



Epidemiological analyses of cattle carcasses affected by cysticercosis and hydatidosis in the State of Rio Grande do Sul from 2014 to 2018¹

Arina Rebeca F. Cauaneque^{2,4} , Daniela L. Azevedo³ , Eduardo F. Costa⁴ ,
Mauro R. Borba⁴  and Luís Gustavo Corbellini^{4*} 

ABSTRACT- Cauaneque A.R.F., Azevedo D.L., Costa E.F., Borba M.R. & Corbellini L.G. 2022. **Epidemiological analyses of cattle carcasses affected by cysticercosis and hydatidosis in the State of Rio Grande do Sul from 2014 to 2018.** *Pesquisa Veterinária Brasileira* 42:e06805, 2022. Laboratório de Epidemiologia Veterinária, Faculdade de Veterinária, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves 9090, Porto Alegre, RS 91540-000, Brazil. E-mail: luis.corbellini@ufrgs.br

Bovine cysticercosis and hydatidosis are frequently identified by inspectors in slaughterhouses from the state of Rio Grande do Sul. Slaughterhouse records can provide valuable information for animal-related diseases and public health surveillance. Analyzing these data can aid set priorities to regions or properties that need more attention. Slaughter condemnation data is collected daily and stored in the Agricultural Defense System (SDA) database of the State Veterinary Services. However, it needs to be turned into useful information in bovine cysticercosis and hydatidosis surveillance programs. This study aimed to discuss how the analysis of condemnation data in the context of epidemiology can be useful for a surveillance system of bovine cysticercosis and hydatidosis. For this purpose, slaughter data of 5,137,870 cattle from 480,000 animal movement permits (GTA) from 97,891 farms from 2014 to 2018 were obtained from the Secretary of Agriculture, Livestock and Rural Development of the State of Rio Grande do Sul (SEAPDR-RS). Differences in the occurrence rates of bovine cysticercosis and hydatidosis among mesoregions over time were assessed through generalized linear models. Cysticercosis was identified in 65,379 (1.27%) carcasses and hydatidosis in 323,395 (6.29%). The occurrence rates of both diseases varied distinctly over time between the regions ($p < 0.01$). Next, a process was developed to identify priority farms to target a surveillance program based on the prevalence. Period prevalence for cysticercosis and hydatidosis was obtained for each farm. The epidemiological indicator was calculated for each farm, dividing the number of affected carcasses by the number of bovines sent to slaughter during the period. The mean prevalence was obtained, and the exact binomial test was applied to identify farms presenting prevalence above the mean. It was observed that 2.48% and 6.17% of the farms had prevalence above the population mean prevalence of cysticercosis and hydatidosis, respectively. The Western mesoregion had the highest percentage of farms with prevalence above the average for cysticercosis (6.9%), followed by the Southwest mesoregion (6.0%). For hydatidosis, the percentage frequency of farms with prevalence above the average was markedly higher in the mesoregions Southeast (32.8%) and Southwest (29.5%). The results showed that analysis of slaughterhouse condemnation data of SDA is useful to identify

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² Departamento de Produção Animal, Faculdade de Ciências Agrárias, Universidade Lúrio, Sanga, Moçambique.

³ Seção de Estatística e Epidemiologia, Secretaria de Agricultura, Pecuária e Desenvolvimento Rural do Rio Grande do Sul (SEAPDR-RS), Porto Alegre, Brazil.

⁴ Laboratório de Epidemiologia Veterinária, Faculdade de Veterinária, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS 91540-000, Brazil. *Corresponding author: luis.corbellini@ufrgs.br

situations in which the occurrence of the diseases is significantly higher than the average to apply additional measures or epidemiological investigations. This information may be useful in plans of epidemiological surveillance programs for controlling bovine cysticercosis and hydatidosis by the State's Official Veterinary Services.

INDEX TERMS: Epidemiology, cattle, carcasses, cysticercosis, hydatidosis, public health.

RESUMO.- [Análise epidemiológica de carcaças bovinas afetadas por cisticercose e hidatidose no estado do Rio Grande do Sul de 2014 a 2018.]

Lesões características de cisticercose e hidatidose bovina são frequentemente identificadas por fiscais em abatedouros no Rio Grande do Sul. Dados de condenações destas propriedades são coletados diariamente e armazenados em banco de dados do Sistema de Defesa Agropecuária (SDA) da Secretaria Estadual de Agricultura, Pecuária e Desenvolvimento Rural (SEAPDR-RS), podendo fornecer informações valiosas para a vigilância de doenças de importância para a saúde animal e saúde pública, bem como, contribuir para a tomada de decisão direcionada a propriedades rurais ou regiões que realmente necessitam de intervenção sanitária. No entanto, estes dados precisam ser transformados em informação útil para programas de prevenção e controle da cisticercose e da hidatidose bovina. O presente trabalho teve como objetivo analisar os dados de condenações de carcaças bovinas abatidas em frigoríficos sob inspeção estadual no Rio Grande do Sul, no período de 2014 a 2018. Foram utilizados dados de 5.137.870 bovinos enviados para abate em 480.000 lotes (GTA emitidas) de 97.891 fazendas. Diferenças nas taxas de ocorrência de cisticercose e hidatidose bovina ao longo do tempo, entre as mesorregiões do Rio Grande do Sul, foram analisadas por meio de modelos lineares generalizados. A cisticercose foi identificada em 65.379 (1,27%) carcaças e a hidatidose em 323.395 (6,29%) carcaças. Ao longo do tempo detectou-se uma tendência de redução nas taxas de ocorrência das duas doenças que, por sua vez, se comportaram de maneira distinta entre as mesorregiões ($p < 0,01$). Por outro lado, desenvolveu-se um processo para identificação de propriedades prioritárias para ação de vigilância com base na prevalência. A prevalência no período para cisticercose e hidatidose foi calculada para cada propriedade. O indicador foi obtido dividindo-se o número de carcaças afetadas pelo número total de animais enviados para abate, ou seja, é a proporção de ocorrência das parasitoses dentre os animais enviados para abate em cada propriedade no período de cinco anos. A prevalência média ou populacional (π), que é a média das prevalências de todas as propriedades, foi calculada e, em seguida, foi aplicado o teste exato binomial para identificar as propriedades com prevalência acima da média para ambas as doenças. Foi observado que 2,48% (2.425/97.841) e 6,17% (6.039/97.841) das propriedades apresentavam prevalências acima da média populacional para cisticercose e hidatidose, respectivamente. Observou-se que a mesorregião Centro Ocidental possui maior frequência percentual de propriedades com prevalência de cisticercose acima da média (6,9%), seguido pela mesorregião Sudoeste (6,0%). Já para hidatidose, a frequência percentual de propriedades com prevalência acima da média foi substancialmente superior nas mesorregiões Sudeste (32,8%) e Sudoeste (29,5%) quando comparada às demais. Os resultados demonstraram que com os dados de condenações de abatedouro do SDA foi possível identificar situações em que a ocorrência das doenças

é significativamente alta e que necessitam de medidas ou investigações epidemiológicas adicionais. O conhecimento dessa informação pode ser útil no planejamento de programas de vigilância epidemiológica para o controle da cisticercose e hidatidose bovina pelos serviços veterinários oficiais do Estado.

