

Updated spatial analysis of areas of occurrence of bovine cysticercosis in the state of Espírito Santo, Brazil

Análise espacial atualizada de áreas de ocorrência de cisticercose bovina no estado do Espírito Santo, Brasil

Júlia Bertoli Gomes¹ , Barbara Rauta de Avelar²  & Isabella Vilhena Freire Martins^{3*} 

¹Undergraduate in Veterinary Medicine, Departamento de Medicina Veterinária, Universidade Federal do Espírito Santo, *campus* Alegre, ES, Brazil.

²Veterinarian, DSc., Programa de Pós-Graduação em Ciências Veterinárias, Departamento de Parasitologia Animal, Instituto de Veterinária da Universidade Federal Rural do Rio de Janeiro, *campus* Seropédica, RJ, Brazil.

³Veterinarian, DSc., Departamento de Medicina Veterinária, Universidade Federal do Espírito Santo, *campus* Alegre, ES, Brazil.

Abstract

The risk of bovine cysticercosis is mutable over time, since population habits, local infrastructure, and bovine herd size change through the years. Hence, the aim of this study was to update the risk map of bovine cysticercosis occurrence in Espírito Santo State, Brazil, by choosing the following risk factors: inadequate sewer service; bovine population per municipality; risk of flooding; and land use and occupation, examined with a mathematical model using the GIS program ArcGis 10.5. The risk map of occurrence demonstrated that the state is composed of 12.8, 24.5, 36.2 and 26.5% of areas of very high, high, medium, and low risk, respectively. The northern area stood out for areas of very high risk, with the cities of Linhares and São Mateus accounting for 99% of the area with this classification. Of the state's 78 municipalities, 15 had a portion of their territory with very high risk, 11 had over 50% of the territory with high risk and all except Irupi (100% of low risk) had some percentage of medium risk. These findings demonstrate the areas where actions to prevent bovine cysticercosis should be preferentially conducted.

Keywords: *Cysticercus bovis*, mapping, epidemiology, one health, zoonoses.

Resumo

O risco de cisticercose bovina é mutável ao longo do tempo, uma vez que os hábitos populacionais, a infraestrutura local e o tamanho do rebanho bovino mudam ao longo dos anos. Assim, o objetivo deste estudo foi atualizar o mapa de risco da ocorrência da cisticercose bovina no Estado do Espírito Santo, Brasil, escolhendo os seguintes fatores de risco: saneamento sanitário inadequado; população bovina por município; risco de inundação; e uso e ocupação do solo, examinados com um modelo matemático usando o programa SIG ArcGis 10.5. O mapa de risco de ocorrência demonstrou que o estado é composto por 12,8, 24,5, 36,2 e 26,5% de áreas de risco muito alto, alto, médio e baixo, respectivamente. A zona norte destacou-se como área de risco muito alto, com os municípios de Linhares e São Mateus respondendo por 99% da área com essa classificação. Dos 78 municípios do estado, 15 tinham uma parcela de seu território com risco muito alto, 11 tinham mais de 50% do território com risco alto e todos exceto Irupi (100% de risco baixo) tinham algum percentual de risco médio. Esses achados demonstram as áreas onde as ações de prevenção da cisticercose bovina devem ser preferencialmente realizadas.

Palavras-chave: *Cysticercus bovis*, mapeamento, epidemiologia, saúde única, zoonoses.

Introduction

Livestock breeding is a significant sector in the Brazilian economy. In 2016, the country had 218.23 million head of cattle, and that year 29.67 million cattle were slaughtered and 1,076,041 tons of beef was exported (Instituto Brasileiro de Geografia e Estatística, 2017). In this respect, studies to comprehend zoonoses transmitted to humans through food of animal origin, for example the cysticercosis taeniasis complex, associated with beef consumption, are important.

