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Classical swine fever: a retrospective analysis of the epizootic situation in the Russian Federation (2007–2021) and forecast for 2022

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SUMMARY

The paper presents trends in the epizootic situation on classical swine fever (CSF) in the Russian Federation, for 2007–2021. Most likely, a drop in the number of CSF outbreaks throughout the country results from two factors: a geographical shift of the disease outbreaks from the European part of Russia to the eastern regions bordering on China (into the wild boar population), as documented between 2015 and 2021, and a large-scale vaccination of domestic pigs practiced in the recent years. The introduction and spread of CSF in the Russian Federation are, most likely, associated with the internal risk factors (i.e. quality of anti-epizootic measures, mainly vaccination) and with the territories, where the virus circulates in wild boars. Expansion of vaccination coverage since 2011 is one of the factors contributing to a decrease in the number of clinical CSF cases registered in domestic pigs of the Russian Federation. The infection spread in domestic pigs is still on a downward trend. For purposes of analysis, current trends of CSF spread in domestic pigs and wild boars in the Russian Federation, as well as the volume of the vaccine used, were visualized in relative numbers (taking into account total number of pigs in the country) used to build a regression model. Currently, vaccination against classical swine fever in the Russian Federation (and its good quality) is an essential prerequisite to contain the infection spread in the country.

Keywords: classical swine fever, the Russian Federation, epizootic situation, retrospective analysis, vaccination

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Классическая чума свиней: ретроспективный анализ эпизоотической ситуации в Российской Федерации (2007–2021 гг.) и прогноз на 2022 г.

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РЕЗЮМЕ

Представлена тенденция развития эпизоотической ситуации по классической чуме свиней в Российской Федерации в 2007–2021 гг. Констатируется факт территориального смещения в 2015–2021 гг. очагов инфекции из европейской части России в восточные, приграничные с Китаем регионы в популяцию дикого кабана и усиления вакцинопрофилактики в домашней популяции в последние годы, что, вероятнее всего, было определяющим в снижении количества очагов классической чумы свиней на всей территории страны. Основные особенности заноса и распространения инфекции в Российской Федерации с большей вероятностью связаны с внутренними факторами риска (качество исполнения противоэпизоотических мероприятий, главным образом вакцинации) и территориями циркуляции вируса среди диких кабанов. К числу факторов, способствующих снижению числа регистрируемых клинических случаев классической чумы свиней в популяции домашних свиней Российской Федерации, можно отнести прирост с 2011 г. объемов вакцинации. Тренд неблагополучия в популяции домашних свиней остается ниспадающим. Тенденции развития эпизоотической ситуации по классической чуме свиней на территории Российской Федерации в популяциях домашних и диких свиней и объемы применения вакцин для целей анализа были визуализированы в относительных величинах, учитывающих общую численность поголовья свиней в стране, которые использовали для построения регрессионной модели. На основе анализа дан прогноз на 2022 г. в условиях сохранения выбранной в стране стратегии борьбы с заболеванием. Вакцинация против классической чумы свиней в Российской Федерации и ее качество на данный момент остается предопределяющим фактором сдерживания распространения эпизоотии на территории страны.

Ключевые слова: классическая чума свиней, Российская Федерация, эпизоотическая ситуация, ретроспективный анализ, вакцинация

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INTRODUCTION

Classical swine fever (CSF) is a transboundary viral disease, which remains one of the most serious swine diseases in the world. It is caused by an RNA virus belonging to *Pestivirus* genus of *Flaviviridae* family [1]. There are three CSF virus genotypes with three to four subgenotypes, that do not directly correlate with the virulence. It is important to note that genetic diversity does not make it possible to obtain true serotypes and it has no impact on the vaccine effectiveness [2, 3]. A wide range of CSF clinical signs (including the ones observed after vaccination) requires a laboratory confirmation of the disease. In most countries with well-developed pig industry CSF occurs, at least, sporadically [4, 5].

Wild boars are a reservoir of the virus, which is able to circulate for a long time in the infected population, thus, posing a threat to poorly protected pig farms and backyards. It can be assumed that the disease is also endemic in certain countries of South and Central America and in some parts of Eastern Europe and Asia [2, 6, 7]. Little is known about the situation in Africa [4, 5].

CSF control strategy in the disease-free countries mainly includes conventional measures to control an outbreak of a highly dangerous disease: quarantine, destruction of all animals in the infected herd, contact tracing, timely and reliable diagnosis, creation of restriction zones, tracing commodities associated with the risk of the virus spread. Once such strategy is in place, vaccination is assumed as a possible, however, an emergency option, although it was practiced at the first stage of the disease control in the currently disease-free countries [2, 8]. Vaccines are used as a routine option to contain the disease in CSF endemic regions of Asia, Eastern Europe, America and some African countries [4, 8].

In Russia, the situation on CSF in domestic pigs is getting less tense [9] in most parts of the country, which is, probably, explained by mass vaccination and strong anti-epizootic measures (passive surveillance, compartmentalization, regionalization). At the same time, taking into account CSF potential for rapid territorial and transboundary spread, it seems appropriate to retrospectively analyze the epizootic situation in the Russian Federation and to discuss the expected course of events, assessing infection status of the wild boar population and the use of vaccination.

MATERIALS AND METHODS

For this research, we used data from the World Animal Health Organization information system (WAHIS) together with the official veterinary reports from the FGBI "Veterinary Center" [5].

The information was processed with the help of descriptive statistics, correlation and regression analysis using STATISTICA 10 software (StatSoft, Inc., 2011).

