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Spatial modeling of oestrosis in sheep in Guantánamo province, Cuba

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A B S T R A C T

Oestrosis is a myiasis caused by larvae of the fly *Oestrus ovis* (Linné 1761, Diptera: *Oestridae*) that occurs worldwide. Oestrosis was first reported in Cuba in the middle of the 1990s in the municipality of Imías, Guantánamo province. Determining the spatial pattern and risk factors for the disease might be useful to help explain the disease occurrence and select options for disease surveillance and control. In the present study, the number and distribution of affected premises was shown to have been similar throughout the period studied (2006–2010). The disease was found to occur mostly in the southern and western parts of the province with high dispersion in an east-west direction over the period of study. Three "hotspots" (Getis-Ord Gi*) were identified in the province in which there was an increased risk of disease occurrence. Geographically Weighted Logistic Regression was used to test associations between environmental variables and disease occurrence. Results demonstrated that areas with lower mean annual rainfall, higher mean temperature, and higher sheep density had the highest risk of disease occurrence. High risk areas are mostly located in the western zone (El Salvador, Niceto Pérez and Guantánamo municipalities) and also in the central zone (coast of San Antonio del Sur and Imías). The associations between oestrosis cases and local environmental characteristics varied geographically within the study area. These results might be useful to improve disease surveillance and control. Treatment of animals in these "hotspots", as well as in other places where the risk is higher should be prioritized to more efficiently reduce the harmful impact of this disease.

1. Introduction

Oestrosis is a myiasis caused by larvae of the fly *Oestrus ovis* (Linné 1761, Diptera: *Oestridae*) that occurs worldwide. These larvae are obligatory parasites of the nasal and sinus cavities of sheep and goats (Zumpt, 1965). The parasite severely impairs the health and welfare of a host and gives rise to serious economic losses, especially in herds reared for meat and dairy production (Alcaide et al., 2003; El-Tahawy, 2010). It is also a potential human health hazard (Hoyer et al., 2016).

The parasite has the ability to persist in different environments (Alcaide et al., 2005a; Angulo-Valadez et al., 2010), but a pattern of seasonality has been observed that appears be associated with the severity of the summer temperatures (Jacquiet and Dorchies, 2002; Horak, 2005; Cepeda-Palacios et al., 2011) and has been reported in a number of diverse studies from all over the world (Caracappa et al., 2000; Alem et al., 2009; Gracia et al., 2010).

The influence of major climatic conditions (e.g., temperature, rainfall, and relative humidity) on either the prevalence or intensity of *Oestrus ovis* infestation in domesticated small ruminants has been studied in many different geographic regions (Jacquiet and Dorchies, 2002; Alcaide et al., 2005b; Matos et al., 2013; Silva et al., 2013). However, these studies mainly focused on correlations between only climatic variables with either oestrosis prevalence or larval burden. To our knowledge, predictive modeling studies and, in particular, spatial modeling studies such as that described by Biggs et al. (1998) in Namibia using simple linear regression are rare. The model used by Biggs et al. (1998) was based on simulated underground temperatures is likely to be translatable into occurrence maps, but the authors limited its use to predicting first larval peak of each season for treatment purposes. Flasse et al. (1998), also in Namibia, developed a method based on satellite imagery to improve the quality of warnings to strengthen predictions of place and time of oestrosis emergence.

In the 1990s, Oestrosis was first reported in Cuba in the municipality of Imías, Guantánamo province (Puebla Domínguez et al., 2005). However, in the almost 20 years since this report, outbreaks have remained mainly limited to this province (SIVE, 2012), which is one of

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the driest and hottest places in the entire country (INSMET, 2018).

In Cuba, where sheep raising is mainly for meat production, the disease is responsible for a loss of 472 kg of sheep live weight/thousand susceptible animals (Alfonso et al., 2014). According to the national yearbook (ONEI, 2015), Guantánamo and its neighboring provinces in the eastern region of Cuba, hold over 50% of the nation's sheep population within 27% of the country's surface area. It is important to acknowledge the unique ability of this species to utilize vast areas of marginal land that is not suitable for other ruminants. Therefore, diseases affecting sheep can have especially disruptive economic and food security effects.

Silva et al. (2012) highlighted the fact that differences in the results of studies carried out in many different countries, regarding the epidemiology of *Oestrus ovis*, are likely to be influenced by varying geographical conditions. Hence assessments of oestrosis epidemiology in specific regions such as Guantánamo province are justified. Furthermore, the highly variable climatic characteristics existing in this single province may offer a unique opportunity to understand the conditions responsible for variations in *Oestrus ovis* occurrence. This is crucial to improve the ability to provide early warning of potential dispersal across a country and to design and prioritize effective control measures. The climatic conditions within this single region, including relative humidity, temperature and rainfall are quite variable and are influenced by topography. This allows for the assessment of the effects of a number of spatial forces and factors related to parasitosis epidemiology in a single, contiguous geographic region.

The spatial distribution of disease occurrence could be influenced by variables such as temperature, rainfall, altitude, and relative humidity as well as by the sheep density. Therefore, the aim of this study was to determine the spatial patterns of oestrosis occurrence and potential risk factors in the study area.