TERMOS DE INDEXAÇÃO: Epidemiologia, bovinos, carcaças, cisticercose, hidatidose, saúde pública.

INTRODUCTION

Infections caused by *Taenia* are among the oldest descriptions of zoonoses globally. The only definitive hosts of *Taenia saginata* are humans, who acquire taeniasis through ingestion of meat containing viable cysticercus (larval stage) (OIE 2014). In the intestine, mature proglottids containing eggs are released through the feces into the environment, where they may remain viable for several weeks or months near the feces. They can also spread through the air, rain or other climatic phenomena, contaminating water or food, which constitute a transmission route to cattle, the intermediate hosts (Thompson 2017). Infected cattle develop cysticercosis characterized by cysticerci at various anatomical sites (Rossi et al. 2020), but preferably in skeletal or cardiac muscles (Marshall et al. 2016). *Echinococcus granulosus* has a similar biological cycle. Dogs and other canids act as definitive hosts while sheep, cattle, goats and other mammals, including humans, act as intermediate hosts (OIE 2017). The relationship between the dog and the sheep is significant for maintaining the biological cycle of transmission of the parasite because sheep tend to have a higher percentage of fertile and viable cysts (Giannetto et al. 2004). The hydatid cyst, which represents the metacestode, develops in the intermediate host's viscera, preferably the liver and lungs, giving rise to hydatidosis (Romig et al. 2015, Stoores et al. 2018).

The clinical and economic significance of cysticercosis and hydatidosis is almost completely confined to metacestode infection (Rossi et al. 2015, Thompson 2017, Henckel et al. 2020), usually identified in the sanitary inspection of bovine carcasses. Slaughterhouse records can provide relevant information to monitoring important diseases to animal health and public health. They constitute an economic control alternative in the face of the growing scarcity of financial resources destined for veterinary services in many countries (Gates et al. 2015, Klink et al. 2015) since data analysis can contribute to targeted action in properties or regions that need intervention.

Rio Grande do Sul (RS) can use inspection data from slaughterhouses as an important source for epidemiological surveillance. Since 2014, the state has had its system for the electronic recording of data from the sanitary inspection carried out by the "Divisão de Inspeção de Produtos de Origem Animal" (Division of Inspection of Animal Origin Products, DIPOA), the sector responsible for slaughtering establishments at the

“Secretaria de Agricultura, Pecuária e Desenvolvimento Rural” (Secretary of Agriculture, Livestock and Rural Development, SEAPDR). However, data on injuries and diseases that affect livestock animals slaughtered in these establishments need to be transformed into information for practical use in programs to control cysticercosis and bovine hydatidosis.

The objectives of the study were: 1) to evaluate the occurrence rates of cysticercosis and hydatidosis and to test the hypothesis that they behave differently between regions in the state, over five years (2014-2018); 2) propose a process for the identification of properties that need to be prioritized in the epidemiological surveillance of both diseases based on the condemnation data of slaughterhouses inspected by SEAPDR.

MATERIALS AND METHODS

A descriptive epidemiological study was carried out to evaluate the occurrence of cysticercosis and bovine hydatidosis in different regions of RS state using retrospective data from the slaughter of cattle under “Serviço de Inspeção Estadual” (State Inspection Service, SIE), from 2014 to 2018, contained in the database of the “Sistema de Defesa Agropecuária” (Agricultural Defense System, SDA) of SEAPDR. The regions were named, according to the classification of the “Instituto Brasileiro de Geografia e Estatística” (Brazilian Institute of Geography and Statistics, IBGE), as (1) Northwest Rio-Grandense; (2) Northeast Rio-Grandense; (3) Middle West Rio-Grandense; (4) Middle East Rio-Grandense; (5) Metropolitan of Porto Alegre; (6) Southwest Rio-Grandense and (7) Southeast Rio-Grandense. From here they will be nominated, respectively: Northwest, Northeast, Western, Eastern, Metropolitan, Southwest, and Southeast.

In the routine slaughter, the carcasses were inspected following Brazilian legislation. Macroscopic examination through visualization, palpation, smell and incision, if applicable, in the different inspection lines, namely head-tongue set, the external and internal surface of the carcass, thoracic, abdominal and pelvic viscera and lymph nodes. The destinations of infected carcasses and viscera vary according to the intensity, as follows: i) condemned = when they show intense infection with bovine cysticercosis. At least eight cysts, viable or calcified, are found, provided that two or more cysts are in at least two sites of choice examined in the inspection line (muscles mastication, tongue, heart, diaphragm and its pillars, esophagus and liver) and four or more cysts are located in the forequarter (neck, chest and shoulder muscles) or hindquarter (upper thigh, rump and shoulder muscles loin); ii) conditionally treated by heat = when more than one cyst (viable or calcified) is found in quantities that do not characterize intense infection; iii) conditionally treated by cold (-10°C for at least 10 days) or salting (21 days under specific conditions) = when a viable cyst is found; iv) intended for direct human consumption without restrictions = when a single calcified cyst is found, after removal and condemnation of the affected area. For hydatidosis, the liver can be condemned, or its damaged portions can be eliminated, depending on whether they show, respectively, diffuse or circumscribed forms (Brasil 2007, Brasil 2017a).

Database organization. All slaughter inspection data are recorded in the SDA of the SEAPDR-RS. The main database of the study was obtained from the extraction of two databases from the SDA: “data of cattle destined for slaughter” and “data on cattle condemned from slaughterhouses under sanitary inspection by DIPOA of the state”. Thus, the central database contained approximately 480,000 observations, with each observation corresponding to a “Guia de Trânsito Animal” (Animal Movement Permits, GTA), and it was merged with the database containing inspection data. Each

GTA consisted of the date (year and month) of issue, municipality of origin, property identification, and the number of animals sent for slaughter. At the same time, the DIPOA database contained the number of affected carcasses, cold-treated carcasses, condemned and identification of the slaughterhouse. According to the type of statistical analysis, the database was grouped by properties, administrative mesoregions, year and month throughout the study period, and destination slaughterhouse.

