SPATIO-TEMPORAL ANALYSIS OF THE SPREAD OF ASF IN THE RUSSIAN FEDERATION IN 2017-2019

BLOKHIN Andrey¹, TOROPOVA Nadezhda¹, BUROVA Olga¹, SEVSKIKH Timofey¹*, GOGIN Andrey¹, DEBELJAK Zoran², ZAKHAROVA Olga¹

¹Federal Research Center for Virology and Microbiology (FRCVM), 601125 Volginsky, Academician Bakoulov Street, bldg. 1, Petushki district, Vladimir Region, the Russian Federation
²Veterinary Specialized Institute “Kraljevo”, 36000 Kraljevo, Serbia

(Received 16 January, Accepted 04 May 2020)

Currently, African swine fever (ASF) is one of the biggest global economic challenges in Europe and Asia. Despite all the efforts done to understand the mechanism of spread, presence and maintenance of ASF in domestic pigs and wild boar, there are still many gaps in the knowledge on its epidemiology.

This study aims to describe spatial and temporal patterns of ASF spread in wild boar and domestic pigs in the country during the last three years. Methods of Spatio-temporal scanning statistics of Kulldorff (SatScan) and Mann-Kendell statistics (space-time cube) were used to identify potential clusters of outbreaks and the presence of hot spots (areas of active flare clusters), respectively. The results showed that ASF in the country has a local epidemic pattern of spread (11 explicit clusters in wild boar and 16 epizootic clusters were detected in the domestic pig population: 11 in the European part and 5 in the Asian part), and only six of them are overlapped suggesting that ASF epidemics in domestic pigs and wild boar are two separate processes. In the Nizhny Novgorod, Vladimir, Ivanovo, Novgorod, Pskov, Leningrad regions, the clusters identified are characterized as sporadic epidemics clusters, while in the Ulyanovsk region, Primorsky Territory, and the Jewish Autonomous Region the clusters are consistent. Considering the low biosecurity level of pig holdings in the far east and its close economic and cultural connections with China as well as other potential risk factors, it can be expected that the epidemic will be present in the region for a long time. The disease has spread in the country since 2007, and now it is reoccurring in some of the previously affected regions. Outbreaks in the domestic pig sector can be localized easily (no pattern detected), while the presence of the virus in wildlife (several consecutive hot spots detected) hampers its complete eradication. Although the disease has different patterns of spread over the country its driving forces remain the same (human-mediated spread and wild boar domestic-pigs mutual spillover). The results indicate that despite all efforts taken since 2007, the policy of eradication of the disease needs to be reviewed, especially measures in wildlife.

Key words: analysis, ASF, clusters, local epidemic, outbreaks.

*Corresponding author: e-mail: sefskikh@mail.ru
INTRODUCTION

African swine fever is a contagious viral disease characterized by fever, acute course, skin cyanosis, multiple haemorrhages in the internal organs, high lethality, and affecting pigs of all species, breeds, and ages. Domestic pigs and wild boar are susceptible to ASF in natural conditions. DNA-containing virus is of the Asfarviridae family (ASFV), causing an infection which transmits to the whole population [1-3].

ASF represents a significant threat to national and global swine industries and food biosecurity due to the lack of vaccines and treatment methods. History of ASF outbreaks in the territory of Transcaucasia, Eastern Europe, Russia, Belgium, and China demonstrates the diversity of mechanisms and ways of ASF transmission. ASF transmission depends on various factors relating to the host, virus, and environment. Many of these factors and their impact have not been studied completely [4-7].

In Russia, ASF was first reported in late 2007. Later ASF occurred in Eastern Europe (Belarus, Ukraine, Lithuania, Latvia, Estonia, Romania, Moldova, Czech Republic, Poland), and China [8-12].

In the Russian Federation regions, the epizootic process of ASF is characterized by epizootics, sporadic outbreaks, and suspicions for an outbreak (among wild boars in the Chechen Republic, mountainous areas of Krasnodarskiy Territory and Tver region) [7,13,14].

