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Fasciola species and their vertebrate and snail intermediate hosts in East and Southern Africa: a review

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Review Article

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Abstract

A systematic review was conducted focusing on the distribution of *Fasciola* species and their snail intermediate hosts (IHs) in East and Southern Africa. The reviewed literature showed that both *Fasciola hepatica* and *F. gigantica* are present in East and Southern Africa, and infect a wide range of domestic and wild ruminants. *Fasciola gigantica* was reported in six East African and five Southern African countries, where *Radix natalensis* (found in low altitudes) was reported to be the main IH. *Fasciola hepatica* was reported in Tanzania and Ethiopia (East Africa), and in South Africa and Zimbabwe (Southern Africa), where *Galba truncatula* (found in high altitudes) was documented as the IH in all countries except in Zimbabwe. Both *Fasciola* species were documented in Tanzania, Ethiopia, Zimbabwe and South Africa. An overlap of the two was observed in areas with an intermediate altitude in Ethiopia and South Africa, where *Pseudosuccinea columella* was widespread and assumed to transmit both species. *Pseudosuccinea columella* has been reported in South Africa and Namibia, and proven to transmit *F. gigantica* in South Africa; its role in Namibia in the transmission of *Fasciola* species has not been reported. Other lymnaeid species such as *R. rubiginosa* were reported in South Africa, and *R. auricularia* in South Africa and Botswana; their role in the transmission of *Fasciola* species has not been proven. Future studies should aim to determine the role of *P. columella* in the geographical spread of the two species in East and Southern African countries.

Introduction

Fasciolosis is a parasitic infection of domestic ruminants, wildlife and humans caused by trematodes of the genus *Fasciola* (Admassu *et al*., 2015; Ibrahim, 2017). *Fasciola hepatica* (Linnaeus, 1758) and *F. gigantica* (Cobbold, 1856), commonly known as 'liver flukes', are the two main species responsible for most infections (Jaja *et al*., 2012). Due to its ability to infect a variety of animal species (Jaja *et al*., 2012), *F. hepatica* has a wider distribution, occurring mainly in temperate areas and highlands of tropical and subtropical regions (Abebe *et al*., 2010; Admassu *et al*., 2015), whilst *F. gigantica* is more restricted to the tropical regions of Africa and Asia (Abebe et al., 2010). However, both species overlap in many African and Asian countries where the ecological requirements of the flukes and their intermediate hosts (IHs) converge (Mas-Coma *et al*., 2005).

The distribution of *F. hepatica* and *F. gigantica* is dependent on the availability of the IHs (Prasad *et al*., 2008). Lymnaeidae snail species act as the IHs of *Fasciola* spp. (Mas-Coma *et al*., 2005) and play a prominent role in the epidemiology and distribution of fasciolosis (Mochankana & Robertson, 2016). The two species vary greatly in their ecological and IH preference requirements (Mas-Coma *et al*., 2009a), and the distribution of the fasciolids is consequently in accordance with the ecological requirements of their respective snail IHs (Quayle *et al*., 2010).

Fasciola hepatica utilizes the European snail species *Galba truncatula* (Muller, 1774) as its IH in some parts of Africa (Brown, 1994; De Kock *et al*., 2003) and other species from the genus *Lymnaea*/*Galba* or *Fossaria* as IHs (Mas-Coma, 2005). In sub-Saharan Africa, the geographical distribution of both *F. hepatica* and *G. truncatula* may be divided into three categories, as suggested by Mas-Coma *et al*. (2009b); (i) the north-western African region; (ii) the large western and central African region; and (iii) the Eastern Africa region from the northern Mediterranean shore to Southern Africa. The distribution of the latter includes large areas in South Africa and Lesotho, with large areas in Egypt in the northern regions, and another large but isolated area in Ethiopia, Kenya and Tanzania in the eastern region (Brown, 1994). *Fasciola gigantica*, on the other hand, is found in the tropical and subtropical regions of Africa, Asia and the Far East (Mochankana & Robertson, 2018), and, according to Mas-Coma *et al*. (2005), its limited geographical distribution is mainly linked to the weaker

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dispersion capacity of its intermediate snail hosts. This species is reported to utilize a greater range of IHs of the genus *Radix* species (Mas-Coma, 2005). These are species that belong to Hubendick's (1951) superspecies of *Radix auricularia* (Linnaeus, 1758), which includes *R. natalensis* (Krauss, 1848) in Africa and *R. rubiginosa* (Michelin, 1831) in Asia (Fretter & Peake, 1987; Brown, 1994). According to Jaja *et al.* (2012), the extended geographical distribution of *G. truncatula* and *R. natalensis* is largely promoted by environmental factors such as rainfall, solar radiation and global warming.

An overlap in the geographical distribution of *F. gigantica* and *F. hepatica* in Africa has been reported (Mas-Coma *et al.*, 2009b). Overlaps are distinguished as either local, when they occur in areas where the climate throughout the year favours the co-existence of both *Galba* and *Radix* species in the same locality, which has been observed in the Nile Delta in Egypt, or zonal, when overlap is observed in highland areas where the cold–mild weather favours *F. hepatica* and *G. truncatula* and the lowlands offer the warm–hot climate for *Radix* spp. and the *F. gigantica* system, and this overlap has been described in East Africa. Against this background, the present review focused on assessing the geographical distribution of *F. hepatica* and *F. gigantica* and their Lymnaeidae intermediate snail hosts in East and Southern Africa based on peer-reviewed publications and reports from this region between 1988 and 2018.

