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Science-based assurance of the disease freedom in reindeer herds of the Russian Arctic zone

Kasim A. Laishev, Alexander A. Yuzhakov
St. Petersburg Federal Research Center of the Russian Academy of Sciences, 39, 14th Line V. O., Saint Petersburg 199178, Russia

ABSTRACT
Reindeer husbandry takes a leading position in the agricultural sector of the Russian Federation Arctic zone. The purpose of the research is to analyze the science-based assurance of the freedom from highly dangerous infectious diseases in reindeer herds of the Arctic zone. It has been established that diseases such as anthrax, brucellosis, footrot, rabies are still relevant for the reindeer husbandry and can cause not only significant economic damage, but also diseases in humans. The analysis of the archival data and literary sources, as well as own research data lead to the following conclusions: the greatest risk of anthrax occurrence and spread is posed by old carcass sites; to eradicate brucellosis, vaccination of animals along with the general disease control measures is necessary; in case of footrot, special attention should be paid to the control of blood-sucking insects and warble flies; to prevent rabies in reindeer herds, it is important to avoid contacts between deer and wild carnivores and consider emergency vaccination. Undoubtedly, the eradication and prevention of the above-mentioned infectious diseases requires constant epidemiological surveillance, including its element – monitoring, with all necessary special management, animal health measures. There is an obvious need for constant surveillance of infectious diseases in the Arctic zone of the Russian Federation using GIS technologies. It is important to pay special attention to the generation of special information layers related to disease characteristics, including deer herd migration routes, sites where anthrax outbreaks were recorded, and the location of disease-infected facilities.

Keywords: review, reindeer, infectious diseases, epizootic situation, science-based assurance

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For correspondence: Kasim A. Laishev, Dr. Sci. (Veterinary Medicine), Professor, Academician of the RAS, Chief Researcher, Department of Animal Husbandry and Sustainable Nature Management of the Arctic, St. Petersburg, Federal Research Center of the Russian Academy of Sciences, 7 Podbelskogo shosse, Pushkin, Saint Petersburg 196608, Russia, *e-mail: layshev@mail.ru*

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Научное обеспечение эпизоотического благополучия в оленеводческих стадах Арктической зоны Российской Федерации

К. А. Лайшев, А. А. Южаков
ФГБУН «Санкт-Петербургский Федеральный исследовательский центр Российской академии наук» (ФГБУН СПб ФИЦ РАН), 14-я линия В. О., 39, г. Санкт-Петербург, 199178, Россия

РЕЗЮМЕ
Северное оленеводство занимает ведущее место в сельскохозяйственной отрасли Арктической зоны Российской Федерации. Целью исследований является рассмотрение вопросов научного обеспечения эпизоотического благополучия по основным особо опасным инфекционным болезням в оленеводческих стадах Арктической зоны. Установлено, что такие болезни, как сибирская язва, бруцеллез, некробактериоз, бешенство, по-прежнему актуальны для оленеводческой отрасли и не только наносят существенный экономический ущерб, но могут быть причиной заболевания людей. В результате анализа архивных сведений и литературных источников, а также материалов собственных исследований сделаны следующие выводы: наибольшую угрозу возникновения и распространения сибирской язвы представляют старые падёжные места; при ликвидации бруцеллеза наряду с общехозяйственными мероприятиями необходима вакцинация животных; при некробактериозе следует особое внимание уделять борьбе с кровососущими насекомыми и оводами; для недопущения возникновения бешенства в оленеводческих стадах важно исключить контакты оленей с дикими плотоядными и рассмотреть возможность экстренной или вынужденной вакцинопрофилактики. Несомненно, ликвидация и профилактика вышеуказанных инфекционных

болезней требует постоянного эпизоотологического надзора, в том числе его элемента – мониторинга, проведения необходимых специальных общехозяйственных и лечебно-профилактических мероприятий. Очевидна необходимость постоянного надзора за инфекционными болезнями в Арктической зоне Российской Федерации с использованием ГИС-технологий. Особое внимание важно уделять формированию специализированных информационных слоев, связанных с эпизоотическими характеристиками, в том числе слоев маршрутов оленьих стад, территорий, на которых регистрировали вспышки сибирской язвы, слоев расположения неблагополучных по болезням объектов.