For the purposes of analysis, CSF trends in domestic pigs and wild boars in the Russian Federation, as well as the volume of the vaccine used, were visualized in relative numbers K1 and K2 for the period from 2007 to 2020. Total pig population in the country was taken into account; K1 is the ratio between the number of outbreaks per year to the total pig population (million animals), K2 is the ratio between the number of animals vaccinated against CSF (million animals) and the total pig population (million animals). K1 and K2 values for 2011–2018 were used to build a regression model [10].

Prognostic values for CSF outbreaks in 2022 were calculated based on "Poisson random walk" model using the Poisson distribution. Calculations were done in the @RISK program using Monte Carlo simulation in 10,000 iterations. The time interval from 2010 to 2021 was chosen for analysis.

The analysis results and the forecast are given in discussion and conclusion.

RESULTS AND DISCUSSION

Epizootic situation on classical swine fever in different countries. According to the official data of the World Organization for Animal Health (WOAH) for 2021, only 38 countries on different continents are officially free from CSF, and 3 countries have separate disease-free zones. A difficult situation is registered in Asian and South American countries. Thus, from 2017 to 2019 more than 300 CSF outbreaks were recorded in Indonesia; more than 150 outbreaks were reported in Vietnam within the same period; more than 50 outbreaks – in China and India (each); 18 outbreaks – in Nepal; 11 outbreaks – in Thailand; more than 230 outbreaks – in Cuba; 150 outbreaks – in Peru; 115 outbreaks – in Ecuador; 25 outbreaks – in Colombia; 11 outbreaks – in the Dominican Republic and Haiti (each) [5].

More than a quarter-century Japan remained free from CSF without vaccination. However, in 2018, the virus was introduced into the wild boar population and the infection spread widely. Next year, compared to the previous year, Japan reported a decrease in the number of outbreaks from 1,633 to 972 due to vaccination of wild boars [5, 11, 12].

In South Korea, since 2017, there has been a rapid increase in the number of seropositive wild boars caught near the demilitarized zone bordering on North Korea. CSF spread in South Korean wild boars was reported from west to southeast, due to such external factors as small-scale hunting, geographical features and road network development. The virus introduction was associated with infection circulating in wild boars in China, where the disease is endemic [13].

In Colombia, 134 CSF outbreaks were reported in the Atlantic coast region within six years (from 2013 to 2018). The first outbreak in 2013 was associated with the import of infected pigs from Venezuela, where, under the current socio-economic circumstances, pig prices were lower from those in Colombia. The role of the illegal trade in pork and animals between the countries is still unknown, but the fact that the Colombian police confiscated 48.8 tons of pork and 778 smuggled live pigs in the departments of Guajira, North Santander, Arauca, Cesar and the metropolitan area of Bogota (from 2013 to 2018) confirms that such trade shall not be underestimated. Most outbreaks (95%) were reported in the backyards. CSF introduction and spread mainly resulted from import of infected pigs (38%) and movement of people (37%) [14].

Brazil remained CSF-free for ten years. In 2018, CSF virus was re-introduced to the country and 38 outbreaks were registered in domestic pigs. In 2019, 30 more outbreaks were recorded in domestic pigs; for 10 months of 2020, 2 outbreaks were also reported in domestic pigs. However, due to the lack of accurate data, it is difficult to judge what exactly caused the situation [15].

Owing to the absence of CSF outbreaks, some countries (mainly African) have declared freedom of their territories from CSF without any official recognition from the WOAH [5].

The WOAH classifies CSF as one of those six diseases, which require official recognition for a country to get the freedom status [5]. As of 2021, 38 countries in the world were recognized CSF-free. In 2021, disease-free status was reinstated in Colombia and Brazil for those zones, which are key pig industry centres in Latin America; and Romania lost its status in 2020 based on the findings of the WOAH mission aimed to check compliance with the provisions of the Terrestrial Animal Health Code. Infection eradication programs were earlier implemented in most officially recognized disease-free countries. Those programmes were implemented step by step, often included vaccination at the first stage to reduce the number of clinical cases and contain the disease spread, however, the vaccination was totally excluded at the final stages, regardless of the large economic costs [2, 16].

The list of the countries where vaccination against CSF is currently practiced (according to WAHIS) includes: Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria (only wild boars), People's Republic of China, Taiwan, Colombia (in some zones), Cuba, Dominican Republic, Ecuador, Macedonia, Haiti, Hong Kong, India, Indonesia, Korea, Madagascar, Moldova, Montenegro, Myanmar, Nepal, Peru, Philippines, Serbia, Timor, Ukraine, Vietnam, Thailand, Russia [5].

Thus, the global epizootic situation on classical swine fever (in Eurasia, Central and South America) remains tense. The main CSF control measures include: vaccination and prevention of involvement of wild boars and domestic pigs (from a poorly protected population) into the epizootic process.

Epizootic situation on classical swine fever in the Russian Federation in 2007–2021. CSF cases are annually registered in Russia. From 2007 to November 2021 (as of 25 November 2021), 42 CSF outbreaks were reported in domestic pigs and 51 in wild boars.

Figure 1 shows that infection trends have different directions for populations of CSF susceptible animals. So, a downward trend is shown for domestic pigs (with an average number of outbreaks per year – 2.47 ± 2.48). On the contrary, an upward trend is shown for wild boars (with an average number of outbreaks per year – 3.00 ± 2.50). Thus, CSF situation tends to improve in the population of domestic pigs; however, it tends to worsen for wild boars.

