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Review

African swine fever in the Russian Federation: Spatio-temporal analysis and epidemiological overview

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ABSTRACT

African swine fever is viral disease of domestic and wild pigs which leads to almost total mortality and causes great economic losses due to absence of vaccine. Having been introduced into the Russian Federation in 2007 the disease has spread widely in the southern region of the country and since 2011 has demonstrated a tendency to form a secondary endemic zone in the central part of the country. In the present study spatio-temporal patterns of ASF diffusion in the populations of wild and domestic pigs are analyzed. The structure of the domestic swine population is conventionally divided into a sub-population at low biosecurity (77% of the total number of outbreaks in domestic pigs) and a population at high biosecurity (23%). The statistics of ASF cases registered in each of these sub-populations is presented. The possible causes of ASF diffusion across the country are discussed. The use of geo-information technologies (GIS) enabled confirmation of the conclusion that an epidemic center has shifted into the central part of Russia. The main conclusions of this study are that: (1) anthropogenic factors play the leading role in the spread of ASF across the territory of the RF; (2) small-scale private holdings (low biosecurity population) are more exposed to ASF virus introduction; (3) there is a high risk of diffusion of ASFV from the secondary endemic zone in the central part of the RF to neighboring regions.

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1. Introduction

African swine fever (ASF) is a viral disease that affects domestic swine and wild pigs that may become epidemic and is characterized by high mortality. Characteristic features are transmissibility and natural endemicity in Africa (Syurin et al., 1998). The Island of Sardinia is the only territory beyond the limits of the Africa that is considered endemic for ASF at the present time. The ASF virus has persisted there since 1978 (Feliziani et al., 2010).

ASF causes great economic losses because there are almost no effective preventive measures (vaccines). The method recommended is the use of sanitary measures such as isolation and

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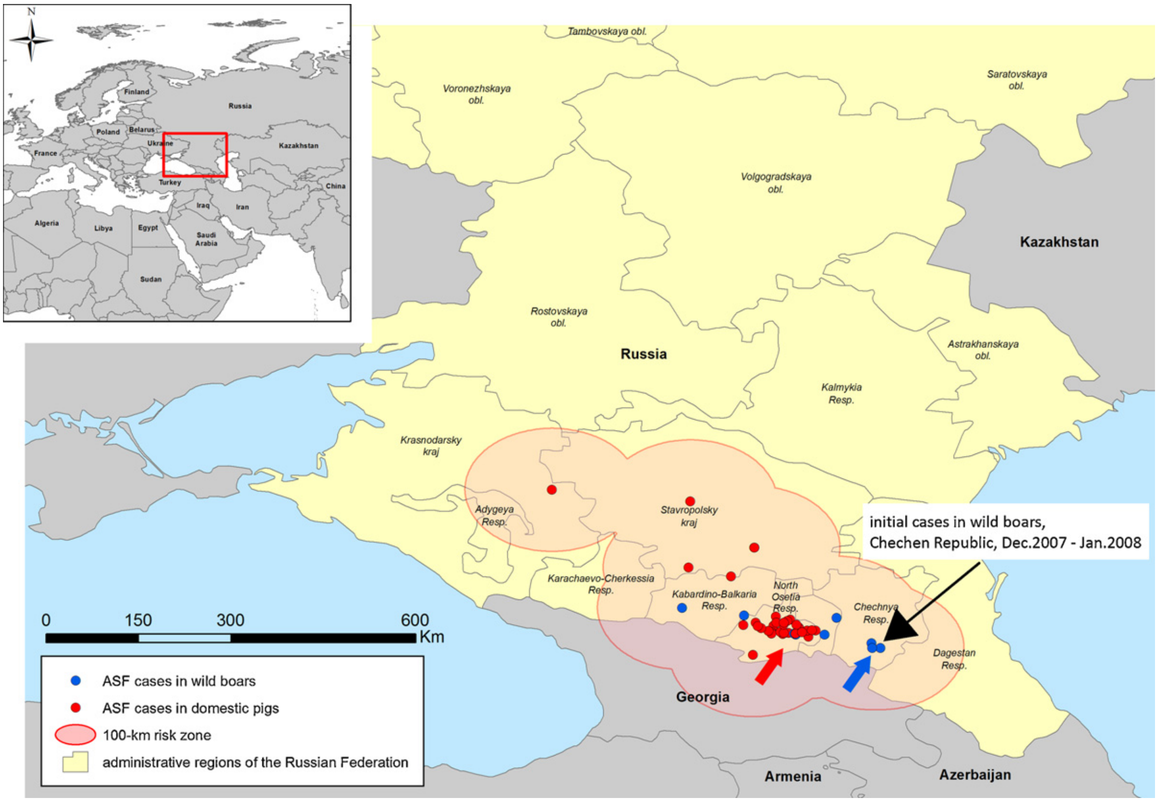

Fig. 1. ASF epidemic situation in 2007–2008. Blue pointer demonstrates a possible route of ASFV introduction in wild boar population; red pointer demonstrates a possible route of ASFV introduction in domestic swine population.

blanket depopulation of susceptible animals in the site of outbreak and in the risk zone as well as a total ban on movement of animals and animal products from affected regions.

