Original Research Article

Prevalence of gastro-intestinal parasites with zoonotic potential in rodents trapped from the Ngorongoro district, Arusha, Tanzania

ABSTRACT

Background: Rodents are prominent reservoirs for several pathogens that cause significant human infections, including parasitic zoonoses responsible for over 60% of human infectious diseases globally. This condition is exacerbated by climate and ecosystem changes, which facilitate the spread of rodents, ectoparasites and carried pathogens. This study aimed to determine the prevalence of zoonotic gastrointestinal parasites present in rodents of the Ngorongoro district, Tanzania, addressing an information gap at the human-wildlife interface.

Methods:A cross-sectional study was conducted in January to March 2022. A total of 606 rodents were live-trapped from indoor, crop fields, and peri-domestic areas, humanely euthanized by using Isoflurane, and examined for helminths and protozoa using simple flotation and formalin ethyl acetate concentration techniques (FECT).

Results: Nine gastrointestinal parasites were identified, with *Trichuris* spp. being the most prevalent helminth (12.7%), followed by *Hymenolepis nana* (11.5%), *Hymenolepisdiminuta* (11.2%), *Capillaria* spp. (6.3%), *Strongyloides*spp. (6.1%), and *Physaloptera* spp. (5.4%). Among protozoa, *Entamoeba* spp. had the highest prevalence (15.5%), followed by *Giardia* spp. (6.8%) and *Cryptosporidium* spp. (2.5%). Overall, 46.9% of the rodents were infected with at least one type of gastrointestinal parasite. The study found no significant influence of sex, age, or habitat on the prevalence of gastrointestinal parasites. However, *Mastomys*sp and *Rattus*sp exhibited significantly higher parasite prevalence compared to *Mus*spp (p=0.040 and p=0.022, respectively). Additionally, Sale village had a notably higher prevalence compared to Orgosorok (p=0.00), Engarasero (p=0.022), and Malambo (p=0.002).

Conclusion: The occurrence of zoonotic parasites highlights the potential for rodent-borne diseases transmission to humans and domestic animals, necessitating enhanced public health awareness and rodent control measures.

Keywords: rodents, gastrointestinal parasites, zoonoses, Ngorongoro district, Tanzania.

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INTRODUCTION

Zoonotic diseases represent a significant proportion of infectious diseases impacting humans globally, with wildlife reservoirs, particularly rodents, posing substantial public health risks [1,2]. Rodents, encompassing over 1,700 species across the *Muridae*, *Microtidae*, and *Sigmodontidae* families, are widespread across diverse global regions [3]. Rodent species such as *Lophuromys* spp. and *Rattus* spp. are notably significant as reservoirs for a range of zoonotic infections [4]. Rodent-borne zoonoses include a diverse array of diseases caused by viruses [5], bacteria [6], helminths [7], and protozoa [8], collectively affecting millions of individuals worldwide and resulting in severe health consequences.

The global rise in gastrointestinal parasitic zoonoses is largely attributed to factors such as mass migration, habitat alterations, and increased interactions at the human-wildlife interface, driven by both natural and anthropogenic influences [9]. Parasitic zoonotic agents like Toxoplasma gondii, Cryptosporidium spp., and Leishmania spp. have become significant threats to human health, especially in immunocompromised individuals [10]. Protozoa are particularly notable for causing emerging infections, although cestodes, trematodes, nematodes, and pentastomids also contribute to zoonotic diseases [10,11]. Rodents remain a major source of these parasites, transmitting them through direct contact, contaminated food or water, and ectoparasites such as fleas, ticks, and mites [10,11].

The Ngorongoro district in Arusha, Tanzania, with its extensive wildlife reserves, expanding agricultural activities, and proximity to the Serengeti National Park, is an ideal area for examining disease dynamics [12]. Frequent human-wildlife interactions in this region elevate the risk of rodent-borne infections among local populations. Previous research by Issae et al. [5,6] in this district reported the occurrence of various rodent-borne bacteria and viruses of public health importance. The lack of detailed research specifically focused on rodent-borne gastrointestinal parasites in the Ngorongoro district leaves a critical knowledge gap in understanding the epidemiology and zoonotic potential of these parasites. Therefore, this study aimed to assess the prevalence and zoonotic potential of gastrointestinal parasites in rodents from the Ngorongoro district. This research provided an essential insight into disease transmission dynamics at the human-animal interface in this region, addressed the existing knowledge gap and informing public health interventions.

MATERIALS AND METHODS

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Description of the study area

The study was done in the Ngorongoro District (Fig. 1) in Tanzania's Arusha Region, spans 14,036 square kilometers with altitudes ranging from 1,009 to 3,645 meters above sea level[5]. Bordered by Monduli District to the east, Karatu District to the south, and Mara Region to the west, it is administratively divided into three divisions; Ngorongoro, Loliondo, and Sale, and comprises 28 wards and 65 villages [5]. As of the 2012 census, the district's population was 174,278, experiencing a moderate temperature and tropical climate with annual rainfall averaging between 800 mm and 1,000 mm[6]. This diverse environment supports various wildlife habitats, including savannahs and forests, and interfaces closely with wildlife reserves like Serengeti National Park, making it ideal for studying zoonotic disease dynamics at the human-wildlife interface[12].

