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Mapping risk of bovine fasciolosis in the south of Brazil using Geographic Information Systems

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ABSTRACT

Fasciolosis, caused by *Fasciola hepatica*, is an endemic disease of ruminants that occurs in several countries of South America where it can lead to decreased production and fertility and, in severe cases, animal death. Although very prevalent, information on the epidemiology of the disease is incomplete in Brazil. The objective of the present study was to define the prevalence of *F. hepatica* in the livers of cattle from slaughterhouses and correlate the data with the animal's origin (climate and altitude) using a Geographic Information System (GIS). The data was used to create an epidemiological map of fasciolosis by state (Rio Grande do Sul, Santa Catarina, Paraná), by municipality ($n = 530$) and by year (2003–2008). Information was analyzed using a databank from slaughterhouses with Federal Inspection Services of the Ministry of Agriculture. The highest cattle infection rate was found in the two most Southern states of Rio Grande do Sul (18.7%) and Santa Catarina (10.1%). Animals from the Campanha region of Rio Grande do Sul and from the central coast area of Santa Catarina had prevalences of greater than 40%. Cattle from low altitudes municipalities were significantly more likely to have the disease ($p < 0.05$). No significant differences were found between high or low prevalence and ambient temperatures. Risk maps resulting from this study provide information on the epidemiology and transmission of *F. hepatica* in Southern Brazil needed for design of appropriate control measures to control economic impacts. *F. hepatica* may represent an important source of zoonotic infection of humans as well; therefore these findings may be complemented by future studies on human infections in high risk areas.

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1. Introduction

Fasciola hepatica is a liver parasite of ruminants that may also infect horses, pigs, wild animals and humans (Torgerson and Claxton, 1999). Fasciolosis has a great worldwide economical impact due to decreases in primary beef production of infected ruminants (Mas-Coma et al., 2005). Gavinho et al. (2008) determined that fasciolosis could account for a significant ($p = 0.004$) reduction of 5.8% of carcass weight between infected and non-infected cattle, representing a reduction of US$35.00 of revenue per head in Brazil. Global economic losses may exceed US$ 200 million per year, with approximately 300 million infected cattle (Mas-Coma et al., 2005).

Fasciolosis occurs mainly in regions where climate conditions favor the development of the organism with temperatures ranging from 10 to 25 °C. Other factors such as altitude, wet soils, the presence of extensive hydrographic flooded areas or swamps, rice cultivation and

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livestock farming also strongly contribute to the maintenance of snail intermediate hosts of the genus *Lymnaea* (Ueno et al., 1982; Müller et al., 1997).

The prevalence of fasciolosis in cattle has been reported from endemic areas of Chile (94%), the USA (California 52.7%; Florida 68%, Louisiana 25%), Ireland (45%), Spain (29.5%), Turkey (29.3%), Peru (29%), Germany (10.7%), Morocco (10.4%), Cambodia (10%) and New Zealand (8.5%) (Tum et al., 2007; Torgerson et al., 1999). Reports of fasciolosis prevalence in Brazil varies from 64.8% in Santa Catarina (Serra-Freire et al., 1995), 15.8% in Rio de Janeiro (Gomes et al., 2002), 14.7% in Rio Grande do Sul (Klimonte et al., 2005), 10.59% in Minas Gerais (Faria et al., 2005) and it has been found in some areas of São Paulo (Ueno et al., 1982; Serra-Freire et al., 1995). In Minas Gerais state, it was possible to detect infected bovines in 70% of the rural farms visited in the municipalities of Itajubá (Lima et al., 2009). Treatment of infected animals may not prevent high death rates in sheep and goats if drug resistant parasites emerge (Oliveira et al., 2008).

