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SPATIAL AND TEMPORAL PATTERNS OF ENZOOTIC RABIES ON THE TERRITORY OF CHERNIHIV OBLAST OF UKRAINE

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Summary. Rabies is particularly dangerous disease of all warm-blooded animals and humans. Ukraine has been experiencing an uneasy epizootic situation on rabies in recent years. The objective of this study was to determine the spatial and temporal patterns of enzootic rabies in Chernigiv Oblast of Ukraine in 2011–2016. Space-time clusters of rabies cases with a 'sporadic' time trend were identified in central and south-western raions of Chernihiv Oblast. Three clusters of a 'new' time trend in the far south-east of the oblast may be connected with the termination of the 2015 oral immunization of wild carnivores against rabies in Poltava and Sumy oblasts.

Keywords: enzootic rabies, epizootic situation, domestic animals, wild animals, surveillance, space–time cluster

Introduction. At the beginning of XXI century rabies epizootic situation in Ukraine remains insufficiently studied and controlled with permanent and periodic fluctuation of prevalence and significant outbreaks of disease (Pötzsch et al., 2006; Hryshok et al., 2009; Nychyk et al., 2013). The territory in Chernihiv Oblast is not an exception.

By the end of 1960 the main source of rabies were dogs. Later rabies epizooty of the 'natural' type began. Its reservoir presented by the wild carnivores. Due to the adaptation of the virus and the new reservoir of infection there has been a change in the manifestation of epizootic disease by moving its center to the countryside with the active participation of enzootic in domestic and farm animals.

There are more than 10 species of wild carnivores, in Chernihiv Oblast which can be a source of rabies virus in nature. As for the number a red fox takes the first place (*Vulpes vulpes*), then a marten and other members of the marten family (badgers, otters, weasels and minks), then — raccoon dogs, wolves and lynxes. The peculiarity of foxes ecology, their synanthropization, permanent contacts with homeless dogs and cats, uncontrolled breeding, the presence of a source of infection are prerequisites for the emergence of rabies and the formation of stable seats of infection. All these elements together with social and economic factors determine the impossibility of rabies eradication (Nedosiekov et al., 2009).

By rabies enzootic its lethal effect generally reduces the population of the main type of reservoir — a red fox. However, enzootic activity increases when the region is populated by new generations of susceptible hosts, creating cycles of peaks every few years (2006, 2010, 2016) (Golik, Polupan and Nedosekov, 2015).

The analysis of the situation for the rabies demonstrated that in contrast to some European countries where the cases of rabies are registered only among wild animals, in Ukraine dogs and cats are involved actively, so we can observe enzootic 'evolution' towards intensification and consolidation the chains of 'natural' and 'city' rabies.

A separate problem in Ukraine is a large population of homeless animals. According to the Central Sanitary and Epidemiologic Service in Ukraine over the past decade 76,000–78,000 calls from citizens about dog bites (26.3–27.8% stray dogs) and 15,000–18,000 appeals concerning contacts with cats are registered every year.

Radical efforts (oral immunization of wild carnivores — ORV) to curb the spread of rabies epizootic in Chernihiv Oblast were conducted in 2006–2010. Generally there have been held five campaigns (in 2006, 2007, twice in 2008 and 2010) by distributing baits by hand in 2006 and 2007, and using air transport twice in 2008 and 2010. Taken into account the lack of systematic and planned use of ORV significant progress in reduced manifestations of rabies could not be reached.

The cases of rabies which are analyzed in this article were documented in existing surveillance system in Ukraine — identifying sick animals or diagnostic shooting wild animals, pathological material delivery to the regional veterinary laboratory and the laboratory research method Flourescent Antibody Test (FAT) (in some cases by biotest).

In this study, space-time patterns of the rabies epizooty in Chernihiv Oblast were identified, and described with spatial cluster techniques, to assist in understanding the natural dynamics of rabies.