Methods

Search strategy

A systematic search of literature between 1988 and 2018 (30 years) was done on the Google Scholar database, using the search terms: *Fasciola* spp., Lymnaeidae, *Lymnaea*, *Pseudosuccinea*, *Galba*, *Radix*, Southern Africa and East Africa, and Boolean operators (AND, OR) were used. The literature search was limited to articles published in English. Additionally, reference lists of the selected articles were screened as potential leads for inclusion. Full-text articles were retrieved and managed in EndNote reference manager version X8 (Clarivate Analytics, Philadelphia, PA, USA).

Inclusion and exclusion criteria

Both published and unpublished reports reporting on the distribution of Lymnaeidae and *Fasciola* species in East and Southern Africa were included in the review. Articles were identified by reading through the titles and abstracts. The literature search on the distribution of *Fasciola* species and their invertebrate hosts in East and Southern Africa included studies focusing on either the geographical distribution or prevalence and identification of *F. hepatica* and *F. gigantica* in naturally infected IHs in East and Southern African countries. All studies focusing on the economic loss and treatment were excluded. A systematic search on the distribution of *Fasciola* species and their IHs included field studies focusing on the association and distribution of both the IHs and *Fasciola* spp. and those that focused solely on the distribution or occurrence of the lymnaeid IHs and experimental studies conducted with *Fasciola* species and Lymnaeidae specimens from East and Southern African countries. The review excluded review papers and studies that did not identify the lymnaeid species up to species level.

Results

The systematic literature search yielded a total of 640 hits, which included abstracts, reports, books and duplicate articles (fig. 1). Twelve additional records obtained through the reference lists of the screened articles, and two unpublished articles, were also included in the list. Fifteen articles were excluded due to duplication, and a total of 639 articles were screened. Four hundred and eighty-seven abstracts and full-texts were excluded because they did not explicitly report on the distribution, occurrence or identification of *Fasciola* and Lymnaeidae species in East and Southern Africa, and four books were excluded. Ninety-one articles were excluded because the studies were either conducted on the same study area and animal species, or they did not identify Lymnaeidae species up to species level. Fifty-seven articles met the criteria and were considered and discussed in this review in relation to the identity and distribution of *Fasciola* and Lymnaeidae species in East and Southern African countries.

Distribution and prevalence of Fasciola species and their vertebrate host(s)

The distribution of *Fasciola* species and their vertebrate hosts in East and Southern Africa is shown in tables 1 and 2. Results show that *F. gigantica* is the predominant species distributed in East and Southern Africa, occurring as the only species in 11 reviewed countries with the exception of South Africa and Zimbabwe in Southern Africa and Ethiopia and Tanzania in East Africa, where both *F. gigantica* and *F. hepaica* have been reported. Results show that both *Fasciola* species utilize a range of vertebrate animal species ranging from domestic to wild ruminants as definitive hosts. Although *Fasciola* infection was common in domestic ruminants (cattle, goats and sheep) in East and Southern African countries (table 1), infections in wildlife have only been reported in Southern African countries during the period under review (table 2). *Fasciola gigantica* infection was reported in nine species of wildlife, while *F. hepatica* was only reported in three (table 2). *Fasciola tragelaphi* infection was reported in cattle in Zimbabwe. Two cases of *Fasciola* spp. infection in humans have been reported in South Africa using *Fasciola* immune fluorescent antibody test (IFAT) assay.

Geographical distribution of lymnaeids in East and Southern Africa

Radix natalensis, *G. truncatula*, *Pseudosuccinea columella*, *R. auricularia* and *R. rubiginosa* have been documented in East and Southern Africa (table 3). All five species were reported in Southern Africa, and only two (i.e. *R. natalensis* and *G. truncatula*) are documented in East African countries. *Radix natalensis* was found to occur in ten of the 12 East and Southern African countries and is presumed to act as the main IH of *F. gigantica*. This species was found to be the only lymnaeid species found in Rwanda, Kenya and Madagascar (East Africa) and Zimbabwe and Zambia (Southern Africa), where only *F. gigantica* was recorded, with the exception of Zimbabwe where a case of *F. hepatica* was also recorded (Mucheka *et al.*, 2015). All five lymnaeid species have been identified using both molecular and morphological techniques in South Africa. An overlap in the distribution and co-habitation among these species was observed and reported in Mpumalanga and KwaZulu-Natal provinces of South Africa. *Galba truncatula* was documented in Ethiopia, Tanzania,

