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Cartographical analysis of African swine fever outbreaks in the territory of the Russian Federation and computer modeling of the basic reproduction ratio

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ABSTRACT

African swine fever (ASF), have been introduced into the Russian Federation from Transcaucasia countries, has spread widely across the territory of the southern region of Russia since 2008. In this work we present an analysis of the spatial and temporal spread of the disease, determine risk factors by means of GIS tools and model the dynamics of the epidemic process both within infected premises (farms) and at the between-farm level to estimate the basic reproduction ratio R_0. The analysis allowed us to make a conclusion about the anthropogenic nature of the risk factors for disease spread. The major significant risk factors identified were: density of the road network, density of domestic swine population and density of water bodies in the study area. The basic reproduction ratio was estimated to range from 2 to 3 at the between-farm level and from 8 to 11 within the infected farms. These initial studies of the ASF epidemic provide information on which to based control and prevention programs.

1. Introduction

One of the main and most important parameters necessary for successful modeling and prediction of infectious disease spread is the basic reproduction ratio, R_0. This parameter is used to predict the speed and scale of disease spread and the level of herd immunity required to control the disease. The basic reproduction ratio is defined as the average number of secondary infections caused by introducing one infected individual (animal) into the population, which consists exclusively of susceptible hosts (Anderson and May, 1992). In this current study we have attempted to estimate the value of R_0 at both the between-farm and within-farm level using a simple Susceptible-Exposed-Infectious-Resistant (SEIR) type epidemic model.

ASF is a highly contagious disease of domestic and wild pigs, characterized by almost 100% mortality and can cause great damage to agriculture and the economy in general. The cause of ASF is a unique DNA virus which is the only member of the Asfarviridae family, genus *Asfivirus*. No vaccine exists against ASF and the only acceptable eradication strategy is total depopulation of pigs within the infected farm and also within the surrounding zone of risk. ASF is considered an endemic disease in most southern and eastern African countries, where the virus is maintained either in an ancient sylvatic cycle between warthogs and ticks of the *Ornithodoros moubata* complex or in a domestic cycle that involves pigs of local breeds, with or without tick involvement (FAO, 2009a,b).

Since 1957 a number of outbreaks of ASF have been reported in Spain, Portugal, Cuba, Brazil and some other European and Central American countries. According to official OIE data, the primary outbreaks of ASF in the Caucasus region were reported in April 2007 from Georgia. Then the disease apparently spread to other parts of the country,

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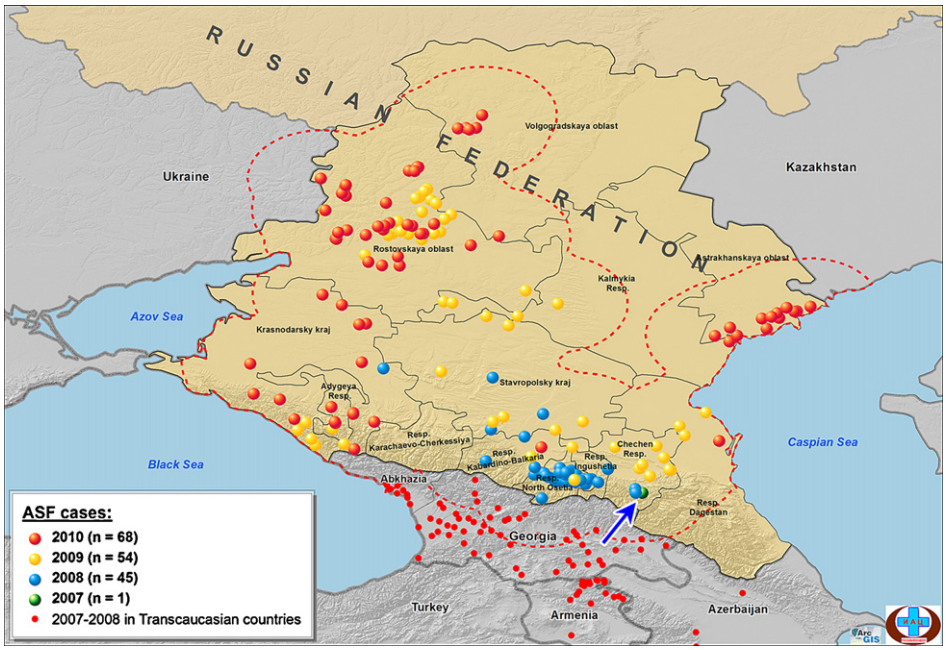