The article aims to evaluate the features of local ASF outbreaks in Russia from 2017 to 2019.

MATERIALS AND METHODS

The Resources and Data Characteristic

Ethical approval: The conducted research is not related to animals’ use.

We used database of ASF outbreaks in domestic pigs and wild boars on the territory of Russia from 2017 to 2019, based on information, and WAHIS international database. We considered outbreaks of ASF in cases of virus detection in the susceptible population (domestic pigs, wild boars) on the specific territory, associated with geographical points. The outbreak data contained such information as exact location, the emergence of the ASF outbreak date, and infected animal species. This information was represented in the form of ArcGIS database.

Geographic information systems (GIS) are used for the analysis of potential risk factors of introduction, patterns and dynamics of ASF spread, and identification of spatial-temporal clusters of local epizootics distribution. [6,14-16].
**Analysis methods**

To detect similar to spatio-temporal clusters outbreaks, we applied a space-time permutation scan statistic for the early detection of disease outbreaks by Kulldorff M. [17]. The method aims at the detection of areas inside of an evaluated space where ASF outbreaks are grouped more densely compared to their common distribution. The statistically significant clusters are represented as annular areas. Inside the clusters, all the outbreaks are considered local epidemics and are associated with each other in one epidemic process. For all the clusters dimensions were (Rmax = 150 km) and (Tmax = 1 year). The search of clusters was carried out for two categories of data 1) for outbreaks in domestic pigs; 2) for cases in wild boar. For further analysis, only statistically significant spatio-temporal clusters were selected from each of the categories. Clusters were selected by their significance, determined by the p-value (≤ 0.05) in the space-time permutation model in the SaTScan software. For each identified cluster, the following characteristics were determined: the territorial status of the cluster in the Russian Federation; the number of outbreaks consisting of the cluster N; cluster radius R; duration of cluster T.

For each cluster, the total amount of ASF outbreaks were calculated in other populations (for clusters of domestic pigs outbreaks in wild boars and vice versa), registered inside of this cluster for the same period.

To estimate the speed of propagation in spatio-temporal clusters, we analyzed the **spatio-temporal density of outbreaks** (STDO), which denotes the number of new outbreaks in a certain territory over a fixed period of time. The calculation was carried out according to the formula: \( \text{STDO}_n = \left( \frac{N_{\text{obs}}}{S_n / T_n} \right) \times 1000 \), where \( N_{\text{obs}} \) is the observed number of outbreaks in the \( n \)-th cluster, \( S_n \) is the cluster area in km\(^2\), and \( T_n \) is the cluster duration, in days [18].

We determined the relative risk in each cluster in the SaTScan program using a model where the risk is defined as the Observed / Expected ratio (ODE). This is the ratio of the number of ASF outbreaks that are actually fixed within the cluster to the amount that would be expected if the outbreaks were randomly distributed throughout the studied space. The higher this indicator, the more significant the cluster, i.e. there is a more compelling reason why the concentration of outbreaks is increased in this place.

**Software**

To detect spatio-temporal clusters, we used SaTScan software [17].

In the capacity of additional analysis of cluster detection, space-time cube method was applied using Space Mining Tools software package in ArcGIS 10.6.1 from ESRI (Redlands, California, USA).
**Spots**

To identify hot or cold spots, we used Getis-Ord Gi* spatial statistics in its temporal interpretation to identify statistically significant ASF outbreak hotspots (Ord and Gettis, 1995), where it is concluded about a presence or absence of a hot spot in the spatio-temporal cube.

Data processing, as well as visualization of the analysis results, was carried out with the use of ArcGIS 10.6.1 [https://www.esry.com/].

**RESULTS**

The ASF outbreak diagram from 2017 to 2019 is presented in Figure 1. During this period, 533 ASF outbreaks were notified in Russia, including 339 among the domestic pig population; and 194 for wild boar population. The period under analysis was characterized by ASF outbreaks not only in the European part of Russia but also in Asia. In 2017-2019 403 outbreaks have been notified in the European part of the country, including 182 among wild boars; and 130 in the Asian part, including 12 in wild boars.

