Spirurida

Superfamily: Spiruroidea

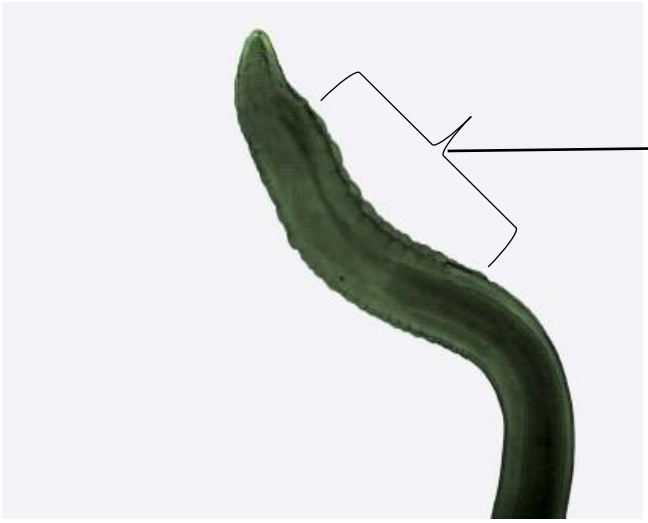
Family: Gongylonematidae

Genus: *Gongylonema*

Species: *Gongylonema neoplasticum*

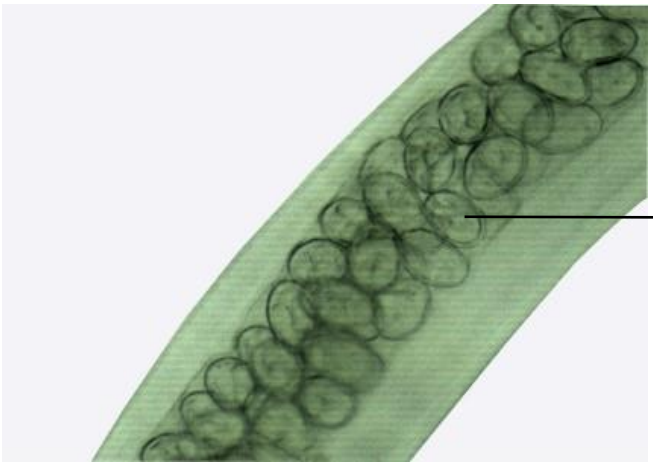
Morphological features

Gongylonema neoplasticum is a gastrointestinal parasite of rats which is observed in the epithelium of the stomach wall. The anterior extremity of the worm was covered by verruciformes or humps which were abundantly found in female but were fewer in male (Figure A) These are the characteristics of the Genus *Gongylonema*. There was a pair of lateral cervical papillae. The buccal opening was small and extended in the dorsoventral direction. Around the mouth, a cuticular elevation enclosed the labia, and eight papillae were located laterodorsally and lateroventrally (Barman *et al*., 2020). Two large lateral amphids were seen. On the lateral sides of the female's tail, phasmidal apertures were observed. The caudal end of the male was asymmetrically alate and bore 10 pairs of papillae and two phasmidal apertures (Robert *et al*., 2005). The elliptical eggs had embryos with the L1 larva still inside the pregnant female (Figure B). The female had blunt tail (Figure C). These are the morphological characteristics of Genus and Species of *Gongylonema* and *G. neoplasticum*, respectively.



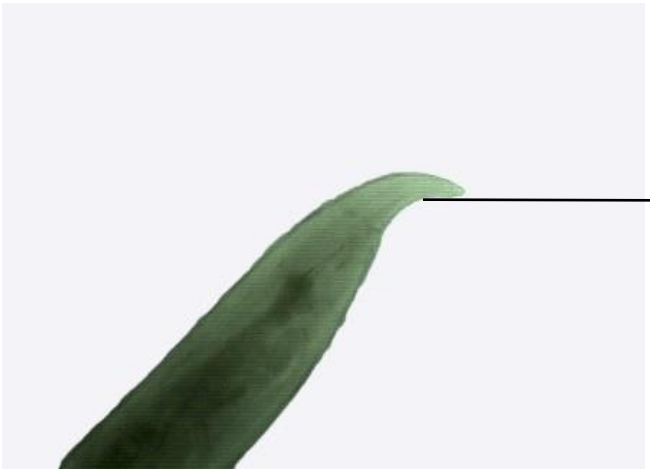
Anterior part of the parasite indicates the numerous cuticular humps also known as verruciforms (X4).

Figure : 7 (A)



Elliptical eggs (X10)

Figure : 7 (B)



Blunt tail.of the parasite (X4).