Bovine cysticercosis caused by *Cysticercus bovis*, the larval form of *Taenia saginata*, is diagnosed based mainly on meat inspection. However, its occurrence is underestimated and is usually linked to socioeconomic, cultural and management factors. Environmental factors such as risk of flooding and land use and occupation, as well as the presence of roads, railways and/or recreational



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*Correspondence

Isabella Vilhena Freire Martins
Departamento de Medicina Veterinária,
Universidade Federal do Espírito Santo - UFES
Alto Universitário
CEP 29500-000 - Alegre (ES), Brasil
E-mail: ivfmartins@gmail.com

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areas close to pastures, are also linked to the presence of parasitized animals (Allepuz et al., 2009; Boone et al., 2007; Rossi et al. 2014).

Due to the heterogeneous spatial distribution of the parasite, associated with variations in the sources of infection of animals, additional health surveillance practices are necessary for effective control (Magaço et al., 2017). Thus, to facilitate or guide control measures, environmental data, such as risk factors, when incorporated into geographic information systems (GIS), are able to provide a broad vision to support prevention of the occurrence of taeniasis cysticercosis complex (Dutra et al., 2012).

The fact that socioeconomic factors and some environmental factors change with time makes it important to revise the mapping of favorable areas for the development of the parasite. Thus, our objective was to update the spatial analysis of the risk of occurrence of bovine cysticercosis in the state of Espírito Santo.

Materials and methods

Characterizing the area studied

The state of Espírito Santo has 78 municipalities, and along with the states of Minas Gerais, Rio de Janeiro and São Paulo forms the Southeast region of Brazil. It is located between parallels 17°53'29" to 21°18'03" south latitude and the meridians 39°41'18" to 41°52'45" west longitude.

The determining factors of the occurrence of bovine cysticercosis

The variables selected to assemble the risk map for the occurrence of bovine cysticercosis in the state of Espírito Santo were inadequate sanitation to human population, cattle population per municipality, land use and occupation, and risk of flooding (Avelar et al., 2016). A database with these variables was created in Microsoft Excel (2017).

Assemblage of thematic maps of each variable

The assemblage of thematic maps referring to each of the selected variables was based on the method described by Avelar et al. (2016).

The map related to inadequate sewer service (ISS) was prepared based on population data from the 2010 Census conducted by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, 2010). The characterization of inadequate sewer service was based on the description provided by the IBGE on the types of sewage: Sewage general mesh or pluvial; septic fosse; rudimentary fosse; ditch and river, lake or sea.

To assemble the map of municipal cattle population (MCP), data referring to the population of cattle in the state were used, obtained from the Municipal Agricultural Production according to the most recent Agricultural Census (Instituto Brasileiro de Geografia e Estatística, 2017).

The vector maps of ISS and MCP were assembled using the Quantum GIS 2.0 software, interpolating the data obtained from the Instituto Brasileiro de Geografia e Estatística, (2010; 2017) with the mesh of census sectors, later converted into raster format.

The land use and occupation (LUO) map provided by the Integrated System of Geospatial Bases of the State of Espírito Santo (GEOBASES) was rasterized and then reclassified. And to create a flood risk map (FR), the land use and occupation map was used along with the slope and altitude maps made from the digital elevation model, which were interpolated and reclassified, considering as the most important classes slope (0 to 3%), altitude (0 to 83 m) and land type areas of mangroves, oceans, rivers and wetlands.

The AHP method proposed by Saaty (1977) was used, applying the decision matrix and using the Saaty fundamental scale, with a consistency ratio of 0.0334. After assigning the statistical weights, the "raster calculator" function was used to generate the statistical model of flood risk, represented by: $FR = a1 \times DEC + a2 \times MDE + a3 \times UOT$, Reclassified as low risk, medium risk, high risk and very high risk of flooding.

Statistical analysis and assembly of the risk map

The thematic maps of the variables flood risk, land use and occupation, cattle population and inadequate sewer service in raster format were reclassified into categories from 1 to 10 according to their importance for the occurrence of the parasitosis.

Data were weighted using Saaty's AHP method. A matrix was used to hierarchically define the importance of factors with a consistency ratio of 0.0433. After assigning the statistical weights of each polygonal vector class, the "raster calculator" function was used to generate the statistical model of risk of the occurrence of bovine cysticercosis, represented by: $BCFO = a_1 \times ISS + a_2 \times MCP + a_3 \times LUO + a_4 \times FR$ ¹.

