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Rabies situation in the Moscow Oblast in 2011–2023 and the role of oral vaccination of wild carnivores against rabies

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ABSTRACT

Rabies is a zoonotic viral disease of all warm-blooded animals caused by a neurotropic virus, member of the *Lyssavirus* genus of the *Rhabdoviridae* family. About 59,000 people die from hydrophobia globally every year. According to the World Health Organization, the red fox (*Vulpes vulpes*) and the common raccoon dog (*Nyctereutes procyonoides*) are the main reservoirs and vectors among carnivores of the rabies virus in Europe. The paper describes animal rabies situation in 2011–2023 and the role of oral vaccination of wild carnivores against rabies in the Moscow Oblast. The region is a part of the Central Federal District and located in the center of the Russian plain bordering seven Oblasts (Tver, Smolensk, Kaluga, Tula, Ryazan, Vladimir and Yaroslavl Oblasts), which are also rabies infected. Notwithstanding the metropolis growth, the number of wild carnivores in the Moscow Oblast remains high. Comprehensive preventive measures to control the population of the wild carnivores are taken to stabilize the rabies situation and decrease the incidence, innovative achievements in laboratory diagnosis are introduced, population immunity of wild carnivores by oral vaccination is improved and the epidemic situation in neighboring regions is analyzed. In 2017 the systemic, consistent and thoroughly organized campaign was started – the oral vaccines were distributed by light aircrafts. The research revealed the correlation between the decrease in annual number of reported rabies cases and increase in the amounts of oral vaccines distributed. The use of controlling devices (camera traps) confirmed that oral rabies vaccines are consumed by the target animals (red foxes). The onward systemic, methodical approach to rabies prevention will mitigate the risks of rabies occurrence in the Moscow Oblast.

Keywords: rabies virus, red fox, common raccoon dog, oral vaccination, epidemic situation, Moscow Oblast

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Эпизоотическая ситуация по бешенству на территории Московской области (2011–2023 гг.) и роль оральной вакцинации диких плотоядных

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РЕЗЮМЕ

Бешенство – зоонозное вирусное заболевание теплокровных животных, возбудителем которого является нейротропный вирус рода *Lyssavirus* семейства *Rhabdoviridae*. Ежегодно в мире от гидрофобии погибает около 59 000 человек. В Европе, по данным Всемирной организации здравоохранения, основными видами диких плотоядных, которые поддерживают природные очаги бешенства, являются лиса (*Vulpes vulpes*) и енотовидная собака (*Nyctereutes procyonoides*). В статье представлена эпизоотическая картина по бешенству животных (2011–2023 гг.), проанализирована роль оральной вакцинации диких плотоядных в Московской области. Регион входит в состав Центрального федерального округа, расположен в центре Русской равнины и граничит

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с семью областями: Тверской, Смоленской, Калужской, Тульской, Рязанской, Владимирской, Ярославской, – которые также являются неблагополучными по бешенству животных. Несмотря на урбанизацию мегаполиса, численность диких плотоядных животных в Московской области остается высокой. В регионе проводится системная профилактическая работа по контролю численности диких плотоядных животных, стабилизации эпизоотической ситуации и уменьшению случаев бешенства, внедряются передовые научные разработки в области лабораторной диагностики, повышения популяционного иммунитета среди диких плотоядных животных путем оральной вакцинации против бешенства, анализируется эпизоотическая ситуация в сопредельных областях. С 2017 г. в Московской области началась системная, планомерная, тщательно организованная кампания – с помощью средств малой авиации стала проводиться тотальная раскладка оральной вакцины. Исследования выявили корреляцию между снижением ежегодного числа регистрируемых случаев бешенства и увеличением объемов использования оральной вакцины. Применение средств внедренного объективного контроля (фотоловушек) подтвердило поедание оральной антирабической вакцины целевыми видами животных (лисицами). Дальнейший системный, методичный подход к профилактике бешенства снизит риски возникновения вспышек этого заболевания в Московской области.

