Veterinary and Animal Science 7 (2019) 100041

Contents lists available at ScienceDirect

Veterinary and Animal Science

journal homepage: www.elsevier.com/locate/vas

Coprological study of trematode infections and associated host risk factors in cattle during the dry season in and around Bahir Dar, northwest Ethiopia

Kassaye Aragaw*, Hana Tilahun

Hawassa University, School of Veterinary Medicine, P.O.Box 05, Hawassa, Ethiopia

ARTICLE INFO

Keywords:
Cattle
Fasciola
Paramphistomes
Schistosoma
Trematodes
Ethiopia

ABSTRACT

This study was conducted to estimate the prevalence and identify risk factors associated with trematode infections in cattle in and around Bahir Dar, northwest Ethiopia. Fecal samples collected from randomly selected 369 cattle were examined using simple sedimentation technique for differential trematode eggs count. The animals were found shedding eggs of three groups of trematodes, namely *Fasciola* spp., paramphistomes and *Schistosoma* spp. The overall prevalence of trematodes was 61.0%, and specific prevalence for *Fasciola*, paramphistomes and *Schistosoma* was 20.1%, 48.5% and 16.5%, respectively. A substantial overlap was observed in the occurrence of *Fasciola* and paramphistomes. The prevalence of all the three trematodes identified in this study was significantly ($P < 0.05$) associated with body condition and breed, while the prevalence of *Fasciola* and paramphistomes was also associated with age. The mean (± SE) fecal egg count per gram of feces (EPG) for *Fasciola*, paramphistomes and *Schistosoma* was 4.3 (± 0.55), 25.7 (± 2.11) and 3.1 (± 0.42), respectively. EPG of *Fasciola* was significantly correlated with EPG of paramphistomes ($P < 0.001$). The EPG for all the three trematodes was associated with body condition and breed of animals ($P < 0.05$), while EPG for paramphistomes was also affected by age of the animals ($P < 0.05$). The prevalence of all the three major trematodes of animal health importance with high rate of mixed infection along with poor body condition, suggests substantial economic loss incurred due to reduced productivity in cattle in the study area.

1. Introduction

Trematode infections, especially fasciolosis, are some of the most economically important helminth diseases hampering the productivity of domestic ruminants worldwide (Dargie, 1987; Mage, Bourgne, Toullieu, Rondelaud, & Dreyfuss, 2002; Njau, Kasali, Scholtens, & Mesfin, 1988). All the trematode species which are parasitic in livestock belong to the subclass Digenea (Hansen & Perry, 1994). The adult trematodes are commonly called 'flukes' and the families which include parasites of major veterinary importance are Fasciolidae, Dicrocoeliidae, Paramphistomatidae and Schistosomatidae (Andrews, 1999; Urquhart, Armour, Duncan, Dunn, & Jennings, 1996).

Fasciola (liver fluke), paramphistomes (rumen/stomach fluke) and *Schistosoma* (blood fluke) are the most important flukes recorded from different parts of the world (Dreyfuss, Alarion, Vignoles, & Rondelaud, 2006).

Fasciolosis is an economically important disease of domestic livestock, in particular cattle and sheep, and occasionally man. *Fasciola hepatica* and *F. gigantica* are the two species most commonly implicated as the etiological agents of fasciolosis (Andrews, 1999). Infection of adult cattle with liver flukes, unless in heavy infections, is usually clinically in apparent. Therefore, under normal conditions, clinical disease is only likely in young cattle (Love, 2017). However, even modest infection can result in significant reduction in milk yield and quality (Urquhart et al., 1996), reduction in weight gain (Hope-Cawdery, Strickland, Conway, & Crowe, 1977; Ross, 1970) and reproductive performance (Elliott, Kelley, Rawlin, & Spithill, 2015). Infection of calves with large number of metacercariae (over 1000), on the other hand, cause clinical fasciolosis similar to the one seen in sheep characterized by weight loss, anemia and hypoproteinemia (Boray, 1969). In addition to its effect on productivity, fasciolosis is a cause of significant economic losses through liver condemnation at slaughter (Abebe et al., 2010; Abunna, Asfaw, Megersa, & Regassa, 2010; Berhe, Berhane, & Tadesse, 2009; Phiri, Phiri, Sikasunge, & Monrad, 2005).

There are several genera of paramphistomes: *Paramphistomum, Cotylophoron, Calicophoron, Bothriophoron, Orthocoelium* and *Gigantocotyle*, of which *Paramphistomum* is the most common and widespread in ruminants (Taylor, Coop, & Wall, 2016). Paramphistomes (amphistomes) are traditionally regarded as having no

* Corresponding author.
E-mail address: kassaye.a@gmail.com (K. Aragaw).

https://doi.org/10.1016/j.vas.2018.11.002
Received 8 August 2018; Received in revised form 25 October 2018; Accepted 1 November 2018
Available online 02 November 2018

clinical significance (Iglesias-Piñeiro et al., 2016). However, heavy infection with immature flukes, which attach to the lining of the upper part of small intestine, may cause severe disease which may even result in death (Lloyd, Boray, & Love, 2007; Rolfe, Boray, Nichols, & Collins, 1991). Moderate infections with the immature fluke may cause reduced weight gains or milk production, or ill-thrift. Most livestock, however, have only light stomach fluke infections with either adult fluke or small numbers of immature fluke that they show no signs of disease (Lloyd et al., 2007).

Schistosomosis in cattle in Africa can be caused by *Schistosoma bovis, S. mattheei* and *S. leiperi*. Schistosomosis is generally considered to be of low importance in large ruminants, and even where a high prevalence of the parasite is detected in slaughtered cattle, clinical signs of the disease are seen only rarely (Urquhart et al., 1996). However, infections sometimes may result in severe clinical signs (Hansen & Perry, 1994).

