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Prevalence and Zoonotic Potential of Parasites in Wild Rats in Jeddah City, Saudi Arabia

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ABSTRACT

Rats have been identified as carriers of various zoonotic parasites and pathogens that can pose a serious threat to human health. This research aimed to identify species of zoonotic parasites and their prevalence in wild rats in Jeddah province, Saudi Arabia. For this purpose, 405 wild rats were collected, including two species of rats: *Rattus norvegicus* (94%) and *Rattus rattus* (6%), from different regions of the city of Jeddah. Ectoparasites were picked, and the gastrointestinal tract, internal organs, and gut contents were examined. The internal parasites were recovered and examined by stereo and light microscope. An examination of the liver was carried out to determine the presence of parasite cysts. The flotation technique was used to examine the fecal samples. Also, stained blood samples were examined with an optical microscope with 100x magnification for blood parasites. The results revealed that the overall prevalence of parasite infestation was 51%, and it was higher in *Rattus norvegicus* (52.2%) than in *Rattus rattus* (37.5%). Eleven species of parasites were recovered: three ectoparasites (*Xenopsylla cheopis, Ctenocephalides felis* and *Ornithonyssus bacoti*) and seven endoparasites (*Cysticercus fasciolaris, Hymenolepis nana, Hymenolepis diminuta, Syphacia muris, Syphacia obvelata, Ascaris lumbercoides,* and *Entamoeba histolytica* cyst) and one parasite in the blood (*Trypanosoma spp*.) The dominant ectoparasite was *Xenopsylla cheopis* while that of endoparasite was *Cysticercus fasciolaris.*

Key words: Rats, Zoonotic, Ectoparasites, Endoparasites, Jeddah, Saudi Arabia.

INTRODUCTION

There are more than 1700 species of rodents worldwide, but only 5-10% are major pest species. Rats are one of the most successful groups of rodents, having evolved to thrive in a wide range of habitats. However, they can also be problematic as agricultural and urban pests, causing significant economic losses (Premaalatha et al. 2017). Due to their commensal relationship with humans, rodents often flourish in areas of high human density, including cities, suburbs, and agricultural regions, where they can find abundant food and shelter (Coomansingh et al. 2019; Herawati and Sudarmaji 2021). The consumption of uncooked or improperly cooked food contaminated with infective larvae, eggs, or metacercariae is the primary source of human infestation with helminth parasites (CDC 2020; Peter 2020). Rodents can contaminate food with their feces or urine while pilfering human food, which can lead to the transmission of zoonotic helminths from rodents to humans (Islam et al. 2020; Abdullah 2023; Štrbac et al. 2023). In some parts of the world, there has been an increasing number of recorded cases of parasitic zoonoses (WHO 2019). In Saudi Arabia, 15 rodent species were reported and three species; *Rattus rattus, Mus musculus,* and *Rattus norvegicus* were the most widely distributed species (Buttiker and Harrison 1982). Because of the highly adaptable and unpredictable nature of rats, they act as reservoir hosts and transmit a wide range of diseases and can serve as definitive and/or intermediate hosts for a variety of parasites that are frequently found in both domestic animals and humans (Huq et al. 1985; Stenseth et al. 2003; Chuluun et al. 2005; Dursahinhan et al. 2023). Various zoonotic parasites, including *Hymenolepis nana*, *Hymenolepis diminuta*, *Taenia taeniformis*, and *Capillaria hepatica*, have been identified in studies conducted by Ito and Itagaki (2003), Tung et al. (2013), Sithay et al. (2020), Tijjani et al. (2020), and Mohd-Qawiem et. al. (2022).

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Additionally, rat fleas can transmit diseases such as *Yersinia pestis*, *Salmonellosis*, *Tularemia*, and *Bartonella*, as confirmed by studies conducted by Kia et al. (2009), Tay et al. (2014), and Farid et al. (2021). This study aimed to identify the parasite species and their prevalence in wild rats in Jeddah, Saudi Arabia, and highlights the potential public health risks associated with these parasites.

