Scientific Papers. Series D. Animal Science. Vol. LXV, No. 2, 2022
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

THE INFLUENCE OF THERMAL VARIATIONS ON THE INCIDENCE OF RABIES IN ANIMAL BIODIVERSITY

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Abstract

This paper presents the results of the study of the epidemiological situation of rabies in the last 10 years on the territory of the Republic of Moldova. It has been found that the most susceptible animal species to rabies virus are cattle (358 cases), dogs (304 cases), foxes (186 cases) and cats (150 cases), which constitute 91.14% of the total number of cases recorded in animals in the last 10 years. The fox is the rabies-reservoir species and the main vector of its spread in wild animal populations. In the livestock sector, cattle are the most affected and constitute 32.69%. Data obtained from the study show that rabies is developing sporadically. In the population of wild animals other than foxes, cases of the disease are not dependent on the existence of infected foxes in that area. It has also been found that there is no significant correlation of rabies in fox and dogs, fox and cattle, or dogs and cattle. At the same time, there has been found a correlation between the number of fox units and rabies cases and a cyclicity of rabies cases every 4 years (2012-2015 and 2016-2019). The influence of thermal variations on the incidence of rabies in living biodiversity has specific oscillating effects according to the years of study, with multiple divergences, which require a well-founded argument, based on the existing importance of the problem approached through high-performance scientific research.

Key words*: animal biodiversity, rabies, temperature.*

INTRODUCTION

Rabies remains a global complex problem, being one of the oldest viral zoonoses known to man. Rabies (lat. *rabies*, derived from rabhas - Old Sanskrit: to be violent) or madness has been recorded, over time, with a variable frequency, on all continents. Some countries, favored by their geographical position or as a result of drastic control measures, have managed to become and/or remain free from rabies (Australia, Iceland, Japan, New Zealand, Hawaii, England, Ireland, Spain, Portugal, Norway, Sweden, etc.). In general, the incidence of rabies cases has varied over time and varies widely across countries and from year to year. About 60,000 deaths are reported in humans each year in the world, but their actual number is of course much higher (OIE, 2018; OIE, 2021; Shankar et al., 2012; Бешенство, 2020). The global economic burden of rabies is estimated at 8.6 billion USD a year. Children under the age of 15 make up 40% of people who are bitten by animals suspected of rabies (FAO, 2018). Rabies is currently considered one of the most neglected diseases in the world, but it is a real burden for the developing countries (Jackson & Wunner, 2007). In the vast majority of human rabies deaths, dogs are the source of infection, accounting for up to 99% of all human rabies transmission, contributing up to 99% of all rabies transmissions to humans (Sudhi, 2014).

Rabies incidence in different countries. The incidence of rabies in different countries varies somewhat, influenced by the population dynamics of the rabies-reservoir species, by their state of immunity, the geographical peculiarities of the areas involved. In Europe, according to the World Organization for Animal Health (OIE), about two-thirds of rabies cases are reported in wild animals, and almost one-third of cases in domestic animals (OIE, 2021; Moga Mânzat, 2000).

All species of homeothermic animals are susceptible to rabies virus infection, but only a few of them are an important reservoir of the disease depending on the geographical region. Globally, the reservoirs differ depending on the continent, namely: in North America the most important reservoir are raccoons (*Procyon lotor*), skunks (*Spilogale gracilis* and *Mephitis*

mephitis) and bats, in South America, bats (*Desmodus rotundus*), in South Africa, jackals (*Canis adustus* and *Canis mesomelas*) and mongooses (*Suricata suricata*). According to the World Health Organization (WHO), in about 95% of human rabies cases reported in Asia and Africa, the dog is the main reservoir (Macpherson et al., 2013). In Europe, the fox (*Vulpes vulpes*) is the natural reservoir of rabies and the main vector of its spread in wild and domestic animal populations. In this context, since 1989, rabies vaccination of foxes has been the main tool in eliminating rabies in many European countries. In this way, it has been possible to reduce the number of cases of the disease or even to obtain the status of "rabies-free" countries (OIE, 2018, 2021; Müller et al., 2015; Najar & Streinu-Cercel, 2012; Shankar, 2012).