Ключевые слова: обзор, северные олени, инфекционные болезни, эпизоотическая ситуация, научное обеспечение

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Для корреспонденции: Лайшев Касим Анверович, д-р вет. наук, профессор, академик РАН, главный научный сотрудник отдела животноводства и рационального природопользования Арктики ФГБУН СПб ФИЦ РАН, шоссе Подбельского, 7, г. Пушкин, г. Санкт-Петербург, 196608, Россия, *e-mail: layshev@mail.ru*

INTRODUCTION

Reindeer husbandry takes a leading position in the agricultural sector of the Russian Federation Arctic zone. The economic significance of this industry is based on the sustainable management of the scarce food resources of the vast territories of tundra, forest tundra, and northern taiga. No livestock species, except for reindeer, can sustainably use about 300 million hectares of the Russian Arctic pastures [1].

According to the Russian Statistics Agency, the number of domesticated reindeer in the country is about 1.6 million animals in 2022. The largest number of reindeer are herded in the Yamalo-Nenets Autonomous Okrug, followed by the Nenets Autonomous Okrug, the Republic of Sakha (Yakutia) and the Chukotka Autonomous Okrug (Fig. 1).

The annual production capacity of reindeer husbandry is the following:

– about 20 thousand tons of high-quality dietary meat and offal;

– more than 400 thousand hides;

– more than 100 tons of antlers in velvet and other valuable by-products.

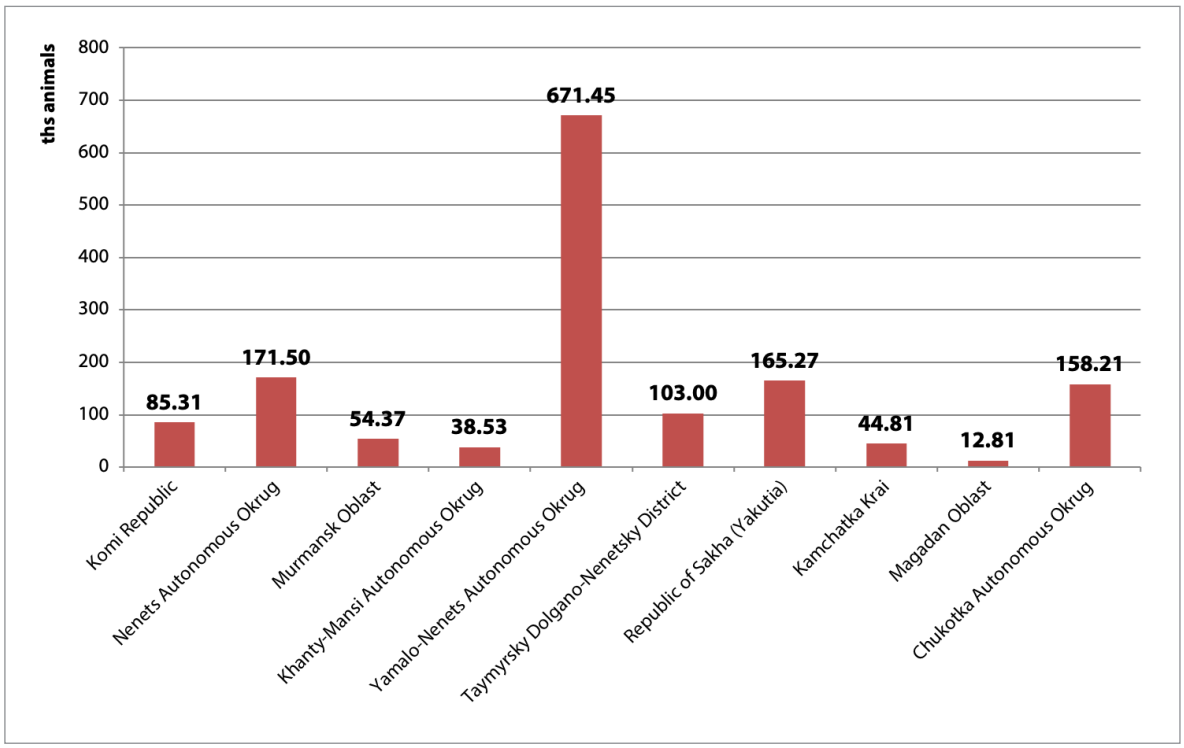

Fig. 1. The number of domesticated reindeer in the regions of the Russian Federation in 2022 (ths animals)

