




# A large-scale epidemiological investigation on trematode infections in small ruminants in Bangladesh

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## Abstract

**Background:** The important trematode species in small ruminants: *Paramphistomum* sp., *Fasciola* spp. and *Schistosoma* spp. seriously affect the productivity of domestic ruminants in endemic areas.

**Methods:** In the present study, we identified the potential risk factors associated with trematodes infections in small ruminants in seven topographic zones of Bangladesh using simple sedimentation and modified Stoll' ova counting technique.

**Results:** A total of 2440 samples were examined, where 965 were found positive with one or more trematode species with an overall prevalence of 39.5% (95% CI, 37.6%–41.5%) and intensity of infection was  $264.77 \pm 9.86$  egg per gram of faeces. Three trematode species were identified namely *Paramphistomum* sp. (34.1%, 32.2%–36.0%), *Fasciola* spp. (7.5%, 6.5%–8.6%) and *Schistosoma* spp. (2.7%, 2.1%–3.5%). Prevalence of co-infection was 4.8%. The spatial distribution of trematode infections varied from 29.5% to 53.6%. Univariate analysis revealed that physiological condition of females, body condition, farming system, deworming and season were significantly ( $p < 0.05$ ) associated with trematodes infections in small ruminants. By multiple logistic regression model, three factors such as physiological condition of females (pregnant and lactating), poor body condition and animals without deworming were identified as potential risk factors for trematodes infection in small ruminants.

**Conclusion:** Trematode infections are prevalent in the study areas and *Paramphistomum* sp. is most common in different areas among the identified trematodes species. Government should take necessary action to appraise an effective control strategy of trematode infections in small ruminants.

## KEYWORDS

Bangladesh, risk factors, small ruminants, trematode infections

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## 1 | INTRODUCTION

Livestock is one of the sub-sectors of agriculture in Bangladesh with the most potential, which plays an indispensable role in promoting human health and the national economy of the country. Trematode infections are predominantly found in livestock and wild life, and cause serious economic loss to livestock globally, especially in humid tropics and sub-tropics, including Bangladesh (Barmon et al., 2014; Biswas et al., 2014; M. N. Hossain et al., 2021; M. S. Hossain et al., 2015; Islam et al., 2017). Fascioliasis (*Fasciola gigantica*—liver fluke), schistosomiasis (*Schistosoma* spp.—blood fluke) and paramphistomiasis (*Paramphistomum* spp.—rumen fluke) are the important and common trematode infections of ruminants. Prevalence varied from 10.0%–32.0% in fascioliasis, 17.5%–43.8% in schistosomiasis, 39.3%–65.3% in paramphistomiasis in goats while in sheep 6.1%–31.0% for fascioliasis, 3.5%–3.8% for schistosomiasis, 13.2%–67.0% for paramphistomiasis in Bangladesh (Dey et al., 2021; Hassan et al., 2011; Poddar et al., 2017; Yasin et al., 2018). Additionally some of them are considered as important zoonotic parasites and have a serious public health concern worldwide (Rojas et al., 2010).

Fascioliasis is prevalent in small ruminants in Bangladesh (Dey et al., 2021; M. A. Rahman et al., 2017) and responsible for economic loss due to liver condemnation, reduced growth rate, anaemia, decreased production, severe morbidity and sudden death (Coelho & Lima, 2003; Kofta et al., 2000). More than 700 million domestic ruminants are at risk and economic loss exceeds US\$ 3 billion per year around the world (Spithill et al., 1999) due to fascioliasis. Globally, approximately 50 million people are affected by human fascioliasis, a neglected tropical disease (NTD) (Nyindo & Lukumbagire, 2015).

Schistosomiasis is an infectious disease of cattle, sheep, goats, buffaloes, horses, cats and humans around the world (Cable, 1967). This parasite is considered a major helminthosis of domestic animals in Africa and Asia (Hassan et al., 2011) and is also the second major parasitic problem for humans in the world affecting 250 million people and about 800 million people, mostly children at risk to this infection. In humans, the disease burden is attributed to 1430 disability-adjusted life years (DALYs) per year (Anisuzzaman & Tsuji, 2020) worldwide, which is higher than leishmaniasis. In animals, the disease causes significant economic losses through morbidity and mortality due to the severe and long-standing chronic nature of infection (Edward & Andrews, 2002). Paramphistomiasis is distributed worldwide but the highest prevalence was reported in tropical and sub-tropical regions, particularly in Asia and Africa (Cable, 1967). Pathogenicity and impact of the disease associated with *Paramphistomum* spp. was previously under-estimated but recently it has been reported to be an important cause of loss of production. Mainly immature flukes are responsible for clinical manifestation of paramphistomiasis because they are plug feeders and embedded in the mucosa of upper ileum and duodenum resulting in severe erosion. Enteritis characterized by oedema, haemorrhage, ulceration and associated anaemia and hypoproteinaemia are noticed in heavy infection. In the Indian subcontinent, immature paramphistomiasis of domestic ruminants is next to fascioliasis and up