![Figure 1. African swine fever (ASF) notifications in domestic pigs and wild boar (2017–2019)](image)

Using the spatial-temporal cluster analysis method, 16 statistically significant clusters were identified in the domestic pig population. Eleven clusters have been detected in the European part and 5 in the Asian part of Russia. Only 6 of them partially match with clusters of ASF outbreaks in the wild boar population during the same period. Outbreaks in wild boar populations formed 11 clusters: 10 clusters in the
European part and 1 in the Asian part of Russia (Fig.2). All clusters in the Asian part of Russia defined as concerted. All the identified local epizootics in the wild boar population, as a rule, followed with outbreaks among domestic pigs. In the regions of the European part of Russia (Nizhny Novgorod, Vladimir, Ivanovo, Novgorod, Pskov and Leningrad regions), the identified clusters are characterized as clusters of sporadic epidemics. Only in the Ulyanovsk region, a cluster was concerted.

The quantitative characteristics of the obtained clusters are given in Table 1. In all susceptible animal populations, 27 statistically significant clusters were identified.

We analyzed the spatio-temporal density of ASF outbreaks (STDO) and obtained the results presented in Table 2.

Values of G (STDO) greater than unity indicate a short period of cluster formation and attenuation. Such clusters include Nos. 1, 3, 4, 6-8, 14, 16, 18-20, 22-24, 26, and 27. Clusters with a high G (STDO) value are most likely associated with the most effective active monitoring after the first outbreak of ASF happened, so subsequent ones were detected in a short time. Values of G (STDO) less than unity indicate clusters that function for a long period of time.

The results of the study of the relative risk, defined as the Observed / Expected ratio (ODE) are presented in Table 3.

Figure 2. Space–time clusters of domestic pig and wild boar of African swine fever (ASF) notifications detected with space-time permutation statistics. Significant clusters have a P-value <0.05.
Table 1. Quantitative characteristics of the clusters

| № cluster | Territorial affiliation                      | Radius, km | Number of outbreaks in the cluster, N | Date of the beginning | Date of the end | Duration, days | Number of outbreaks within the cluster among wild boars |
|-----------|---------------------------------------------|------------|--------------------------------------|-----------------------|----------------|----------------|--------------------------------------------------------|
| 1         | Central Russia                              | 138        | 50                                   | 01.09.2019            | 30.09.2019     | 30             | 4                                                      |
| 2         | Asian Russia                                | 72         | 5                                    | 01.08.2019            | 31.08.2019     | 31             | 7                                                      |
| 3         | Central Russia (Kaliningrad region)         | 4          | 2                                    | 01.11.2017            | 30.11.2017     | 30             | 0                                                      |
| 4         | Central Russia                              | 12         | 10                                   | 01.06.2017            | 30.09.2017     | 122            | 2                                                      |
| 5         | Central Russia                              | 133        | 27                                   | 01.08.2018            | 31.10.2018     | 93             | 17                                                     |
| 6         | Central Russia                              | 38         | 6                                    | 01.01.2018            | 31.01.2018     | 31             | 0                                                      |
| 7         | Asian Russia                                | 137        | 45                                   | 01.06.2018            | 30.06.2018     | 30             | 0                                                      |
| 8         | Central Russia (Kaliningrad region)         | 26         | 6                                    | 01.07.2017            | 31.07.2017     | 31             | 11                                                     |
| 9         | Central Russia                              | 137        | 26                                   | 01.07.2017            | 31.10.2017     | 123            | 6                                                      |
| 10        | Asian Russia (Omsk region)                  | 121        | 31                                   | 01.04.2019            | 31.08.2019     | 153            | 0                                                      |
| 11        | Central Russia                              | 125        | 3                                    | 01.04.2017            | 30.04.2017     | 30             | 1                                                      |
| 12        | Central Russia                              | 121        | 4                                    | 01.03.2017            | 31.03.2017     | 31             | 0                                                      |
| 13        | Central Russia                              | 132        | 16                                   | 01.09.2018            | 30.09.2018     | 30             | 0                                                      |
| 14        | Central Russia                              | 54         | 11                                   | 01.08.2019            | 30.09.2019     | 61             | 1                                                      |
| 15        | Asian Russia                                | 85         | 9                                    | 01.09.2019            | 31.10.2019     | 61             | 1                                                      |
| 16        | Asian Russia                                | 85         | 8                                    | 01.01.2018            | 31.01.2018     | 31             | 1                                                      |
| M±m       |                                             | 89,75±12,15| 16,19±3,79                           | -                     | -             | 57,38±10,44   | -                                                      |
Table 1. ASF clusters in wild boar population