There are several reports of coproscopic and abattoir surveys indicating the widespread prevalence of liver and stomach flukes in cattle in Ethiopia (Abebe et al., 2010; Abunna et al., 2010; Ameni, Erko, & Bogale, 2001; Fromsa, Meharenet, & Mekibib, 2011; Yeneneh, Kebede, Fentahun, & Chanie, 2012). Prevalence of *Schistosoma* spp. in cattle in some parts of the country with permanent water bodies, seasonal flooding and high rainfall has also been recorded (Ameni et al., 2001; Chanie, Dejen, & Fentahun, 2012; Fromsa et al., 2011; Habtamu & Wolde Mariam, 2011; Habtamu, Negash, Sirak, & Chanie, 2013; Yeneneh et al., 2012). Some studies demonstrated the occurrence of mixed trematode infections in cattle in Ethiopia (Ameni et al., 2001; Fromsa et al., 2011). Several studies in cattle in Ethiopia demonstrated considerable financial loss due to liver condemnation at slaughter due to *Fasciola* infection (Abebe et al., 2010; Abunna et al., 2010; Berhe et al., 2009).

For a rational and sustainable helminth control programme, a comprehensive knowledge of the epidemiology of parasites and their interaction with the host in a specific climate and management system is a prerequisite (Barger, 1999). Therefore this study was conducted with the objectives to estimate the prevalence and identify risk factors associated with infection of cattle with trematodes in and around Bahir Dar.

2. Materials and methods

2.1. Study area and animals

The study was conducted in Bahir Dar town and adjoining Sebatamit village (about 4 km east of Bahir Dar), northwest Ethiopia. Bahir Dar, the capital of Amhara Region, is located on the southern shore of Lake Tana, the largest lake in Ethiopia and the sources of the *Abay* (Blue Nile) river. The town is located approximately 578 km northwest of Addis Ababa, at a latitude and longitude of 11°36′N and 37°23′E and an elevation of 1,800 meters above sea level. The climate conforms to the Ethiopian *woynadega* (mid altitude area) with average annual rainfall of 1500 mm, humidity of 57.88 % and mean annual minimum and maximum temperatures of 10 and 30 °C, respectively. The main rainy season extends from late June to late September. The area has poor drainage and there is annual over flooding during the rainy seasons leaving pockets of water bodies for long period during the dry season (Aregay, Bekele, Ferede, & Hailemelekot, 2013). Both the traditional extensive and semi-intensive farming are practiced in the study area. Sebatamit is a suburban village about 4 km from Bahir Dar located on the bank of the River *Abay*.

The study involved cattle above 6 months of age, both sexes and local and crossbred (Friesian–Zebu) animals managed under the traditional smallholder husbandry system where cattle are often kept outdoor and grazed on communal pastures all day. The animals graze in the vicinities of Lake Tana, the Blue Nile River and its tributaries (Andasa and Tikurit) (Habtamu & Wolde Mariam, 2011). The study was conducted from November 2011 to April 2012.

2.2. Study design and sampling technique

The study was a cross-sectional study involving 369 animals selected using simple random sampling method. Sample size was calculated according to Thrusfield (2005) with 40% estimated prevalence of the parasites (Habtamu & Wolde Mariam, 2011; Solomon & Wossene, 2007) and desired 95% confidence interval and 5% precision.

2.3. Fecal sample and data collection

Feces were collected directly from the rectum of the study animals with gloved hands and were placed in clean universal bottles. The locality, breed, age, sex and body condition of each study animal were recorded at the time of sample collection. Age was estimated using dentition according to Torell, Bruce, Kvasnicka, and Conley (2003) which involves noting the time of appearance and the degree of wear on the temporary and permanent teeth. Cattle estimated to be less than 4 years old were considered as young cattle while those 4 years and above as adults. Body condition was categorized into 3 broad categories (lean, medium and fat) using recommendations by Nicholson and Butterworth (1986).

2.4. Coprological examination

Coprological examination was made at Bahir Dar Regional Veterinary Laboratory; fecal samples, when not examined immediately on arrival, were stored in a refrigerator at 4 °C until examined. Simple sedimentation technique for detection and count of trematode eggs (DAFWA, 2013; Hansen & Perry, 1994; Svendsen, 1997) was used with minor modifications. Briefly, 3 g of feces was put in a container and 40-50 ml tap water was added and mixed thoroughly. The suspension was filtered through a tea strainer and allowed to stand for 5 min. The supernatant was discarded carefully and the sediment was re-suspended in tap water. The sedimentation process was repeated multiple times until the fecal debris and coloring material was removed and the supernatant appear clear. After the last sedimentation the supernatant was removed very carefully and the sediment was recovered into a test tube and re-suspended in about 5 ml tap water, a drop of methylene blue was added, and allowed to stand for 5 min. for effective staining of the debris which leaves the trematode eggs un-stained, all the material was transferred into a Petri dish and examined under low power objective. Trematode egg counts were performed by moving the Petri dish in such a way that every field was examined. Yellow color of *Fasciola* spp. eggs was used to differentiate them from those of paramphistomes (Urquhart et al., 1996). The differential EPG was calculated by dividing the specific parasite egg count in a sample of 3 g by three.

2.5. Data management and statistical analyses

Data collected during sample collection and results of coprological examinations were entered and stored for analysis into Microsoft Excel spread sheet. The effect of age, sex, breed and body condition on infection with trematodes was analyzed using multiple logistic regression model/analysis. Univariable logistic analysis was used to assess the relationship between mixed and single trematode infections with body condition. The Goodman and Kruskal's gamma statistics was used as a measure of correlation of occurrence of the three trematodes. A Venn diagram (Dohoo, Martin, & Stryhn, 2009) was produced to illustrate the level of coinfection with trematodes. The egg count data (EPG) were log transformed [$\log_{10}$(EPG + 1)] and EPG difference between sex, age and breed was analyzed using two-sample *t*-test, while one-way analysis of variance (ANOVA) was used to test the EPG between body conditions. Pair wise comparison of means was carried using the Bonferroni adjustment. An animal positive for at least 1 egg was considered positive for the respective trematode infection. Linear regression was used to determine relationships among the EPG of the three trematodes. All

Table 1
Prevalence of trematodes in cattle in and around Bahir Dar (n = 369).