The prospects for the reindeer husbandry development are:

– deep processing of products (offal, glands, blood, hides), as well as promotion of reindeer products among consumers;

– export of products by large regional farms, optimization of supplies to the domestic market by small farms and private owners;

– development of ethnotourism and related activities (hunting, fishing, picking wild plants).

The main risk factors for the industry development include:

1) pastures:

– deliquination, overgrowth and decrease in plant community performance due to high grazing load;

– reduction of areas suitable for grazing due to commercial exploitation of lands, their use for hydrocarbon and mineral output, transport infrastructure;

– contamination of plant feeds with heavy metals at the local level (accidental pollution) and due to global atmospheric transport;

– changes in the species composition of the plant community due to global climatic changes, an increase in the proportion of herbaceous plants in the total phytomass;

2) organizational and economic measures:

– complicated logistics for the supply and export of products and high transportation costs (up to 50–60% of the product cost);

– lack of snowmobile maintenance services;

– low wages for reindeer herders, an acute shortage of qualified personnel (reindeer herders and veterinarians);

– low level of social protection and medical care for reindeer herders and their families, a shortage of women to start a family due to harsh living conditions;

3) diseases:

– epizootological and epidemiological risks associated with the endemic areas of anthrax and other infectious diseases;

– the emergence of new infectious diseases and pests due to global warming and occurrence of new vectors;

– decreased nonspecific resistance due to lack of feed.

The purpose of this analytical study was to summarize and analyze data on the situation related to major highly dangerous infectious diseases of reindeer, focusing on the main causes of their occurrence, as well as measures to prevent and control them.

MATERIALS AND METHODS

The results of the work are based on the analysis of archival data and literary sources, as well as on the own research data. Historical and comparative analysis, structural analysis, visualization, systematization, analog and generalization methods were used. The work was carried out at the St. Petersburg Federal Research Center of the Russian Academy of Sciences and on the reindeer farms of the Russian Arctic.

RESULTS AND DISCUSSION

Anthrax. The greatest danger for the occurrence and spread of the disease is represented by old carcass sites. In the past, during the outbreaks, in the absence of the disease control tools and methods, the reindeer herders left diseased and dead animals and migrated further and further on with a healthy herd until the outbreak stopped. Thus, a "trail" of unburied animals remained on the routes of reindeer herd migrations, forming the so-called carcass sites, covering the area of tens or even hundreds of square kilometers. There are more than 100 registered sites in the Arkhangelsk Oblast and the Komi Republic, more than 60 sites in Yamal, about 40 sites in Taymyr, more than 200 in Yakutia, there is a high number of them in other northern regions [2].

The particular danger of such infected territories is that they do not have concrete, well-defined registered borders. There are only landmarks, and the areas of sites are from 1 to 150 km^2 (Fig. 2).

The question "what to do with such a big number of carcass sites" has repeatedly been raised for a long time;