Figure : 7 (C)

Figure 7: Different body parts of *Gongylonema neoplasticum*,

4.1.6. Oriental rat flea (*Xenopsylla cheopis*)

Classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Siphonaptera

Family: Pulicidae

Genus: *Xenopsylla*

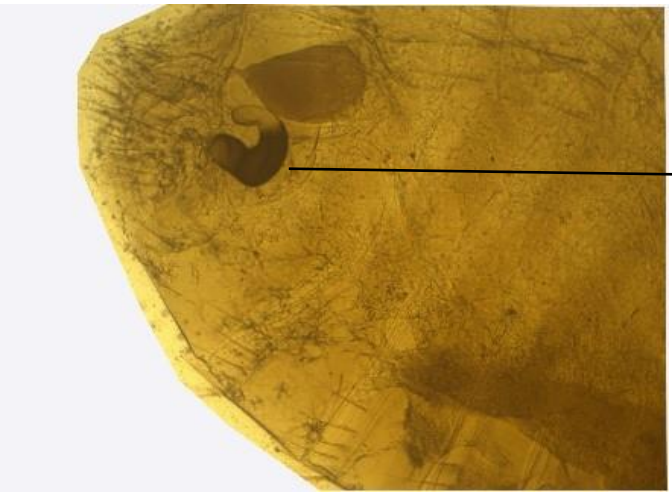
Species: *Xenopsylla cheopis*

Morphological features

Adult *Xenopsylla cheopis* are about 1.5 to 4mm in length and have a laterally compressed body. Like all fleas, *X. cheopis* adults are wingless. Adults vary from light brown to dark brown in order to camouflage themselves in the host's fur. Adult *Xenopsylla cheopis* lack both genal and pronotal ctendium (combs of bristles in the front and back). Males and females are sexually dimorphic. Females have dark-colored spermatheca that resemble small sacs, a distinguishing characteristic of this species. Males have complex genitalia that are easily distinguishable from the females (Brown, 1975; James and Harwood, 1969; Rothschild, *et al.*, 1970). The results of this study showed that chitinous exoskeleton, a three-part body (head, thorax and abdomen), three pairs of jointed legs, compound eyes and one pair of antennae (Figure A). Adult fleas grow to about 3 mm long, are usually brown, and have bodies that are "flattened" sideways or narrow, enabling them to move through their host's fur. This are the morphological character of Order Siphonaptera. They lack wings, but have strong claws preventing them from being dislodged, mouthparts adapted for piercing skin and sucking blood, and hind legs extremely well adapted for jumping that are matched with Family Pulicidae. The oriental rat flea has no genal or pronotal combs. This characteristic can be used to differentiate the oriental rat flea from the cat flea and dog flea (Figure A). Female flea possess spermathica for storing sperm (Figure B). Male *Xenopsylla cheopis* have clasper (Figure C).

Three segments of flea a. Head b. Thorax c. Abdomen (X4).

Figure: 8 (A)



Female *Xenopsylla cheopis* with spermatheca (X10).

Figure: 8 (B)

Male *Xenopsylla cheopis*, with clasper (X4).

Figure 8: Different body parts of *Xenopsylla cheopis*

4.2. Prevalence

4.2.1. Prevalence of parasites (endoparasite and ectoparasite) in rats of Bangladesh

The study was carried out in a total of 87 rats from different parts of Bangladesh, of which the number of infected rats with both helminthes and ectoparasites was 54 (62.08%) (Figure 9).

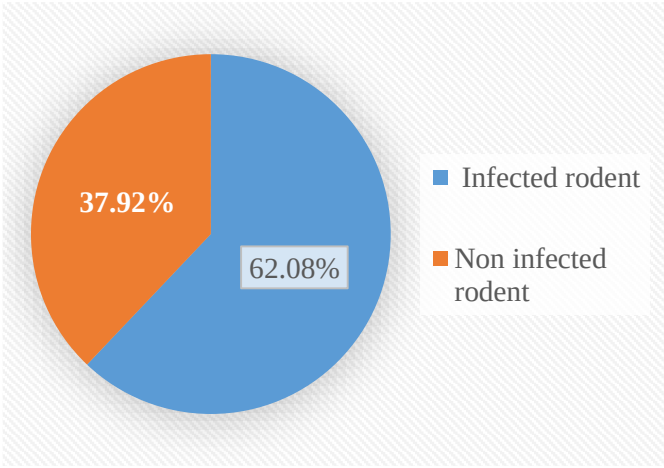


Figure 9: Overall prevalence of parasites in rats

4.2.2. Prevalence of endoparasite and ectoparasite associated with sex of rats

Among the collected 87 rats samples 58 were male and 29 were female. The number of male rats infected by endoparasites and ectoparasites was 37 (63.79%) and the number of infected female was only 17 (58.62%).