Geographic Information Systems technology (GIS) provides a useful tool to establish relationships of disease data to environmental features at known infected sites. Significantly associated environmental features can then be extrapolated to areas where there is no data to produce epidemiological disease risk maps (Malone et al., 1998; Fuentes, 2006). Environmental remote sensing data may be incorporated within a GIS and used for routine health management programs, including control and prevention of *F. hepatica* (Torgerson and Claxton, 1999).

Although fasciolosis is an important zoonotic disease, study of this aspect has been neglected in many countries (Robinson and Dalton, 2009), including Brazil. Since there is no comprehensive epidemiological study available of fasciolosis in Brazil, the aim of the present study was to use GIS to analyze the prevalence of *F. hepatica* in the liver of cattle from slaughterhouses in Southern Brazil, and to correlate differences in risk to climate and altitude.

2. Materials and methods

The livers of 12.3 million slaughtered cattle from Rio Grande do Sul, Santa Catarina and Paraná states in Brazil were inspected to determine *F. hepatica* infection rates at establishments that were registered with Federal Inspection Service of the Ministry of Agriculture, Livestock and Supply (SIF/MAPA).

The southern region of Brazil is composed of three states: Rio Grande do Sul, Santa Catarina and Paraná, and have a total of 1188 municipalities (Fig. 1). A database was assembled including geographical coordinates (latitude and longitude), total number of cattle slaughtered and total number of infected livers from 530 municipalities, representing the municipalities that slaughtered cattle under federal inspection. In addition, information on climate and altitude provided by the National Institute for Space Research (INPE – Ministry of Science and Technology), were obtained for analysis. The 530 municipalities were divided into three '*F. hepatica* prevalence' groups: Group 1, with the highest prevalence (>36%); Group 2 with intermediate prevalence (5–18%); and Group 3 with the lowest prevalence (<2%) rates.

These data were then analyzed using ArcGIS 9, version 9.2 software, to georeference the coordinates of each municipality to GIS map layers on environmental features in the south of Brazil. The prevalence of livers infected with *F. hepatica* each year (2003–2008) was the attribute selected in the program to create the initial epidemiological maps. The final risk map was generated using the kriging function of the spatial analyst tool of ArcGIS to define the epidemiological risk areas of the disease. The margin of error (d) was calculated, using the formula:

$$d = t[(N-n)/(N-1)] \cdot \frac{1}{2} [P \times Q/n] \cdot \frac{1}{2}$$

where (t) is a constant used in the calculation error (4.96), (N) is the total of municipalities, (n) is the municipalities with positive cases, and ($P \times Q$) is the probability of events (constant 2500).

The correlation between the prevalence of infection and climatic temperature and the prevalence of infection and altitude from municipalities of each of the 3 prevalence groups was calculated using Spearman's correlation coefficient (Analyze-it 2.21, 2009).

3. Results and discussion

Rio Grande do Sul (RS) and Santa Catarina (SC) states had the highest prevalence of condemned livers due to *F. hepatica*, with condemnation rates of 18.66% and 10.14%, respectively (Table 1). These results are in agreement with earlier studies in RS in which an average 14.7% liver condemnation rate was reported (Klimionte et al., 2005), but significantly differ from the 64.82% liver condemnation rates previously reported in coastal areas at low elevation that are prone to flooding SC (Serra-Freire et al., 1995).

Results illustrated in Fig. 2 show that the prevalence of fasciolosis was markedly higher in the Campanha region of RS and in the Central coast region of SC, the lowest altitude areas of both states. A significantly lower infection rate was observed above latitude 26°39′00″ S in Paraná (PR) state. The margin of error calculated for the 530 municipalities studied, of 1188 municipalities total, was 3.24.

The epidemiology of *F. hepatica* infection in cattle is influenced by the geography of the land (Torgerson et al., 1999). Municipalities in the high impact group, moderate impact group and low impact group had average *F. hepatica* infection rates of 40.81% (±3.47), 10.6% (±4.07), and 1.51%

Table 1
The number of cattle slaughtered and the number of livers infected with *Fasciola hepatica* in Rio Grande do Sul, Santa Catarina and Paraná in the south of Brazil from 2003 to 2008.