Fig. 1. The distribution of African swine fever outbreaks in Georgia, Abkhazia, Armenia, Azerbaijan and Russia during 2007–2010 (the blue pointer indicates a possible route of the introduction of ASF into the Russian Federation by wild boars from the territory of ASF-affected Transcaucasia along the Shatoy gorge; the dotted red line indicates a 100-km zone of immediate risk around all the outbreaks into Russian Federation). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

affecting Abkhazia and South Ossetia. In the summer of the same year foci of ASF were reported in Armenia and Azerbaijan (Nagorno-Karabakh). In November, ASF virus was discovered in dead wild swine (boars) in the territory of the Chechen Republic, Russian Federation, based on PCR testing. Thus, by the end of 2007 ASF had spread widely in the Caucasus (affecting all countries in the region, including Russia) and had become epidemic (FAO, 2007, 2008).

In June 2008 the first outbreaks of ASF among domestic animals were reported from the Republic of North Ossetia. Almost simultaneously, 4 affected areas were detected. Despite strict quarantine measures that were applied to prevent the spread of ASF, between 2008 and 2009 the disease spread further across the southern territories. ASF outbreaks were reported from 5 sub-federal units of the Caucasus region of the Russian Federation: Kabardino-Balkaria, Ingushetia, Stavropol'sky and Krasnodarsky krays, and Rostovskaya oblast. The disease continued spreading among domestic swine in North Ossetia and wild swine (boars) in the Chechen Republic.

ASF continued spreading in the territory of the southern Russian region in 2009. In this year 54 cases were reported, of which 19 were from wild boars and 35 were from domestic pigs. In 2010 (as of the beginning of September) a further 68 outbreaks of ASF were reported in the territory of the southern region; 18 of these were among wild boars. The disease also spread into the territory of Astrakhanskaya and Volgogradskaya oblasts. Moreover, in 2008 and 2009 two remote cases were reported in Orenburgskaya (2008) and Leningradskaya (2009) oblasts, located a distance of 1100 and 1500 km from the affected southern region, respectively. These cases were linked to the purchase of contaminated meat products from the southern region. Strict quarantine measures were applied and prevented ASF from spreading further.

Thus, in the period 2007–2010, 168 cases of ASF were reported in the territory of the Russian Federation, 166 of which were in the Southern and North-Caucasian Federal districts. Fig. 1 shows ASF spread and the 100-km risk zones. The size of the zone of immediate risk was adopted according to the *Instruction on prevention and eradication of ASF* which is the main official document on prevention and eradication of ASF in the Russian Federation (Anon., 1980). The objectives of the study presented here were to (1) analyze the spatio-temporal dynamics of ASF spread in the territory of the Russian Federation, (2) apply geostatistical methods to identify geographic and socio-economic factors that may be associated with the risk of introduction and spread of the disease, and (3) estimate the basic reproductive ratio of ASF in the affected region.

2. Materials and methods

2.1. Data source

Data for this study was acquired from WAHID (OIE) database. Reported ASF outbreaks in the territory of the Russian Federation during the period 2007–2010 (http://www.oie.int/wahis/public.php?page=home) were selected from the database. For each record, the following information was available: date of reporting, start date of outbreak, location of outbreak (both latitude/longitude and name of locality), species affected (domestic or wild), number of affected animals, and number of susceptible