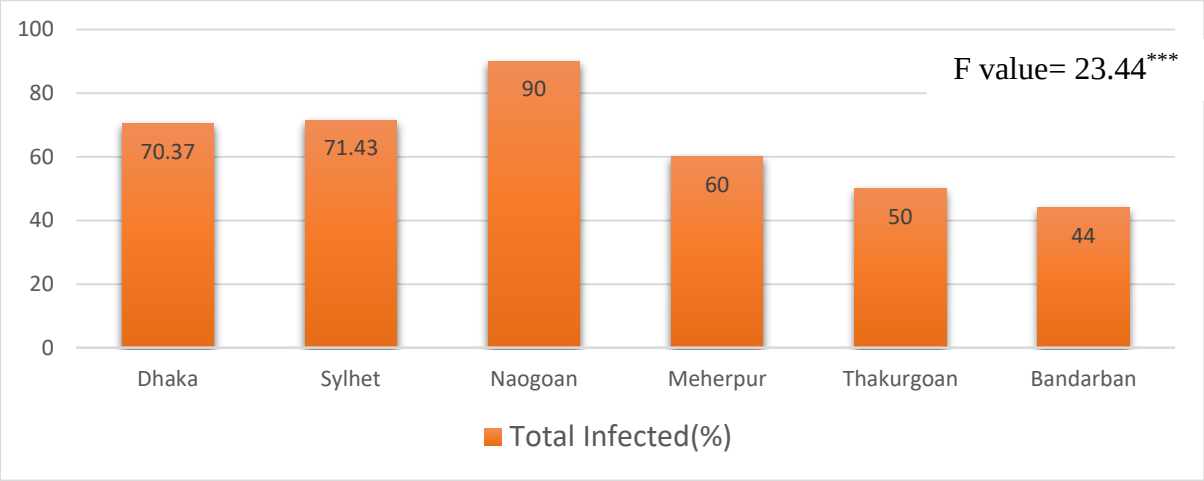
Table 1: Prevalence of infection based on sex rats

Parasite	Sex	No of rat examined	Mean of parasite (SD)	Mean difference
Ectoparasite	Female	29	0.43 (0.81)	-0.11^{ns}
	Male	58	0.54 (0.75)	
Endoparasite	Female	29	2.77 (5.34)	-0.37^{ns}
	Male	58	2.40 (4.67)	

ns = Non significant, SD= Standard deviation

4.2.3. Prevalence of parasites (endoparasites and ectoparasite) of rats in different parts of Bangladesh

The highest prevalence of parasites (endoparasites and ectoparasite) found of the examined rats in Naogaon were 90% followed by 71.43 % in Sylhet, 70.37% in Dhaka, 60% in Meherpur, 50% in Thakurgaon, 44% in the Bandarban. The prevalence of parasites in different locations of Bangladesh is significantly different (Figure 10).



*** Indicates 1% level of significance

Figure 10: Prevalence of parasites of rats in different parts of Bangladesh

4.2.4. Prevalence of endoparasite in different locations of Bangladesh

Among the collected rats, 60.34% male and 44.83% female were infected with single or multiple type of endoparasites. The highest number of infection was found in Naogaon 70% followed by 62.96% in Dhaka, 60% in Meherpur, 57.14% in Sylhet, 50% in Thakurgaon, 40% in Bandarban (Figure 11).