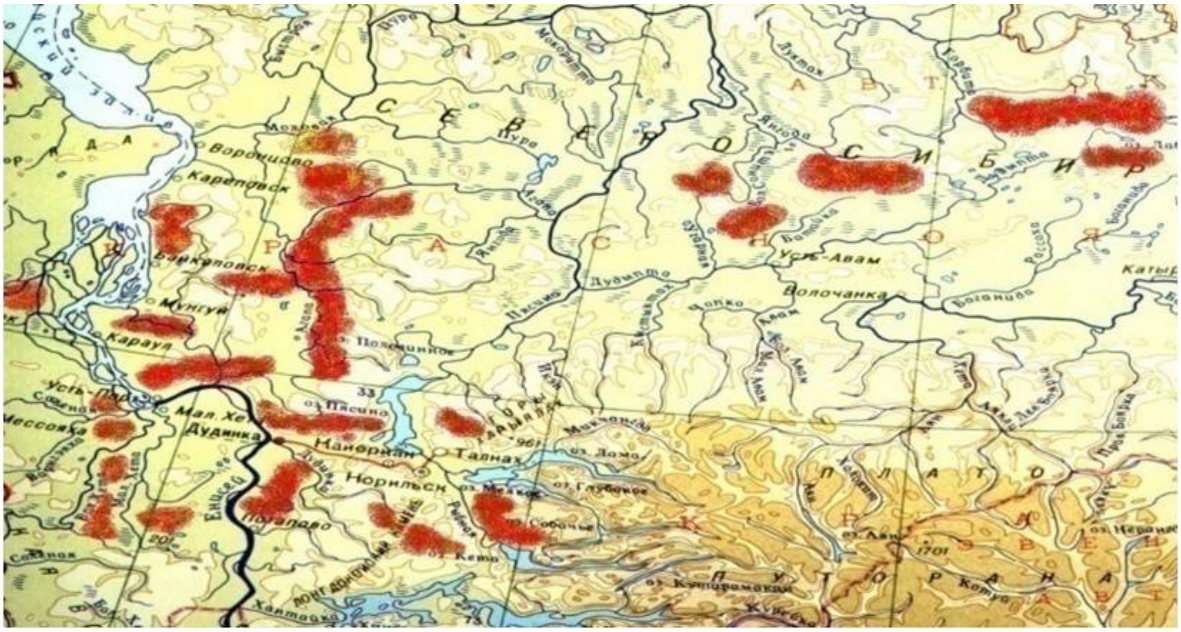

Fig. 2. Location of old carcass sites in the Taymyr Peninsula

discussions about the feasibility of blanket reindeer vaccination in the setting of transport difficulties, high labor intensity and costs of veterinary and preventive measures to be taken in reindeer husbandry have been held.

On the one hand, anthrax spores are known to survive and remain pathogenic in the soil for more than 70 years, therefore, carcass sites can still be potentially dangerous [3]. This is confirmed by anthrax cases among deer in the state farms "Popigaisky" (1969) and "Oktyabrsky" (1977), who grazed their herds in old carcass sites.

On the other hand, N. F. Gamaleya noted that anthrax spores can lose virulence and even be lysed under unfavourable conditions [4]. Ipatenko N. G. et al. emphasized that *Bacillus anthracis* spore germination heavily depends on a number of conditions: minimum temperature of 15 °C, organic matter content up to 14%, maximum humidity of 50% and minimum pH of 7.0 [5].

It should also be noted that domesticated reindeer herds are constantly grazing on the carcass sites, and they are not always vaccinated against anthrax, while a large number of constantly migrating wild animals are present in the region, earthworks and mining are actively carried out [6], however, with the exception of sporadic cases in the Taymyr Peninsula and in the Republic of Sakha (Yakutia), the disease has not been reported for more than 80 years.

Based on the data available and comprehensive studies conducted in the Yamalo-Nenets Autonomous Okrug, it was suggested that anthrax cases in deer herds are of external origin. In this context, it was decided to exclude the anthrax vaccination of reindeer from the routine vaccination plan in this region in 2007. However, in 2016, an anthrax outbreak occurred in one of the herds of domesticated deer in the Yamalo-Nenets Autonomous Okrug. The occurrence was explained by the exposure to the bacteria preserved in soil after unusual heat waves, which melted the permafrost. The animals were grazed on pastures where anthrax was reported in 1938–1941. 2,650 reindeer got diseased; 36 people got infected and one died after coming into contact with diseased and dead animals [7, 8, 9, 10]. Currently, vaccination against anthrax in the Yamalo-Nenets Autonomous Okrug is performed to the full extent.

To prevent anthrax infection and induce active artificial immunity in anthrax-risk areas, a lyophilized vaccine, containing live spores of strain 55 or STI is widely used. Immunity is formed 10 days after immunization and lasts for at least 12 months [2].