Ключевые слова: вирус бешенства, красная лисица, енотовидная собака, оральная вакцинация, эпизоотическая ситуация, Московская область

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INTRODUCTION

Rabies is an infectious disease of mammalian animals caused by a neurotropic virus (genus *Lyssavirus*, family *Rhabdoviridae*). Rabies virus (RABV), as a typical lyssavirus occurs in different parts of the globe, has reservoir hosts, which maintain the viral circulation [1]. From the primary reservoir host, the virus is transmitted to other susceptible animals and to humans (Fig. 1). In Europe, such animals are the red fox (*Vulpes vulpes*) and the raccoon dog (*Nyctereutes procyonoides*) [2].

Lyssavirus species affect only mammals. The evolution of lyssaviruses is associated with the animal species in which the virus can maintain an independent cycle of development. These are a wide range of mammalian species within the *Carnivora* and *Chiroptera* orders. They are spread on various continents of the globe, excluding Antarctica. It is generally accepted that bats are the true primary reservoir hosts of almost all lyssaviruses. However, unlike all other lyssaviruses, rabies viruses (RABVs) as the typical species for lyssaviruses have established multiple independent transmission cycles in a broad range of carnivore host reservoirs. Typical carnivore host reservoirs for RABV are dogs, jackals, raccoon dogs, coyotes, skunks; in Eurasian and American arctic and subarctic regions is the arctic fox (*Alopex lagopus*) [1, 3].

In the Russian Federation, rabies cases are reported in many regions of the country, including the Moscow Oblast [4, 5], which is part of the Central Federal District (CFD) and located in the center of the Russian Plain. The region is adjacent to the Tver, Smolensk, Kaluga, Tula, Ryazan, Vladimir, and Yaroslavl Oblasts, which are also rabies infected. The fauna of the CFD regions includes reservoir hosts of the rabies virus that maintain the sylvatic cycle of the disease. The main role in this process is played by the red fox (*Vulpes vulpes*), which is one of the most common predatory mammals among canines inhabiting the Moscow Oblast. It is a medium-sized carnivorous various shaded red predator, which dwells in burrows and sees well in the dark. The diet includes mainly small rodents [6, 7, 8, 9, 10, 11]. The density of the fox population

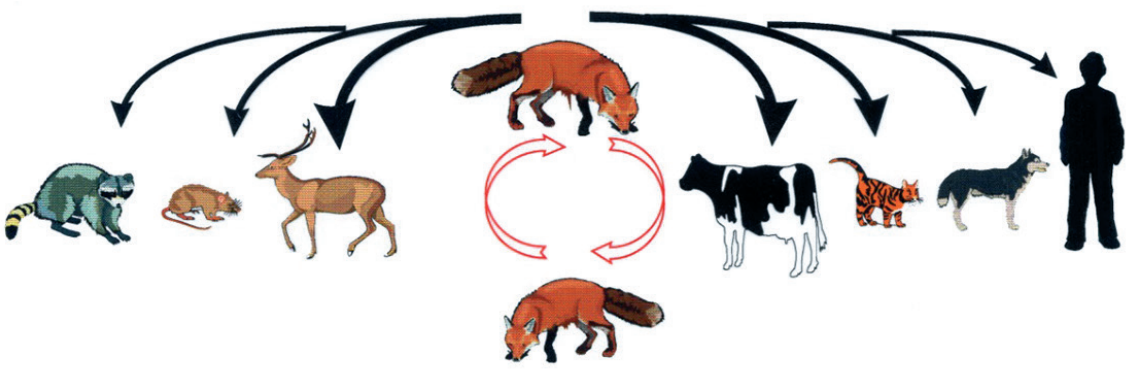

Fig. 1. Circulation and transmission of the rabies virus explained by the example of the red fox, Vulpes vulpes (https://www.who-rabies-bulletin.org/sites/default/files/epi_1.jpg)

per 1,000 hectares in the Moscow Oblast varies depending on the area. Fox harvesting in 2010–2021 was not regular due to the lack of demand for fox pelts [11].