After standardizing and filtering the data, the patterns of low risk, medium risk, high risk and very high risk were obtained.

Prevalence data

Prevalence data of bovine cysticercosis were obtained from the Serviço de Inspeção Federal (SIF) in the period 2016-2022 of the State Espírito Santo (Sistema de Informações Gerenciais do Serviço de Inspeção Federal, 2022).

Results

The thematic maps of MCP, ISS, FR and LUO (Figure 1) are the result of the selection of risk factors for the occurrence of the parasitosis. The interpolation of these maps, followed by reclassification, generated the final Risk Map for the Occurrence of Bovine Cysticercosis in the State of Espírito Santo (Figure 2), in which areas of very high, high, medium and low risk can be observed, corresponding respectively to 12.8, 24.5, 36.2 and 26.5% of the state's territory.

Of the 78 municipalities, 15 (19.23%) presented some percentage of very high risk, highlighting Linhares and São Mateus with more than 99% of their territory with this classification, followed by Cariacica with 23.26% very high risk areas. Cariacica (75.33% high risk) and 10 (12.82%) more municipalities had more than 50% of their territory composed of areas with high risk, with emphasis on eight municipalities: Aracruz (99.8%); Barra de São Francisco (92.97%); Cachoeiro de Itapemirim (95.71%); Conceição da Barra (99.65%); Ecoporanga (99.68%); Nova Venécia (93.57%); Pinheiros (99.33%); and Serra (99.59%) with more than 90% of territory with this classification.

In relation to the territorial extension of the state, the areas of medium risk were the most prevalent. All municipalities presented some percentage of this classification, with the exception of Irupi. Thirty (38.5%) of these 78 municipalities had more than half of the territory composed of areas of medium risk, and in 20 (20.64%) this percentage exceeded 90%. Irupi was the only municipality with 100% low risk, being part of the 34 (43.59%) municipalities having more than 50% of the territory with low risk, while in 29 (37.18%) of these, the areas were greater than 90%. The mean prevalence of bovine cysticercosis of the Espírito Santo state was 0.53% into years 2016 - 2022. The municipalities with highest prevalence were Alegre, Ecoporanga, Linhares, Mucurici and Viana with 0.05; 0.04; 0.04; 0.03 and 0.03% respectively.

Discussion

The areas of high and very high risk represented approximately 37% of the state's territory, an increase of more than 100% compared to the study presented by Avelar et al. (2016), in which these classifications together presented a sum close to 12%. Areas of medium risk still had the highest percentage, previously with 55.60% (Avelar et al., 2016) and now with 36.2%.

Espírito Santo has approximately 1.6 million head of cattle (Instituto Brasileiro de Geografia e Estatística, 2017), approximately 140 thousand head less than in 2007. Even so, of the ten municipalities with the highest cattle population, seven are in the northern region of the state and presented increases in the population of these animals between the 2006 and 2017 Agricultural Censuses (Instituto Brasileiro de Geografia e Estatística, 2006, 2017). Among them we can highlight Ecoporanga, with the largest bovine herd, and Linhares, with the second largest herd. These two accounted for more than 99% of areas of high and very high risk.

¹ BCFO: Risk of the Occurrence of Bovine Cysticercosis; ISS: Inadequate sewer service; MCP: municipal cattle population; LUO: land use and occupation; FR: flood risk; and a_1, a_2, a_3, a_4 : model constants.