Speaking about anthrax prevention in reindeer, the focus should be made on the current research by scientists from the Pechora Veterinary Department of the Research Institute of Agriculture of the Komi Republic under the guidance of professor E. S. Kazanovsky and the All-Russian Scientific Research Institute of Veterinary Virology and Microbiology on the combined prevention of anthrax and infestations with warble flies. The results of the studies showed the good compatibility and the possibility of using iver-, avermectins and anthrax vaccine based on 55-VNIIVViM strain in one injection. It has been established that the pharmaceutical composition has a high preventive effectiveness against warble fly parasitizing larvae and induces stable immunity against anthrax with high antibody titers. Currently, unfortunately E. S. Kazanovsky's et al. methodological recommendations have not been approved and are not applied in practice [11].

Brucellosis. The first suspicion of brucellosis in reindeer herding farms in the Chukotka Peninsula were expressed in 1939 by A. V. Rudakov, but in natural conditions, brucellosis was first diagnosed in reindeer in Taymyr by serological and allergic skin tests in 1948 by I. M. Golosov, and in 1955 V. A. Zabrodin was the first to isolate *Brucella* strains from reindeer. For the first time, *Brucella* species specific for reindeer were isolated from wild animals by V. A. Zabrodin in the Taymyr Peninsula from the affected limb of a wild reindeer. Subsequent studies established a high brucellosis prevalence in wild reindeer in the Taymyr Peninsula, in some years reaching 35–40%. Later, when studying the epizootology of brucellosis, *Brucella* strains were isolated from other animal species (wolf, blue and white arctic fox, wolverine, ermine, sable, silver fox). Herewith, based on their morphological, tinctorial and biochemical properties, these strains were identical to *Brucellas* isolated from domesticated and wild reindeer, and belonged to *Brucella suis* biovar 4. These studies confirm that brucellosis endemic areas have established in certain Arctic territories of the Russian Federation [12, 13].

In the 60–80s of the last century, brucellosis was widespread in the reindeer farms of the Taymyr Peninsula (Dolgano-Nenets), Evenki, Yamalo-Nenets and Chukotka Autonomous Okrugs, the Kamchatka Oblast and the Yakut ASSR. The brucellosis prevalence in some herds reached 30–40%, and the number of clinically diseased animals was 20–25% [14].

The current brucelosis situation in domesticated reindeer herds of the Russian Arctic zone is described in the table.

When analyzing the economic damage to reindeer husbandry from brucellosis infection, it should be borne in mind that it includes losses from increased infertility and

Table
Number of reported reindeer brucellosis-infected localities in 2015–2021

RF Subject	2015	2016	2017	2018	2019	2020	2021
Khanty-Mansi Autonomous Okrug	0	0	1	0	0	0	0
Yamalo-Nenets Autonomous Okrug	7	6	6	9	9	7	5
Taymyrsky Dolgano-Nenetsky Municipal District	0	1	1	2	3	1	0
The Republic of Sakha (Yakutia)	45	42	42	37	35	26	21
Chukotka Autonomous Okrug	1	1	1	1	1	1	1
Total	53	50	51	49	48	35	27

abortions in females, weak, often dead new-born calves, emergency culling and slaughter of animals showing clinical signs of the disease and positive reactors in diagnostic tests, irregular economic activities due to quarantine restrictions in infected herds, additional costs for diagnostic and health improvement measures.

Particularly noteworthy is the risk of reindeer brucellosis to the health of humans, especially those who consume products from diseased animals, mainly non heat-treated (traditional cuisine of indigenous minorities of the northern regions), as well as those involved into reindeer herding or primary processing of reindeer products [15, 16].

Initially, to prevent and control brucellosis many researchers recommended using only general animal health measures in reindeer husbandry, however, experience has shown that this is not enough to eradicate brucellosis in reindeer, since there are brucellosis endemic areas, and the technological features of this industry do not allow taking proper and comprehensive actions.

Currently, health status is improved using vaccines based on *Brucella abortus* 82 strain in accordance with the approved guidelines [17].

In the light of my own experience with reindeer brucellosis, I would like to note the following:

1. It is impossible to solve the brucellosis problem in reindeer herds without vaccination. Long-term efforts were made to eradicate brucellosis without using vaccines in the Magadan Oblast, but no particular achievements have been gained.

