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Original Research

Modelling African swine fever presence and reported abundance in the Russian Federation using national surveillance data from 2007 to 2014

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A B S T R A C T

African swine fever (ASF) is a viral disease of swine that has been present in the Russian Federation since 2007. Counts of ASF outbreaks reported in the Southern regions of the country (2007–2014) were aggregated to a grid of hexagons, and a zero-inflated Poisson model accounting for spatial dependence between hexagons was used to identify factors associated with the presence of ASF outbreaks and factors associated with the number of ASF reports in affected hexagons. Increasing density of pigs raised on low biosecurity farms was found to be positively associated with the probability of occurrence of at least one ASF outbreak in a hexagon and with the average number of reported ASF outbreaks amongst affected hexagons. Increasing human population density and increasing distance from the closest diagnostic laboratory were additional variables associated with number of reported ASF outbreaks amongst affected hexagons. The model was shown to have good predictive ability.

1. Introduction

African swine fever (ASF) is a highly contagious viral disease that affects all classes of domestic and non-domestic swine including domestic pigs, wild boar, warthogs and bush pigs (Costard et al., 2012). In domestic pigs and wild boar, some ASF virus (ASFv) strains result in mortality rates of almost 100% (Blome et al., 2012; Sanchez-Vizcaino et al., 2012; Guinat et al., 2014). There is currently no vaccine available. Because of its large economic impact in affected countries, ASF is listed as a notifiable disease by the World Organization for Animal Health (OIE).

In 2007, ASFv was introduced into Georgia from Africa, probably through the transport of infected swill fed to pigs in the region of the sea port Poti. In just a few months, ASFv spread across the country and entered the Russian Federation (RF) in late 2007, probably as a result of the movement of infected wild boar (FAO, 2013; Sanchez-Vizcaino et al., 2013). Initially restricted to the southern regions of the RF, ASFv expanded its geographical distribution in 2011 when it was introduced into central and northern regions where it started to spread locally (Sanchez-Vizcaino et al., 2013). In 2014, ASFv was identified in both domestic pigs and wild boars in several countries of the eastern European Union, including Estonia, Latvia, Lithuania and Poland. Due to a relatively high transmission rate combined with a case fatality rate of almost 100% in naïve pigs and wild boar (Blome et al., 2012; Guinat et al., 2015), the fact that the virus is able to survive

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for lengthy periods in both the environment and pork products (EFSA, 2014; Davies et al., 2015) and the absence of both vaccine and treatment, understanding the epidemiology of ASF and identifying risk factors for disease occurrence is paramount to allow for the timely prevention and control of ASFv.

On the African continent, ASF was shown to be associated with many different risk factors, including density of free-ranging pigs, movement of pigs and pig products, low biosecurity measures, the practice of swill-feeding, purchase of pigs, proximity of slaughter houses and human behaviour (Randriamparany et al., 2005; Penrith and Vosloo, 2009; Fasina et al., 2012; Chenais et al., 2015; Nantima et al., 2015). In the RF, two studies have used national surveillance data to investigate risk factors for ASF occurrence in the RF. In their early paper, Gulenkin et al. (2011) used linear regression to model the density of outbreaks reported in domestic pigs in the Southern regions between 2007 and 2010, and showed that the risk of ASF outbreaks increased with increasing density of domestic pigs, rivers, main highways and secondary roads. Korennoy et al. (2014) used the maximum entropy method to model the distribution of ASF outbreaks reported between 2007 and 2012 and found that increasing disease risk was associated mostly with increasing rural population density and increasing density of pigs raised on low biosecurity farms.

While these two studies provide important insights into the risk of ASF, their main limitation is that they do not account for a potential spatially heterogeneous reporting rate of ASF outbreaks, which has been suggested to be one of the most important challenges of ASF control in the Russian Federation as a consequence of inefficient control measures and inadequate compensation strategies (FAO, 2013). As in ecological studies focused on the modelling of site occupancy by cryptic wildlife populations (MacKenzie et al., 2002), the observed spatial distribution of a disease is a combination of its true distribution and of a reporting bias. The methods used in these two studies cannot explicitly differentiate between variables associated with the true ASF distribution and variables that potentially influence the reporting rate or local abundance of outbreaks. As a result, some of the retained explanatory variables could be associated with an increased reporting rate rather than an increased ASF risk, and the measure of the identified associations with the ASF risk could be confounded by variables influencing the reporting rate.

Extensively used in ecology to model the distribution of wildlife species that cannot be observed with certainty (Martin et al., 2005), zero-inflated count models could be a useful approach in epidemiology to model the distribution of an infectious disease observed through the lens of an imperfect surveillance system, i.e. when the probability of reporting outbreaks is less than one (Vergne et al., 2015b). These models allow one to distinguish between variables influencing the likelihood of occurrence of at least one outbreak and those influencing the number of reported outbreaks in affected areas. In animal health, this approach has been used to model bovine abortions in France (Bronner et al., 2013) and highly pathogenic avian influenza in Vietnam (Lockhart, 2008) and Thailand (Vergne et al., 2014).

In this study, we used a conditional autoregressive zero-inflated Poisson regression approach to model the distribution of ASF outbreaks reported in the Southern regions of the RF between 2007 and 2014, in order to identify variables associated with the distribution of reported outbreaks.

2. Materials and methods

The analysis was restricted to the territories of the North Caucasus and of the South of the European region of the RF as this zone has one of the highest pig densities in the country and was most affected since the start of the epidemic. The surveillance system is based on the reporting of suspicions by farmers to regional veterinary services. These suspicions are subsequently confirmed using laboratory diagnostic techniques by the State Research Institute of Veterinary Virology and Microbiology which maintains the national dataset of ASF outbreaks. This dataset includes several characteristics of the infected farms as well as the location of the outbreaks recorded as the longitude and latitude of the centroid of the town to which the infected farms belong (Korennoy et al., 2014). All outbreaks reported to the veterinary authorities between 2007 and 2014, involving domestic pigs from this region, were included in this study. The data were sourced from the official website of the Russian federal service for veterinary and phytosanitary surveillance (http://fsvps.ru/fsvps/asf; last update: August 2014). Overall, 104 outbreaks in domestic pigs were reported during the period of interest. The study area was partitioned into a regular grid of 389 hexagons of 60-km diameter (hexagons are more similar to circles than squares which allows for a more efficient aggregation of data around their centroids), and counts of ASF outbreaks were aggregated to the hexagon level. The outcome variable was therefore the number of outbreaks reported in the domestic pig population in each hexagon during the study period. Fig. 1A presents the spatial distribution of the outcome variable.

The putative explanatory variables used in this analysis focused on anthropogenic, swine-related and environmental variables. The anthropogenic variables included human population density, distance to the nearest regional capital, distance to the nearest diagnostic laboratory, and road density. Human population data were obtained for the year 2013 from the Federal State Statistics Services. The location of regional capitals and information about the road network were extracted from the database distributed by ESRI-CIS (http://www.esri-cis.ru/). The location of regional veterinary diagnostic laboratories was obtained from the Federal Service for Veterinary and Phytosanitary Surveillance. Similar to Korennoy et al. (2014), distribution of pigs kept in high and low biosecurity farms was based on estimates generated by the Federal State Statistics Service in 2011. High biosecurity farms were defined as large holdings, often comprising of more than a thousand pigs, typically owned by the State or private companies, regularly visited by a veterinarian (they often have their own) and associated with several biosecurity measures, including access restrictions and disinfection procedures; low biosecurity farms were defined as backyard or small-scale