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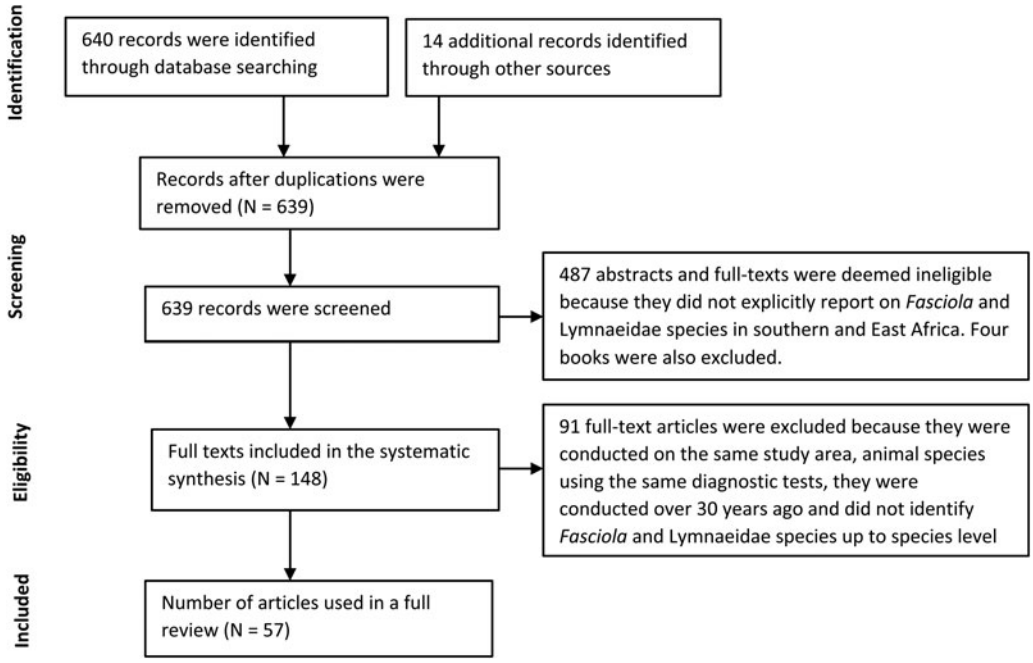

Fig. 1. PRISMA diagram.

Uganda, South Africa and Lesotho – countries where *F. hepatica* has been documented, with the exception of Uganda. In Tanzania, *R. natalensis* and *G. truncatula* have been reported to occur in locations with different altitudes, with the former mainly found in lower altitudes and the latter in higher altitudes (Walker *et al.*, 2008). Similar observations were made in Uganda (Howell *et al.*, 2012) and Ethiopia (Kedir *et al.*, 2012; Assefa *et al.*, 2015). However, unlike in Tanzania and Uganda, an overlap in the distribution of both *Fasciola* species was observed in Ethiopia, which occur at the intermediate of the lower and the higher altitude (Kedir *et al.*, 2012). In Namibia, *R. natalensis* and *P. columella* have been documented, with the former occurring abundantly in the northern rivers, where the latter has not yet been found, and these species also overlap in the Orange River (Curtis, 1991). In Botswana, *R. natalensis* and *R. auricularia* have been identified, and these species act as the IHs of *F. gigantica*, which has been documented in the country.

Prevalence of Fasciola spp. in East and Southern Africa

Results from the reviewed articles showed that the overall prevalence of fasciolosis in cattle was the same with both faecal egg count and fluke count at post-mortem, and prevalence as determined by faecal egg count was higher in goats and sheep compared to the prevalence using the fluke count at post-mortem (table 4). Based on the faecal egg count technique, the overall prevalence of fasciolosis was significantly higher in cattle (14.5%) ($P = 0.002$) compared to that of sheep (10.9%) and goats (9.4%) (table 4). The same trend was observed with the fluke count technique, where more flukes were found in cattle (14.5%), followed by sheep (3.7%) and, lastly, goats (2.5%) (table 4). In cattle, the prevalence ranged from 0.74% to 58% and from 0.09% to 75.8% based on the egg count and fluke count technique, respectively (table 4). In goats, the prevalence ranged from 2.4% to 26%, and in sheep from 3.6% to 26.3% based on the fluke count technique (table 4). The prevalence of fasciolosis in wildlife was 52.5% (21 of $n = 40$) for Kafue lechwe in Zambia (Munyeme *et al.*, 2010), 12.5% (one of $n = 8$) for Kudu in South Africa (Van Wyk & Boomker, 2015) and 0.52% (one of $n = 191$) for Impala in Swaziland (Gallivan *et al.*, 1996).

Factors associated with the distribution and prevalence of Fasciola spp. in East and Southern Africa

Diagnostic techniques

Faecal egg count and fluke count techniques showed no difference in the overall mean prevalence of fasciolosis (14.5%) in cattle. However, the overall mean prevalence in goats and sheep was higher with the faecal egg count technique (9.4% and 10.9%, respectively) when compared with the fluke count technique (2.5% and 3.7%, respectively).

Season

Phiri *et al.* (2005a) observed that the prevalence of fasciolosis was higher during the rainy and the cold–dry seasons in Zambia, using both the faecal egg and fluke count techniques. The hot–dry season exhibited low fluke abundance (13.8%), with a gradual increase in fluke prevalence (21.7%) during the rainy and the cold–dry seasons (24.8%). A similar trend was observed with the faecal egg count technique; 34.5% during the hot–dry season, increasing to 39.1% during the rainy season. Both flukes and faecal egg counts peaked during the post-rainy season, with a prevalence of 41.3% and 45.0%, respectively. *Fasciola gigantica* infection was also reported to be higher in the wet highlands as compared to the dry lowlands of Zimbabwe (Pfukenyi & Mukaratirwa, 2004). The authors recorded a highest prevalence of 54.3% in February and December (rainy months), and lowest (17.8%) in September (dry month). The wet season had a significantly higher prevalence (45.6%) ($P < 0.001$) as compared to the dry season (27.8%). In Tanzania, Nzalawahe & Komba (2013)

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Table 1. Checklist of *Fasciola* species and their domestic ruminant hosts reported in East and Southern Africa (1988–2018).