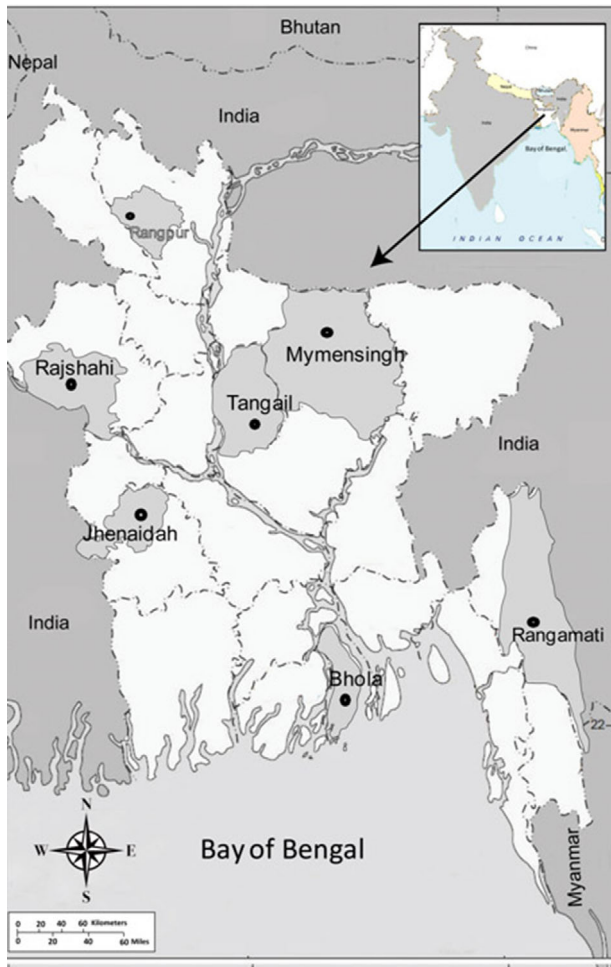
to 30% mortality in cattle or 75%–88% in sheep and goats was reported (Taylor et al., 2007).

Trematodes are snail borne helminthes and their prevalence and severity in a certain geographical region are greatly influenced by many dependent and independent variables including the micro-climate, management, availability of intermediate host and susceptible population in that particular region (M. H. Rahman et al., 1996). Although, it is essential to find out the epidemiological as well as risk factors in a particular region to formulate a strategic control program of the disease, only some sporadic/ scattered studies on prevalence of fascioliasis, schistosomiasis and paramphistomiasis in small ruminants were conducted in different areas of Bangladesh (Dey et al., 2021; Islam et al., 2017; A. K. M. A. Rahman et al., 2017; Yasin et al., 2018) and spatial distribution of the diseases based on country wide data is yet to be done. Importantly, understanding the spatial distribution of a particular disease and identifying clusters, hotspots, risk factors and risk mapping are vital to focus scarce resources for conducting treatment and control programs on already affected areas or areas at risk. Therefore, the aim of the study is to identify potential risk factors of trematode infections in small ruminants in Bangladesh.

## 2 | MATERIALS AND METHODS

### 2.1 | Study area

A cross sectional study was conducted from July 2017 to June 2018 to determine the prevalence of trematode infections in small ruminants in Bangladesh. Bangladesh lies between 20°34' N and 26°38'N; and between 88°01'E and 92°41'E. It has seven topographical zones on the basis of soil topography such as Madhupur tract, Barind tract, Tista silt, Brahmaputra Alluvium, Gangetic Alluvium, coastal saline tract and hill tract of Bangladesh (Figure 1). In this study, each upazila from each topographic zones was selected and samples were collected from Madhupur (Tangail district, Madhupur tract), Godagari (Rajshahi district, Barind tract), Badarganj (Rangpur district, Tista silt), Mymensingh Sadar (Mymensingh district, Brahmaputra Alluvium), Shaikopa (Jhenaidah district, Gangetic Alluvium), Char Fasson (Bhola district, coastal saline tract) and Rangamati Sadar (Rangamati district, hill tract). The soil topography and surface elevation from the sea level slightly vary among seven topographic zones. Surface elevation ranges from less than 1.0 m in coastal saline tract to about 1000 m in the Hill tract. Tista silt possesses the second highest position according to surface elevation. The Madhupur and Barind tract are also elevated at 15–40 m from the sea level. The elevation of Gangatic Alluvium and Brahmaputra Alluvium is fairly low (1–10 m) (Shamsud-duha et al., 2009). The soil pH among the seven topographic zones varies from 5.5 to 8.5. But no distinct climatic difference was reported among the seven zones although the country is situated in both tropical and sub-tropical areas. In Bangladesh, three seasons can be distinguished; namely the cool-dry winter (November–February), the hot dry summer (March–June) and the hot-wet rainy season (July–October)