State	Total number of slaughtered cattle	Number infected with *F. hepatica*	%
Paraná	6.727.459	48.235	0.71
Rio Grande do Sul	4.839.446	903.040	18.66
Santa Catarina	699.147	70.928	10.14
Total	12.266.052	1.022.203	29.51

Source: SIF/MAPA.

Fig. 1. Map of Brazil showing the states of Parana, Santa Catarina and Rio Grande do Sul (grey) where *Fasciola hepatica* liver condemnation rate data were collected from cattle slaughtered in 2003 to 2008.

(±0.44), respectively (Table 2). Municipalities included in the high impact group were mostly located in low elevation areas between 5 and 154 m above sea level in RS close to the border of Uruguay, and in the central region of the coast of SC, between 2 and 100 m (INPE, 2009). Municipalities from the low risk group were mostly located in the West and North of SC with altitudes ranging from 470 to 1042 m, as well as the entire state of PR, with altitudes between 317 and 920 m (INPE, 2009). The moderate risk group was located in the North of RS with altitude between 230 and 590 m and in the West, South and Northeast of SC with altitude between 79 and 834 m. The correlation coefficient between infection rate and altitude for all municipalities of three groups was −0.80. Low risk municipalities were found at higher altitudes in PR where the economic impact of the disease is minimal because the environment is unsuitable for the survival of the intermediary host (Mas-Coma et al., 2001). This may be associated with high rates of evaporation of soil moisture, low temperatures and generally more mountainous terrain that hinders the accumulation of water and local flooding and consequently the survival of the intermediate host (Mas-Coma et al., 2001).

Regarding the influence of ambient temperatures, high risk group municipalities had an average temperature of 19.5 °C (±0.30); moderate risk group municipalities had an average temperature of 19.7 °C (±0.25); and low risk group municipalities had an average temperature of 18.1 °C (±0.78) (INPE, 2009). The correlation of infection rate and temperature for all municipalities was 0.24. Fasciolosis prevalence was simultaneously higher (2.03%) in the three Southern states in 2006 (Fig. 3), suggesting a significant annual variation in climatic effect on the rate of infection by the parasite in this year due to increase rainfall, since temperature did not reveal significant changes.

The thermal regimes found in the south of Brazil are suitable for the snail host (*Lymnaea viatrix*). For the intermediate host survival, a minimum temperature of 10 °C and maximum between 18 and 27 °C is required (Kendall, 1953). Under suitable environmental conditions, the snail *Lymneae truncatula* can grow to sexual maturity in 3–4 weeks, depending on the amount of food available and the number of parasites (Kendall and Ollerenshaw, 1963). Boray and Enigk (1964) demonstrated that cysts of *Lymnaea tomentosa* in Australia remain viable for only 3