In order to develop more effective control strategies using parenteral rabies vaccination of pets or ORV, it is necessary to examine the disease patterns in space and time, with the goal of understanding how such patterns might support the development of more efficient rabies control strategies (Recuenco et al., 2007; de Andrade et al., 2016).

The aim of the research was to examine spatio-temporal distribution of rabies outbreaks in 2011–2016 in Chernihiv Oblast.

Materials and methods. The database, containing of 463 animal rabies cases in Chernihiv Oblast of Ukraine for the time period 2011–2016 was constructed. Every case of rabies was georeferenced to the centroid of the nearest village.

Spatio-temporal data analysis was performed with Spatial Statistics, Spatial Analyst, Space Time Pattern Mining toolsets of ESRI ArcMap 10.3.

Standard deviational ellipses (ellipse size = 1 standard deviation, excluding weights) were built to compare central tendency, dispersion, and directional trends of rabies cases for each year.

To estimate where more cases occur during study period we used Kernel density estimation (KDE) method. The optimal search radius for KDE was calculated following Fotheringham, Brunsdon and Charlton (2000):

$$h_{opt} = \left(\frac{2}{3n}\right)^{\frac{1}{4}} \sigma,$$

where σ is the standard distance — a measure of dispersion around the spatial mean of the rabies cases locations. Standard distance was calculated with the Spatial Statistics toolbox in ArcGIS 10.3.

To identify spatio-temporal trends of rabies cases Emerging hotspot analysis was performed. This tool is based on Getis-Ord G* statistic to find out statistically significant clusters of high values (hotspots) and Mann-Kendall statistic to detect time trend in each location. This analysis requires the point data to be aggregated into cells that have specific spatial and temporal size composed into space-time cube in the study area. We chose 14 km spatial cell size (the average rabies-threatened distance) and temporal size — 2 months (average incubation period for rabies). We used 47 km neighborhood distance at which the highest autocorrelation is detected on our data by Spatial Autocorrelation by Distance tool.

Results. The cases of rabies in animals during 2011–2016 were observed in all raions of Chernihiv Oblast except Varvynskyi raion, located in the far south-east of the region. During this period there were registered 463 cases of rabies: 313 cases of rabies among domestic animals and 150 — in wild (Table 1).

Table 1 — Rabies cases, Chernihiv Oblast, 2011–2016

Species	2011	2012	2013	2014	2015	2016	Grand Total
beaver		1		1			2
badger						1	1
wolf		1			3	1	5
cattle	1	10	7	9	8	5	40
boar			1				1
fine cattle		3			1	3	7
raccoon dog	7	3	6	1	14	4	35
horse	1	1	2				4
cat	28	39	30	8	28	47	180
roe					1		1
mole		1					1
marten	1	3					4
fox	16	16	17	8	15	24	96
mouse					1		1
muskrat			1				1
lynx	1					1	2
dog	12	13	19	5	8	25	82
Grand Total	67	91	83	32	79	111	463

During 2011–2016 the laboratory confirmed the diagnosis for rabies in 17 species. However, most of the cases were among domestic animals (dogs and cats) — 262 cases or 56.6%. The percentage of foxes accounted for 20.7% of cases.

In carrying out mapping of all 463 cases of rabies their accumulation was found within Chernihivskyi, Kulikivskyi, Borznianskyi, Nosivskyi, and Bobrovytskyi raions of the oblast (Fig. 1). This can be connected with the higher population density in these areas and therefore greater concentration of domestic animals. Another factor that undoubtedly affects the intensity of epizootic is the volume of specific prevention measures of rabies. However, differences in the implementation of these measures as preventive and necessary in problem areas in different raions of the region were found.

Least number of rabies cases were found in north-eastern and south-eastern regions. One of the theories of uneven rabies epizootic in Chernihiv Oblast, there is an indirect positive impact on the epizootic situation of rabies ORV, constantly carried out on the borders of Sumy and Poltava Oblasts during 2006–2015.