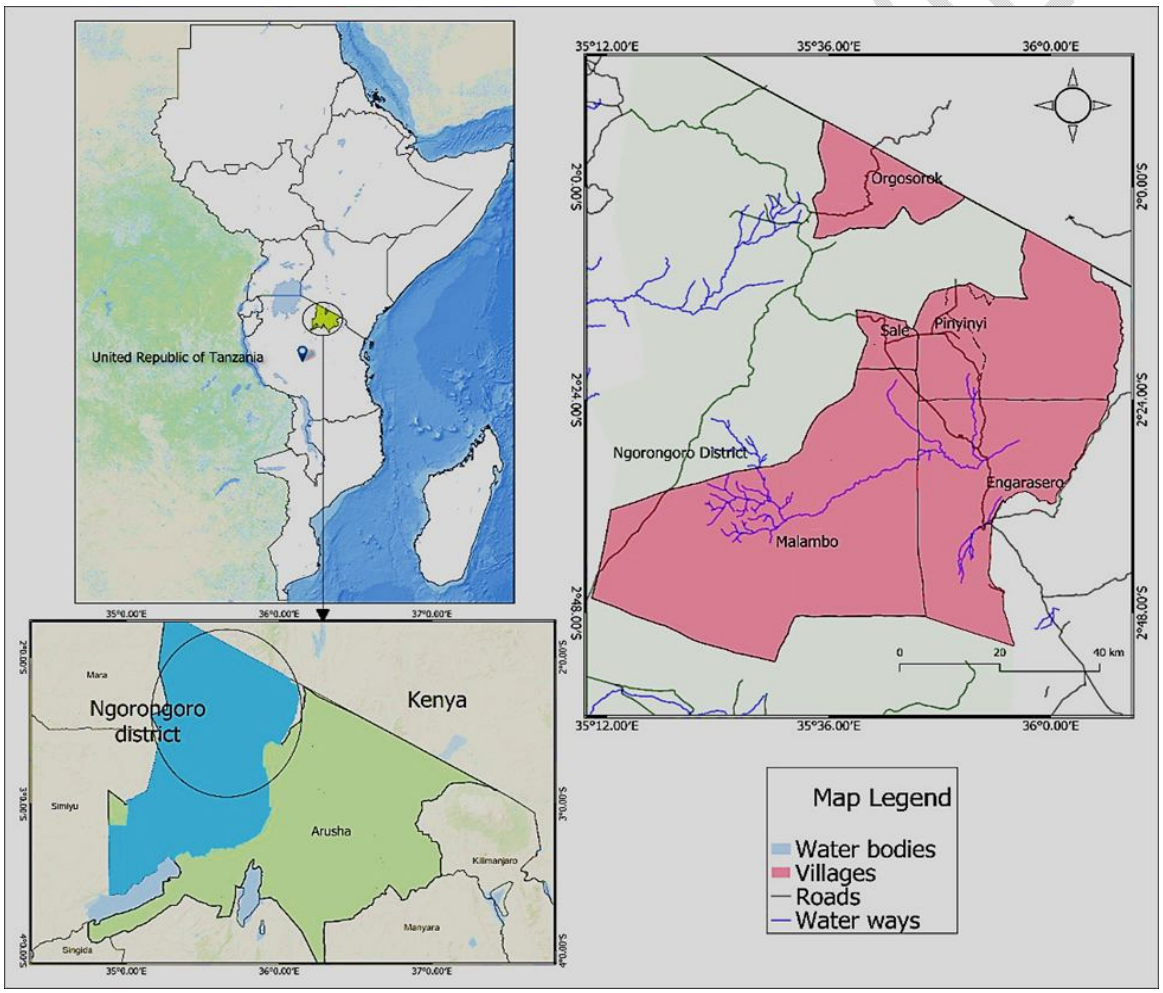

Figure 1: A geographic map delineating Arusha and Ngorongoro districts, pinpointing the specific villages involved in the study, was created using QGIS software version 3.26.1. by Issaeet al. [12].

Study design and sampling protocol

In January to March 2022, a cross-sectional study was implemented to assess the prevalence of significant public health parasites in rodents. The study targeted households within selected villages, using the list of households in each village as the sampling frame [5]. Village selection criteria included considerations such as the presence of both domestic and wild animal populations. A purposeful sampling approach guided the selection of households, focusing on the availability of rodents. Approximately 30 to 50 households per village were included based on the willingness of participants to participate, with written consent obtained from the household heads prior to rodent trapping [6].

Rodent trapping and Gastrointestinal tracts collection (GIT)

Rodents were captured for sample collection using Sherman LFA live traps (HB Sherman Traps, Inc., Tallahassee, FL) and modified wire cage traps baited with a mixture of peanut butter, maize bran, and sardines [5,6]. Trapping efforts targeted diverse habitats including peri-domestic, crop fields around houses, and indoor. Traps were set at 5 p.m. for seven days and checked at 8 a.m. each morning[5,6]. Morphological identification of rodents was conducted at the genus level according to the Happold manual [13]. Rodents were anaesthetized using Isoflurane, and dissected according to a previously established protocol [6]. Some of intestine and stomach samples were preserved in 10% formalin for the Formalin-Ether Concentration Technique (FECT), while some were preserved in 70% alcohol for a simple flotation test for parasite identification in the laboratory.