2. The vaccine based on *Brucella abortus* 19 strain has been undeservedly neglected. It is the most stable and most potent strain. Therefore, it is necessary to recommend the use of this vaccine, especially in the regions where brucellosis endemic areas have formed (Taymyr, north-west of the Republic of Sakha (Yakutia) and north-east of Yamal). The effectiveness of such vaccination has been confirmed by the positive results of reindeer immunization in the Taymyr Peninsula. This vaccine is criticized for its long-term post-vaccination titers, but if administered in small doses, the titers disappear within 6–9 months, and long-term post-vaccination titers in reindeer were reported after the use of vaccines based on other strains.

3. Immunization doses of brucellosis vaccines for reindeer should be reviewed and approved. Reindeer are significantly smaller than cattle, and it is not feasible to administer 1/2, 1/4 of the full cattle dose, since it has been proved in theory and practice that high antigen doses, on the contrary, suppress the immune system, and consequently, the development of strong immunity.

4. The issue of diagnostic reactions and diagnostic antibody titer in reindeer requires additional studies. Now some specialists use ELISA to diagnose brucellosis in reindeer, and they do not know what to do with positive reactors. Are positive titers equal to 1:25, 1:50 so dangerous if there are no clinical signs and the brucellosis agent has not been isolated by bacteriological testing?

Footrot. Footrot of reindeer in the Russian North conditions was firstly studied by N. I. Ekkert, who described its major clinical signs in 1898 [18]. In 1909 E. N. Pavlovsky wrote that digital suppurative inflammation causing great damage to the nomads of circumpolar tundra was reported every year in the tundra and forests of the Arkhangelsk governorate [19]. The disease can affect 1.5 to 50% of reindeer in herds.

According to I. M. Golosov and B. V. Maslukhin [20], and state statistical reports, 42,834 reindeer died from footrot in the Taymyr National District over 16 years (1950–1965). As noted by I. G. Machakhtyrov [21], in the 90s of the last century, 10 to 50 thousand reindeer got diseased in the Republic of Sakha (Yakutia) as a whole, and the mortality rate reached 32.1%.

Currently, footrot of reindeer is not included into official statistical data, in our opinion, this is due to the need to impose quarantine restrictions in case of a positive result, which is not beneficial to animal owners, but this means, the causative agent is still circulating in reindeer herds. This is confirmed by studies of the reindeer rumen microbiome: *Fusobacterium necrophorum* species were isolated from more than 50% of animals [22, 23].

Speaking about the prevention of this disease in reindeer herds, it should be noted that many scientists are working on the creation of the specific means to control this disease in reindeer. Currently, footrot vaccines have been developed, but they are rarely used in reindeer husbandry, since they either cause post-vaccination complications or do not fit into the reindeer husbandry technology. However, the development of the vaccines to prevent footrot of reindeer is an important and relevant issue.

Currently, the most effective treatment is the wound debridement and subsequent antimicrobial therapy with drugs mainly based on oxytetracycline (for example, Nitox). Combined systemic drugs are now widely used: Tetracine, Fusobaksan-2 and Fusobarin, Necrofar-C, as well as a topical drug – Necrogel, which can increase the effectiveness of footrot treatment compared with a conventional therapy by more than 2–3 times. We believe that work in this area needs to be continued. Research on antibacterial aerosols to treat wounds and improve tissue regeneration as well as long-term protection of wounds from re-infection are promising.

General animal health and hygiene measures aimed at increase of natural resistance of the body and protecting from harmful environmental factors are of paramount importance in the disease control strategy.

First of all, the footrot issue, of course, should be considered in association with blood-sucking insect and warble fly control. Together with the scientists from the All-Russian Scientific Research Institute of Veterinary Entomology and Arachnology (Tyumen), we have tested new drugs to control gnats and warble flies in reindeer herding farms of the Yamalo-Nenets Autonomous Okrug and the Taymyrsky Dolgano-Nenets Municipal District. The production tests proved that the footrot incidence in herds in which reindeer were treated against gnats and warble flies was 6.5 times lower than in non-treated herds [24]. Research in this area should be continued, and first of all they must be aimed at the development of insecticides and repellents providing longer protection.