Retrospective data obtained after examination of CSF outbreaks show that, within the analyzed time period, the outbreaks in domestic pigs were reported on the farms with low biosecurity levels, where animals were often fed food wastes or where failures in vaccination against CSF were observed. A serious problem arouse from the impossibility to find accurately the pathogen source and its transmission paths on such farms. Virtually all the options were plausible: introduction with feed; feeding food wastes to the animals; because of pig handlers; import of live animals; contacts between free-ranging domestic pigs and wild boars, etc. Taking into account multiple ways of the disease introduction, there is a permanent risk of further virus spread in the pig population on poorly protected farms. Therefore, it was difficult to detect the ways of further spread while searching for connections between suspicious/disease-related farms.

The pathogen introduction into the wild boar population poses a significant risk of CSF spread. Alongside with it, an increase in the number of CSF cases registered in the recent years in the Far East is alarming.

The analysis of CSF territorial distribution in the Russian Federation from 2016 to 2020 (no cases detected in 2021) showed that the disease was registered in wild boars in the Primorsky Krai and the Amur Oblast, and in domestic pigs it was only reported in the Primorsky Krai and the Moscow Oblast (Fig. 2).

Since 2013, there has been a geographical shift of CSF-affected area to the western and eastern borders of the Russian Federation. In addition to it, since 2015, CSF outbreaks were reported exclusively along the eastern border of the country: in the Amur Oblast and the Primorsky Krai with one backyard incident in the Zibrovo village, the Serpukhov District of the Moscow Oblast being an exception. On 7 July 2018, CSF was diagnosed there with the help of polymerase chain reaction carried out by GBUV MO "Moscow Regional Veterinary Laboratory". The fact that no data are available on other confirmatory laboratory tests (i.e. differentiation of the detected genetic material: an epizootic or vaccine strain) raises doubts about reliability of the made diagnosis.

The FGBI "ARRIAH" regularly receives materials for CSF laboratory tests. In 2020, pathological material was received from the Primorsky Krai, taken from wild boars shot in three districts of the region: Shkotovsky (FGBI "GOOH "Orlinoye"), Pogranichny (near the settlement of Sofye-Alekseyevskoe), Spassky (near the settlement of Novovladimirovka).

Initially, the received material was tested in the FGBI "Primorsky Interoblast Veterinary Laboratory" using real-time reverse transcription polymerase chain reaction (RT-PCR). The test resulted in detection of CSF RNA. Later on, the FGBI "ARRIAH" tests confirmed CSF agent in the samples, and helped to type the detected virus. For this purpose, E2 gene fragment of the virus was amplified, sequenced and subjected to a comparative analysis.

Phylogenetic analysis showed that the Primorsky isolates of 2020 belong to subgenotype 2.1 of CSF virus (Fig. 3). At the same time, isolates from the Shkotovsky and Spassky raions belong to Cluster 2.1d and are genetically very close to Primorsky isolates recovered in 2015–2019.

The CSF virus isolate from the border region belongs to a different cluster and is genetically closely related to the virus isolated from a wild boar in the Amur Oblast in 2019.