Coprological analysis and identification of the GIT parasites

Each fecal sample underwent physical examination in a Petri dish to detect adult worms, larvae, and tapeworm segments. A simple test tube flotation technique involved measuring approximately 2 grams of fecal sample into a plastic cup, adding 50 ml of supersaturated salt solution, and straining the mixture through a tea strainer into another cup. The resulting suspension was then transferred to a test tube, covered with a cover slip, and left for 20 minutes before microscopic examination[14].

The Formalin-ether concentration technique (FECT) involved collecting gastrointestinal material with an applicator stick, which was transferred to a beaker and mixed with 8 mL of saline. After filtration through gauze into a centrifuge tube, the filtrate was centrifuged at 1500 rpm for 5 minutes, discarding the supernatant afterward. Ethyl acetate (3 mL) and a 10% formalin solution (7 mL) were added to the tube, mixed thoroughly, and centrifuged again for 10 minutes. The resulting layers separated into ethyl acetate, formalin, and sediment. The sediment was carefully transferred to a clean, grease-free glass slide, stained with iodine, and

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covered with a coverslip for microscopic examination of eggs, oocysts and cysts [3].Parasites were identified by examining the sizes and morphological characteristics of cysts, eggs, oocysts, and trophozoites [15, 16]. However, species-level identification was limited by microscopy constraints and lack of fund for molecular techniques.

Data analysis

Laboratory data were recorded in Microsoft Excel 12 (Excel, 2007) and imported into SPSS (version 29, 2023) for further processing, where statistical analyses included frequencies, percentages, and standard deviations. The influence of categorical variables on prevalence was evaluated using a logistic regression test at a 5% significance level ($P < 0.05$).

RESULTS

Gastro-intestinal parasites of rodents

A total of 606 rodents were trapped and 46.9% of them harbored at least one intestinal parasite, with *Entamoeba* species being the most prevalent (15.5%), followed by *Trichuris* species (12.7%), *Hymenolepis nana* (11.6%), and *Hymenolepisdiminuta* (11.2%) (Table 1).The highest overall prevalence (64.3%) of GIT parasites was observed in Sale village compared to the other villages (Table 1). Helminths' eggs and protozoan cysts images are demonstrated in appendix 1 and 2.

Table 1. Abundance of gastro-intestinal parasites of rodents captured from villages of Ngorongoro district

Locations (Village)	**Engarasero (n =116)**	**Malambo (n =96)**	**Orgosorok (n =177)**	**Pinyinyi (n =88)**	**Sale (n=129)**	**Total (n=606)**
Parasite's species	**No. +ve(%)**	**No. +ve(%)**	**No. +ve(%)**	**No. +ve(%)**	**No. +ve(%)**	**T.P (%)**
Trichuris spp	17 (14.7)	11 (9.5)	11 (6.2)	12 (13.6)	26 (20.2)	77 (12.7)
H. diminuta	13 (11.2)	6 (5.2)	11 (6.2)	12 (13.6)	26 (20.2)	68 (11.2)
H. nana	12 (10.3)	12 (10.3)	16 (9.0)	9 (10.2)	21 (16.3)	70 (11.6)
*Capilaria*spp	5 (4.3)	6 (5.2)	9 (5.1)	6 (6.8)	12 (9.3)	38 (6.3)
*Strongloides*spp	10 (8.6)	5 (4.3)	5 (2.8)	8 (9.1)	5 (3.9)	33 (5.4)
*Physaloptera*spp	13 (11.2)	3 (2.6)	8 (4.5)	2 (2.3)	11 (8.5)	37 (6.1)
Helminths (O.P)	39 (33.6)	26 (22.4)	40 (22.6)	35 (39.8)	65 (50.4)	205 (33.8)
Entamoeba spp	15 (12.9)	18 (15.5)	21 (11.9)	15 (17.0)	25 (19.4)	94 (15.5)
Giardia spp.	7 (6.0)	5 (4.3)	8 (4.5)	6 (6.8)	15 (11.6)	41 (6.8)
Cryptosporidium	2 (1.7)	6 (5.2)	1 (0.6)	2 (2.3)	4 (3.1)	15 (2.5)
GIT-protozoa (O.P)	21 (18.1)	24 (20.7)	29 (16.4)	19 (21.6)	39 (30.2)	132 (21.8)
GITP O. P	53 (45.7)	43 (44.8)	61 (34.5)	44 (50.0)	83 (64.3)	284 (46.9)

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Note: No. +ve; Number of rodents positive, (%); Prevalence of infection, O. P= Overall Prevalence, T.P: Total prevalence, n =: Total number of rodents captured in the study sites.

Variation in Gastro-intestinal parasite prevalence in rodents by age, sex, and habitat

Out of 606 captured rodents, adults had higher (35.9%) infection rates for several parasites, while juveniles had higher prevalence of *Entamoeba*spp (16.0%) and *Strongyloides*spp (8.3%). Female rodents (48.7%) exhibited a slightly higher overall prevalence of parasite infections compared to males (43.8%) as shown in Table 2.