MATERIALS AND METHODS

Study Area

Jeddah is the second largest Saudi city (~550 km²) (Kholedi et al. 2012), located on the western coastal plain on the Red Sea of Saudi Arabia, between latitude 20˚ 50` 29", 22˚20`44" N and longitude 38˚48`59", 39˚18`13"E (Fig. 1). Jeddah Governorate consists of 19 main municipalities divided into three sectors: the northern, southern, and central. Jeddah occurs under a warm, arid climate, with temperate winters and hot, humid summers, with irregular rainfall during the rainy months from November to May, with an annual average of about 52.5 mm/year (Al-Dubai et al. 2017; Abdullah et al. 2019). The average relative humidity is ~85% from September to October and ~34% from April to June (Abdullah et al. 2019).

Trapping and Identification of Rats

The rats were trapped using food-baited traps in cooperation and participation with pests control companies. The traps containing live rats were taken to the Parasitology and Microbiology Department of the Public Health Pests Laboratory. Captured rats were euthanized by using carbon dioxide, weight and length (length of body with and without the tail) were measured and samples were taken by an experienced veterinarian (Klangthong et al. 2015). The morphological characteristics of all rats and their sex were registered, and keys developed by Chen (1986) and Wilson and Reeder (2005) were used to identify the rats.

Sampling

Ectoparasites

To collect ectoparasites, the hairs of euthanized rats were brushed, and the parasites were stored in 70% ethanol until they could be identified. Identification of the specimens was carried out using light and dissecting microscope, following the method described by Baker (1999).

Endoparasites

The rats were dissected and subjected to standard postmortem examination (Fiette and Slaoui 2011). The internal organs and the gut contents (small and large intestine and cecum) were examined visually, followed by the stereo and light microscope examination for recovering internal parasites. The examination of the liver was carried out to determine the presence of parasite cysts (Stojčević et al. 2004; Sumangali et al. 2012). The parasites retrieved from the gut and liver were identified by using taxonomic keys, as described by Jones et al. (1994) and Eslami (1997).