Parasite species	Number positive	Prevalence (95% CI)
Fasciola	74	20.1% (16.3, 24.5)
Paramphistomes	179	48.5% (43.4, 53.6)
Schistosoma	61	16.5% (13.1, 20.7)
Fasciola + Paramphistomes	45	12.2% (9.2, 16.0)
Fasciola + *Schistosoma*	9	2.4% (1.3, 4.6)
Paramphistomes + *Schistosoma*	27	7.3% (5.1, 10.5)
Fasciola + Paramphistomes + *Schistosoma*	4	1.1% (0.4, 2.9)
Mixed	85	23.0% (19.0, 27.6)
Trematodes	225	61.0% (55.9, 65.8)

statistical analyses were made using Stata 13.1 for Windows (Stata Corporation, College Station, TX). A P value of less than 0.05 was considered statistically significant.

3. Results

3.1. Prevalence

The overall prevalence of trematodes observed in this study was 61.0 % (95% CI: 55.9, 65.8). Specific prevalence was 20.1% (95% CI: 16.3, 24.5), 48.5% (95% CI: 43.4, 53.6), and 16.5% (95% CI: 13.1, 20.7) for *Fasciola* spp., paramphistomes and *Schistosoma* spp. respectively. Single infection with the respective trematodes (when an animal was infected with only one of the three trematodes) was 3.8% (95% CI: 2.3, 6.3), 28.7% (95% CI: 24.3, 33.6) and 6.0% (95% CI: 3.9, 8.9), respectively. Mixed infections with at least two parasites were recorded in 85 (23.0%, 95% CI: 19.0, 27.6) cattle (Table 1).

There was a substantial overlap in the infection of individual animals with *Fasciola*, paramphistomes and *Schistosoma* (Fig. 1). The overlap was significant (gamma = 0.457) between *Fasciola* and paramphistomes, while it was random for *Schistosoma* vs. *Fasciola* (0.104) and *Schistosoma* vs. paramphistomes (− 0.023).

Table 2 shows the results of multivariable logistic regression analysis of association between trematodes prevalence and potential predictors. Prevalences of *Fasciola*, paramphistomes and *Schistosoma* were significantly associated with body condition and breed of the study animals ($P < 0.01$). The prevalence of all the three trematodes was higher in animals with lean body condition than with fat body condition and in local cattle than crosses. Cattle younger than four years were associated with higher prevalence of *Fasciola* and paramphistomes

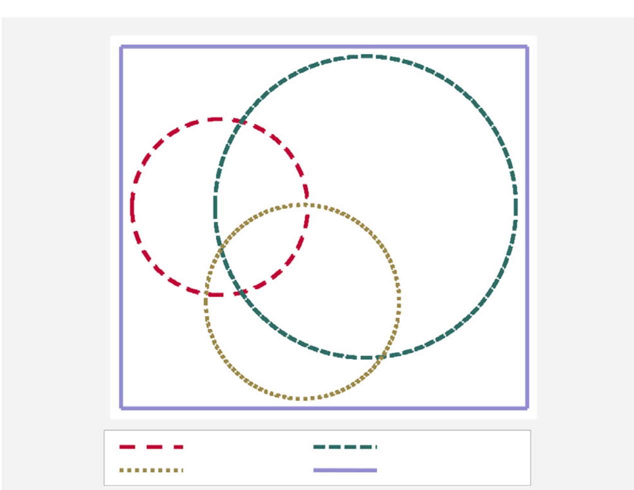

Fig. 1. A Venn diagram showing overlap in coprological prevalences of *Fasciola*, paramphistomes and *Schistosoma* in cattle.

($P < 0.05$). Only Schistosoma prevalence was associated with sex, where females were more affected than their male counterparts ($P < 0.05$). Fasciola prevalence, however, showed a tendency to be greater in females than in males (P = 0.058).

We have attempted to assess the association between mixed infections of trematodes with body condition. Body condition was significantly associated with concurrent infection with *Fasciola* and paramphistomes ($P < 0.01$) and paramphistomes and *Schistosoma* ($P < 0.001$). Highest prevalences of co-infections were observed in animals with lean body condition than animals with better body conditions. However, while co-infections involving paramphistomes were significantly associated with body condition, single infection with paramphistomes did not ($P > 0.05$) (Table 3).

Interestingly, there was no animal with fat body condition score in those with single *Fasciola* infection. But the number of observation (n = 14) was not sufficient to make statistical comparison. The number of animals found co-infected with *Fasciola* and Schistosoma (n = 9) and with single *Schistosoma* (22) were also not sufficient to make statistical comparisons and therefore were omitted from the analysis.

3.2. Fecal egg count

The mean (± SE) count of *Fasciola,* paramphistomes and *Schistosoma* eggs was 4.3 (± 0.55), 25.7 (± 2.11) and 3.1 (± 0.42) per gram of feces (Table 4), with a range of 0 to 57, 0 to 371 and 0 to 43, respectively. Mean fecal egg count per gram of feces (EPG) for all the three trematodes identified in this study was significantly associated with body condition score of the study animals ($P < 0.001$). EPG was highest in cattle with lean body condition. EPG was also significantly different a mong breeds ($P < 0.05$); indigenous animals shed higher number of trematode eggs (for all the 3 species) compared to crossbred animals. Fecal egg count of only paramphistomes was, however, affected by age ($P < 0.001$) whereby EPG was higher in younger catt le of < 4 years compared to cattle ≥ 4 years. Sex did not significantly affect trematode egg counts ($P > 0.05$) (Tab le 4).

A positive correlation ($r^2 = 0.0443$, $P = 0.000$) was obtained between *Fasciola* and para mphistomes EPG. However, there were no correlations ($r^2 = 0.0028$, $P = 0.313$) between *Fasciola* and *Schistosoma* EPG and between paramphistomes and *Schistosoma* EPG ($r^2 = 0.0001$, $P = 0.815$).

4. Discussion

In this study, the highest prevalence and EPG was recorded for paramphistomes (48.5%, 25.7) followed by *Fasciola* (20.1%, 4.3) and *Schistosoma* (16.5%, 3.1). Similar pattern of occurrence, where paramphistomes top the prevalence followed by *Fasciola* and *Schistosoma*, respectively has been reported for the three trematodes from different parts of Ethiopia (Ameni et al., 2001; Yeneneh et al., 2012) and elsewhere in Africa (Nzalawahe, Kassuku, Stothard, Coles, & Eisler, 2014). Keyyu, Monrad, Kyvsgaard, and Kassuku (2005) reported consistently higher prevalence of paramphistomes than *Fasciola gigantica* in cattle managed under different conditions in Tanzania.