**FIGURE 1** Seven topographic zones of Bangladesh from where samples were collected from sheep and goats

(Ahmed et al., 1989). Samples were collected very carefully by one sample collecting team in each of the three seasons by maintaining a sampling calendar.

## 2.2 | Study design

A simple random sampling method was employed to collect samples. The sample size was calculated to be 378 from each topographic zone of Bangladesh based on the formula,  $n = 1.96^2 (P_{exp} (1 - P_{exp})) / d^2$ , where  $n$  = sample size,  $P_{exp}$  = expected prevalence,  $d$  = desired precision (Thrusfield, 1995). We used expected prevalence 56% ( $p = 0.56$ ) as per available literature, a precision of 5% ( $d = 0.05$ ), and confidence level 95% (i.e., 1.96).

## 2.3 | Data collection

A prescribed questionnaire with the information of the host, management system and owners was used by the participants. Data were col-

lected by examining the animals and by interviewing the owners. The variables included in this study were species, sex, age, physiological condition of female, body condition (e.g., body condition score [BCS]), farming system, deworming, knowledge about trematode infections and education level of farmers and seasons (Supporting Information 1).

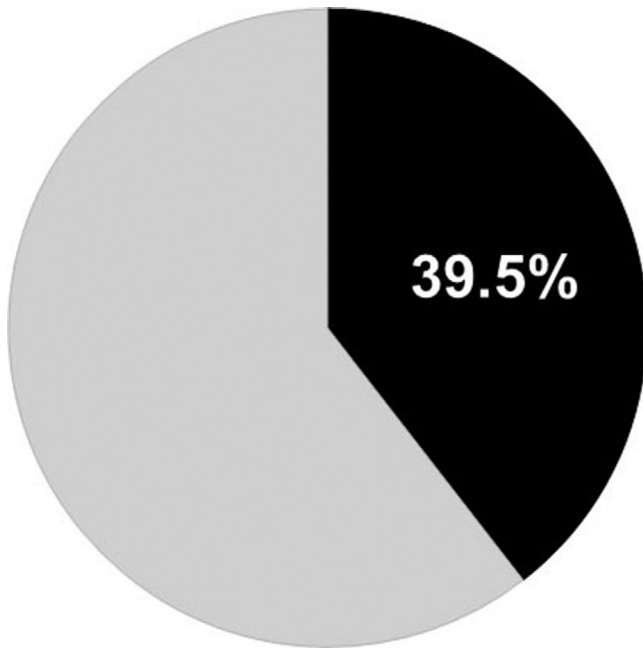
The age of the animal was categorized into three groups such as kids (1–6 months), young (>6–18 months) and old (>18 months) according to the eruption chart of teeth and also by interviewing farmers (Samad, 2008). The physiological condition of females was categorized as pregnant, lactating and non-pregnant. Body condition was categorized as poor body conditioned animals ( $BCS \leq 2$ ) and good body conditioned animals ( $BCS > 2$ ) following the parameters described previously (Dey et al., 2020, 2021). Briefly, in case of  $BCS \leq 2$ , animals were emaciated and weak. The backbone was visible with continuous ridge and the flank was hollow. Ribs could be seen or were covered with small amount of fat. The intercostal spaces were smooth but could be penetrated. In  $BCS > 2$ , animals were apparently healthy. The backbone was not prominent or could not be seen or was found covered with a layer of fat. The intercostal space could be felt by pressure or found covered with excessive fat. The farming system of animals was categorized as backyard and semi-intensive; flock size was grouped as  $\leq 5$ ,  $>6$ – $20$  and  $>20$  and housing was categorized as muddy and concrete/slatted.