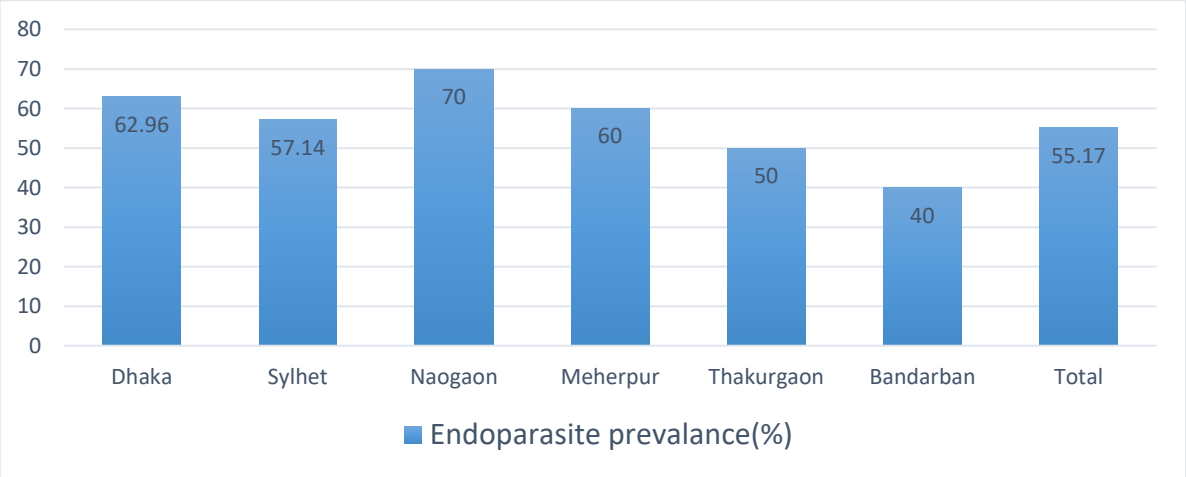


Figure 11: Prevalence of endoparasite from different locations of Bangladesh

4.2.5. Prevalence of ectoparasites in different location of Bangladesh

In this study, single ectoparasite species namely *Xenopsylla cheopis*, the oriental rat flea was found. Highest prevalence was found in Sylhet (42.86%) followed by (40%) in Naogaon, (30%) in Meherpur (29.63%) in Dhaka, (28%) in Bandarban and (25%) in Thakurgaon (Figure 12).

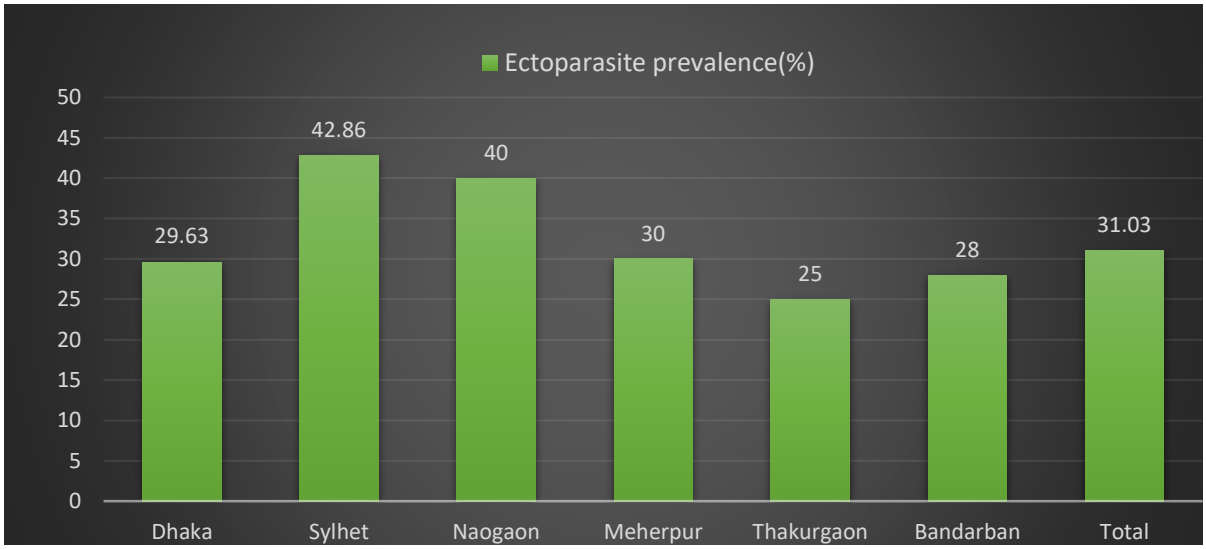


Figure 12: Prevalence of ectoparasite (*X. cheopis*) in different location of Bangladesh

4.2.6. Prevalence of parasites (endoparasite and ectoparasite) in different rat species in Bangladesh

The species *Bandicota bengalensis* (80%) had the highest infection followed by *Rattus norvrgicus* (79.17%), *R. rattus* (60%), *Mus musculus* (36.36%) (Figure 13).