Protective and restrictive measures can prevent the spread of the disease in disease-free countries, regions or farms. Effectiveness of control and prevention depends on the conscientiousness of people who implement such measures and on good timing of implementation (efficient response).

Elimination of ASF in affected counties is a time- and money-consuming undertaking: for example, in Spain ASF was present for 35 years before it was finally eradicated (Penrith and Vosloo, 2009; Morilla et al., 2002).

The goal of this study is to provide an epidemiological overview of the ASF epidemics in the period from 2007 to 2012 in the Russian Federation using statistical analysis and geo-information technologies.

2. Materials and methods

2.1. Data sources

We have used data on outbreaks of ASF in Russia for the period from 2007 to 2012 (as of 13.08.2012) available on the World Animal Health Database (WAHID), OIE (WAHID, 2012).

For geospatial analysis we have used a set of geo-data "Digital model of the territory of the Russian Federation in the scale of 1:1,000,000" (Esri-CIS).

2.2. Software

Statistical analysis was performed using the software packages (Microsoft Office) and STATISTICA-8 (Statsoft).

Geospatial data analysis was performed using the geo-information system ArcView 10.1 and built-in software tools from the package Spatial Statistics Tools (Esri). We have used the software tool "Mean Center" to determine the shift of the epidemical center of ASF in the period from 2007 to 2012.

3. Results and discussion

3.1. History of epidemics

ASF became widespread in the Trans-Caucasian region in 2007. Wild boar contributed to the entry of ASF into the Russian Federation at the end of 2007. The first cases of ASF were registered in the Shatol'skoe Ushchel'e of the Chechen Republic (November 2007). The first outbreaks in domestic swine were reported in June 2008 in the Republic of North Ossetia. In the second half of 2008 OIE posted reports of 44 outbreaks of ASF in the Republic of North Ossetia, the Chechen Republic, the Republic of Kabardino-Balkaria, the Krasnodarskii and Stavropol'skiy Kray (Fig. 1).

Extensive swine-rearing with a great number of backyards played a significant role in wide and fast spread of ASF in the Caucasus region. Local farmers are accustomed to keep swine outdoors, which could be described as a tradition in this region. Apparently, this method of swine – keeping resulted eventually in infection of domestic swine via direct contacts with wild boar. Aside from that, the first remote outbreak of ASF was registered in the Orenburgskaya Oblast, more than 1000 km away from the affected area in the Caucasus.

Development of the epidemic process in 2009 was characterized by a significant increase in the number of outbreaks in the southern region of the Russian Federation. Fifty-four new outbreaks of ASF were registered and the total number of outbreaks reached 100 (reported to OIE). The borders of the infected zone expanded

