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HOME RANGES OF THE RED FOX, *VULPES VULPES* (CARNIVORA, CANIDAE) AND EUROPEAN BADGER, *MELES MELES* (CARNIVORA, MUSTELIDAE), IN OAK FORESTS OF SLOBOZHANSHCHYNA, UKRAINE

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Home Ranges of the Red Fox, *Vulpes vulpes* (Carnivora, Canidae) and European Badger, *Meles meles* (Carnivora, Mustelidae), in Oak Forests of Slobozhanshchyna, Ukraine. Brusentsova, N. — The research was carried out in 6 territories located in oak forests of Slobozhanshchyna in 2007–2016. Family home ranges were determined using the average nearest neighbour distance between all setts of a sett system for the badgers and between breeding burrows for the foxes. The use of fox and badger family home ranges in different seasons and years was estimated by changes in the use of burrows at the monitoring site of Gomilshanski Lisy National Nature Park. In the oak forests, 173 burrows were studied, among which 75 are used by badgers and 45 by foxes. The area of most of the badger family home ranges in the oak forests is 28–88 ha. The area of the fox family home ranges in the oak forests is 86 to 892 ha. In the oak forests of Slobozhanshchyna, badger and fox family home ranges correspond to the data for similar biotopes in Europe. Seasonal changes of the badger family home range used at the monitoring site in Gomilshanski Lisy NNP in general correspond to literature radio tracking data. Changes in use of the fox family home range depend on fluctuations of the abundance of rodents.
Key words. *Vulpes vulpes, Meles meles,* oak forest, home range, Slobozhanshchyna, GIS, geospatial analysis.

Introduction

Home range is an area used by animals to meet their vital needs (foraging, birth and nurture of cubs, use of shelters). When protected by individuals of one family group, it is called the family home range (FHR) (Burt, 1943; Panov, 2010). The size and shape of family home ranges depend on the amount of food and other resources, their seasonal and spatial variability (Cavallini, 1996; Johnson et al., 2002; Kowalczyk et al., 2003; Kauhala et al., 2006; van Apeldoorn et al., 2006). When population density is high, animals use small family home ranges and actively mark the boundaries of the territory. Instead, when population density is low, animals use large family home ranges with undetectable boundaries (Cavallini, 1996; Hutchings et al., 2002; Frafjord, 2004). The fox and badger share some resources: habitats overlap largely, dietary overlaps partly, foxes use badger setts for breeding and resting (Kauhala et al., 1998; Kowalczyk et al., 2008; Keuling et al., 2011). The burrowing activity of these species in the forests affects the state of the soil, vegetation, as well as creates shelters for other species (Reichman & Smith, 1990; Kurek et al., 2014).

Different types of social interactions are known for the red fox (*Vulpes vulpes*) and the European badger (*Meles meles*) under different living conditions. These animals can live alone, in pairs or groups (Cavallini, 1996; Johnson et al., 2002). According to the Resource Dispersion Hypothesis (RDH), if the resources are dispersed and rich enough, multiple individuals can collapse into groups that share the same space at little cost to each other (Macdonald & Johnson, 2015).

Most methods of studying home ranges are based on radio telemetry data by radio tracking (Kowalczyk et al., 2003; Kauhala et al., 2006; Huck et al., 2008). Using transmitters allows locating individuals from a few days to several months or even years. In Ukraine, transmitters for environmental and ethological research are rarely used because they and the software for analysis are expensive. Therefore, studies on animal home ranges have not been carried out yet. In this situation, methods to estimate family home ranges based on the location of shelters deserve more attention (Kharitonov, 2005; van Apeldoorn et al., 2006). This approach will be simpler to apply when combined with the capabilities of GIS tools and will allow covering large territories.

The aims of the present study were to examine fox and badger family home ranges in oak forests of Slobozhanshchyna. Such research was carried out in Ukraine for the first time, particularly in oak forests.