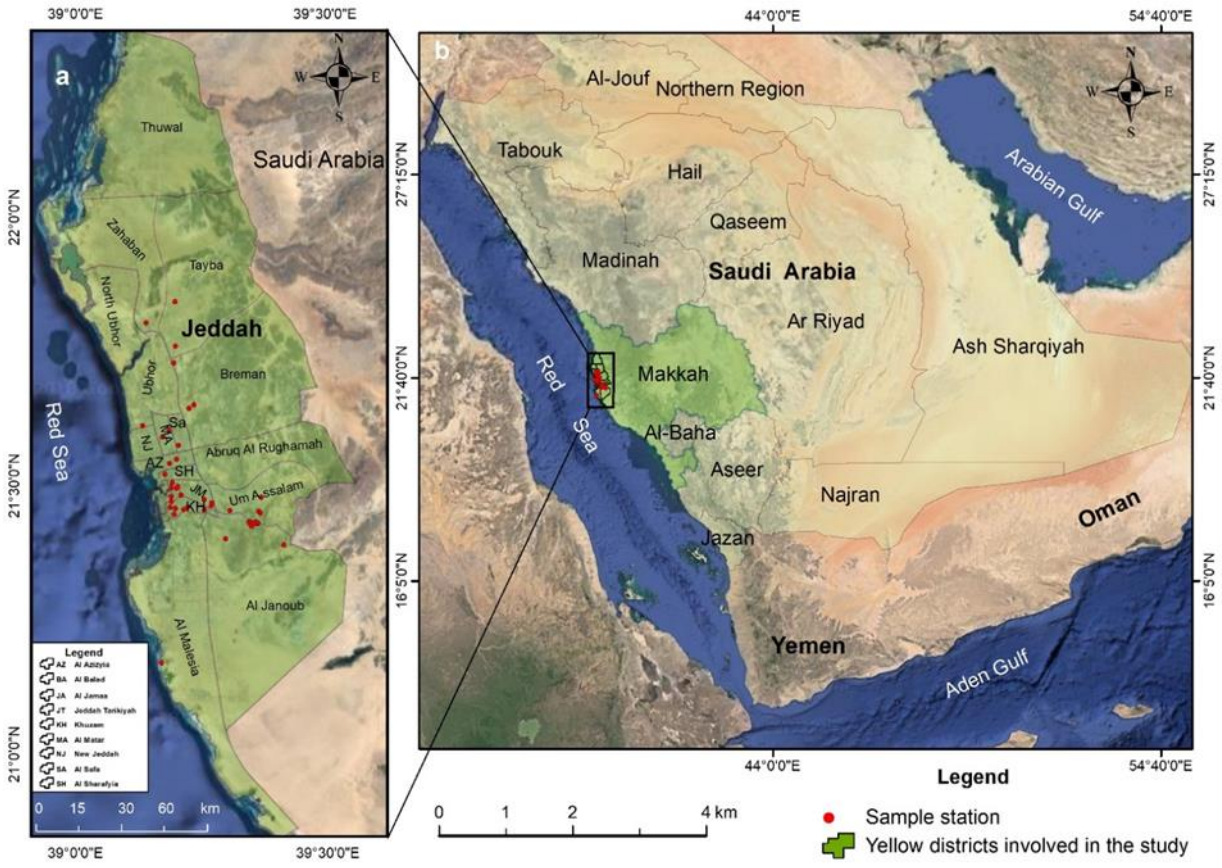

Fig. 1: Maps of sampling area in Jeddah Governorate, Saudi Arabia.

Fecal samples were collected from the distal colon of each rat and examined for helminth eggs and protozoal cysts using the flotation technique (Dryden et al. 2005). The eggs and cysts were identified according to morphological characteristics (Sirois 2014).

Blood Samples

Using a needle and syringe, blood was drawn from the heart and collected in EDTA tubes. A thin blood smear was prepared then fixed with methanol and stained with Giemsa. The smears were examined with an optical microscope with 100x magnification (Hoare 1972).

Statistical Analysis

The proportion of infested and non-infested animals was summarized using descriptive statistics, specifically prevalence, and percentages. Chi-square analysis was utilized to investigate the relationship between variables, with statistical significance defined as $P<0.05$.

RESULTS

Two types of rats were collected: *Rattus norvegicus* (94%) and *Rattus rattus* (6%) with a total number of 405. The average weight was 310g, and females were more represented (54%) than males (46%) (Table 1).

The total prevalence of parasite infestation was 51% and it was higher in *Rattus norvegicus* (52.2%) than in *Rattus rattus* (37.5%). The prevalence in *Rattus norvegicus* males was higher than in females, while in *Rattus rattus*, the reverse results were noticed. No significant difference was observed in the prevalence of parasite infestation either between the two species of rats or between sexes in the same species ($P >0.05$) (Table 2).

We noticed from the infested rats that 118 rats carried one type of parasite, 89 carried from 2-4 types of parasites and one female *Rattus norvegicus* carried 5 types of parasites (Table 3).

The types of parasites recovered were identified as ectoparasites (three types): *Xenopsylla cheopis* (Rat flea), *Ornithonyssus bacoti* (Rat mite), and *Ctenocephalides felis* (Cat flea). Moreover, the endoparasites that recovered either by post-mortem (gross) or fecal examination (seven types) were: *C. fasciolaris*, *H. nana* worm/egg, *H. diminuta* worm/egg, *Syphacia spp.* Worm /egg (*Syphacia muris* egg and *Syphacia obvelata* egg), *A. lumbercoides* egg, and *E. histolytica* cyst (Table 4) (Fig. 2-4). *Xenopsylla cheopis* was found to be the most prevalent ectoparasite, with a total prevalence of 11.8%. On the other hand, *C. fasciolaris* was the most prevalent endoparasite with a total prevalence of 18.5%. Only one blood parasite was recorded, *Trypanosoma spp.*, and its prevalence in *Rattus norvegicus* was higher (9.6%) than in *Rattus rattus* (0.25%) (Fig. 5).

In some grossly detected worms, the prevalence of *H. nana* and *Syphacia spp.* worms was lower than that of their eggs, detected by fecal examination, while in the case of *H. diminuta*, the result was the opposite. In the case of *A. lumbercoides*, we did not detect the worm, but the eggs were observed. No statistically significant difference was observed in the prevalence of different parasite types of infestation between the two species of rats ($P>0.05$) except ($P<0.05$) in the case of infestation by *C. fasciolaris* ($X^2=5.798$, df=1, P=0.016) and *H. nana* egg ($X^2=5.326$, df=1, P=0.021).