2. Materials and methods

2.1. Study area

The study was conducted in Guantánamo province, in southeastern Cuba, located between latitude 19°54′ and 20°30′ N., longitude 74°08′ and 75°30′W., with an area of 6,164.47 km^2 (Fig. 1). Guantánamo province is subdivided into 10 municipalities, namely El Salvador, Manuel Tames, Yateras, Baracoa, Maisí, Imías, San Antonio del Sur, Caimanera, Guantánamo, Niceto Pérez (ONEI, 2015).

The Nipe-Sagua-Baracoa Massif dominates (75%) the province with its highest point, named the peak "El Gato", at 1,184 m". The mountains have a climate characterized by rainforests with cool temperatures and low evaporation throughout the year, while Guantánamo Basin and the southern coastline have poor rainfall, high temperatures and high evaporation (ECURED, 2016).

2.2. Case definition

The study was based on passive surveillance data recorded from 2006 to 2010 in ovine growing sites in Guantánamo province. Sites with suspected cases were visited by the provincial Veterinary Authority (Animal Health Department, AHD) following reports by owners of clinical signs suggestive of oestrosis (Scott, 2018). AHD visits were made and herds tracked when complaints were filed because of larval detection either by a sheep's buyer or farmers who slaughtered animals. During investigation of the suspected cases, some slaughtered or dead animals were necropsied and theirs heads carefully examined for L2 and L3 *Oestrus ovis* larvae in the nasal fossae and cranial sinuses. The oestrosis status of the premises was considered confirmed when *Oestrus ovis* developmental instars were identified using stereo-microscopic methods (Zumpt, 1965). Premises in which at least one affected and confirmed animal was registered were considered a case herd. In this study, a premise was defined as a geographic site where sheep are kept that has a unique identification.

2.3. Data and data sources

The provincial AHD kindly provided data on all oestrosis outbreaks affecting sheep growing sites in Guantánamo province registered from 2006 to 2010. Data concerning affected premises were stored in spreadsheets (Microsoft Excel® 2010). The registered information recorded for the affected premises included premise's or owner's name, province, municipality, latitude and longitude, year of case occurrence and number of susceptible and dead animals at the time of the visit. The AHD also provided information on sheep population density per square km. Meteorological data for the study period were provided by the provincial weather station of the Cuban Institute of Meteorology.

2.4. Statistical analysis

The proportions of cases by years were compared using the Wald test in the software Epidat 3.1 (Hervada Vidal et al., 2004). The cumulative incidence was also calculated.

A spatial join tool was used to count the number of affected premises by quadrants in a 1 square kilometer grid used by the AHD for epidemiological surveillance in Cuba. A grid of 6526 quadrants of 1 square kilometer each was used to randomly select 240 Controls quadrants where the disease was not reported and 80 Case quadrants in which disease cases were reported, using a ratio of 3:1 for control and cases. The 1 km^2 grid used in this study is used by the national epidemiological surveillance system, as well as by the diseases notification system in Cuba. It has been accepted since 1987 by the Veterinary Service in collaboration with PANAFTOSA

Spatial autocorrelation (Global Moran's I) was used to identify spatial clustering and distances at which spatial processes were most pronounced (Moran, 1950; Li et al., 2007). Directional distribution (1 standard deviation ellipse) tool in ArcGIS 9.3.1 (ESRI, 2009) was used to describe the spatiotemporal pattern of affected premise occurrences by year in the province.

The fixed distance band was calculated using the Global Moran's I, and the Euclidean metric was used as a distance method. Hot spot Analysis (Getis-Ord Gi*) (Getis and Ord, 1992) in ArcGIS 9.3.1 (ESRI, 2009) was used for detecting clusters of high and low numbers of affected premises; this tool identifies significant spatial clusters of high values (hot spot) and low values (cold spot).

The Geographically Weighted Logistic Regression (GWLR) was used to model the numbers of oestrosis cases (affected premises) in Guantánamo province. The centroids of each quadrant were used as input geographical coordinates for the analysis. Environmental conditions such as mean temperatures (°C), annual rainfall (mm), altitude (m) and relative humidity (%) as well sheep density (head/km^2) were used as independent variables, while the dependent variable was the presence of at least one affected premise in each quadrant.

A global logistic regression was performed first, followed by a local geographically weighted logistic model and were compared. The software used for the GWLR was the GWR4 (Nakaya, 2014). Simple correlation analyses were performed to confirm that the variables were not highly correlated with one another, and multicollinearity was tested using the variance inflation factor (VIF). An adaptive kernel size was used; the size of the bandwidth for each kernel and regression point was optimized using Akaike's Information Criterion (AIC). The percentage of deviance was also analyzed; this is also known as a type of pseudo R square. The residuals of the model were tested for identifying spatial clustering by using Moran's I (Anselin, 2004). The predictive accuracy of the local model was assessed using the ROC (Receiver Operating Characteristic) curve.

Thematic maps for the variables contributing to explain the occurrence of oestrosis cases and were created using ArcGIS 9.3.1 (ESRI, 2009). In addition, a risk map was made using Inverse Distance