The Moscow Oblast surrounds the city of Moscow and is a region in which the rabies situation is under special control. Despite the high urbanization levels in the megalopolis, the number of wild carnivores in the Moscow Oblast remains high. The geographical position in the central part of the East European Plain with favorable climatic and landscape conditions for the habitat of carnivores contribute to that [12]. An increase in the fox population density, in our opinion, is the main risk factor for the maintenance of rabies sylvatic cycle and incidence in the Moscow Oblast. This is confirmed by the data published by N. I. Osipova [13].

Rabies remains a global threat. It causes great economic damage to agriculture. The rabies virus accumulates in the saliva and brain of infected animals and is transmitted through biting and licking. The transmission through contacts does not evoke any explosive outbreaks of rabies and its rapid spread, as it happens with highly contagious diseases, for example, foot-and-mouth disease. Many species of farm animals are considered to be dead end hosts (cattle, sheep, goats, pigs, horses) in the rabies epizootic chain. They usually die when infected, although all diseased animals and animals during the incubation period are the source of the virus, and dead animals and virus contaminated environmental objects become transmission factors.

Low ambient temperatures are favourable for the preservation of the virus virulence. In this regard, the carcasses of animals killed by rabies pose a real danger, since the virus remains alive in them for 2–3 weeks, and at subzero temperatures for several months [14, 15].

It is difficult to overestimate the social significance of the disease, since rabies poses a real threat to humans. Human deaths from rabies are also reported in the Russian Federation. This is the case when an individual does not seek medical assistance after an animal bite, scratch or licking. The sylvatic rabies contributes to the maintenance of rabies virus circulation in the Russian Federation, therefore, the risk of human infection is always high. Rabies cases are reported more often in spring and summer. A rabid animal causes typical injuries to humans. Especially dangerous targets are head, face, and fingers. The exposed human shall be immunized against rabies as soon as possible. For specific prophylaxis, COCAV rabies vaccine is used. For severe cases, after multiple bites, combined therapy scheme using the COCAV vaccine and specific gamma globulin has been developed. In order to prevent rabies in humans, it is necessary to raise awareness among public through mass-media [16]. About 59,000 humans die from rabies every year in the world [17].

All this identifies the challenges faced by the Moscow Oblast Veterinary Service when developing animal rabies control plans. In addition to constantly changing economic environment of the metropolis, it is important to take into account the biology and ethology, firstly, of foxes and raccoon dogs, changes in their food supplies and population density. The threshold value of the fox population density when sylvatic rabies is reported is more than one individual per 1 km^2 [18].

Advanced scientific developments in laboratory diagnosis, aimed at improvement of population immunity among wild carnivores through oral rabies vaccination are introduced in the Moscow Oblast, and the disease situation in the neighboring regions is analyzed.

Oral vaccination of wild carnivores remains a recognized method of rabies prevention in the complex of disease control measures taken by the veterinary services both in our country and abroad [19, 20].

The aim of the research was an in-depth study of the animal rabies situation in the Moscow Oblast, as well as an assessment of the oral immunization role for wild carnivores.

MATERIALS AND METHODS

Data from statistical reports of the Moscow Oblast State Veterinary Service for the period from 2011 to 2023 were used for the work. The data were processed by descriptive and evaluative epidemiological and statistical methods. To determine the territorial-geographical location of rabies cases search engines, like Google Earth Pro and Yandex, were used.

The final diagnosis of rabies was made after confirmation by laboratory tests in accordance with approved GOST 26075-2013 "Animals. Methods of Laboratory Diagnostic of Rabies"[1] and "Recommended practice for the diagnosis of animal rabies by immunofluorescence"[2].