| №   | Cluster affiliation | Radius, km | Number of outbreaks in the cluster, N | Date of the beginning | Date of the end | Duration, days | Number of outbreaks within the cluster among domestic pigs |
|-----|---------------------|------------|---------------------------------------|-----------------------|----------------|---------------|-----------------------------------------------------------|
| 17  | Central Russia      | 93         | 10                                    | 01.03.2017            | 31.08.2017     | 184           | 20                                                        |
| 18  | Central Russia      | 36         | 5                                     | 01.07.2019            | 31.07.2019     | 31            | 2                                                         |
| 19  | Central Russia (Kaliningrad region) | 55         | 40                                    | 01.06.2018            | 28.02.2019     | 273           | 23                                                        |
| 20  | Central Russia      | 89         | 13                                    | 01.09.2017            | 30.09.2017     | 30            | 0                                                         |
| 21  | Central Russia      | 75         | 22                                    | 01.10.2017            | 28.02.2018     | 151           | 4                                                         |
| 22  | Central Russia (Kaliningrad region) | 26         | 7                                     | 01.11.2017            | 30.11.2017     | 30            | 1                                                         |
| 23  | Central Russia      | 87         | 8                                     | 01.10.2018            | 31.10.2018     | 31            | 2                                                         |
| 24  | Asian Russia        | 43         | 3                                     | 01.08.2019            | 31.08.2019     | 31            | 6                                                         |
| 25  | Central Russia      | 84         | 3                                     | 01.01.2017            | 31.01.2017     | 31            | 32                                                        |
| 26  | Central Russia      | 59         | 11                                    | 01.07.2019            | 31.07.2019     | 31            | 2                                                         |
| 27  | Central Russia      | 5          | 4                                     | 01.09.2017            | 30.09.2017     | 30            | 0                                                         |

M±m - 59,27±8,8  11,45±3,3 - -  77,55±25,68 -
Table 2. Space-time density of ASF outbreaks in clusters of domestic pigs and wild boars.

| Number of clusters | STDO of clusters in domestic pigs | Number of clusters | STDO of clusters in wild boar |
|--------------------|-----------------------------------|--------------------|-------------------------------|
|                    | G (STDO)                          |                    | G (STDO)                      |
| 1                  | 2.8                               | 17                 | 0.2                           |
| 2                  | 0.9                               | 18                 | 3.9                           |
| 3                  | 32.6                              | 19                 | 1.5                           |
| 4                  | 18.1                              | 20                 | 1.7                           |
| 5                  | 0.5                               | 21                 | 0.8                           |
| 6                  | 4.3                               | 22                 | 10.8                          |
| 7                  | 2.5                               | 23                 | 1.1                           |
| 8                  | 9.1                               | 24                 | 1.7                           |
| 9                  | 0.3                               | 25                 | 0.4                           |
| 10                 | 0.4                               | 26                 | 3.2                           |
| 11                 | 0.2                               | 27                 | 69.8                          |
| 12                 | 0.3                               |                    |                               |
| 13                 | 0.9                               |                    |                               |
| 14                 | 1.9                               |                    |                               |
| 15                 | 0.6                               |                    |                               |
| 16                 | 1.1                               |                    |                               |