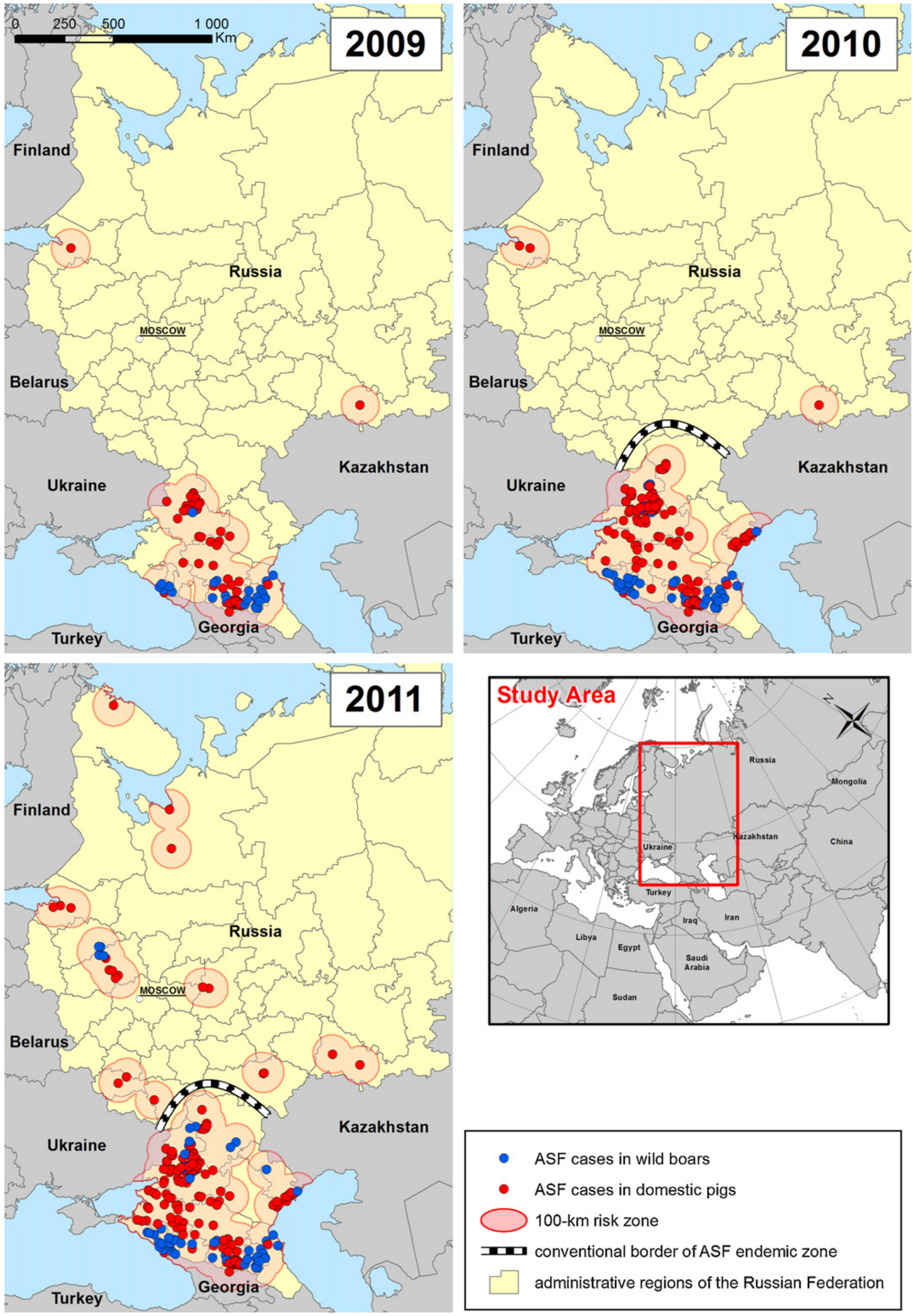

Fig. 2. ASF epidemic situation in 2009–2011.

considerably and by the end of the year included the Rostovskaya oblast as well. Like the previous year, only one remote outbreak was registered in the Leningradskaya Oblast in 2009 (Fig. 2).

In 2010 ASF spread to new territories in the southern region of the RF. New outbreaks were identified in the Astrakhanskaya Oblast and the Volgogradskaya Oblast. The total number of outbreaks rose to 177. ASF was registered in the South and North-Caucasian Federal Districts for three consecutive years (2008–2010), therefore this area should be considered as the endemic zone (Fig. 2).

In 2011 the situation changed greatly. The number of remote outbreaks increased dramatically (22 out of 52 registered outbreaks): the disease from the endemic zone started to spread toward the European part of Russia, covering new territories such as the Saratovskaya Oblast, the Nizhny-Novgorodskaya Oblast, the Voronezhskaya Oblast, the Kurskaya Oblast, the Tverskaya Oblast, the Leningradskaya Oblast, the Murmanskaya Oblast and the Arkhangelskaya Oblast (Fig. 2).

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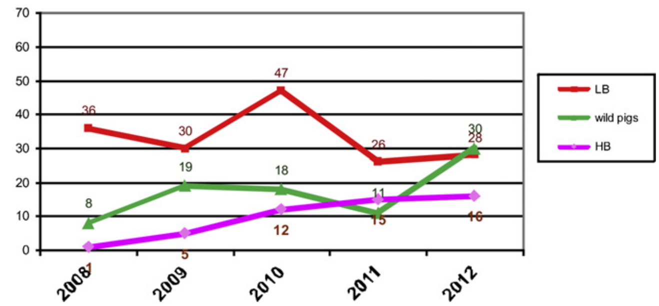

Fig. 3. Dynamics of ASF cases in three sub-populations in 2008–2012.

In the first six months of 2012 the situation has not changed substantially: outbreaks were still registered in the permanently affected region as well as in the previously ASF-free regions. However, the majority of outbreaks were registered in the Krasnodarskiy Kray, the Volgogradskaya Oblast and in the Tverskaya Oblast. A second (besides the southern one) endemically affected region has formed in the Tverskaya Oblast since 2012.