Tetracycline in teeth and bones of carnivorous animals was determined in accordance with the "Guidelines for the detection of tetracyclines by fluorescence method in animal teeth and bones to control the oral rabies vaccine consumption"[3] and the recommendations of A. M. Gulyukin [21]. For sample preparation, a Buehler low-speed precision cutter (USA) was used to determine the tetracycline marker by making 1–2 mm thick cuts of teeth and jaws of wild carnivores.

For the assessment of epidemiological surveillance results, the method of retrospective epidemiological analysis was used.

RESULTS AND DISCUSSION

The effectiveness of the disease control comprises a whole range of measures developed by the Moscow Oblast Veterinary Service, which are adjusted to concrete conditions:

– strict recording of susceptible animals in order to implement rabies vaccination plans among pets and livestock, zoo animals, as well as to comply with the regulatory requirements for appropriate and humane keeping of domestic carnivores;

– interaction with employees of hunting farms to control the fox density;

– oral vaccination of wild carnivores against rabies;

– short-term and long-term forecasting;

– awareness raising campaigns among public with regards to the rabies dangers and prevention.

Rabies prevention and control with an ultimate goal of its eradication also involves the development and implementation of a constant monitoring of this infectious

[1] https://docs.cntd.ru/document/1200104625 (in Russ.)

[2] Sukharkov A. Yu., Eremina A. G., Nazarov N. A., Egorov A. A., Metlin A. E., Shulpin M. I. Recommended practice for the diagnosis of animal rabies by immunofluorescence: MR 33-16. Vladimir: FGBI "ARRIAH", 2016. 14 p. (in Russ.)

[3] MG 36-16 Guidelines for the detection of tetracyclines by fluorescence method in animal teeth and bones to control the oral rabies vaccine consumption. Vladimir: FGBI "ARRIAH", 2016. 11 p. (in Russ.)

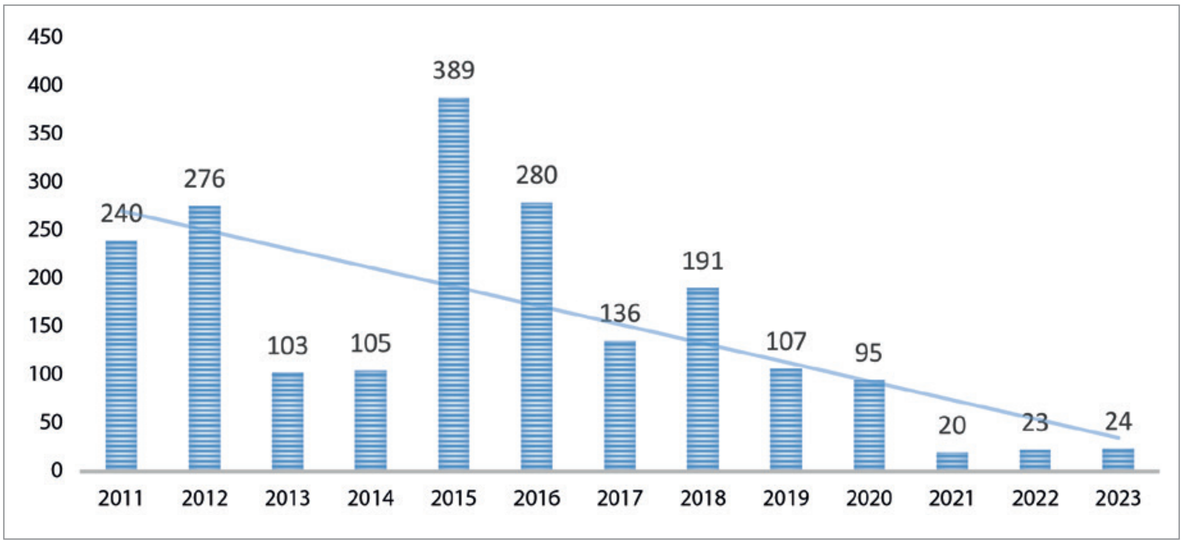

Fig. 2. Animal rabies incidence reported in the Moscow Oblast in 2011–2023 and its trend

disease in a certain area over a certain period of time, i.e. epidemiological surveillance and control.