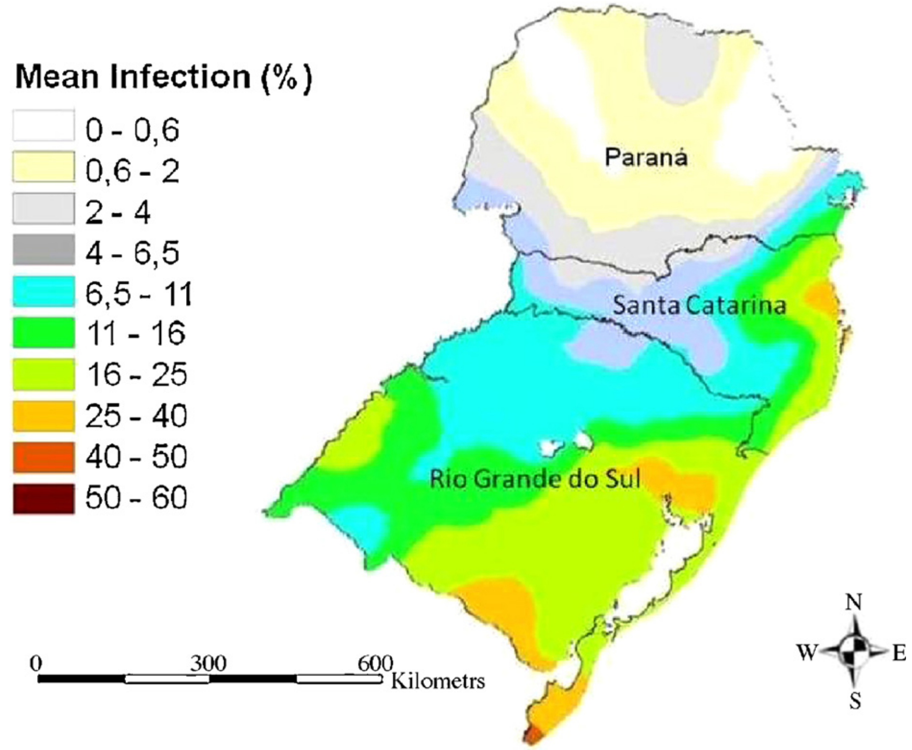

Fig. 2. Probability map prepared by the Kriging method of liver condemnations due to *F. hepatica* infection in cattle slaughtered from 2003 to 2008.

days at 20 °C and a relative humidity of 75–80%, while at 10 °C and 90% moisture they can survive 122 days. The cause of decline in pasture infectivity is related to the death of metacercariae (Ollerenshaw, 1971).

The production of beef cattle in association with sheep in the presence of intermediate hosts, particularly in RS, may predispose the spread of the disease and may be an important factor to be considered under Southern Brazil conditions. Although the prevalence of *F. hepatica* may be influenced by the use of treatment and control methods on cattle hosts, our findings suggest that the prevalence of *F. hepatica* in cattle is closely related to topography, as previously described by Dalton (1999).

This study resulted in a risk map for fasciolosis in the southern states of Brazil, showing the geospatial distribution of a disease that causes significant economic losses, with low production of meat, milk and wool, decreased fertility and increased expenditures on antiparasitic drugs (Müller et al., 1999). The ambient temperatures observed in high risk areas and municipalities are within the optimum range temperature for the *F. hepatica* cycle. Altitude was shown to be a significant determinant of *F. hepatica* prevalence.

Although the risk map was generated with a low margin of error, it is relevant that the present data only represent the total number of animals slaughtered under Federal Inspection. It does not consider additional data from animals slaughtered under State and Municipality Inspection Services and there is considerable illegal slaughtering. The federal condemnation rates used for this study for Rio Grande do Sul were 50.61% of livers (4.958.749/9.798.195 bovine slaughtered), 61.23% for Santa Catarina (1.104.161/1.803.308) and 42.01% for Paraná (4.874.044/11.601.503) (IBGE, 2009).

At present, human cases of fasciolosis are not considered of great importance within the area studied. The south of Brazil was colonized by people of many origins (Portuguese, Germans and Italians) who may consume raw vegetables from swampy environments, but it is estimated that many of these areas are not grazed by infected animals. There is marked heterogeneity of human fasciolosis prevalence in different epidemiological scenarios with different transmission patterns throughout the world (Mas-Coma et al., 2009). Although fasciolosis is a common disease associated with domestic animals, it is recognized now by the World Health Organization (WHO) as a serious problem of public health in humans as well (Rokni et al., 2002) and it may be concluded that well-known situations and patterns of fasciolosis may not always explain the disease characteristics in a given area. Thus, when dealing with an endemic zone not studied previously, the scenarios and patterns of human infection above must always be considered merely as the starting point. Once the epidemiology and transmission characteristics of a new area, such as Southern Brazil, have been adequately assessed appropriate control measures can be designed (Mas-Coma et al., 2009).