The higher prevalence and EPG of paramphistomes may partly be explained by the fact that the adult parasite is considered non pathogenic and subsequently is not targeted by anthelmintic treatment. It might also be related to the biology of the parasite and the intermediate hosts. Adult paramphistomes may survive in the host for years (Hansen & Perry, 1994) and are very prolific expelling many eggs (Dorchies, 2006) while multiplication of the parasite in infected snails is massive (Hansen & Perry, 1994). The intermediate hosts of paramphistomes are also extremely adaptable and prolific breeders (Hansen & Perry, 1994). Limitation of availability of effective drugs against paramphistomes (Dorchies, 2006) might have also contributed to the relative high prevalence of the parasite. The common anthelmintics used for routine de-worming against important nematodes and liver

Table 2
Results of multivariable logistic regression analysis showing association between coprological prevalence of trematodes and risk factors in cattle in and around Bahir Dar.

Variable	Level	N	*Fasciola*			Paramphistomes			*Schistosoma*		
			No. (%) positive	OR (95% CI)	*P* value	No. (%) positive	OR (95% CI)	*P* value	No. (%) positive	OR (95% CI)	*P* value
Sex	Male	185	33 (17.8)	1		85 (45.9)	1		28 (15.1)	1	
	Female	184	41 (22.3)	1.7 (0.981, 3.0)	0.058	94 (51.1)	1.4 (0.9, 2.3)	0.132	23 (17.9)	2.0 (1.1, 3.7)	0.034
BC	Fat	94	3 (3.2)	1		35 (37.2)	1		3 (3.2)	1	
	Medium	124	24 (19.4)	7.1 (2.0, 24.5)	0.002	52 (41.9)	1.1 (0.6, 2.1)	0.652	14 (11.3)	3.4 (0.9, 12.5)	0.061
	Lean	151	47 (31.1)	13.2 (3.9, 44.5)	0.000	92 (60.9)	2.5 (1.4, 4.4)	0.002	44 (29.1)	11.7 (3.5, 39.6)	0.000
Age	≥4 years	241	41 (17.0)	1		93 (38.6)	1		44 (13.3)	1	
	<4 years	128	33 (25.8)	1.956 (1.1, 3.5)	0.022	86 (67.2)	3.9 (2.4, 6.3)	0.000	17 (18.3)	0.7 (0.4, 1.4)	0.384
Breed	Cross	193	28 (14.5)	1		80 (41.5)	1		17 (8.8)	1	
	Local	176	46 (26.1)	2.4 (1.3, 4.3)	0.004	99 (56.3)	2.5 (1.5, 4.0)	0.000	44 (25.0)	3.6 (1.8, 6.9)	0.000
Overall		369	74 (20.1)			179 (48.5)			61 (16.5)		

BC, body condition

Table 3
Results of univariable logistic regression analysis showing association between body condition and trematode infection in cattle in and around Bahir Dar.

Infection with	BC	No. examined	No. Positive	%	OR (95% CI)	*P* value
FasPara	Fat	94	3	3.2	1	
	Medium	124	14	11.3	3.9 (1.1, 13.9)	0.038
	Lean	151	28	18.5	6.9 (2.0, 23.4)	0.002
ParaSch	Fat	94	2	2.1	1	
	Medium	124	4	3.2	1.5 (0.3, 8.6)	0.626
	Lean	151	21	13.9	7.4 (1.7, 32.5)	0.008
Paramphistomes (single infection)	Fat	94	30	31.9	1	
	Medium	124	34	27.4	0.8 (0.5, 1.5)	0.471
	Lean	151	42	27.8	0.8 (0.5, 1.4)	0.494

FasPara, *Fasciola* and paramphistomes; ParaSch, paramphistomes and *Schistosoma*; BC, body condition

fluke in Ethiopia such as albendazole, ivermectin and triclabendazole have little or no effect on paramphistomes (Rolfe & Boray, 1988, 1993). Higher and increasing prevalence of paramphistomes compared to liver fluke has been documented in France partly due to the lack of an effective treatment against cattle paramphistomosis (Mage et al., 2002).

The prevalence of *Fasciola* spp. observed in our study is comparable to the 24% prevalence reported by Yeneneh et al. (2012). It was however lower compared to other recent reports from areas adjoining Lake Tana (Gebrie, Gebreyohannes, & Tesfaye, 2015; Tsegaye, Abebaw, & Girma, 2012) and reports from other parts of the country (Ameni et al., 2001; Fromsa et al., 2011; Taye, Jagema, Tadese, Mulatu, & Lelisa, 2016; Telila, Abera, Lemma, & Eticha, 2014). The difference in prevalence may be due to difference in the amount of rainfall and other climatic conditions over the years in the area, and differences in climato-ecological conditions among the study areas (Yilma & Mesfin, 2000). The relative low prevalence of *Fasciola* may also be associated with expanding veterinary services in the area. The high prevalence of *Fasciola* reported from parts of the country with no major permanent water bodies as compared to our study area may show the relative importance of *F. hepatica* in cattle fasciolosis in the country. The snail intermediate hosts of *F. hepatica* are amphibious (Andrews, 1999) and hence do not necessarily need aquatic environment for survival and proliferation. Several abattoir surveys conducted in different parts of the country demonstrated co-infection of cattle with *F. hepatica* and *F. gigantica* (Abebe et al., 2010; Abunna et al., 2010; Aregay et al., 2013; Berhe et al., 2009; Fromsa et al., 2011; Yilma & Mesfin, 2000).

The prevalence of paramphistomes recorded in the present study (48.5%) was comparable to an earlier report (45.8%) from an area not far from our study area (Yeneneh et al., 2012) and western Ethiopia (44.2%) (Fromsa et al., 2011) which is characterized by a humid tropical climate of heavy annual rainfall (Vanleeuwen, Tolosa, Sirak,

Table 4
Mean (± SE) count of *Fasciola*, paramphistomes and *Schistosoma* eggs per gram of feces by risk factors in cattle in and around Bahir Dar.

