International Journal of TROPICAL DISEASE & Health

Volume 45, Issue 11, Page 34-45, 2024; Article no.IJTDH.121716
ISSN: 2278–1005, NLM ID: 101632866

Prevalence of Gastro-intestinal Parasites with Zoonotic Potential in Rodents Trapped from the Ngorongoro District, Arusha, Tanzania

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijtdh/2024/v45i111603

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121716

Original Research Article

Received: 19/06/2024
Accepted: 22/08/2004
Published: 02/11/2024

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.

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Cite as: *Issae, Amina Ramadhani, and Abdul Ahmed Selemani Katakweba. 2024. "Prevalence of Gastro-Intestinal Parasites With Zoonotic Potential in Rodents Trapped from the Ngorongoro District, Arusha, Tanzania". International Journal of TROPICAL DISEASE & Health 45 (11):34-45. https://doi.org/10.9734/ijtdh/2024/v45i111603.*

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%), *Hymenolepis diminuta* (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.

1. INTRODUCTION

Zoonotic diseases represent a significant proportion of infectious diseases impacting humans globally, with wildlife reservoirs, particularly rodents, posing substantial public health risks (Ribas et al. 2013, Gitonga et al. 2016). Rodents, encompassing over 1,700 species across the *Muridae*, *Microtidae*, and *Sigmodontidae* families, are widespread across diverse global regions (Tijjani et al. 2020). Rodent species such as *Lophuromys* spp. and *Rattus* spp. are notably significant as reservoirs for a range of zoonotic infections (Catalano et al. 2018). Rodent-borne zoonoses include a diverse array of diseases caused by viruses (Issae et al. 2023), bacteria (Issae et al. 2023), helminths (Sohn et al., 2014), and protozoa (Samiji et al., 2022), 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 (Fagir et al., 2009). Parasitic zoonotic agents like Toxoplasma gondii, Cryptosporidium spp., and Leishmania spp. have become significant threats to human health, especially in immunocompromised individuals (Mustapha et al., 2009). Protozoa are particularly notable for causing emerging infections, although cestodes, trematodes, nematodes, and pentastomids also contribute to zoonotic diseases (Mariën et al., 2022, Issae et al., 2023). 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 (Mustapha et al., 2019, Mariën et ., 2019).

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 (Issae et al., 2023). Frequent human-wildlife interactions in this region elevate the risk of rodent-borne infections among local populations. Previous research by Issae et al. (2023), Issae et al., (2023) 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.

2. MATERIALS AND METHODS

2.1 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 Issae et al. (2023). 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 Issae et al. (2023). 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 Issae et al. (2023). 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 (Issae et al., 2023).

2.2 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 Issae et al. (2023). 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 Issae et al. (2023).

2.3 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 Issae et al. (2023), Issae et al. (2023). 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 Issae et al. (2023), Issae et al. (2023). Morphological identification of rodents was conducted at the genus level according to the Happold manual (Happold 2013). Rodents were anaesthetized using Isoflurane, and dissected according to a previously established protocol (Issae et al., 2023). 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.