Table 2
Rate of infected livers by fasciola (%) and average temperature[a] (°C) of cities in the areas with high and low impact by year.

Cities	2003		2004		2005		2006		2007		2008	
	%	T (°C)[a]	%	T (°C)[a]	%	T (°C)[a]	%	T (°C)[a]	%	T (°C)[a]	%	T (°C)[a]
Group 1, high risk												
Aceguá (RS)	41.4	17	40.6	17.2	32.8	16.2	33.3	16.6	24.9	16.1	25.7	16.3
Chuí (RS)	62.5	16.1	33.2	16.3	29.4	15.9	45.3	15.5	63.9	16	72.4	15.9
Gaspar (SC)	34.49	23.2	51.9	23.3	45.6	22.6	31.7	22.9	25.9	22.6	35.1	22.9
Dom Pedrito (RS)	26.4	16.7	23	16.9	27	15.4	24.7	16	21.8	15.1	17.0	15.5
Ihota (SC)	22.91	22.4	32.9	22.6	25.1	21.8	22.2	22	2.68	21.8	14.1	22.4
Itapema (SC)	46.9	22.5	65.1	22.6	37.9	21.8	77.2	22.1	40.1	21.9	69.5	22.5
St. Vitória Palmar (RS)	37.4	18.2	38.9	18.5	34.3	18	41.6	18.4	42.0	17.6	38.9	17.9
Tijucas (SC)	69.65	22.7	65.1	23	62.0	22.4	78.6	22.6	70.7	22.3	54.5	22.9
Mean	42.7	19.8	43.8	20	36.7	19.3	44.3	19.5	36.5	19.2	40.9	19.5
Group 2, moderate risk												
Água Doce (SC)	4.9	16.6	7.5	17.5	6.8	17.3	9.2	18.0	8.4	17.7	9.1	17.2
Capinzal (SC)	15.4	20.1	17.3	23.2	12.5	23.8	5.0	25.4	25.6	23.3	11.7	24.7
Entre Ijuís (RS)	12.1	21.3	10.6	22.5	7.5	19.8	15.4	20.6	1.36	21.3	22.9	19.6
Ibirubá (RS)	8.9	25.9	12.0	22.5	7.2	24.7	2.4	22.3	13.7	21.8	10.0	22.9
Jaborá (SC)	8.8	18.4	10.4	18.7	10.5	19.9	6.1	19.5	12.5	18.7	9.7	18.9
Rio dos Cedros (SC)	25.6	17.7	31.7	18.8	24.1	18.1	7.1	17.9	5.5	18.0	14.5	17.6
São José do Cedro (SC)	8.4	16.3	5.8	15.1	4.8	16.5	3.1	15.1	4.5	15.9	5.4	16.1
Nonoai (RS)	9.8	19.2	10.5	19.4	8.8	20.1	7.5	19.9	12.1	19.8	4.2	20.7
Mean	11.7	19.4	13.2	19.7	10.2	20.0	6.9	18.1	10.4	18.8	10.9	19.7
Group 3, low risk												
Cerro Azul (PR)	0.1	22.1	0.2	25.2	0.5	23.4	0.1	25.4	0.3	26.3	0.1	25.9
Formosa do Sul (SC)	4.5	19.3	5.1	18.4	3.3	18.9	3.7	18.6	4.1	19.5	4.2	19.1
Japira (PR)	0.1	22.9	0.1	23.5	0.1	23.7	0.2	22.7	0.1	23.8	0.1	23.6
Lapa (PR)	0.1	17.2	0.2	18.2	0.1	17.9	0.3	17.5	0.1	17.7	0.1	18.1
Otacílio Costa (SC)	3.4	16.7	4.6	16.8	3.9	16.1	9.2	16.9	11.1	17	3.7	16.6
Palmital (PR)	0.1	15.3	0.1	15.9	0.1	15.8	0.1	16.2	0.2	16.1	0.1	16
Passos Maia (SC)	0.6	16.2	1.2	16.4	0.4	16.2	0.5	16.9	1	16.3	0.2	16.5
Ponte Serrada (SC)	0.5	16.1	0.8	15.4	0.6	15.9	1.4	16.4	1.1	16.1	1.3	16.3
Mean	1.2	18.2	1.5	18.7	1.1	18.4	1.9	16.8	2.2	17.8	1.2	19

[a] Data mean temperature (in °C) for council from the National Institute for Space Research (INPE).