## 2.4 | Sample collection and coprological examination

Fresh faecal samples were collected directly from the rectum using index finger by wearing sterile hand gloves and immediately placed kept in suitable airtight screw cap vials containing 10% formalin. For partial screening, samples were examined using simple sedimentation technique as described previously (Yasin et al., 2018). The sediment was examined in triplicates. Positive samples were considered for quantification of egg/ova. To determine faecal egg counts (FEC), modified Stoll's Ova Counting technique was performed as described previously (Thienpont et al., 1986). Briefly, 3 g of faecal samples was weighted and taken into a beaker with 42 ml 0.1% NaOH solutions. A homogenous mixture was prepared and strained through a series of sieves (400, 100 and 45 mm) to remove coarse particles. After stirring the sediment, 0.15 ml suspension were taken on a glass slide, covered with gridding slide (22 × 40 mm gridding area) and examined under compound microscope using 10× objective. Each sample was examined in triplicates. Eggs were identified following keys and description given by Soulsby (Soulsby, 1982) and Thienpont et al. (1986). The number of eggs in a sample was multiplied by 100 to estimate the number of eggs per gram of faeces.

## 2.5 | Statistical analyses

The data were analyzed using Statistical Package for the Social Sciences (SPSS) version 20.0. At first, data were organized for univariate analysis to find out the effect of individual risk factors on trematode



**FIGURE 2** Overall prevalence of trematode parasites in small ruminants in Bangladesh. Faecal samples from goats (1891) and sheep ( $n = 549$ ) were collected, preserved in 10% formalin, and examined under microscope using simple sedimentation technique

infections. The variables that resulted significant ( $p < 0.05$ ) in the univariate analysis were selected as potential candidates for multivariable analysis (multiple logistic regression with backward stepwise elimination). The  $p$  values for data inclusion and exclusion were set at 0.05 and 0.1, respectively. The final model was constructed with a significance level of  $p \leq 0.05$ . Kruskal–Wallis test was used to compare the mean EPG value of faecal egg count.

### 3 | RESULTS

#### 3.1 | Overall prevalence and intensity of trematode infections in small ruminants in Bangladesh

A total of 2440 faecal samples from small ruminant were randomly collected and examined and 965 samples were found positive with one or more species of trematodes with an overall prevalence of 39.5% (Figure 2). The overall intensity of infection was calculated as  $264.77 \pm 9.86$  egg per gram of faeces in seven topographic zones of Bangladesh. The spatial distributions of prevalence and intensity of trematodes infection were ranged from 29.5%–53.6% and  $156.94 \pm 6.13$ – $423.58 \pm 42.29$ , respectively in seven topographic zones in Bangladesh. The highest prevalence was found in Barind tract and the lowest in hill tract. But intensity of infection was the highest in Jhenaidah (Gangatic Allivium) and the lowest in Tangail (Madhupur tract) (Table 1). The detected ova of trematodes were *Paramphistomum* sp. (34.1%,  $269.90 \pm 11.33$ ), *Fasciola* spp. (7.5%,  $135.87 \pm 7.19$ ) and *Schistosoma*

**TABLE 1** Prevalence trematodes infection of small ruminants in different topographic areas of Bangladesh

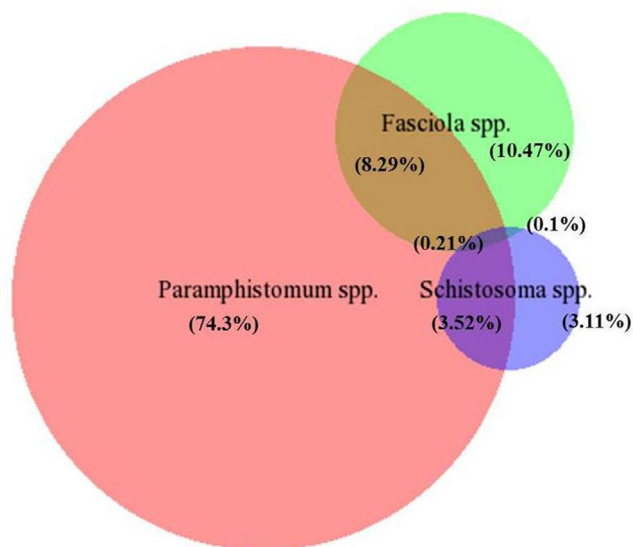
Regions	Paramphistomum sp.	Fasciola spp.	Schistosoma spp.	Infected/Prevalence(%)	EPG	
					Range	Mean $\pm$ SE
Bhola (274)	86 (31.4)	5 (1.8)	30 (10.9)	100 (36.5 <sup>abc,d</sup> )	100–2900	311.00 <sup>a</sup> $\pm$ 42.19
Rangpur (380)	131 (34.5)	46 (1.8)	3 (0.8)	158 (41.6 <sup>d</sup> )	100–2300	285.44 <sup>b</sup> $\pm$ 25.52
Rangamati (363)	89 (24.5)	21 (5.8)	7 (1.9)	107 (29.5 <sup>c</sup> )	100–2900	263.55 <sup>c</sup> $\pm$ 23.21
Jhenaidah (290)	111 (38.8)	32 (11.0)	4 (1.4)	123 (42.4 <sup>b,d</sup> )	100–2300	423.58 <sup>d</sup> $\pm$ 42.29
Mymensingh (433)	164 (38.8)	14 (3.2)	23 (5.3)	186 (43.0 <sup>b,e</sup> )	100–1000	184.41 <sup>e</sup> $\pm$ 9.50
Tangail (426)	119 (27.9)	36 (8.5)	0 (0.0)	144 (33.8 <sup>a,c</sup> )	100–500	156.94 <sup>f</sup> $\pm$ 6.13
Rajshahi (274)	129 (47.1)	30 (10.9)	0 (0.0)	147 (53.6 <sup>e</sup> )	100–2100	286.39 <sup>g</sup> $\pm$ 25.13
<b>Overall (2440)</b>	<b>833 (34.1)</b>	<b>184 (7.5)</b>	<b>67 (2.7)</b>	<b>965 (39.5)</b>	<b>100–4900</b>	<b>264.77 <math>\pm</math> 9.86</b>