Table 3. Relative risk of ASF outbreaks in clusters in domestic pigs and wild boars.

| Number of clusters | ODE of clusters in domestic pigs | Number of clusters | ODE of clusters in wild boar |
|--------------------|----------------------------------|--------------------|------------------------------|
|                    | ODE                              |                    | ODE                           |
| 1                  | 42.273                           | 17                 | 9.272                         |
| 2                  | 29.639                           | 18                 | 6.754                         |
| 3                  | 135.724                          | 19                 | 4.312                         |
| 4                  | 79.173                           | 20                 | 10.291                        |
| 5                  | 50.337                           | 21                 | 5.718                         |
| 6                  | 497.443                          | 22                 | 10.963                        |
| 7                  | 24.159                           | 23                 | 25.907                        |
| 8                  | 737.089                          | 24                 | 24.558                        |
| 9                  | 33.508                           | 25                 | 23.388                        |
| 10                 | 49.980                           | 26                 | 6.901                         |
| 11                 | 131.007                          | 27                 | 9.355                         |
| 12                 | 626.201                          |                    |                               |
| 13                 | 328.976                          |                    |                               |
| 14                 | 101.019                          |                    |                               |
| 15                 | 439.083                          |                    |                               |
| 16                 | 24.327                           |                    |                               |
DISCUSSION

The study of the monthly dynamics of ASF from 2017 to October 2019 shows the largest peaks in year 2017 and 2019. The most significant number of outbreaks among domestic pigs and wild boars related to the same periods from July to the beginning of autumn. However, for wild boars, the peak of outbreaks remained stable during the winter of 2017-2018. Therefore, we can see changes in seasonal dynamics in the manifestation of ASF in Russia compared with previously published data [19], where it was shown that peaks of outbreaks among domestic pigs usually happen in May and the beginning of summer, and in wild boars in autumn and winter (hunting season). Changes in the seasonal dynamics of ASF could be related to the implementation of planned monitoring of ASF in wild populations.

The study of the spatial spread of ASF shows that it has both local epidemic patterns linked to commercial contacts and to the introduction of the virus into new regions without dependence on distance. The emergence of ASF in Irkutsk region in 2017 is an example of the introduction of the disease to the remote territory. Local outbreaks in the European part of Russia (including Kaliningrad region) are associated with both economic activities and the circulation of the virus among wild boars. In general, for 10 clusters of ASF among domestic pigs, outbreaks in wild boars were confirmed. Obtained data corresponds with previously published results [20,21]. Within 2 clusters of ASF in wild boars (№ 20 and № 27) no outbreaks among domestic pigs were reported. That indicates the development of ASF in wild boars clusters without risk factors associated with human activities.

In Kaliningrad region, 2 clusters of ASF in domestic pigs were included in clusters of ASF in wild boars. Taking into account that ASF outbreaks in domestic pigs were reported before outbreaks in wild boars, the source of the disease was considered to be domestic pigs and products of pig farming.

The same situation was identified in Volgograd and Belgorod regions. Originally clusters were formed by outbreaks in domestic pigs. Later outbreaks formed clusters of ASF in wild boar populations. The cluster of ASF outbreaks in wild boars (№27) was small (Rcl = 5 km) and coincide with the territory of Nature Park «Volga-Akhtuba floodplain». Probably it is related to constant monitoring of ASF in wild nature. This obstacle does not exclude the wider spread of the disease in the population of wild boars in the floodplain of the Volga river.

In Vladimir and Ivanovo regions a cluster of ASF in wild boars was formed earlier than in domestic pigs. We suggest that ASF virus persistently circulates in wild boars in these regions. Example of cluster in neighboring Nizhny Novgorod region confirms our hypothesis: cluster was formed in wild boars, but no cases in domestic pigs were reported.