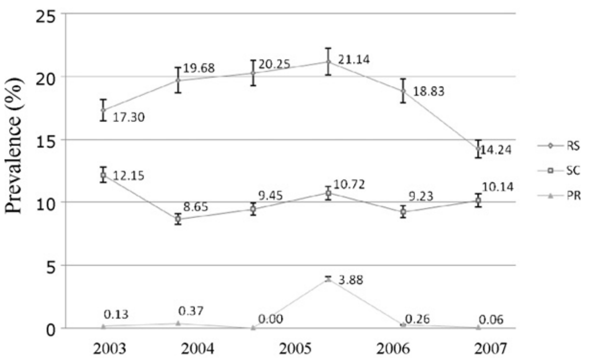

Fig. 3. Average prevalence of infected liver by year in the states of Rio Grande do Sul, Santa Catarina, and Paraná.

4. Conclusion

The states of RS and SC presented the highest incidence in livers with *F. hepatica* under Federal Inspection in Southern Brazil. The Campanha area in RS and the central region of the coast of SC were identified as high risk areas for *F. hepatica* that should be targeted for control of economic losses in livestock and increased vigilance for potential zoonotic human infection.

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References

Boray, J.C., Enigk, K., 1964. Laboratory studies on the survival and infectivity of *Fasciola hepatica* and *Fasciola gigantica* metacercariae. Z. Tropenmed. Parasitol. 15, 324–331.
Dalton, J.P., 1999. Fasciolosis. Oxford, London.
Faria, R.N., Cury, M.C., Lima, W.S., 2005. Prevalence and dynamics of natural infection with *Fasciola hepatica* (Linnaeus, 1758) in Brazilian cattles. Rev. Med. Vet. 156 (2), 85–86.
Fuentes, M.V., 2006. Remote sensing and climate data as a key for understanding fasciolosis transmission in the Andes: review and update of an ongoing interdisciplinary project. Geospat. Health 1 (1), 59–70.
Gavinho, B., Kulek, A.C.G., Molento, M.B., 2008. Quantitative determination and geographic distribution of *Fasciola hepatica* in bovines slaughtered in São José dos Pinhais, PR. In: XVI Encontro de Iniciação ar203*ãoCientificadaUFPR.Curitiba*(*CD − Rom*).
Gomes, F.F., Oliveira, F.C.R., Pile, E.A., Lopes, C.W.G., 2002. Estabelecimento de foco de fasciolose hepática em propriedade do município de Campos dos Goytacazes no estado do rio de janeiro, Brasil. Rev. Bras. Parasitol. Vet. 11 (2), 53–56.
Instituto Brasileiro de Geografia e Estatística (IBGE), Banco de Dados Agregados – SIDRA, 2009. Available in http://www.sidra.ibge.gov.br/. Access in: May 18/2009.
Kendall, S.B., 1953. The life-history of *Limnaea truncalata* under laboratory conditions. J. Helminthol. 34, 17–28.

Kendall, S.B., Ollerenshaw, C.B., 1963. The effect of nutrition on the growth of *Fasciola hepatica* in its snail host. Proc. Nutr. Soc. 22, 41–46.

Klimionte, R., Molento, M.B., Tielet, C., Gavião, A., 2005. Ocorrência da *Fasciola hepatica* no fígado de Bovinos abatidos no Rio Grande do Sul, RS – Brasil. Rev. Patol. Trop. 34, 14–21.