DISCUSSION

The overall parasites prevalence in collected rats reported in this study (51.3%) was higher than that reported by Gholipoury et al. (2016) (38.5%) and lower than that detected by Stojčević et al. (2004) (72.6%) and Sumangali et al. (2012) (66.7%). This might be explained by the difference in geographical situations, climates, seasons, rat age, and gender (Archer et al. 2017).

Table 1: Characteristics of rat species

Types of rat	Total No. (%)	Length /cm	Weight/gm	Male No. (%)	Female No. (%)
Rattus norvegicus	381 (94)	17.6/38.7	316	179 (47)	202 (53)
Rattus rattus	24 (6)	17/36.2	205	7 (29)	17 (71)
Total	405	17.5/38.5	310	186 (46)	219 (54)

Table 2: Prevalence of parasites in rats

	Prevalence %						
	Rattus norvegicus			*Rattus rattus*			Total
	♂	♀	Total	♂	♀	Total	
Number of examined	179	202	381	7	17	24	405
Number of infested	99(55.3%)	100(49.5%)	199(52.2%)	1(14.2%)	8(47%)	9(37.5%)	208(51.3%)
P value			0.257			0.131	0.161

Table 3: Rats according to the number of parasitic infestations

Number of parasites type/rat	*Rattus norvegicus*			*Rattus rattus*			Total
	♂	♀	Total	♂	♀	Total	
1	54	58	112	1	5	6	118
2	31	29	60	0	3	3	63
3	9	10	19	0	0	0	19
4	5	2	7	0	0	0	7
5	0	1	1	0	0	0	1
Total	99	100	199	1	8	9	208

Three types of ectoparasites were detected; The prevailing type was rat flea (*Xenopsylla cheopis*) (11.8%) and the lowest was cat flea *(Ctenocephalides felis*) (0.25 %). The infestation with the rat mite (*Ornithonyssus bacoti)* was 2.25% and no ticks or lice were discovered. This finding agrees with the findings of Kia et al. (2009), Solanki et al. (2013), Harrison et al. (2015) and Rehman et al. (2022) where fleas were predominant among the ectoparasites. However, the results did not agree with the studies of Hasson and Al-Zobaidi (2011), Asiry and Fetoh

Table 4: Prevalence and parasite types in rats

	Type of Parasite	Prevalence %						Total	P value
		Rattus norvegicus			*Rattus rattus*				
		♂	♀	Total	♂	♀	Total		
ECTO*	*Xenopsylla cheopis*	23(5.6)	22(5.4)	45(11)	1(0.25)	2(0.5)	3(0.75)	48(11.8)	0.919
	Ctenocephalides felis	1(0.25)	0	1(0.25)	0	0	0	1(0.25)	0.801
	Ornithonyssus bacoti	2(0.5)	6(1.5)	8(2)	0	1(0.25)	1(0.25)	9(2.25)	0.505
ENDO*	A-GIT:								
	H. nana worm	2(0.5)	2(0.5)	4(1)	0	0	0	4 (1.0)	0.613
	H. diminuta worm	0	3(0.75)	3(0.75)	0	0	0	3(0.75)	0.662
	Syphacia spp. Worm	15(3.7)	6(1.5)	21(5.2)	0	1(0.25)	1(0.25)	22(5.4)	0.777
	B-Liver:								
	C. fasciolaris	30(7.4)	45(11.1)	75(18.5)	0	0	0	75(18.5)	0.016
	C-Fecal examination:								
	S. muris egg	17(4.2)	11(2.7)	28(6.9)	0	1(0.25)	1(0.25)	29 (7.1)	0.557
	S. obvelata egg	23(5.6)	15(3.7)	38(9.3)	0	2(0.5)	2(0.5)	40 (9.8)	0.793
	H. nana egg	3(0.75)	3(0.75)	6(1.5)	0	2(0.5)	2(0.5)	8 (2.0)	0.021
	H. diminuta egg	0	1(0.25)	1(0.25)	0	0	0	1(0.25)	0.801
	E. histolytica cyst	22(5.4)	14(3.4)	36(8.8)	0	0	0	36(8.8)	0.114
	lumbercoides egg	3(0.75)	8(1.9)	11(2.7)	0	1(0.25)	1(0.25)	12 (2.9)	0.719
BL.*	*Trypanosoma spp.*	30(7.4)	9(2.2)	39(9.6)	0	1(0.25)	1(0.25)	40 (9.8)	0.333