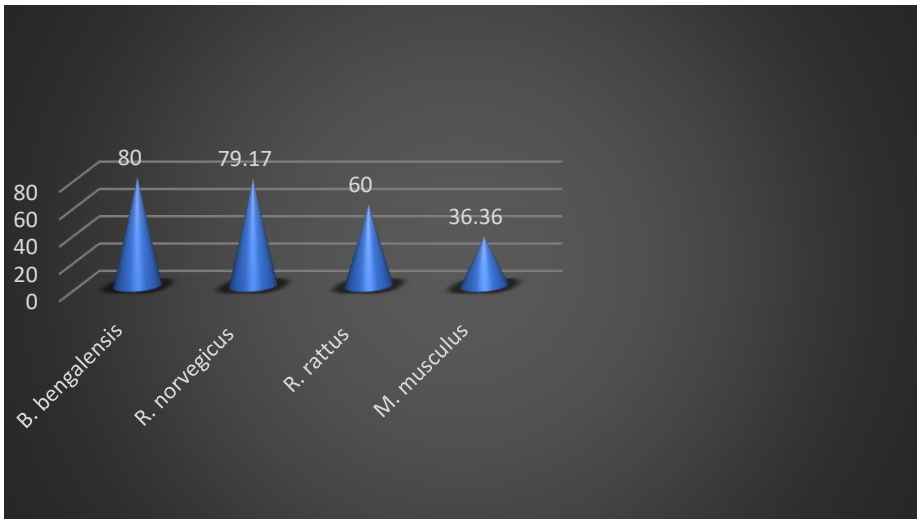


Figure 13: Prevalence of parasites in different rat species in Bangladesh

4.2.7. Prevalence of endoparasites in different rat species in Bangladesh

Among the collected rats, 55.17% rats were infected by single or multiple endoparasitic species. The rat species *Bandicota bengalensis* (72%) had the highest infection, followed by *Rattus norvrgicus* (70.83%), *R. rattus* (60%), *Mus musculus* (30.30%) (Figure 14).

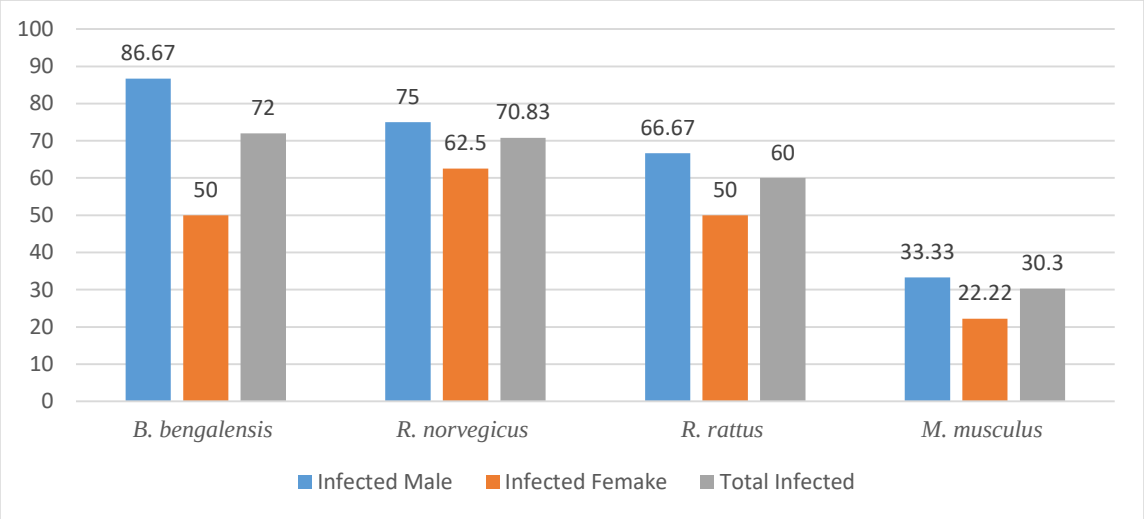


Figure 14: Prevalence of endoparasites in different rat species in Bangladesh

4.2.8. Prevalence of single and mixed infection in rats

Both male and female of rats examined were found to be infected with one or more species of endoparasites and ectoparasites. Thirty three out of 54 rats (61.11%) had mixed endoparasitic and ectoparasitic infection, and only 21 (38.89%) had single infection (Figure 15).

