DOI: 10.29326/2304-196X-2021-10-4-277-284

Semi-quantitative risk assessment of peste des petits ruminants introduction with wild animals into Russian Federation

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SUMMARY
The Russian Federation was officially recognized free from peste des petits ruminants (PPR). As far as the disease infects both domestic and wild small ruminants, it is important to identify the level of the threat associated with the wild fauna diversity in the neighboring countries, where PPR outbreaks were reported. For that reason, habitats of various disease susceptible animal species were examined. Habitats of the wild susceptible animals were mapped for further examination of the interactions between different animal species using zoological research data; PPR outbreaks in wild animals were also designated in the map thus allowing for the detection of the potential routes of the infection spread in the population and introduction to the country. Analysis of the PPR epidemic situation in the country demonstrated that the disease cases were reported in wild mountain animals (ibices and moufflons) and migratory steppe animals (gazelles and saigas). Risk of this highly contagious viral disease spread in wild small ruminants in Mongolia was reported (probability 0.77). Expert survey was carried out for the determination of possible trends and factors of the infection introduction with the wild susceptible animals, through which small ruminant epizootologists assessed the risk probability. During the survey it was determined that PPR was expected to be introduced from Mongolia (probability 0.81), and of major significance were seasonal migrations of wild animal populations. The resulted semi-quantitative parameters of the potential risk can be recommended for the arrangement and implementation of measures aimed at prevention of PPR introduction and spread in the intact domestic and wild small ruminant populations inhabiting the territory of the Russian Federation.

Keywords: peste des petits ruminants (PPR), analysis, wild small ruminants, risk, disease spread, epidemic situation, PPR introduction into the Russian Federation

Acknowledgements: The study was funded by the FGBI "ARRIAH" within the framework of "Veterinary Welfare" research work.

For citation: Shcherbinin S. V., Korennoy F. I., Akimova T. P., Karaulov A. K. Semi-quantitative risk assessment of peste des petits ruminants introduction with wild animals into Russian Federation. *Veterinary Science Today*. 2021; 10 (4): 277–284. DOI: 10.29326/2304-196X-2021-10-4-277-284.

Conflict of interest: The authors declare no conflict of interest.

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УДК 619:616.98:578.831.2: 636.3:616-036.22(470)

Полуколичественная оценка риска заноса чумы мелких жвачных на территорию Российской Федерации с дикими восприимчивыми животными

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РЕЗЮМЕ

Российская Федерация признана страной, благополучной по чуме мелких жвачных. Поскольку данное заболевание поражает как домашних, так и диких мелких жвачных, необходимо оценить уровень угрозы, связанный с разнообразием дикой фауны в граничащих с Россией странах, в которых зарегистрированы вспышки чумы мелких жвачных. Для этого было проведено исследование ареалов обитания различных видов диких животных, восприимчивых к данному заболеванию. С целью изучения взаимодействия популяций различных видов животных с использованием данных зоологических исследований была составлена карта ареалов обитания диких восприимчивых животных, на которой также отмечены вспышки чумы среди диких животных, позволяющие выявить существующую возможность распространения инфекции внутри этих популяций и заноса инфекции на территорию страны. В ходе анализа эпизоотической ситуации по чуме мелких жвачных установлено, что в приграничных государствах зафиксированы случаи заболевания диких горных (горные козлы и бараны) и степных мигрирующих (джейраны и сайгаки) животных. Выявлена опасность распространения данной высококонтагиозной вирусной болезни среди диких мелких жвачных Монголии (вероятность реализации события 0,77). При определении возможных направлений и факторов заноса инфекции с дикими восприимчивыми жвачными был проведен экспертный опрос, в котором специалисты в области эпизоотологии болезней мелкого рогатого скота оценили вероятность реализации опасности. В ходе опроса было установлено, что ожидается занос чумы мелких жвачных в Российскую Федерацию со стороны Монголии (вероятность 0,81), а самым значимым фактором являются сезонные миграции популяций диких жвачных. Полученные полуколичественные показатели уровня вероятной угрозы можно рекомендовать к использованию при планировании и реализации мер по недопущению заноса и распространения чумы мелких жвачных в интактные популяции домашнего и дикого мелкого рогатого скота на территории Российской Федерации.