Values in parenthesis indicate percentage. *ECTO =Ectoparasites *ENDO=Endoparasites *BL.=Blood parasites

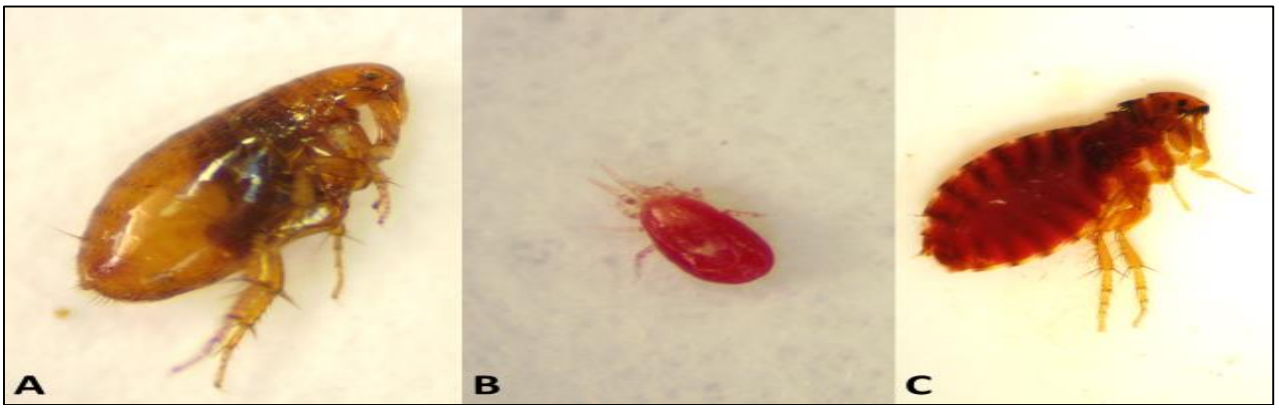

Fig. 2: Ectoparasites of rats (by stereo microscope): A- *Xenopsylla cheopis*, B- *Ornithonyssus bacoti*, *C- Ctenocephalides felis.*

