PLOVDIV UNIVERSITY "PAISII HILENDARSKI"
FACULTY OF BIOLOGY • DEPARTMENT OF "ECOLOGY AND ENVIRONMENTAL CONSERVATION"

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"A comparative study on some aspects of the ecology of the fox (Vulpes vulpes L., 1758) and the stone marten (Martes foina Erxl., 1777) in habitats of different types"

ABSTRACT

of the dissertation work for the
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Professional field: 4.3. Biological sciences
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The dissertation contains 103 pages and includes 3 tables, 32 figures, 2 appendices, 275 literary sources, of which 35 in Cyrillic and 240 in Latin.

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The defense materials are available to those interested in the Department of Ecology and Environmental Conservation and in the library of the University of Plovdiv "Paisii Hilendarski".

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1. INTRODUCTION

Carnivorous mammals often play an important role in structuring ecosystems. They regulate the abundance of herbivores and shape their behavior, influence plant distribution, and shape plant communities through seed dispersal (Roemer et al., 2009). They facilitate the flow of nutrients between neighboring ecosystems (Roemer et al., 2009; López-Bao et al., 2015). As some of the most widespread carnivores in Europe, the fox (*Vulpes vulpes*) and the marten (*Martes foina*) play a key role in nutrient flow.

It is important to know the diet of carnivorous mammals to understand their impact in different ecosystems. Due to the lack of such information, or its neglect, for most of the 20th century the fox and the marten were considered "vermine" that destroyed "useful" wild and domestic animals, and even hunters were motivated to hunt them to complete extinction (Petkov, 1929; Markov, 1988).

Studies of medium-sized and small predatory mammals have remained in the background over the years. Large representatives such as wolves and bears have been more often the object of scientific interest. In the last 20 years, predators such as the fox and the marten have become more interesting objects for research. They use various food resources, and are far from limited to meat. Fruits and insects are often found in the components of their fecal samples, in some seasons even more often than mouse-like rodents. This makes them more difficult to study in some respects, because the researcher is required to know (or learn) the seeds of different plants, segments of insect bodies and the fur of different mammals in order to fully determine the diversity of food resources used by medium-sized and small predators.

Studies of the food spectrum of the fox and the stone marten can lead to the mitigation of the “human-wildlife” conflict. Among settlements with developed poultry farming, they are known as pests and are mistakenly believed to mainly hunt feathered game or poultry. Many

studies show that the main food of both predators is mainly mouse-like rodents, causing damage to agricultural crops and fruits.

In Bulgaria, no comparative study of the food niches and activity of the two predators in agricultural areas and mountain habitats has been conducted to date. Agricultural areas are rarely selected for research with camera traps due to the high probability of the devices being stolen. Our study was conducted in two agricultural regions and in a mountainous region with lower anthropogenic impact.

The role of the stone marten and the fox in natural ecosystems, as well as in settlements, can be established by studying their feeding habits, daily activity during different seasons, in order to establish the adaptive responses of the two species and whether there is competition between them in the studied areas.

2. AIM AND OBJECTIVES

The aim of this study is to establish the adaptive responses of the fox and the stone marten in terms of food and daily activity in an environment that is anthropogenically influenced, in particular – agricultural regions.

To achieve this goal, we set the following tasks:

1. Study of the food spectrum of the fox and the stone marten in habitats with different altitudes and anthropogenic load (agricultural activity) by collecting and processing faecal samples and determining the species diversity in their food.

2. Determine the differences in the scope of the food niche of the fox and the stone marten according to the region and season.

3. Monitor the daily activity of the fox and the stone marten according to the habitat and season by setting camera traps.

4. Compare the food spectrum and daily activity of the two species with the results of the studied habitats and seasons.

3. MATERIAL AND METHODS

3.1. Trophic spectrum

Processing of faecal samples

A total of 1440 excrement samples were collected – 360 per species from two regions – mountainous (Central Stara Planina) and agricultural regions (Hrabrino and Parvenets; Lyaskovo and Malka Vereya) from the Upper Thracian Lowland (Fig. 1) in the period September 1, 2021 – August 31, 2022. Each month, 30 excrements from a fox and 30 from a stone marten were collected and placed in separate plastic bags. In laboratory conditions provided by the Faculty of Biology of the University of Plovdiv „Paisii Hilendarski“, each sample was placed in 70% ethyl alcohol for 24 hours in order to kill the probable parasites or their eggs. The processing continued with washing in running water through a sieve (0.5 mm mesh) and drying at room temperature. After processing, the macrocomponents were separated to determine the species composition of the ingested food using a reference collection including the species composition of the most common berries, insects, birds and mammals from the study areas, developed during the field studies (Seebeck, 1978; Jedrzejewska & Jedrzejewski, 1998).

In our analysis, we defined 9 main food categories: fruits, domestic mammals, wild mammals, rodents, wild birds, domestic birds, amphibians and reptiles, insects and others (litter, grass, etc.). The determination of the components was carried out to the lowest possible taxon.