Variable	Level	N	*Fasciola*		Paramphistomes		*Schistosoma*	
			Mean (SE)	*P* value	Mean (SE)	*P* value	Mean (SE)	*P* value
Sex	Male	185	4.2 (0.81)	0.439	23.9 (2.86)	0.293	2.8 (0.57)	0.368
	Female	184	4.3 (0.74)		27.5 (3.25)		3.5 (0.61)	
BC	Fat	94	0.4 (0.29)[a]	0.000	8.9 (1.71)[a]	0.000	0.2 (0.13)[a]	0.000
	Medium	124	2.9 (0.68)[b]		14.3 (2.17)[a]		1.5 (0.45)[a]	
	Lean	151	7.7 (1.13)[c]		45.6 (4.22)[b]		6.2 (0.89)[b]	
Age	≥4	241	4.0 (0.67)	0.174	19.7 (2.21)	0.000	3.6 (0.55)	0.131
	<4	128	4.7 (0.94)		37.0 (4.25)		2.3 (0.62)	
Breed	Cross	193	2.5 (0.58)	0.001	24.3 (3.15)	0.022	1.7 (0.45)	0.000
	Local	176	6.1 (0.93)		27.3 (2.75)		4.6 (0.71)	
Overall		369	4.3 (0.55)		25.7 (2.11)		3.1 (0.42)	

[a,b,c]Means of a particular parasite EPG under a variable with different superscripts are significantly different ($P < 0.05$)
BC, body condition; SE, standard error of mean

Nemera, & Belaineh, 2014). Studies conducted near a large marshy area traversed by a river (Ameni et al., 2001) in northeastern Ethiopia (75%) and around a small lake (Kifleyohannes, Kebede, Hagos, Weldu, & Michael, 2015) in northern Ethiopia (65.3%) demonstrated higher prevalence of paramphistomes. Many other studies in Ethiopia, however, reported lower prevalence of the parasite compared to our finding (G. Mariam, Mohamed, Ibrahim, & Baye, 2014; Kemal & Terefe, 2013; Telila et al., 2014; Yohannes, Birasa, Damena, Tasew, & Degefu, 2013). The higher prevalence of paramphistomes, whose intermediate hosts are aquatic snails, observed in the present study could be explained by the fact that our study was conducted near permanent water bodies as opposed to some of the other studies which were conducted in drier areas with no major permanent water bodies.

Prevalence of *Schistosoma* observed in our study (16.5%) was comparable to the findings of Chanie et al. (2012) (13.7%) in an area adjacent to Lake Tana and Fromsa et al. (2011) (13.5%) from western Ethiopia. The prevalence was, however, low compared to earlier reports from Lake Tana basin (Habtamu & Wolde Mariam, 2011; Habtamu et al., 2013; Yeneneh et al., 2012) and a report from northeastern Ethiopia (28%) (Ameni et al., 2001). The variations observed among studies in trematode prevalence in general may be attributed to differences in climato-ecological conditions among study areas, difference in rainfall between study years, differences in study seasons and difference in animal management practices.

Prevalence as well as EPG of all the three trematodes considered in this study were highest in lean animals compared to animals with medium and fat body condition. Heavy infection with *Fasciola* in cattle, especially in young stock, may result in severe disease characterized by anemia, hypoalbuminemia (edema), ill thrift and weight loss (Boray, 1969; Love, 2017; Urquhart et al., 1996). Similarly, heavy infection with immature stomach flukes may cause decreased appetite, listlessness and weight loss (Rolfe et al., 1991).

Even moderate infections with *Fasciola* (Hope-Cawdery et al., 1977; Ross, 1970; Wamae, Hammond, Harrison, & Onyango-Abuje, 1998) and immature paramphistomes (Lloyd et al., 2007) may affect weight gain. Loss of appetite, which might contribute to the poor body condition, is also one of the clinical signs of chronic fasciolosis (Love, 2017).

However, it should be noted that it is difficult to separate the effects of the different genera of trematodes on body condition as they tend to occur together. Our finding supports previous reports which associated fasciolosis (Fromsa et al., 2011; Meshesha & Tesfaye, 2017; Phiri, Phiri, & Monrad, 2006), paramphistomosis (Fromsa et al., 2011; G. Mariam et al., 2014; Melaku & Addis, 2012) and schistosomosis (Fromsa et al., 2011; Lulie & Guadu, 2014) with poor body condition.

The significant association of paramphistomes (when an animal was considered paramphistomes positive irrespective of its status to the other two trematodes) with body condition observed in our analysis was not repeated when animals infected only with paramphistomes (single infection) were considered. It is possible that the result was influenced by those animals which were also co-infected with other trematodes (especially *Fasciola*) in the former, as paramphistome positive animals were more likely to be also positive to *Fasciola* than their paramphistome negative counterparts. It is also possible that animals found with single paramphistome infection in the study were dewormed with anthelmintics effective against liver fluke and possibly to nematodes. The result may even suggest additive or synergistic pathogenic effect of co-infection with trematodes. High mortality rate in concurrent infection involving *F. gigantica* and *Schistosoma bovis* in dairy cows has been reported from the Sudan (A/Rahman et al., 2007). After observing a positive correlation ($r^2 = 0.12$) between *F. gigantica* and paramphistomes worm count in naturally infected cattle, Yabe et al. (2008) suggested that the heterologous interaction of these two parasites may compound the economical effects of liver flukes to the livestock industry.

The prevalence of *Fasciola* and paramphistomes and EPG of paramphistomes were higher in young cattle, less than 4 years old, compared to their adult counterparts. Concurrent with our finding other researchers also recorded higher prevalence of *Fasciola* in younger cattle (Aregay et al., 2013; Meshesha & Tesfaye, 2017). However, many studies on paramphistomes in Ethiopia and elsewhere didn't find difference in prevalence among age groups (Fromsa et al., 2011; G. Mariam et al., 2014; Khedri, Radfar, Borji, & Mirzaei, 2015; Kifleyohannes *et al.*, 2015; Phiri et al., 2006). The variation might be partly attributed to differences in classification of age categories among the studies. Development of immunity due to exposure to *Fasciola*, which limits the lifespan of the primary infection, slows the migration of secondary infection and eventually reduces the number of flukes established (Urquhart et al., 1996), may be responsible for lower prevalence of *Fasciola* in older cattle. Similarly, development of a good acquired immunity against paramphistomes (Rolfe et al., 1991) has been stated.

