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Prevalence, Distribution and Risk Factors for Trematode Infections in Domesticated Ruminants in the Lake and Southern Zones of Tanzania: A Cross-Sectional Study

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Simple Summary: Trematode infections (fascioliasis and schistosomiasis) is a worldwide emerging snail-borne zoonotic diseases with a great spreading capacity linked to animal and human movements, climate change, and anthropogenic modifications of freshwater environments. There is a lack of information regarding prevalence, distribution and risk factors of trematode infections in domesticated ruminants in Tanzania. This study aims to fill the knowledge gap by determining the prevalence, distribution, and risk factors for trematode infections in domesticated ruminants in two ecological zones of Tanzania. Fecal samples were collected from domesticated ruminants and examined for trematode infections using sedimentation techniques. The highest trematode infections *F.gigantica*, paramphistomes, and *S. bovis* were found in the Lake Victoria zone (Simiyu region) compared to the Southern Hingland zone (Iringa region). To our knowledge, this is the first study reporting trematode infection in domesticated ruminants in the Lake Victoria zone. This calls for trematode infections prevention and control interventions.

Abstract: Trematode infections cause long-term suffering and debilitation, posing a significant threat to global animal health and production and leading to considerable economic losses. Studies on the epidemiology and control of these infections in Tanzania are limited, and most have been conducted in abattoir settings. The study aims to fill the knowledge gap by determining the prevalence, distribution, and risk factors for trematode infections in domesticated ruminants in two ecological zones of Tanzania. A cross-sectional study was conducted in Lake Victoria and the southern highlands of Tanzania. Rectal fecal samples were collected and examined for Fasciola spp., paramphistomes, and schistosome infections using the sedimentation technique. A total of 1367 domesticated ruminants were sampled and examined for trematode infections. Prevalence of trematode infections was found to be 65.7%. The individual frequency of *F. gigantica*, paramphistomes, and *S. bovis* (based on egg morphology only,) was 35.1%, 60.2% and 3.1%, respectively. Adult cattle were more likely to be infected with paramphistomes (AOR: 1.98; 95% CI: 1.40-2.78) and *S. bovis* (AOR: 8.5; 95% CI: 1.12–64.19) than weaners. It was found that trematode infections in domesticated ruminants are prevalent across Tanzania, therefore effective and community-acceptable prevention and control strategies are highly needed.

Keywords: domesticated ruminants; fasciola; paramphistome; trematode; schistosoma; Tanzania

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1. Introduction

Trematode infections, particularly fasciolosis and schistosomiasis, are among the most common helminth infections in domestic ruminants worldwide [1,2]. Adult trematodes are sometimes referred to as "flukes," and the families that contain parasites of veterinary interest include Schistosomatidae, Fasciolidae, Paramphistomatidae, and Dicrocoeliidae [4,5]. The genera Fasciola (liver fluke), Paramphistomes (rumen/stomach fluke), and Schistosoma (blood fluke) [5] have similar life cycles in which domestic ruminants and humans (except rumen flukes) are definitive hosts, while wild animals serve as reservoirs [6]. The species *F. gigantica* [7], *F. hepatica* [8], *S. bovis* [9], paramphistomes species and *Dicrocoelium hospes* [10] have been widely reported in Tanzania.

The presence of these parasites is widespread in tropical and subtropical regions globally, thriving in areas with favorable climatic, ecological, and hygienic conditions [11,12]. In most African countries south of the Sahara, these infections are considered to be endemic [13]. The presence and distribution of freshwater snail intermediate hosts often influence the occurrence of trematode infections [14,15], which in turn vary with climatic circumstances [16].

Globally, trematode infections are a considerable veterinary and public health burden [17]. Moreover, they threaten domesticated ruminant health and production due to reduced fertility and productivity, liver condemnation, stunted growth, and premature death [18–20]. In the southern highlands of Tanzania, almost 100% of the total condemnations of bovine liver in slaughter slabs, poor growth rate, reduced milk production, and infertility are attributed to these infections [21,22].

Bovine trematode infections in Tanzania have been reported in all geographical zones by abattoir surveys [23–27], and studies on the epidemiology and control of these parasites in cattle have been carried out in the southern highlands [5–8,28]. In these studies, the prevalence of fasciolosis and schistosomiasis ranged from 18%-94% in domesticated ruminants depending on the production system used [21,22].

Despite these findings, there is a paucity of information regarding the magnitude, distribution, and risk factors for trematode infections in domesticated ruminants in many parts of Tanzania. This study was therefore conducted to address this gap to generate baseline data that will provide the scientific evidence needed to design effective and locally accepted control interventions against trematode infections.

2. Materials and Methods

2.1. Study Area

The study was conducted from March to May 2023 in the Misungwi, Bariadi, and Iringa District Councils of the Mwanza, Simiyu, and Iringa regions, respectively. Within the Misungwi district, the study was carried out in Kanyelele, Koromije, and Ibongoya B villages. In the Bariadi district, the study was conducted in Pugu and Itubukilo A villages. On the other hand, in the Iringa rural district, the study was conducted in Lupembelwasenga, Usengelindeti, and Migori villages (See Figure 1). The study districts and villages were selected purposively based on the available domesticated ruminant population, disease history, and disease ecology described in routine reports from the respective local District Veterinary Offices.