It is important to identify possible carriers, to recognize the manifestation (presence) of the disease in a healthy population as early as possible, to prove the absence of rabies in susceptible animal subpopulations, and to establish the disease trend. To do this, well-known strategies are used: monitoring, screening, examination, observation, etc.

Every year since 2011, state epidemiological monitoring plans, covering rabies tests, have been implemented in the Moscow Oblast. They are implemented by the institutions subordinate to the Rosselkhoznadzor. In addition, diagnostic test plans are implemented at the level of the Russian Federation Subject, which also cover testing for rabies. According to the regulatory documents of the Russian Federation, data on tests performed shall be provided to the relevant organizations using the approved templates. Test reports shall be entered into the Rosselkhoznadzor information systems "Assol" and "Vesta".

This system is used to detect the disease, prevent and reduce morbidity, and ultimately eradicate rabies in the designated areas.

As can be seen in Figure 2, rabies was reported annually in the Moscow Oblast in 2011–2023. The rises and falls in the disease manifestation over the years are clearly visible, which confirms the rabies cycle nature. The beginning of the observation period coincides with an increase in the total number of reported cases (2011–2012), followed by a decline and a new rise. The highest rabies incidence was reported in 2015. In general, the trend is decreasing.

The species structure of animals involved in the rabies epizootic process is shown in Figure 3. The highest incidence over the entire observation period was reported in wild carnivores (65%), followed by domestic carnivores (33%) and farm animals (2%). It should be noted that the objectivity of reports on animal rabies has increased since "Sirano" system was introduced in our country.

A relatively high incidence of rabies among carnivores during the observation period suggests the sylvatic cycle of the disease, when the vectors, in particular diseased foxes, can carry the virus to potential victims or can transmit the virus to susceptible animals (stray cats, dogs and farm animals). Monitoring tests have shown that the number of stray domestic carnivores, as a rule, increases in autumn, when the summer season is over. This