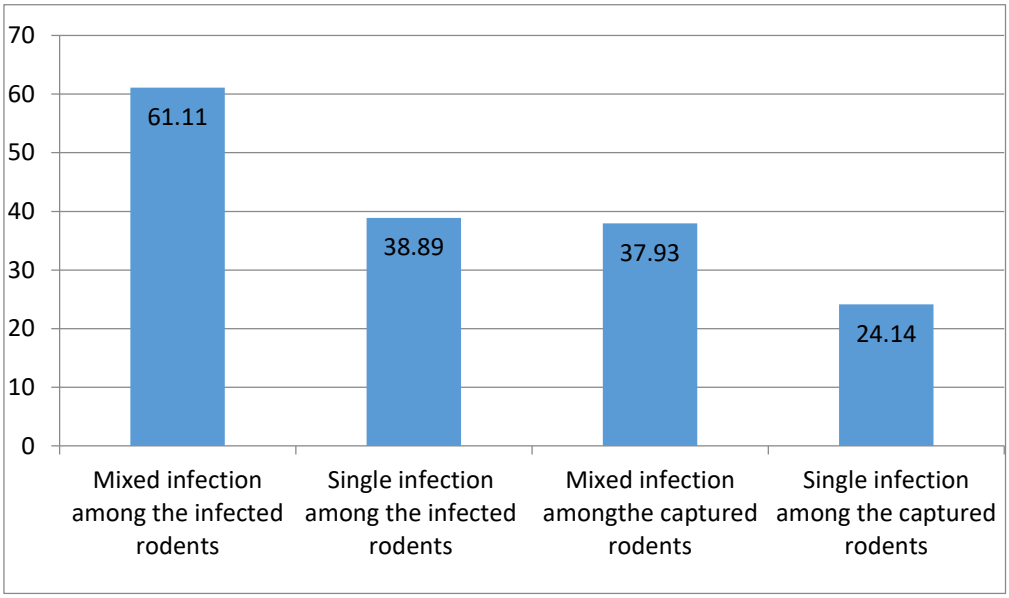


Figure 15: Prevalence of single and mixed infection in rats

4.2.9. Pattern of mixed and single type parasitic infection in different areas of Bangladesh

All of the infected rats collected from Bandarban had mixed infection with 2 to 3 zoonotic endoparasitic and ectoparasitic species followed by 57.89% in Dhaka, 40% in Sylhet, 33.33% in Naogaon, 50% in Meherpur, 50% in Thakurgaon (Figure 16).

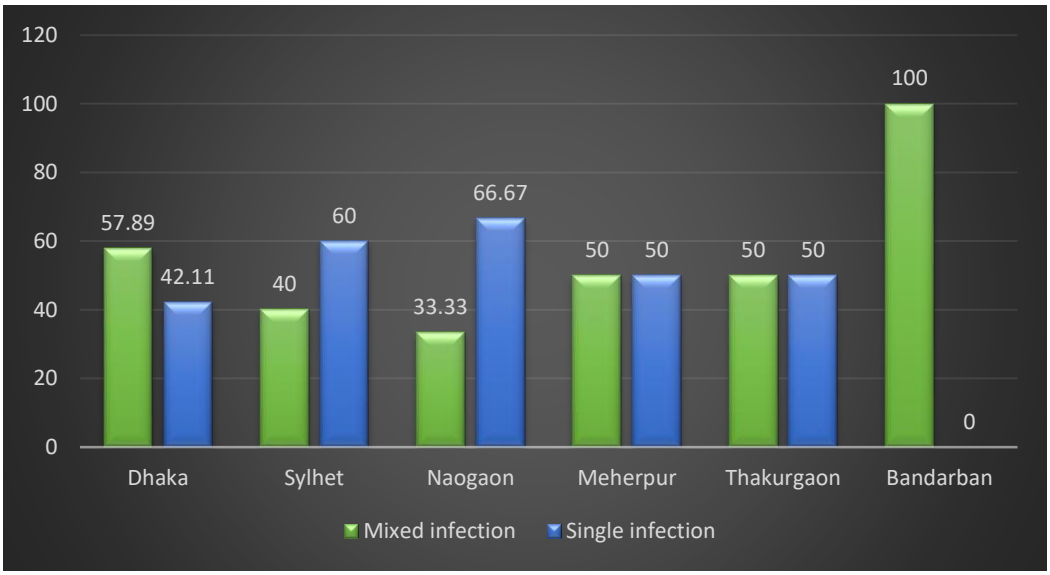


Figure 16: Pattern of mixed and single type parasitic infection in different areas of Bangladesh

4.2.10. Prevalence of different zoonotic endoparasites

All the recovered endoparasites except the species *Heterakis spumosa* has public health significance. The prevalence of *M. monliformis* was the highest (21.11%), followed by *G. neoplasticum* (17.77%), *T. taeniformis* (12.22%) and *H. diminuta* (10%).

Table 2: Prevalence of different zoonotic parasites

Area	*Moniliformis moniliformis* (%)	*Gongylonema neoplasticum* (%)	*Taenia taeniformis* (%)	*Hymenolepis diminuta* (%)
Dhaka	3.7	37.04	11.11	33.33
Sylhet	42.82	0	14.29	0
Naogaon	50	0	50	0
Meherpur	40	0	20	0
Thakurgaon	37.5	0	12.5	0
Bandarban	20	24	0	0
Total	**21.11**	**17.77**	**12.22**	**10**

4.2.11. Prevalence of parasites in rats collected from different nitches

The highest number of infected rats came from the houses in the slum areas, contributing to (75%), followed by local rent houses (72.22%), rice mill godwon (66.67%), stationary shops (62.50%), and paddy fields (33.33) and poultry shed (0%) .