In Ulyanovsk region an equal number of outbreaks were detected in wild boars and domestic pigs (11 cases) during the analyzed period. Outbreaks were bound with
the same locations and formed clusters with the same radius. The disease was first reported in the wild boar population, and after one month in domestic pigs. In Saratov region, the cluster of ASF in wild boars was also formed earlier than in domestic pigs. All these facts point out on circulation of ASFV in wild nature.

In the Asian part of Russia, 5 clusters of ASF in domestic pigs were formed, and 3 of them were associated with cases in wild boars. All clusters were bordering China, where ASF was notified since 2018. In Primorsky Territory one cluster of ASF in wild boars (№24) was formed. This cluster has a radius of 43 km and partially overlays the more significant cluster of ASF in domestic pigs. It shows that the emergence of disease in wild boars can be associated with human activities.

Comparison of clusters in wild boars and domestic pigs on the territory of Russia shows 51.4% prevalence in squares of ASF clusters in domestic pigs. It demonstrates that the economic and commercial activities of householders have a significant value in the process of disease spread and development of local epizootics.

Analysis of the spatiotemporal outbreak density (STDO) showed that most of the long-functioning clusters are formed by ASF outbreaks in the domestic pig population (50.0%). In the wild boar population, only 3 long-functioning clusters were detected (27.3%). This may indicate that outbreaks of ASF in the wild population are secondary and their occurrence is associated with outbreaks of the disease in domestic pigs.

The highest relative risk of ASF in clusters is formed by outbreaks of the disease in domestic pigs (Nos. 8, 12, 6, 15, 13). In the wild boar population, the relative risk is not high, which may be due to the low density of animals and the lack of ASF spread in their population.

In the affected regions, an ASF control strategy is being implemented, including measures:

- Federal Plan (recommendations, affected, unaffected and at risk regions);
- Regional programs (85 regions, prevention and eradication, no coordination);
- Decrease the number of pigs in unprotected sector (backyards);
- Compartmentalization (4 biosecurity levels);
- Decrease the density of wild boar (0.25 heads/1000 ha);
- Monitoring programs;
- Animal identification and electronic certification.

**CONCLUSIONS**

1. During the analyzed period ASF spread in regions of the Asian part of Russia, where 130 outbreaks were notified, 12 of them were among wild boars. The cluster of ASF in wild boars was formed in Primorsky Territory and was associated with outbreaks in domestic pigs.
2. Seasonality of ASF changes for both wild boars and domestic pigs. The disease mostly reported during summer and the beginning of autumn.

3. Local epizootics of ASF were identified in European and Asian parts of Russia using spatio-temporal cluster analysis.

4. Two clusters of ASF in wild boars, not associated with outbreaks in domestic pigs and human activities, were identified.

5. ASF outbreaks in the wild boar population are caused by ASF outbreaks in domestic pigs.

Acknowledgements

The work was supported by the Ministry of Science and Education in the framework of the state assignment.

Authors’ contributions

BAA and ZOI have made substantial contributions to conception and design, analysis and interpretation of data. TNN and BOA have made acquisition of data. STA, GAE and DZ prepared and critically revised the manuscript. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors read and approved the final manuscript.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

1. Iglesias I, Rodriguez A, Feliziani F, Rolesu S, de la Torre A: Spatio-temporal analysis of African swine fever in Sardinia (2012–2014). Trends in Domestic Pigs and Wild Boar. Transbound Emerg Dis 2017, 64(2):656–662.

2. Mazur-Panasiuk N, Zmudzki J, Wozniakowski G.: African swine fever virus – persistence in different environmental conditions and the possibility of its indirect transmission. J Vet Res. 2019, 63 (3):303-310.

3. Li F, Wang J, Zhang J, Liu X, Wang L, Zhang J, Wu X, Guan Y, Chen W, Wang X, He X, Bu Z: Replication and virulence in pigs of the first African swine fever virus isolated in China. Emerg Microbes Infect 2019, 8 (1):438-447.

4. Abrahantes JC, Gogin A, Richardson J, Gervelmeyer A: Epidemiological analyses on African swine fever in the Baltic countries and Poland. EFSA Journal 2017, 15 (3).