Ключевые слова: чума мелких жвачных, анализ, дикие мелкие жвачные, риск распространения заболевания, эпизоотическая ситуация, занос чумы мелких жвачных на территорию РФ

Благодарности: Работа выполнена за счет средств ФГБУ «ВНИИЗЖ» в рамках тематики научно-исследовательских работ «Ветеринарное благополучие».

Для цитирования: Щербинин С. В., Коренной Ф. И., Акимова Т. П., Караулов А. К. Полуколичественная оценка риска заноса чумы мелких жвачных на территорию Российской Федерации с дикими восприимчивыми животными. *Ветеринария сегодня*. 2021; 10 (4): 277–284. DOI: 10.29326/2304-196X-2021-10-4-277-284.

Конфликт интересов: Авторы заявляют об отсутствии конфликта интересов.

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INTRODUCTION

Peste des petits ruminants (PPR) known as goat plague and stomatitis-pneuma enteritis syndrome, is an infectious viral disease of domestic and wild small ruminants which poses threat to food security and balanced recourses in Africa, Middle East and Asia.

PPR outbreaks have been reported in the disease-free regions of the world and cause economic losses [1].

The recent reports and reviews on the PPR cases demonstrate the ongoing geographic expansion of the nosoarea in non-vaccinated susceptible populations of domestic small ruminants which contributes to there virus spread in areas where domestic animals and other species of susceptible species coexist. Thus, PPR caused high morbidity and mortality of the Mongolian saiga (*Saiga mongolica*), resulting in 80% decrease in the population and threatening with this subspecies extinction. The PPR clinical signs were also registered in other wild cloven-hoofed animals in Asia. In Pakistan PPR was detected in Sindh ibex (*Capra aegagrus blythi*). Recent PPR outbreaks were detected in China in Siberian ibex (*Capra ibex sibirica*), argali (*Ovis ammon*) and goitered gazelle (*Gazella subgutturosa*) [2–10].

In several PPR endemic countries there is more and more serological evidence of PPR reinfection in different wild animal species but the disease in these populations has not been confirmed [11, 12].

The wild fauna involvement in PPR spread is still understudied, however, the role of domestic small ruminants as the source of infection for wild fauna is obvious. Wild small ruminants are commonly found in PPR affected countries and inhabit most of the pastures together with small ruminants. It indicates that wild susceptible animals have a great potential for the disease transmission both between the populations of wild animals and between wild and domestic animals [13].

This fact becomes especially critical for the border regions of the Russian Federation with high density of the small ruminant population when the epidemic situation in neighboring countries is tense [14] and susceptible wild animal species are diverse.

The aim of the research was to determine the potential for PPR spread by susceptible wild animal populations in the RF border regions with subsequent assessment of the risks of the disease introduction into the territory of our country with wild small ruminants.

MATERIAL AND METHODS

In the framework of risk assessment of PPR introduction to the RF with wild ruminants the habitat of wild animal species susceptible to this disease as well as their diurnal activity were studied. PPR outbreaks in target species populations were taken into account. Estimates (score)

reflecting the potential for the infection spread between the populations were determined. To study the interrelation between the populations of different animal species using the data of zoological tests a map demonstrating habitats of wild susceptible animals was generated. The map shows PPR outbreaks in wild animals allowing to detect the possibility of PPR spread within these populations and the infection introduction to the RF territory. The cartographic materials were compiled using ArcGIS program.

There were determined three factors capable of influencing the potential for the infection spread between the populations: different populations inhabiting common territory (a), PPR outbreaks in wild fauna (b) diurnal activities (c). To determine the significance of scores each estimate was characterized (Table 1).