The Bariadi and Misungwi district councils are located in the northwestern part of Tanzania to the southeast of Lake Victoria. Both districts experience a low rain season from October to December and a high rain season between March and May of each year, while the dry period usually runs from January to the end of February and from June to the end of September of each year. The districts receive 700 mm to 950 mm of rain annually [29]. The temperatures in the two districts range from190°C to 290°C [29].

The Iringa Rural District Council is located in the southern highlands of Tanzania. The highland region in the eastern part of the district consists of many hills and valleys, along with numerous permanent rivers, streams, and ponds. In contrast, the flat lowland on the western side is semi-arid and characterized by dry grazing land with thickets and scattered bushes, as described by Mahoo

[30]. The annual rainfall in highland areas ranges from 500 mm to 2700 mm, while in lowland areas; the rainfall is less than 600 mm [31].

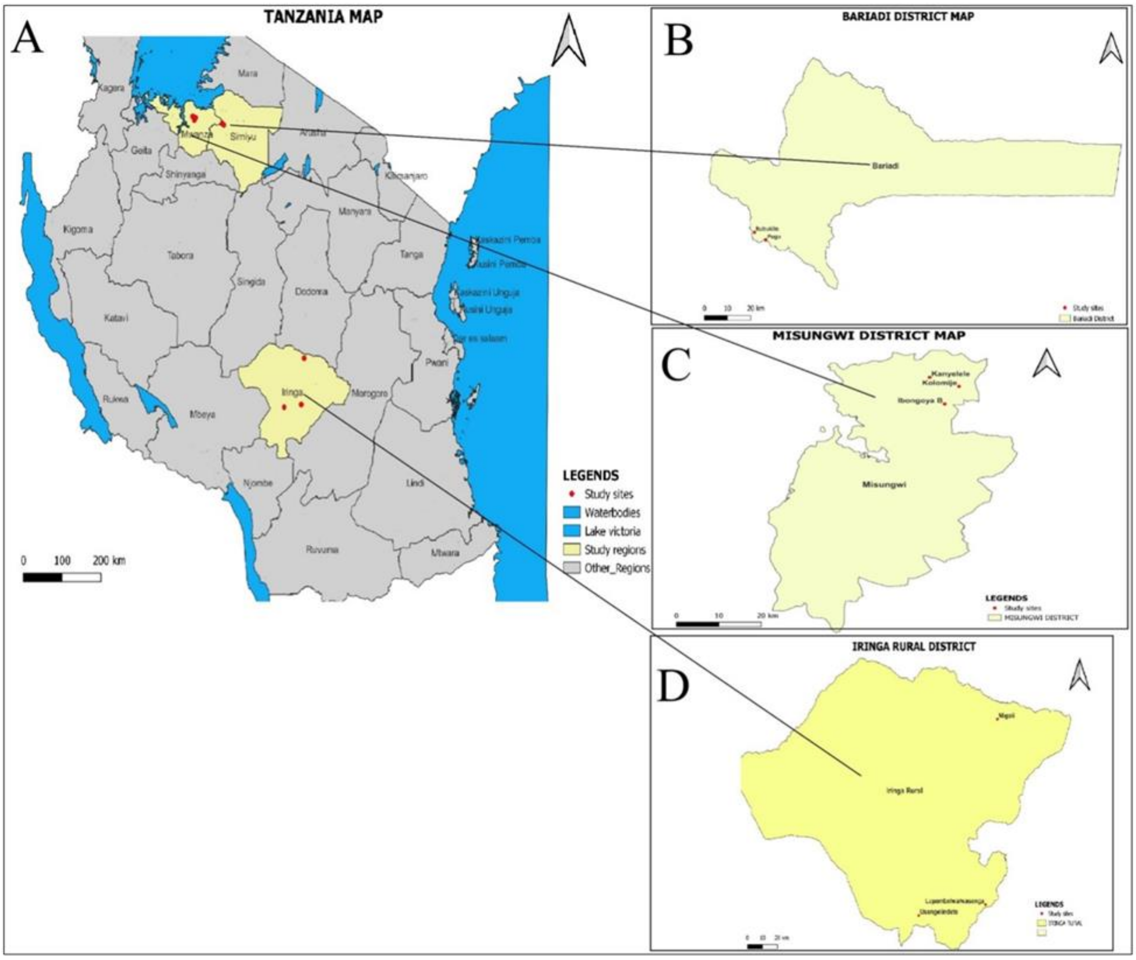

Figure 1. A map showing the study areas: A=Tanzania map, B=Bariadi District, C=Misungwi District, D=Iringa Rural District.