3.2. Analysis of ASF epidemics in different swine populations in Russia

In view of the fact that the development of the epidemic process depends on habitat and swine – keeping system, we divided the total population of susceptible animals into 3 sub-populations in order to get more reliable data. The following assumptions were made:

- *Swine population at backyards and small-scale private holdings* characterized by low level of biosecurity or by its complete absence, and therefore considered as *Low Biosecurity* (*LB*). It is also characterized by the high intensity of contacts between backyards, by frequent trade ties and by low level of veterinary medical treatment.
- *Swine population on large farms with high level of biosecurity measures* (*HB*).
- *Wild pig population* (their characteristics are associated with population and environmental properties of groups/families).

The analysis of ASF outbreaks dynamics in these three sub-populations allowed us to obtain the following data (Fig. 3):

(A) The number of outbreaks on HB farms continues to grow in spite of the registration peak in 2010 and the decrease in the number of outbreaks in LB in 2011.
(B) On 13.08.2012 the peak was registered in the wild boar population ($n = 30$). ASF in wild boar has certain distinctive features:

(1) a lot of outbreaks were registered on hunting farms (39%), which implement surveillance of susceptible wild populations (incidence diagnosis), but even on such farms it is very difficult to control and define livestock number accurately;
(2) in most cases the source of infection is not identified;
(3) increase in the number of outbreaks in 2012, inter alia, is due to monitoring by shooting vs predominantly incidence diagnosis performed in the previous years.

The detailed analysis was performed over the three-year period from 2009 till 2011 as it reflects most accurately the current situation in Russia. During these 3 years (2009–2011) 45.2 (95% CI: 13.9–76.0) outbreaks of ASF were registered in the domestic swine population:

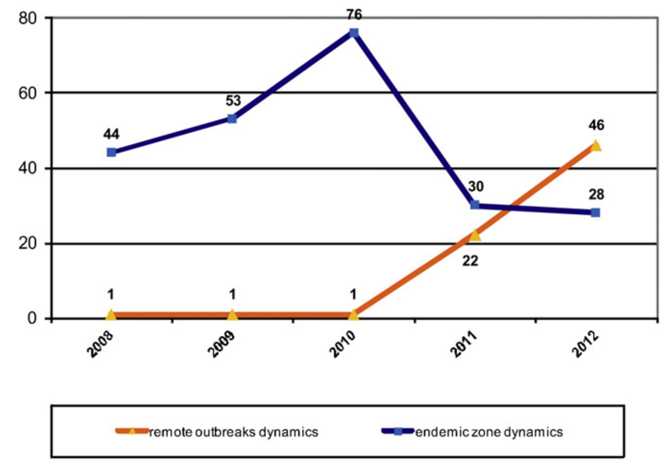

Fig. 4. Dynamics of ASF cases within the endemic zone and outside of it.

(1) 10.6 (0–23.4) outbreaks on farms (HB). At the same time a seasonal increase was noted in the period from May to October; the most likely explanation for this increase is the change in the economic activities in the backyard sector (LB), when infected food or materials in large quantities can enter the swine populations on large-scale enterprises.
(2) 34.3 (6.6–62.0) outbreaks on LB. The increase can be explained by seasonal regrouping of animals within herds and within regional sub-populations due to specific swine-keeping practices in the region.
(3) 16.0 (5.2–26.8) outbreaks in wild boar. A significant number of the ASF outbreaks (39%) occurred on hunting farms.

3.3. Emergency response factor

Urgency of response and implementation of quarantine measures are the crucial factors for effective control of ASF. Time from infection and manifestation of clinical signs to diagnosis and introduction of emergency measures is considered to be an indicator.

We have used data on backyard farms (LB) for this analysis due to the following reasons:

1. More data are available for this group than for others, and therefore the expected result is more reliable statistically;
2. Data on wild boar are not suitable for interpretation because they are largely based on incidence diagnosis;
3. Data on large-scale farms are subject to greater variability due to many factors that cannot be assessed (inaccurate determination of entry date, almost no data on stock segregation structure, the date of implementation of measures, etc.). As a rule, biosecurity measures are implemented urgently at such facilities, even before laboratory confirmation of diagnosis.