WHO, OIE and Food and Agriculture Organization of the United Nations (FAO) proposed to jointly eliminate as soon as possible the risks posed by rabies to both animal (either domestic or wild), and human health, and as a basic goal they pointed out that by 2030 there should be recorded zero human deaths due to rabies (Блохин et al., 2019; FAO, 2021; OIE, 2018; Robardet et al., 2019; WHO, 2021).

In order to reduce the number of rabies cases in the national territory, the Republic of Moldova has joined the WHO, OIE and FAO initiative to combat rabies and thus in 2019 approved the Measure Plan for the surveillance, control and eradication of rabies in the foxes of the Republic of Moldova for the years 2019-2023, to obtain the status of a rabies-free country.

According to the Measure Plan for the surveillance, control and eradication of rabies in the foxes of the Republic of Moldova for the years 2019-2023, to ensure the progressive reduction of rabies in the Republic of Moldova, until obtaining the status of a "rabies-free" country, it is expected to implement concrete action measures, one of which is the rabies vaccination of fox populations with vaccine baits (HG, 2019). For the successful implementation of the above-mentioned Plan, it is necessary to study the influence of environmental factors (especially temperature) on the incidence of rabies in animals.

MATERIALS AND METHODS

We performed a descriptive study evaluating the trend of rabies disease in the Republic of Moldova, both in wild animals and in humans between the years 2012-2021. We also performed an analysis of the literature and gathered epidemiological data from the WHO Rabies Bulletin Europe database, from the European Center for Disease Prevention and Control (ECDC) Epidemiological Reports and from the Annual Reports of the National Agency for Food Safety of the Republic of Moldova.

The materials analyzed for this paper were presented by the National Agency for Food Safety, the I.P. Republican Center for Veterinary Diagnosis, Institute of Zoology and the State Hydrometeorological Service. The statistical processing of the obtained cipher material was performed by the established methods for the biological field.

RESULTS AND DISCUSSIONS

The Republic of Moldova is one of the countries with the highest number of rabies cases in Europe, surpassed only by Ukraine, where about 1400 cases of rabies in animals and approximately 12 fatal cases in humans are registered annually (OIE, 2018, 2021).

Rabies is registered throughout the national territory, but most frequently it is registered in the districts of Edinet, Ungheni, Anenii Noi, Causeni, Falesti, Straseni, Nisporeni, Soroca, Cahul and Chisinau (Figure 1).

Figure 1. Distribution of rabies cases on the national territory for the years 2012-2021

According to the data presented by the I.P. Republican Center for Veterinary Diagnosis during the 2012-2021 study period, it has been found that most cases of rabies were reported in cattle, dogs, foxes and cats (Table 1). If we refer to dogs then most positive cases were recorded in rural areas. This is explained by the fact that the dogs from rural areas have been in more frequent contact with wildlife and thus increase the cases of disease transmission from wild animals to the domestic ones (wild animals-dogs-domestic animals).

Table 1. Number of rabies cases by animal species for the years 2012-2021 (10 years)

Year	Foxes		Dogs		Cats		Cattle		Other animals	
	cases	%	cases	%	cases	%	cases	%	cases	%
2021	3	13.0	8	34.8	3	13.0	8	34.8	1	4.3
2020	15	16.9	22	24.7	12	13.5	37	41.6	3	3.4
2019	17	18.3	22	23.7	14	15.1	34	36.6	6	6.5
2018	16	18.0	24	27.0	15	16.8	29	32.6	5	5.6
2017	13	22.0	13	22.0	7	11.9	22	37.3	4	6.8
2016	12	12.5	34	35.4	17	17.7	25	26.0	8	8.3
2015	30	15.0	51	25.6	25	12.5	74	37.0	20	10.0
2014	33	21.0	57	36.3	18	11.5	26	16.6	23	14.6
2013	25	19.7	37	29.1	19	15.0	42	33.0	4	3.1
2012	22	13.6	36	22.2	20	12.3	61	37.7	23	14.2
Total (10 years)	186	16.98	304	27.76	150	13.69	358	32.69	97	8.85

The data in Table 1 show that the fox is the main reservoir of rabies in wildlife. The presence of rabies in wildlife is a major risk for both animals and humans, thus being considered the most important anthropozoonosis with serious consequences (100% lethality) for animals and humans.