5. Boklund A, Cay B, Depner K, Földi Z, Guberti V, Masiulis M, Miteva A, More S, Olsevskis E, Satran P, Spiridon M, Stahl K, Thulke HH, Viltrop A, Wozniakowski G, Broglia A, Abrahantes JC, Dhollandier S, Gogin A, Verdoneck F, Amato L, Papanikolaou A, Gortazar
C: Epidemiological analyses of African swine fever in the European Union (November 2017 until November 2018). EFSA Journal 2018, 16 (11).

6. Lu Y, Deng X, Chen J, Wang J, Chen Q, Niu B: Risk analysis of African swine fever in Poland based on spatio-temporal pattern and Latin hypercube sampling, 2014-2017. BMS Vet Res 2019, 15:160.

7. Schulz K, Conraths FJ, Blome S, Staubach C, Sauter-Louis C: African Swine Fever: Fast and Furious or Slow and Steady. Viruses 2019, 11 (9):866.

8. Bosch J, Rodríguez A, Iglesias I, Muñoz MJ, Jurado C, Sánchez-Vizcaíno J M, De La Torre A: Update on the Risk of Introduction of African swine fever by Wild Boar into Disease-Free European Union Countries. Transbound Emerg Dis 2017, 64 (5):1424-1432.

9. De La Torre A, Bosch J, Iglesias I, Muñoz MJ, Mur L, Martínez-López B, Martínez M, Sánchez-Vizcaíno JM: Assessing the Risk of African swine fever Introduction into the European Union by Wild Boar. Transbound Emerg Dis 2015, 62 (3):272-279.

10. Lichoti JK, Davies J, Kitala PM, Githigia SM, Okoth E, Maru Y, Bukachi SA, Bishop RP: Social network analysis provides insights into African swine fever epidemiology. Prev Vet Med 2016, 126:1-10.

11. Kukielka EA, Jori F, Martinez-Lorez B, Chenais E, Masembe C, Chavernac D, Ståhl K: Wild and Domestic Pig Interactions at the Wildufe-Livestock Interface of Murchison Falls National Park, Uganda, and the Potential Association with African Swine Fever Outbreaks. Front Vet Sci 2016, 3:31.

12. Sternberg-Lewerin S, Chenais E, Booqvist S, Liu L, LeBlanc N, Aliro T, Masembe C, Ståhl K: African swine fever outbreak on a medium-sized farm in Uganda: biosecurity Breaches and within-farm virus contamination. Trop Anim Health Prod 2017, 49(2):337-346.

13. Iglesias I, Munoz MJ, Motes F, Perez A, Gogin A, Kolbasov D, de la Torre A: Reproductive ratio for the local spread of African swine fever in wild boars in the Russian Federation. Transbound Emerg Dis 2016, 63(6):237–245.

14. Korennoy FI, Gulenkin VM, Malone JB, Mores CN, Dudnikov SA, Stevenson MA.: Spatiotemporal modeling of the African swine fever epidemic in the Russian Federation, 2007–2012. Spat Spatiotemporal Epidemiol 2014, 11:135–141.

15. Mur L, Sanchez-Vizcaino JM, Fernandez-Carrion E, Jurado C, Rolesu S, Feliziani F, Laddomada A, Martínez-López B: Understanding African Swine Fever infection dynamics in Sardinia using a spatially explicit transmission model in domestic pig farms. Transbound Emerg Dis 2018, 65 (1):123-134.

16. Nielsen JP, Larsen TS, Halasa T, Christiansen LE: Estimation of the transmission dynamics of African swine fever virus within a pig house. Epidemiol Infect 2017, 145 (13):2787-2796.

17. Kulldorff M, Heffernan R, Hartman J, Assuncao RM, Mostashari FA: Space-time permutation scan statistic for the early detection of disease outbreaks. PLoS Med. 2005, 2:216–224.