The estimates were assigned to wild animal species (Table 2) and the arithmetic mean of these estimates was calculated. Then the average estimates were converted to a fraction of the maximum possible score. Thus, the capability of the infection to spread by the wild ruminant populations was determined (Table 3). The data obtained were rated according to the risk level.

After the major directions of PPR introduction with wild ruminants were determined, a survey was conducted in the framework of which the experts in the field of epizootology and small ruminant diseases assessed the probability of the disease introduction to the Russian Federation and gave scores from 1 to 5, where 1 – the least probability, and 5 – the greatest probability of the event occurrence. Due to the survey it was possible to identify the most probable factor, as well as the direction of the introduction of PPR into the country.

Analysis of expert opinions (Table 4) was performed according to the following algorithm [16]:

X*i*, *j* – average estimates of the factors of PPR introduction to the RF under study;

Y*i* – the value of the probability of PPR introduction into the RF.

Herewith, the risk value for Y*i* ranged from 0 to 1, that's why the probability of introduction was calculated according to the formula:

$$(\sum Yi / X) / R,$$

where $\sum Yi$ – the sum of estimates X*i*, *j*;

X – the maximum number of scores for three factors [12];

R – maximum risk.

In all the tests the risk level was rated on the scale [17, 18]: $R \leq 0.3$ – negligible risk of the event occurrence; $0.3 < R \leq 0.5$ – low risk of the event occurrence; $0.5 < R \leq 0.7$ – moderate risk of occurrence; $0.7 < R \leq 0.9$ – high risk of the event occurrence.

RESULTS AND DISCUSSION

The Russian Federation is recognized free from PPR. In order to prevent the infection introduction and spread into the area with the naïve small ruminant population and to maintain the disease free status the risk of the infection introduction with wild fauna was assessed.

The OIE Terrestrial Code recommends to asses the risks of the infectious disease introduction by detection and analysis of the factors facilitating the infection agent transmission and spread in susceptible animal populations followed by the quantitative and qualitative process assessment [15].

A quick overview of PPR susceptible wild ruminants. West Caucasian tur (*Capra caucasica*) and Daghestan tur (*Capra cylindricornis*) – cloven hoofed mammals belonging to the *Capra* genus, *Bovidae* family, inhabiting Caucasian mountains at an altitude of 3,000 m above sea level. In winter the animals descend 1,500–2,000 m and cover up to 10 km within the habitat. In summer they are active usually at night and in winter during the day.

Siberian ibex (*Capra sibirica*) – cloven hoofed mammals belonging to the *Capra* genus, *Bovidae* family, inhabiting mountainous regions in Tajikistan, Kyrgyzstan, Mongolia, RF, Kazakhstan, China, Afghanistan, and Pakistan. They are mostly active during the day. They are sedentary animals migrating short distances searching for food. They live at the altitude 500–5,000 m above sea level.

Common ibex (*Capra aegagrus*) – cloven hoofed mammals belonging to the *Capra* genus, *Bovidae* family, inhabiting Turkey, most part of the Asia Minor, in the Caucasus and in a part of Pakistan. The altitudinal range – from 1,200 to 4,500 m above sea level. They are active mostly during the day and travel the distance of 1–2 km per day within the habitat.

Markhor (*Capra falconeri*) – cloven hoofed mammals belonging to the *Capra* genus, *Bovidae* family, inhabiting Western Himalayas, Kashmir, Little Tibet and Afghanistan,

Table 1
Specification of the estimates (scores) for determination of the probability of the disease spread with wild fauna