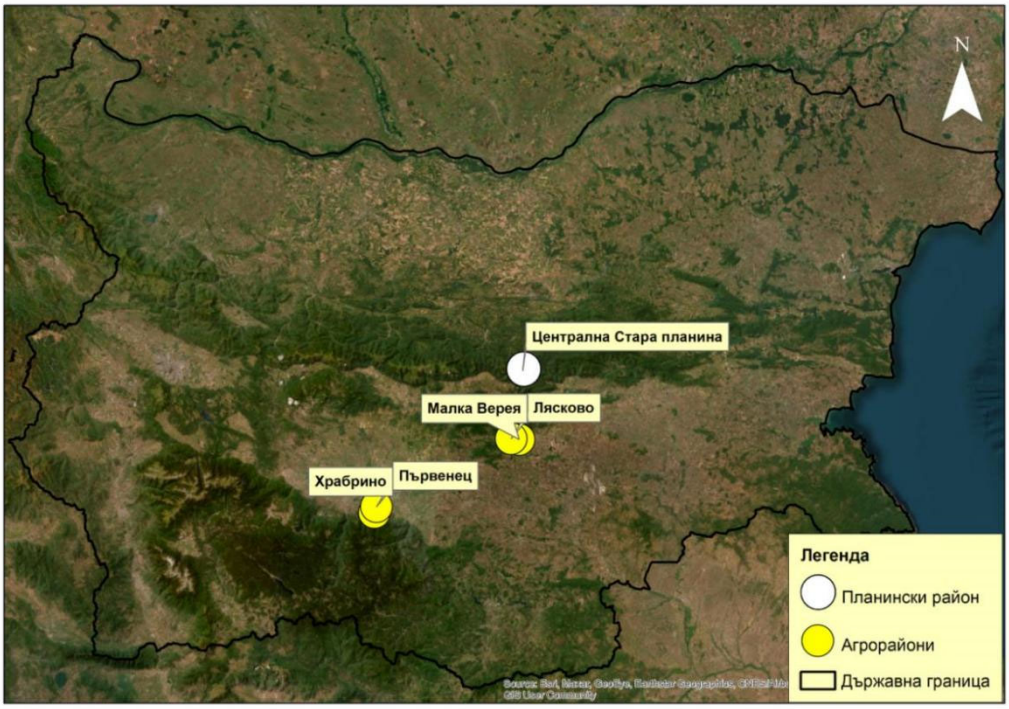

Fig. 1. *Map of the areas for collecting faeces*.

Statistical analysis

We calculated the relative frequency of occurrence (RFO%) of all food components and food groups by dividing the number of occurrences of a particular food component by the sum of the occurrences of all food components. Trophic niche width (B) was calculated according to Levins (1968): B = 1/pi2, where pi is the proportion of the ith food component and standardized niche width: BA = (B-1)/(n-1), ranging from 0 to 1, where n is the total number of resource taxa (Krebs, 1989). Trophic niche overlap was calculated following Pianka (1973): Ojk = ∑pij . pik/√∑pij2 . ∑pik2, where Ojk is the percentage overlap between species j and species k; pij and pik are the proportions of resource i in the diets of species j and species k.

For statistical data processing, the statistical package PAST v. 4.0 (Hammer et al., 2001) was used. To test the normal distribution of the data, the Shapiro-Wilk test (Shapiro & Wilk, 1965) was used. When comparing the trophic spectrum of the two species in the same area, the non-parametric Mann-Whitney U-test for independent variables was applied, since the data did not have a normal distribution (Fowler et al.

1998). Differences with $p<0.05$ [$\alpha=5\%$] were considered statistically significant.

3.2. Study of diurnal activity during different seasons (Autumn-Winter and Spring-Summer)

The study of diurnal activity was carried out in three different areas – the "Zlatiyata" Protected Area in Northwestern Bulgaria; the "Maritsa – Parvomay" Protected Area in the Upper Thracian Lowland and an area in the Central Stara Planina (Fig. 2).

The study was conducted from 01.09.2021 to 31.08.2022. A total of 15 camera traps (BolyGuard BG590-K2) were placed – 5 in each of the studied areas. No baits were used. The devices were placed at an angle of 45-90 degrees to the paths of wild animals. The height at which they were mounted on nearby trees was adjusted to the size of the studied species, the slope of the terrain and the available vegetation. The cameras were set to take 3 consecutive photos, followed by a 5-minute inactive interval. For independent observation (one case), only photos separated by a 30-minute interval were accepted, as it is considered that it guarantees the capture of different individuals (Forrester et al., 2016). The captured animals were determined by distinctive features that allow them not to be confused with similar animals inhabiting the same territories.

The activity of the given species was represented by the percentage of photos received for the respective time interval, with the day being divided into 12 intervals (two hours each). The data were presented graphically.