Material and methods

The research was conducted in 2007–2016 in 6 oak forests of Slobozhanshchyna, Ukraine. Slobozhanschyna is a historical region, which includes parts of Sumy, Kharkiv, Luhansk, and Donetsk Regions of Ukraine and parts of Belgorod, Kursk, and Voronezh Regions of Russia. The research areas, which are located in the Kharkiv Region (Ukraine) and Belgorod Region (Russia), are represented by deciduous forests growing on the right high banks of the Siverskyi Donets, Kharkiv, Merla, and Vorskla rivers with a developed ravine system. The main trees are *Quercus robur, Tilia cordata, Fraxinus excelsior, Acer platanoides, Acer campestre* and *Acer tataricum*. Most of the shrubs are represented by *Euonymus europaea, Euonymus verrucosa*, and *Corylus avellana*. The location of the studied territories is shown on fig. 1. Three territories are located in protected areas (Gomilshanski Lisy National Nature Park, Slobozhanskyi National Nature Park, Les na Vorskle sector of the Belogorye State Nature Reserve), two territories make up the green zone of Kharkiv city (Lisopark 1, Lisopark 2), and one territory is a part of a forestry (Pristin forest).

During the study, underground shelters in oak forests were mapped using GPS. The burrows were revised 4 times a year in different seasons and, in addition, in late May–early June to determine the breeding burrows. All meetings and traces of animal life (tracks, trails, digging soil, remains of food, etc.) were recorded and in-
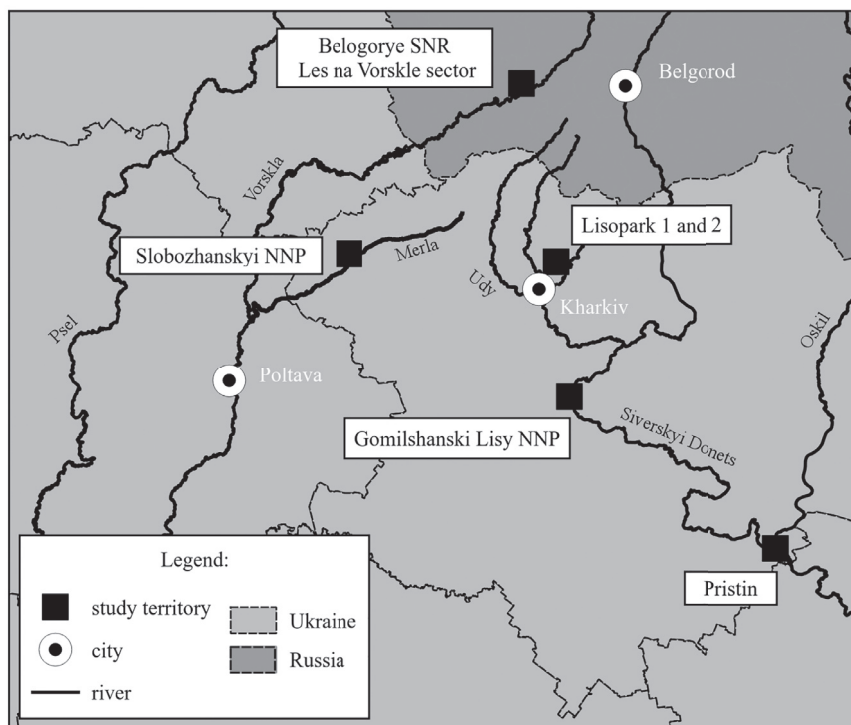

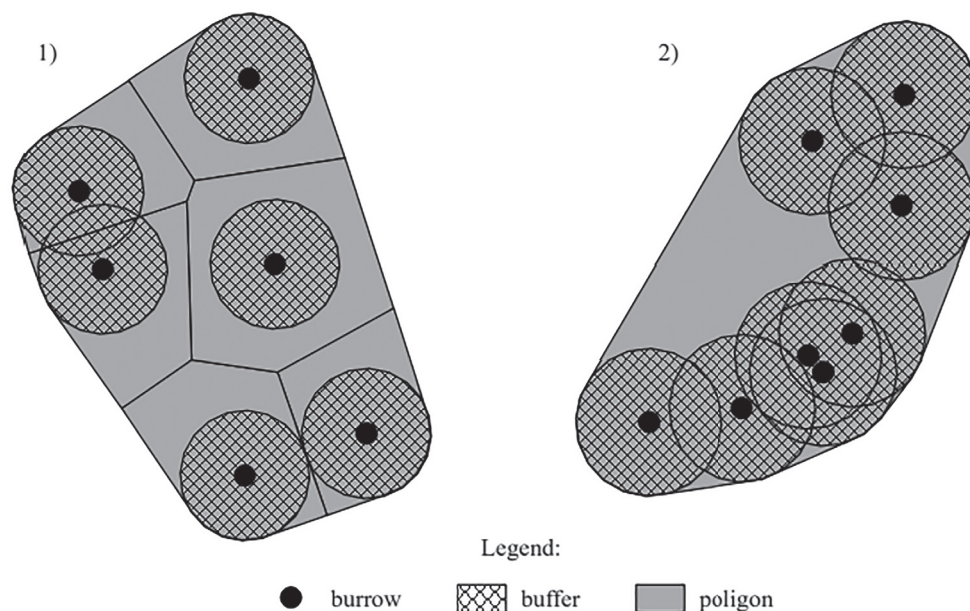Fig. 1. The location of the studied territories.