Region	Country	Host	Diagnostic method	*Fasciola* spp.	References
East Africa	Ethiopia	Cattle	Egg morphology	*F. gigantica*	Moje *et al.*, 2015
	Ethiopia	Cattle	Fluke morphology	*F. gigantica* and *F. hepatica*	Abebe *et al.*, 2010; Regassa *et al.*, 2012; Aregay *et al.*, 2013; Mebrahtu & Beka, 2013; Assefa *et al.*, 2015; Betebo, 2017; Eshetu *et al.*, 2017
	Ethiopia	Goats	Fluke morphology	*F. gigantica* and *F. hepatica*	Kedir *et al.*, 2012
	Ethiopia	Sheep	Fluke morphology	*F. gigantica* and *F. hepatica*	Kedir *et al.*, 2012; Amsalu, 2017
	Kenya	Cattle	Fluke morphology	*F. gigantica*	Kithuka *et al.*, 2002
	Kenya	Cattle	Fluke morphology	*F. gigantica*	Njeruh *et al.*, 2004; Mungube *et al.*, 2006
	Kenya	Goats	Fluke morphology	*F. gigantica*	Njeruh *et al.*, 2004; Mungube *et al.*, 2006
	Kenya	Sheep	Fluke morphology	*F. gigantica*	Njeruh *et al.*, 2004; Mungube *et al.*, 2006
	Tanzania	Cattle	Egg morphology	*F. gigantica*	Keyyu *et al.*, 2006; Nzalawahe *et al.*, 2014
	Tanzania	Goats	Egg morphology	*F. gigantica*	Mhoma & Kanyari, 2011
	Tanzania	Cattle	Fluke morphology	*F. gigantica*	Mwabonimana *et al.*, 2009; Kamwela *et al.*, 2013
	Tanzania	Cattle	Egg and fluke morphology	*F. gigantica*	Nzalawahe & Komba, 2013
	Tanzania	Goats	Egg and fluke morphology	*F. gigantica*	Nzalawahe & Komba, 2013
Southern Africa	Botswana	Cattle	Egg morphology	*F. gigantica*	Mochankana & Robertson, 2018
	Botswana	Cattle	Fluke morphology	*F. gigantica*	Mucheka *et al.*, 2015
	South Africa	Cattle	Molecular	*F. gigantica* and *F. hepatica*	Mucheka *et al.*, 2015
	South Africa	Human	IFAT	*Fasciola* spp.	Black *et al.*, 2013
	Zambia	Cattle	Egg morphology	*F. gigantica*	Phiri *et al.*, 2006
	Zambia	Cattle	Fluke morphology	*F. gigantica*	Phiri *et al.*, 2005a; Phiri *et al.*, 2005b; Yabe *et al.*, 2008
	Zimbabwe	Cattle	Egg morphology	*F. gigantica*	Pfukenyi *et al.*, 2006
	Zimbabwe	Cattle	Molecular	*F. gigantica* and *F. hepatica*	Chauke *et al.*, 2014; Mucheka *et al.*, 2015
	Zimbabwe	Cattle	Fluke morphology	*F. gigantica*	Pfukenyi & Mukaratirwa, 2004
	Zimbabwe	Cattle	Fluke morphology	*F. tragelaphi*	Mukaratirwa & Brand, 1999

IFAT, immune fluorescent antibody test.

showed a significant seasonal variation in the occurrence of fasciolosis, with the highest (77.5% and 28%) recorded during the dry season and the lowest (74% and 26.5%) during the wet season in cattle and goats, respectively. There were also variations observed in the cumulative monthly prevalence, with the highest prevalence in cattle obtained in October (89.4%) and lowest (61.7%) in June, whilst in goats the highest prevalence of 33.9% was obtained in September and the lowest (22.4%) in October (Nzalawahe & Komba, 2013).

Age

Both young and adult animals seem to be equally susceptible to *Fasciola* infection. Studies in Ethiopia showed a significantly higher prevalence of *Fasciola* infection in young animals (Kedir *et al.*, 2012; Regassa *et al.*, 2012; Aregay *et al.*, 2013; Assefa *et al.*, 2015; Betebo, 2017), while other studies showed that adults had a significantly higher prevalence of *Fasciola* infection (Phiri *et al.*, 2005a, b; Pfukenyi *et al.*, 2006; Mebrahtu & Beka, 2013;

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Table 2. Checklist of *Fasciola* species and their wildlife hosts reported in East and Southern Africa (1988–2018).

Region	Country	Host	Diagnostic method	*Fasciola* spp.	References
Southern Africa	South Africa	Kudu (*Tragelaphus strepsiceros*)	Fluke morphology	*F. hepatica*	Van Wyk & Boomker, 2015
	Swaziland	Impala (*Aepyceros melampus*)	Fluke morphology	*F. gigantica*	Gallivan *et al.*, 1996
	Zambia	Kafue lechwe (*Kobus leche*)	Fluke morphology	*F. gigantica*	Munyeme *et al.*, 2010
	Zimbabwe	Blue wildebeest (*Connochaetes taurinus*)	Fluke morphology	*F. gigantica*	Jooste, 1989
	Zimbabwe	Bushbuck (*Tragelaphus scriptus*)	Fluke morphology	*F. gigantica*	Jooste, 1989
	Zimbabwe	Common duiker (*Sylvicapra grimmia*)	Fluke morphology	*F. gigantica*	Jooste, 1989
	Zimbabwe	Eland (*Taurotragus oryx*)	Fluke morphology	*F. gigantica*	Jooste, 1989; Mucheka *et al.*, 2015
	Zimbabwe	Giraffe (*Giraffa camelopardus*)	Fluke morphology	*F. gigantica*	Jooste, 1989
	Zimbabwe	Impala	Fluke morphology	*F. gigantica*	Jooste, 1989
	Zimbabwe	Kudu	Fluke morphology	*F. gigantica*	Jooste, 1989
	Zimbabwe	Sable antelope (*Hippotragus niger*)	Fluke morphology	*F. gigantica*	Jooste, 1989
	Zimbabwe	Tsessebe (*Damaliscus lunatus*)	Fluke morphology	*F. gigantica*	Jooste, 1989
	Zimbabwe	Common duiker	Molecular	*F. hepatica*	Mucheka *et al.*, 2015
	Zimbabwe	Sable antelope	Molecular	*F. hepatica*	Mucheka *et al.*, 2015