Each subscript letter denotes a subset of area categories whose column proportions do not differ significantly from each other at the 0.05 level; CI, Confidence Interval; EPG, Egg per gram of faeces; SE, Standard error.

**TABLE 2** Prevalence of identified trematodes of small ruminants in Bangladesh

Name of parasites	Infected	Prevalence(%)	95% CI (%) Ranges	EPG	
				Mean ± SE	
<i>Paramphistomum</i> sp.	833	34.1	32.2–36.0	100–4900	269.90 ± 11.33
<i>Fasciola</i> spp.	184	7.5	6.5–8.6	100–1000	135.87 ± 7.19
<i>Schistosoma</i> spp.	67	2.7	2.1–3.5	100–3000	165.67 ± 43.35
<b>Overall</b>	<b>965*</b>	<b>39.5</b>	<b>37.6–41.5</b>	<b>100–4900</b>	<b>264.77 ± 9.86</b>

\*Total no. of animals affected is less than the summation of individual infection because same animal was infected with more than one type of trematode species; CI, Confidence Interval; EPG, Egg per gram of faeces; SE, Standard error.



**FIGURE 3** A Venn diagram showing overlap in coprological prevalences of *Paramphistomum* sp., *Fasciola* spp., and *Schistosoma* spp. in small ruminants

spp. (2.7%, 165.67 ± 43.35) (Table 2). Prevalence of infection with *Paramphistomum* sp. was 24.5%–47.1% in different topographic zones. Infection with *Fasciola* spp. varied from 1.8%–11.0%. Interestingly, prevalence of *Schistosoma* spp. was the highest in Bhola (10.9%) and absent in Tangail and Rajshahi. Co-infection with more than one trematodes was detected in 117 animals (4.8%) with the combination of *Paramphistomum* sp. and *Fasciola* spp. (80, 8.29%); *Paramphistomum* sp. and *Schistosoma* spp. (34, 3.52%); *Fasciola* spp. and *Schistosoma* spp. (1, 0.1%); *Paramphistomum* sp., *Fasciola* spp. and *Schistosoma* spp. (2, 0.21%) (Figure 3).

### 3.2 | Potential factors associated with trematode infections in small ruminants

In all examined samples (2440), trematode infections were more or less equally distributed in goats (39.7%) and sheep (39.0%), and male (39.4%) and female (39.6%). According to age group, young and adults were more susceptible to trematode infections than animals' kids and

mean faecal egg count were higher in young (272.16 ± 15.52) and adults (265.12 ± 13.35) than kids (203.26 ± 15.18). Our study revealed that non-descriptive breed was insignificantly more susceptible to infections than black Bengal goats. Trematode infections were significantly associated with physiological condition of females, body condition, deworming and farming system of animals. The status of animal owners' knowledge about trematodes infections and education level were insignificantly associated with trematodes infections. Mean faecal egg counts were significantly associated with poor body condition of animals, animals without anthelmintic treatment and farmers with no institutional education background (Table 3). Seasons had a significant association with the prevalence and intensity of trematodes infections in small ruminants. Significantly, higher prevalence and intensity of trematodes infection were observed in rainy (43.3%, 256.93 ± 16.05) and summer season (48.0%, 303.76 ± 18.28) than that in winter (27.8%, 209.40 ± 11.90) (Table 4).

### 3.3 | Risk factors associated with trematodes infection in small ruminants

In the present study, according to multiple logistic regression models, physiological condition of females (pregnant and lactating), poor body condition and animals without anthelmintic treatment were identified as risk factors. The stressed females that is, pregnant and lactating females were 1.45 times and 1.34 times more susceptible to trematodes infections than non-stressed females. Prevalence of trematode infections was 1.32 times more in poor conditioned animals than good-conditioned animals. Animals not treated with anthelmintics against trematodes infections were 1.56 times more prone to trematode infections than animals treated with anthelmintics (Table 5).

