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DIET COMPOSITION OF THE RED FOX, *VULPES VULPES* LINNAEUS, 1758 (CANIDAE, CARNIVORA) IN WESTERN UKRAINE

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Here, we examined 70 samples of foxes from western Ukraine to determine their diet composition and assess the impacts of several factors on a diet. We analysed fox faeces (22 items) and the stomach contents (48 items) of individual animals killed via hunting or traffic accident. The diet of the red fox included plants (24 items) and animals (24 items), and Poaceae (herb) and the common voles (Microtus arvalis Pallas, 1778) occurred most frequently. There was a positive correlation between invertebrates and lower vertebrates (amphibians and reptiles). The collection method and the season had significant impacts on the occurrence of some types of food in the diet, whereas latitude and longitude had no effects on the diet composition in the study.

Key words: Trophic connections, nutrition of predators, influencing factors.

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INTRODUCTION

One of the main issues in researching the ecology of carnivorous mammals is the study of their diet and trophic relationships because these factors have a significant impact on both the number of predators and terrestrial ecosystems in general. Studies on predatory mammals are essential because they are at the top of the food chain and affect the prey population and their populations via competition (Soe et al. 2017). Such studies are vital for the conservation of different species of animals (Balestrieri et al. 2011).

The red fox (*Vulpes vulpes* Linnaeus, 1758) is a typical predator in the northern hemisphere (Lanszki et al. 2006). Its ability for polyphagia and its high ecological flexibility determines its essential role as a predator. Some European researchers consider it the most important species among predators (Tryjanowski et al. 2002, Plumer et al. 2014, Davis et al. 2015).

Many publications are aimed at clarifying the trophic niche of this predator and how it is sharing the niche with other predators: golden jackal (*Canis aureus* Linnaeus, 1758), pine marten (*Martes martes* Linnaeus, 1758), raccoon dog (*Nyctereutes procyonoides* Gray, 1834) (Goszczyñski 1986, Baltrûnaitë 2001, Baltrūnaitė 2002). Usually, the works (Dell'Arte et al. 2007, Davis et al. 2015) dedicated to investigating the factors influencing the fox's diets are performed in small areas and on relatively small sample sizes, making it hard to prove their impact on a diet with statistical significance. However, these studies are an essential source of data for meta-analysis (Diaz-Ruiz et al. 2013, Soe et al. 2017). In particular, the work of Egle Soe and colleagues gives a clear idea of fox nutrition in Europe, as well as how geographical latitude affects it.

In the Ukraine territory, respective studies are scarce and have mainly been conducted in the southern and eastern regions (Lebedeva 2000, Rozhenko 2006). In the western regions, the most recent studies on the red fox were performed in the 1950s (Tatarinov 1956, Polushina & Vladyshevskiy 1963), and only fragmentary studies have been conducted in these regions since the mid-2000s (Lushchak et al. 2006, Martsiv 2018, Martsiv & Dykyy 2019, 2020). Also, the review (Soe et al. 2017) proves some lack of data on fox nutrition from Eastern Europe, particularly from Ukraine.

To fill this gap, in this investigation, we aimed to describe red fox diet peculiarities in western Ukraine and test how certain factors affect the diet.

MATERIALS AND METHODS

Sampling

We examined 70 samples (faeces and stomach contents) from red foxes (*Vulpes vulpes* Linnaeus, 1758) in the territory of western Ukraine at 29 different spots (Fig. 1) between 2016 and 2020. The map of the collection spot was designed using QGIS (QGIS.org, 2018). The sample consisted of 48 stomach and 22 faeces samples.

The collection of materials was conducted upon the local legislation.

We were analysing the stomach content of the animals, knocked down by car accidents