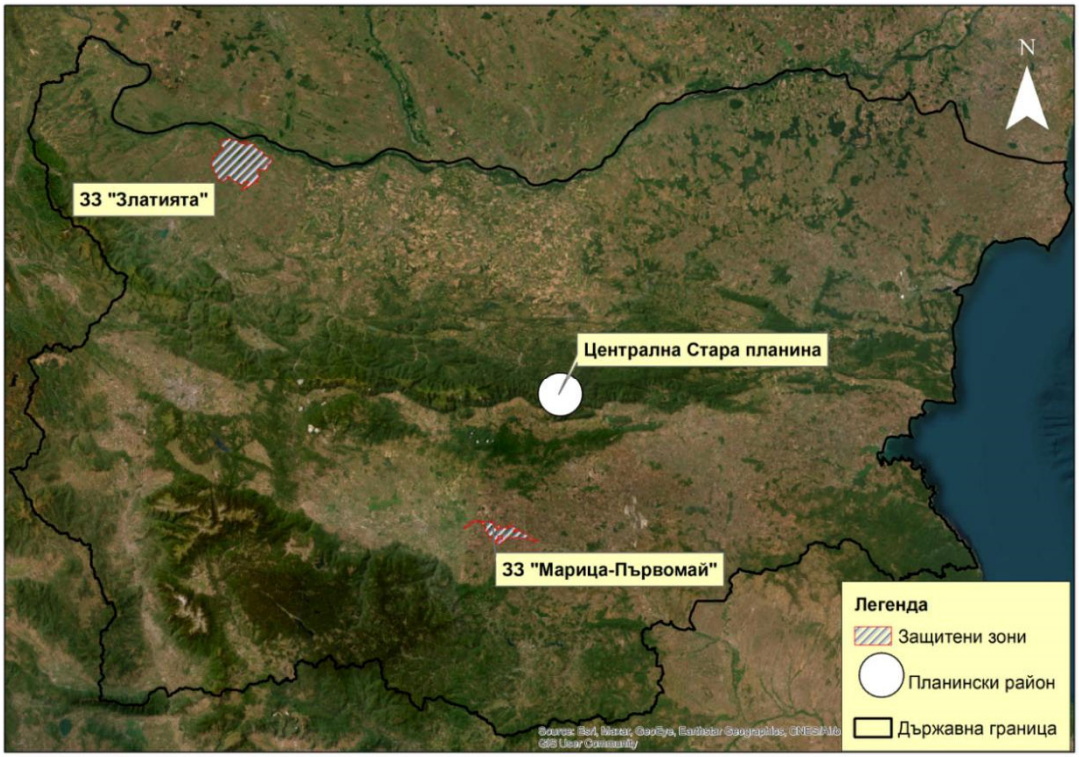

Fig. 2. *Map of the territories for placing camera traps.*

4. RESULTS AND DISCUSSION

4.1. Study of the food niche of the fox and the stone marten

4.1.1. Composition of the food of the fox and the stone marten in the agricultural region during the autumn-winter period

We identified 539 food components in 360 excrement samples of stone marten in agricultural regions of Central Bulgaria for the study period – 2021-2022 (Table 1). The most common components are fruits, followed by insects and rodents.

Table 1. Number of cases (n) and relative frequency of occurrence (RFO%) of dietary components in coproscopic samples (180 for each period) of *Martes foina* and *Vulpes vulpes* in agricultural areas of Central Bulgaria.

Food components	Autumn – Winter		Autumn – Winter		Spring – Summer		Spring – Summer		Total for the year		Total for the year	
	M. foina		*V. Vulpes*		*M. foina*		*V. Vulpes*		*M. foina*		*V. Vulpes*	
	n	RFO%	n	RFO%	n	RFO%	n	RFO%	n	RFO%	n	RFO%
Fruits	**153**	**49.84**	**112**	**37.97**	**95**	**40.95**	**104**	**37.55**	**248**	**46.01**	**216**	**37.76**
Vitis sp.	40	13.03	25	8.47	3	1.29	3	1.08	43	7.98	28	4.90
Mespilus sp.	32	10.42	13	4.41	12	5.17	16	5.78	44	8.16	29	5.07
Pyrus sp.	1	0.32	2	0.68	0	0	0	0.00	1	0.18	2	0.35
Prunus domestica	3	0.98	12	4.07	5	2.15	12	4.33	8	1.48	24	4.20
Prunus avium	1	0.32	1	0.34	1	0.43	1	0.36	2	0.37	2	0.35
Ficus carica	2	0.65	6	2.03	1	0.43	0	0.00	3	0.56	6	1.05
Rosa canina	40	13.03	34	11.53	17	7.33	6	2.17	57	10.57	40	6.99
Morus sp.	0	0.00	0	0.00	39	16.81	47	16.97	39	7.23	47	8.22
Malus domestica	0	0.00	0	0.00	9	3.88	7	2.53	9	1.67	7	1.22
Rubus sp.	4	1.30	0	0.00	0	0.00	2	0.72	4	0.74	2	0.35
Crataegus monogyna	2	0.65	2	0.68	0	0.00	0	0.00	2	0.37	2	0.35
Unindet. fruits	28	9.12	17	5.76	8	3.45	10	3.61	36	6.68	27	4.72
Domestic mammals	**6**	**1.95**	**16**	**5.42**	**0**	**0.00**	**2**	**0.72**	**6**	**1.11**	**18**	**3.15**
Capra domesticus	6	1.95	7	2.37	0	0.00	1	0.36	6	1.11	8	1.40