## 4 | DISCUSSION

Small ruminants contribute to the livelihoods of millions of rural poor in South Asia. Small and marginal farmers as well as landless, particularly women are increasingly relying on keeping of sheep and goats for their socioeconomic upliftment (Dey et al., 2020). But sheep and goat rearing under intensive and extensive production systems is highly susceptible to a wide range of helminths (Abede & Esayas, 2001).



**TABLE 3** Potential factors associated with trematodes infection in small ruminants

Risk Factor	Infected (%)	95% CI (%)	OR 95% CI	EPG	
				Range	Mean $\pm$ SE
Species					
Goat (1891)	751 (39.7 <sup>a</sup> )	37.5–41.3	1.03 (0.84–1.25)	100–2900	246.60 <sup>a</sup> $\pm$ 10.41
Sheep 549	214 (39.0 <sup>a</sup> )	34.9–43.1		100–2300	328.50 <sup>b</sup> $\pm$ 24.92
Sex					
Female (1562)	619 (39.6 <sup>a</sup> )	37.2–42.0	1.00 (0.85–1.19)	100–2900	276.74 <sup>a</sup> $\pm$ 13.34
Male (878)	346 (39.4 <sup>a</sup> )	36.2–42.6		100–2100	243.57 <sup>a</sup> $\pm$ 13.63
Age					
1–6 months (246)	92 (37.4 <sup>a</sup> )	31.5–43.6	1.06 (0.79–1.40)	100–700	203.26 <sup>a</sup> $\pm$ 15.18
>6–18 months (914)	377 (41.2 <sup>a</sup> )	38.1–44.5	1.10 (0.93–1.31)	100–2900	279.31 <sup>a</sup> $\pm$ 17.69
>18 months 1280	496 (38.8 <sup>a</sup> )	36.1–41.4		100–2100	265.12 <sup>a</sup> $\pm$ 13.35
Breed					
Non descriptive breed (282)	119 (42.2 <sup>a</sup> )	36.4–48.0	1.12 0.87–1.45	100–4900	257.90 <sup>a</sup> $\pm$ 14.0
Black Bengal Goats (1609)	632 (39.3 <sup>a</sup> )	36.9–41.7		100–1200	222.69 <sup>a</sup> $\pm$ 17.59
Pregnant (240)	107 (44.6 <sup>a</sup> )	38.4–50.9	1.41 (1.05–1.89)	100–1700	297.20 <sup>a</sup> $\pm$ 29.83
Physiological condition of female					
Lactating (475)	205 (43.2 <sup>b</sup> )	38.9–47.6	1.33 (1.06–1.67)	100–2100	270.73 <sup>a</sup> $\pm$ 22.18
Non pregnant (847)	307 (36.2 <sup>c</sup> )	33.0–39.5		100–2900	273.62 <sup>a</sup> $\pm$ 19.94
Body condition					
Poor conditioned animal (1285)	556 <sup>a</sup> (43.3)	40.6–46.0	1.39 (1.18–1.63)	100–2900	309.54 <sup>a</sup> $\pm$ 17.53
Good conditioned animal (1155)	409 (35.4 <sup>b</sup> )	32.7–38.2		100–2500	231.83 <sup>b</sup> $\pm$ 11.06
Farming system					
Backyard (2005)	813 (40.5 <sup>a</sup> )	38.4–42.7	1.26 1.02–1.57	100–2900	291.45 <sup>a</sup> $\pm$ 29.32
Semi-intensive (435)	152 (34.9 <sup>b</sup> )	30.6–39.5		100–2500	259.78 <sup>a</sup> $\pm$ 10.34
Deworming					
No (2306)	930 (40.3 <sup>a</sup> )	38.3–42.3	1.91 1.28–2.83	100–2900	322.86 <sup>a</sup> $\pm$ 57.70
Yes (134)	35 (26.1 <sup>b</sup> )	19.4–34.1		100–1600	262.58 <sup>b</sup> $\pm$ 10.00
Knowledge about trematodes infections					
No (2237)	897 (40.1 <sup>a</sup> )	38.1–42.1	1.32 (0.98–1.80)	100–2900	266.78 <sup>a</sup> $\pm$ 10.43
Yes (203)	68 (33.5 <sup>a</sup> )	27.4–40.2		100–1200	238.24 <sup>a</sup> $\pm$ 25.83
Education level					
Illiterate (1979)	794 (40.1 <sup>a</sup> )	37.9–42.3	1.13 (0.92–1.40)	100–2900	276.20 <sup>a</sup> $\pm$ 11.51
Literate (461)	171 (37.1 <sup>a</sup> )	32.8–41.5		100–1600	211.70 <sup>b</sup> $\pm$ 14.90

Values with different letters within a column differ significantly ( $p < 0.05$ ); CI, Confidence Interval; EPG, Eggs per gram of faeces; OR, Odds Ratio; SE, Standard error.