On the average, the number of days from the start of an outbreak to the diagnosis confirmation is 4.6 (2.4–6.7) (for the period from 2009 to 2011) on LB. Forty percent of outbreaks on LB ($n = 37$) have similar results: it takes no longer than 24 h from the point of suspicion to establishment of laboratory diagnosis. The most likely reason for such a short time period is inefficient epidemiological investigation in the course of which the start date of the outbreak is replaced by the date of laboratory confirmation of diagnosis. In 59% of cases it took 1–2 days from "the start date to laboratory confirmation of diagnosis", in 23.5% of cases 2–6 days and in the remaining 17.5% 10–30 days. Given very frequent contacts between backyard farms and low level of segregation, one can assume that on average 5–8 days pass from start date to laboratory confirmation, and as a

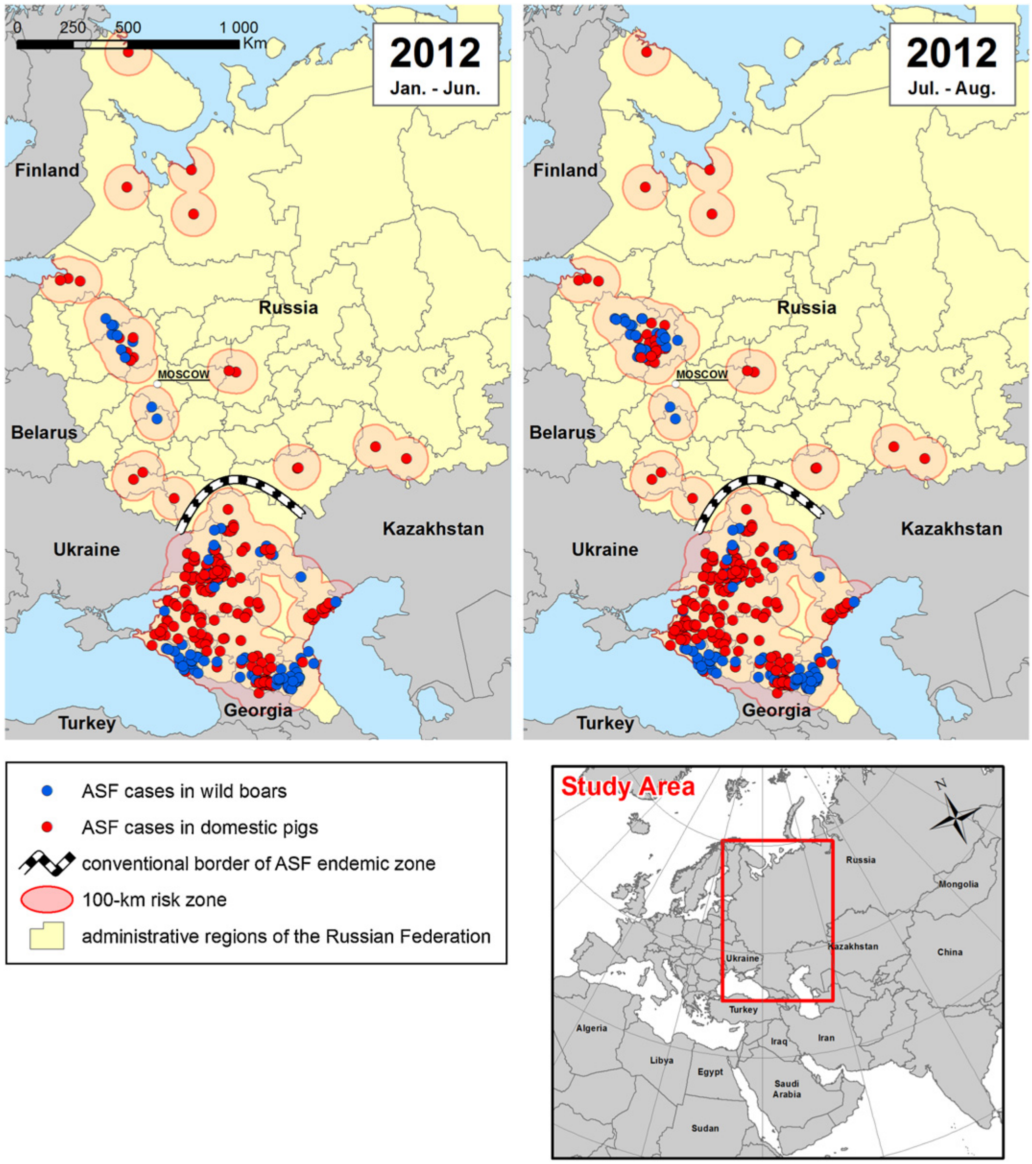

Fig. 5. ASF epidemic situation in 2012 (as for 13.08.12).

result the territory or population of the entire settlement will be affected completely or significantly by that time.

The number of susceptible animals in the outbreak averaged 167.3 heads (95.9–238.7). In terms of livestock number on affected LB, 50% LB had 35 heads or less, 11.5% LB – 35 to 100 heads, 36% LB – more than 100 heads, and 3 LB (2.5%) – more than 1000 heads.