Descriptive analysis. The information generated from the data obtained was described using graphs and frequency tables. Initially, one-dimensional descriptive analyzes were carried out on the number of GTA issued per property, animals slaughtered, number of carcasses affected, number of municipalities of origin and properties of origin of the animals. Subsequently, two-dimensional descriptive analyzes were carried out to verify the number of affected carcasses per year, the number of occurrences of rural properties by prevalence ranges, and the proportion of GTA containing at least one affected animal. Database organization and descriptive analyzes were performed with the Tidyverse package in the R statistical program (Wickham 2017).

Generalized linear models. Four generalized linear models (GLM) were prepared to verify two hypotheses: (i) difference between the rates of occurrence of cysticercosis and hydatidosis in the carcasses; (ii) difference in the rates of conditional treatment by cold and of condemnation of carcasses for cysticercosis over the years in the mesoregions. The rates analysis of the conditional treatment of carcasses by cold and condemnation of carcasses for hydatidosis over the years and in the mesoregions was not included because they were low (around 0%).

For the construction of the GLM, the GTA (database “data of cattle destined for slaughter”) was grouped by month and year. The numbers of slaughtered and affected animals within each region of origin of RS in the respective period were added, totaling 420 observations (12 months * 5 years * 7 mesoregions). Each line corresponded to the slaughter month. Outcomes (response variables) were (i) affected carcass count, (ii) conditionally cold treated carcass count, and (iii) condemned carcass count. The explanatory variables were the mesoregion of origin of the slaughtered animals and the years (analyzed as a categorical variable). The interaction between “year*mesoregion” was tested to assess whether the occurrence rates over the years occurred differently between the mesoregions.

A quasi-Poisson regression model was fitted using the variance function “mu” and “random_residual” of the SAS Studio software version 9.3 to adjust the confidence interval by a dispersion factor. The link function used was *log*. As the model estimated occurrence rates, offset variables were created using the functions *log* (number of slaughtered/10,000) and *log* (number of affected/1,000) to estimate the results as the number of carcasses affected per 10,000 slaughtered and number of carcasses subjected to conditional cold treatment or condemned for every 1,000 affected, respectively. The models were performed using the SAS Studio software using the PROC GLIMMIX procedure, and the estimates of the marginal averages were extracted using the LSMEANS function. The models’ residuals were visualized through graphics using the command PLOTS=Residual Panel.

Identification of properties to be prioritized in surveillance programs. The objective of this analysis was to identify properties with prevalence higher than the population average (π) to discuss an analytical model that can be used in a surveillance program for animal health protection. The database with data from the GTA (“data of cattle destined for slaughter”) was used, which, in practice, corresponds to the batches of animals sent for slaughter. The data

were grouped by properties, obtaining the total number of cattle sent for slaughter and the total number of GTA issued in each property in five years. Additionally, the number of GTAs containing at least one positive animal was also calculated for each property, making it possible to calculate the proportion of “infected batches” among the entire batches sent for slaughter per property. The database “data on cattle condemned from slaughterhouses under sanitary inspection by DIPOA of the state” were grouped by properties. The total number of cysticercosis and hydatidosis in each rural establishment was obtained. Then, the two databases were merged, creating the “analytical data table” with the variables necessary for this analysis.

In-period prevalence for cysticercosis and hydatidosis was calculated for each farm. The indicator was obtained by dividing the number of carcasses affected by the number of animals sent for slaughter. It is the proportion of parasites occurrence among the animals sent for slaughter in each property in five years. Then, the average or population prevalence (π), the average of the prevalences of all properties, was calculated. The exact binomial test was performed to test the alternative (one-tailed) hypothesis of superiority with the mean prevalence (π), with the following arguments (function “bin.test”, software R, version 3.5.1.):

x = number of carcasses affected;

n = the total number of cattle sent for slaughter;

p = mean prevalence parameters (π) for cysticercosis (0.81%) and hydatidosis (4.89%).

The properties that showed a p -value ≤ 0.01 represented prevalence above the population mean and were coded with “1”; the remaining ones were coded with “0”. A conservative p -value was chosen to reduce the type I error (false positives). A logistic regression model was then carried out to assess whether there is an association between the mesoregions and the “above-average” prevalence, adjusted by the number of animals sent for slaughter. The model was run in SAS Studio using the PROC LOGISTIC procedure, where multiple comparisons with Bonferroni adjustment were tested. The estimated probability for each mesoregion considering an average number of 100 cattle was calculated using the CONTRAST function.

The visualization of the properties distribution with an above-average prevalence for cysticercosis and hydatidosis was done through graphical representations by points in spatial bases of mesoregions obtained from the IBGE (2018). The geographic coordinates of the properties' location were considered, and each property represented a specific point on the map. Sixty-five (65) properties for cysticercosis and 304 properties for hydatidosis were not included because their geographic coordinates were unavailable. A heat map was made to verify the presence of a distribution pattern of the points. A radius of 15 kilometers was chosen to allow better visualization of the point aggregates. Progressive colors were used to represent the density in each area. Analyzes were performed in QGIS software version 3.14.

RESULTS

From 2014 to 2018, 480,919 GTA were issued for sending cattle to state inspection slaughterhouses in the Rio Grande do Sul, from 97,841 rural properties. The total number of animals slaughtered and inspected in the period was 5,137,870. There was heterogeneity regarding the number of batches sent for slaughter: 75% of the properties issued up to 5 GTA; the remaining 25% issued from 6 to 1,415 GTA. The median was 2 GTA, 50% of the properties sent up to two batches for slaughter in five years. As for the number of cattle per GTA issued, 25% of the batches contained up to two animals, with a minimum of one and a maximum of 150 cattle (median = 5 animals). When grouping the municipalities into mesoregions, it was found that about 35% (171,648) of the GTA were sent to slaughterhouses in mesoregions other than the property's origin, corresponding to 51% (2,646,253) of the slaughtered cattle.

Cysticercosis and hydatidosis were identified in 65,379 (1.27%) and 323,395 (6.29%) carcasses. There was no expressive variation in the occurrence rate of diseases over the years (Table 1). Of the 497 municipalities where the GTA came from, 475 (95.57%) registered cases of cysticercosis and 492 (98.99%) of hydatidosis. There was a higher occurrence of cysticercosis in the Western (1.86%) and Northeast (1.65%) regions and a lower occurrence in the Northwest (1.12%), Metropolitan (1.19%), Southeast (1.19%), Southwest (1.19%) and Eastern (0.91%) regions. For hydatidosis, the occurrence was higher in the Southeast (16.03%) and Southwest (9.75%) regions, followed by the Eastern (4.68%), Western (4.06%), Metropolitan (3.10%), Northwest (2.80%) and Northeast (2.25%).