Table 3. Checklist of Lymnaeidae species reported in East and Southern Africa (1988–2018).

Region	Country	Diagnostic method	*Fasciola* spp.	References
East Africa	Ethiopia	Snail morphology	*G. truncatula*	Eguale *et al.*, 2006
	Kenya	Snail morphology	*R. natalensis*	Wamae & Cheruiyot, 1990; Dida *et al.*, 2014
	Madagascar	Molecular and snail morphology	*R. natalensis*	Da Costa *et al.*, 1994; Stothard *et al.*, 2000
	Rwanda	Snail morphology	*R. natalensis*	Deutsch, 1992
	Tanzania	Snail morphology	*R. natalensis* and *G. truncatula*	Utzinger & Tanner, 2000; Walker *et al.*, 2008; Dida *et al.*, 2014; Nzalawahe *et al.*, 2014
	Uganda	Molecular and snail morphology	*R. natalensis* and *G. truncatula*	Stensgaard *et al.*, 2006; Howell *et al.*, 2012
Southern Africa	Botswana	Molecular and snail morphology	*R. auricularia* and *R. natalensis*	Appleton *et al.*, 2003 Malatji *et al.*, in press
	Lesotho	Snail morphology	*G. truncatula*	De Kock *et al.*, 2003
	Namibia	Snail morphology	*R. natalensis* and *P. columella*	Curtis, 1991
	South Africa	Molecular and snail morphology	*G. truncatula*, *P. columella*, *R. auricularia*, *R. natalensis* and *R. rubiginosa*	De Kock & Wolmarans, 1998; De Kock *et al.*, 2003; De Wolmarans & De Kock, 2006; Kock & Wolmarans, 2008; Moema *et al.*, 2008; Perissinotto *et al.*, 2014; Appleton & Miranda, 2015; Kemp *et al.*, 2016; Malatji *et al.*, 2019
	Zambia	Snail morphology	*R. natalensis*	Phiri *et al.*, 2007
	Zimbabwe	Snail morphology	*R. natalensis*	Pfukenyi *et al.*, 2006

Moje *et al.*, 2015; Amsalu, 2017; Eshetu *et al.*, 2017; Mochankana & Robertson, 2018).

Sex

Both males and females seem to be equally likely to have fasciolosis. Studies showed that *Fasciola* infection due to either *F. gigantica* or *F. hepatica* was more prevalent in males (Kithuka *et al.*, 2002; Njeruh *et al.*, 2004; Kedir *et al.*, 2012; Munyeme *et al.*, 2010; Betebo, 2017); however, the difference was not significant, with the exception to that reported by Kedir *et al.* (2012) in small ruminants. Other studies showed that fasciolosis occur mostly in females (Phiri *et al.*, 2005a, b; Aregay *et al.*, 2013; Mebrahtu & Beka, 2013; Amsalu, 2017; Eshetu *et al.*, 2017; Mochankana & Robertson, 2018). However, the difference in the prevalence between sex was not significant with exception to that reported by Mochankana & Robertson (2018).

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Table 4. Prevalence of fasciolosis in domestic ruminants in East and Southern Africa based on faecal egg and fluke counts (1988–2018).