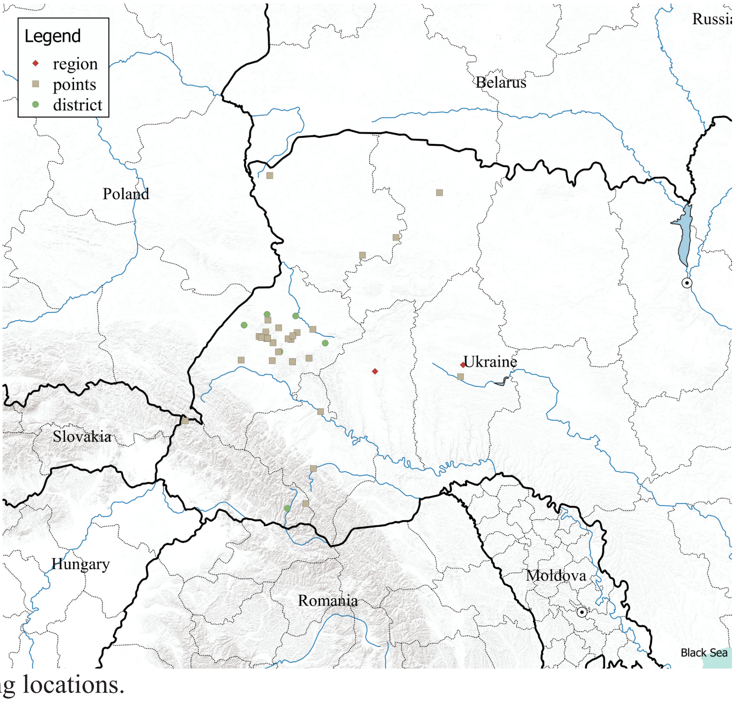

Fig. 1. Sampling locations.

or gotten from hunters during hunter season. Collected carcasses were frozen or cooled before transporting to the laboratory for necropsy. We separated the stomach from the gastrointestinal tract, opened stomachs and preserved contents in the 70 % alcohol solution in the hermetically sealed utensils. Then, we used a microscope (Carl Zeiss Q1) and binoculars (PZO NSK) to determine the remains.

Faeces of foxes were collected on forest byways and field paths. To determine the material, we soaked it for a day in the water. All samples we washed alternately through three sieves of minimal 0,54 mm mesh under running water. After clear separation, we identified objects of each fraction using the keys (Day 1966, Pucek 1984, Zagorodniuk 2002).

Data analysis

For analysis, we grouped the data into eight food groups: plants, invertebrates, lower vertebrates, birds, rodents, other mammals, domestic animals, polyethene. Some undigested mammals could not be identified and were added to “other mammals”. We used hierarchical cluster analysis to analyse the data structure of the sample. First, we calculated the Sørensen index for each pair of samples and then built the similarity matrix based on those calculations for the whole sample. After that, we visualised the matrix by hierarchical cluster analysis with the method of the average link. We added the factors (year, region, method of collection, season) on the graph to explain the obtained results. For these calculations, we used Primer 6 (Clarke & Gorley 2006).

The entire sample was divided into two subgroups, depending on the method of collection. The per cent frequency of occurrence (%FO = number of samples containing a specific food item/total number of samples × 100) (Balestrieri et al. 2011) was calculated for food groups separately for each subgroup. We used Fisher’s exact test to assess the statistical significance of the differences in the %FO of each food group between subgroups of the sample. To investigate whether there was a relationship in the occurrence between the different food groups, we estimated Spearman’s correlation coefficient for all possible pairs of food groups (separately for each subgroup of the sample). Because of repeated tests (in both trials) on related data, we used Holm’s procedure for correcting the level of significance. We performed these calculations in the R environment (R core Team 2020).

To investigate the factors influencing the occurrence of a specified food category, we used generalised linear models (GLMs) with presence or absence data as responses. For all models, we tested the potential collinearity of predictors using the R package *performance*. As predictors, we included season (winter-spring or summer-winter), collection method (faeces or stomach contents), longitude and latitude. We fitted eight binomial GLMs (link function – logit) and calculated the exhibitor for each model’s coefficient for estimating odds. For fitting GLMs, we used the R function *glm*. We used the R environment (R core Team 2020) for these calculations.

RESULTS

General description of the sample

In total, we found 49 items in the samples. Twenty-four were of plant origin, 24 were of animal origin, and one item was anthropogenic material (polyethene). The following items were found a high frequencies: herbaceous plants (67%), common vole (38.5%), insects (18.5%), chickens (18.5%), apples (16%), indeterminate birds (16%), indeterminate mammals (16%), indeterminate plants (14%), leaves (11%), indeterminate rodents (11%) and plant seeds (10%) (Table 1). In general, items of plant origin were found in 90% of the studied samples, items of animal origin in 97% and polythene in 5% of the studied foxes.

Cluster analysis

Cluster analysis divided the data set into five groups of approximately equal size (Fig. 2).

