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Impact of meteorological factors on the prevalence of porcine pasteurellosis in the southcentral of Mainland China

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ABSTRACT

Using data collected from 2006 to 2014, we applied geographic information system (GIS) mapping and spatial clustering analysis to evaluate prevalence of porcine pasteurellosis in all 31 provinces of Mainland China. All provinces have been affected, but our results show that there is a very high incidence in provinces of the southcentral of Mainland China. Six provinces comprise the area and account for 14082 outbreaks or 74.66% of the total 18862 number: Guangxi (4574), Sichuan (3493), Chongqing (2443), Guangdong (1584), Guizou (1041) and Yunnan (947). This study aims to evaluate the relation between meteorological factors and number of cases of porcine pasteurellosis in the southcentral of Mainland China. Local meteorological variables and case data of porcine pasteurellosis were provided by authorities. Spearman rank correlation analysis and cross-correlation analysis were used to control for collinearity and lag effects. A zero-inflated Poisson model was used to estimate the probability of an impact of meteorological factors in the epidemiology of porcine pasteurellosis. The results of this model indicated that ENSO have a positive effect on the occurrence of the disease. And there is a positive correlation between mean monthly temperature, relative humidity of the current and previous month and the number of cases of the disease. In contrast, average wind speed of the current month negatively correlated to the number of newly reported cases. Our findings indicate that there may exist meteorological conditions in the southcentral of Mainland China that increase the risk for the appearance of porcine pasteurellosis. Moreover, these meteorological variables may be used to estimate the number of disease' cases in this region.

1. Introduction

Between January 2006 and December 2014, 18862 cases of porcine pasteurellosis have been registered in Mainland China. According to data provided by the Ministry of Agriculture, porcine pasteurellosis was the most frequent swine disease in this period of time. Pasteurellosis is caused by *Pasteurella multocida* (*P. multocida*). It is one of the most important respiratory diseases affecting farm animals such as poultry, rabbits, cattle, goats and pigs. The disease causes pneumonia, genital infections, abscesses, and septicemia. Due to enormous economic losses in animal breeding, pasteurellosis continues to be a cause of concern in large parts of the world (Mohamed and Abdelsalam, 2008; McVey, 2009; Ahmad et al., 2014). In swine, it may play a crucial role in the Porcine Respiratory Disease Complex (PRDC) which is regarded as one of the most common and costly diseases of pigs (Cardoso-Toset et al., 2013).

As *P. multocida* is an opportunistic pathogen, suitable environmental conditions could increase the spread of pasteurellosis (Cardoso-Toset et al., 2013). According to the corresponding references, *P. multocida* affects 50–60% of rabbits in September and October, while its prevalence decreases to less than 20% during the rest of the year. In sheep aged over three months, the majority of outbreaks is reported in May, June, and July (McKay et al., 1996; Rad et al., 2011). By conducting spatiotemporal studies, we found similar epidemiological characteristics for porcine pasteurellosis in the southcentral of Mainland China. The southcentral of Mainland China consists of six provinces, Guangxi, Guangdong, Sichuan, Chongqing, Yunnan and Guizhou, and encompasses 1,540,070 km^2. Provinces in this region differ in sociometric, topographic and agricultural factors but share a similar climate characterized by high temperature, humidity and precipitation, during the months of augmented incidence of porcine pasteurellosis, so we hypothesize that the meteorological factors play an important role in the epidemiology of porcine pasteurellosis.

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While recent literature describes the relation between climatic conditions and infectious diseases in men and animals, to our knowledge, this is the first study regarding porcine pasteurellosis (Jones et al., 2008; Campbell-Lendrum et al., 2009; Hasnain et al., 2012). The purpose of our research was to assess the relation between porcine pasteurellosis cases and meteorological factors in the southcentral of Mainland China and to predict risks based on a zero-inflated Possion regression model in order to aid targeted prevention and surveillance.

2. Materials and methods

2.1. Swine farming in study area

There are two types of swine farms in the area where this study was realized, intensive livestock farming and small households. Intensive livestock farms produce in large scale industrialized production systems, the pig number of these farms is greater than 500. They require approval by the local administrative department of agriculture and must meet a high standard regarding facilities, production management and epidemic prevention systems. Small households usually keep animals in free-range systems or open-front barns. According to the official statistical data (http://www.stats.gov.cn/), the proportion of intensive livestock farming in the Guangdong province is 68%, in Sichuan and Chongqing is 56%, in Guangxi is 31.2%, in Yunnan is 30.1% and in Guizou is only 12%.

Furthermore, according to the data provided by the China Food Association, the most commonly consumed meat in Mainland China is pork and demands are stable throughout the year. Since the oestrus of sows is of the year in the region of interest, there is no obvious seasonality in swine farming operations and population figures such as the total population and age distribution remain constant all year long.