This eminent danger for domestic animals and humans has been accentuated lately as the foxes started nesting more and more often even in the localities (Table 2). This state of affairs increases the risk of rabies in both animals and humans.

Table 2. Distribution of fox breeding units in favorable ecosystems for 2021

Species	Agrocoenoses (2540 thousand ha)	Human settlements (314 thousand ha)	Forest Fund (335 thousand ha)
Foxes (*Vulpes vulpes*)	14.2 thousand	6 thousand	3.8 thousand

According to the Institute of Zoology, the density of foxes in autumn in the Republic of Moldova in the last 10 years is about 36,000 animals (Table 3). From a numerical point of view, in recent years, the population of foxes in the Republic of Moldova has remained constant, which means that their density is 10-12 specimens per 1000 ha. This amount is ten times higher than the optimal number of this species (1-2 foxes per 1000 ha).

Table 3. The (estimated) number of foxes in the Republic of Moldova for the years 2012-2021

Year	Herd of foxes (specimens) (thousand)		Effective (growth thousand)
	Effective spring	Effective autumn	
2021	24000	35000	11000
2020	25000	37000	12000
2019	29000	36000	7000
2018	28000	35000	7000
2017	28000	34000	6000
2016	27000	33000	6000
2015	26000	29000	3000
2014	28000	38000	10000
2013	30000	41000	11000
2012	32000	42000	10000
10 year average	27700	36000	8300

Data showing the total number of rabies cases in animals according to the reference years are distributed as follows in Figure 2.

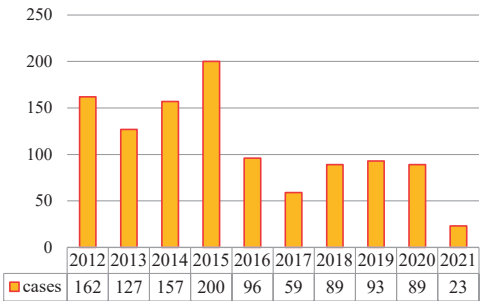

Figure 2. The total number of cases of rabies among animals for the years 2012-2021 (heads)

The data in Figure 2 show that the number of animal rabies cases is higher in the years 2012-2015 with a maximum of 200 cases in 2015 and an average of 161 cases in this period (4 years). In subsequent years, there has been a sharp decline in rabies in animals as compared to the previous period. The "relatively low" level is maintained during the years 2016-2020 with a maximum of 96 cases registered in 2016 and an average of 84 cases in these 4 years. The explanation of the established phenomenon is mainly predetermined by the reduction of the average number of foxes in the autumn unit in their natural habitat from 37,500 thousand in 2012-2015 to 34,500 thousand in 2016-2019.

At the same time, we mention that in 2021, from the data available at the time of writing this article, there were only 23 cases of rabies. The small number of rabies cases can be explained by the fact of application of prophylaxis measures by starting the vaccination of wildlife by terrestrial methods of distribution of vaccine baits directly in front of the mapped burrows throughout the country. Concomitantly, the baits were distributed by air via four special aircraft, automatically with the help of a "thrower" with a frequency of 25 baits per km^2 and a distance between the flight lines of 500 meters. Therefore, the applied intervention significantly reduced the number of cases of rabies, demonstrating the effectiveness of the measures taken and the post-vaccination resistance of the animal unit to the rabies virus produced by enhancing the body's immune properties and increasing the biological response of animals to this morbidity.

The research continued by studying the influence of ambient temperature on the incidence of rabies cases in wild and domestic animals. The temperature on the territory of the Republic of Moldova was recorded in three meteorological stations in the north in Briceni district, in the center in Chisinau municipality and in the south in Cahul. Based on the recorded data, the average temperature was calculated throughout the country during the years 2012-2021. The results of the study are presented in Table 4.