Contrary to our expectation and some earlier reports from Ethiopia (Gebrie et al., 2015; Habtamu & Wolde Mariam, 2011), local cattle were found to be more affected with the three trematodes and shed higher number of eggs in their feces than crossbred animals. This difference is likely to be due to exposure difference rather than difference in natural resistance, as studies involving *F. gigantica* suggested that local cattle (*Bos indicus*) appear to be more resistant than *B. taurus* to infection with *Fasciola* (Bitakaramire, 1973; Castelino & Preston, 1979). It is possible that more attention is paid to valuable (crossbred) animals that their chance of grazing fluke infested areas is limited and/or they are more frequently de-wormed than local animals. In agreement with our observation some studies reported higher prevalence of trematodes in local cattle than crossbred animals (Islam, Begum, Alam, & Mamun, 2011; Meshesha & Tesfaye, 2017; Tsegaye et al., 2012).

We found a high correlation (gamma = 0.457) between *Fasciola* and paramphistomes occurrence and their EPG ($r^2 = 0.044$). Similarly, Phiri et al. (2006) recorded a positive correlation ($r^2 = 0.043$) between EPGs of *F. gigantica* and paramphistome species. Yabe et al. (2008) recorded even stronger correlation ($r^2 = 0.120$) between these two trematodes using worm burdens. The correlation may be partially explained by the existence of common factors that contribute to the occurrence of these parasites.

In this study, few animals (n = 9) harbored both *Fasciola* and *Schistosoma* and neither the occurrence nor the EPG of these trematodes were correlated. Yabe et al. (2008) recorded a similar finding and explained it with the significant liver pathology both trematodes cause which may exclude establishment of the other when one infection is established.

In conclusion, the present study demonstrated that the major trematodes of animal health and welfare importance are relatively highly prevalent in the study area especially in young cattle with high rate of mixed infections. The finding suggests that there is considerable economic loss due to trematode infections through reduced production efficiency of cattle in the study area. The prevalence of *Fasciola* spp. and *Schistosoma* spp. may also show the risk these parasites could pose to public health. Introduction of measures which would help minimize exposure of cattle to the parasites, such as keeping cattle away from grazing high risk areas, and strategic use of anthelmintics effective against mixed trematode infections especially in young stock may be considered. Empirical diagnosis and treatment of cattle, especially showing poor growth or weight loss, in the study area should take trematodes into consideration.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

This research work was approved by the Research and Publication Committee of the School of Veterinary Medicine of Hawassa University.

Funding

This research work was partially funded by Hawassa University, Ethiopia.

Acknowledgements

The authors gratefully appreciate the all rounded co-operations provided by the staff of Bahir Dar Regional Veterinary Laboratory especially Drs. Nuria and Almaz and Ato Getachew. We are also grateful to all the farmers who kindly co-operated with us during data collection and allowed us to use their animals for this study.

References

Abebe, R., Abunna, F., Berhane, M., Mekuria, S., Megersa, B., & Regassa, A. (2010). Fasciolosis: Prevalence, financial losses due to liver condemnation and evaluation of a simple sedimentation diagnostic technique in cattle slaughtered at Hawassa Municipal abattoir, southern Ethiopia. *Ethiopian Veterinary Journal, 14*(1), 39–52.

Abunna, F., Asfaw, L., Megersa, B., & Regassa, A. (2010). Bovine fasciolosis: Coprological, abattoir survey and its economic impact due to liver condemnation at Soddo municipal abattoir, Southern Ethiopia. *Tropical Animal Health and Production, 42*, 289–292.

Ameni, G., Erko, B., & Bogale, T. (2001). Preliminary study on the major bovine trematode infection around Kemissie, Northeastern Ethiopia and treatment trial with praziquantel. *Bulletin of Animal Health and Production in Africa, 49*, 62–67.

Andrews, S. J., & Dalton, J. P. (1999). *The life cycle of Fasciola hepatica. Fasciolosis*. Wallingford, UK: CABI Publishing1–29.

A/Rahman, M. B., Mohammed, Z. A., Osman, A. Y., Bakhiet, H. A., Mohammed-Ahmed, O., & Osman, H. M. (2007). Concurrent infection of *Schistosoma bovis* and *Fasciola gigantica* in a dairy cattle in Khartoum State, Sudan. *The Sudan Journal of Veterinary Research, 22*, 63–70.

Aregay, F., Bekele, J., Ferede, Y., & Hailemelekot, M. (2013). Study on the prevalence of bovine fasciolosis in and around Bahir Dar, Ethiopia. *Ethiopian Veterinary Journal, 17*(1), 1–11.

Barger, I. A. (1999). The role of epidemiological knowledge and grazing management for helminth control in small ruminants. *International Journal of Parasitology, 29*, 41–47.

Berhe, G., Berhane, K., & Tadesse, G. (2009). Prevalence and economic significance of fasciolosis in cattle in Mekelle Area of Ethiopia. *Tropical Animal Health and Production, 41*(7), 1503–1504.

Bitakaramire, P. K. (1973). The incidence of fascioliasis in different breeds in Kenya. *Bulletin of Epizootic Diseases of Africa, 21*, 145–152.

Boray, J. C. (1969). Experimental fascioliasis in Australia. *Advances in Parasitology, 7*, 95–209.

Castelino, J. B., & Preston, J. M. (1979). The influence of breed and age on the prevalence of bovine fascioliasis in Kenya. *British Veterinary Journal, 135*, 198–203.

Chanie, M., Dejen, B., & Fentahun, T. (2012). Prevalence of cattle schistosomiasis and associated risk factors in Fogera cattle, South Gondar zone, Amhara National Regional State, Ethiopia. *Journal of Advanced Veterinary Research, 2*(3), 153–156.