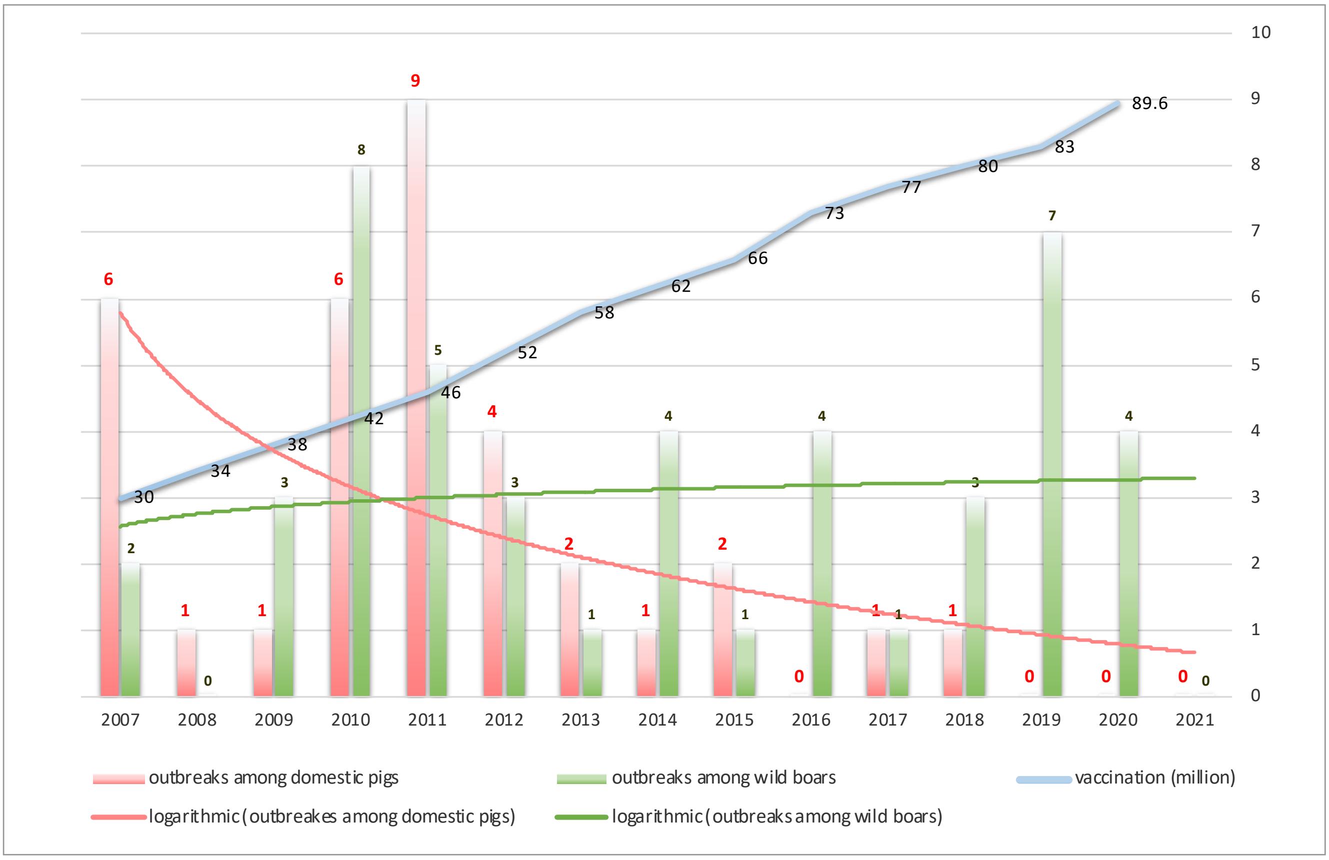

Fig. 1. Number of CSF outbreaks in the Russian Federation among domestic pigs and wild boars in 2007–2021

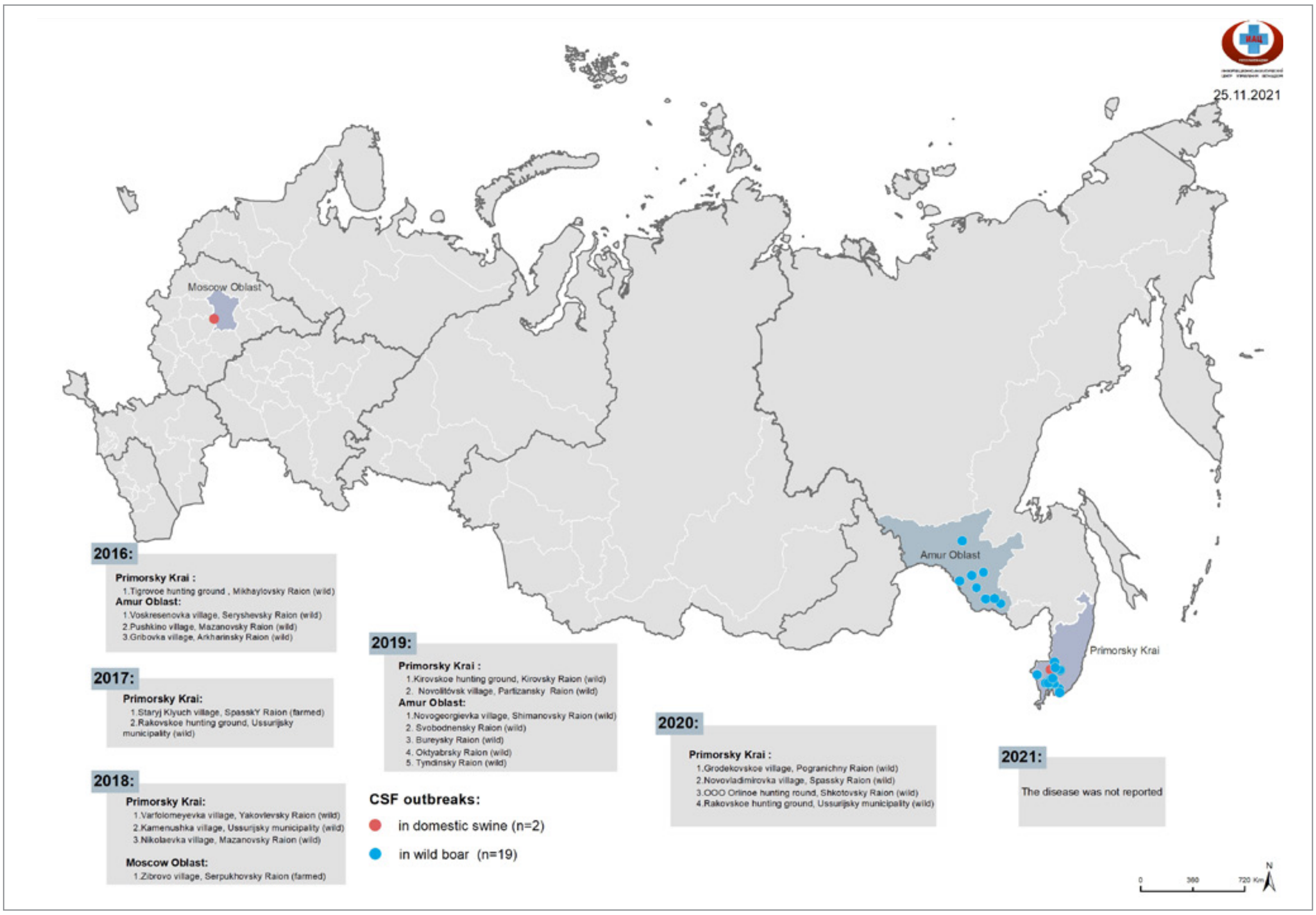

Fig. 2. Territorial distribution of CSF outbreaks in the Russian Federation in 2016–2021

CSF virus subgenotype 2.1 is endemic in China and Southeast Asia, and it can be assumed that it was originally introduced into the Far Eastern Federal District from the PRC. Earlier, the disease outbreaks were repeatedly recorded in the regions of the Russian Federation bordering on China. The isolates that caused these outbreaks (Primorsky/2007, EAO/2012, Amur/2014 and Primorsky/2015) are genetically close to the Chinese isolates of CSF virus, thus suggesting that the disease was imported. It is worth noting that CSF virus in China is very diverse: subgenotypes 1.1, 2.1, 2.2 and 2.3 circulate in the country [3, 9, 17]. The situation that so far only subgenotype 2.1 of CFS virus has been detected in the Far Eastern Federal District can be explained by the fact that this particular genotype is predominant in the PRC [18]. There are 4 clusters today in China (2.1a, 2.1b, 2.1c and 2.1d) within the subgenotype 2.1 [9].