2.2. Data collection and processing

Data concerning number of cases of porcine pasteurellosis reported between January 2006 and December 2014 were obtained from the Official Veterinary Bulletin as published on the website of the Ministry of Agriculture of China (http://www.moa.gov.cn/zwllm/tzgg/gb/sygb/). The case numbers correspond to the provincial level. Official monthly reported outbreaks of *P. multocida* from January 2006 to December 2014 contain the data of 31 provinces in Mainland China.

In the context of epidemiologic history, veterinarians attending swine farms interpreted clinical signs and reported suspected cases. In order to accurately diagnose the disease, a strict clinical examination was performed following standard operational procedures. Then, tissue samples were taken from tonsils, lungs, submandibular tissue (jowl), mediastinal and mesenteric lymph nodes, liver, spleen and kidney and send to a veterinary laboratory to complete histopathological and microbiological analyses and confirm the tentative diagnosis. The applied surveillance system consisted of different surveillance components. In addition to conventional passive surveillance, we benefited from the intensive, nationwide door-to-door surveys launched by the Chinese government in every autumn.

The primary risk factors considered in this analysis included monthly temperature range (ΔT), monthly minimum temperature ($T_{\min}$), monthly maximum temperatures ($T_{\max}$), mean monthly temperature (T), relative humidity (Hum), rainfall (Rain) and average wind speed (Wind). Meteorological data were collected from the $0.5^{\circ} \times 0.5^{\circ}$ grid meteorological datasets, publicly available at the Chinese Meteorological Data Sharing Service System, a high resolution source of weather data (Zhang et al., 2009). Data can be assigned to each county, but since counties generally contain only one grid point, all counties took climatic information from the grid point closest to their administrative centroids(Zhao et al., 2014).

Within the study area, all six provinces have a subtropical climate. However, due to the fact that the ENSO (El Niño/Southern Oscillation) is indeed meteorological factor affecting the region of interest, spatial-temporal variability can be observed. To address this variability, we included the Multivariate ENSO Index (MEI) and seasonal factor in the model. The MEI has been used for world-wide monitoring of the ENSO phenomenon and data are obtained in the Earth System Research Laboratory (Wolter and Timlin, 2011).

2.3. Spatiotemporal pattern analysis

First, we used clustering analysis to evaluate the spatial pattern characteristics (Quick and Law, 2013). According to the study of Zhang, Moran's I statistics are more reliable than Getis-Ord Gi* statistics when the area of interest is situated on the edge of the whole region (Zhang and Zhang, 2007). As the area of interest is located at the border of Mainland China, we decided to use Moran's index values. Due to different conditions, spatial autocorrelation showed variations in the location. In some places, positive correlations were observed, and in others negative ones. This is called spatial heterogeneity. In order to identify this spatial heterogeneity, local Moran's I statistics have to be used (Bone et al., 2013). Local Moran's I index was used for statistically significant cluster identification. While a high positive Local Moran's I value for a determined location indicates similarity to those regions surrounding it, two high values next to each other point at two statistically significant clusters that form a 'hot region' (Burra et al., 2002; Kulldorff et al., 2003). Subsequently, we analyzed time series of disease and took statistical tests of its autocorrelation coefficient (AC) and partial autocorrelation coefficient (PAC) by Q_{LB} statistics (Arranz, 2005).

The cluster analysis was accomplished with ArcGIS 10.2 (ESRI, Redlands, CA); the time series and autocorrelation analysis were accomplished with Stata/SE 10.0 for Windows (Stata Corp, College Station, TX, USA).

2.4. Risk factor model

The distribution of the number of reported outbreaks contained an abundance of zeros because there were no reported outbreaks in some provinces for many months during the study period. To deal with disease outbreaks characterized by 'excessive' nonoccurrence, we decided to use zero-inflated Poisson regression (ZIP) (Cameron and Trivedi, 1998). The ZIP model sees the occurrence of the event as two possible processes: the zero count process and the Poisson count process. The data of the zero count process comes from the occurrence of zero-event, it explains the phenomenon of zero expansion; Poisson count process corresponds to the occurrence of events that follow Poisson distribution (Gómez-Rubio and López-Quílez, 2010; Cameron and Trivedi, 2013).

Spearman rank correlation analysis was performed between every two climate factors to control for collinearity and variable selection for the final model was conducted based on the Akaike information criterion (AIC) (Jafarzadeh et al., 2014). With the aim of identifying the lag effect of meteorological factors on porcine pasteurellosis, we adapted the cross-correlation analysis and included all statistically significant variables in the regression model (Zhao et al., 2014). The covariates included the number of outbreaks of porcine pasteurellosis during the previous month and a seasonal factor. These covariates account for the temporal autocorrelations of disease outbreaks (Jafarzadeh et al., 2014).

Finally, the Intraclass Correlation Coefficient (ICC) was used to measure the degree of consistency between the actual value and the predicted value. The ICC is proposed by Bartko in 1966 and used