Lima, W.S., Soares, L.R.M., Barçante, T.A., Guimaraes, M.P., Barçante, J.M.P., 2009. Occurrence of *Fasciola hepatica* (Linnaeus, 1758) infection in Brazilian cattle of Minas Gerais, Brazil. Rev. Bras. Parasitol. Vet. 18 (2), 27–30.

Malone, J.B., Gomes, R., Hansen, J.M., Yilma, J., Slingenberg, F., Snijders, F., Nachtergaele, E., 1998. A geographic information system on the potential distribution and abundance of *Fasciola hepatica* and *F. gigantica* in east Africa based on Food and Agriculture Organization databases. Vet. Parasitol. 78, 87–101.

Mas-Coma, S., Funatsu, I.R., Bargues, M.D., 2001. *Fasciola hepatica* and lymnaeid snails occurring at very high altitude in South America. Parasitology 123, 115–127.

Mas-Coma, S., Bargues, M.D., Valero, M.A., 2005. Fascioliasis and other plantborne trematode zoonoses. Int. J. Parasitol. 35, 1255–1278.

Mas-Coma, S., Valero, M.A., Bargues, M.D., 2009. Fasciola, lymnaeids and human fascioliasis, with a global overview on disease transmission, epidemiology, evolutionary genetics, molecular epidemiology and control. Adv. Parasitol. 69, 44–68.

Müller, G., Jesus, L.P., Paulsen, R.M.M., Souza, C.A., 1997. Prevalência de fasciolose na região sul do Rio Grande do Sul, Brasil. In: Congresso Brasileiro de Veterinária, Gramado – RS, Anais, p. 186.

Müller, G., Berne, M.E.A., Raffi, L.L., Jesus, L.P., Paulsen, R.M.M., Sinkoc, A.L., 1999. Influência da temperatura na longevidade infectiva de metacercárias de *Fasciola hepatica*. Rev. Bras. Ag. 5 (2), 164–165.

Oliveira, D.R., Ferreira, D.M., Kloss, A., Stival, C.C., Romero, F., Ollerenshaw, C.B., 2008. Some aspects of the epidemiology of fasciolosis on Britain. Pro. Mal. Sci. 39, 238–243.

Ollerenshaw, C.B., 1971. Some observations on the epidemiology of fasciolosis in relation to the timing of molluscicide applications in the control of the disease. Vet. Rec. 88, 152–164.

Robinson, M.W., Dalton, J.P., 2009. Zoonotic helminth infections with particular emphasis on fasciolosis and other trematodiases. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 364, 2763–2776.

Rokni, M.B., Massoud, J., O'neill, S.M., Parkinson, M., Dalton, J.P., 2002. Diagnosis of human fasciolosis in the Gilan providence of Northern Iran: application of cathepsin L_ELISA. Parasitology 44, 175–179.

Serra-Freire, N.M., Bordin, E.L., Lessa, C.S.S., Scherer, P.O., Farias, M.T., Malacco, M.A., Corrêa, T.C., Tschumi, J.A., 1995. Reinvestigação sobre a distribuição da *Fasciola hepatica* no Brasil. Hora Vet. 1, 19–21.

Torgerson, P., Claxton, J., 1999. Epidemiology and control. In: Dalton, J.P. (Ed.), Fasciolosis. Oxford, London.

Tum, S., Puotinen, M.L., Skerratt, L.F., Chan, B., Sothoeun, S., 2007. Validation of a geographic information system model for mapping the risk of fasciolosis in cattle and buffaloes in Cambodia. Vet. Parasitol. 143, 364–367.

Ueno, H., Gutierres, V.C., Mattos, M.J., Müller, G., 1982. Fasciolosis problems in ruminants in Rio Grande do Sul, Brazil. Vet. Parasitol. 11, 185–191.