It shall be also noted that, in 2017, CSF was registered in wild boars in the north of South Korea (in province Gyeonggi-do), and then in 2018–2019 (in Gangwon-do province). 16 CSF virus strains, isolated in 2017–2019 from wild boars, were identical to YC16CS strain (subgenotype 2.1d) isolated in 2016 during CSF outbreak in breeding pigs not far from the border on North Korea [13].

As mentioned above, all the Primorsky isolates of 2015–2020 belong to subgenotype 2.1 of CSF virus, which is predominant in China, therefore, it can be assumed that it has been circulating in wild boars in the Primorsky

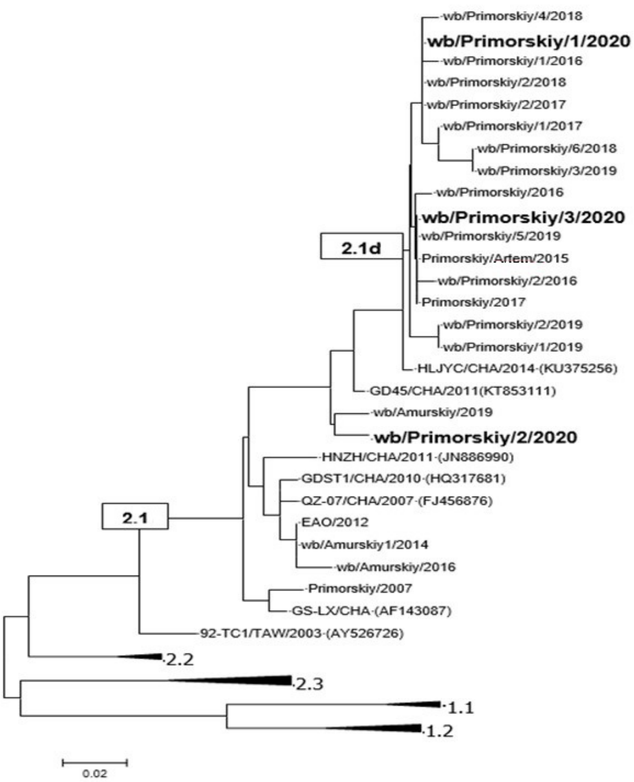

Fig. 3. Position of CSF virus Primorsky isolates (2020) in the phylogenetic tree (comparison of E2 gene nucleotide sequences; wb – wild boar)

Krai since 2015. Thus, S. V. Terebova et al. [19–21] noted that in 2015–2019 a natural and anthropurgic focus was very likely formed in this region. As shown in the available reports, risks of CSF spread in the Primorsky Krai remained high due to the facts that individual populations in some backyards were not vaccinated for a long time or vaccination coverage was insufficient; animals were purchased from unreliable sources without veterinary accompanying documents; and CSF-affected free-range pig farms are located close to the forest edges.

According to the Chinese researchers, C-strain-based vaccines (Chinese vaccine strain – C-strain) are able to induce protection against all the identified CSF virus subgroups [3, 18, 22, 23]. Mass vaccination of domestic pigs in the Russian Federation with domestically produced live vaccines also induces protection in most susceptible animals, regardless of the circulating virus isolates [2, 24]. It helps to reduce significantly the risk of pathogen introduction from infected wild boars, especially in areas located far from the affected ones. However, such a risk shall be also taken into account, when situation with the vaccination refusal changes. Taking into account the difficult situation on CSF in China and close economic ties between our countries (including the option of illegal cross-border transportation of products contaminated with CSF pathogen), one shall not exclude the re-introduction of new CSF subgenotypes into the Far Eastern Federal District and the formation of natural and anthropurgic foci.

Vaccination. The mass vaccination of animals supposedly resulted in a decrease in the number of reported CSF cases in Russia [9, 24, 25]. The use of live attenuated vaccines in the country makes it impossible to differentiate vaccinated animals from the infected ones, although these vaccines are believed to induce a more effective and long immune response [2, 22, 26].

Those factors that help to reduce the number of CSF outbreaks in domestic pigs include: routine vaccination, regionalization of the Russian territory, strong anti-epizootic measures, a decrease in the number of poorly protected farms [9, 24, 25]. Thus, in 2007–2018, population of domestic pigs on small farms with low biosecurity level (backyards, small-scale farms, the farm of an individual entrepreneur, etc.) decreased from 7.6 to 2.9 million. However, the number of pigs on large-scale farms, on the contrary, increased from 8.7 to 20.8 million over the same period. However, implementation of all the above-mentioned measures (especially vaccination refusal) is not sufficient to radically change the epizootic situation.