2.2. Study Design and Sampling Procedure

A cross-sectional study was conducted around Lake Victoria and the southern highland Zone of Tanzania. Rectal fecal samples collected by veterinary technicians were concealed inside sterile surgical gloves that had been turned inside out. Domesticated ruminants information such as age (classified as weaners and adults), sex, breed (local-breed and cross-breed), and body condition (lean, median, fat) were recorded. Unique numbers and dates were used to label the samples, after which they were stored in an ice-packed cool box and transported to the laboratory of the National Institute for Medical Research (NIMR), Mwanza Centre, for laboratory examination.

The formula n = (Z2 * p * (1-p))/d2 was used to determine the sample size. This was based on an expected prevalence (p) of bovine fascioliasis of 33% as reported by Nzalawahe *et al*., [32], and a desired absolute precision (d) of 3% with a 95% confidence interval (CI) as per Thrusfield's [33]. A total of 1367 domesticated ruminants were sampled and examined.

2.3. Coprological Examination

Fecal samples from domesticated ruminants were processed by the fecal sedimentation method [34]. In brief, approximately 10 grams of fecal material was placed in a plastic container and mixed with 30 ml of tap water. Using 500 ml conical beakers, the fecal suspension was sieved through a wire mesh with an aperture of 250 µm and then filled with tape water. The suspension in a beaker was then allowed to settle for approximately 15 minutes.

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Thereafter, the process of decanting the supernatants and re-suspending the sediments in tape water was repeated three times. Eventually, all the sediment was placed into a Petri dish, stained with 1% methylene blue, and observed under a microscope at 10x magnification for parasitic eggs [11]. The number of trematode eggs was determined by thoroughly examining every section of the Petri dish. To ensure accuracy, two lab technicians independently examined the same samples. The eggs were counted and identified based on specific morphological characteristics [35]. To calculate the egg per gram of feces, the number of specific parasite eggs present in a 10 g sample was divided by ten.

2.4. Mapping of Study Villages and Study Farms

The study villages and farms participating in the research were geographically mapped using handheld differential geographic global positioning system (GPS) units from Trimble Navigation Ltd. in California, USA, which had an approximate accuracy of ± 1 meter. The GPS data was downloaded with differential correction into a GPS database (GPS Pathfinder Office 2.8 from Trimble Navigation Ltd., California, USA), and the mapping process was carried out using ArcView version 9.2 software from Environmental Systems Research Institute, Inc. in Redlands, CA (refer to Figure 2 for details).

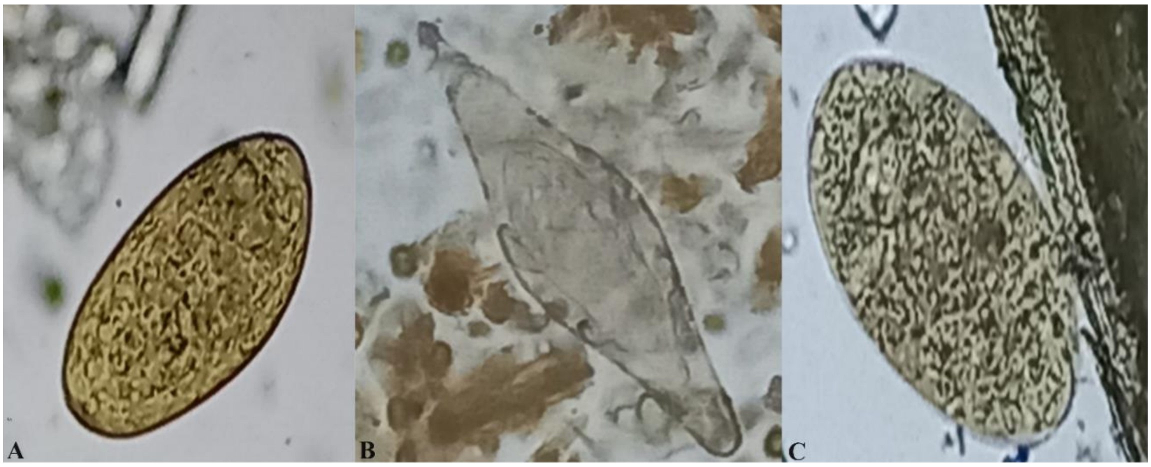

Figure 2. Fasciola egg (A), *S. bovis* egg (B) and paramhistome egg (C).

2.5. Statistical Analysis

The information obtained during the collection of samples and the findings from the coprological analysis were entered into the Census and Survey Processing System (CSPro) software by the U.S. Census Bureau in the United States. The cleaned dataset was transferred to Stata version 15.1 developed by Stata Corporation located in College Station, TX, USA. The data was summarized using descriptive statistics, and proportions were used to summarize categorical variables, which were then compared using the chi-square test. The egg count data (EPGs) underwent log transformation [log10(EPG+1)], and differences in EPGs between sex, age, and breed were examined using two-sample t-tests, while one-way analysis of variance (ANOVA) was utilized to compare the EPGs between different body conditions. Positive for at least one egg was the criteria for considering an animal to be infected. Statistical significance was considered for P values ≤ 0.05. Associations between parasitic infections and risk factors were tested using multiple logistic regression analysis. QGIS® spatial software version 2.2 was utilized to represent the distribution of trematode infections.