Table 4. Average monthly temperature for the years 2012-2021 in the Republic of Moldova (ºC)

Month	Year									
	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
January	0.21	0.22	-2.66	-0.80	-4.86	-3.16	-0.73	-2.03	-2.56	-2.70
February	0.13	3.94	2.26	-1.43	-0.81	4.61	0.53	-1.01	0.86	-8.42
March	3.51	7.62	7.20	0.93	7.60	6.13	5.03	7.81	1.92	4.33
April	8.32	11.13	10.33	14.91	9.53	13.13	10.13	11.10	12.21	12.93
May	15.32	14.21	16.46	18.86	16.10	14.63	17.10	16.33	18.70	18.33
June	19.91	21.22	22.60	21.23	20.93	21.01	20.13	19.62	20.62	22.41
July	23.61	22.70	21.56	21.66	21.76	22.96	23.53	22.00	21.16	25.36
August	21.31	23.42	22.93	23.63	22.83	22.22	23.93	22.13	21.81	22.73
September	15.31	19.71	17.86	17.52	18.01	18.52	19.31	17.66	14.31	18.66
October	9.70	14.23	11.86	12.76	10.73	7.93	9.56	9.73	10.76	12.43
November	6.70	4.81	7.90	2.56	5.36	3.44	6.56	3.72	8.16	6.03
December	0.53	2.10	2.80	-1.03	2.93	0.72	2.63	-0.31	0.06	-3.33
Annual average	10.38	12.14	11.75	10.89	10.84	11.00	11.47	10.55	10.66	10.72

The data in Table 4 show that the average annual temperature in the Republic of Moldova during the years of study is in the range of 10.38°C to 12.14°C. The minimum average temperature was 10.38°C in 2021, and the maximum average temperature was 12.14°C in 2020 (difference 1.76°C).

It is known that the rabies virus is quickly destroyed by sunlight and heat, but it is also well preserved in low temperatures and frost for long periods (Turcitu, 2007; Шевченко, 2013). In this context (Литусов, 2018) states that at 0ºC, the virus is stored for several weeks. He also mentions that in animal carcasses at low temperatures the virus can be

stored for up to 4 months. Based on this statement, it can be concluded that in the cooler years the rabies virus is preserved longer in the environment, causing the infection of more animals and increasing the number of rabies cases.

Table 5. Average annual temperature and number of rabies cases in the years 2012-2021 in the Republic of Moldova

Year	Cases of rabies (heads)	Temperature (°C)
2021	23	10.38
2020	89	12.14
2019	93	11.75
2018	89	10.89
2017	59	10.84
2016	96	11.00
2015	200	11.47
2014	157	10.55
2013	127	10.66
2012	162	10.72

However, the data in Table 5 show that the influence of thermal variations on the incidence of rabies cases in animal biodiversity has specific oscillating effects according to the years of study, with multiple divergences and the frequency of rabies cases is not subject to the above statement.

CONCLUSIONS

Although the number of animals detected with rabies has clearly decreased in recent times, the disease continues to cause material damage and obvious risks to the biodiversity of the wildlife, the national economy and civil society. The frequency constancy is defined by the occurrence of repeated cases of rabies in animals in the same localities, becoming outbreaks of major epidemiological significance. It should be noted that the large number and diversity of wild and domestic animals involved in the epidemiological process increases the potential for rabies cases in the animal and human population.

The data obtained from the study show that rabies is evolving sporadically. In the wildlife population other than foxes, cases of the disease are not dependent on the existence of infected foxes in the respective area. It has also been found that there is no significant correlation of rabies in fox and dogs, fox and cattle, or dogs and cattle. At the same time, there has been found a correlation between the number of fox units and rabies cases and a cyclicity of rabies cases every 4 years (2012-2015 and 2016-2019). The influence of thermal variations on the incidence of rabies in living biodiversity has specific oscillating effects according to the years of study, with multiple divergences, which require a well-founded argument, based on the existing importance of the problem approached through high-performance scientific research.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Institute of Physiology and Sanocreatology and was financed from the Project 20.80009.7007.25 “Methods and procedures for maintenance and conservation of biodiversity depending on the integrity of gametogenesis and food variability”.

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