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Table 2: Distribution of gastro-intestinal parasites based on age, sex and habitats of the rodents (n=606)

Group of GIT parasite	Species identified	Number (%) of rodents with different species of helminths and protozoa gastro-intestinal parasites							
		Age		Sex		Habitat			
		Juvenile (n=169)	Adult (n=437)	Male (n=224)	Female (n=382)	Indoor (n=110)	Peridomestic (n=348)	Farms(n=148)	TOTAL (N=606)
		No. +ve(%)	No. +ve (%)	No. +ve(%)	No. +ve (%)	No. +ve (%)	No. +ve(%)	No. +ve (%)	T.P (%)
Helminths	*Trichuris* spp	18 (10.7)	59 (13.5)	30 (13.4)	47 (12.3)	15 (13.6)	49 (14.1)	13 (8.8)	77 (12.7)
	H. diminuta	16 (9.5)	52 (11.9)	20 (8.9)	48 (12.6)	9 (8.2)	50 (14.4)	9 (6.1)	68 (11.2)
	H. nana	16 (9.5)	54 (12.4)	27 (12.1)	43 (11.3)	17 (15.5)	40 (11.5)	13 (8.8)	70 (11.6)
	*Capillaria*spp	9 (5.3)	29 (6.6)	13 (5.8)	25 (6.5)	8 (7.3)	23 (6.6)	7 (4.7)	38 (6.3)
	*Strongloides*spp	14 (8.3)	19 (4.3)	11 (4.9)	22 (5.8)	6 (5.5)	21 (6.0)	6 (4.1)	36 (5.9)
	*Physalopteras*pp	11 (6.5)	26 (5.9)	15 (6.7)	22 (5.8)	4 (3.6)	24 (6.9)	9 (6.1)	37 (6.1)
	Helminths O. P	48 (28.4)	157 (35.9)	68 (30.3)	137 (35.9)	39 (35.5)	130 (37.4)	36 (24.3)	205 (33.8)
Protozoa	*Cryptosporidium* spp	4 (2.4)	11 (2.5)	3 (1.3)	12 (3.1)	2 (1.8)	12 (3.4)	1 (0.7)	15 (2.5)
	Entamoeba spp	27(16.0)	67 (15.3)	30 (13.4)	64 (16.8)	20 (18.2)	57 (16.4)	17 (11.5)	94 (15.5)
	Giardia spp.	8 (4.7)	33 (7.6)	17 (7.6)	24 (6.3)	9 (8.2)	26 (7.5)	6 (4.1)	41 (6.8)
	Protozoa O.P	37 (21.9)	95 (21.7)	19 (8.5)	89 (23.3)	26 (23.6)	82 (23.6)	24 (16.2)	132 (21.8)
	GITP O. P	71 (42.0)	213 (48.7)	98 (43.8)	186 (48.7)	55 (50.0)	178 (51.1)	51 (34.5)	284 (46.9)

Note: GITP O. T= Gastrointestinal Tract Parasites Overall Prevalence. O.P = Overall Prevalence

Prevalence of GIT parasite according to rodent species trapped

The study found an overall prevalence of 33.8% for helminths and 21.8% for protozoa, with higher prevalence rates observed in *Mastomys*spp and *Rattus*spp compared to other rodent species (Table 3).

Table 3: Prevalence of gastrointestinal parasites according to species of captured rodents(n=606)

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Rodent species	***Mastomys*spp(n =329)**	***Ratus* spp(n =84)**	***Arvicanthis*(n =91)**	***Acomys*(n =65)**	***Mus* spp (n=16)**	**Field mice (n=14)**	**Total (n=606)**
Parasite's species	No: +ve (%)	No: +ve (%)	No: +ve (%)	No: +ve (%)	No: +ve (%)	No: +ve (%)	T.P (%)
Trichuris spp	48 (14.6)	12 (14.3)	7 (7.7)	9 (13.8)	0 (0.0)	0 (0.0)	77 (12.7)
H. diminuta	41 (12.5)	9 (10.7)	13 (14.3)	4 (6.2)	1 (6.3)	0 (0.0)	68 (11.2)
H. nana	46 (14.0)	17 (20.2)	7 (7.7)	0 (0.0)	0 (0.0)	0 (0.0)	70 (11.6)
*Capilaria*spp	27 (8.2)	6 (7.1)	3 (3.3)	1 (1.5)	1 (6.3)	0 (0.0)	38 (6.3)
*Strongloides*spp	23 (7.0)	4 (4.8)	5 (5.5)	1 (1.5)	0 (0.0)	0 (0.0)	33 (5.4)
*Physalopteras*pp	31 (9.4)	5 (6.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	37 (6.1)
Helminths (O.P)	139 (42.2)	32 (38.1)	19 (20.9)	13 (20.0)	1 (6.3)	1 (7.1)	205 (33.3)
Entamoeba spp	57 (17.3)	17 (20.2)	10 (11.0)	8 (12.3)	1 (6.3)	1 (7.1)	94 (15.5)
Giardia spp.	26 (7.9)	7 (8.3)	4 (4.4)	4 (6.2)	0 (0.0)	0 (0.0)	41 (6.8)
Cryptosporidium	9 (2.7)	1 (1.2)	3 (3.3)	1 (1.5)	0 (0.0)	0 (0.0)	15 (2.5)
Protozoa (O.P)	83 (25.2)	20 (23.8)	14 (15.4)	12 (18.5)	1 (6.3)	1 (7.1)	132 (21.8)
GITP O. P	186 (56.5)	47 (56.0)	27 (29.7)	20 (30.8)	2 (16.7)	2 (14.3)	284 (46.9)

Note: No. +ve; Number of rodents positive, (%); Prevalence of infection, O. P= Overall Prevalence, T.P: Total prevalence, n =: Total number of rodents captured in the study site

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Prevalence of mixed infestation of gastrointestinal parasites

Based on habitats, high infection rate of both helminths and protozoa was observed in peri domestic rodents (10.1%). According to sex, female rodents showed high prevalence of mixed infection of 9.7%. Lastly based on age, adults have high prevalence of mixed infection of 8.4% (Supplementary Table 1).