3. Results

3.1. Animal Population Characteristics

A total of 1367 domesticated ruminants (739 cattle, 319 goats, and 309 sheep) were sampled and examined for trematode infections. Most of the sampled animals were female; 57.9% (428/739) were

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cattle, and 64.4% (199/309) were sheep. A total of 83.7% (267/319) of the goats were males. Compared with crossbred breeds, local breeds were more common in each group of examined animals, accounting for 98.4% (729/739) of cattle, 100% (319/319) of goats and 100% (309/309) of sheep. In terms of age, adult animals constituted the majority of the animals sampled: 73.5% (543/739) for cattle, 61.1% (195/319) for goats, and 63.1% (195/309) for sheep.

3.2. Prevalence of F. gigantica, Paramphistomes and S. bovis

Prevalence of trematode infections was found to be 65.7%. The individual frequency of *F. gigantica*, paramphistomes, and *S. bovis* (based on egg morphology only, Figure 2) was 35.1%, 60.2% and 3.1%, respectively. (Table 1). All animal species (cattle, goats and sheep) were co-infected with all three parasite species, but sheep were more often co-infected than other animal species (Table 1). The most frequently observed co-infections were between *F. gigantica* and paramphistome at 29.7% (95% CI: 27.3-32.2%).

The Simiyu region was found to have high burden of *F. gigantica* (43% (95% CI: 36.2-50.0), paramphistomes (84.1% (95% CI: 78.3-88.8) and *S. bovis* infections (7.7% (95% CI: 4.4-12.2) in cattle compared to the Mwanza and Iringa regions (Table 2). Comparatively, the Simiyu region exhibited the highest prevalence of *F. gigantica*, paramphistomes, and *S. bovis* in goats and sheep compared to the other study regions (Table 2).

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Table 1. The prevalence of trematode infections (*F. gigantica, Paramphistomes* and *S bovis*) by animal species.

	Cattle N=739		Goats N=319		Sheep N=309		Total N=1367	
	++	%(95%CI)	++	%(95%CI)	++	%(95%CI)	++	%(95%CI)
F.gigantica	289	39.1 (35.6-42.7)	75	23.5 (19.0-28.6)	116	37.5 (32.1-43.2)	480	35.1 (32.6-37.7)
paramphistomes	484	65.5(61.9-68.9)	155	48.6 (43.0-54.2)	184	59.6 (53.8-65.1)	823	60.2 (57.6-62.8)
S.bovis	24	3.3 (2.1-4.8)	7	2.2(0.9-4.5)	12	3.9 (2.0-6.7)	43	3.1(2.3-4.2)
***F. gigantica*+ paramhistomes**	247	33.4 (30.0-37.0)	65	20.4(16.1-25.2)	94	30.4(25.3-35.9)	406	29.7(27.3-32.2)
F. gigantica*+ *S.bovis	16	2.2 (1.2-3.5)	5	1.6(0.5-3.6)	11	3.6 (1.8-6.3)	32	2.3 (1.6-3.3)
Paramphistomes + *S. bovis*	23	3.1(1.9-4.6)	7	2.2(0.9-4.5)	11	3.6 (1.8-6.3)	41	3.0 (2.2-4.0)
F. gigantica* + paramphistomes + *S. bovis	16	2.2 ((1.2-3.5)	5	1.6 (0.5-3.6)	10	3.2(1.6-5.9)	31	2.3(1.5-3.2)
Overall Prevalence	**527**	**71.3 (67.9-74.5)**	**165**	**51.7(46.1-57.3)**	**206**	**66.7(61.1-71.9)**	898	65.7(63.1-68.2)

N: Examined domesticated ruminants, ++: infected domesticated ruminants, CI: confidence interval.

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Table 2. The prevalence of trematode infections (*F. gigantica,* paramphistomes and *S. bovis*) by region.

	F.gigantica						**Paramphistomes**						***S. bovis***					
	Cattle		**Goat**		**Sheep**		**Cattle**		**Goat**		**Sheep**		**Cattle**		**Goat**		**Sheep**	
Region	**++**	**%(95%CI)**	**++**	**%(95%CI)**	**++**	**%(95%CI)**	**++**	**%(95%CI)**	**++**	**%(95%CI)**	**++**	**%(95%CI)**	**++**	**%(95%CI)**	**++**	**%(95%CI)**	**++**	**%(95%CI)**
SIMIYU	89	43(36.2-50.0)	42	37.8(28.8-47.5)	52	48.1(38.4-58.0)	174	84.1(78.3-88.8)	71	64.0(54.3-72.9)	81	75(65.7-82.8)	16	7.7(4.4-12.2)	5	4.5(1.5-10.2)	12	11.1(0.6-18.6)
IRINGA	110	35.7 (30.4-41.3)	3	2.6 (0.5-7.4)	23	20.7(13.6-29.4)	186	60.4(54.7-65.9)	40	34.8((26.1-44.2)	57	51.4(41.7-60.9)	6	2(0.7-4.2)	1	0.9(0.0-4.7)	0	0(0.0-0.3)
MWANZA	90	40.2 (33.7-46.9)	30	32.3(22.9-42.7)	41	45.6(35.0-56.4)	124	55.4(48.6-62.0)	44	47.3(36.9-57.9)	46	51.1(40.3-61.8)	2	0.9(0.1-3.2)	1	1.1(0.0-5.8)	0	0(0.0-0.4)