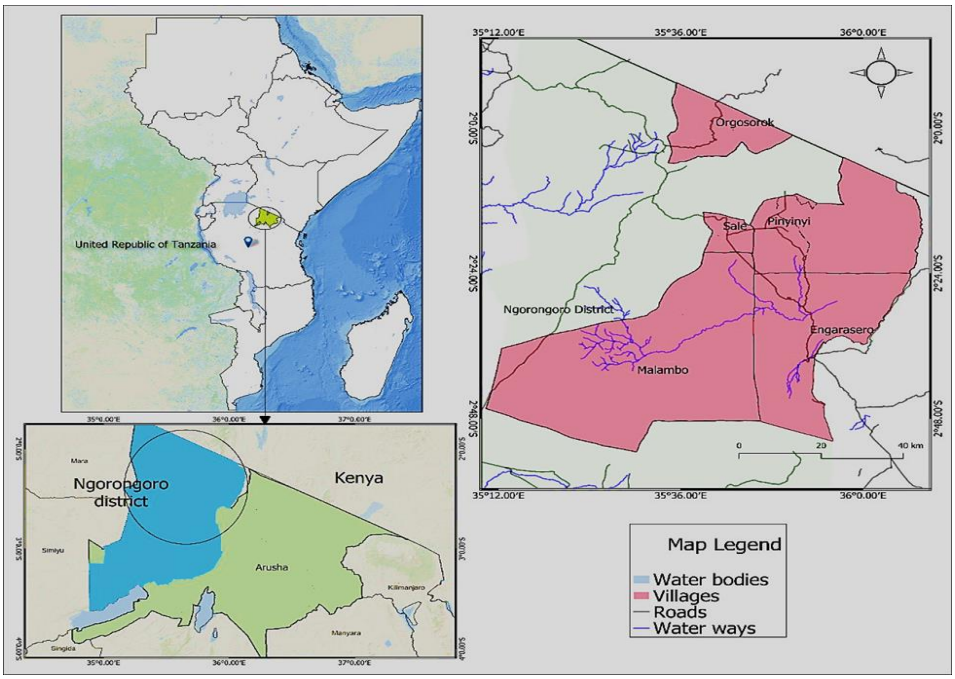

Fig. 1. A geographic map delineating Arusha and Ngorongoro districts, pinpointing the specific villages involved in the study, was created using QGIS software version 3.26.1. by Issae et al. (2023)

2.4 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 World Health Organization (1991).

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 covered with a coverslip for microscopic examination of eggs, oocysts and cysts (Tijjani et al., 2020). Parasites were identified by examining the sizes and morphological characteristics of cysts, eggs, oocysts, and trophozoites (Shiba and Shaji Uga 1996, Zajac et al., 2021). However, species-level identification was limited by microscopy constraints and lack of fund for molecular techniques.

2.5 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 ($P < 0.05$).

3. RESULTS

3.1 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 *Hymenolepis diminuta* (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 Figs. 2 and 3.

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)

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.