Country	Host	Total examined	Positive	Prevalence (95% CI)	References
Faecal egg counts					
Ethiopia	Cattle	1151	164	14.2	Regassa *et al.*, 2012
Ethiopia	Cattle	384	141	36.7	Aregay *et al.*, 2013
Ethiopia	Cattle	573	291	50.8	Assefa *et al.*, 2015
Ethiopia	Cattle	400	67	16.8	Moje *et al.*, 2015
Tanzania	Cattle	482	203	46.1	Keyyu *et al.*, 2006
Tanzania	Cattle	241	80	33.2	Nzalawahe *et al.*, 2014
Botswana	Cattle	8646	64	0.74	Mochankana & Robertson, 2018
Zambia	Cattle	841	453	53.9	Phiri *et al.*, 2005b
Zambia	Cattle	709	331	46.7	Phiri *et al.*, 2006
Zambia	Cattle	50	29	58.0	Yabe *et al.*, 2008
Zimbabwe	Cattle	16,264	2500	15.4	Pfukenyi *et al.*, 2006
Total		**29,741**	**4323**	**14.5**	
Ethiopia	Goats	128	12	9.4	Kedir *et al.*, 2012
Ethiopia	Sheep	384	56	14.6	Kedir *et al.*, 2012
Ethiopia	Sheep	576	49	8.5	Amsalu, 2017
Total		**960**	**105**	**10.9**	
Fluke counts					
Ethiopia	Cattle	3251	931	28.6	Abebe *et al.*, 2010
Ethiopia	Cattle	1151	249	21.6	Regassa *et al.*, 2012
Ethiopia	Cattle	413	165	40.0	Aregay *et al.*, 2013
Ethiopia	Cattle	450	110	24.4	Mebrahtu & Beka, 2013
Ethiopia	Cattle	196	107	54.6	Assefa *et al.*, 2015
Ethiopia	Cattle	400	120	30.0	Moje *et al.*, 2015
Ethiopia	Cattle	384	156	40.6	Eshetu *et al.*, 2017
Ethiopia	Cattle	384	117	30.5	Meshesha & Tesfaye, 2017
Kenya	Cattle	5,421,188	427,931	7.9	Kithuka *et al.*, 2002
Kenya	Cattle	1584	147	9.3	Njeruh *et al.*, 2004
Kenya	Cattle	23,606	6079	25.8	Mungube *et al.*, 2006
Tanzania	Cattle	123,790	8302	6.7	Mwabonimana *et al.*, 2009
Tanzania	Cattle	34,204	6663	19.5	Kamwela *et al.*, 2013
Tanzania	Cattle	8410	6376	75.8	Nzalawahe & Komba, 2013
Botswana	Cattle	1,394,721	1250	0.09	Mochankana & Robertson, 2016
Zambia	Cattle	677	331	48.9	Phiri *et al.*, 2005b
Zambia	Cattle	50	34	68.0	Yabe *et al.*, 2008
Zimbabwe	Cattle	2,474,232	917,565	37.1	Pfukenyi et al., 2006
Total		**9,489,091**	**1,376,633**	**14.5**	
Ethiopia	Goats	128	22	17.2	Kedir *et al.*, 2012
Kenya	Goats	2,062,828	48,889	2.4	Njeruh *et al.*, 2004
Kenya	Goats	17,743	1171	6.6	Mungube *et al.*, 2006
Tanzania	Goats	485	29	6.0	Mhoma *et al.*, 2011
Tanzania	Goats	8424	2295	26.0	Nzalawahe & Komba, 2013
Total		**2,089,608**	**52,406**	**2.5**	

(*Continued*)

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Table 4. (*Continued.*)

Country	Host	Total examined	Positive	Prevalence (95% CI)	References
Ethiopia	Sheep	576	61	10.6	Amsalu, 2017
Ethiopia	Sheep	384	101	26.3	Kedir *et al.*, 2012
Kenya	Sheep	1,700,281	61,955	3.6	Njeruh *et al.*, 2004
Kenya	Sheep	6036	314	5.2	Mungube *et al.*, 2006
Total		**1,707,277**	**62,431**	**3.7**	

CI, confidence interval.

Body condition score

Animals with a poor (low) body condition score seemed to be more susceptible to infection and had a higher fasciolosis prevalence than those with moderate and higher body condition scores. For instance, studies showed a prevalence ranging from 26.92% to 60.48% in cattle with poor body condition scores, compared to 20.83%–36.1% in those with moderate and 11.0%–22.45% in those with good body condition (Mebrahtu & Beka, 2013; Assefa *et al.*, 2015; Moje *et al.*, 2015; Betebo, 2017). Amsalu (2017) and Kedir *et al.* (2012) also showed a similar trend in sheep and goats; a prevalence of 13.5%, 8.2% and 7.9% in sheep, and 44.6%, 22.7% and 15.4% in goats with poor, moderate and good body condition scores, respectively. Some studies showed a significant association between the body condition scores and *Fasciola* infection prevalence ($P < 0.05$) (Mebrahtu & Beka, 2013; Assefa *et al.*, 2015; Moje *et al.*, 2015; Betebo, 2017; Eshetu *et al.*, 2017), whilst others found no statistical association (Mebrahtu and Beka, 2013). However, Aregay *et al.* (2013) and Munyeme *et al.* (2010) showed that cattle and Kafue lechwe with good condition scores were largely infected (39.30% and 75%) with fasciolosis compared to those with poor condition scores (39.30% and 12.5%), but the association was not statistically significant (Munyeme *et al.*, 2010; Aregay *et al.*, 2013).

Discussion

Fasciola hepatica and *F. gigantica* have been proven to utilize diverse mammalian species as their vertebrate hosts, ranging from domestic ruminants to wildlife (Jaja *et al.*, 2012) in East and Southern Africa. However, *Fasciola* infection due to one or both *Fasciola* species seems to be common in domestic ruminants throughout the reviewed countries, but rare in wildlife and humans, probably due to limited studies in wildlife in the two regions.

Results showed that both *Fasciola* species are present in Southern African wildlife. *Fasciola hepatica* was documented in kudu in South Africa (Van Wyk & Boomker, 2015), sable antelope and common duiker in Zimbabwe (Mucheka *et al.*, 2015). *Fasciola gigantica* was reported in ten wildlife species in Zimbabwe (Jooste, 1989; Mucheka *et al.*, 2015), in an impala from a game reserve previously used as a cattle ranch in Swaziland (Gallivan *et al.*, 1996) and Kafue lechwe in the Kafue basin in Zambia (Munyeme *et al.*, 2010). According to Boomker (2007), fasciolosis is rare in free-ranging antelopes, and the presence of *F. hepatica* infection in kudu might have been accidental as they are generally browsers and are less likely to get exposed to aquatic vegetation. *Fasciola hepatica* infection recorded in kudu may be attributed to the water source (dam), which provided a favourable environment for freshwater snails that serve as IHs for the liver fluke, and was regularly accessed by cattle (Van Wyk & Boomker, 2015). According to Muma *et al.* (2007) and Munyeme *et al.* (2008), contact between wildlife and cattle via sharing grazing land or drinking water most likely facilitates bi-modal transmission of the parasite.