In the hypothesis tests (MLG) to verify the difference between the occurrences rates of cysticercosis and hydatidosis in the carcasses and for both destinations (conditional cold treatment or condemnation for cysticercosis), it was verified that the space-time interaction “year*mesoregion” was statistically significant ($p < 0.001$). The rates occurred in different ways from 2014 to 2018 between the mesoregions. The average values estimated by the models are illustrated in Figure 1-4. According to the average annual estimates extracted from the models (solid red lines) (Fig.1-4), the rates of occurrence of cysticercosis over the years, compared to the reference year (2014), reduced until the year 2018, except for the year 2016 (Fig.1). On the other hand, the rates of occurrence of hydatidosis showed a much less accentuated reduction and, except for 2015, rates in subsequent years were lower than the reference year (2014) (Fig.2). After relative stability, steady increasing trends over time were observed for dependent cold treatment rates and cysticercosis condemnation rates after 2016 (Fig.3 and 4).

Table 1. Distribution of the annual occurrence rate of cysticercosis and hydatidosis in bovine carcasses slaughtered under state inspection of Rio Grande do Sul (2014-2018)

Year	No. of animals inspected	Cysticercosis		Hydatidosis	
		Total no.	%	Total no.	%
2014	1,049.934	14,856	1.41	73,554	7.01
2015	1,020.560	13,331	1.31	70,941	6.95
2016	1,002.548	15,610	1.56	55,452	5.53
2017	1,025.685	13,330	1.30	60,500	5.90
2018	1,039.143	8,252	0.79	62,948	6.06
TOTAL	5,137.870	65,379	1.27	323,395	6.29

When evaluating the occurrence by rural properties, 13.3% (12,973/97,841) and 28.1% (27,522/97,841) sent cattle affected by cysticercosis and hydatidosis, respectively (Fig.5). In the process of identifying priority properties for surveillance, it was observed that 2.48% (2,425/97,841) and 6.17% (6,039/97,841) of the properties had prevalences above the population average for cysticercosis and hydatidosis, respectively. The flowchart of the identifying properties process, occurrence data and a subsequent logistic regression model are illustrated in Figure 5. Table 2 contains the frequency distribution of these properties by prevalence range for both diseases. The highest properties frequency (87.92%) is in the

range of >0% to 15% of cysticercosis prevalence, while for hydatidosis, the highest properties frequency (38.19%), is in the range of 15% to 30%. Table 3 contains the frequency distribution of properties by proportion range of “affected batches” (i.e., the proportion of occurrence of GTA containing at least one affected animal), considering the establishments that issued at least 5 GTA in the period (average of one per year). There were 103 (6.53%) properties in the range of 90 to 100% for cysticercosis and 403 properties (13.59%) in the same range for hydatidosis - most of the animals' batches sent for slaughter from these properties contained at least one affected animal. To illustrate a case, a farm that sent 635