Fig. 2. Examples of determination the family home range boundaries in 1) foxes and 2) badgers.

cluded into a database. The badger family home ranges were determined based on underground shelters used by individuals of badger family groups. The average of the nearest distances for each sett groups was calculated. Buffer zones with the radius of the calculated mean of the nearest distances were constructed around point objects (setts). The buffers were united into a poligon, which also was the family home range (fig. 2). Fox family home ranges were determined based on breeding burrows in a similar way. The buffer zones around breeding burrows were defined by the radius from a half of the average nearest distances to the neighbouring shelter. Buffers were united into a poligon. The internal boundaries between fox family home ranges were determined by Voronoi diagram (Voronoi tessellation, Dirichlet tessellation). The determination of family home ranges, spatial calculations and visualization of the results were performed using QGIS tools. The use of fox and badger family home ranges in different seasons and years was estimated by changes on the burrows use at the monitoring site located in Gomilshanski Lisy NNP.

Results

In the oak forests, 173 burrows were studied, among which 75 are used by badgers and 45 by foxes. The burrows are unevenly distributed within the studied territories (table 1). During the research, 10 badger families were found. Each family used a main sett and 4–13 secondary setts. Setts not being used by badger family groups were also found. During our study, the badger family home ranges did not change significantly. Their basis is a system of burrows, so it is possible to represent the size and location even for abandoned family territories. In Gomilshanski Lisy NNP and the Pristin forest, the location of burrow systems and old setts with a large number of entrances (8–11) indicates the presence of 1–2 abandoned family territories. For the green zone of Kharkiv City, only one badger family home range and no fox breeding burrows were found (Lisopark 2).

The highest density of badger family home ranges was found in Gomilshanski Lisy NNP and Pristin. The area of most of the badger FHRs in the oak forests is 28–88 ha (table 2). The smallest family home ranges are located in Lisopark 2 (14 ha) and Slobozhanskyi NNP (15 ha). In Lisopark 2, setts are located in the most remote from buildings part of the forest near a stream. In Slobozhanskyi NNP, the setts of badger family home range No. 1 are situated in the ravine slopes of the oak forest between a field and a waterlogged alder forest. The largest FHR is located in Slobozhanskyi NNP (629 ha) occupying the elevated dry part of the oak forest.

T a b l e 1. Badger and fox family home ranges in the upland oak forests

Territory	S, ha	N burrows	N badger FHRs*	N fox FHRs
Gomilshanski Lisy NNP	1800	79	4 (1–2)	2-4
Slobozhanskyi NNP	1588	27	3	2–3
Les na Vorskle	1038	23	1 (1)	2–6
Lisopark 1	1540	10	0 (?)	?
Lisopark 2	930	6	1	?
Pristin	400	28	1 (1–2)	2
Total	7296	173	10 (3–5)	8–14

* The number of possibly abandoned family home ranges is given in brackets.

The average of nearest neighbour distance for the setts used by a single badger family group varies within 0.089–0.622 km. The largest number of setts was found on the badger family home range No. 4 at Gomilshanski Lisy NNP and No. 3 at Slobozhanskyi NNP. During the study, family groups of badgers used either all underground shelters within the home range or there were 1–3 unused setts. The distances between the main setts are 0.556–3.836 km.

In the oak forests, foxes use badger setts for breeding. The nearest neighbour distances between breeding burrows are 0.762–3.073 km. The highest density of fox breeding burrows was observed in Les na Vorskle and Pristin (5.78 and 5 burrows/1000 ha). These oak forests are small isolated parts of the forest with nice protective conditions, which are surrounded by settlements, gardens, fields, and rivers on all sides. The area of fox family home ranges in the oak forests is 86 to 892 ha.