Factors	Score	Characteristics
a) Inhabiting common territory	1	The habitats of different populations exist separately. The representatives of the population belonging to a certain species don't enter the populations of other species (due to natural or artificial barriers: mountains, territories of other countries, water reservoirs, etc.)
	2	The habitats of different populations exist separately or come into contact with each other. The representatives of the population belonging to one species can enter the population of another species (for instance, populations located in the territory of one country, but in the opposite parts of the country, or hoofed steppe animals, inhabiting the regions at the foot of the mountains where mountain hoofed species live)
	3	The population of one species is a part of the population of another species
b) PPR outbreaks in wild fauna	1	No PPR outbreaks were observed in wild fauna
	2	PPR outbreaks in the wild fauna were observed more than 24 months ago
	3	PPR outbreaks in the wild fauna were observed less than 24 months ago [15]
c) Diurnal activity	1	The periods of grazing and rest don't coincide (for instance, the animals of one population are active during the day and the animals of another population – at night)
	2	Coincidence of the beginning of the rest period of one animal species and the beginning of the active period of another species
	3	Grazing and rest periods coincide

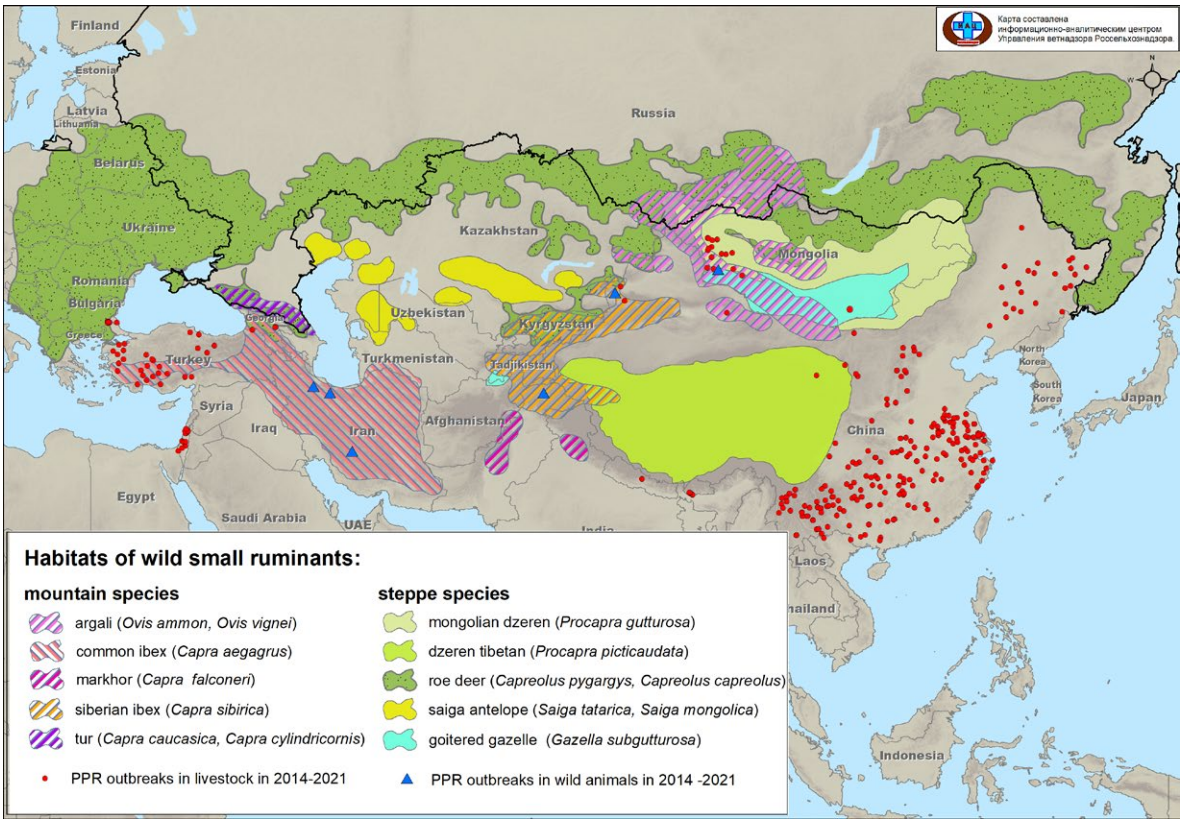

Fig. 1. Habitats of wild small ruminants

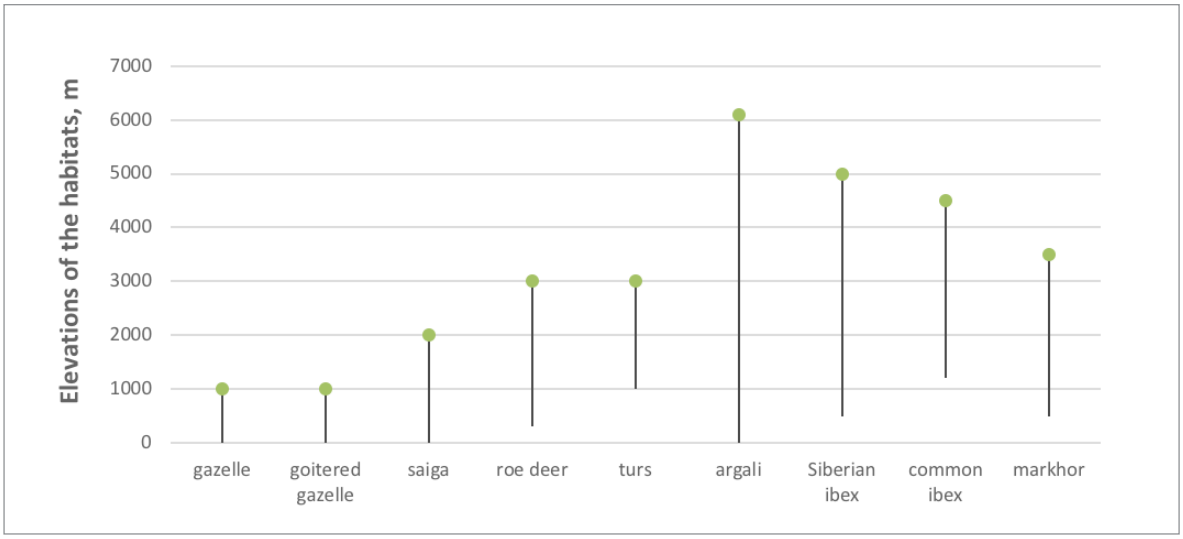

Fig. 2. Distribution of elevations of the habitats of the PPR-susceptible wild ruminants inhabiting the disease infected countries

as well as the mountains along the Panj River, in the Kugitangtau, Babatag and Darvaz ranges in Tajikistan. The altitudinal range is from 500 to 3,500 m above sea level. They are active mainly during the day and cover up to 1–2 km within the habitat per day.

Mountain sheep, or argali, (*Ovis ammon*) – cloven-hoofed mammals from the *Ovis* genus of the *Bovidae* family. Inhabit the mountains and foothills of the West, Central Asia, to the north – to the Transcaucasia, the Kazakh highlands and Southern Siberia, to the south – to the Himalayas, to the east to the Greater Khingan Range, inclusive. They live at an altitude of 1,300–6,100 m above sea level. They are mostly sedentary animals, which can migrate horizontally no more than 5 km. They are active throughout the day resting or grazing.

Mongolian gazelle (*Procapra gutturosa*) and Tibetan gazelle (*Procapra picticaudata*) – cloven hoofed mammals from genus of *Procapra*, *Bovidae* family, inhabiting the