Table 3: Prevalence of parasites in rats collected from different nitches

City structure	(%) of infected male rats	(%) of infected female rats	(%) of total infected rats
Houses of slum areas	76.92	71.42	75
Local rent houses	76.92	60	72.22
Rice mill godown	66.67	66.67	66.67
Stationary shops	66.67	50	62.50
Paddy fields	37.50	25	33.33
Poultry shed	0	0	0

DISCUSSION

In this present study, all 87 rats were trapped from different urban and rural areas of Dhaka, Sylhet, Naogaon, Meherpur, Thakurgaon and Bandarban Rats are semi-domesticated and omnivorous, and are very often seen in buildings, streets, sewage channels, crops fields, waste disposal sites, farms, slaughter houses and food storage of the different cities in Bangladesh. This study gives an overview on the intestinal helminth infection and ectoparasitic infection of rats in Bangladesh. Five species of helminth, namely, *Hymenolepis diminuta, Cysticercus fasciolaris* (larval form of *Taenia taeniaformis*), *Moniliformis. moniliformis, Heterakis spumosa* (non-zoonotic) and *Gongylonema neoplasticum* and the only ectoparasite species *Xenopsylla cheopis* were recovered.

The above parasites have also been previously reported sporadically in rats from different parts of Bangladesh (Huq, 1969; Shaha, 1974; Bhuiyan *et al*., 1996; Khanum *et al*., 2001; Alam *et al*., 2003; Khanum & Arefin, 2003; Khanum *et al.,* 2009; Muznebin *et al*., 2009 and Gofur *et* al., 2010). Furthermore, many authors reported similar parasites in different parts of India (; Coomansingh *et al*., 2009; Bashan *et al*., 2012; Priyanto *et al*., 2014) as well as the world (Seong *et al*., 1995; Wahed et al., 1999; Madi *et al*., 2001; Soliman *et al.*, 2001; Stojcevic *et al*., 2004; Waugh *et al*., 2006 Pakdel *et al*., 2013; and Porta *et al*., 2014). The existence of rats, reservoir hosts for different type of the zoonotic parasites, in close association to human activities may facilitate the transmission of zoonotic diseases (Sumangali *et al*., 2012, Amarasingh and Premathilake; 2014 and Guimarães *et al*., 2014).

Among the collected 87 rats samples 58 were male and 29 were female. The number of male rats infected by endoparasites and ectoparasites was 37 (63.79%) and the number of infected female was only 17 (58.62%). The present study reported that the prevalence of endoparasites in male and female was 60.34% and 44.83% respectively. Gofur *et al*., 2010, reported that prevalence of helminth parasites in male and female was 80% and 73.33%, respectively. Senussi (2016), showed that males had higher parasitic infection rate (24%) than females (20%) in *R. rattus*. Higher prevalence in male was also reported by other authors (Mafiana *et al*., 1997; Katranovski *et al*., 2010; Hindi *et al*., 2013 and Porta *et al*., 2014). More activity of male than female may be one of the crucial factors behind the higher infection in male. Besides, male have larger house territories which could increase their exposure to infection. Moreover, the male hormone, testosterone, has negative effects in the immune functions (Calhoum, 1962; Grossman, 1989 and Folstad and Karter, 1992) which may allow the male rats to become more

susceptible to parasitic infection. On the other hand, reproductive females show a stronger site specific organization leading to less exposure to infection.

The highest number of endoparasite found in Naogaon (70%) followed by Dhaka (62.96%), Meherpur (60%), Sylhet (57.14%), Thakurgaon (50%) and Bandarban (40%). The pivotal causes of highest infection in rats in Naogaon district might be due to the presence of huge numbers of rice mill godowns, soil made duplex house, low land paddy field that are inundated during the rainy season, pushing the rats towards house. These factors enhance rat density close to human habitat, and thereby play important role to spread infection to the human and non-infected rats.

In this study single ectoparasite species, *Xenopsylla cheopis*, the oriental rat flea was recorded. Highest number of infection was found in Sylhet (42.86%) followed by Naogaon (40%), Meherpur (30%), Dhaka (29.63%), Bandarban (28%) and Thakurgaon (25%). Previously, Phillips (1980) reported *X. cheopis* and *X. astia*, the two plague fleas, as highly prevalent in rats in many large towns in Sri Lanka, including Kandy. Hilly tract bushy area, high humidity, water logging condition, and heavy rainfall may be the causes of heavy infection in Sylhet.

The rat species, *Bandicota bengalensis* (80%) had the highest infection followed by *Rattus norvrgicus* (79.17%), *R. rattus* (60%), *Mus musculus* (36.36%) with both endoparasite and ectoparasite. 55.17% rats were found to be infected by single or multiple endoparasitic species. *Bandicota bengalensis* (72%) had the highest endoparasitic infection, followed by, *Rattus norvrgicus* (70.83%), *R. rattus* (60%), *Mus musculus* (30.30%). Bhuiyan *et al*. (1996), reported that 83.33% *B. bengalensis* and 82.08% *R. rattus* were found to be infected. Whereas, Gofur *et al*., (2010) reported that about 76.67% *R. norvegicus* were infected with helminth parasites in Bangladesh. High prevalence (58.5%) of endoparasitic infection was also recorded in black rat collected from Jhan Younis and Jabalia in Palestine (Hindi and Haddaf, 2013) and 40.5% from India (Singla *et al*., 2008). Commonly, *B. bengalensis* and *R. norvegicus* dig burrows with characteristics pile of earth around the entrance. The burrow system is extensive and elaborate. They live in the burrow with colony formation, grooming each other, shearing food. Thus the spread of infection among this species is higher than the *R. rattus* and *M. musculus*.