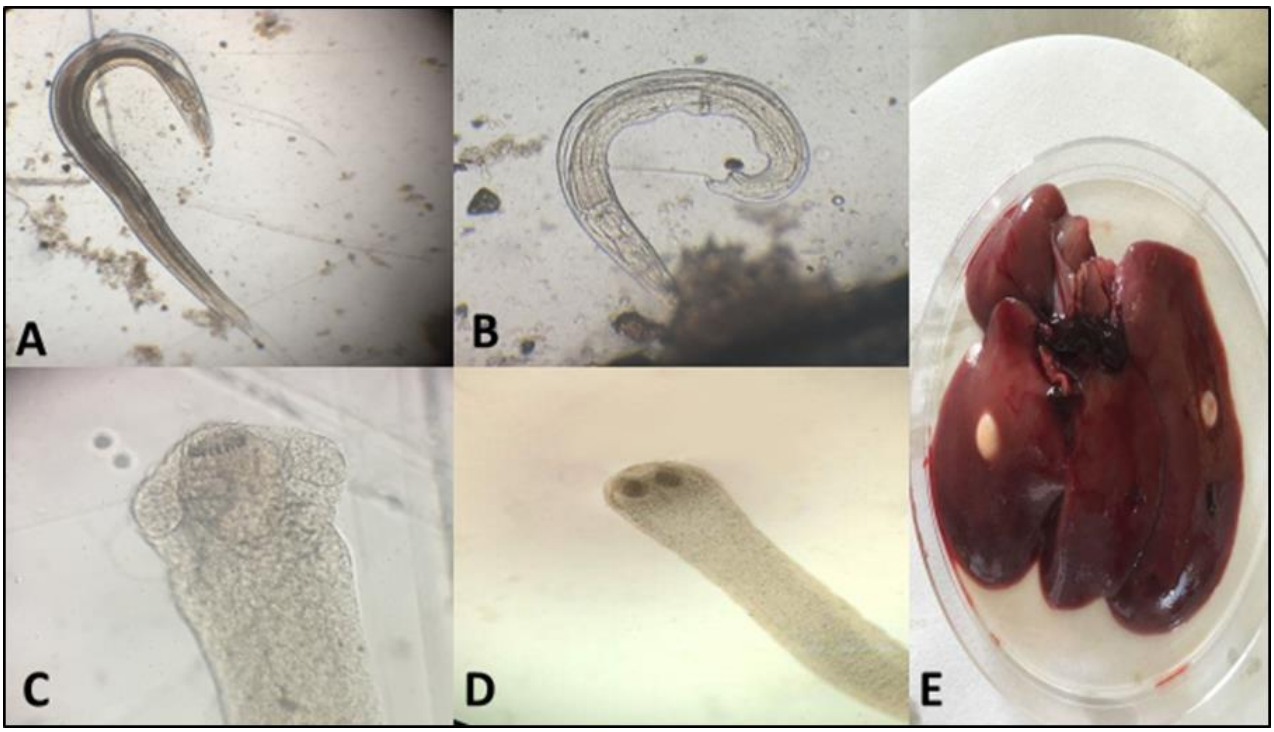

Fig. 3: Endoparasites of rats: A- *Syphacia spp.* Female, B- *Syphacia spp.* Male, C-*H. nana*, D- *H. diminuta*, E- *C. Fasciolaris.*

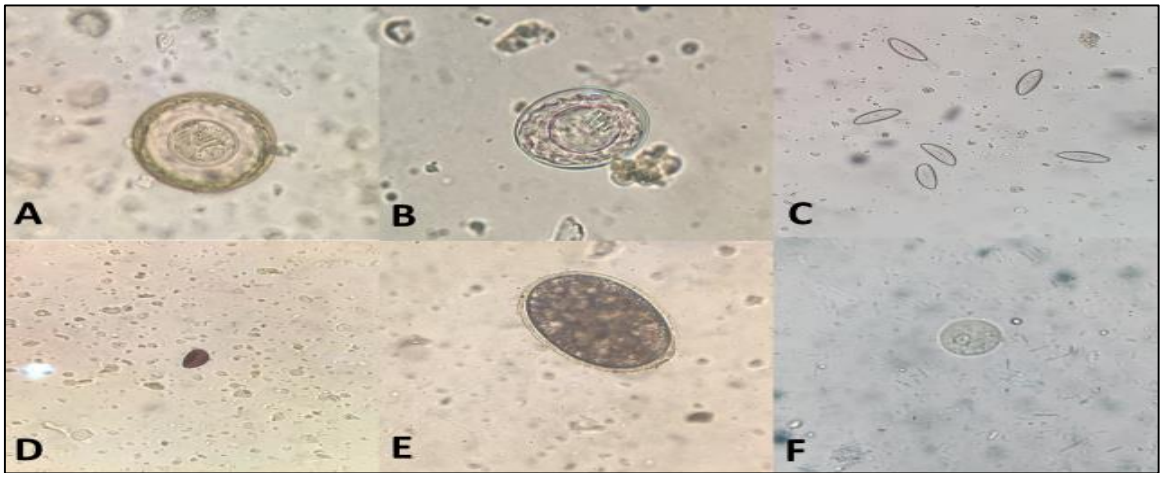

Fig. 4: Eggs and cysts in rat feces: A- *H. diminuta* egg, B- *H. nana* egg, C- *S. obvelata* egg, D- *S. muris* egg, E- *A. lumbercoides* egg, F- *E. histolytica* cyst.