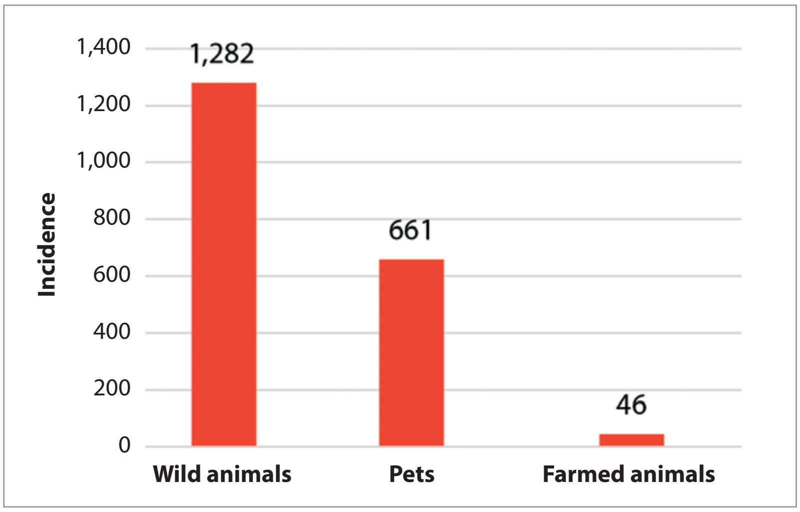

Fig. 3. Species structure of animal rabies in the Moscow Oblast in 2011–2023

Fig. 4. Light aircraft for oral vaccine distribution

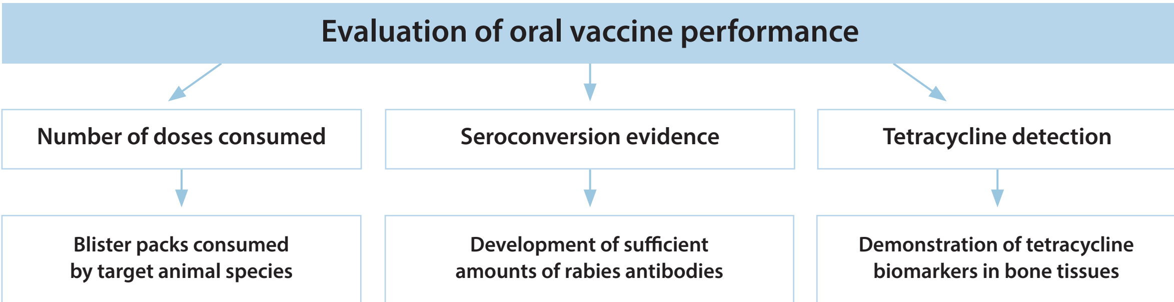

Fig. 5. Evaluation of oral vaccination results

peculiarity was highlighted by B. L. Cherkassky [22]. It is necessary to implement awareness raising campaigns among the public in the urban territories, where special conditions for the rabies virus circulation are created.

Stray animals bring additional risks of rabies occurrence and increase in its incidence. To solve the social and economic problem of stray animals in the Moscow Oblast a management system has been created to improve the coordination and interaction of services, directly or indirectly responsible for trapping and keeping of stray animals. This will increase the effectiveness of control and measures taken to regulate the number of stray animals.

Due to the fact that wild carnivores are the main rabies reservoir, oral vaccination has been initiated in the region. The first field trials conducted in Switzerland in the 70s of XX century, showed that oral immunization is an effective method of animal rabies control. The possibility of using a live attenuated strain of rabies virus embedded into a special bait attractive for wild carnivores was demonstrated. The attenuated virus penetrates the lymphoid tissue through the oral cavity of the animal, activates the immune response inducing resistance to the infection with the virulent virus. Oral immunization is currently a highly effective method of the disease control. The modern strategy of rabies control invariably includes specific prevention of the disease among domestic carnivores [14]. The experience of the European Union countries, the USA, and Canada has shown that the consistent long-term use of oral rabies vaccines in wildlife effectively reduces the incidence, until the disease is eradicated.

The main purpose of oral immunization is to induce and strengthen specific immunity in susceptible wild carnivores. The presence of specific virus neutralizing antibodies in the sera of the target vaccinated animals in a titer of ≥ 0.5 IU/cm^3 provides sufficient protection in the target animal species [23, 24].

Rabivak-O/333 (vaccine for oral immunization of wild carnivores against rabies, Pokrovsky Plant of Biological Products, Russia) and Rabistav (vaccine against rabies of wild carnivores, Stavropol Bioplant, Russia), registered and authorized in the Russian Federation, were used in the Moscow Oblast. When handling the vaccines, all rules prescribed in the instructions for their use were carefully followed.

Oral rabies vaccines are constructed as follows: a blister or capsule with a viral suspension is embedded into a bait in the shape of a rectangular block, weighing 25–55 g.

At the beginning, when the oral vaccination was introduced, the vaccine was distributed using two methods: manual baiting in the territory of the Moscow Oblast municipalities at the rate of 25–30 doses of the vaccine per 1 km^2, and aerial distribution in hard-to-reach areas 2 times a year. Personal safety measures were obligatorily observed during the distribution process.

Since 2017, light aircrafts have been used in the Moscow Oblast to distribute oral vaccines (Fig. 4), in compliance with the international requirements. The distribution pattern is based on GPS mapping. Before the vaccination campaign, the area was mapped; flight charts were made to depict the planned routes for the vaccine distribution, zones to be covered by light aircraft were defined and approved; controlled forest areas were highlighted.