This study reveals that the highest number of infected rats were found from the houses in the slum areas (75%), followed by local rent houses (72.22%), rice mill godown (66.67%), stationary shops (62.50%), rice fields (33.33%) and permanent poultry shed (0%). The pronounced growth of urban slum settlements, most of which has occurred in tropical regions

of the world with poor resources in developing countries like Bangladesh. Over the past 50 years, the urban ecology has been transformed creating new habitats for rats. Lack of access to proper services and poor housing and sanitation in slum communities boost parasitic infection by rats (Glass *et al*. 1989, 2005; Childs *et al*. 1991; Ko *et al*. 1999). Slum communities are characterized by untended refuse, open sewers and overgrown vegetation, which promote rat infection. There is high possibility of transmission of parasites to human because of continuous contact with hosts. Due to availability of food stuff, low maintenance and lack of hygiene practices the presence of infected rats are very high in the rice mill godown and stationary shop. There could hardly find any house are free from rats. The study showed that *M. musculus, R. rattus* and *B. bengalensis* were highly available in local rent houses. In rice fields, availability of infected rats are slightly less than other selected areas due to lack of hosts. Interestingly none of the rats (n=11) in permanent poultry shed found to be infected with any parasites. The main cause behind this findings may be due to the facts that the rats take food from the supplied poultry feed, habituated within the shed and have zero connection with outer environment as well as other infected rats.

The most successful rats 70.12% being trapped by using the rat bait trap was in the Naogaon district followed by 64.28% in Dhaka city, 59.52% in Bandarban, 55.55% in Meherpur, 44.44% in Thakurgaon and 38.89% in Sylhet district. Available food stuffs in rice mill godowns of Naogaon district incrase prolificacy of rats.

This study reveals the significant number of zoonotic parasitic infections in rats throughout Bangladesh. These types of parasites affect not only human but also livestocks and crops. So, this devastating scenario should consider the local Govt. authorites to run comprehensive investigation. The human fecal samples should also be examined to understand the infection rate in human and the actual distribution these zoonotic parasites.

CHAPTER 5

SUMMARY AND CONCLUSION

Bangladesh is abundant with rats. This study may contribute to generate knowledge on the understanding of range and helminthic parasitism in peri-domestic rats from diverse regions of Bangladesh. This study was performed in the six selective region of the country aimed to find out the prevalence and morphological identification of zoonotic parasites of the four types of rats such as *B. bengalensis*, *R. rattus*, *R. norvegicus* and *M. musculus* are common in the country. The study was carried out in a total of 87 rats from different parts of Bangladesh, of which the number of infected rats with both helminthes and ectoparasites was 54 (62.08%). The highest prevalence of parasites (endoparasites and ectoparasite) found of the examined rats in Naogaon were 90% followed by 71.43 % in Sylhet, 70.37% in Dhaka, 60% in Meherpur, 50% in Thakurgaon, 44% in the Bandarban. All the recovered endoparasites except the species *Heterakis spumosa* has public health significance. The prevalence of *M. monliformis* was the highest (21.11%), followed by *G. neoplasticum* (17.77%), *T. taeniformis* (12.22%) and *H. diminuta* (10%). Considering the infestation of sampled rats with various zoonotic parasites, it is strongly recommended to take measures in order to control rodent populations in the mentioned regions of current study and make local people aware of the risk of disease transmission to humans through rodents. Sampling area of this study is only six selective region of Bangladesh. A comprehensive study plan should be implemented throughout Bangladesh to know the real scenario of the prevalence of rat-borne zoonotic parasites. Studies focused on determining the prevalence of helminths infestation, risk factors for the parasitism, and the geographic distribution of helminths in shrews are needed to understand the helminth burden and guide effective prevention and control measures. Therefore, polymerase chain reaction-based molecular diagnosis and advanced scientific investigations are imperative to understand the helminth diversity and discovery of new helminth species transmission cycles and zoonotic potentials. The information presented here improves our understanding of the major parasitic infections that rats harbor and can transmit to human and animal populations in Bangladesh. In order to avoid unpleasant situations adequate preparations of rat control should be implemented throughout Bangladesh.

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