Seasonal and annual dynamics of family territories use

Seasonal and annual changes in the use of FHRs by badgers and foxes were investigated in 2007–2009 at the monitoring site located in Gomilshanski Lisy NNP. During the observation period, in the badger family home range No. 1 and No. 3 the pronounced main setts were found, where the animals spent the most time (fig. 3). However, at the family home range No. 1, badgers used several setts with the same frequency in 2011 and it is impossible to determine which burrow was the main one. In the badger family home range No. 2, a pronounced main sett was not revealed. In the badger family home range No. 4, two main setts existed for 4 years. They were the most used in all seasons.

T a b l e 2. Badger family home ranges

Territory	No. FHR	Average NND, km	S, ha	N entrances in main sett	N setts*	N unused setts*
Gomilshanski Lisy NNP	1	0.147 ± 0.105	40	6	7	1
	2	0.131 ± 0.109	49	?	8	0
	3	0.161 ± 0.092	31	4	5	0
	4	0.134 ± 0.091	88	4 and 3	14	6
Slobozhanskyi NNP	1	0.101 ± 0.072	15	?	5	0
	2	0.622 ± 0.292	629	5	6	2
	3	0.125 ± 0.137	55	6	11	2
Les na Vorskle	1	0.112 ± 0.052	28	2	8	1
Lisopark 2	1	0.087 ± 0.02	14	4	5	1
Pristin	1	0.208 ± 0.066	55	7	5	0

* Some of them are used by foxes.

In 2007, badgers were active and visited some shelters in the FHRs, because the winter was warm (fig. 4). In the coldest winter in 2011, animals of family No. 3 and No. 4 were wintering in the main setts, and in the family home ranges No. 1 and No. 2 signs of the badgers' presence in general could not been identified. In autumn 2009, the presence of
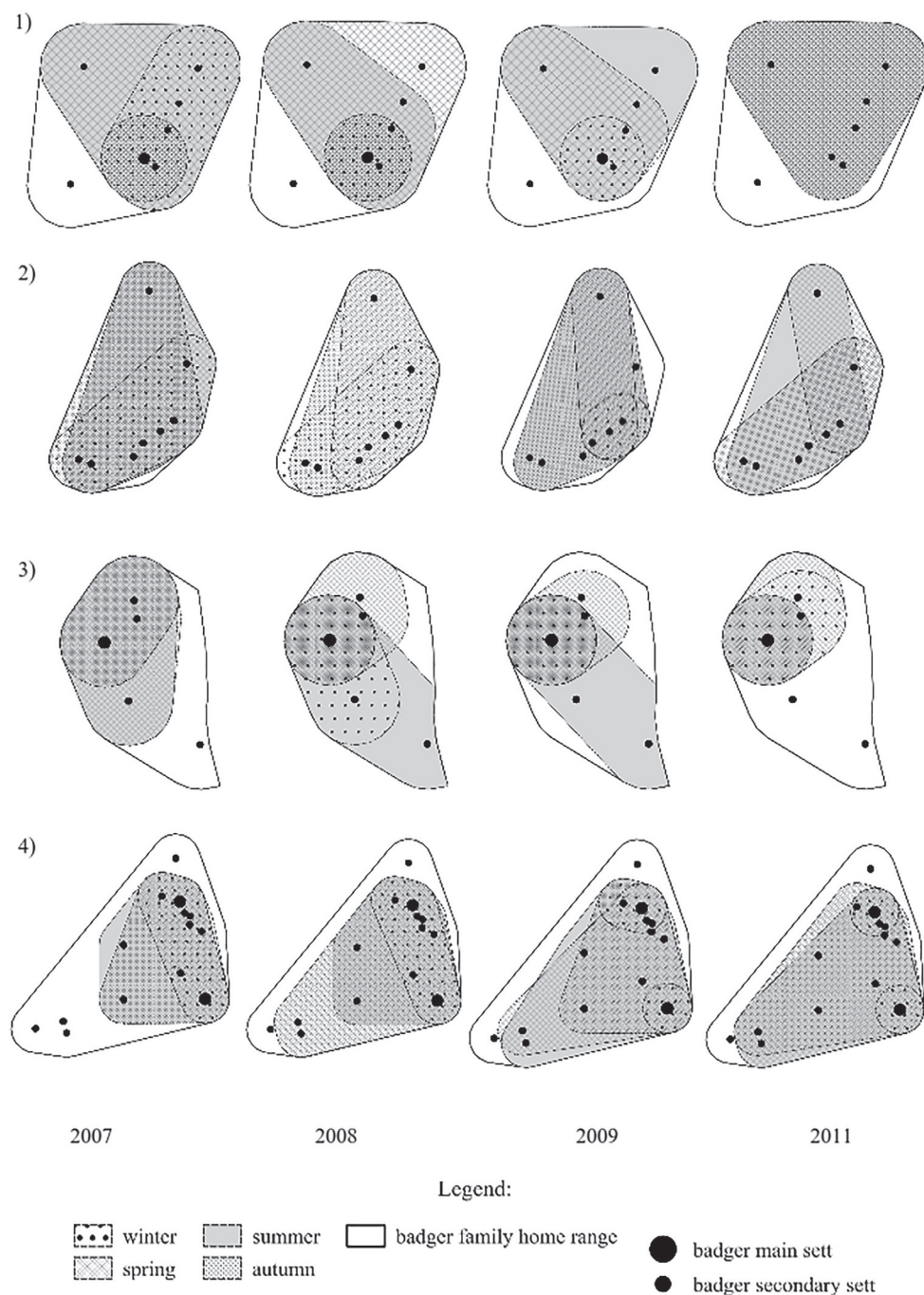