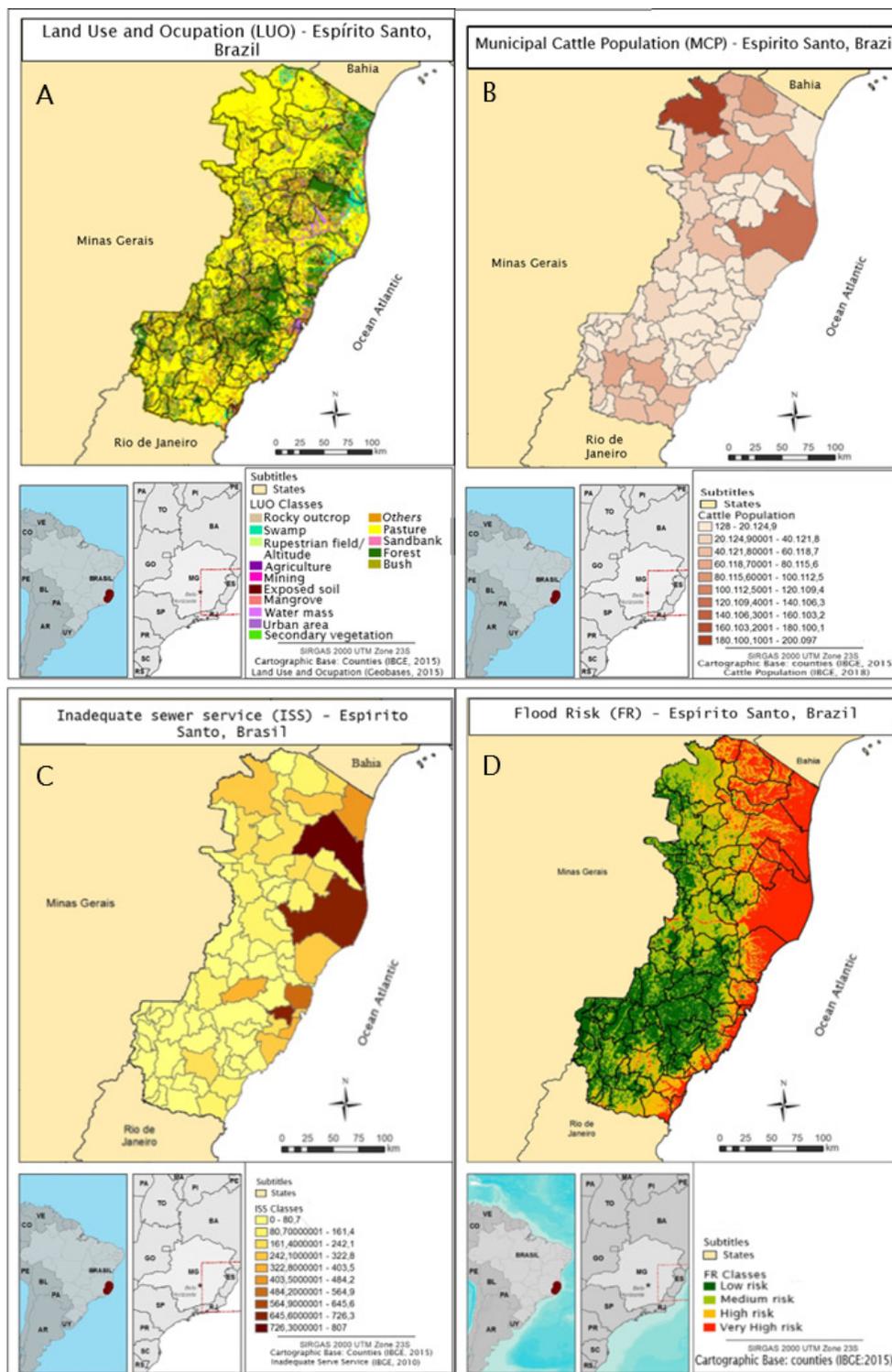
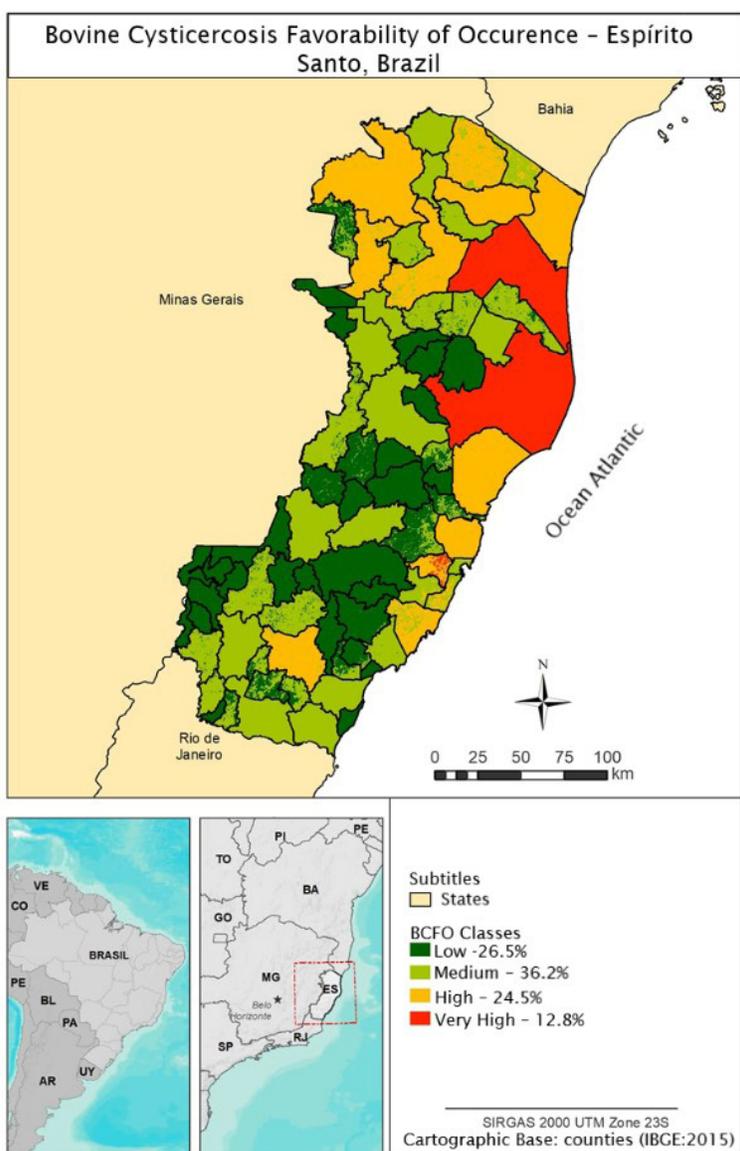