Oryctolagus cuniculus	0	0.00	4	1.36	0	0.00	0	0.00	0	0.00	4	0.70
Felis silvestris catus	0	0.00	1	0.34	0	0.00	0	0.00	0	0.00	1	0.17
Ovis aries	0	0.00	4	1.36	0	0.00	1	0.36	0	0.00	5	0.87
Wild mammals	**6**	**1.95**	**36**	**12.20**	**6**	**2.59**	**13**	**4.69**	**12**	**2.23**	**49**	**8.57**
Lepus europaeus	1	0.32	5	1.69	2	0.86	2	0.72	3	0.56	7	1.22
Sus scrofa	4	1.30	20	6.78	0	0.00	0	0.00	4	0.74	20	3.50
Capreolus capreolus	1	0.32	11	3.73	4	1.72	11	3.97	5	0.93	22	3.85
Rodents	**48**	**15.63**	**58**	**19.66**	**14**	**6.03**	**54**	**19.49**	**62**	**11.50**	**112**	**19.58**
Sylvaemus sylvaticus	7	2.28	12	4.07	5	2.15	7	2.53	12	2.22	19	3.32
Mus sp.	26	8.47	25	8.47	5	2.15	34	12.27	31	5.75	59	10.31
Arvicolinae	11	3.58	9	3.0	1	0.43	7	2.53	12	2.23	16	2.80
Glis glis	4	1.30	12	4.07	3	1.29	5	1.81	7	1.30	17	2.97
Rattus norvegicus	0	0.00	0	0.00	0	0.00	1	0.36	0	0.00	1	0.17
Wild Birds	**21**	**6.84**	**3**	**1.02**	**16**	**6.90**	**14**	**5.05**	**37**	**6.86**	**17**	**2.97**
Passeriformes	18	5.86	0	0.00	16	6.90	14	5.05	34	6.31	14	2.45
Unidentified birds	3	0.98	3	1.02	0	0.00	0	0.00	3	0.56	3	0.52
Domestic birds	**0**	**0.00**	**0**	**0.00**	**4**	**1.72**	**3**	**1.08**	**4**	**0.74**	**3**	**0.52**
Gallus gallus domesticus	0	0.00	0	0.00	4	1.72	3	1.08	4	0.74	3	0.52
Amphibians and reptiles	**0**	**0.00**	**0**	**0.00**	**2**	**0.86**	**5**	**1.81**	**2**	**0.37**	**5**	**0.87**
Serpentes	0	0.00	0	0.00	2	0.86	2	0.72	2	0.37	2	0.35
Lacertilia – undet.	0	0.00	0	0.00	0	0.00	3	1.08	0	0.00	3	0.52
Insects	**56**	**18.24**	**38**	**12.88**	**89**	**38.36**	**71**	**25.63**	**145**	**26.90**	**109**	**19.06**
Coleoptera	36	11.73	28	9.49	85	36.64	68	24.55	121	22.45	96	16.78
Orthoptera, Caelifera	1	0.32	0	0.00	0	0.00	2	0.72	1	0.18	2	0.35
Unindet. insects	19	6.19	10	3.39	4	1.72	1	0.36	23	4.27	11	1.92
Other	**17**	**5.54**	**32**	**10.85**	**6**	**2.59**	**11**	**3.97**	**23**	**4.27**	**43**	**7.52**
Waste	3	0.98	13	4.41	1	0.43	3	1.08	4	0.74	16	2.8
Pebbles, grass	13	4.23	19	6.44	5	2.15	7	2.53	18	3.34	26	4.55
Eggshell	0	0.00	0	0.00	0	0.00	1	0.36	0	0.00	1	0.17
Other	1	0.32	0	0.00	0	0.00	0	0.00	1	0.18	0	0.00
Total	**307**	**100**	**298**	**100**	**232**	**100**	**277**	**100**	**539**	**100**	**572**	**100**

4.1.2. Composition of the food of the fox and the stone marten in the agricultural region throughout the year

Both predators used mainly fruits throughout the year in the studied agricultural regions (Fig. 3). On the other hand, a significant difference was observed in the occurrence of rodents – in the fox their percentage was higher. Insects were the third most common food group at the fox' and the second – at the stone marten', although their activity is traditionally higher in the warmer months.

The groups of food components of wild birds, wild mammals, domestic birds, amphibians and reptiles and others had a significantly lower frequency of occurrence. Contrary to the popular opinion that the fox and the stone marten are "vermin" that should be exterminated (Markov, 1988), domestic animals such as chickens and small livestock are found much less frequently than mice and other rodents, which are known to be serious pests.

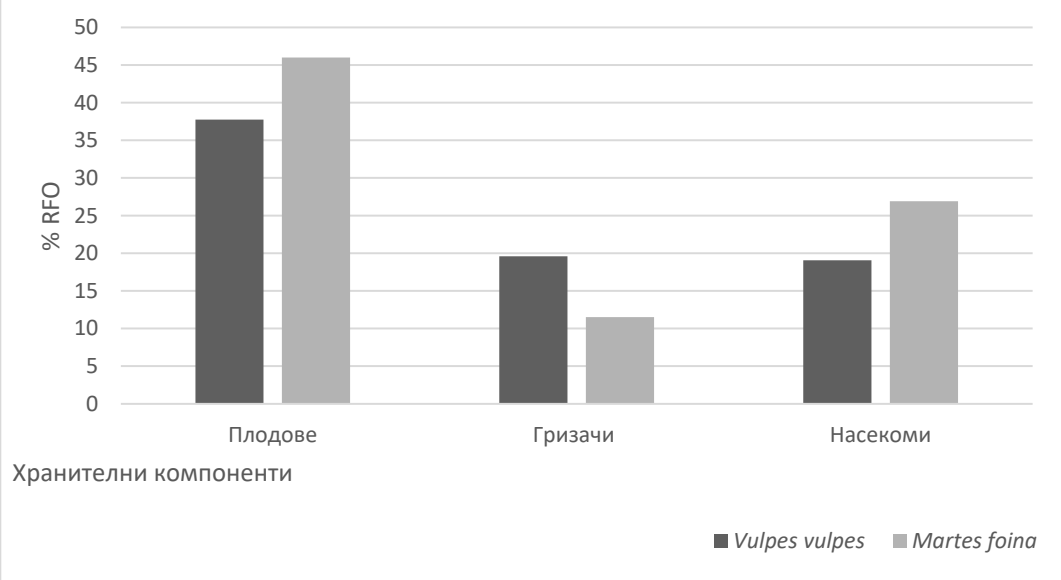

Fig. 3. *Annual comparison of the most common nutritional components in the diet of foxes and stone martens in the studied agro-region.*

Studies of fox diet that establish high year-round consumption of fruits in agro-regions, as our study found, whether wild or cultivated, are

few. They have been conducted mainly in Mediterranean countries, such as Italy (Rosa et al., 1991; Martinoli & Preatoni, 1995), Greece (Papakosta et al., 2010; Bakaloudis et al., 2012; Bakaloudis et al., 2015), North-West Portugal (Santos-Reis et al., 2005).