Table 1. Red fox diet objects

Objects of the diet	**Absolute amount**	**Relative frequency of occurrence (%) * relative to other objects**	**Relative frequency of occurrence (%) * regarding the number of samples**
Plants			
Indeterminate plants	10	4,1	14,3
Malus domestica Borkh., 1803	11	4,5	15,7
Pyrus communis Linnaeus, 1753	4	1,6	5,7
Cydonia oblonga Mill., 1768	1	0,4	1,4
Prunus domestica Linnaeus, 1753	3	1,2	4,3
Prunus subgen Cerasus (Mill.) A.Gray, 1856	1	0,4	1,4
Rubus idaeus Linnaeus, 1753	1	0,4	1,4
Rubus caesius Linnaeus, 1753	2	0,8	2,9
Vitaceae	2	0,8	2,9
Rosa canina Linnaeus, 1753	1	0,4	1,4
Vaccinium myrtillus Linnaeus, 1753	4	1,6	5,7
Daucus carota Linnaeus, 1753	1	0,4	1,4
Helianthus	6	2,4	8,6
Triticum	2	0,8	2,9
Fabaceae	1	0,4	1,4
Avena sativa Linnaeus, 1753	2	0,8	2,9
Juglans regia Linnaeus, 1753	1	0,4	1,4
Seeds	7	2,9	10,0
Leaves	8	3,3	11,4
Straw	2	0,8	2,9
Needles of conifer	1	0,4	1,4
Polypodiophyta	1	0,4	1,4
Herbaceous plants	47	19,2	67,1
Bark / branches / wood	5	2,0	7,1
Invertebrates			0,0
Mollusca	3	1,2	4,3
Insecta	13	5,3	18,6
Vertebrates			0,0
Amphibia	1	0,4	1,4
Reptilia	1	0,4	1,4
Pisces	3	1,2	4,3
Indeterminate birds	11	4,5	15,7

Objects of the diet	Absolute amount	Relative frequency of occurrence (%) * relative to other objects	Relative frequency of occurrence (%) * regarding the number of samples
Gallus gallus domesticus Linnaeus, 1758	13	5,3	18,6
Columba livia Gmelin, 1789	1	0,4	1,4
Perdix perdix Linnaeus, 1758	3	1,2	4,3
Indeterminate mammals	11	4,5	15,7
Indeterminate rodents	8	3,3	11,4
Apodemus sylvaticus Linnaeus, 1758	1	0,4	1,4
Microtus arvalis Pallas, 1778	27	11,0	38,6
Rattus norvegicus Berkenhout, 1769	2	0,8	2,9
Cricetus cricetus Linnaeus, 1758	2	0,8	2,9
Sciurus vulgaris Linnaeus, 1758	1	0,4	1,4
Felis catus Linnaeus, 1758	3	1,2	4,3
Sus scrofa Linnaeus, 1758	4	1,6	5,7
Capra hircus Linnaeus, 1758	2	0,8	2,9
Oryctolagus cuniculus domesticus Linnaeus, 1758	4	1,6	5,7
Capreolus capreolus Linnaeus, 1758	3	1,2	4,3
Muscardinus avellanarius Linnaeus, 1758	1	0,4	1,4
Cattle (rumen)	2	0,8	2,9
Lepus timidus Linnaeus, 1758	1	0,4	1,4
Total	**245**	**100,0**	**100,0**

Plants were evenly present in all clusters as almost all samples contained leftovers of plants, indicating that plants are an essential component of fox diets and that the studied factors did not affect the group's consumption.

Cluster 1 (Fig. 2) was most significantly separated from the entire population. All samples in this cluster contained domestic animals (*Felis catus* Linnaeus, 1758, *Capra hircus* Linnaeus, 1758, *Oryctolagus cuniculus domesticus* Linnaeus, 1758). On the other hand, invertebrates and lower vertebrates were absent here.

Each sample of cluster 2 (Fig. 2) contained wild mammals (*Capreolus capreolus* Linnaeus, 1758, *Sus scrofa* Linnaeus, 1758, *Lepus timidus* Linnaeus, 1758). Invertebrates (Coleoptera) and birds (Passeriformes) were also prominently represented in the samples of this cluster, whereas rodents were absent.