Influence of different variables on the prevalence of GIT parasites

The study found that sex, age,and habitats had no significant impact on parasite prevalence in rodents, but *Mastomys*spp and *Rattus* spp had significantly higher infection rates compared to Mus spp, and Sale village had a significantly higher prevalence of GIT parasites compared to other villages (Table 4).

Table 4: Logistic regression analysis of the relationship among variables and the general prevalence of GIT parasites

Variable	OR	Confidence interval (95%)	P-value
Sex			
Female	Reference	-	-
Male	1.187	0.82-1.71	0.358
Age			
Adult	Reference	-	-
Juveniles	0.794	0.53- 1.18	0.256
Habitats			
Crop farms	Reference	-	-
Indoor	1.445	0.64-3.28	0.379
Peri-domestic	0.686	0.40-1.18	0.170
Species of rodent			
Mu spp	Reference	-	-
*Mastomys*spp	0.107	0.01-91	0.040*
Ratus spp	0.071	0.01-0.68	0.022*
*Arvicanthis*spp	0.358	0.04-3.16	0.355
*Acomys*spp	0.462	0.05-4.19	0.492
Field mice	2.045	0.10-40.78	0.639
Villages (locality)			
Sale	Reference	-	-
Orgosorok	0.061	0.06-0.63	0.000***
Engarasero	0.964	0.09-1.05	0.022*
Malambo	0.714	0.76-0.97	0.002**
Pinyinyi	0.983	1.01-2.80	0.223

*** = *Significant at p<0.001, *=Significant at p<0.05*, OR =Odd Ratio

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DISCUSSION

Rodents often host parasites that can lead to parasitic zoonoses, posing health risks to humans, domestic animals, and wildlife [1]. This study found that 46.9% of rodents were infected with at least one gastrointestinal (GIT) parasite, many of which have zoonotic potential and pose significant public health risks. Key zoonotic parasites identified include *Hymenolepis* sp., *Trichuris* sp., *Capillaria* sp., *Trichostrongylus* sp., and protozoan parasites such as *Entamoeba* sp., *Giardia* sp., and *Cryptosporidium* sp. The high prevalence of gastrointestinal parasites in rodents may be linked to improper disposal of waste from both humans and domestic animals in the study area. This study's finding of a high diversity of gastrointestinal parasite species aligns with other research from Nigeria[17], Sudan[9], West Africa[4], and various countries globally[18], which also reported wild rodents being infected by multiple parasite species.

Cestode worms of the genus *Hymenolepis* pose a significant health risk to humans, with documented cases in Oman, Jordan, Yemen, Qatar, and Palestine [18] The high prevalence of *Hymenolepis* spp. in rodents, particularly *Hymenolepis nana* (12.4%) and *Hymenolepisdiminuta* (11.9%), is alarming due to the potential for auto-infection and contamination of food intended for human consumption [3]. In addition to cestodes, *Trichuris* spp., or whipworms, are parasitic nematodes with a global occurrence of approximately 500 million human cases [19]. This study observed a 12.7% prevalence rate of *Trichuris* spp. in rodents, consistent with findings in wild rats in Iran [20]. underscoring the widespread distribution and public health implications of these parasites. Together, these findings highlight the significant zoonotic potential of rodent-borne parasites and the need for vigilant public health education to alleviate the risk of transmission to humans.

The study identified a 16.8% prevalence of *Entamoeba* spp. in rodents, which aligns with global rates such as 20% in Iran [21], 16.9% in Egypt [22], and 17.9% in Malaysia [3], indicating the influence of geographic and environmental factors. In contrast, Europe exhibits lower infection rates, primarily among travelers or immigrants, attributed to improved sanitation and cooler climates [23]. Amoebiasis affects approximately 50 million people annually, resulting in 40,000 to 100,000 deaths, emphasizing the necessity for continuous surveillance to prevent transmission from rodents to humans [3]. Additionally, the study reported a 14.6% prevalence of *Giardia* species in rodents, consistent with previous research [24,25]. *Giardia* is a significant gastrointestinal parasite responsible

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for giardiasis in humans and animals, suggesting that rodents may serve as important reservoirs for these parasites [18].

Moreover, this investigation identified *Cryptosporidium* spp.,with a 2.5% prevalence among studied rodents, consistent with related research [26,27,28]. Although traditionally not considered a human pathogen, studies have reported widespread human infection with *Cryptosporidium muris*, suggesting potential health risks from rodents [29].Transmission to humans can occur through direct contact with infected individuals or contaminated surfaces, as well as through the ingestion of contaminated food or water, posing risks to both human and animal health [30]. Observations during the study revealed poor disposal of livestock manure, free-roaming dogs and cats in the villages, and a lack of toilets in some households, all of which may contribute to the transmission of parasites to small mammals as well.