The reviewed studies also showed that the highest prevalence of fasciolosis in domestic ruminants in East Africa was reported in Ethiopia in cattle (Assefa *et al.*, 2015), sheep and goats (Kedir *et al.*, 2012), and in Tanzanian cattle and sheep in communal grazing areas where irrigation was practiced (Nzalawahe & Komba, 2013). In Southern Africa, the highest prevalence of fasciolosis was reported in domestic ruminants from the Kafue basin in Zambia (Yabe *et al.*, 2008). In wildlife, the prevalence of fasciolosis was highest in the Kafue lechwe from the Kafue wetlands in Zambia (Munyeme *et al.*, 2010), followed by kudu in South Africa (Van Wyk & Boomker, 2015) and impala from a game reserve previously used as a cattle ranch in Swaziland (Gallivan *et al.*, 1996).

The overall mean prevalence of fasciolosis was highest in cattle, followed by sheep and then goats. According to Kedir *et al.* (2012), the interspecies variation in the prevalence is probably due to the difference in the feeding behaviour of the animal species, as well as their general immunological response to parasitic infection. Cattle and sheep are generally grazers, while sheep nibble nearer to the ground and goats browse; hence, the feeding behaviour of cattle and sheep increases the chances of exposure to infective stages of parasites compared to goats (Kedir *et al.*, 2012; Legesse *et al.*, 2014), and contact of goats with infective stages may be caused by the scarcity of browse feed or due to a decrease in vegetation cover, compelling goats to graze around water points and irrigation lands (Legesse *et al.*, 2014). Furthermore, *Fasciola* infection in goats (Nzalawahe & Komba, 2013) and sheep (Wamae & Cheruiyot, 1990; Mungube *et al.*, 2006) has been reported to cause an acute form of fasciolosis, characterized by high mortality rate (Mungube *et al.*, 2006; Nzalawahe & Komba, 2013). In cattle, fasciolosis generally manifests as a chronic disease due to immunity acquired following the first infection (Mungube *et al.*, 2006), which reduces the migration of the immature flukes to the liver (Mungube *et al.*, 2006; Nzalawahe & Komba, 2013). According to Nzalawahe & Komba (2013), this phenomenon has not been described in sheep and goats. However, Kedir *et al.* (2012) reported that unlike goats, sheep acquire resistance to fasciolosis.

Our results also showed that the overall prevalence of fasciolosis in cattle was similar based on faecal egg count and fluke count methods, but higher in sheep and goats based on the faecal egg count as compared to the fluke count method. However, most studies recorded a higher prevalence with the fluke count method.

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The egg count method has a low sensitivity due to the fact that *Fasciola* eggs only appear in faeces about 8–15 weeks post-infection (Sanchez-Andrade *et al.*, 2002). Pfukenyi & Mukaratirwa (2004) reported higher prevalence of fasciolosis based on the fluke count method, as post-mortem studies include immature flukes, which cannot be detected by coprological examinations. Although the faecal egg count technique is commonly used in the diagnosis of fasciolosis in animals and humans, species identification is often based on assumptions since *Fasciola* eggs cannot be used to distinguish species.

Risk factors that may influence the transmission of *Fasciola* spp. may include age, sex and body condition of the host. However, according to Rangel-Ruiz *et al.* (1999), determining the major risk factors influencing the transmission of fasciolosis is complicated, mainly because adult *Fasciola* may persist inside the definitive host for more than one year, consistently producing eggs.

Although both *Fasciola* species have been observed to occur in both regions of study, *F. gigantica* was more common, and geographical distribution was found to be consistent with that of its IHs. *Radix natalensis*, the African native IH of *F. gigantica*, was observed to occur in ten of the 11 countries where lymnaeid species have been reported as either the only species or in conjunction with other species. In some cases, this species has been found with more than one type of cercariae, including Gymnocephalous cercariae, which represent either fasciolids or amphistomes; however, co-infection by two different cercariae has never been reported (Wamae & Cheruiyot, 1990; Phiri *et al.*, 2007; Moema *et al.*, 2008; Walker *et al.*, 2008). Other lymnaeid species have been reported to transmit *F. gigantica* elsewhere in the world (Brown, 1994; Grabner *et al.*, 2014; Appleton & Miranda, 2015) and *R. auricularia* has been reported in South Africa and Botswana (Malatji *et al.*, 2019), *R. rubiginosa* in South Africa (Appleton & Miranda, 2015) and *P. columella* in South Africa (De Kock & Wolmarans, 1998; Wolmarans & De Kock, 2006; De Kock & Wolmarans, 2008; Perissinotto *et al.*, 2014; Kemp *et al.*, 2016) and Namibia (Curtis, 1991). In South Africa, *P. columella* has been found naturally infected with *F. gigantica* and *Echinostoma* spp. (Malatji & Mukaratirwa, 2019) and found to co-exist with *R. natalensis* in KwaZulu-Natal and Mpumalanga provinces, where both *F. gigantica* and *F. hepatica* overlap (De Kock & Wolmarans, 1998; Wolmarans & De Kock, 2006; De Kock & Wolmarans, 2008; Malatji *et al.*, 2019). These findings have led to the assumption that this species could be playing a major role in the transmission of both *Fasciola* species in the two provinces of South Africa, whereas its role in the transmission of *Fasciola* species in Namibia is not known.