Fig. 6. Camera trap "Filin 120"

Fig. 7. Approaching and consuming of vaccine baits by foxes in the controlled area

Spring vaccination campaign was conducted in late March, April, and early May (depending on weather conditions). The second vaccination was performed in autumn, in September – October. Due to the fact that after spring vaccination, fox cubs have colostral immunity, the third vaccination was conducted in June or early July.

The vaccination campaign effectiveness was evaluated (Fig. 5), which included visual determination of the bait up-take at the control sites, sampling and their laboratory testing to determine the tetracycline marker in teeth and bones and the level of rabies antibodies in wild carnivores.

The active use of the oral vaccines against rabies among wild carnivores required correction of the vaccination effectiveness evaluation, search for and introduction of new methods. Therefore, we have studied the possibility of using camera traps. The camera trap is a fully automatic camera with GSM functions, which is disguised from animals using a special case. "Filin 120" camera trap was used for this work (Fig. 6). It is triggered by a motion sensor and automatically captures images or videos when an animal appears in the controlled area at a distance of up to 20 m.

Thus, for the first time in Russia, a remote method for rabies oral vaccine up-take control and efficacy evaluation was used in the Moscow Oblast. The camera trap automatically sends images to a mobile phone using a GSM/GPRS network. The MMS make it possible to receive 1–99 images, which are processed by a computer (Fig. 7).

The camera trap data showed that all distributed vaccine baits were willingly consumed during the first two days by the main target animal species – the fox. The uptake rate at the controlled areas was calculated and was equal to 70–90%.

The vaccine uptake is also controlled by the tetracycline marker. When consumed, tetracyline binds to growing bones, in particular, to tooth tissue, and can be detected by the fluorescence method in teeth or mandible bones [25].

The analysis of the rabies epizootic process in 2013–2015, conducted by M. I. Gulyukin and A. A. Shabeykin [26], showed that there was an increase in the disease incidence in most of the European territory of Russia. The oral vaccination campaign carried out in the country did not give the expected effect, except in some isolated regions. According to A. A. Shabeykin [27], the sylvatic nature