To assess the overall vaccination against CSF in the Russian Federation, veterinary reports (forms 1-vet and 1-vet-A) were analyzed, taking into account statistical data on the number of domestic pigs. For 27 years (from 1991 to 2017), a correlation was established (r = -0.49769 at $p < 0.05$) between an increase in the vaccination coverage and a decrease in the number of registered CSF outbreaks in the domestic pigs (Fig. 4). The K1 value tended to reach 2.5 only from 2011 (at K2 = 0.13 ± 0.15 ($M \pm m$) from 2011), at the same time from 1991 to 2011 K1 did not exceed 3.0 and averaged 1.84 ± 0.35 ($M \pm m$), while K2 was 10.06 ± 11.65 ($M \pm m$) (at min = 0.45; max = 39.00). Therefore, we chose for analysis the period starting from 2011.

Using a regression analysis, we assessed dependence of the number of registered CSF outbreaks (using K2 coefficient) and vaccination (K1 coefficient) from 2011 to 2018 (Table).

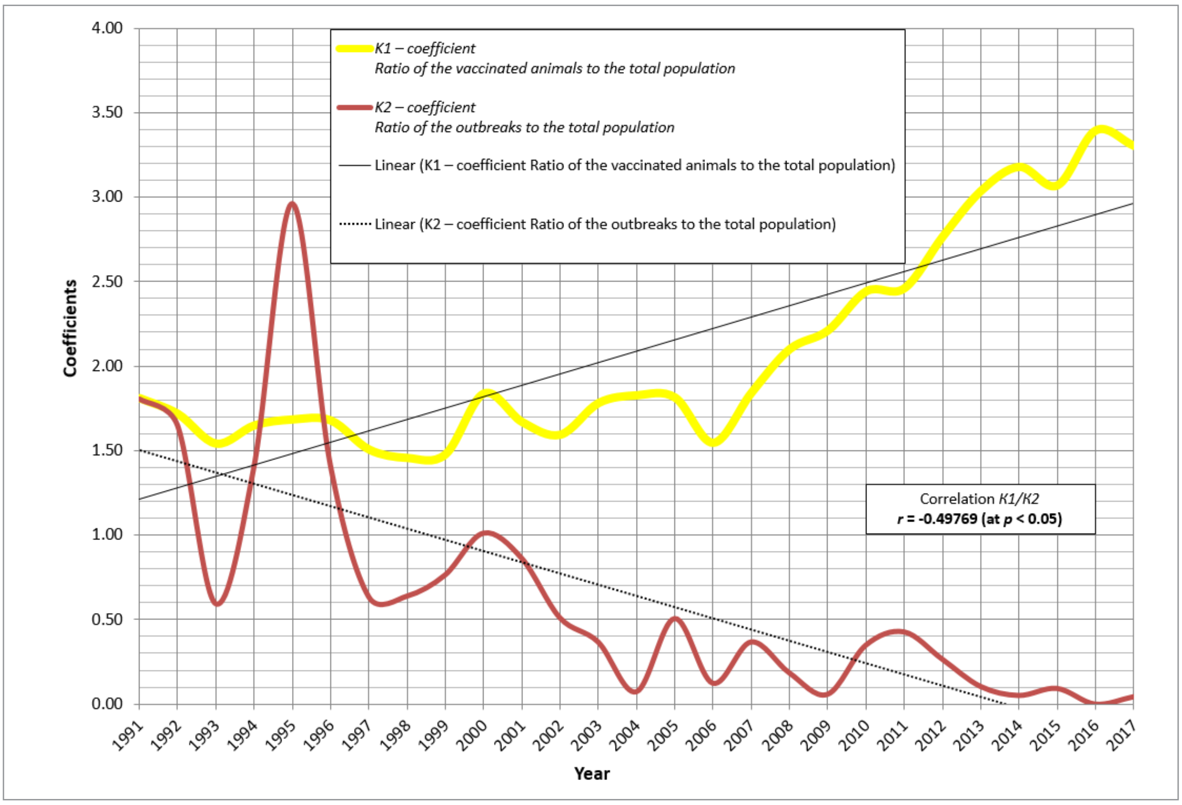

Fig. 4. Coefficient K1 (number of vaccinated animals) and K2 (number of outbreaks) in 1991–2017

The determination coefficient (*R*-square) in the presented model (0.948 > 0.8) indicates that the correlation between analyzed K1 and K2 parameters can be well explained, given that the strong inverse correlation between K1 and K2 (r = -0.97) is significant ($p < 0.05$). The analysis of variance indicates the significance of differences in mean values ($F < F_0$; 0.0000444645), the coefficient of "*x*" variable is negative (*t*-statistics indicate its significance; $p < 0.000045$) and remains within the negative limits of the 95% confidence interval. Coefficient "Y" also maintains its sign within the 95% confidence interval and is significant ($p < 0.00002$). The absolute error of approximation (MAPE = 39%) is in the range of 20% < A < 50%, so we can say that the model-fitting accuracy is satisfactory.

Based on the data of the obtained regression model, vaccination of livestock with K1 value = 3.372 will allow to reach K2 < 0.0001 (which means 1 outbreak per 10,000 years, which is evaluated as a "minor risk").

Thus, expansion of the CSF vaccination coverage from 2011 can be among the factors that contribute to a decrease in the number of CSF clinical cases in domestic pigs of the Russian Federation.