The prevalence index of LB averaged 0.46 (0.37–0.56) which undoubtedly points to the importance of delimitation of boundaries of an outbreak within a separate backyard farm. In this case, it will be more interesting to trace "prevalence between backyards", i.e. backyard prevalence within the frame of one outbreak that is delimited by a village or by part of it. Most likely all the slaughtered pigs had been infected; therefore there is a high probability that the number of infected animals identified in one outbreak or in one backyard does not always reflect the real picture.

The mean values of mortality and morbidity for ASF were 72.4% (64.3–80.4) and 37.8% (28.9–46.6), respectively.

So taking into account the number of susceptible animals on LB we can say that in most cases implementation of quarantine measures and determination of boundaries of an outbreak is limited by a separate backyard or a village part, whereas the entire village should be considered as an epidemiological unit.

3.4. Notification of ASF outbreaks within and outside the endemic zone

As demonstrated in Fig. 4, the situation changed in 2011. Previously there was a steady and proportional increase in the number of outbreaks while the situation practically did not change spatially. But in 2011 the number of remote outbreaks increased dramatically.

Eight out of 17 regions in the endemic zone were affected in 2011 (30 outbreaks). Nine constituent entities of the Federation outside the endemic area were also affected – 22 outbreaks were registered there. So the number of outbreaks within and outside of the endemic zone leveled off, indicating dissemination of the disease.

On 13.08.2012, 46 cases of ASF had been registered outside the endemic zone, while within the endemic zone only 28 outbreaks were registered. Thus a diffuse spread of ASF in Russia was observed (Fig. 5).

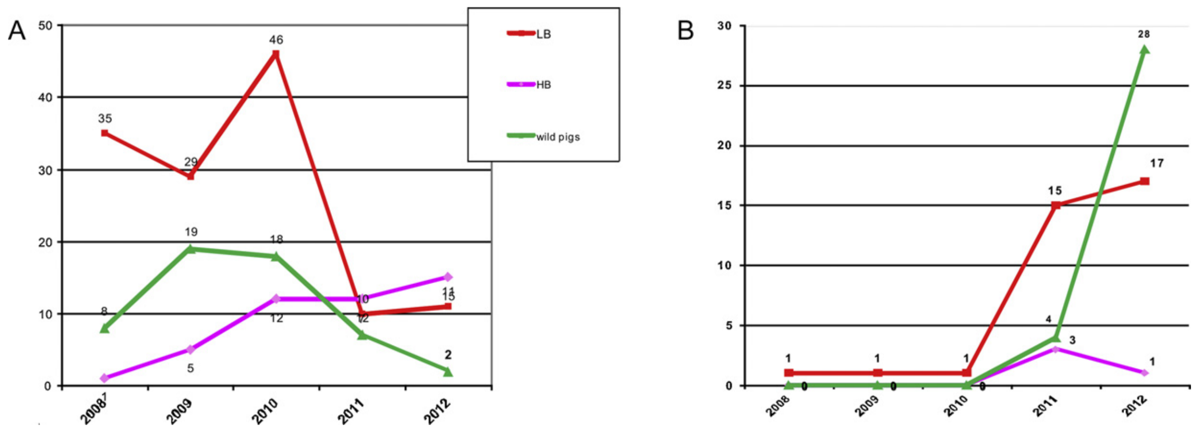

Fig. 6. Dynamics of ASF cases by sub-populations within the endemic zone (A) and outside of it (B).

The peak of the outbreaks was registered in one of the most protected populations within the endemic zone in 2010–2011 – on specialized swine breeding farms (Fig. 6A). Twelve large-scale swine breeding farms (HB) were affected by ASF in 2010 and 2011. In 2012 there were already 15 affected HB farms in the endemic zone (as of 08.13.2012).

By the end of 2011 the infection was registered outside the endemic zone in such federal districts as Central, Privolzhskyi, North-West (Fig. 5).

New outbreaks of ASF in previously disease-free territories indicate that one of the main pathways for ASF entry is an unauthorized supply of pig products from the endemic zone. The direct cause of transmission is kitchen/catering waste used for pig-feeding without preliminary heat treatment. Thus, the hypothesis that antropogenic factors are of prime importance in the release of ASF virus from the site of outbreak is confirmed (Shectsov et al., 2008; Gulenkin et al., 2011).