18. Abdrakhmanov SK, Tyulegenov SB, Korennoy FI, Sultanov AA, Sytnik II, Beisembaev KK, Bainiyazov AA, Munsey AE, Perez AM, VanderWaal K: Spatiotemporal analysis of foot-and-mouth disease outbreaks in the Republic of Kazakhstan, 1955-2013. Transbound Emerg Dis 2018, 00:1-11.

19. Khomenko S, Beltrán-Alcrudo D, Rozstalnyy A, Gogin A, Kolbasov D, Pinto J, Lubroth J, Martin V: African Swine Fever in the Russian Federation: Risk Factors for Europe and Beyond. EMPRES Watch. FAO, Rome 2013. [http://www.fao.org/docrep/018/aq240e/ aq240e.pdf]
20. Malkhazova SM, Korennoy FI, Petrova ON, Gulenkin VM, Karaulov AK: Spatial-temporal analysis of the local distribution of African swine fever in the Russian Federation in 2007-2015. MosUniver Bullet. Series 5, Geography 2017, 5:33-40.

21. Vergne T, Gogin A, Pfeiffer DU.: Statistical Exploration of Local Transmission Routes for African Swine Fever in Pigs in the Russian Federation, 2007–2014. Transbound Emerg Dis 2017, 64(2):504–512.

**PROSTORNO-VREMENSKA ANALIZA ŠIRENJA AFRIČKE KUGE SVINJA U RUSKOJ FEDERACIJI U PERIODU 2017-2019**

BLOKHIN Andrey, TOROPOVA Nadezhda, BUROVA Olga, SEVSIKIH Timofey, GOGIN Andrey, DEBELJAK Zoran, ZAKHAROVA Olga

Trenutno, afrička svinjska kuga (ASK) predstavlja u Evropi i Aziji jedan od najvećih globalnih ekonomskih izazova. Uprkos trudu koji je uložen u istraživanja mehanizama širenja, prisustva i održavanja ASK kod domaćih i divljih svinja, još uvek su prisutne praznine u poznavanju njene epidemiologije.

Ova studija ima za cilj da opiše prostorne i vremenske obrasce širenja ASK među domaćim i divljim svinjama u Ruskoj Federaciji tokom poslednje tri godine.

U cilju određivanja potencijalnih klastera i prisustva “vrućih mesta” (područja aktivnih klastera) primenjene su statističke metode prostorno-vremenskog skeniranja (Kulldorff- Stat Scan i Mann-Kendell). Rezultati su pokazali da ASK u zemlji ima svojstva širenja lokalne epidemije (11 izričitih klastera u evropskom području i 5 u azijskom), pri čemu se od njih samo šest preklapalo, što nam sugeriše da epidemija ASK kod domaćih i divljih svinja predstavlja dva zasebna procesa. U regijama Nizhny Novgorod, Vladimir, Ivanovo, Novgorod, Pskov, i Lenjingrad identifikovani su sporadični klasteri epidemije, dok su u Ulyanovsk-u, Primorsky i u Jevrejskoj Autonomnoj Regiji klasteri bili konzistentno prisutni. Imajući u vidu nizak nivo biosigurnosti na farmama na Dalekom Istoku, kao i njegove bliske ekonomsko i kulturno-geografske veze sa Kinom, kao i ostale potencijalne faktore rizika, može se predpostaviti da će u ovoj regiji epidemija biti dugo prisutna. Oboljenje se širi u državi od 2007. godine i sada se ponovo javlja u predhodno zahvaćenim oblastima. Pojava oboljenja među domaćim svinjama se lako lokalizuje, dok prisustvo virusa kod divljih životinja (nekoliko uzastopnih „vrućih mesta”) otežava potpunu eradicaciju. Iako oboljenje pokazuje različite šablone širenja, načini ostaju isti (posredovanje ljudima, prenos sa divljih na domaću svinje). Rezultati pokazuju da uprkos svim naporima koji su preduzeti od 2007. godine, prilaz eradicaciji mora da se revidira, posebno mere koje se sprovode za divlje životinje.