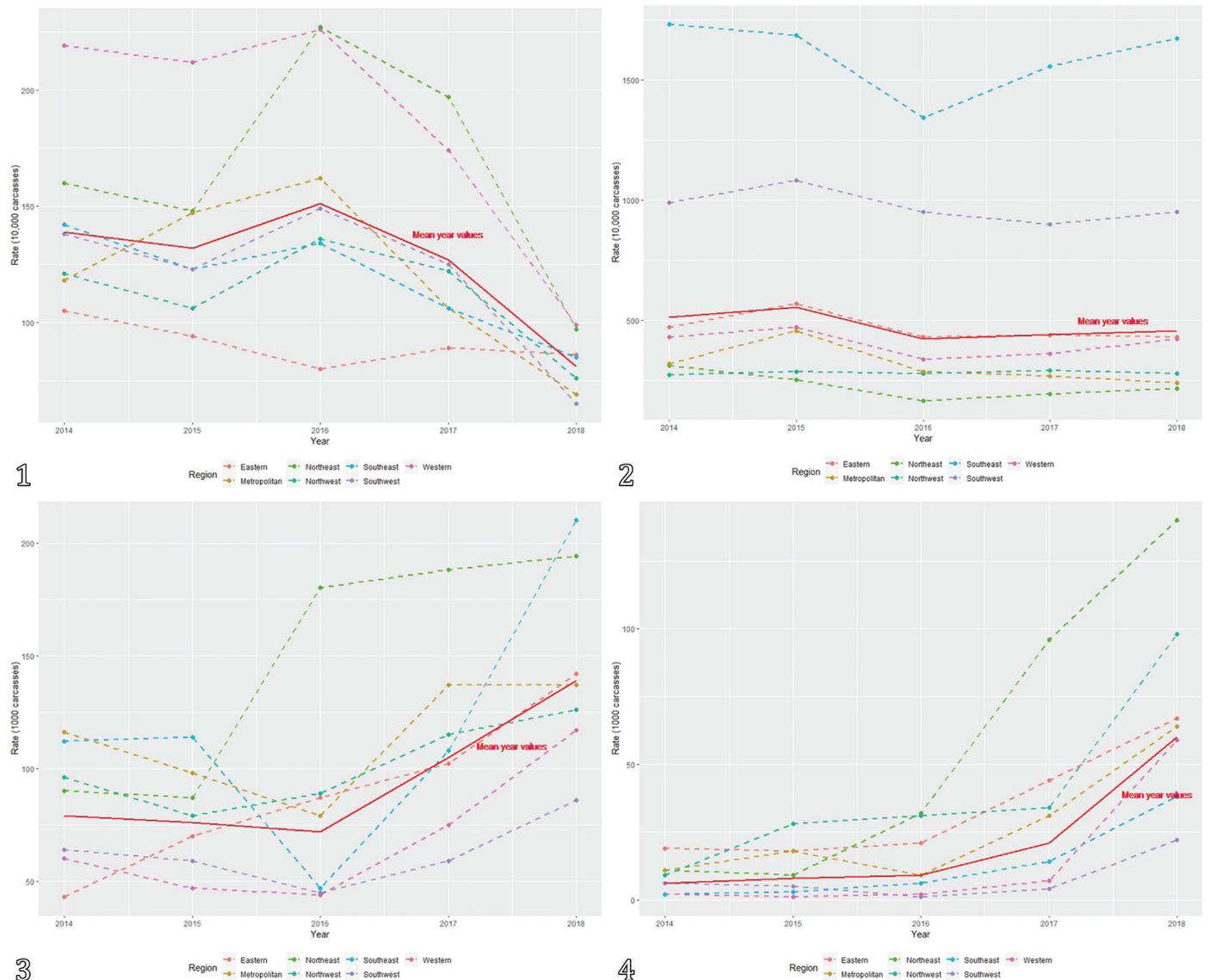


Fig.1-4. (1-2) Results of the Poisson model (GLM) to estimate the occurrence rate (every 10 thousand carcasses) of cysticercosis and hydatidosis in carcasses inspected from 2014 to 2018 in seven mesoregions of Rio Grande do Sul. (1) Mean rate of occurrence of cysticercosis by mesoregion. (2) Mean rate of occurrence of hydatidosis by mesoregion. (3-4) Results of the Poisson model (GLM) to estimate the condemnations rate (per 1000 carcasses) due to cysticercosis in carcasses inspected from 2014 to 2018 in seven mesoregions of Rio Grande do Sul. (3) Average rate of carcasses destined for conditional cold treatment per mesoregion. (4) Average rate of totally condemned carcasses per mesoregion. The solid red line corresponds to the overall average rate estimated over the years.

cattle for slaughter in 15 batches (GTA issued) had 76 animals affected by cysticercosis (11.97% prevalence), and 100% of the batches had at least one affected animal. For hydatidosis, a farm that sent 678 cattle for slaughter in 21 batches had 381 affected animals (56.2% prevalence), and 100% of the batches had at least one affected animal.

The proportion of properties with above-average prevalence within each mesoregion is illustrated in Figure 6-7. It was observed that the Western mesoregion has the highest percentage frequency of properties with an above-average prevalence of cysticercosis (6.9%), followed by the Southwest mesoregion (6.0%). As for hydatidosis, the percentage frequency of properties with above-average prevalence was substantially higher in the Southeast (32.8%) and Southwest (29.5%) mesoregions when compared to the others. There was an association between mesoregion and property with above-average prevalence for both diseases ($p < 0.0001$), suggesting a pattern of occurrence according to the region. In the case of cysticercosis, it was observed in the multiple comparisons that the Western region was more likely to present properties with above-average prevalence when contrasted with all other mesoregions. By the logistic regression model, the estimated probability of higher than average prevalence was 6.67% in this mesoregion. For hydatidosis, the Southwest region was more likely to have properties with above-average prevalence when contrasted with all other mesoregions. The

estimated probability of occurrence of prevalence higher than the average estimated by the model was 33.4% in this mesoregion.

The representation in descriptive thematic maps showed that properties with above-average prevalence are distributed throughout the state. Spatial aggregates are observed in more significant numbers in cysticercosis than in hydatidosis (Fig.8-9).

DISCUSSION

The study results demonstrate that the occurrence rates of cysticercosis and hydatidosis in cattle slaughtered from 2014 to 2018 at slaughterhouses inspected by the DIPOA-SEAPDR behaved differently between the mesoregions of the animals' origin over time. The spatiotemporal assessment of the occurrence of diseases is essential. It allows verifying possible changes and trends in the patterns of occurrence and predicting future situations that may help prevent and control

Table 2. Frequency distribution of rural properties in Rio Grande do Sul identified with above-average prevalence* by cysticercosis and hydatidosis prevalence range

Prevalence ranges (proportion)	Cysticercosis		Hydatidosis	
	Property no.	%	Property no.	%
> 0-0.15	2,132	87.92	1,147	18.99
0.15-0.3	156	6.43	2,306	38.19
0.3-0.45	27	1.11	1,303	21.58
0.45-0.6	7	0.29	447	7.40
0.6-0.75	9	0.37	403	6.67
0.75-0.9	2	0.08	126	2.09
0.9-1.0	92	3.79	307	5.08
TOTAL	2,425		6,039	

* Identification by the exact binomial test.

Table 3. Frequency distribution of rural properties in Rio Grande do Sul with above-average prevalence for cysticercosis and hydatidosis by proportion range of occurrence of GTA containing at least one affected animal over the total of GTA emitted*

Proportion range**	Cysticercosis		Hydatidosis	
	Property no.	%	Property no.	%
0-0.15	83	5.26	9	0.30
0.15-0.3	354	22.45	76	2.56
0.3-0.45	428	27.14	340	11.46
0.45-0.6	270	17.12	480	16.18
0.6-0.75	197	12.49	821	27.68
0.75-0.9	142	9.00	837	28.22
0.9-1.0	103	6.53	403	13.59
	1,577		2,966	

GTA = "Guia de Trânsito Animal" (Animal Movement Permits); * Only establishments that issued at least five GTA in the period, ** number of GTA (animals' batches) containing at least one affected animal out of the total GTA issued from 2014 to 2018 on each property.

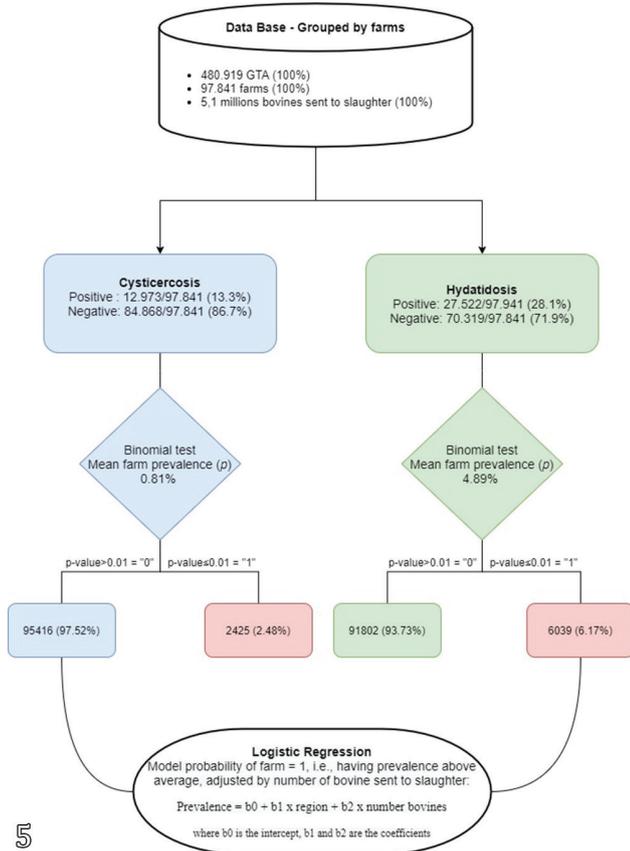


Fig.5. Flowchart of the identifying process of priority properties for a surveillance action based on prevalence and subsequent logistic regression analysis to assess the association between mesoregion and properties with above-average prevalence.

measures (Doherr & Audige 2001). Studies that evaluated hypotheses of spatiotemporal occurrence of condemnations in slaughterhouses in the state are scarce.