N: Examined domesticated ruminants, ++: infected domesticated ruminants, CI: confidence interval.

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The associations between trematode infections and demographic characteristics (sex, age, and breed) of cattle, goats, and sheep are shown in Table 3, Table 4, and Table 5, respectively. Adult cattle (24+ months) were at higher risk of infection with paramphistomes (AOR: 1.98; 95% CI: 1.40-2.78) and *S. bovis* (AOR: 8.5; 95% CI: 1.12–64.19) than younger cattle (Table 3). Locally bred cattle were more susceptible to paramphistomes infection (AOR: 8.19; 95% CI: 1.76-38.09) than were crossbred cattle and low risk of infection with *F. gigantica* (AOR: 0.61; 95% CI: O.19-1.92) and *S. bovis* (AOR: 0.25; 95% CI: 0.03-2.21) (Table 3).

Adult goats (24+ months) were more susceptible to *F. gigantica* infection (AOR: 1.59; 95% CI: 0.92-2.77), paramphistomes (AOR: 1.07; 95% CI: 0.8-1.68) and *S. bovis* (AOR: 3.9; 95% CI: 0.46-32.82) than younger goats, however these associations were not statistically significant (Table 4). Compared with male goats, female goats were less likely to be infected with *F. gigantica* (AOR: 0.83; 95% CI: 0.47-1.46) and *S. bovis* (AOR: 0.97; 95% CI: 0.18-5.12) (Table 4).

Female sheep had a 1.63 times higher likelihood of being infected with *S. bovis* compared to male sheep (AOR: 1.63; 95% CI: 0.43-6.17) (Table 5). Adult sheep had higher odds of being infected with *F. gigantica* (AOR: 2.11; 95% CI: 1.28-3.51), paramphistomes (AOR: 1.93; 95% CI: 1.20-3.10), and *S. bovis* (AOR: 2.94; 95% CI: 0.63-13.71) compared to younger sheep. The differences in infection rates between age groups were statistically significant for *F. gigantica* ($P < 0.004$) and paramphistomes ($P < 0.007$), but not for *S. bovis* (Table 5).

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Table 3. Multiple logistic regression analysis of variables associated with *F.gigantica,* Paramphistomes and *S. bovis* infections among cattle.

		F.gigantica					Paramphistomes					*S. bovis*				
	N	**++**	**%**	**AOR**	**95% CI**	**p value**	**++**	**%**	**AOR**	**95% CI**	**p value**	**++**	**%**	**AOR**	**95% CI**	**p value**
Sex																
Male	311	114	36.7				207	66.6				6	1.93			
Female	428	175	40.9	1.17	0.87-1.59	0.303	277	64.7	0.86	0.63-1.19	0.368	18	4.21	1.93	0.75-4.98	0.171
Age																
6-24 months	195	71	36.4				104	53.3				1	0.51			
24+ months	543	218	40.2	1.16	0.83-1.64	0.380	379	69.8	1.98*	1.40-2.78	<0.001	23	4.24	8.5*	1.12-64.19	0.038
Breed																
Cross	12	6	50				2	16.7				1	8.33			
Local	727	283	38.9	0.61	0.19-1.92	0.395	482	66.3	8.19*	1.76-38.09	0.007	23	3.16	0.25	0.03-2.21	0.211

N: Examined domesticated ruminants, ++: infected domesticated ruminants, CI: Confidence interval, AOR: Odds ratio, * p<0.05.

Table 4. Multiple logistic regression analysis of variables associated with *F. gigantica*, Paramphistomes and *S. bovis* infection among goats.

		F.gigantica					Paramphistomes					*S. bovis*				
	N	**++**	**%**	**AOR**	**95% CI**	**p value**	**++**	**%**	**AOR**	**95% CI**	**p value**	**++**	**%**	**AOR**	**95% CI**	**p value**
Sex																
Male	267	69	25.8				135	50.6				7	2.6			
Female	52	6	11.5	0.83	0.47-1.46	0.512	20	38.5	1.19	0.73-1.95	0.486	0	0.0	0.97	0.18-5.12	0.972
Age																

6-24 months	124	23	18.6				59	47.6				1	0.8			
24+ months	195	52	26.7	1.59	0.92-2.77	0.099	96	49.2	1.07	0.68-1.68	0.764	6	3.1	3.9	0.46-32.82	0.210
Breed																
Cross	0															
Local	319	75	23.5	NA			155	48.6	NA			7	2.2	NA		

N: Examined domesticated ruminants, ++: infected domesticated ruminants, CI: Confidence interval, AOR: Odds ratio.