Fig. 3. The use of badger family home ranges at the monitoring site located in Gomilshanski Lisy NNP.
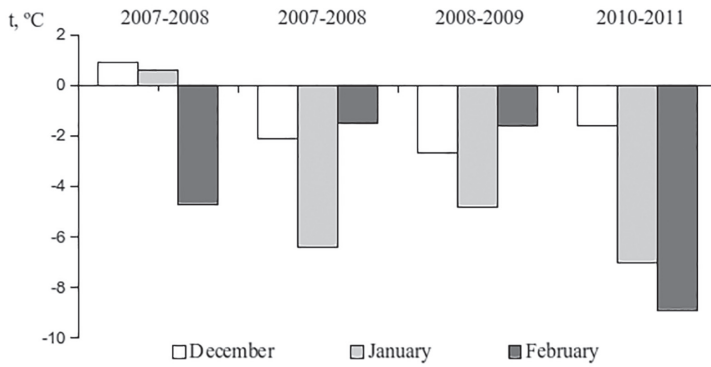
Fig. 4. Winter average monthly temperatures in Kharkiv City in 2007–2009 and 2011 (http://www.pogodaiklimat.ru).

badgers in the FHR No. 1 also was not recorded. FHR No. 2 was not revised in summer 2008. In general, the badger family home ranges are actively used in spring and summer.

Foxes within the monitoring site at Gomilshanski Lisy NNP use burrows year round. During the observation period, they were breeding every year in another burrow. No more than two breeding burrows per year were detected, but significant activity was observed for some shelters during the breeding season. Family home ranges also were calculated based on these actively used burrows. Perhaps, these family groups did not breed or the cubs died (fig. 5).

According to calculations, the smallest fox family home ranges were used in 2007 (111–172 ha), while the largest in 2009 (488–892 ha). The distance between breeding burrows was 0.945, 1.61 and 1.136 km.

Discussion

Deciduous forests, especially mature ones, are important for badgers and foxes, because these habitats are rich in key food resources (earthworms, small rodents) and shelters. Many studies have shown the connection between good quality habitat and small home-range size in these animals (Cavallini, 1996; Johnson et al., 2002; Kowalczyk et al., 2003; Kauhala et al., 2006). In the oak forests of Slobozhanshchyna, badger family home
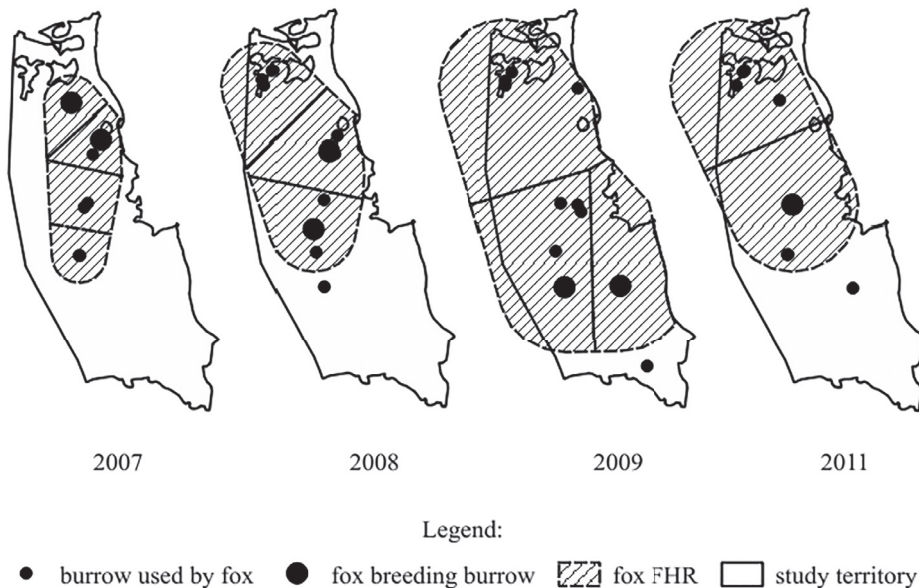