In a meta-analysis study, Rossi et al. (2020) reported a reduction in the prevalence of cysticercosis over time in several Brazilian states. In general, a reduction in occurrence rates was observed over the years, which was more pronounced for cysticercosis than for hydatidosis. The results corroborate the findings of Alberti et al. (2018), who reported a decreasing trend in the occurrence of cysticercosis and hydatidosis from 2013 to 2016 in five municipalities in the southern region of the state of Rio Grande do Sul, probably due to the strengthening of communication and health education.

Cysticercosis and hydatidosis were identified, respectively, in 65,379 (1.27%) and 323,395 (6.29%) carcasses inspected. These results are lower than the findings by Henckel et al. (2020) for cysticercosis (3.44%), Mazzutti et al. (2011), and Barzoni et al. (2013) for hydatidosis (8.68% and 10.28%, respectively) during an analysis of cattle slaughterhouse records in the Rio Grande do Sul. However, the study by Henckel et al. (2020) included data from only one slaughterhouse, which may reflect specific differences depending on the characteristics of the population of animals slaughtered in that establishment. Mazzutti et al. (2011) included data from previous years (2005 to 2010) from slaughterhouses under federal inspection. Considering the trend of reduction in rates over time and the population studied, the difference in results is expected. Finally, Barzoni et al. (2013) included data only from the western border of Rio Grande Sul from

1999 to 2007, reflecting the epidemiological situation of a region in years different from those reported in this study.

Information on the occurrence of hydatidosis in other states is scarce (Reis et al. 2017). Rue (2008), using data from the “Ministério da Agricultura, Pecuária e Abastecimento” (Ministry of Agriculture, Livestock and Food Supply, MAPA), found that, in 2004, the prevalence of hydatidosis in cattle in the states of Santa Catarina, Paraná and Mato Grosso do Sul was 0.48%, 0.12% and 0.002%, respectively. Hubener (2016), in a study of hydatidosis occurrence in a slaughterhouse in the Central-West region of São Paulo from 2014 to 2015, found a prevalence of 0.64%. The prevalences recorded in this study indicate that, despite the apparent reduction in the occurrence of diseases in the state, in comparative terms, hydatidosis is more critical in RS. The actual occurrence of hydatidosis in the Rio Grande do Sul is supported by state regulations enacted to combat hydatidosis in animal and human populations (SES-RS 1970). However, it is known that the occurrence is higher in some regions, especially those where sheep production is abundant (PAHO & WHO 2017). In these regions, livestock activity is most extensive, where slaughter takes place without supervision, and dogs have free access to contaminated viscera (Rue et al. 2011, Barzoni et al. 2013, Suñe et al. 2018). The higher occurrence of hydatidosis in the Southeast and Southwest regions presented in this study may be directly related to the more significant risk factors that contribute to maintaining the parasite’s biological cycle.

The distribution of cysticercosis and hydatidosis occurrence rates showed statistically significant differences over the five years studied between the mesoregions. The variations in the

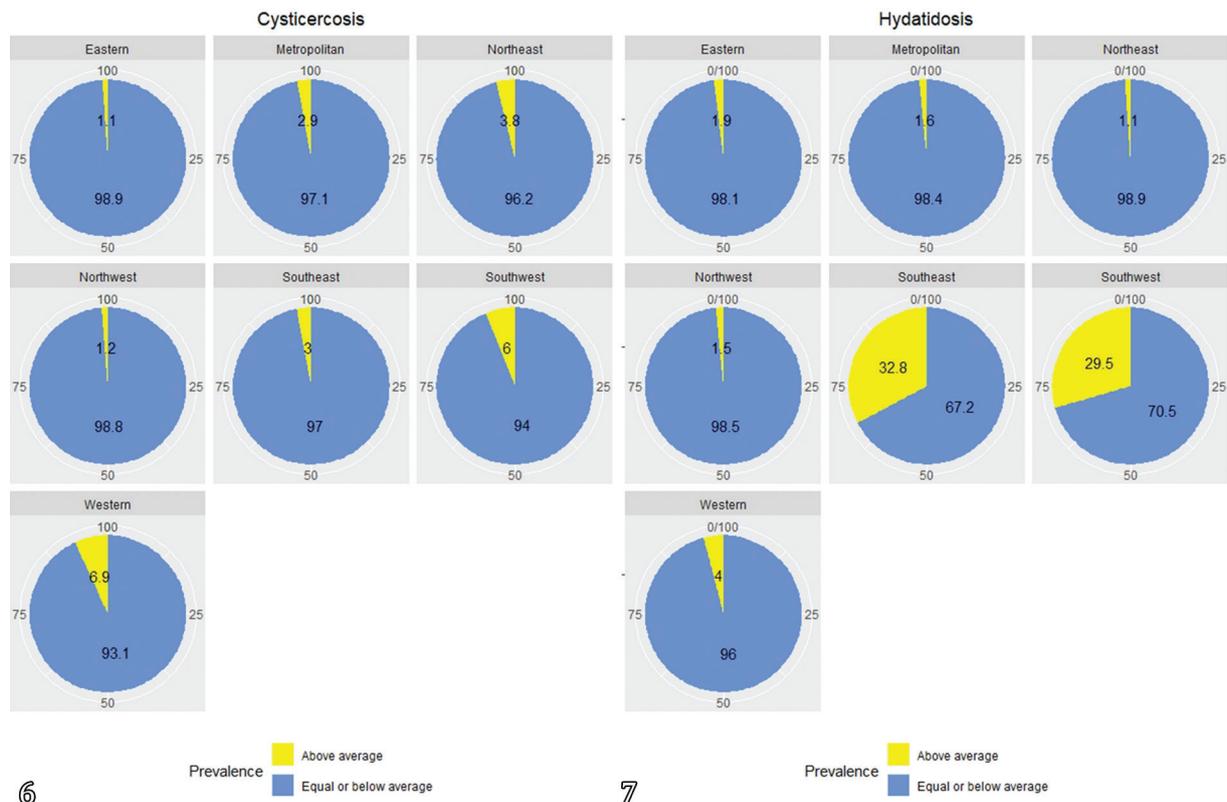


Fig.6-7. Occurrence proportion of properties with above-average prevalence in each mesoregion of Rio Grande do Sul state for (6) cysticercosis and (7) hydatidosis.

occurrences between the mesoregions may be due to different ecological factors. Regional differences were reported in previous epidemiological studies evaluating the occurrence of the disease in RS. Bica (2015) reported high rates of occurrence of cysticercosis in Osório municipality (Metropolitan region) in an epidemiological study on the occurrence of lesions compatible with cysticercosis, hydatidosis and tuberculosis in animals slaughtered in slaughterhouses under sanitary inspection by DIPOA in the state of Rio Grande do Sul, from 2009 to 2014. In this study, the highest occurrence of cysticercosis in the Osório region was associated with lake formations and the lack of a functioning sewage treatment system.