Most samples of cluster 3 (Fig. 2) contained invertebrates (Gastropoda, Coleoptera). Rodents (*Microtus arvalis* Pallas, 1778) were numerous, whereas other mammals and birds were absent.
All samples of cluster 4 (Fig. 2) contained

Table 2. Comparison of the prevalence of food groups using Fisher's exact test

	Stomach content, %	Faeces, %	p-value	p-value (Holm)
Plants	85.42	100.00	0.08933	0.53598
Invertebrates	8.33	45.45	0.000718	0.005745
Lower vertebrates	8.33	4.55	1	1
Birds	45.83	22.73	0.1113	0.5565
Rodents	66.67	27.27	0.003939	0.027573
Domestic animals	20.83	4.55	0.1542	0.6168
Mammals	25.00	31.82	0.5732	1
Plastic	25.00	9.09	0.585	1

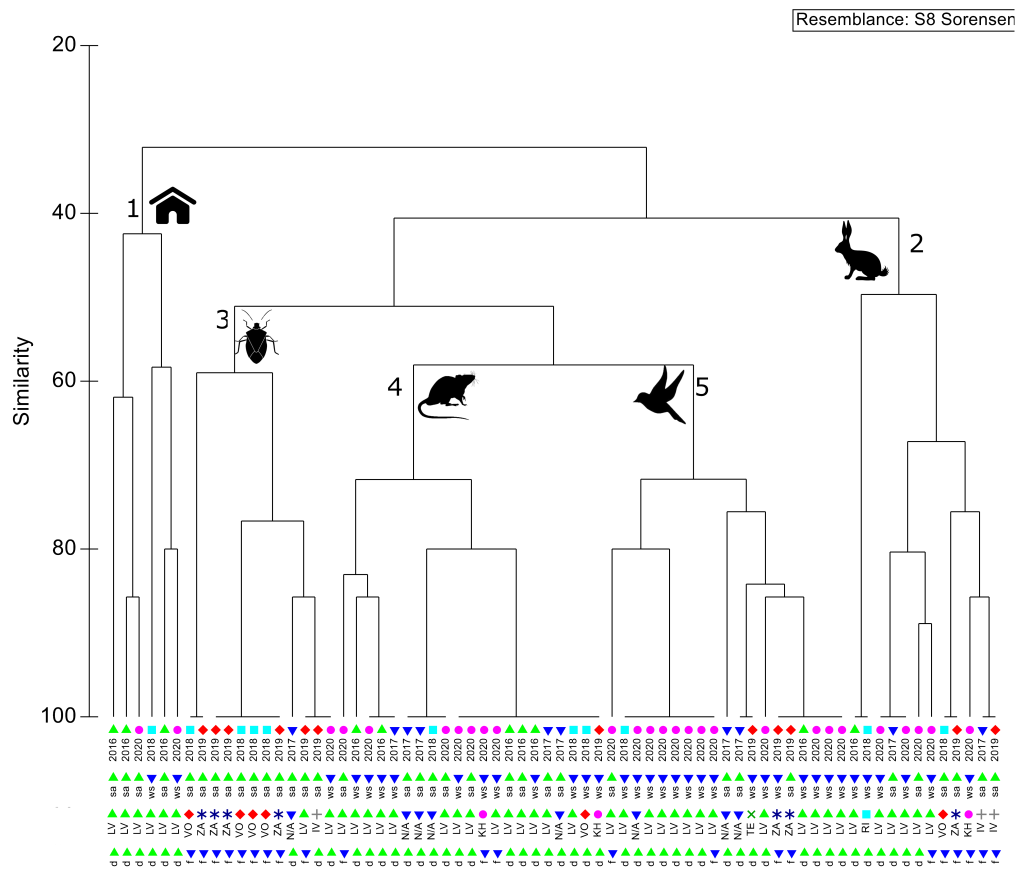

Fig. 2. Cluster analysis.
sa – summer-autumn season, ws – winter-spring season;
LV – Lviv region, VO – Volyn region, ZA – Zakarpattia region, N/A – Western Ukraine (exact data on region of origin are not available), KH – Khmelnytskyi region, TE – Ternopil region, RI – Rivne region, IV – Ivano-Frankivsk region;
d – stomach contents (dissection), f – faeces sample.

rodents (*Microtus arvalis* Pallas, 1778, *Rattus norvegicus* Berkenhout, 1769, *Cricetus cricetus* Linnaeus, 1758, *Sciurus vulgaris* Linnaeus, 1758, *Muscardinus avellanarius* Linnaeus, 1758). Some samples contained domestic animals and mammals, whereas invertebrates and lower vertebrates were absent.