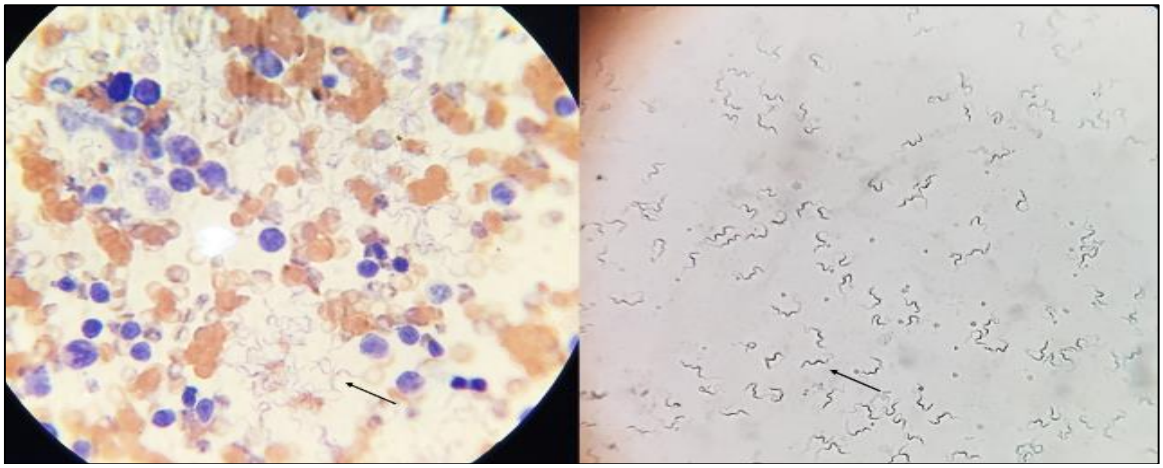

Fig. 5: Blood parasites of rats: *Trypanosoma spp.*

(2014), Hamidi et al. (2015), Moravvej et al. (2015), Premaalatha et al. (2017) and Sharma et al. (2018) where fleas represent the lowest prevalence among the other ectoparasites (tick, mite, and lice).

The changes in ectoparasites existence may be due to season, host age, size of a rat,variations in climate, and location of capture (Kia et al. 2009). The species of rat did not have any significant effect on the prevalence of ectoparasites infestation and this agrees with Solonki et al. (2013) and Asiry and Fetoh (2014).

The potential risk of discovered ectoparasites in this study can be illustrated by the fact that *O. bacoti*, commonly known as the rat mite, is capable of parasitizing both wild and domestic rats, as well as biting humans as an accidental host. This species has been identified as a minor vector for the transmission of several diseases of public health significance including, *Coxiella burnetii* (Q-fever), *Rickettsia typhi* (murine typhus), *Rickettsia akari* (human rickettsial pox), *Francisella tularensis, Francisella pestis*, and *Trypanosoma cruzi* (Chaga's disease). In addition, the mite bites cause severe dermatitis (Baker 1999; Moro et al. 2005; Baumstark et al. 2007; Salinas-Estrella et al. 2023).

While the rat flea (*Xenopsylla cheopis*) is recognized as a vector for *Yersinia pestis*, the bacterium responsible for causing the plague, it is generally believed that the disease has been eradicated (Kia et al. 2009). In addition, fleas are known to transmit several diseases as vectors, including *Tularemia*, *Salmonellosis*, *Bartonella*, and Murine Typhus, and also serve as intermediate hosts for certain species of tapeworms (*H. diminuta and H. nana*) that can infect humans. Tay et al. (2014) and Klangthong et al. (2015) confirmed the zoonotic importance of fleas by detecting *Bartonella* DNA in *X. cheopis* fleas collected from rats. Similarly, Tay et al. (2014) found that *Ctenocephalides felis* has been associated with the natural maintenance of several species of *Bartonella* bacteria.

Endoparasites (worm and/or egg or cyst) detected in our study are categorized as cestodes (*C. fasciolaris, H. nana*, and *H. diminuta*) and nematodes (*A. lumbercoides, S. muris* and *S. obvelata*) and protozoa (*E. histolytica* cyst). The main cestode discovered is *C. fasciolaris* followed by *H. nana* and *H. diminuta* which agree with the studies of Singla et al. (2008), Sumangali et al. (2012), Tung et al. (2013) and disagree with Shafiyyah et al. (2012), Meshkekar et al. (2014), Rahdar et al. (2016) and Iliev et al. (2017) where *H. nana* was the dominant cestode than *C. fasciolaris*. All 3 types of cestodes are zoonotic but *C. fasciolaris* (larval stage of the cat cestode *Taenia taeniaeformis*) has rare human cases (Deplazes et al. 2019). Both *H. nana* and *H. diminuta* can infect humans, and in cases of serious infection, they can cause

symptoms such as diarrhea and abdominal pain (Abdel-Hafez 1987; Imam et al. 2015; Ismail et al. 2018; Rabiee et al. 2018; Kandi 2019; Shahnazi et al. 2019). An increase in temperature and poor sanitation conditions in an environment can increase the probability of transmission of these zoonotic parasites to humans (Paramasvaran et al. 2009).