Figure 1. Thematic maps: A - Land Use and Occupation (LUO), B - Municipal Cattle Population (MCP), C - Inadequate Sewer Service (ISS), D - Flood Risk (FR), Espírito Santo, Brasil.

Other municipalities, among the ten with the highest cattle population and especially in the northern region, are Montanha, Pinheiros and Barra de São Francisco, which had more than 80% of high risk areas, and São Mateus, with more than 99% of very high risk. Herd size is an important factor for the occurrence of the parasitosis cycle, since these animals are the intermediate hosts of *T. saginata* (Bavia et al., 2012; Dutra et al., 2012).



*The Risk Map is result of the interpolation of the following variables: Land Use and Occupation, Municipal Cattle Population, Inadequate Sewer Service, Flood Risk in the program Quantum GIS 2.0.

Figure 2. Risk Map for the Occurrence of Bovine Cysticercosis in the State of Espírito Santo.

Human population density, an important criterion since humans are the definitive hosts of the parasitosis, was considered a risk factor by Alves et al. (2017) and Rossi et al. (2015). However, this factor must be related to inadequate sanitation, because even in highly populated regions, adequate sanitation reduced the risk of cattle contact with *T. saginata* eggs (Abunna et al., 2008; Bavia et al., 2012; Boone et al., 2007; European Food Safety Authority, 2004). The municipalities with the highest number of households that have inadequate sanitation are found in the northern region of the state. Once again, São Mateus and Linhares stand out with the highest percentage of households with this classification. In the metropolitan region, the municipality of Cariacica, with 23.26% of areas of very high risk and 75.33% of high risk, presented a high percentage of inadequate sewer service.

Discharging untreated sewage into waterways helps disperse cestode eggs to pastures. Floods are related to this dispersion, since they increase the contact of animals with contaminated water, in addition to contaminating new pastures (Cabaret et al., 2002; European Food Safety Authority, 2004; Laranjo-González et al., 2016). Falçoni et al. (2014) reported a higher occurrence in cases

of cysticercosis during the rainy season. The municipalities that had highest chances of flooding are located in the north of the state, a flatter region, also previously described as being the region with the worst sewage treatment and the highest number of cattle, and, in turn with the highest risk of occurrence of bovine cysticercosis.