In our opinion, the proper winter grazing and mineral supplementation of animals during winter and early spring seasons are important for the prevention of footrot and other diseases of reindeer. Together with the staff of the Naryan-Mar agricultural research station, a concentrated feed containing carbohydrates, vitamins and minerals was developed, which can be successfully used for feeding reindeer in winter and spring. Economic efficiency of the feed additive use in a 1,800 reindeer herd

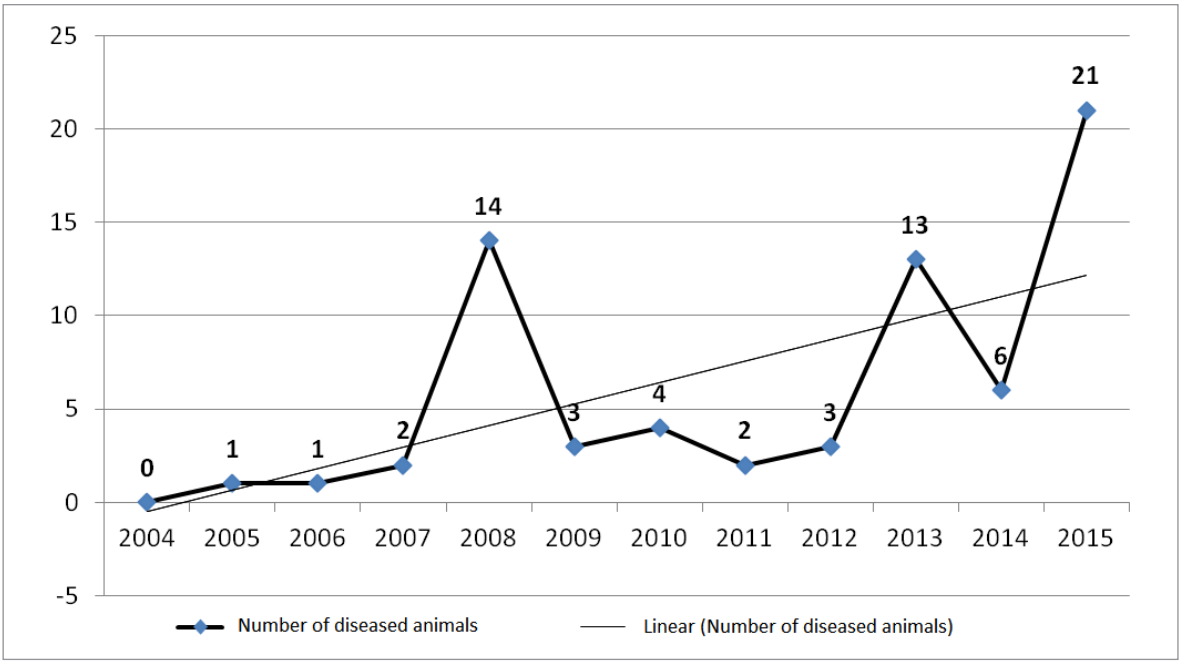

Fig. 3. The dynamics of rabies incidence in the Nenets Autonomous Okrug in 2004–2015

within 40 days is more than 1.2 million rubles. Together with Biotrof+ LLC, research is being conducted on the topic "Microbiome of *Rangifer tarandus* rumen in the Russian Arctic". In the course of the studies microorganisms from reindeer rumen were obtained, being a potential source of cellulases and biodegraders of toxins, produced by micromycetes. Currently, a range of therapeutic and prophylactic drugs are being developed on the basis of these microorganisms [25].

Rabies. Previously, animal rabies in the Russian Arctic zone was reported quite rarely and most often it was called "dikovanie" (the state of being furious). The peculiarities of rabies manifestation in the high latitudes contributed to the formation of the concept that an independent animal disease exists in the tundra zones known as "dikovanie", or, in other words, Arctic rabies, but currently the causative agent of "dikovanie" is recognized as a geographical variant of the classic rabies virus [26]. In recent years, rabies has been periodically reported in the Nenets and Yamalo-Nenets Autonomous Okrugs, and the Republic of Sakha (Yakutia).