A significantly higher prevalence of gastrointestinal parasites was recorded in Sale village compared to other villages, probably due to environmental conditions and hygiene practices. For example, a study conducted by Issaeet al [12] found that some households visited in Sale villagelacked toilets. This indicates that community members defecate in the environment, which can increase the transmission rate of parasites among animals, including rodents.

High prevalence of multiple infections was notably observed in rodents, particularly in females (10.1%), adults (9.7%), and peri-domestic habitats (8.4%), reflecting the abundance of adult female rodents captured from these environments. Female rodents had a higher overall prevalence of gastrointestinal parasites infestations (43.8%) compared to males.Female rodents experience hormonal fluctuations due to their reproductive cycles, which can affect their immune systems. Example estrogen and progesterone influenced immune responses, potentially making females more susceptible to parasitic infections [31]. Similar patterns of higher prevalence rates among females without significant correlation to sex have been observed in Iran [32].

Adult rodents exhibit a higher infection rate (48.7%) of gastrointestinal parasites compared to juveniles (42%) primarily due to longer exposure time and the accumulation of infections over their lifespan [33]. Additionally, adult rodents engage in behaviors that increase their risk of getting parasites, such as foraging over larger areas and having more social interactions [34]. Furthermore, physiological and nutritional stresses associated with

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adulthood, such as reproduction and resource competition, can weaken their immune system, making them more susceptible to parasitic infections [35].

Among the rodent species examined, *Mastomys*spp exhibited the highest prevalence (56.5%), followed closely by *Rattus* spp at 56%, due to their abundance and proximity to human settlements, aligning with earlier research on high protozoan prevalence in the *Rattus* genus [11,32,36].*Mastomys* and *Rattus* species often live-in close proximity to humans, increasing their exposure to anthropogenic sources of food and waste [36,37]. This close contact facilitates the transmission of zoonotic diseases between humans and these rodents. The highest prevalence of gastrointestinal (GIT) parasites was detected in peri-domestic settings (51.1%), followed by indoor environments (50%) and crop farms near homes (34.5%). This pattern reflects the close interactions between humans, domestic animals, and rodents in these areas. During the study, researchers observed close interactions among humans, cattle, sheep, goats, dogs, and small mammals in the study villages, likely contributing to the high prevalence of GIT parasites.

CONCLUSION AND RECOMMENDATION

In conclusion, this study highlights the significant public health risks posed by rodent-borne parasites. The high prevalence of *Hymenolepis* spp., *Trichuris* spp., *Entamoeba* spp., *Giardia* spp., and *Cryptosporidium* spp. in rodents highlights the potential for zoonotic transmission. The close interactions between humans, domestic animals, and rodents, particularly in peri-domestic surroundings, indoor environments, and crop farms near homes, facilitate the transmission of zoonotic parasites. This study underscores the importance of vigilant public health education and continuous surveillance to mitigate the risk of parasite transmission from rodents to humans, including domestic animals. Efforts to improve sanitation, enhance environmental conditions, and implement effective hygiene practices are crucial in reducing rodent populations and safeguard public health.

ETHICAL APPROVAL

Sokoine University of Agriculture approved the study (Ref. No. SUA/ADM/R.1/8A/718), with additional permissions obtained from local authorities in the Arusha region (Ref. No. FA.132/95/01/38) and Ngorongoro district (Ref. No. AB.114/354/01/134). All animal handling procedures complied with the Tanzanian Animal Welfare Act (2008).

Consent:

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An inform written consentwas obtained from the household heads prior to rodent trapping.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

REFERENCES

1. Ribas A, López S, Makundi RH, Leirs H, de Bellocq JG. Trichuris spp.(Nematoda: Trichuridae) from two rodents, Mastomysnatalensis and Gerbilliscusvicinus in Tanzania. The Journal of Parasitology. 2013 Oct 1;99(5):868-75.
2. Gitonga J, Simbauni J, Oguge N. Habitat fragmentation and occurrence of intestinal parasites among the Praomysdelectorum sub-populations in Taita and Kyulu hills, Kenya. South Indian Journal of Biological Sciences. 2016;2(3):354-9.
3. Tijjani M, Abd Majid R, Abdullahi SA, Unyah NZ. Detection of rodent-borne parasitic pathogens of wild rats in Serdang, Selangor, Malaysia: A potential threat to human health. International Journal for Parasitology: Parasites and Wildlife. 2020 Apr 1;11:174-82.
4. Catalano S, Sène M, Diouf ND, Fall CB, Borlase A, Léger E, Bâ K, Webster JP. Rodents as natural hosts of zoonotic Schistosoma species and hybrids: an epidemiological and evolutionary perspective from West Africa. The Journal of infectious diseases. 2018 Jul 2;218(3):429-33.