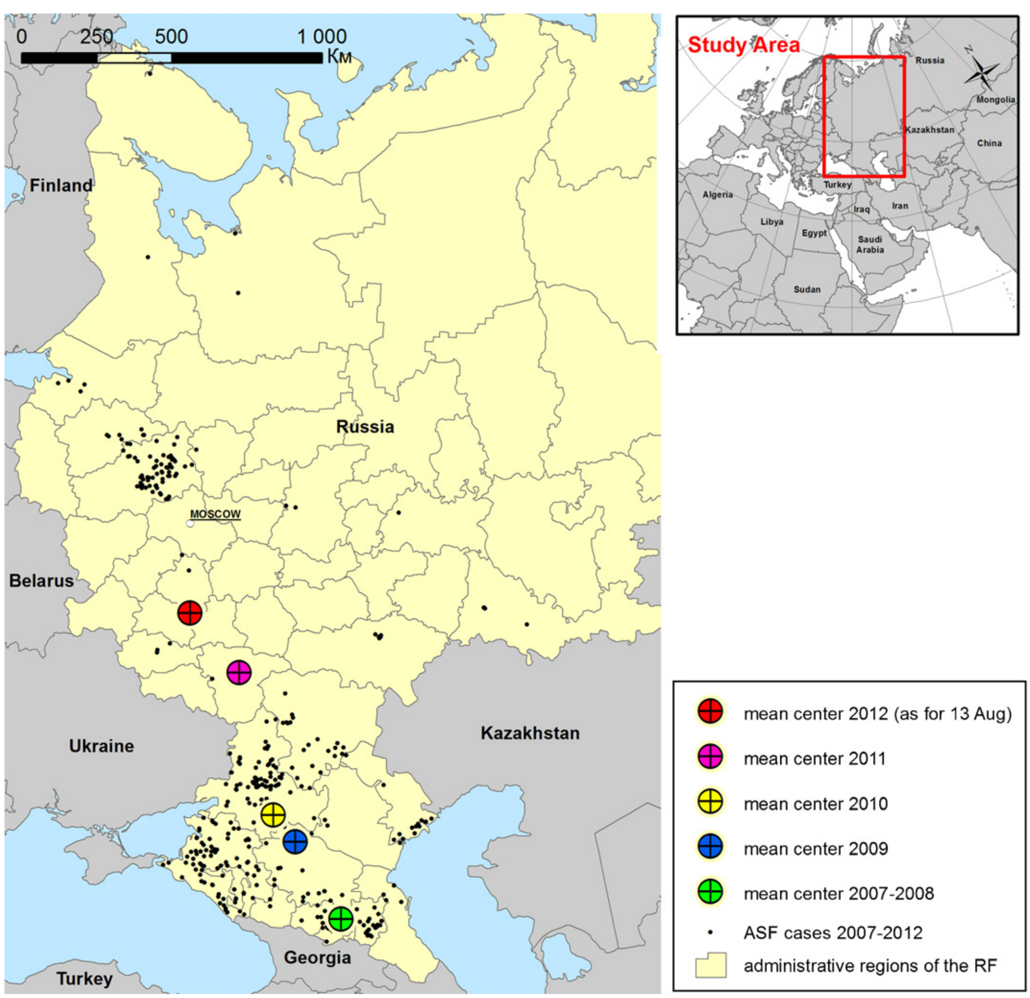

Fig. 7. The shift of conventional epidemic center of ASF from 2007 to 2012.

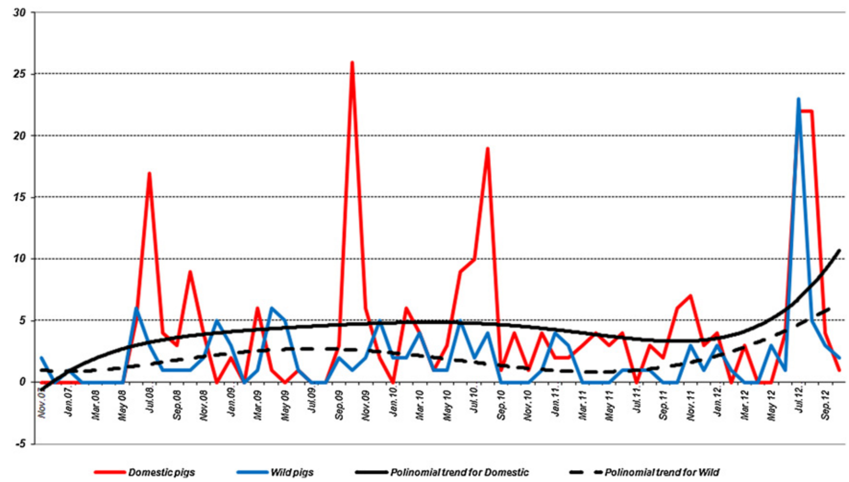

Fig. 8. Dynamics of ASF cases in 2007–2012 and polynomial trends.