Table 5. Multiple logistic regression analysis of variables associated with *F. gigantica*, paramphistomes and *S. bovis* infection among sheep.

		F. gigantica					**Paramphistomes**					*S. bovis*				
	N	**++**	**%**	**AOR**	**95% CI**	**p value**	**++**	**%**	**AOR**	**95% CI**	**p value**	**++**	**%**	**AOR**	**95% CI**	**p value**
Sex																
Male	108	42	38.9				69	63.9				3	2.7			
Female	199	73	36.7	0.89	0.55-1.46	0.650	115	57.8	0.76	0.46-1.24	0.265	9	4.5	1.63	0.43-6.17	0.472
Age																
6-24 months	112	30	26.8				56	50.0				2	1.8			
24+ months	195	85	43.6	2.11*	1.28-3.51	0.004	128	65.7	1.93*	1.20-3.10	0.007	10	5.1	2.94	0.63-13.71	0.168
Breed																
Cross	0	0	0				0	0				0	0			
Local	309	116	37.5	NA			184	59.6	NA			12	3.9	NA		

N: Examined domesticated ruminants, ++: infected domesticated ruminants, CI: Confidence interval, AOR: Odds ratio, * p<0.05.

3.3. Spatial Distribution of Infections with F. gigantica, Paramphistomes and S. bovis

Infections with *F. gigantica*, paramphistomes, and *S. bovis* showed varying prevalence across regions and districts, with the Lake Victoria zone exhibiting the highest prevalence (Table 2 and Figure 3). Pugu village in the Simiyu region had the highest prevalence rates of *S. bovis* in cattle, goats, and sheep, with rates of 7.8% (95% CI: 3.4-14.9%), 7.4% (95% CI: 2.0-17.9%), and 12.7% (95% CI: 5.3-24.5%) respectively.

F. gigantica was found to be more prevalent in Kanyelele village (Mwanza region) in sheep, at a prevalence of 70.0% (95% CI: 50.6-85.2), while for cattle, the highest prevalence was found in Usengelindete village (Iringa region), at 54.6% (95% CI: 44.8-64.2), and for goats, in Itubukilo village (Simiyu region), at 42.1% (95% CI: 29.1- 55.0)

The highest prevalence of paramphistomes was found in Itubukilo A Village for both cattle and sheep, at 88.6% (95% CI: 80.9-93.9%) and 88.7% (95% CI: 77.0-95.7%), respectively. The greatest percentage of paramphistomes was found in Lupembelwasenga village (80.0%, 95% CI: 51.9-95.7%).