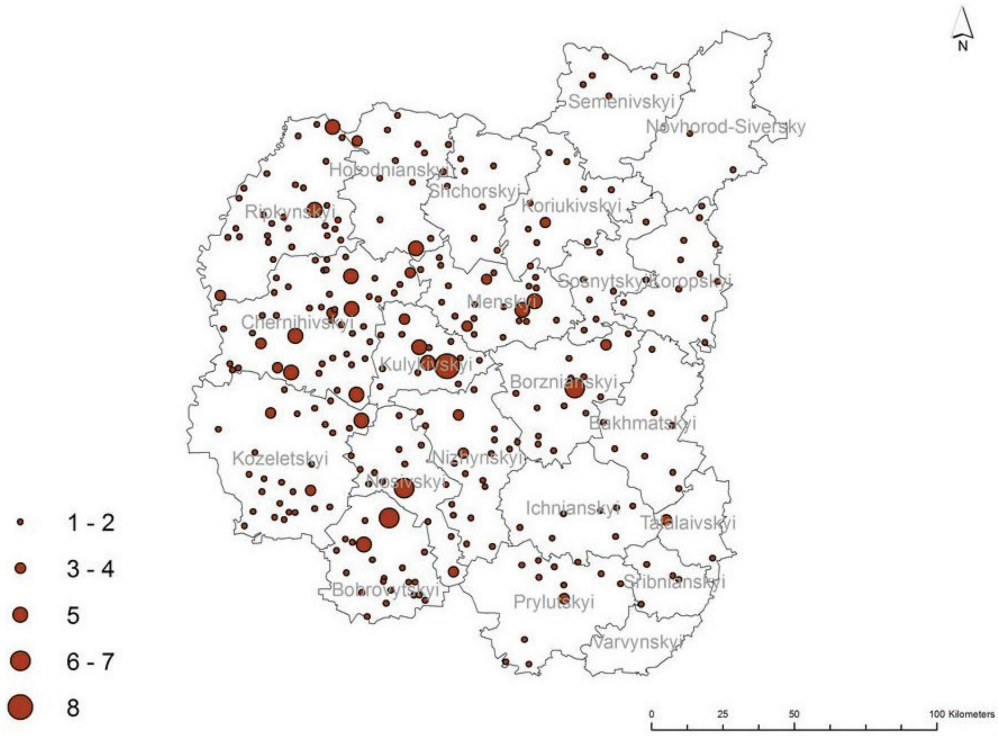

Figure 1. The map of number of rabies cases at sites, Chernihiv Oblast, 2011–2016

Ellipses of standard demonstrated showed that in 2011–2012 spatial trends of rabies cases were lying on the axis of southwest-northeast. The central tendency of rabies cases in 2011 located much farther to the east and north than in later years. Ellipses of 2011–2016 were on the axis of the southeast-north-west, mostly in central and western areas of the oblast. The standard deviational ellipse of rabies cases is located more south than in previous years and the closest to the south-north axis in 2016. Thus, if in 2011, outbreaks of rabies were mainly observed in the northeastern and central regions, in subsequent years, the outbreaks distribution has shifted to west and south (Fig. 2).

The central tendency of the ellipse for 2011–2016 for wild animals was located 23 km further north-west than for domestic ones (Fig. 3).

KDE analysis revealed the spatial clusters of rabies cases located in the central, western and south-western raions. Most rabies density of domestic animals was also observed in the central, western and south-western regions. However, the clusters of cases among wild animals were preferably in the north-western regions which are more forested and have less human population (Fig. 4).

Emerging Hotspot Analysis revealed 18 clusters with spatial temporal trend 'sporadic' (a place in which hotspot appears and disappears; a place where less than 90% of the time intervals were statistically significant hotspots and none of the intervals was statistically significant coldspot) in the central and southwestern areas of the region: Kulikivskyi, Bobrovytskyi, Ichnianskyi, partly Nosivskyi, Nizhynskyi, Kozeletskyi and in the south of Prylutskyi (Fig. 5).