Fasciola hepatica infections have been reported in ruminants in Ethiopia (Abebe *et al.*, 2010; Kedir *et al.*, 2012; Regassa *et al.*, 2012; Aregay *et al.*, 2013; Mebrahtu & Beka, 2013; Assefa *et al.*, 2015; Moje *et al.*, 2015; Amsalu, 2017; Betebo, 2017; Eshetu *et al.*, 2017), South Africa and Zimbabwe (Mucheka *et al.*, 2015). In Tanzania, this species has been detected in *G. truncatula* (Walker *et al.*, 2008) and this lymnaeid is known as the main IH of *F. hepatica* worldwide (Mas-Coma *et al.*, 2005). *Galba truncutula* has been documented in Ethiopia (Eguale *et al.*, 2006), South Africa (De Kock *et al.*, 2003), Tanzania (Walker *et al.*, 2008) and Uganda (Howell *et al.*, 2012). According to Howell *et al.* (2012), the presence of this lymnaeid species within the Mount Elgon National park of Uganda, where the presence of *F. hepatica* has not been reported, raises concerns of transmission of *F. hepatica* should it be introduced in the area. Although *F. hepatica* has been reported in cattle and wildlife in Zimbabwe (Mucheka *et al.*, 2015), the IH of this species in Zimbabwe is yet to be determined. Other than *F. hepatica* and *F. gigantica*, *F. tragelaphi* has been reported in cattle in Zimbabwe (Mukaratirwa & Brand, 1999); however, the IH of this species is yet to be identified.

The geographical distribution of *F. hepatica* and *F. gigantica* have been observed to be influenced by different altitudes, associated with the existence of the ecological conditions conducive for their IHs. *Fasciola hepatica* has been observed to be predominant in cold (temperate) regions, with an altitude of approximately 1800 m above sea level in Ethiopia (Kedir *et al.*, 2012; Assefa *et al.*, 2015), 3000 m in Kiulo Plateau in Tanzania (Walker *et al.*, 2008) and an altitude above 3500 m in Mount Elgon of Uganda (Stensgaard *et al.*, 2006). These altitudes are not conducive for the survival of *R. natalensis*, the IH of *F. gigantica*. *Fasciola gigantica* is commonly found in areas with a lower altitude. In Ethiopia, this species is found in areas with an altitude below 1200 m above sea level (Kedir *et al.*, 2012). In Uganda, *F. gigantica* was found in cattle between altitudes of 1000 m and 1500 m, declining concurrently with the growing scarcity of the population of the IH, *R. natalensis*, ceasing at an altitude of 1800 m (Howell *et al.*, 2012). Both *Fasciola* species have been observed to overlap in South Africa (Mucheka *et al.*, 2015) and Ethiopia, where mixed infection of both species have been found in cattle (Abebe *et al.*, 2010; Kedir *et al.*, 2012; Regassa *et al.*, 2012; Aregay *et al.*, 2013; Moje *et al.*, 2015; Amsalu, 2017; Betebo, 2017; Eshetu *et al.*, 2017). In South Africa, both *Fasciola* species have been reported to overlap in Mpumalanga and KwaZulu-Natal (Mucheka *et al.*, 2015), where the invasive species *P. columella* exists (De Kock & Wolmarans, 1998; Wolmarans & De Kock, 2006; De Kock & Wolmarans, 2008; Perissinotto *et al.*, 2014). According to Kedir *et al.* (2012), the overlap and co-infection of the two *Fasciola* species is common in areas with an altitude range of 1200–1800 m (Kedir *et al.*, 2012).

Conclusion

In conclusion, this review has revealed that both *F. hepatica* and *F. gigantica* are present in East and Southern Africa. Furthermore, both species mainly infect cattle, followed by small ruminants (sheep and goats) and, to a lesser extent, wildlife. Both *Fasciola* species utilize different lymnaeid species with different geographical distributions, influenced by their ecological requirements and the environmental conditions. *Fasciola gigantica* utilizes *R. natalensis* as the IH, and this species is mainly found in areas with lower altitudes, while *F. hepatica* uses *G. truncatula* as the IH and is found in areas with high altitudes and lower temperatures. In South Africa and Ethiopia, *F. hepatica* and its IH, *G. truncatula*, are present, whereas in Zimbabwe, only a single case of *F. hepatica* was reported and the IH of this species has not been reported. *Galba truncatula* has been reported in Mount Elgon of Uganda, where *F. hepatica* has apparently not been reported, and the presence of this species raises concerns of potential rapid transmission of fasciolosis due to *F. hepatica* should the species be introduced into the area. *Fasciola gigantica* transmitted by *R. natalensis* was observed to be more prevalent and widespread in all reviewed countries, save South Africa and Ethiopia, where *F. hepatica* was reported to be the more prevalent species. Apart from *R. natalensis* and *G. truncatula* being reported as the IH species of *F. gigantica* and *F. hepatica*, respectively, other species have

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also been identified in South Africa, Namibia and Botswana, although their role in the transmission of *Fasciola* species has not been proven. *Radix auricularia* has been identified in Botswana and South Africa, *R. rubiginosa* in South Africa and *P. columella* in South Africa and Namibia, where it has been observed to share habitats with *R. natalensis*. Their role in the transmission of *Fasciola* spp. in Eastern and Southern Africa is yet to be determined.

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