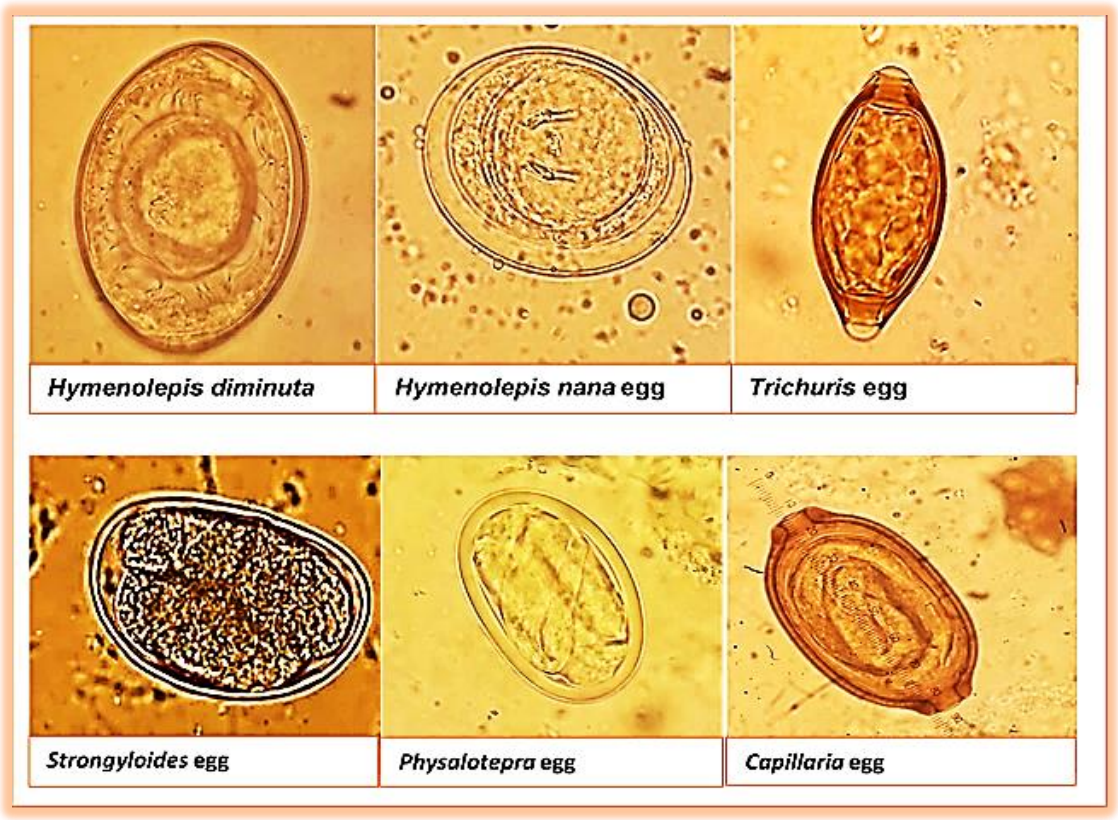

Fig. 2. Images of helminths eggs found in the rodents' intestinal samples

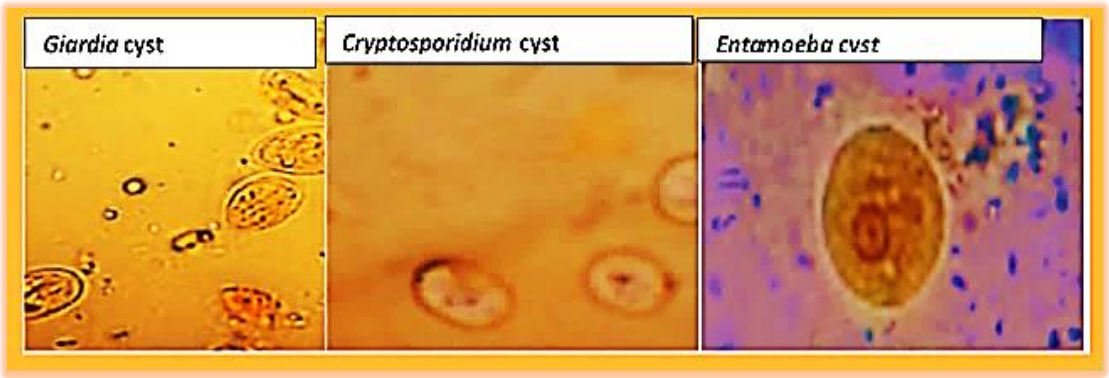

Fig. 3. Images of protozoa cysts found in rodents' intestinal samples

3.2 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.

3.3 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).

3.4 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% (Appendix Table A1).

3.5 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 *Rattu*s 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).

4. DISCUSSION

Rodents often host parasites that can lead to parasitic zoonoses, posing health risks to humans, domestic animals, and wildlife (Ribas et al., 2013). 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 (Mafiana et al., 1997), Sudan (Fagir et al., 2009), West Africa (Catalano et al., 2018), and various countries globally (Islam et al., 2020), 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 (Islam et al., 2020) The high prevalence of *Hymenolepis* spp. in rodents, particularly *Hymenolepis nana* (12.4%) and *Hymenolepis diminuta* (11.9%), is alarming due to the potential for auto-infection and contamination of food intended for human consumption (Tijjani et al., 2020). In addition to cestodes, *Trichuris* spp., or whipworms, are parasitic nematodes with a global occurrence of approximately 500 million human cases (Pullan et al., 2014). This study observed a 12.7% prevalence rate of *Trichuris* spp. in rodents, consistent with findings in wild rats in Iran (Arzamani et al., 2017). 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 (Rahdar et al., 2017), 16.9% in Egypt (Abdel-Latef and Nagy Mahrous 2015), and 17.9% in Malaysia (Tijjani et al., 2020), 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 (Cui et al., 2019). 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 (Tijjani et al., 2020). Additionally, the study reported a 14.6% prevalence of *Giardia* species in rodents, consistent with previous research (Bitto and Aldras 2009, Asghari et al., 2022). *Giardia* is a significant gastrointestinal parasite responsible for giardiasis in humans and animals, suggesting that rodents may serve as important reservoirs for these parasites (Islam et al., 2020).

Moreover, this investigation identified *Cryptosporidium* spp., with a 2.5% prevalence among studied rodents, consistent with related research (Torres et al., 2000, Tan et al., 2019, García-Livia et al., 2020). Although traditionally not considered a human pathogen, studies have reported widespread human infection with *Cryptosporidium muris*, suggesting potential health risks from rodents (Palmer et al., 2003). 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 (Meerburg et al., 2009). 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.

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)
	Physaloptera spp	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

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

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)
Physaloptera spp	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

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*

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 Issae et al (2023) found that some households visited in Sale village lacked 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 (Klein 2024). Similar patterns of higher prevalence rates among females without significant correlation to sex have been observed in Iran (Seifollahi et al., 2016).

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 (Scott and Dobson 1989). Additionally, adult rodents engage in behaviors that increase their risk of getting parasites, such as foraging over larger areas and having more social interactions (Hudson et al., 1992). Furthermore, physiological and nutritional stresses associated with adulthood, such as reproduction and resource competition, can weaken their immune system, making them more susceptible to parasitic infections (Guerra et al., 2019).