Recently, during a systematic review and meta-analysis, Rossi et al. (2020) found a high prevalence in the southern region of Brazil (3.4%) compared to the others. The authors point out that basic sanitation alone is not enough to prevent infection. The act of defecating in the field and the little use of toilets can contribute to the endemicity of taeniasis/cysticercosis (Rossi et al. 2020). They also highlighted that extensive cattle raising could expose the animals to uncontrolled surface water sources. The presence of flooded pastures, regions with high rainfall, proximity to rivers, and low water quality constitute risk factors. The Rio Grande do Sul is one of the Brazilian states with excellent surface water availability, and rainfall is evenly distributed throughout the year (Rio Grande do Sul 2018). Flooding of rivers or estuaries contaminated directly or indirectly by untreated sewage discharges indicates that contaminated water is among the main risk factors associated with disease transmission. Eggs can be transported by water over long distances, infecting animals that ingest it during the journey (Alberti et al. 2018, Henckel et al. 2020). Henckel et al. (2020) reported that the regions with the highest risk of cysticercosis in the Rio Grande do Sul were Porto Alegre, Caxias do Sul, Santa Maria, Ijuí and Passo Fundo. The higher occurrence of cysticercosis in Porto Alegre and Caxias do Sul was associated with high population density. In Santa Maria, it was associated with the large cattle production,

assuming that the higher the population density, the greater the possibility of environmental contamination by *Taenia* eggs and the greater the cattle production, the greater the number of animals destined for slaughter (Henckel et al. 2020). The regions with the highest occurrence reported by these authors belong to the Metropolitan, Northeast, Western and Northwest Mesoregions, which coincides with that of more significant occurrence (Western and Northeast) found in this study. The difference in the prevalence of cysticercosis can be attributed to regional factors within the state.

Regarding the carcass destination model, all mesoregions increased the number of carcasses treated by cold or condemned from 2016. However, in the Northeast region, the increase occurred from 2015 and coincided with the increased occurrence of cysticercosis. This increase can be explained by the ability to detect lesions characteristic of the disease. Two likely situations that explain this fact are: (i) the hiring of new inspectors that took place in 2014 to assist in the demand for inspection services in slaughterhouses in the state (Rio Grande do Sul 2014); (ii) the update of the RIISPOA, in 2017, which defined more objective criteria for the evaluation of carcasses (Brasil 2017b). It is assumed that, once the new inspectors were hired, the system's sensitivity in detecting lesions characteristic of cysticercosis and hydatidosis increased, culminating in the first increase in condemnations from 2016. The presence of trained inspectors and specific regulation on the destination of affected carcasses may have influenced the significant increase in the rate of carcasses destined for conditional cold treatment and condemned in 2017.

The Brazilian legislation was updated in the data period used by the study in 2017. The legislation foresaw partial rejection in cases of "...discreet or moderate infestation... the carcasses are collected in cold rooms or deboned and the meat treated with brine...". If the infestation was greater than in the previous case "...but that does not reach generalization, the carcass will be destined for heat sterilization" (Brasil 1952). The decree published in 2017, which revoked the one from

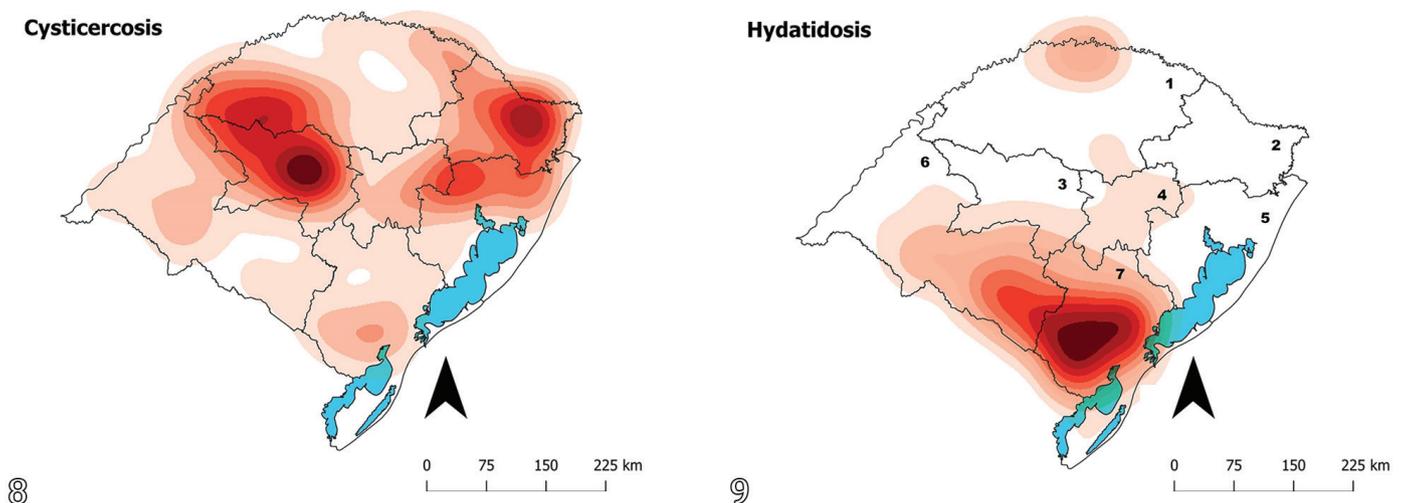


Fig.8-9. Heat map of the geographic distribution of rural properties diagnosed, respectively, for (8) cysticercosis and (9) hydatidosis in the Northwest (1), Northeast (2), Western (3), Eastern (4), Metropolitan (5), Southwest (6), and Southeast (7) regions of Rio Grande do Sul. (8) Data from the 425 properties with a positive "Guia de Trânsito Animal" (Animal Movement Permits, GTA) proportion above the population mean proportion for cysticercosis. (9) Data from the 255 properties with positive GTA proportion above the population mean proportion for hydatidosis.