Table 2
Matrix of estimated factors scores of PPR spread with wild ruminants

$X_{a, b, c}$ 1…3*	Turs (*Capra caucasica, Capra cylindricornis*)			Siberian ibex (*Capra sibirica*)			Mountain sheep (*Ovis ammon*)			Common ibex (*Capra aegagrus*)			Markhor (*Capra falconeri*)		
Mongolian gazelle (*Procapra gutturosa*)	1	1	1	2	2	2	3	2	2	1	2	2	1	1	2
	1	2	1	2	2	2	3	2	2	1	2	2	1	2	2
Tibetan gazelle (*Procapra picticaudata*)	1	1	1	1	2	2	1	2	2	1	2	2	1	1	2
	1	1	1	1	1	2	1	1	2	1	1	2	1	1	2
Saiga (*Saiga tatarica*)	1	1	3	1	2	3	1	2	3	1	2	3	1	1	3
	1	1	3	1	1	3	1	1	3	1	1	3	1	1	3
Roe deer (*Capreolus*)	3	1	2	3	2	1	3	2	2	2	2	1	1	1	1
	3	1	2	3	1	1	3	1	2	2	1	1	1	1	1

*

$X_{a, b, c}$ 1…3	Turs (*Capra caucasica, Capra cylindricornis*)			
Mongolian gazelle (*Procapra gutturosa*)	1	1	1	– parameters a, b, c for turs;
	1	2	1	– parameters a, b, c for dzerens.

bunchgrass and partially desert steppes of Central Asia, located at altitudes from 800 to 1,000 m above sea level (Southern Altai, southern Tuva and Transbaikal, Western China, Mongolia, Tibet, Himalayas). Daily activity is polyphasic. They are most active in the evening and at the beginning of the night, as well as in the morning until 10–11 o'clock. In June – July, gazelles feed during the day with short rest breaks. The animals rest most of the night.

Goitered gazelle (*Gazella subgutturosa*) – clove-hoofed mammals from the *Gazella* genus of the *Bovidae* family, living in the desert and semi-desert regions of Tajikistan and Mongolia (the historical habitat included Kyrgyzstan, Iran, Armenia, Georgia and Dagestan). At the beginning of the XXI century, their population encountered 140 thousand animals in total, but by 2009 there was a massive extinction of these ungulates. The average density in the current habitats ranges from 0.003 (Mongolia) to 0.3 individuals per 1,000 ha (Tajikistan). In summer, animals are active from early to late morning. They mix with the Mongolian gazelle population. The total number at the moment does not exceed 11 thousand animals.

Saiga (*Saiga tatarica*) – are migratory bovids. Most of the animals inhabit the southern territories of Kazakhstan, wildlife parks of the Astrakhan Oblast, and the Republic of Kalmykia in the Russian Federation, in Western Mongolia. They live on flatlands, as well as at altitudes reaching 2,000 m above sea level. Animals make seasonal migrations: they spend the winter in places where the height of the snow cover does not exceed 15–20 cm, at the beginning of summer they migrate to more northern regions. In summer, they are active mainly at night, in winter – during the day.

Roe deer (*Capreolus pygargus, Capreolus capreolus*) are New World deer of relatively small size, slender and

Table 3
PPR spread risk levels according to factor scores of PPR spread with wild ruminants

∑X (R)	Turs (*Capra caucasica, Capra cylindricornis*)	Siberian ibex (*Capra sibirica*)	Mountain sheep (*Ovis ammon*)	Common ibex (*Capra aegagrus*)	Markhor (*Capra falconeri*)
Mongolian gazelle (*Procapra gutturosa*)	1.16 (0.38)***	2.0 (0.66)**	2.3 (0.77)*	1.6 (0.55)**	1.5 (0.5)***
Tibetan gazelle (*Procapra picticaudata*)	1.0 (0.33)****	1.5 (0.5)***	1.5 (0.5)***	1.5 (0.5)***	1.3 (0.43)***
Saiga (*Saiga tatarica*)	1.6 (0.55)**	1.83 (0.61)**	1.83 (0.61)**	1.83 (0.61)**	1.6 (0.55)**
Roe deer (*Capreolus*)	2.0 (0.66)*	1.83 (0.61)**	2.16 (0.72)*	1.5 (0.5)***	1.0 (0.33)****

Risk levels: * high risk, ** moderate risk, *** low risk, **** insignificant risk.