All samples in cluster 5 (Fig. 2) contained wild avifauna (*Columba livia* Gmelin, 1789; *Perdix perdix* Linnaeus, 1758); rodents (*Microtus arvalis* Pallas, 1778) were common, whereas other mammals and invertebrates were absent.

Fisher's exact test

We observed statistically significant differences in the frequencies of food categories for different collection methods. In particular, we found significant differences in the groups of invertebrates and rodents (Table 2).

Correlation

We found a positive, statistically significant correlation only between the occurrence of invertebrates and lower vertebrates (r = 0.45455 p = 0.0328244) in samples of stomach contents. For faeces samples, no correlations were observed.

Generalised linear models

We observed a statistically significant effect of the collection method on the occurrence of invertebrates in the diet (coefficient = 2.3900 (10.9135), z = 2.626, p = 0.00863). The faecal collection increased the probability of occurrence of invertebrates in a given sample, whereas season, latitude and longitude had insignificant impacts.

However, there was a statistically significant effect of season on the occurrence of birds in the diet (coefficient = 1.3090 (3.702469), z = 2.000, p = 0.0455). The winter-spring season increased the probability of the occurrence of birds in each sample, whereas the collection method, latitude and longitude were insignificant.

A statistically significant effect of the collection method on the occurrence of rodents in the diet was observed (coefficient = - 1.7817 (0.1683), z = - 2.423, p = 0.0154). Faecal collection decreased the probability of the occurrence of rodents in a given sample, whereas season, latitude and longitude were insignificant.

Collection method (coefficient = - 2.6410 (0.0713), z = - 2.120, p = 0.03398) and season (coefficient = - 2.4512 (0.0862), z = - 2.582, p = 0.00981) had a statistically significant impact on the occurrence of domestic animals in the diet. Faecal sampling and sampling in winter-spring resulted in a lower probability of the occurrence of rodents in a given sample, whereas latitude and longitude were insignificant.

We did not find any impact of the investigated factors on the occurrence of the following food groups: plants, lower vertebrates, mammals, polyethene.

DISCUSSION

Analysis of the results showed that plant foods were important in the diet of foxes, as they occurred in 90% of cases. Most likely, the predator consumed this type of food for the normal functioning of the gastrointestinal tract (Rozhenko 2006). However, apples may serve as a source of energy due to their high carbohydrate content. The consumption of plant components enables the species to compensate for energy losses if there are no rodents or to compensate for seasonal unavailability of feed (Rozhenko 2006). Out of eight food groups, five had their own clusters, whereas three other groups were distributed within these clusters. Four factors might explain the cluster analysis results: year, season, region, and collection method. However, none of the factors we superimposed on the dendrogram provided a clear explanation of the classification obtained, but some of them might explain specific clusters. The factor "year" had no impact on grouping since it was the most evenly distributed factor among all clusters. Similarly, the factor "location" was randomly distributed within the clusters. The other two factors showed better grouping inside specific clusters.

We compared the results of different analysis approaches and should point out that GLM tries to explain the impacts of each factor on the occurrence of a specific food group in the individual sample, taking into account data within the entire sample. On the other hand, the reason for grouping samples into the cluster is the similarity of the samples in the quality composition. By adding factors to cluster analysis, we tried to find the additional reasons for grouping samples into the clusters.

The first cluster consisted predominantly of samples obtained by stomach examination in the summer-autumn season. The method of collection indicated that all these foxes were killed either during hunting or on the road. Considering that they had leftovers of domestic animals in their stomachs, we could characterise this group as relatively tolerant to the presence of humans. Also, domestic animals are more available to the predators during this season as they are kept outside more often. The result of the GLM supported the impacts of both factors.

We could neither use the season nor the collection method as an explanation for the second cluster. Other analysis approaches also did not yield any significant results for the leading food group of this cluster. However, each sample contained the food group “other mammals”. We assumed that these foxes used relatively easy methods of food provisioning because the group “other mammals” mainly consisted of wild boar and European deer, indicating that these foxes fed on carrion because the species is not able to hunt such large prey. Also, the samples of this cluster did not contain leftovers of domestic animals, suggesting a unique trophic behaviour of foxes from this group; they live in the wild and do not prey next to human settlements, avoiding urbanised ecosystems.