Despite the large territorial extension of the northern region, pasture areas are more often located in the municipalities close to the border between Minas Gerais and Bahia, in the northwest region of the state. The municipalities with areas of very high risk in the north of the state (Linhares and São Mateus) did not have as many pasture areas, which increased the animal density per hectare and consequently the risk of infection. This pattern is explained by the fact that most Brazilian cattle are kept in extensive grazing systems (Dutra et al., 2012), causing greater contact between animals and pastures possibly contaminated with *T. saginata* eggs.

According to Falçoni et al., (2014), who analyzed federal and state inspection data in Espírito Santo from 2009 to 2012, the occurrence of bovine cysticercosis was considered moderate. When analyzing the data on the number of animals slaughtered by municipality in Espírito Santo, provided by the Federal Inspection System (SIG) in 2014 to 2018, a total of 165,431 cattle were slaughtered in Linhares, representing 17.26% of the 958,349 animals slaughtered in the entire the state (Sistema de Informações Gerenciais do Serviço de Inspeção Federal, 2019). This indicates the importance of socio-educational measures for the control of bovine cysticercosis, since this municipality has areas of very high risk for its occurrence. Between the years 2016 to 2022, this same municipality was among the three that had the highest prevalence of bovine cysticercosis with 0.04%, preceded by Ecoporanga (0.04%) and Alegre (0.05%).

Dutra et al. (2012) reported a 0.91% prevalence of bovine cysticercosis in the state of Espírito Santo in slaughterhouses for the years 2007 to 2010. Besides that, Avelar et al. (2016) for slaughterhouses reported a prevalence between 2009 and 2012 of 0.37% for the north and central regions and 1.02% for the metropolitan and south regions, totaling approximately 0.70% of prevalence in the state. Falçoni et al. (2014) for the same years reported prevalences of 0.87% and 0.83% for data from federal inspection and state inspection, respectively. During the years 2016 to 2022, the prevalence was 0.53%, despite the increase in high and very high risk areas, the prevalence of cysticercosis decreased over the years. The increase in these areas was probably related to the increase in the cattle population, considering the municipality of Alegre first in cases of bovine cysticercosis, which had a 14% increase in the cattle herd, it went from 52,247 (2006) heads to 60,791 (2017) (Instituto Brasileiro de Geografia e Estatística 2006, 2017). With 100% of its territory with low risk, the municipality of Irupi has a large part of its territory covered by native forest, along with low risk of flooding, in addition to a low number of cattle slaughtered. According to the SIG (Sistema de Informações Gerenciais do Serviço de Inspeção Federal, 2019), only 61 cattle were slaughtered in the municipality, a situation not favoring the taeniasis-cysticercosis life cycle.

A large part of the state has medium risk for the occurrence of the parasitosis, so control and prevention actions are essential, due to the harm caused to people who eat contaminated meat and the disposal of infected carcasses (Cipriano et al., 2015). Prevention is essential to avoid economic losses caused by the condemnation of carcasses containing cysts.

Studies indicate that the SGI technology for the analysis of bovine cysticercosis is recent and effective, allowing the mapping of areas with high risk of zoonosis incidence, allowing greater control and better guidance to inspection service. These studies also favor the establishment of more drastic preventive measures in places of very high risk.

Conclusion

The spatial analysis of the risk of occurrence of bovine cysticercosis in the state of Espírito Santo possible to update the areas at risk, allowing the identification of an increase in areas with high and very high risk for bovine cysticercosis.

Ethics statement

Not applicable.

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Conflict of interests

No conflict of interest.

Authors' contributions

Júlia Bertoli Gomes - Development of methodology; preparation and writing the initial draft.
Barbara Rauta de Avelar - Writing, Review and Editing manuscript. Isabella Vilhena Martins - Review and Editing manuscript.

Availability of complementary results

https://wp.scielo.org/wp-content/uploads/Lista-de-Repositorios-Recomendados_pt.pdf

The work was carried out at Veterinary Parasitology Laboratory, Department of Veterinary Medicine of Federal University of Espírito Santo, Alegre, ES, Brasil.

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