Similar results are found in stone martens, which prefer fruits all year round in Greece (Papakosta et al., 2010) and Italy (Balestrieri et al., 2013). In many other countries, fruits are a preferred food during certain seasons: from summer to winter in the Czech Republic (Czernik et al., 2016); spring and summer in Luxembourg (Baghli & Engel, 2001); summer and autumn in Hungary (Lanszki et al., 2019);

The second most common prey for foxes in the agricultural areas of our study are rodents. However, in Europe, murine rodents are the preferred food of this predator. This is shown by studies from Italy (Delattre et al., 1986; Peracino, 1992; Peracino et al., 1992; Canova & Rosa, 1994; Lucherini & Crema, 1994; Cavallini & Volpi, 1995; Cavallini & Volpi, 1996; Cagnacci et al., 2003), Great Britain (Southern & Watson, 1941; Lockie, 1956; Lever, 1965; Hewson, 1976; Zharkov, 1935; Chirkova, 1950. 2021; Cherkasova and Zagainova, 2021; Scopin et al., 2021).

Older studies from the beginning of the 20th century in Russia also show the same. Small rodents are usually found in 60-80%, and sometimes in 100% of the examined stomachs and excrements. Rarely, their frequency of occurrence drops to 50% or even slightly lower (Chirkova, 1947). According to studies by Zharkov et al. (1932), the fox's diet consists mainly of rodents. Of these, voles and mice come first (49.2%), followed by hamsters and ground squirrels. The fox often consumes rabbits. Some studies from Russia have found that rodents are the most common food only in certain seasons (Tkachenko, 2021; Cherkasova and Zagainova, 2021). Similar data is provided by a study from Germany, in which rodents are the preferred food in summer, autumn and winter (Drygala et al., 2013). In the Mediterranean, various studies have found that shrews are caught significantly less often in agricultural areas, and rodents are much more often preyed upon by

foxes. Although various studies have recorded poorer biodiversity in agricultural areas (Duelli, 1997; Kleijn et al., 2001; Tscharntke et al., 2005), this trend cannot provide a satisfactory explanation for the decrease in shrews in the fox's diet (Jedrzejewski & Jedrzejewska, 1992; Dell'Arte et al., 2007). It is possible that the agricultural habitat matrix favors rodents such as mice, rats and voles, which are more territorial than shrews, leading to a decline in their population, as indicated in studies of the diet of other predators in similar Mediterranean agroecosystems (Bontzorlos et al., 2005; 2009).

Rodents are also a preferred food for the fox in Bulgaria, as shown by various year-round studies (Drenski and Atanasov, 1935; Raichev & Georgiev, 2008).

Rodents are also predominant in the food spectrum of the stone marten in Europe, although in the agro-regions of our study they rank after insects in the annual food spectrum. This is clear from various studies in Russia (Ryabov, 1976; Belyachenko et al., 2010), the Czech Republic (Rysava-Novakova & Koubek, 2009; Novakova & Vohralik, 2017), Poland (Posluszny et al., 2007), Germany (Rodel & Stubbe, 2006), France (Ansorage, 1989b; Gruppe & Kruger, 1990), Portugal (Carvalho & Gomes, 2004) and Italy (Martinoli & Preatoni, 1995; Pozio & Gradoni, 1981).

Studies from the first half of the 20th century in Russia show that insects are also an important part of the fox's diet – the third most common food group in our study. Both in our country and in studies from Russia, large beetles (Coleoptera) from the families Scarabidae, Carabidae, Sylphidae, Tenebrionidae, Hysteridae, Coccinelidae are preferred (Zharkov et al., 1932; Baranovskaya & Kolosov, 1935; Serazhnin, 1955; Pavlov, 1953; Chirkova, 1947). Grasshoppers (Orthoptera), known as pests of agricultural crops, are also often found (Chirkova, 1947). Insects from the order Coleoptera are common in the fox's diet in spring, summer and autumn (Ricci et al., 1998). In most areas of Britain surveyed, Coleoptera and earthworms (Annelida) along with various other invertebrates also feature in the fox's diet, sometimes in

abundance (Anon, 1965; Burrows, 1968; Jeffries, 1974; Lever, 1957; Scott, 1943; Southern & Watson, 1941).

Coleoptera are the preferred food of the stone marten in south-west Spain and it feeds less frequently with mammals, birds, reptiles and fruit, which rank last in abundance (Amores, 1980).Insects are also highly abundant in Northwestern Portugal (Santos-Reis et al., 2005).

From the analysis of the available literature, we see that our results are similar to agro-regions of countries with a Mediterranean climate such as Greece and Italy. The high year-round consumption of fruits and the high seasonal consumption of insects from the order Coleoptera indicate that these groups provide an important food resource, but do not completely displace rodents, which are the main food for the studied predators in Europe.

4.1.3. Composition of the diet of foxes and stone martens in a mountain area during the autumn-winter period

In the mountain area, as well as in agro-regions, fruits are also the most used food during the year for both species, followed by rodents and insects (Table 2). The appearance of fruits and rodents characteristic of mountain areas such as the rusty wood vole (Myodes glareolus) is noted.

Table 2. Number of occurrences (n) and relative frequency of occurrence (RFO%) of food components in faecal samples (180 for each period) of *Martes foina* and *Vulpes vulpes* in a mountainous region of Central Bulgaria.