DAFWA. (2013). Detection of trematode eggs and Eimeria leuckarti-sedimentation method (FEST) – Faecal Samples, Department of Agriculture and Food, Western Australia. https://www.agric.wa.gov.au/sites/gateway/files/DAFWA%20approved%20fluke%20egg%20sedimentation%20test%20%28FEST%29.pdf, Accessed date: 13 August 2016.

Dargie, J. D. (1987). The impact on production and mechanisms of pathogenesis of trematode infections in cattle and sheep. *International Journal for Parasitology, 17*, 453–463.

Dohoo, I., Martin, W., & Stryhn, H. (2009). *Veterinary Epidemiological Research* (2nd ed.). Charlottetown, Prince Edward Island: AVC Inc.

Dorchies, Ph. (2006). Flukes: Old parasites but new emergence. *Proceedings of the XXIV World Buiatrics CongressVol. 16*Consultada.

Dreyfuss, G., Alarion, N., Vignoles, P., & Rondelaud, D. (2006). A retrospective study on the metacercarial production of *Fasciola hepatica* from experimentally infected *Galba truncatula* in central France. *Parasitology Research, 98*(2), 162–166.

Elliott, T. P., Kelley, J. M., Rawlin, G., & Spithill, T. W. (2015). High prevalence of fasciolosis and evaluation of drug efficacy against *Fasciola hepatica* in dairy cattle in the Maffra and Bairnsdale districts of Gippsland, Victoria, Australia. *Veterinary Parasitology, 209*(1-2), 117–124.

Fromsa, A., Meharenet, B., & Mekibib, B. (2011). Major trematode infections of cattle slaughtered at Jimma municipality abattoir and the occurrence of the intermediate hosts in selected water bodies of the zone. *Journal of Animal and Veterinary Advances, 10*(12), 1592–1597.

G. Mariam, T., Mohamed, A., Ibrahim, N., & Baye, D. (2014). Prevalence of fasciolosis and paramphistomosis in dairy farm and house hold in Hawassa town. *European Journal of Biological Sciences, 6*(2), 54–58.

Gebrie, Y., Gebreyohannes, M., & Tesfaye, A. (2015). Prevelance of bovine fasciolosis in and around Bahir Dar, north west Ethiopia. *Journal of Parasitology and Vector Biology, 7*(4), 74–79.

Habtamu, A., & Wolde Mariam, S. (2011). Repeated simple sedimentation technique and prevalence of bovine schistosomosis in selected sites of Bahir Dar woreda. *Ethiopian Veterinary Journal, 15*(1), 49–57.

Habtamu, A., Negash, T., Sirak, A., & Chanie, M. (2013). Pathology of natural infections of *Schistosoma bovis* in cattle in Ethiopia. *Global Veterinaria, 11*(2), 243–247.

Hansen, J., & Perry, B. (1994). *The epidemiology, diagnosis and control of helminth parasites of ruminants, a hand book*. Nairobi, Kenya: International Laboratory for Research on Animal Disease (ILRAD).

Hope-Cawdery, M. J., Strickland, K. L., Conway, A., & Crowe, P. J. (1977). Production effects of liver fluke in cattle. I. The effects of infection on live weight gain, food intake and food conversion efficiency in beef cattle. *British Veterinary Journal, 133*, 145–159.

Iglesias-Piñeiro, J., González-Warleta, M., Castro-Hermida, J. A., Córdoba, M., González-Lanza, C., Manga-González, Y., & Mezo, M. (2016). Transmission of *Calicophoron daubneyi* and *Fasciola hepatica* in Galicia (Spain): Temporal follow-up in the intermediate and definitive hosts. *Parasites and Vectors, 9*, 610.

Islam, M. N., Begum, N., Alam, M. Z., & Mamun, M. A. A. (2011). Epidemiology of intestinal schistosomiasis in ruminants of Bangladesh. *Journal of Bangladesh Agricultural University, 9*(2), 221–228.

Kemal, J., & Terefe, Y. (2013). Prevalence of gastrointestinal parasitism of cattle in Gedebano Gutazer Wolene district, Ethiopia. *Journal of Veterinary Medicine and Animal Health, 5*(12), 365–370.

Keyyu, J. D., Monrad, J., Kyvsgaard, N. C., & Kassuku, A. A. (2005). Epidemiology of *Fasciola gigantica* and amphistomes in cattle on traditional, small-scale dairy and large-scale dairy farms in the southern highlands of Tanzania. *Tropical Animal Health and Production, 37*(4), 303–314.

Khedri, J., Radfar, M. H., Borji, H., & Mirzaei, M. (2015). Prevalence and intensity of *Paramphistomum* spp. in cattle from South-Eastern Iran. *Iranian Journal of Parasitology, 10*(2), 268–272.

Kifleyohannes, T., Kebede, E., Hagos, Y., Weldu, K.,G., & Michael, M. (2015). Prevalence of paramphistomosis in ruminants in Ashenge, Tigray Ethiopia. *Acta Parasitologica Globalis, 6*(2), 83–86.

Lloyd, J., Boray, J. C., & Love, S. (2007). Stomach fluke (paramphistomes) in ruminants. Primefact 452, NSW DPI http://www.wormboss.com.au/files/pages/worms/flukes/stomach-fluke/Prime_Fact_452_Stomach_flukeparamphistomesin_ruminants.pdf, Accessed date: 19 June 2017.

Love, S. (2017). Liver fluke- a review. Primefact 813, NSW DPI.

Lulie, B., & Guadu, T. (2014). Bovine schistosomiasis: A threat in public health perspective in Bahir Dar town, northwest Ethiopia. *Acta Parasitologica Globalis, 5*(1), 1–6.

Mage, C., Bourgne, H., Toullieu, J. M., Rondelaud, D., & Dreyfuss, G. (2002). *Fasciola hepatica* and *Paramphistomum daubneyi*: Changes in prevalences of natural infections in cattle and in *Lymnaea truncatula* from central France over the past 12 years. *Veterinary Research, 33*(5), 439–447.