1952, provided that “When more than one viable or calcified cyst is found, and less than the one fixed for intense infection..., it should be destined for conditional use by the use of heat...”, while “When a viable cyst is found, considering the research in all the chosen places examined in the inspection line and in the corresponding carcass, it must be destined for the conditional treatment by cold or salting...” (Brasil 2017a). There were no records of heat treatment or salting in the database used. There may have been a registration failure, or the carcasses were condemned because many establishments do not have the necessary structure for brining or heat treatment.

The increase in condemnation and treatment of carcasses is positive because it indicates inspection agents’ certain level of preparation. However, it can cause losses to producers in economic terms due to the costs of rejecting and treating the affected carcasses. Economic losses resulting from cysticercosis have been estimated from US\$175,000 to US\$4 million due to the treatment, condemnation and disposal of carcasses in various countries. In turn, the annual losses associated with hydatidosis have been estimated at values ranging from US\$ 72,000 to US\$ 212 million in the productivity of different animal species (Jansen et al. 2018b, Laranjo-González et al. 2018, Rezende et al. 2018, Henckel et al. 2020). These numbers point out the need to adopt efficient control measures to reduce the occurrence of these zoonoses. The construction of septic tanks where basic sanitation is not possible is essential for controlling these diseases. Also, the promotion of health education as a way of making the population aware of the importance of adopting good agricultural and hygiene practices to avoid infection in definitive hosts, the primary source of propagation of the *Taenia* eggs (Barzoni et al. 2013, Rossi et al. 2015, Craig et al. 2017). However, identifying problem properties to direct health education efforts is an efficient way to reduce the losses caused by these diseases and promote public health.

As for the objective of identifying properties that deserve to be prioritized in future epidemiological surveillance programs for cysticercosis and bovine hydatidosis, the exact binomial model was used to classify establishments “above” the average prevalence for each of the diseases. The unilateral alternative hypothesis (H1) means that the proportion of cases of a given property is more significant than the mean prevalence in the population, which are 0.81% for cysticercosis and 4.89% for hydatidosis. When using a *p*-value less than or equal to 0.01 as a cut-off point for the decision to reject the null hypothesis (H0), the chances of a type 1 error, that is, of finding false positives, are reduced. In a situation of low prevalence, increasing specificity becomes advantageous, as the vast majority of establishments are below average, the process becomes more accurate, but the chances of false negatives increase. However, in the situation of scarce public resources, it is beneficial to choose a cut-off point that offers greater precision given the epidemiological situation of the disease. It is assumed to have reached an accessible number of properties to direct a health communication and education program, considering the initial number of about 97 thousand properties. Identifying properties based on condemnations data becomes vital given the need for more cost-effective surveillance programs, given the growing scarcity of financial resources for veterinary services in many countries (Stärk 2017).

Surveillance is a method of continuous data collection to monitor animal health or risk factors in the population. It should provide knowledge to recommend and adopt preventive and control measures. Inspection data from slaughterhouses are sources for diagnosing asymptomatic parasites (Costa et al. 2019) and are valid for epidemiological surveillance systems. In practice, animal movement and inspection data are collected daily and stored in the SDA, but there is no specific surveillance system for this purpose. When defining criteria for identifying problem properties, it was observed that there is a strong association with the mesoregion of origin. The Western mesoregion, followed by the Southwest, had an above-average prevalence of cysticercosis properties frequency. At the same time, there was a much higher probability of finding a property with an above-average prevalence in the Southwest and Southeast mesoregions for hydatidosis. This information is beneficial to, for example, focus actions on properties in these regions to identify risk factors and, thus, understand the causes and particularities that lead to the greater occurrence of these diseases in specific regions and develop a communication program and education with recommendations directed to the risk factors found.

In contrast to the frequency of positive carcasses by region, when analyzing the frequency of properties with above-average prevalence in each mesoregion (Fig.6), the Southwest mesoregion appeared with the second-highest frequency for cysticercosis. The carcass analysis does not consider the rural property (Fig.1). This frequency may have occurred because the intra-herd prevalence varies a lot, as could be observed through the prevalence ranges (Table 3), which cannot be observed when analyzing the carcass data grouped by mesoregion. Another relevant point is the presence of properties that frequently send batches with infected animals, both for cysticercosis and hydatidosis. Properties were observed whose proportion of “positive GTA” reached 90% to 100%. At least one affected animal in most GTA was sent by these properties, which may mean that the transmission problem is constant within the property or the producer is an intermediary and buys animals from numerous sources. The practice of moving animals between farms during the production cycle in Brazil makes it challenging to identify properties where animals were infected. The use of animal movement network analysis to map farms that serve as sources of infection proved to be effective in reducing the prevalence of cysticercosis in the state of Mato Grosso do Sul (Aragão et al. 2017).

According to the descriptive map, properties with above-average prevalence are distributed throughout the state. There are areas with a higher concentration of diseases, such as the Western and Northeast regions for cysticercosis and the extreme South for hydatidosis.

The present study results from secondary data must be interpreted with caution. The authors are not directly responsible for data collection, and *post-mortem* inspection in slaughterhouses has low sensitivity. Since the search for lesions is performed by visual examination of the most likely sites (Jansen et al. 2018a), it may underestimate the average frequency of animals affected with cysticercosis/hydatidosis. However, according to Schärer (2015), slaughterhouse-based surveillance may be a more appropriate and cost-effective option when compared to obtaining primary data on rural properties.

CONCLUSIONS

Hydatidosis is more frequent than cysticercosis in bovine carcasses inspected in the Rio Grande do Sul slaughterhouses.

There was a trend towards reducing the average rates of cysticercosis and hydatidosis over the period evaluated. Also, the occurrence rates differed between the mesoregions over time, with a higher concentration of cysticercosis observed in the Western and Northeast regions, while the highest concentration for hydatidosis was found in the extreme south. The variations can be explained, in part, by regional differences according to the presence of risk factors for the occurrence of these infections. On the contrary, an increase in condemnation and cold treatment rates due to cysticercosis was observed.

Furthermore, the study demonstrated that, through the analysis of condemnation data, it is possible to identify properties with above-average prevalence for these diseases, thus providing important information for designing less expensive epidemiological surveillance programs.

Conflict of interest statement.- The authors declare that they have no competing interests.

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