Food components	Autumn – Winter		Autumn – Winter		Spring – Summer		Spring – Summer		Total for the year		Total for the year	
	M. foina		*V. Vulpes*		*M. foina*		*V. Vulpes*		*M. foina*		*V. Vulpes*	
	n	RFO%	n	RFO%	n	RFO%	n	RFO%	n	RFO%	n	RFO%
Fruits	**130**	**50.39**	**85**	**35.86**	**119**	**47.41**	**63**	**31.82**	**249**	**48.92**	**148**	**34.02**
Mespilus sp.	67	25.97	38	16.03	13	5.18	14	7.07	80	15.72	52	11.95
Prunus avium	0	0.00	0	0.00	59	23.51	10	5.05	59	11.59	10	2.30
Rosa canina	15	5.81	24	10.13	14	5.58	11	5.56	29	5.70	35	8.05
Morus sp.	0	0.00	0	0.00	21	8.37	11	5.56	21	4.13	11	2.53
Rubus idaeus	0	0.00	1	0.42	0	0.00	0	0.00	0	0.00	1	0.23
Rubus sp.	24	9.30	14	5.91	12	4.78	11	5.56	36	7.07	25	5.75

Prunus spinosa	21	8.14	0	0.00	0	0.00	0	0.00	21	4.13	0	0.00
Prunus domestica	0	0.00	4	1.69	0	0.00	1	0.51	0	0.00	5	1.15
Prunus cerasifera	0	0.00	0	0.00	0	0.00	4	2.02	0	0.00	4	0.92
Ficus carica	1	0.39	1	0.42	0	0.00	0	0.00	1	0.20	1	0.23
Fagus sylvatica	0	0.00	2	0.84	0	0.00	1	0.51	0	0.00	3	0.69
Cornus mas	0	0.00	1	0.42	0	0.00	0	0.00	0	0.00	1	0.23
Unindet. fruits	2	0.78	0	0.00	0	0.00	0	0.00	2	0.39	0	0.00
Domestic mammals	**0**	**0.00**	**0**	**0.00**	**2**	**0.80**	**5**	**2.53**	**2**	**0.39**	**5**	**1.15**
Capra domesticus	0	0.00	0	0.00	2	0.80	5	2.53	2	0.39	5	1.15
Wild mammals	**1**	**0.39**	**18**	**7.59**	**11**	**4.38**	**5**	**2.53**	**12**	**2.36**	**23**	**5.29**
Lepus europaeus	1	0.39	0	0.00	6	2.39	0	0.00	7	1.38	0	0.00
Capreolus capreolus	0	0.00	11	4.64	5	1.99	4	2.02	5	0.98	15	3.45
Sus scrofa	0	0.00	6	2.53	0	0.00	1	0.51	0	0.00	7	1.61
Canis aureus	0	0.00	1	0.42	0	0.00	0	0.00	0	0.00	1	0.23
Rodents	**69**	**26.74**	**93**	**39.24**	**59**	**23.51**	**46**	**23.23**	**128**	**25.15**	**139**	**31.95**
Sylvaemus sylvaticus	13	5.04	29	12.24	13	5.18	12	6.06	26	5.11	41	9.43
Microtus sp.	0	0.00	51	21.52	0	0.00	26	13.13	0	0.00	77	17.70
Myodes glareolus	15	5.81	8	3.38	6	2.39	5	2.53	21	4.13	13	2.99
Arvicolinae	38	14.73	0	0.00	38	15.14	0	0.00	76	14.93	0	0.00
Glis glis	3	1.16	5	2.11	2	0.80	3	1.52	5	0.98	8	1.84
Wild birds	**12**	**4.65**	**13**	**5.49**	**8**	**3.19**	**12**	**6.06**	**20**	**3.93**	**25**	**5.75**
Passeriformes	12	4.65	13	5.49	8	3.19	12	6.06	20	3.93	25	5.75
Domestic birds	**0**	**0.00**	**0**	**0.00**	**1**	**0.40**	**1**	**0.51**	**1**	**0.20**	**1**	**0.23**
Gallus gallus domesticus	0	0.00	0	0.00	1	0.40	1	0.51	1	0.20	1	0.23
Amphibians and reptiles	**1**	**0.39**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**	**1**	**0.20**	**0**	**0.00**
Salamandra salamandra	1	0.39	0	0.00	0	0.00	0	0.00	1	0.20	0	0.00
Insects	**43**	**16.67**	**24**	**10.13**	**51**	**20.32**	**64**	**32.32**	**94**	**18.47**	**88**	**20.23**
Coleoptera	42	16.28	24	10.13	51	20.32	62	31.31	93	18.27	86	19.77
Orthoptera, Caelifera	1	0.39	0	0.00	0	0.00	2	1.01	1	0.20	2	0.46
Other	**2**	**0.78**	**4**	**1.69**	**0**	**0.00**	**2**	**1.01**	**2**	**0.39**	**6**	**1.38**
Waste	2	0.78	1	0.42	0	0.00	0	0.00	2	0.39	1	0.23
Pebbles, grass	0	0.00	3	1.27	0	0.00	1	0.51	0	0.00	4	0.92
Eggshell	0	0.00	0	0.00	0	0.00	1	0.51	0	0.00	1	0.23
Total	**258**	**100**	**237**	**100**	**251**	**100**	**198**	**100**	**509**	**100**	**435**	**100**

4.1.4. Composition of the diet of foxes and stone martens in a mountainous area throughout the year

The annual comparison shows that fruits are the most used food resource throughout the year, followed by rodents and insects (Fig. 4). During the year, stone martens resorted to fruits more often than foxes, while foxes caught more rodents. Insects also have a high percentage of RFO, but unlike in agricultural areas, they remain the third most common in the diet of foxes and stone martens in the mountainous area.