Immunization of pigs against CSF is mostly known as a forced measure, unable to stop virus-carriage in the previously infected herd [7, 27, 28]. In the pig herds, even among the vaccinated ones, there are always unprotected animals with a weak immune system due to the low age-associated immunoreactivity of piglets and suppression of the post-vaccination immunity with colostral antibodies. Latently infected sows transplacentally transmit the pathogen to the young, who become virus-carriers [1, 27–30]. It has been reported that the mass use of live vaccines affects the adaptive evolution of CSF virus, including recombination of epizootic and vaccine strains [23]. These disadvantages of the vaccination are viewed as a potential risk of the long-term virus circulation on the affected farms. Therefore, when country's status of freedom from CSF is determined, the international recommendations (Chapter 1.6 of the Terrestrial Animal Health Code) take this into account and prescribe not to immunize either domestic pigs or captive wild boars against CSF in the last 12 months; or, if vaccination was carried out, it is recommended to differentiate immune pigs from the infected ones [5, 7].

On the other hand, in many countries, where CSF eradication programs were successfully implemented without any vaccination, flaws in epizootic surveillance and infection control systems were fraught with the mass disease spread. Thus, in 1997–1998, 429 CSF outbreaks were registered in the Netherlands; in 2000, 16 outbreaks were reported in the UK, and 49 outbreaks were reported in Spain in 2001–2002. In 2006–2007, 1,597 CSF outbreaks were reported in domestic and wild pigs in Romania. To stabilize the epizootic situation in the country, a decision was made to temporarily return to immunization of domestic pigs. In 2006–2009, CSF was registered in Croatia (129 outbreaks among domestic pigs), Hungary (225 outbreaks in wild boars), Bulgaria (12 outbreaks in domestic and 4 in wild pigs), Slovakia (more than 10 outbreaks in wild pigs) [5, 9, 24]. After 10 years of CSF freedom, in 2018, 38 outbreaks were reported in Brazil in domestic pigs, and after 11 months of 2019 there were more than 30 outbreaks. Measures taken to stabilize the situation in the country were mainly aimed at strengthening the system of CSF epizootological surveillance and control in the disease-affected areas [15]. In Japan, where vaccination was not practiced for more than 26 years, CSF was reported in 2018 in wild boars and pigs. Spatiotemporal analysis conducted in Gunma and Saitama prefectures revealed anthropogenic factors in the disease spread. In response to the outbreaks, from March to May 2019, wild boars from certain areas of Aichi and Gifu prefectures were twice subjected to peroral immunization using commercial Pestiporc Oral vaccine (IDT Biologika GmbH, Germany), which failed to prevent CSF spread, although a decrease

Table
Regression analysis of CSF registered outbreaks (using coefficient K2) and vaccination (using coefficient K1), from 2011 to 2018

Year	K2 (Y)	K1 (*x*)	(Y) Calculated	Regression residuals (0)
2011	0.427807487	2.459893048	0.396101668	0.031705819
2012	0.265957447	2.765957447	0.263219277	0.00273817
2013	0.104712042	3.036649215	0.145694436	-0.040982394
2014	0.051282051	3.179487179	0.083679218	-0.032397167
2015	0.093023256	3.069767442	0.131315667	-0.038292411
2016	0	3.395348837	-0.010040318	0.010040318
2017	0.043478261	3.334782609	0.016255407	0.027222854
2018	0.042194093	3.367088608	0.00222928	0.039964813

MAPE (∑([0]/Y) / n × 100%) = 39%
Mean absolute percentage error (MAPE) is satisfactory (20% < A <50%)

Regression statistics	
Multiple *R*	0.973724123
R-square	0.948138669
Adjusted *R*-square	0.939495113
Standard error	0.035700785
Observations	8

Analysis of variance

	df	*SS*	*MS*	*F*	Significance level of *F*
Regression	1	0.139808953	0.139808953	109.6931347	4.44645E-05
Residual	6	0.007647276	0.001274546		
Total	7	0.147456229			

Data on coefficients of the regression equation

	Coefficient	Standard error	*t*-statistics	*P*-value	Low 95%	High 95%
Y-intersection	1.464100669	0.12814027	11.42576543	2.6961E-05	1.1505527	1.7776486
Variable *x*	-0.434164811	0.041453852	-10.47344904	4.44645E-05	-0.5355987	-0.3327309

in the number of cases in the severely affected areas was noticeable [11]. Similar results of wild boar vaccination in the Primorsky Krai in 2004–2016 also demonstrated that the mass mortality of wild boars was reduced, however, the virus circulation was not prevented [19, 20].

The negative aspects associated with no-vaccination CSF eradication policy (stamping out, logistical and technological costs for biosafety and control, ethical issues) suggest that immunization is the key measure to control future outbreaks, taking into account serious concern about the global threat posed by re-emergence of a population immunologically naive to CSF. Therefore, the most urgent task today is to continue research with the purpose to create more effective vaccines against CSF [2, 22, 26].

Regarding DIVA strategy, it is worth noting that the first generation of marker vaccines (commercial subunit E2 vaccines), despite their safety, did not demonstrate the same high effectiveness as live attenuated vaccines did [2, 22]. In some countries, work is ongoing to create vaccines that could be used as part of the DIVA strategy. However, their use for CSF control and eradication must be combined with well-organized and implemented epizootological surveillance, quarantine measures at the borders and biosafety of the pig industry [22].

We believe that today CSF zoning of the Russian Federation with creation of disease-free zones without vaccination and preservation of vaccination in disease-affected (risk) zones is the most progressive way as demonstrated by the already implemented FMD zoning of the country's territory [5]. In terms of general veterinary and sanitary and quarantine measures, FMD and CSF zoning are similar, but CSF-focused surveillance shall be strengthened separately, as well as CSF-related quarantine measures in the existing zones. In our opinion, the CSF control with the use of live attenuated vaccines practiced for decades in the Russian Federation paved the way for vaccination refusal in future and for successful eradication of this infection, as demonstrated by officially CSF-free countries or countries with CSF-free zones [2, 14, 15].