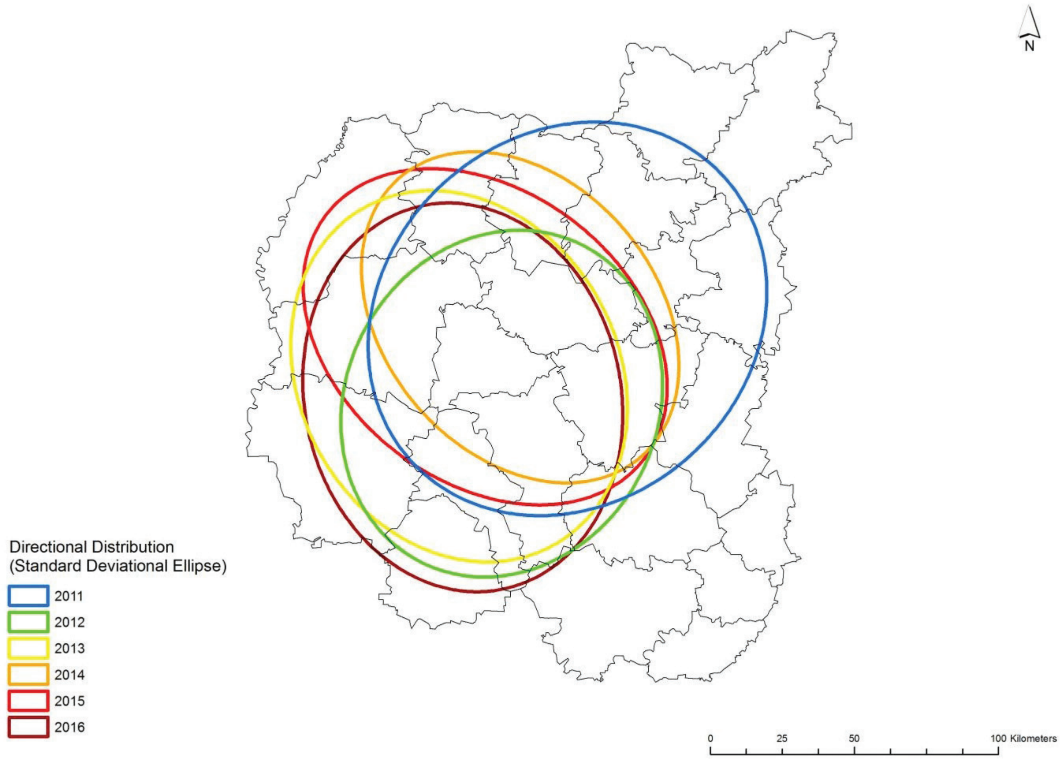

Figure 2. Ellipse of standard deviations (size 1 standard deviation) of rabies cases, Chernihiv Oblast, 2011–2016