**TABLE 4** Univariate analysis of seasons as the potential risk factors for GI trematodes infection in small ruminants

Risk factor	Infected(%)	(95% CI)	OR95% CI	EPG		
				Range	Mean ± SE	
Seasons	Rainy 767	332 (43.3 <sup>a</sup> )	39.8–46.8	1.97 1.60–2.43	100–2300	256.93 ± 16.05
	Summer 832	399 (48.0 <sup>a</sup> )	44.5–51.3	2.39 1.95–2.92	100–2900	303.76 ± 18.28
	Winter 841	234 (27.8 <sup>b</sup> )	24.9–31.0		100–1200	209.40 ± 11.90

Values with different letters within a column differ significantly ( $p < 0.05$ ); CI, Confidence Interval; EPG, Egg per gram of faeces; OR, Odds Ratio; SE, Standard error.

**TABLE 5** Results of final multivariable analysis of potential risk factors associated with GI trematodes infection in small ruminants

Risk factors	OR	95% CI	p-Value
Physiological condition of female (Pregnant)	1.45	1.08–1.95	0.012
Physiological condition of female (Lactating)	1.34	1.06–1.68	0.013
Body condition (Poor conditioned animals)	1.32	1.07–1.63	0.009
No deworming	1.56	0.98–2.47	0.05

CI, Confidence Interval; OR, Odds Ratio. Significant,  $p < 0.05$ .

All trematode species, parasitic in livestock belong to the subclass Digenea. Veterinary important trematodes, belong to the family Fasciolidae, Dicrocoeliidae, Paramphistomatidae and Schistosomatidae resulting impairment of immunity and reduced production of animals (Cable, 1967).

Prevalence of trematode infections in small ruminants varies among seven topographic zones of Bangladesh. Among the seven zones, the hill tract is the most elevated from the sea level. It encompasses mainly hilly area and lacks sufficient water bodies. Aquatic and semi-aquatic environment including drains, furrow, slow moving streams temporary moist areas, bank of rivers and ponds are the essential habitats for the vector snail of trematodes parasites to complete their lifecycle. Due to the lack of aquatic habitat, trematode parasites get less chance to establish their lifecycle, which is responsible for lower prevalence and mean faecal egg count of trematode infections in the hilly areas. Trematode infection was also low in Madhupur tract. Beside the soil topography, vegetation and agro-ecology of the area may be responsible for lower prevalence of fluke infection. Backyard animals in this area habitually intake pineapple and papaya leaves that contain ananain and papain with proven anthelmintic activity to reduce parasitic infection (Behnke et al., 2008). In this study, prevalence of *Paramphistomum* sp. was the highest, which confirms with the findings reported for the three trematodes from different parts of the world (Keyyu et al., 2006; Nzalawahe et al., 2014) and mean faecal egg count was the highest in case of *Paramphistomum* sp. This parasite is detected by different authors with varying level of prevalence by examining the faecal sample in domestic and wild animals (M. A. Rahman et al., 2017; S. M. Rahman et al., 2014). The highest prevalence of

*Paramphistomum* sp. might be explained by the fact that the adult parasite is highly prolific and may survive in the host for years (Dorchies, 2006). The multiplication of this parasite within the infected snails is also massive. They are prolific breeders, and the adaptation capacity is extreme (Hansen & Perry, 1994). Also, routine deworming schedule are not practiced in Bangladesh. Farmers only treat the animals after clinical manifestations. The broad spectrum anthelmintics such as albendazole, ivermectin and triclobandazole are used as chemoprophylaxis against important nematodes and trematodes which have little or no effects on *Paramphistomum* sp. (Rolfe et al., 1991).

*Fasciola* spp. is predominant in ruminants and wildlife, and have been reported from more than 75 countries worldwide including those in Africa and Asia (Dorny et al., 2009; Mas-Coma, Bargues, & Valero, 2005). The prevalence of *Fasciola* spp. observed in this study is comparable to the prevalence of 8.4% reported by previous author (M. A. Rahman et al., 2017). *Lymnaea auricularia* and *L. truncatula* are the intermediate host for *Fasciola* spp. in Bangladesh and responsible for the transmission of the parasite. *L. auricularia* is widely distributed and has been shown to be the paramount intermediate host of *F. gigantica* in Bangladesh (Yasin et al., 2018). The prevalence of *Fasciola* spp. varies from region to region, and is influenced by environmental conditions, animal species, breeding method, animal management practices and availability of intermediate host, snail (Kaplan & Başpınar, 2009).