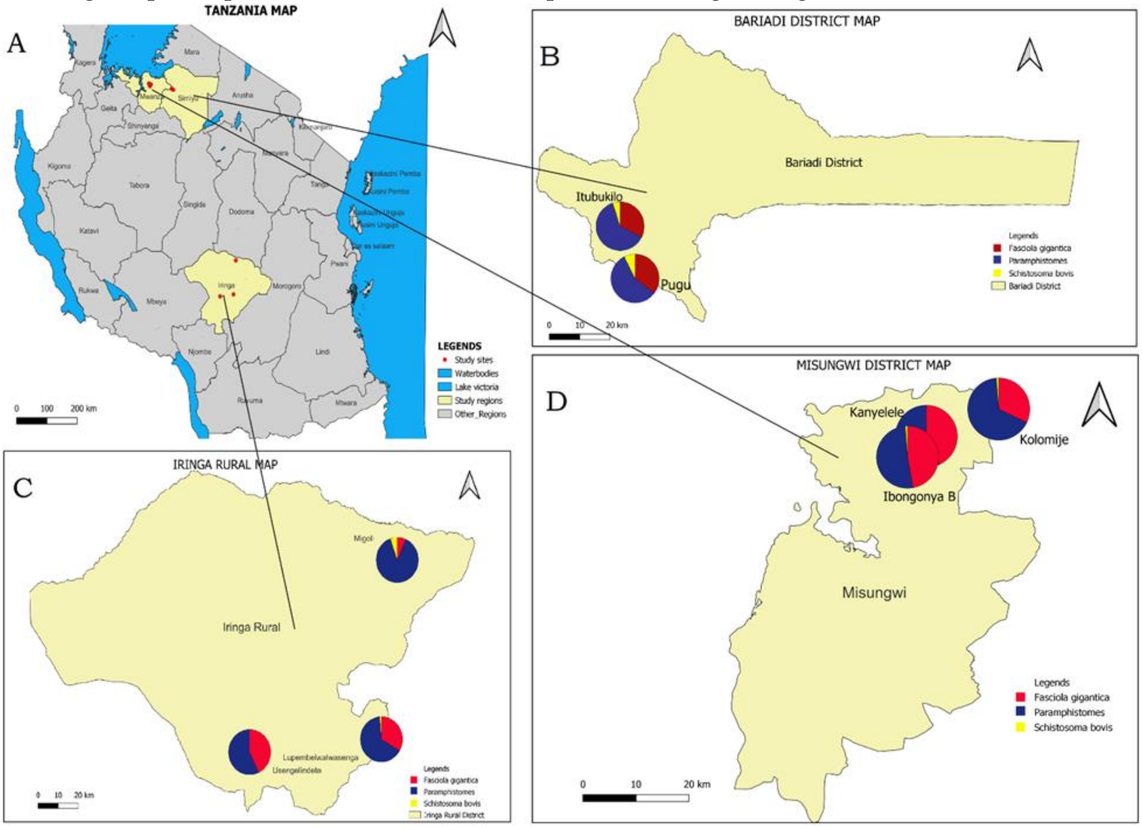

Figure 3. A map showing trematode infections distribution across villages sampled in the Bariadi, Misungwi and Iringa rural district councils of Tanzania.

3.4. Fecal Egg Count

The average (±SE) fasciola, paramphistomes, and schistosoma egg counts in cattle were 2.4 (0.06), 3.0 (0.06), and 0.8 (0.05), respectively, with ranges of 0.7 to 6.1, 0.7 to 6.3, and 0.7 to 1.4. In goats, the mean epg were 2.5 (0.14), 2.6 (0.09), and 0.8 (0.10), with ranges of 0.7 to 5.9, 0 to 6.2, and 0.7 to 1.4. For sheep, the averages were 2.6 (0.11), 2.9 (0.10), and 0.9 (0.09), with ranges of 0.7 to 6.6, 0.7 to 6.5, and 0.7 to 1.4, respectively.

In goats, there was a significant correlation between age and the average epg for fasciola ($P<0.011$), and paramphistomes showed a significant correlation with body condition ($P<0.028$). Paramphistomes had a higher mean fecal egg count per gram of feces compared to fasciola and schistosoma (Tables 6 and 7).

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Table 6. The mean (±SE) count of Fasciola, paramphistomes and Schistosoma eggs per gram by risk factor in cattle.

Variable name	N	Fasciola		Paramphistomes		Schistosome	
		Mean (SE)	**P value**	**Mean (SE)**	**P value**	**Mean (SE)**	**P value**
Sex							
Male	311	2.5(0.87)	0.362	3.0(0.92)	0.833	0.7(0.00)	0.223
Female	428	2.4(0.80)		3.0(0.07)		0.8(0.06)	
Animal age							
Weaners	195	2.3(0.13)	0.186	3.0(0.13)	0.921	0.7(0.00)	
Adult	543	2.4(0.07)		3.1(0.06)		0.8(0.05)	
Breed type							
Local	727	2.4(0.06)	0.673	3.0(0.05)	0.937	0.8(0.05)	
Cross breed	12	2.2(0.20)		2.9(1.15)		1.4(0.00)	
Animal body condition							
Fat	191	2.3(0.12)	0.435	2.9(0.09)	0.234	0.6(0.00)	
Medium	309	2.5(0.06)		2.8(0.06)		0.8(0.05)	
Lean	239	2.4(0.07)		3.1(0.09)		1.1(0.17)	
Overall	739	2.4(0.06)		3.0(0.06)		0.8(0.05)	

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Table 7. The mean (±SE)) count of Fasciola, paramphistomes and Schistosoma eggs per gram by risk factor in goats and sheep.

	Goat							Sheep						
Variable	**N**	**Fasciola**		**Paramphistomes**		**Schistosome**		**N**	**Fasciola**		**Paramphistomes**		**Schistosome**	
		Mean (SE)	**P value**	**Mean (SE)**	**P value**	**Mean (SE)**	**P value**		**Mean (SE)**	**P value**	**Mean (SE)**	**P value**	**Mean (SE)**	**P value**
Sex														
Male	88	2.6(0.28)	0.791	2.5(0.16)	0.606	0.6(0.00)	0.576	108	2.8(0.18)	0.379	2.8(0.15)	0.743	0.9(0.23)	0.731
Female	231	2.5(0.15)		2.6(0.11)		0.8(0.13)		202	2.6(0.15)		2.9(0.12)		0.8(0.10)	
Age														
Weaners	124	3.0(0.28)	0.011	2.6(0.13)	0.987	1.4(0)		115	2.9(0.29)	0.101	2.8(0.17)	0.947	0.7(0.00)	0.417
Adult	195	2.3(0.14)		2.6(0.12)		0.7(0.00)		195	2.5(0.11)		2.9(0.11)		0.9(0.11)	
BCS														
Lean	8	2.1(0)		3.1(1.33)				20	2.5(0.6)		2.7(0.43)		0.7(0.00)	
Medium	247	2.5(0.13)		2.7(0.09)	0.028	0.8(0.66)		216	2.7(0.13)	0.765	2.7(0.11)	0.067	0.9(0.11)	
Fat	64	0.7(0)		1.9(0.26)				71	2.2(0.16)		3.2(0.17)			
Overall	319	2.5(0.14)		2.6(0.09)		0.8(0.10)		309	2.6(0.11)		2.9(0.10)			

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4. Discussion

The burden of trematode infections of *F. gigantica*, paramphistomes, and *S. bovis* in domesticated ruminants in various ecological zones (specifically the Lake Zone (Mwanza and Simiyu) and Southern Highlands) of Tanzania has been investigated for the first time in this study.