Table 4
Average score of PPR introduction risk event

No.	Directions of the introduction	Average score of the possible factors of PPR introduction to the RF ($\bar{X}i, j$)			
		1*	2**	3***	Y*i*
1	Georgia	**4.4**	2.2	4.3	**0.73**
2	Turkey	2.3	1.0	3.9	0.48
3	Iran	2.1	1.1	3.6	0.45
4	Kazakhstan	**4.7**	2.5	4.2	**0.76**
5	China	4.3	2.3	3.6	0.68
6	Mongolia	**4.9**	2.9	**4.4**	**0.81**

* introduction during wild animal migrations;
** introduction with wild animals during mating period;
*** introduction due to contacts between the wild and domestic animals on shared pastures;
Y*i* – PPR introduction *p*-value.

subtle constitution. They exhibit territoriality during the reproductive period. They are sedentary and seasonally migrating populations. Animals live in the forest-steppe, inhabiting semi-deserts and deserts, in high-mountainous regions they ascend to an altitude of 3,000 m above sea level; they are active early in the morning and at dusk. They are widely spread in the southern border regions of the Russian Federation, as well as in adjacent territories. They are kept mostly in wildlife sanctuaries and national parks [17, 19, 20].

Figure 1 shows the cartography of the habitats of wild small ruminants and the diagram of distribution of elevations of the habitats of each described species is shown in Figure 2.

Assessment of PPR introduction with susceptible wild animals. Estimates of factors of PPR spread in the populations of wild susceptible ruminants (Table 2) and the results of their processing (Table 3) were converted to probability values for the potential PPR spread by different populations of wild ruminants (in case there