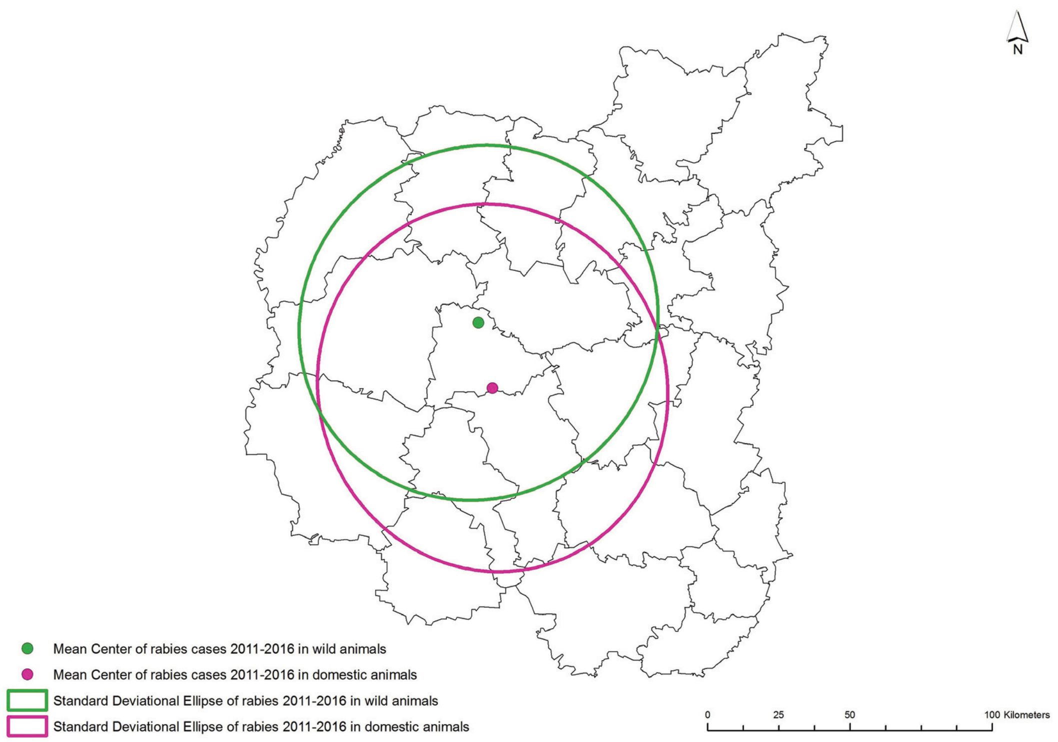

Figure 3. Ellipse of standard deviations (size 1 standard deviation) of rabies cases in wild and domestic animals, Chernihiv Oblast, 2011–2016

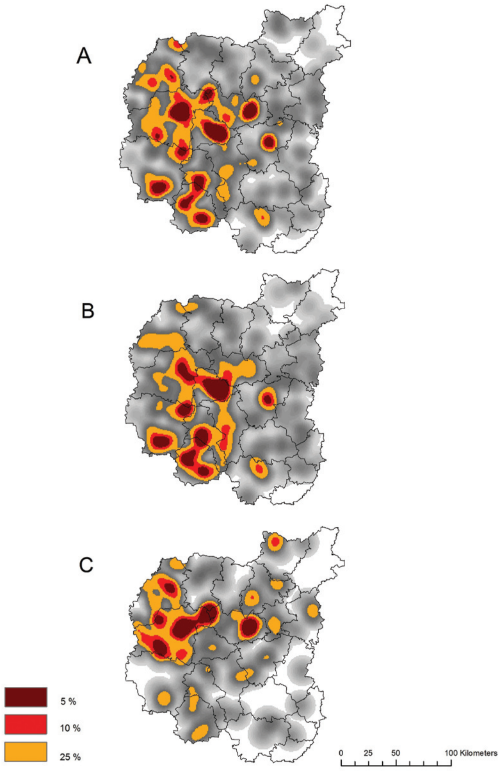

Figure 4. Rabies hotspots derived from kernel density estimation at three different thresholds (upper 5, 10, and 25% of density values), Chernihiv Oblast, 2011–2016: A — total cases, B — cases in domestic animals, C — cases in wild animals

Finding of these 18 clusters may have practical importance in these areas to intensify the work with stray animals, regulation of rabies reservoir species (mainly foxes), increasing amounts of specific prevention of rabies through parenteral immunization of animals and other activities, aimed at the eradication of rabies.

In addition, Emerging Hotspot Analysis revealed three clusters of the 'new' trend (a location is statistically significant hotspot in the last time step and has never been statistically significant hotspot earlier), placed in the far southeastern region on perimeter of Varvynskyi raion. The appearance of these clusters may be linked to termination in recent years ORV on the territory of neighboring Poltava and Sumy oblasts due to the difficult economic situation in Ukraine. So, this may be one more confirmation of theories about the presence of indirect pressure on the epizootic situation of rabies in Chernihiv Oblast of oral immunization of wild animals, which was held in Poltava and Sumy Oblasts.