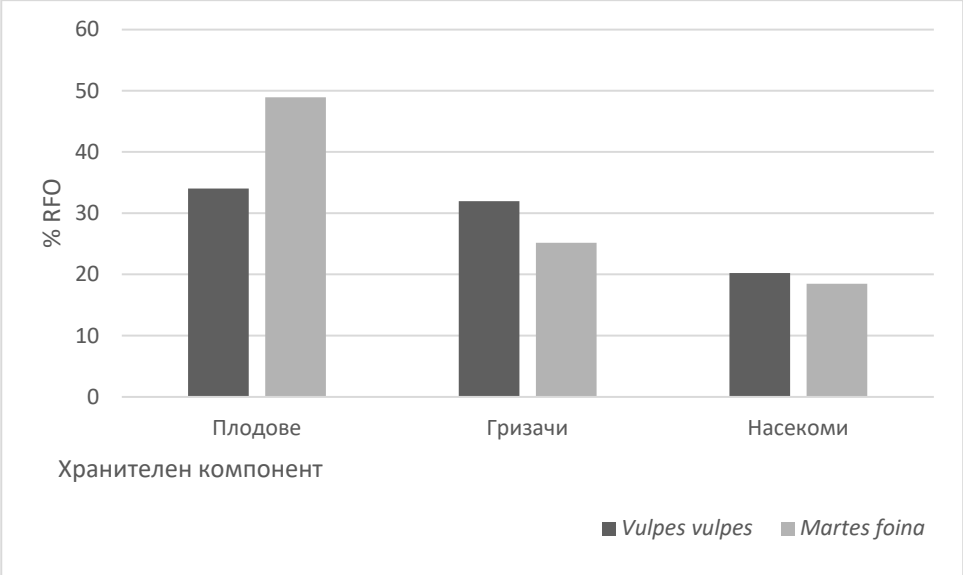

Fig. 4. *Annual comparison of the most common nutritional components in the diet of foxes and stone martens in the studied mountain region.*

In studies conducted on the territory of Europe, the fox eats fruits all year round in the lower parts of Mediterranean countries, in contrast to our results. An exception is a study by Russell & Storch (2004) in the German Alps. In most analyses of the fox's food spectrum, fruits have a high frequency of occurrence between spring and autumn. In summer, fruits are most common in the fox's diet in the Central Rhodopes (Kyurkchiev, 2008). In our study, as well as in that of Rosa et al. (1991), fruits from the Rosaceae family are significantly present, represented in our country mainly by rose hips, which are often found year-round in the

diet of foxes and stone martens. Tkachenko (2021) found that the presence of cultivated plants and domestic animals in the food spectrum decreases with increasing distance between the fox's habitat and settlements. This is somewhat similar to our study, which shows a higher consumption of wild berries (blackberries, rose hips, etc.), characteristic of higher altitudes and areas with lower anthropogenic impact.

In winter, a high consumption of berries by the stone marten was reported in a study by Such & Calabuig (2003). In the Central Balkans, berries, rodents and insects are the main food of the stone marten in anthropogenic and areas with low anthropogenic impact (Peeva, 2016). Plant food is preferred in the mountainous areas around the town of Tran, which distinguishes the marten there from the Pirin, Eastern and Western Rhodopes, Vitosha and Osogovo mountains (Petrov et al., 2016a). Berries are also a main food resource in the towns located in Sakar (Georgiev, 2013). Hisano (2018) claims that the stone marten consumes various fruit species with a large number of cultivated plants, which proves an opportunistic type of behavior.

In Bulgaria, only one study of the food spectrum of the stone marten in the Upper Thracian Lowland shows such a high consumption of fruits throughout the year (Georgiev, 2013). Most studies on the trophic spectrum of both species in Bulgaria show that they catch mainly rodents and only in their absence or low numbers do they attack other animals or feed on carrion (Vasileva et al., 2005; Raichev & Georgiev, 2008; Kyurkchiev, 2008; Georgiev & Raichev, 2009; Kirkova et al., 2011; Hisano et al., 2013; Petrov et al., 2016a; b). These authors consider insects and fruits as additional food resources, which are consumed more often in the spring-autumn period, while in our study fruits are the group with the highest frequency of occurrence.

According to Pandolfi et al. (1996) even in winter fruits are an important food resource for foxes and stone martens in Mediterranean regions. The subject of future studies is whether higher temperatures in winter in recent years lead to a high presence of fruits in the food spectrum of both predators in Bulgaria.

Murine rodents in the diet of foxes from different regions of Russia are ubiquitous and occupy a significant place. This largely coincides with our study, although rodents are the group in second place after fruits in terms of frequency of occurrence. In foxes from the forest-tundra of the Kola Peninsula, mouse-like rodents were found in 100% of the stomachs examined, in the Moscow region – in 79%, in the plains of the former Tatar ASSR – in 76%, in the mountainous part of Crimea – in 61% and in the territory of the Caucasus State Reserve – in 84% (Gerasimov, 1953). A 100% frequency of occurrence was also established in a study conducted in the 1930s and 1940s in the North Caucasus (Chirkova, 1947). In the same period, a similar study in the Moscow region by Baranovskaya and Kolosov (1935) also showed that mouse-like rodents are the most preferred food of the fox. Geptner et al. (1950) claim that with a high number of rodents, the fox can feed on them all year round. Of interest is a study concerning an isolated population of foxes on the island of Urup (Scopin et al., 2021). It highlights the high adaptability of the species to the impoverishment of the food base. It was conducted during a period of low abundance of the only rodent on the island – the gray rat – and shows how the fox adapts to the lack of its preferred (according to the studies listed so far) food. The occurrence of bird remains is twice as high, especially in the northern part of the island, where there are forest communities.

It has often been noted by various authors from Western Europe that small mammals such as voles, rats and shrews always make up a significant part of the fox's diet (Jedrzejewski & Jedrzejewska, 1992; Ferrari, 1995; Dell'Arte et al., 2007; Jankowiak & Tryjanowski, 2013). It has also been confirmed by Papageorgiou et al. (1988) in a study covering the whole of Greece. This can be explained by the specificity of Mediterranean ecosystems (Blondel & Aronson, 1999), compared to the ecosystems of Central and Northern Europe, where habitats are less complex and have clearer patterns of spatial predation (Myers et al., 2000).