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 (Mariën et al., 2022, Seifollahi et al., 2016, Isaac et al., 2018). *Mastomys* and *Rattus* species often live-in close proximity to humans, increasing their exposure to anthropogenic sources of food and

waste (Isaac et al., 2018, Preisser 2019). 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.

5. 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.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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.

CONSENT

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

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).

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the African Centre of Excellence for Innovative Rodent Pest Management and Biosensor Technology Development (ACEII-IRPM and BTD) at Sokoine University of Agriculture, Morogoro, Tanzania, for their financial support for this study. They also appreciate the assistance and cooperation received from the community members, government officials, local leaders in Ngorongoro district, and laboratory technicians at Institute of Pest Management and Department of Microbiology and Parasitology in Sokoine University of Agriculture.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table A1. Prevalence of mixed infestation of gastrointestinal parasites according to age, sex and habitats (n=606)

Species identified	Number (%) of rodents with mixed species of gastrointestinal parasites						
	Age		Sex		Habitats		
	Juvenile (n=169)	Adult (n=437)	Male (n=224)	Female (n=382)	Indoor (n=110)	Peri domestic (n=348)	Farms (n=148)
	Number +ve (%)	Number +ve (%)	Number +ve (%)	Number +ve (%)	Number +ve (%)	Number +ve (%)	Number +ve (%)
H. diminuta & H.nana	6 (3.6)	14 (3.2)	7 (3.1)	13 (3.4)	1 (0.9)	14 (4.0)	5 (3.4)
H. nana & Caillaria spp	0 (0.0)	3 (0.7)	1 (0.4)	2 (0.5)	3 (2.7)	0 (0.0)	0 (0.0)
H.nana & Trichuris spp	6 (3.6)	9 (2.1)	6 (2.8)	9 (2,4)	2 (1.8)	9 (2.6)	4 (2.7)
Strongloides spp & H. nana	4 (2.4)	5 (1.1)	4 (1.8)	5 (1.3)	1 (0.9)	8 (2.3)	0 (0.0)
Physaloptera spp & H.nana	2 (1.2)	7 (1.6)	4 (1.8)	5 (1.3)	1 (0.9)	6 (1.7)	2 (1.4)
H. diminuta & Caillaria spp	2 (1.2)	3 (0.7)	1 (0.4)	4 (1.0)	1 (0.9)	2 (0.6)	2 (1.4)
H.diminuta & Trichuris spp	2 (1.2)	13 (3.0)	4 (1.8)	11 (2.9)	2 (1.8)	12 (3.4)	1 (0.7)
Strongloides spp & H. diminuta	3 (1.8)	6 (1.4)	2 (0.9)	7 (1.8)	1 (0.9)	8 (2.3)	0 (0.0)
Physaloptera spp & H. diminuta	1 (0.6)	5 (1.1)	2 (0.9)	4 (1.0)	0 (0.0)	5 (1.4)	1 (0.7)
H.diminuta & H.nana & Trichuris spp	2 (1.2)	4 (0.9)	3 (1.3)	3 (0.8)	0 (0.0)	5 (1.4)	1 (0.7)
H.diminuta & H.nana & Strongloides spp	2 (1.2)	4 (0.9)	1 (0.4)	5 (1.3)	0 (0.0)	6 (1.7)	0 (0.0)
H.diminuta & H.nana & Physaloptera spp	1 (0.6)	3 (0.7)	2 (0.9)	2 (0.5)	0 (0.0)	3 (0.9)	1 (0.7)
Cryptosporidium spp & *Entamoeba spp*	0 (0.0)	4 (0.9)	1 (0.4)	3 (0.8)	1 (0.9)	2 (0.6)	1 (0.7)
Cryptosporidium spp & Giardia spp.	0 (0.0)	3 (0.7)	1 (0.4)	2 (0.5)	0 (0.0)	3 (0.9)	0 (0.0)
Giardia spp.& Entamoeba spp	1 (0.6)	6 (1.4)	2 (0.9)	5 (1.3)	3 (2.7)	3 (0.9)	1 (0.7)
GIT Helhminths & Protozoa	**14 (8.3)**	**37 (8.4)**	**14 (6.3)**	**37 (9.7)**	**10 (9.1)**	**35 (10.1)**	**6 (4.1)**

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