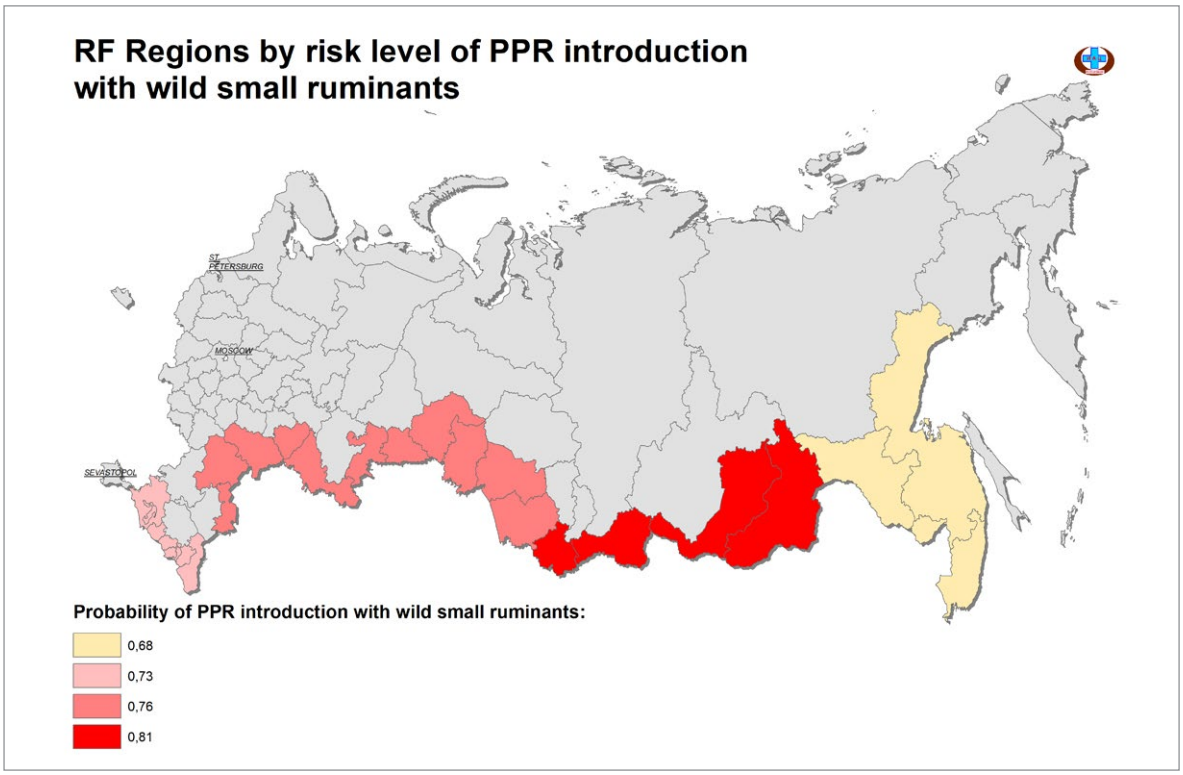

Fig. 3. Russian Federation entities with different levels of PPR introduction risk

are contacts between mountainous and steppe populations).

Based on the data on the behavior of tested animals, their geographical distribution, presence of mountains in the border regions of the Russian Federation and publications, describing the epidemic process in other animals [4, 13], it was suggested that contacts between steppe (migrating) and mountainous (non-migrating) PPR susceptible hoofed animals can play a significant role in the disease spread.

The research showed that interrelations between the Mongolian gazelle (*Procapra gutturosa*) and the mountain sheep (*Ovis ammon*) populations have the greatest potential demonstrating a high risk of the event occurrence (0.77 probability). The animals of these populations inhabit the common area (Mongolia and the northern China), the periods of their activity coincide and PPR outbreaks were recorded in these populations. Considering the fact that these populations are neighbors PPR introduction to the RF is possible in case of outbreaks in these populations.

The contacts between the mountain sheep (*Ovis ammon*) and roe deer (*Capreolus*) also have a high potential for PPR spread (0.72 probability) which indicates that there is a threat of PPR introduction to the Russian Federation with ungulates inhabiting Mongolia.

The least potential for PPR spread may demonstrate the contacts between the Tibetan gazelle (*Procapra picticaudata*) and turs (*Capra caucasica, Capra cylindricornis*), as well as roe deer (*Capreolus*) and markhor (*Capra falconeri*). These animals don't demonstrate any coincidence of the factors, their populations are disconnected and the probability of their inhabiting a common area approaches zero.

Therefore, we can conclude that there is a high risk of PPR spread by the populations of wild susceptible animals inhabiting Mongolia (0.77 and 0.72 probability). It means that it is necessary to enhance the measures preventing the disease introduction in the Far East direction and further disease spread [21].

The results of the expert survey of the specialists in the field of epizootology and small ruminant diseases are given in Table 4 and RF Subject rating according to the risk of PPR introduction to their territory – in Figure 3.

The analysis of the expert survey (Table 4) showed that the most probable factor of the infection introduction to the RF is migrations of potentially infected wild ruminants. Herewith, Mongolia (introduction probability – 0.81), Kazakhstan (introduction probability – 0.76) and Georgia (introduction probability – 0.73) demonstrate high risk. Other directions (China, Turkey and Iran) demonstrate a moderate risk (probability of introduction 0.68; 0.48 and 0.45 accordingly).

CONCLUSION

Based on the work performed a conclusion can be made that PPR outbreaks in wild fauna pose serious threat for the infection spread to the disease free herds. The most probable factor of the disease introduction, according to the experts, is seasonal migrations of wild animals. Presence of many wild animal populations in the Far East direction may contribute to the disease spread. Herewith, the experts consider that the probability of the disease introduction from Mongolia is high (0.81 probability).

When planning activities for preventing PPR introduction and spread in the RF in the framework of activities for maintaining the free status it is important to take into account the results of the research and enhance the surveillance in border regions and in the wild ruminant populations.

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Received 09.07.2021
Revised 27.07.2021
Accepted 23.08.2021

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