However, to confirm the existence of ORV pressure on the epizootic situation in related areas additional analysis of earlier periods' data is required — before the event.

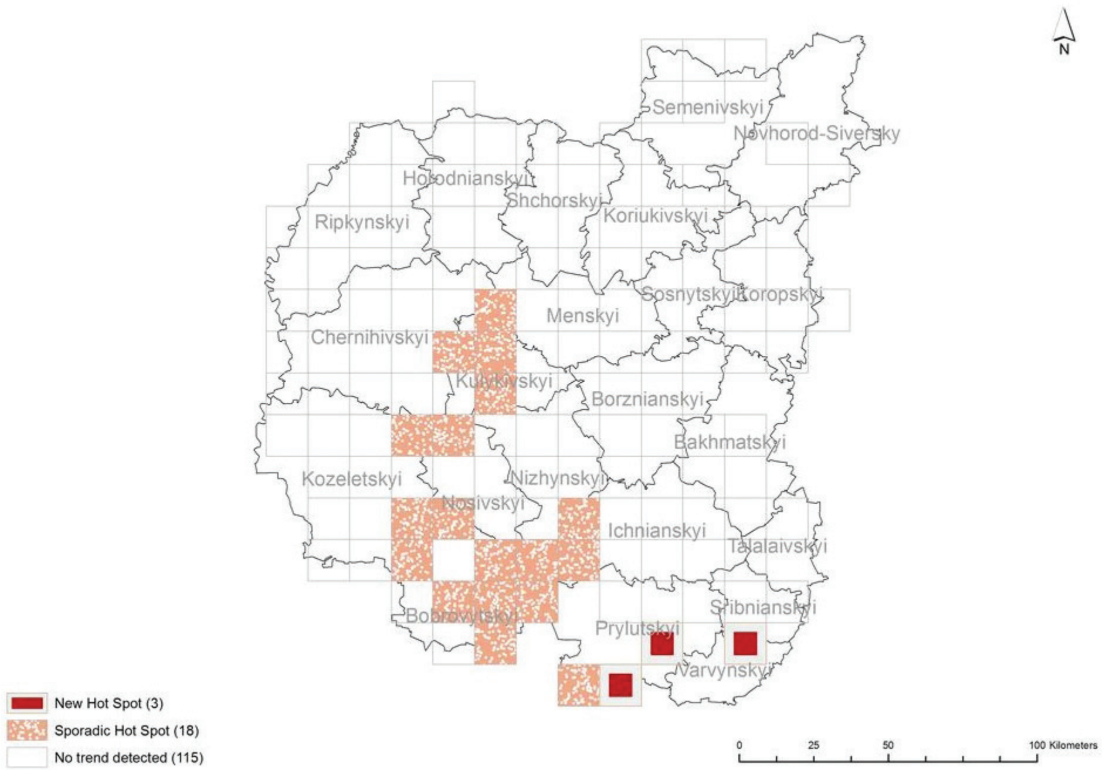

Figure 5. Emerging Hotspot Analysis of rabies cases in wild and domestic animals, Chernihiv Oblast, 2011–2016

Conclusions. Areas with high incidence of animal rabies were identified in Chernihiv Oblast. These areas should activate the work on rabies prevention throughout parenteral vaccination of domestic and agricultural animals, regulate the population of stray animals and wild carnivores.

Three clusters of the 'new' time trend in the far south-east of the oblast may be connected with the termination of oral immunization from rabies of wild carnivores in 2015 in neighboring Poltava and Sumy Oblasts. To validate this hypothesis the data from these oblasts both before and after ORV are needed.

Prospects for further research. Determination of spatial patterns and identification of rabies cases clustering can be useful for making decisions on the efficient allocation of diseases control efforts. We will continue our research with materials from other areas in order to improve the monitoring of rabies in Ukraine and to conduct more effective prevention activities.

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