CSF outbreaks expected in 2022 in the Russian Federation. Modeling for the possible number of CSF cases in 2022 showed that an average of 3 (95% confidence interval: 0–5) outbreaks can be expected in the population of domestic pigs, and 3 (0–6) outbreaks in the wild boar population (Fig. 5).

CONCLUSION

Over the past decade, there has been a geographical shift of CSF-affected area from the central to the eastern regions of the Russian Federation along the borders. However, unlike the previous years 2019–2020, the CSF trend showed an upward direction in the wild boar population (a growth), which is associated with the disease spread in the Primorsky Krai and the Amur Oblast. If the existing level of specific prevention is in place, the long-term forecasts suggest that the situation with a low number of outbreaks in domestic pigs will persist (sporadic CSF outbreaks).

The short-term forecasts for 2022 suggest that there will be 0–5 CSF outbreaks in the population of domestic pigs (with the expected average of 3) and 0–6 outbreaks in the population of wild boars (with the expected average of 3). These are domestic pigs on small-scale pig farms with low biosafety (biosecurity) level (where violations (non-compliances) are reported during vaccination), who are expected to become a CSF target population in 2022.

The main peculiarities of the infection spread in the Russian Federation are more likely associated with the internal risk factors (i.e. quality of antiepizootic measures, mainly vaccination) and the territories of the virus circulation among wild boars. In terms of wild boars, the susceptible animals from the Primorsky Krai bordering on the PRC and the DPRK will be the main CSF target in 2022, as a high probability was earlier reported in the area (since 2015) to form a natural and anthropurgic foci of the infection and CSF virus was widespread in the wild boar populations of the region (China, South Korea, the DPRK and the Primorsky Krai of the Russian Federation). At the same time, one shall not exclude potential anthropogenic impact which may result in penetration of the infection into any regions of the Russian Federation.

Thus, expansion of the CSF vaccination coverage from 2011 can be among the factors that contribute to a decrease in the number of CSF clinical cases in domestic pigs of the Russian Federation. Currently, vaccination

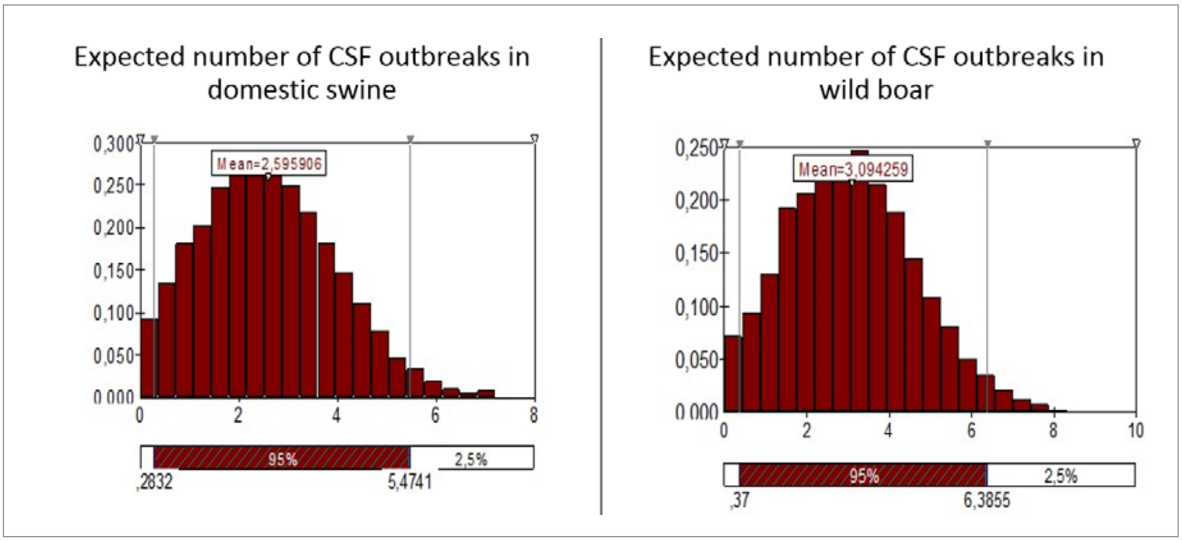

Fig. 5. The projected number of CSF outbreaks in the population of domestic pigs and wild boars for 2022

against CSF (and its good quality) in the Russian Federation is an essential prerequisite to contain the infection spread in the country. Infection spread in domestic pig population is still on a downward trend.

To make a reasonable choice of a future CSF control strategy, it is required to introduce an effective system of epizootological surveillance that will be able to confirm freedom from the infection or to determine the exact area of infection (including latent carriers) in domestic pigs and wild boars in different regions of the country. It is unacceptable to confirm freedom from the disease, simply relying on the fact that there are no notified CSF outbreaks in the population, where vaccination is widely practiced.

If a decision is made to refuse vaccination, new measures shall be efficiently implemented step by step (being tried and tested on farms with a high level of biosecurity). First, they shall be implemented in the areas of the lowest CSF risk occurrence, and only after that, if successful, throughout the whole country.

We believe that CSF zoning of the Russian Federation with creation of disease-free zones without vaccination and preservation of vaccination in disease-affected (risk) zones is the most progressive way, as demonstrated by the already implemented FMD zoning of the country's territory.

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