Thus, in the territory of the Nenets Autonomous Okrug, rabies in carnivorous animals and reindeer is reported annually, creating a complicated epizootological and epidemiological situation in the regions. The dynamics of the rabies incidence in this district in 2004–2015 reflects the problem in 2008, 2013 and 2015 (Fig. 3) [27].

Microscopic examinations using fluorescent antibodies (FA) technique of pathological samples (brain) from various animal species, which died in the Okrug, 70 (54%) of 130 samples were positive, among them 37% were samples from domesticated reindeer, 53% from wild animals (Arctic foxes – 33%, foxes – 20%), 10% from stray dogs. Animal cases were reported in the winter-spring periods (February – March) during active migration and breeding seasons of wild carnivores. In the same period or somewhat later (April – May), taking into account the latency period, cases among domesticated reindeer were reported.

CONCLUSION

Thus, it has been established that diseases such as anthrax, brucellosis, footrot, rabies are still relevant for the reindeer husbandry and can cause not only significant economic damage, but also diseases in humans. Summarizing the above, the following conclusions can be drawn: the risk of anthrax occurrence and spread is mostly associated with old carcass sites; brucellosis eradication requires animal vaccination along with general animal health measures; speaking about footrot, special attention should be paid to the control of blood-sucking insects and warble flies; to prevent rabies in reindeer herds, it is necessary to exclude contacts between reindeer and wild carnivores and consider the possibility of vaccination. Undoubtedly, the eradication or prevention of the above-mentioned infectious diseases requires constant epizootological supervision, appropriate special management and animal health measures.

There is an obvious need for constant surveillance of infectious diseases in the Arctic zone of the Russian Federation using GIS technologies. It is important to pay special attention to the generation of special information layers related to disease characteristics, including deer herd migration routes, areas where anthrax outbreaks were recorded, and locations of disease-infected facilities. For example, if the layers of locations of carcass sites, cyclone sites infected with a pathogen, migration routes of wild animals, etc. are known, it is possible to plan the droving routes that reduce the risk of certain infectious disease occurrence in deer and, most importantly, to actively introduce comprehensive veterinary and preventive measures.

In conclusion, it should be noted that the review takes into account only the most significant infectious diseases of reindeer. Of course, reindeer herding establishments should take into account foot-and-mouth disease, paratuberculosis and other infectious and emergent diseases, depending on the region. For example, in Taymyr and Yamal, a head disease has been repeatedly reported, the etiology of which is still understudied.

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INFORMATION ABOUT THE AUTHORS / ИНФОРМАЦИЯ ОБ АВТОРАХ

Kasim A. Laishev, Dr. Sci. (Veterinary Medicine), Professor, Academician of the RAS, Chief Researcher, Department of Animal Husbandry and Environmental Management of the Arctic, St. Petersburg Federal Research Center of the Russian Academy of Sciences, Saint Petersburg, Russia;
https://orcid.org/0000-0003-2490-6942, e-mail: layshev@mail.ru

Alexander A. Yuzhakov, Dr. Sci. (Agriculture), Associate Professor, Chief Researcher, Department of Animal Husbandry and Environmental Management of the Arctic, St. Petersburg Federal Research Center of the Russian Academy of Sciences, Saint Petersburg, Russia; *https://orcid.org/0000-0002-0633-4074, e-mail: alyuzhakov@yandex.ru*

Лайшев Касим Анверович, д-р вет. наук, профессор, академик РАН, главный научный сотрудник отдела животноводства и рационального природопользования Арктики, ФГБУН СПб ФИЦ РАН, г. Санкт-Петербург, Россия; *https://orcid.org/0000-0003-2490-6942, e-mail: layshev@mail.ru*

Южаков Александр Александрович, д-р с.-х. наук, доцент, главный научный сотрудник отдела животноводства и рационального природопользования Арктики, ФГБУН СПб ФИЦ РАН, г. Санкт-Петербург, Россия; *https://orcid.org/0000-0002-0633-4074, e-mail: alyuzhakov@yandex.ru*

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