The Tverskaya Oblast is considered to be the most affected region in the number of remote outbreaks at the moment (13 August 2012). The first ASF outbreaks in domestic swine in the Tverskaya Oblast were notified by OIE in June 2011. There are some factors that contributed to further spread of the disease in the population of domestic swine and to the release of the infection into wildlife: inefficient animal disease control measures and uncooperative farmers who hide the information about swine mortality and disposal on their farms. Because of the inefficient animal disease control measures applied in the previous years, the source of the virus has not been eliminated completely. In 2012 it resulted in a dramatic increase in the number of ASF outbreaks in the domestic pig population as well as in wild pigs. All of the data show that the outbreak in the Tverskaya Oblast is developing independently, without re-entry from the outside, but we should not exclude reciprocal re-infection between the domestic swine and wild pigs as well as preservation of the outbreak. This suggests a high probability that a secondary epidemic outbreak is developing in this region, and detection of ASF cases in wild boar in the Tverskaya Oblast and in the neighboring Novgorodskay Oblast confirms this suggestion (Fig. 5).

There is a spurt in the number of remote outbreaks vs a decrease in the total number of detected outbreaks in 2011. Incidentally, the majority of the cases were registered on backyard farms LB ($n = 15$). We have registered 17 cases of ASF on LB farms in first six months of 2012. In 2011 we registered 3 cases on HB farms (Fig. 6B), in the first half of 2012 we have registered only one case.

There has been a spurt in the number of cases in wild boar (28) in 2012. However, it can be explained by inaccurate delimitation of the boundaries of outbreaks and extended monitoring by shooting animals in this population.

Thus, the increase in the number of remote outbreaks that had started in 2011 in these conventional sub-populations has continued in 2012. It appears that backyard farms (LB) have been and are the main driving force for long-distance spread, as they are practicing animal feeding with unsterilized kitchen waste.

Outbreaks in wildlife are likely to be connected with outbreaks in the backyard sector – first outbreaks occur in the backyards, then in the wildlife. Thus, infected wild boar, affected backyard farms and re-infection of domestic swine and wild pigs have formed a new "completely affected area". Sooner or later there will be a breach in the biosecurity system on the HB farms that are situated in this area. The presence of a non-eradicated virus source will eventually result in infection of a susceptible animal.

And as shown in Fig. 5, this situation started to develop under the scenario of 2011. The human factor is the only reason for biosecurity breaches on HB farms (unauthorized entry, disregard of set rules, etc.).

The shift of the mathematically calculated epidemic center of ASF in the territory of Russia also confirms the deterioration of the spatial situation – the center shifted toward the central – European region (Fig. 7).

In 2007 the epidemic center was located in the territory of the Chechen Republic, in 2008 it shifted to the Republic of North Ossetia, in 2009 to the Stavropol'skyi Kray and in 2010 to the Krasnodarskyi Kray. Every year we register the shift of the epidemic center of ASF in a north-westerly direction, associated with an increase in the number of outbreaks and spread of ASF to new territories.

The epidemic center of ASF did not leave the main pig-breeding regions of Russia from 2009 to 2010 (the Krasnodarskii Kray, the Stavropol'skii Kray, the Rostovskaya Oblast). In 2011 the epidemic center shifted to the Voronezhskaya Oblast, which happened due to a significant increase in the number of outbreaks outside the endemic zone, i.e. the epidemic center had shifted dramatically toward the Central Federal District by 2011 – an alarming move toward the Belgorodskaya Oblast and the Voronezhskaya Oblast. These regions are characterized by well developed swine rearing in comparison not only with the central part of Russia, but also with the whole country. There is also a drift near Russian and Ukraine borders.[1]

Most probably, in 2012 the ASF epidemic will develop in the country in accordance with the trends identified in the previous years, i.e.:

- shift of the epidemic center toward the Central Russia;
- increase of affected regions outside the ASF endemic zone with the diffusive nature of the spread of outbreaks being preserved;
- expansion of a secondary cluster of ASF in the Central Federal District of Russia in domestic swine and wild pigs, including the regions bordering on the Tverskaya Oblast.

This forecast is supported by analysis of outbreaks for the entire period of observation (Fig. 8). To describe alternately increasing/decreasing values we have used a polynomial

[1] As of the time of writing this article, another outbreak of ASF was officially reported in the Zaporozhskaya Oblast, Ukraine, on a LB farm.

trend which allows us to reveal the wavelike nature of outbreaks as well as the increase in the number of affected settlements in the country, especially outside the epidemic zone.

4. Conclusions

1. The anthropogenous factor is the leading one in the spread of ASF in Russia.
2. The backyard livestock is the main target population for ASF.
3. There is a trend of diffuse spreading of ASF in the territories bordering on primary and secondary epidemic zones.

Conflicts of interest

No conflicts of interests exist.

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