The results indicated that domesticated ruminants in the study regions of Tanzania have a high prevalence of *S. bovis*, paramphistomes, and *F.gigantica* infections. Cattle showed a higher prevalence of *S. bovis*, paramphistomes, and *F.gigantica* compared to small ruminants, which is consistent with findings from the study conducted in Côte d'Ivoire by Kouadio *et al*.,[13]. This could be attributed to the fact that goats primarily consume leaves and heaths in elevated areas, while sheep graze on open land, and cattle graze near water bodies. As a result, cattle are at a greater risk of being exposed to water, where the infective parasite stage is present, leading to transmission.

It was found that paramphistomes and *F. gigantica* are the predominant trematode infections in cattle, goats, and sheep. This aligns with earlier research conducted in Tanzania and other parts of Africa [7,32,36]. The study found that paramphistomes had the highest average fecal egg count per gram of feces (epg) followed by *F. gigantica* and *S. bovis*. A similar pattern of infection load for these three trematodes has been documented in various regions of Tanzania and other parts of Africa [32,37].

In this study, the high occurrence of paramphistomes could be attributed to the fact that the adult parasite is highly productive and capable of surviving in the host for extended periods [38]. Paramphistome parasites are known for their high reproductive capacity and their ability to thrive in harsh conditions [39]. Additionally, many broad-spectrum anthelmintics, such as albendazole, ivermectin, and triclabendazole, which are commonly used to prevent important nematode and trematode parasites, have minimal or no impact on paramphistomes [40].

The prevalence of *S. bovis* infection in this study was lower compared to other trematodes, aligning with the findings of Nzalawahe study [32]. Furthermore, schistosomal eggs are not always excreted in feces because they are sometimes left trapped in tissues, which may result in a low prevalence in fecal samples [41]. Additionally, the host organism immune response against schistosomes is directed towards the suppression of worm fecundity, resulting in reduced egg output rather than elimination of adult worms [42].

The higher occurrence of *F. gigantica* may be attributed to the higher prevalence of Fasciola in the study regions. In contrast, a study conducted in southern Ethiopia also demonstrated a higher prevalence of *F. gigantica* in cattle [43]. The predominant co-infection of trematodes in this study was observed between *F. gigantica* and paramphistomes. This could be attributed to the similarities in the life cycles of these parasites, which both rely on lymnaeid snails as intermediate hosts [44,45].

The observed distribution of trematode infections in this study is likely determined by the natural ecology of the study areas. These water bodies not only provide habitats for intermediate snail hosts of parasites [46], but also animal-water contact sites, and aquatic plants that can be consumed by domesticated animals, all of which play essential roles in maintaining the transmission cycle of trematode infections. The results of previous study conducted in the southern highlands of Tanzania indicated that the spread of trematode infection is impacted by the management of domesticated ruminants [7]. This finding aligns with a study carried out in Mali, which demonstrated that factors such as climate, the presence of water bodies, and the type of domesticated ruminant rearing systems can affect the prevalence of trematode infections [47].

Adult cattle were more infected by paramphistome and *S. bovis* infections compared to younger animals, likely due to prolonged exposure to contaminated water while grazing. This pattern has also been observed in Nigeria [48] and Tanzania [46].

The study limitations include the small sample size for goats and sheep in comparison to cattle across all study villages. Additionally, the study did not document the treatment history, which could have impacted the prevalence of trematode infections. The identification of parasite species relied solely on egg morphology. Nonetheless, this study underscores the significance of trematode infections of veterinary importance in Tanzania. It is also the first study to provide a comprehensive overview of the magnitude and distribution of these trematode infections among domesticated ruminants in the Lake Victoria Zone (Mwanza and Simiyu regions) of Tanzania.

5. Conclusions

The study revealed that paramphistomes and *F. gigantica* were more prevalent trematode infections in cattle, goats, and sheep sampled from the Lake Victoria zone (Mwanza and Simiyu) and southern highlands (Iringa region) of Tanzania. The findings clearly show that trematode infections are prevalent across the two study areas, with the highest prevalence found in the lake zone (Mwanza and Simiyu regions); thus, effective and community-acceptable prevention and control interventions are needed to break the transmission cycle and hence reduce fecal egg contamination of the environment and open water sources.

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Informed Consent Statement: Informed consent was obtained from the owners of all animals involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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