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5. Issae A, Katakweba AA, Kicheleri R, Chengula A, Kasanga C. Metagenomics screening of viruses in Arusha, north Tanzania: a one health perspective across wild rodents, domestic dogs and humans. Journal of Ideas in Health. 2023 Sep 27;6(3):939-47.
6. Issae AR, Katakweba AS, Kicheleri RP, Chengula AA, Van Zwetselaar M, Kasanga CJ. Exploring pathogenic and zoonotic bacteria from wild rodents, dogs, and humans of the Ngorongoro district in Tanzania using metagenomics next-generation sequencing. Zoonotic Diseases. 2023 Sep 1;3(3):226-42.
7. Sohn WM, Na BK, Song HJ, Kim CM, Nam GJ. Intestinal helminthic infections in striped field mice, Apodemusagrarius, from two southern regions of Korea. The Korean journal of parasitology. 2014 Aug;52(4):419.
8. Samiji AM, Katakweba AS, Phiri EC. Trypanosomes infection in rodents and their zoonotic potential from Ruaha ward in Kilosa district, Tanzania. Tanzania Journal of Agricultural Sciences. 2022 Oct 20;21(1):126-33.
9. Fagir DM, EL-RAYAH EA. Parasites of the Nile rat in rural and urban regions of Sudan. Integrative Zoology. 2009 Jun;4(2):179-87.
10. Mustapha T, Daskum AM, Majid RA, Unyah NZ. A review on rodent-borne parasitic zoonosis: public health risk to humans. South Asian Journal of Parasitology. 2019;3(3):1-5.
11. Mariën J, Vanden Broecke B, Tafompa PJ, Bernaerts L, Ribas A, Mnyone LL, Mulugu LS, Leirs H. Host related factors determine co-occurrence patterns between pathogenic bacteria, protozoa, and helminths in populations of the multimammate mouse, Mastomysnatalensis. bioRxiv. 2022 Jan 15:2022-01.
12. Issae A, Chengula A, Kicheleri R, Kasanga C, Katakweba A. Knowledge, attitude, and preventive practices toward rodent-borne diseases in Ngorongoro district, Tanzania. Journal of Public Health in Africa. 2023 Jun 6;14(6).
13. Happold M, Happold DCD eds. Mammals of Africa, 2013 (3). London: Bloomsbury.
14. World Health Organization. Basic laboratory methods in medical parasitology. World Health Organization; 1991.
15. Shiba KR, Shaji Uga NK. Atlas of Medical Parasitology. Kobe University School of Medicine Kobe, Japan. 1996:78.

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16. Zajac AM, Conboy GA, Little SE, Reichard MV. Veterinary clinical parasitology. John Wiley & Sons; 2021 Jul 7.
17. Mafiana CF, Osho MB, Sam-Wobo S. Gastrointestinal helminth parasites of the black rat (Rattus rattus) in Abeokuta, southwest Nigeria. Journal of Helminthology. 1997 Sep;71(3):217-20.
18. Islam MM, Farag E, Hassan MM, Bansal D, Awaidy SA, Abubakar A, Al-Rumaihi H, Mkhize-Kwitshana Z. Helminth parasites among rodents in the Middle East countries: a systematic review and meta-analysis. Animals. 2020 Dec 9;10(12):2342.
19. Pullan RL, Smith JL, Jasrasaria R, Brooker SJ. Global numbers of infection and disease burden of soil transmitted helminth infections in 2010. Parasites & vectors. 2014 Dec;7:1-9.
20. Arzamani K, Salehi M, Mobedi I, Adinezade A, Hasanpour H, Alavinia M, Darvish J, Shirzadi MR, Mohammadi Z. Intestinal helminths in different species of rodents in north Khorasan province, northeast of Iran. Iranian journal of parasitology. 2017 Apr;12(2):267.
21. Rahdar M, Vazirianzadeh B, Alborzi A. Study of internal parasites of rodents in ahvaz, south-west of Iran. Jundishapur journal of health sciences. 2017 Jan 1;9(1).
22. ABDEL-LATEF K, NAGY MAHROUS LI. RODENTS AS A POTENTIAL SOURCE OF SOME ZOONOTIC ENTERIC PARASITES IN BENI-SUEF PROVINCE. Assiut Veterinary Medical Journal. 2015 Apr 1;61(145):201-9.
23. Cui Z, Li J, Chen Y, Zhang L. Molecular epidemiology, evolution, and phylogeny of Entamoeba spp. Infection, Genetics and Evolution. 2019 Nov 1; 75:104018.
24. Bitto A, Aldras A. Prevalence of Giardia and Cryptosporidium in muskrats in northeastern Pennsylvania and New Jersey. Journal of Environmental Health. 2009 Apr 1;71(8):20-8.
25. Asghari, A., Motazedian, M.H., Asgari, Q., Shamsi, L., Sarkari, B., Shahabi, S. and Mohammadi-Ghalehbin, B., 2022. Occurrence, genetic characterization, and zoonotic importance of Giardia duodenalis in various species of rodents (Mus musculus, Rattus norvegicus, and Rattus rattus). *Comparative Immunology, Microbiology and Infectious Diseases*, *85*, p.101812.
26. Torres J, Gracenea M, Gomez MS, Arrizabalaga A, Gonzalez-Moreno O. The occurrence of Cryptosporidium parvum and C. muris in wild rodents and insectivores in Spain. Veterinary Parasitology. 2000 Oct 20;92(4):253-60.