In this study, *Schistosoma* spp. possessed the lowest prevalence among observed trematode infections. In *Schistosoma* spp., infection in final host occurs by penetrating the skin of susceptible animals through schistosome cercariae, the infective stage, while they graze in water. Lower prevalence of *Schistosoma* spp. may be attributed to the grazing behaviour of animals. As small ruminants show a distinct aversion to immersion in water even avoiding walking through it, this may reduce their potential for exposure of the species (Yasin et al., 2018).

Among trematodes co-infection, the majority were *Paramphistomum* sp. co-infections with *Fasciola* spp. This may be due to similarity in the lifecycles of these parasites, and the involvement of same intermediate hosts, lymnaeid snails (Keyyu et al., 2006). The infective stage, metacercariae of these parasites, is found in the same places and might be ingested together by the animals (Szmidi-Adjidé et al., 2000). This positive relationship between the two parasites has been reported previously (Phiri et al., 2006; Yabe et al., 2008).

In this study, significantly higher prevalence was observed in pregnant and lactating animals than non-pregnant animals. Major hormonal and nutritional changes occur during pregnancy, thus, making the

individual susceptible to helminth infections around parturition (Mpairwe et al., 2014). Previous evidence shows that pregnant animals might be at a greater risk for helminth infections than non-pregnant animals (Hernández-Bello et al., 2010).

Poor body condition was significantly associated with trematode infections in small ruminants, which was supported by the previous observation (Shinggu et al., 2019). Parasites are usually deleterious for their hosts, and have typically been connected with poor body condition of host (Cornet & Sorci, 2010). Animals with poor body condition resulting from nutritional or other health challenges are related with low resistance or susceptibility to parasitic infections. Consequently, animals frequently infected with different parasites have hampered intake of food and utilization of nutrients resulting in worsening condition, stunted growth and production loss (Coop & Kyriazakis, 1999).

Significantly higher trematode infections were found in untreated animals than those of treated animals, which is in line with the previous study (Kanyari et al., 2009). In Bangladesh, educational background of marginal farmers is low and they have no knowledge about parasitic infection especially trematodes. They are unwilling to receive veterinary service and do not maintain deworming schedule for their animals.

Animals reared in scavenging system were significantly more susceptible to trematode infections than that of semi-intensive system, which confirms the finding of earlier report (Elelu & Eisler, 2018). In scavenging management system, animals graze on communal land; at the bank of river or pond and at the side of irrigation canal where green grass is available. In Bangladesh, due to lack of enough pasture land, animals reared by scavenging system use communal land for grazing. The snail intermediate hosts are also present at the water bodies of these locations and are likely to be contaminated with the infective stage of trematode parasites (Yasin et al., 2018). On the other hand, animals reared in semi-intensive system are provided selective fodder, which have less chance of getting infected by the infective stage of flukes (Nzalawahe et al., 2014).

Significantly higher trematode infections were observed in summer and rainy seasons than winter season, which is in agreement of the findings reported previously (Ardo & Aliyara, 2014). Higher prevalence of trematode infections in summer and rainy season may be due to the high abundance of vector snails in marshy land and canals, which provide suitable niches for metacercaria development (Dipeolu et al., 2000; Tahir, 2002).

## 5 | CONCLUSIONS

This study has revealed that trematode infections are highly prevalent in small ruminants in all seven topographic zones in Bangladesh. Among the three species of trematode, *Paramphistomum* sp. Is widely prevalent in small ruminants in different zones. Physiological condition of female (pregnant and lactating), poor body conditioned animals and animals without anthelmintic treatment are identified as potential risk factors for trematode infection in small ruminants. More trematode infections were recorded in summer and rainy seasons. For the betterment of live-

stock production and human food security, government should take necessary initiatives to generate awareness among marginal farmers. Collectively, our data could be helpful for the formulation of effective control measures against economically important snail borne trematode that affects livestock production performance.

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## CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

## ETHICAL APPROVAL

The authors tried to maintain the highest possible ethical standards in their works without any injury of animals. The study was approved by the Animal welfare and ethical committee of Bangladesh Agricultural University (06/AWEC/2017).

## AUTHOR CONTRIBUTION

Anita Rani Dey: Data curation; Formal analysis; Methodology; Software; Validation; Visualization; Writing – original draft. Nurjahan Begum: Conceptualization; Investigation; Methodology; Project administration; Supervision; Writing – review & editing

## PEER REVIEW

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## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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