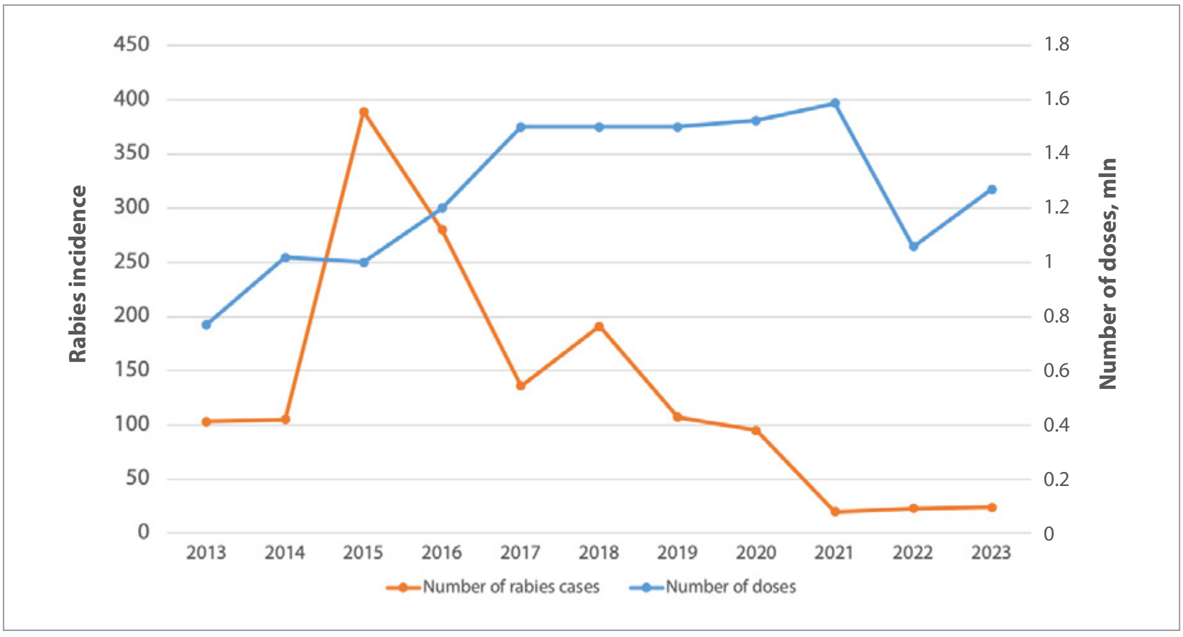

Fig. 8. Rabies incidence and number of the used oral vaccine doses in the Moscow Oblast in 2013–2023

of rabies in the Russian Federation underlies its spread geography, seasonality, outbreak periodicity and species involved in the epizootic process, and parameters of species- and spatiotemporal manifestations of the epizootic process are subject to constant changes. The large regions of the country, the size of the disease distribution area, the variety of geographical conditions, and the renewal of the reservoir animal population are the factors that significantly complicate the task of wild carnivore vaccination in Russia. This dictates the need to further improve the strategy of oral rabies vaccination.

Spatial analysis of the data and digital models of the epizootic processes created by A. A. Shabeykin [28] made it possible to determine rabies epizootic development patterns with regard to natural zones and provinces of the Russian Federation. In the conditions of mixed forest biomes, there is a shift towards higher number of rabies cases reported among wild carnivores. Rabies incidence in raccoon dogs is at its maximum level in forest biomes, where this animal species is most likely an additional biological reservoir of the rabies virus.

In the Moscow Oblast, too, despite the ongoing oral vaccination of wild carnivores in 2013, 2014, 2015 (0.770; 1.018; 1 million doses of vaccine were used, respectively), the number of rabies cases increased, reaching its maximum (389 cases) by 2015.

Since the oral vaccination method has proved its effectiveness in many countries of the world, a systematic, consistent and thoroughly arranged vaccination campaign was launched in the region. "Recommended practice for rabies oral vaccination of carnivores in the Moscow Oblast"[4] was developed and approved by the Main Veterinary Department of the Moscow Oblast and the annual number of the vaccines used increased: from 1.2 million doses in 2016 up to 1.587 million doses in 2021. The number of rabies cases in the wild fauna started decreasing. A slight increase in the rabies incidence in 2018 (191 cases) was replaced by a significant decrease by 2021 (20 cases), after which a kind of plateau was formed by 2023, when 24 cases of rabies were reported (Fig. 8).

A retrospective analysis of the rabies situation in the Moscow Oblast showed that in 2011–2023 there were three rises and falls in the intensity of the rabies epizootic process. The peaks occurred in 2012, 2015 and 2018. Despite the subsequent sharp decrease in the reported rabies incidence in the region, the disease is persisting in wild fauna, which suggests the presence of sylvatic rabies.

CONCLUSION

The rabies situation in the Moscow Oblast at the beginning of the period under review (from 2011 to 2015) can be considered tense. It was characterized by the sylvatic cycle of rabies and the epizootic periodicity [29]. The reservoirs are mainly red foxes. The subsequent implementation of the set of disease control measures, including intensive annual oral vaccination of wild carnivores in compliance with strict recommendations for its use, has reduced the reported incidence and the intensity of the epizootic process in the region. The Moscow Oblast Veterinary Service confirmed the high importance of constant monitoring of all handling of rabies-susceptible animals.

It was shown that a decrease in the number of annually reported rabies cases correlated with an increase in oral vaccine doses used. The data recording devices (camera traps) confirmed the up-take of oral rabies vaccine by target animal species (foxes).

The introduction of advanced scientific developments in laboratory diagnostics, enhancement of population immunity among wild carnivores through oral vaccination and analysis of the animal disease situation in neighboring regions have improved the animal rabies situation in the Moscow Oblast.

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