Melaku, S., & Addis, M. (2012). Prevalence and intensity of *Paramphistomum* in ruminants slaughtered at Debre Zeit industrial abattoir, Ethiopia. *Global Veterinaria, 8*(3), 315–319.

Meshesha, M., & Tesfaye, W. (2017). Prevalence of fasciolosis in cattle slathered at Hosanna municipal abattoir, southern Ethiopia. *International Journal of Advanced Research in Biological Sciences, 4*(2), 40–46.

Nicholson, M. J., & Butterworth, M. H. (1986). *A guide to condition scoring of Zebu Cattle*. Addis Ababa, Ethiopia: International Livestock Center for Africa-ILCA29.

Njau, B. C., Kasali, O. B., Scholtens, R. G., & Mesfin, D. (1988). Review of sheep mortality in the Ethiopian highlands, 1982-1986. *ILCA Bulletin, Addis Ababa, Ethiopia, 31*, 19–22.

Nzalawahe, J., Kassuku, A. A., Stothard, J. R., Coles, G. C., & Eisler, M. C. (2014). Trematode infections in cattle in Arumeru District, Tanzania are associated with irrigation. *Parasites and Vectors, 7*, 107.

Phiri, A. M., Phiri, I. K., Sikasunge, C. S., & Monrad, J. (2005). Prevalence of fasciolosis in Zambian cattle observed at selected abattoirs with emphasis on age, sex and origin. *Journal of Veterinary Medicine, Series B, 52*, 414–416.

Phiri, A. M., Phiri, I. K., & Monrad, J. (2006). Prevalence of amphistomiasis and its association with *Fasciola gigantica* infections in Zambian cattle from communal grazing areas. *Journal of Helminthology, 80*(1), 65–68.

Rolfe, P. F., & Boray, J. C. (1988). Chemotherapy of paramphistomosis in sheep. *Australian Veterinary Journal, 65*(5), 148–150.

Rolfe, P. F., & Boray, J. C. (1993). Comparative efficacy of moxidectin, an ivermectin/clorsulon combination and closantel against immature paramphistomes in cattle. *Australian Veterinary Journal, 70*(7), 256–266.

Rolfe, P. F., Boray, J. C., Nichols, P., & Collins, G. H. (1991). Epidemiology of paramphistomosis in cattle. *International Journal of Parasitology, 21*, 813–819.

Ross, J. G. (1970). The economics of *Fasciola hepatica* infections in cattle. *British Veterinary Journal, 126*(4), xiii–xixv.

Solomon, W/M., & Wossene, A. (2007). Prevalence study of ruminant fasciolosis in areas adjoining upper Blue Nile basin, north western Ethiopia. *Ethiopian Veterinary Journal, 11*, 67–81.

Svendsen, E. D. (1997). *The Professional Handbook of the Donkey* (3rd ed.). London: Whittet Books Ltd375–376.

Taye, M., Jagema, T., Tadese, A., Mulatu, E., & Lelisa, K. (2016). Study of ruminant fasciolosis in selected districts in upper Awash River basin, south western Shoa, Ethiopia. *Journal of Veterinary Science and Technology, 7*(5).

Taylor, M. A., Coop, R. L., & Wall, R. L. (2016). *Veterinary parasitology* (4th ed.). West Sussex, UK: Wiley Blackwell390–393.

Telila, C., Abera, B., Lemma, D., & Eticha, E. (2014). Prevalence of gastrointestinal parasitism of cattle in East Showa zone, Oromia regional state, Central Ethiopia. *Journal of Veterinary Medicine and Animal Health, 6*(2), 54–62.

Thrusfield, M. (2005). *Veterinary epidemiology* (3rd ed.). London: Blackwell science Ltd228–246.

Torell, R., Bruce, B., Kvasnicka, B., & Conley, K. (2003). *Methods of determining age of cattle. Cattle Producer's Library: CL712*. Reno, NV: University of Nevada. http://www.unce.unr.edu/publications/files/ag/other/cl712.Pdf, Accessed date: 9 October 2011.

Tsegaye, B., Abebaw, H., & Girma, S. (2012). Study on coprological prevalence of bovine fasciolosis in and around Woreta, Northwestern Ethiopia. *Journal of Veterinary Medicine and Animal Health, 4*(7), 89–92.

Urquhart, G. M., Armour, J., Duncan, J. L., Dunn, A. M., & Jennings, F. W. (1996). *Veterinary parasitology* (2nd ed.). Harlow, UK: Blackwell Science Ltd102–120.

Vanleeuwen, J. A., Tolosa, T., Sirak, A., Nemera, M., & Belaineh (2014). Seroprevalence of *Mycobacterium avium* ssp *paratuberculosis* infection in Ethiopian dairy farms. *Bulletin of Animal Health and Production in Africa, 62*, 95–100.

Wamae, L. W., Hammond, J. A., Harrison, L. J. S., & Onyango-Abuje, J. A. (1998). Comparison of production losses caused by chronic *Fasciola gigantica* infection in yearling Friesian and Boran cattle. *Tropical Animal Health and Production, 30*(1), 23–30.

Yabe, J., Phiri, I. K., Phiri, A. M., Chembensofu, M., Dorny, P., & Vercruysse, J. (2008). Concurrent infections of *Fasciola, Schistosoma* and *Amphistomum* spp. in cattle from Kafue and Zambezi river basins of Zambia. *Journal of Helminthology, 82*, 373–376.

Yeneneh, A., Kebede, H., Fentahun, T., & Chanie, M. (2012). Prevalence of cattle flukes infection at Andassa livestock research center in north-west of Ethiopia. *Veterinary Research Forum, 3*(2), 85–89.

Yilma, J. M., & Mesfin, A. (2000). Dry season bovine fasciolosis in northwestern part of Ethiopia. *Revue de Médecine Vétérinaire, 151*(6), 493–500.

Yohannes, M., Birasa, D., Damena, D., Tasew, S., & Degefu, H. (2013). Bovine trypanosomosis and gastrointestinal helminthosis in settlement villages of Bedele district, south-western Ethiopia. *Ethiopian Veterinary Journal, 17*(1), 41–45.