Fig. 5. Fox family home ranges in May–June in 2007-2009 and 2011 in Gomilshanski Lisy NNP.

ranges correspond to the data for similar biotopes in Europe (Johnson et al., 2002; Kauhala et al., 2006), so do the fox family home ranges (Cavallini, 1996; Kauhala et al., 2006). The absence of badger use shelters in Lisopark 1, the small number of setts in the green zone of Kharkiv City, and the increased number of setts in Pristin forest indicate the changes in animal populations, from the rising burrowing activity to the disappearance of the species in general, influenced by anthropogenic factors in non-protected areas. The green zone of Kharkiv City is a popular recreation place for the city's residents. Pristin forest is a small part of the forest, surrounded by villages, fields, and a recreation area on the riverbank.

The absence of fox breeding burrows in Lisopark 1 and Lisopark 2 does not indicate the absence of species. During this study, the author and the inhabitants of Kharkiv City often observed fox footprints and foxes within the green zone. In anthropogenic environment, foxes can use man-made structures as shelters (Legeida, 2007; Keuling et al., 2011). Nevertheless, in this study such places were not found.

The updated data on badger family home ranges are presented in this article in comparison with the previous studies (Brusentsova, 2014). The badger unused sett systems in this study were able to make up the badger family territories in the past. It is evidence for the depressed state of badger populations in the oak forests of Slobozhanshchyna. Seasonal changes of badger family home range used at the monitoring site of Gomilshanski Lisy NNP generally correspond to literature radio tracking data (Kowalczyk et al., 2003; Kauhala et al., 2006).

The fluctuation of the number of foxes, and, accordingly, the area of fox family territories, depends on the richness of the food base. The availability of the main food resources, such as voles and mice, significantly varies in different years. As it is well known from the literature, foxes prefer the voles of the genus *Microtus* and bank voles (*Myodes (Clethrionomys) glareolus*), which can be a significant part of the foxes' diet in the forests (Jędrzejewski & Jędrzejewska, 1992; Sidorovich et al., 2008). In the east of Ukraine, the high abundance of rodents was recorded in 2007–2008. In 2009, it was lower, especially of the voles (Zorya, 2010; Skubak, 2015). It can explain changes in the fox family home ranges at the monitoring site of Gomilshanski Lisy NNP.

The study of the animals family home ranges based on the average nearest neighbour distance between the burrows does not provide, of course, accurate information about the territory boundaries. This method helps determine the importance of the territory for badger and fox family groups living in which they use most often. During this study, it was difficult to identify the affiliation of some used burrows to any family territories. Such burrows were excluded from the calculations. Their affiliation to one or another family territory can be detected by radio tracking only. In addition, there are different methods of calculating home ranges by radio telemetry data. The home range for the same animal can differ significantly, according to these methods (Huck et al., 2008).

Conclusions

The study of fox and badger family home ranges were carried out for the first time in oak forests of Slobozhanshchyna. For 6 oak forest territories, the burrows' number, species home range number, and their usage were determined. The changes in animal populations were fixed under the influence of anthropogenic factors in non-protected areas.

In the oak forests of Slobozhanshchyna, badger and fox family home ranges corresponds to the data obtained for European deciduous forests. The studies at the monitoring site located in Gomilshanski Lisy NNP showed a difference in the use of family home ranges for different seasons and years. These differences were determined by the climate and abundance of food.

Calculating home ranges based on the average nearest neighbour distance is a simple and accessible method. It is suitable for monitoring studies in any territories with regular verification of shelters.

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