The factor “season” is a reasonable explanation for the third cluster. In spring-summer, the availability of invertebrates is higher than in winter-spring. Furthermore, most samples of this cluster were obtained via the examination of faeces. GLM and the exact Fisher test support the result of cluster analysis. We also found a positive correlation between invertebrates and lower vertebrates (amphibians and reptiles), which could be related to the peculiarity of the diet of this group of foxes. Amphibians feed on invertebrates (insects), and the fox hunts amphibians. Consequently, invertebrates (insects) are a part of the diet of foxes, often occurred in the diet of foxes with amphibians as undigested contents of their stomachs.

The best factor to explain the formation of the fourth cluster was the method of collection. This result coincides with the result obtained with GLM and the exact Fisher test. We assume that as an explanation, rodents are deeply digested by foxes and could therefore not be often found in the faeces samples.

The season and the collection method explained the fifth cluster. However, the GLM supported only the factor “season”. The increase in wild birds in the winter-spring season was due to the nesting period, making both female and young birds more available prey. The relatively high prevalence of rodents in this cluster could explain why the “collection method” is essential.

The analysis showed that the season was an important factor impacting the predator’s diet, as food items are more available and easier to obtain. There is evidence for the importance of the collection method in such studies (Balestrieri et al. 2011). However, we found a lower impact of the collection method on our results, most likely because of slight differences in the analyses or differences among the fox populations. In any case, neither our sample size nor the sample sizes in other studies were large, pointing to the need for more comprehensive studies in this field.

We found that the foxes’ diet’s composition did not depend on the study region within western Ukraine. However, other scientists have reported a significant effect of latitude and longitude on the predator’s diet (Soe et al. 2017), but that study covered almost Europe. We, therefore, assume that the distances between our study regions were not large enough to track changes in diet composition, although they differed geographically in some aspects.

Based on our results, the diet of foxes throughout the territory of western Ukraine is relatively homogeneous, despite the diversity of natural areas (Mixed forest (Polissya), Forest-Steppe and Carpathians). Based on published data (Rozhenko 2006), we assume that the foxes in Ukraine consume a similar diet. Food items may vary by region, but these are food items within one category (rodents, pets, plants, etc.). For example, in our study area, foxes feed on gastropods, whereas in the southern part of Ukraine, they prey on bivalves (Rozhenko 2006).

Reviewing of researches on the fox diet show that latitude has a significant effect on diet composition. For instance, rodents are more common for the fox diet in northern Europe (Dell'arte et al. 2007, Panzacchi et al. 2008), while the hares, fruits, and seeds are the dominant part of the fox diet in southern regions of Europes (Diaz-Ruiz et al. 2013). According to our research, voles, insects play an essential role in the diet on the territory of Ukraine, but herbaceous plants are common as well. Thus, such diet composition corresponds to the geographical location of Ukraine between the northern and south parts of the continent.

The seasonal changes in the fox's diet are closely related to its geographical location. For example, in the northern regions in the cold season, the variety of feeds is low and includes voles frequently. A wider variety of the diet is typical for the southern regions throughout the year, but the number of invertebrates increases in warm periods. Hares in this area are pretty frequent, so their portion in the diet of foxes is almost unchanged across the year and depends more on the size of the victim population (Soe et al. 2017). The diet of foxes in the territory of Western Ukraine is somewhat similar to the diet of this predator in the northern regions of Europe, as voles dominate the diet. However, as in the southern regions, the fox consumes many fruits and seeds in the cold season. Another feature of the diet is the absence of hares. The probable reason for this is that the density of the hare population is low on the territory (Novytskyi 2016). The populations of large carnivorous (lynx, wolf) that compete with foxes are also small in Ukraine (Shkvyrya 2005). Accordingly, the number of foxes in the study area is excessively high, making them use alternative food, namely food of anthropogenic origin (domestic animals).

CONCLUSIONS

The diet of the red fox within the territory of western Ukraine is relatively homogeneous. Common voles (*Microtus arvalis* Pallas, 1778 - 38.5%) and cereal residues (grass; 67%) predominate. The season has a significant impact on the formation of the fox's diet, as it can facilitate or hinder access to certain types of food. The diet of foxes that prey on wild mammals always lacks domestic animals, which shows the unique trophic behaviour of individuals from a group of foxes we studied. Some individuals do not seek food near human settlements, avoiding urbanised ecosystems.

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