UNDER PEER REVIEW

27. Tan TK, Low VL, Ng WH, Ibrahim J, Wang D, Tan CH, Chellappan S, Lim YA. Occurrence of zoonotic Cryptosporidium and Giardia duodenalis species/genotypes in urban rodents. Parasitology International. 2019 Apr 1;69:110-3.
28. García-Livia K, Martín-Alonso A, Foronda P. Diversity of Cryptosporidium spp. in wild rodents from the Canary Islands, Spain. Parasites & Vectors. 2020 Dec; 13:1-9.
29. Palmer CJ, Xiao L, Terashima A, Guerra H, Gotuzzo E, Saldías G, Bonilla JA, Zhou L, Lindquist A, Upton SJ. Cryptosporidium muris, a rodent pathogen, recovered from a human in Peru. Emerging Infectious Diseases. 2003 Sep;9(9):1174.
30. Meerburg BG, Singleton GR, Kijlstra A. Rodent-borne diseases and their risks for public health. Critical reviews in microbiology. 2009 Aug 1;35(3):221-70.
31. Klein S L. Hormonal and immunological mechanisms mediating sex differences in parasite infection. *Parasite Immunology*, 2004; 26(6-7), 247-264.
32. Seifollahi Z, Sarkari B, Motazedian MH, Asgari Q, Ranjbar MJ, AbdolahiKhabisi S. Protozoan parasites of rodents and their zoonotic significance in Boyer-Ahmad District, Southwestern Iran. Veterinary medicine international. 2016;2016(1):3263868.
33. Scott ME, Dobson A. The role of parasites in regulating host abundance. Parasitology Today. 1989 Jun 1;5(6):176-83.
34. Hudson PJ, Dobson AP, Newborn D. Do parasites make prey vulnerable to predation? Red grouse and parasites. Journal of animal ecology. 1992 Oct 1:681-92.
35. Guerra A, Ghosh P, Wyman S. The effects of life history and environmental factors on parasite load and host health in rodent populations. *Parasitology Research*, 2019: 118(7), 2143-2152. doi:10.1007/s00436-019-06384-4
36. Isaac C, Igbinosa BI, Ohiolei JA, Osimen CE. Endoparasites of small mammals in Edo State, Nigeria: Public health implications. The Korean journal of parasitology. 2018 Feb;56(1):93.
37. Preisser W. Latitudinal gradients of parasite richness: a review and new insights from helminths of cricetid rodents. Ecography. 2019 Jul;42(7):1315-30.

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APPENDIX

Appendix 1: Images of helminths eggs found in the rodents' intestinal samples

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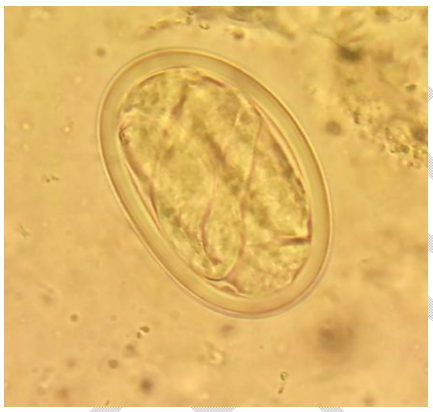
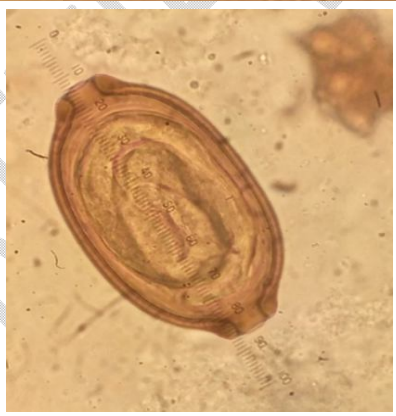
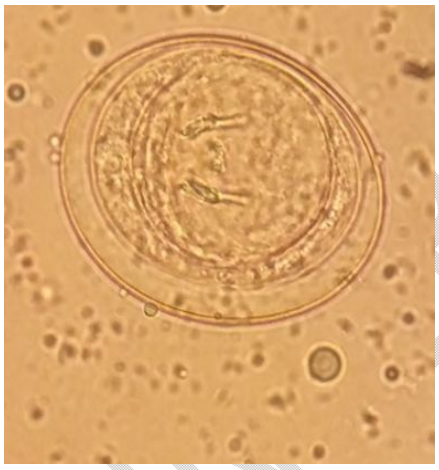
***Hymenolepisdiminuta* egg**

***Hymenolepis nana* egg**







***Strongyloides*egg**

***Physalotepra*egg**

***Capillaria*egg**

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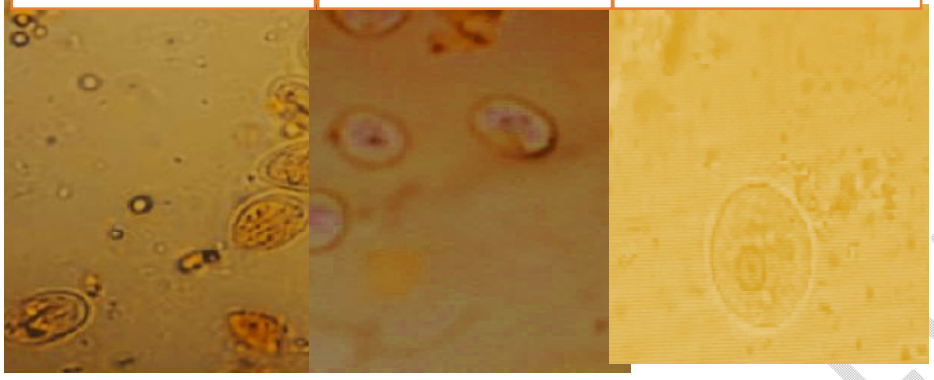
Appendix 2: Images of protozoa cysts found in rodents' intestinal samples

Giardia cyst		
		

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