In our study, we detected 3 types of nematodes; *S. muris* and *S. obvelata* worm and/or egg, and *A. lumbercoides* egg, and the most predominant nematode was *S. obvelata*. This finding is compatible with Kia et al. (2010), Pakdel et al. (2013), Arzamani et al. (2017) and Iliev et al. (2017) and not compatible with Kataranovski et al. (2010) and Gaherwal et al. (2011) where *S. muris* was the predominant. It has been reported that *Syphacia obvelata* can infect humans, and the transmission of this zoonotic infection occurs through food contamination by rat feces (Riley 1919). *Syphacia spp.* also has a direct life cycle, and the eggs of these tapeworms can become infective in as little as 6 hours after being deposited (Kellogg and Wagner 1982).

Eggs of *A. lumbricoides* were detected in both rat species and different stages (un-embryonated, embryonated, corticated, and decorticated). Accidentally, *Ascaris spp.* eggs may be found in rat feces, this does not indicate true infection but indicates coprophagy, so it is called 'pseudoparasite' meaning that these rats ingest Ascaris eggs from infected human feces which then passage through the rat's alimentary tract and distributed via defecation. The rat may therefore play an unrecognized role in the transmission of Ascariasis (Stojčević et al. 2004; Belmain 2006; Archer 2017) and this can explain why the Ascaris worm not recovered in our finding.

The presence of *E. histolytica*, reported in this study was also documented among rats by Shafiyyah (2012), Lau et al. (2014), Rahdar et al. (2016), Seifollahi et al. (2016) and Nayyef (2017).

E. histolytica has zoonotic importance and can be transmitted to man from several types of animals, including rats (Levine 1985; Dhaliwal and Juyal 2013). According to Neal (1951), naturally infected rats with *E. histolytica* were found in a localized area where cases of human amoebiasis were also discovered. This suggests that the infection in rats may have originated from humans and highlights the potential role of rats as reservoir hosts for this zoonotic parasite.

The prevalence of *Trypanosoma spp.* detected in our report was lower than that reported by Laha et al. (1997), Linardi (2002), and Seifollahi et al. (2016) but higher than those reported by Shafiyyah (2012) and Archer et al. (2017). Rat species are primarily infected with *Trypanosoma lewisi*, a parasite that normally infects rats and is transmitted by fleas. Rats can become infected through ingestion of flea feces or the fleas themselves, which is the principal mode of transmission. *Trypanosoma lewisi* is an animal species that typically does not cause disease in humans and is considered nonpathogenic. However, in certain circumstances, such as in the presence of specific environmental, host, and organism-related factors, it can potentially acquire virulence and emerge as a human pathogen causing serious illness (Shafiyyah et al. 2012). There have been nine reported cases of *T. lewisi* infection in humans worldwide, including in Malaysia, India, Gambia, and Thailand. The affected patients were often immunologically weak infants who lived in poor hygiene conditions and had close contact with contaminated rats in and around their homes (Truc et al. 2013; Cassan et al. 2018).

Conclusion

Our study provided clear evidence that wild rats in Jeddah province harbor zoonotic parasites, which can be transmitted to humans. In light of these findings, it is strongly recommended that measures be taken to control rat populations and increase awareness among the local community about the risks of diseases transmitted through rats.

Authors' Contributions

ES did the conceptualization, performed the methodology, and wrote the original draft. NMA and FA did the conceptualization and supervised the data. AA collected the field samples and performed the methodology. SME and TAM prepared the figures and tables and reviewed the manuscript. EOA did the conceptualization and reviewed and commented on all the drafts. All authors contributed to the article and approved the submitted version.

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Conflict of Interest

There is no conflict of interest related to this research.

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