Rodents also occupy the largest volume of the fox's diet in the Central Rhodopes in autumn (Kyurkchiev, 2008). In Osogovo, rodents are again the predominant group in the fox's diet in the spring season (Vasileva et al., 2005), as well as in the autumn-winter period in Sarnena Sredna Gora (Kirkova et al., 2011).

In Bulgaria, sexual preferences for food have been established in Sarnena Sredna Gora. Males and females prefer rodents. Rabbits, reptiles, fish and plants are the least present in its diet. Fruits and other mammals, apart from those listed, are absent (Hisano et al., 2013). In winter in the same region, rodents are the main food for stone martens, and insects are in second place (Raichev, 2002). In the Balkan Mountains, the main food resource does not change during the same season. After rodents, birds and insects are the most common food (Hisano et al., 2014).

The most frequent occurrence, as well as the main part of the biomass in the feces of a fox on Urup Island, belong to insects and crustaceans (Scopin et al., 2021). In spring in the Central Rhodopes, insects are also the most common food in the fox's diet, followed by rodents, reptiles and large mammals (Kyurkchiev, 2008). In Osogovo, insects are most often found in the summer (Vasileva et al., 2005).

In the Czech Republic, the stone marten's diet includes 42 invertebrate species (Cervus, hornets, snails, etc.), and 47 plant species (cherry, apple, rosehip, etc.) (Novakova & Vohralik, 2017).

Bumblebees, large orthopterans and other insects are a common additional source of food for the stone marten in Poland (Skalski & Wierzbowska, 2008). It turns out that it prefers mainly insects living in nests, which it catches in meadow habitats. In forests, it hunts mainly Cervus. The species composition of insects depends strongly on the habitat, in particular on the local entomofauna. (Sklodowski & Posluszny, 2005; Wierzbowska & Skalski, 2010).

In our study, wild birds and mammals, domestic birds, amphibians and reptiles and other objects were considered as additional food with a significantly lower percentage in the samples collected by both species in both regions annually. We defined the wild and domestic mammals

(mainly ungulates) found in the samples as taken in the form of carrion left or discarded in the wild. The presence of domestic birds such as chickens is extremely rare. The so-called "harm" that foxes and stone martens inflict on poorly protected chicken coops is much less than the benefit – regulation of rodent populations (Serafini & Lovari, 1993; Coonan et al., 2000) on the one hand, and the dispersal of seeds through feces (endozoochory) on the other (Jordano et al., 2007). According to the literature review, endozoochory in medium-sized and small carnivores is a poorly studied phenomenon, which is very important. Dispersal of seeds far from the fruiting plant is essential for the persistence and recovery of plant populations and genetic diversity in fragmented landscapes (Nakashima & Do Linh San, 2022). These unique characteristics of seed dispersal by medium-sized carnivores are strongly associated with their morphological and behavioral characteristics (e.g. dental morphology, short gut length and deposition of feces in specific locations) (Herrera, 1989). The seeds of many plants remain intact by the teeth and digestive system of predatory mammals, while in others (omnivores and herbivores) the seeds in the feces are damaged (Perea et al., 2013).

4.1.5. Width and overlap of the food niche of the fox and the stone marten

Applying the Levins formula (1968) to our data, we found that both predators have a wider trophic niche in agricultural areas compared to mountainous areas (Table 3). Agricultural areas offer a greater variety of food products than mountains (Serafini & Lovari, 1993; Martin, 1994). The trophic niches of the studied species are also wider in the autumn-winter period than in the spring-summer period, especially pronounced in the food of the fox. Our results are consistent with those of other studies (Storch et al., 1990; Serafini & Lovari, 1993; Martin, 1994; Sidorovich et al., 2000; Padial et al. 2002; Papakosta et al., 2010).

Table 3. Width (Levins, 1968) and overlap (Pianka, 1973) of the food niches of fox and stone marten in agricultural and mountainous areas.

Area	Food niche width						Annual overlap of food niches
	M.foina Autumn -winter	*M.foina* Spring-summer	*V. vulpes* Autumn-winter	*V. vulpes* Spring-summer	*M.foina* year	*V. vulpes* year	
Agricultural region	0.36	0.30	0.84	0.37	0.29	0.41	0.80
Mountainous area	0.30	0.35	0.46	0.40	0.24	0.40	0.65

The overlap of trophic niches between stone martens and foxes was high in both habitats, which is an expression of the competition between them was high in both habitats, especially in agroregions, (0.802). No statistical differences were found between the species composition of the diet of the two species in agricultural (Mann-Whitney U-test, U=503, z=0.054, p=0.96), as well as in mountainous areas (Mann-Whitney U-test, U=233, z=0.851, p=0.39), which is a result of the high overlap of the niches. The significant overlap in the diet of the two predators is considered a signal of strong indirect competition (Papakosta et al., 2014; Scholz et al., 2020).

4.2. Seasonal and diurnal activity of foxes and stone martens

4.2.1. Fox and marten activity in the Zlatiyata Protected Area

The fox and the stone marten (Fig. 5) exhibit bimodal nocturnal activity during the autumn-winter period in the Zlatiyata Protected Area as a model for the typical agricultural landscape of Northwestern Bulgaria.

Fig. 5. Fox (*V. vulpes*), on the left, and stone marten (*M. foina*), on the right, in the "Zlatiyata" Nature Reserve.

The stone marten has a peak of activity before midnight 22:00-00:00 during the study period. Compared to the autumn-winter period, the fox changes its peak of activity (Fig. 6). During the spring-summer period, the peaks of the bimodal activity of the fox shift approximately four hours earlier than those during the autumn-winter period.

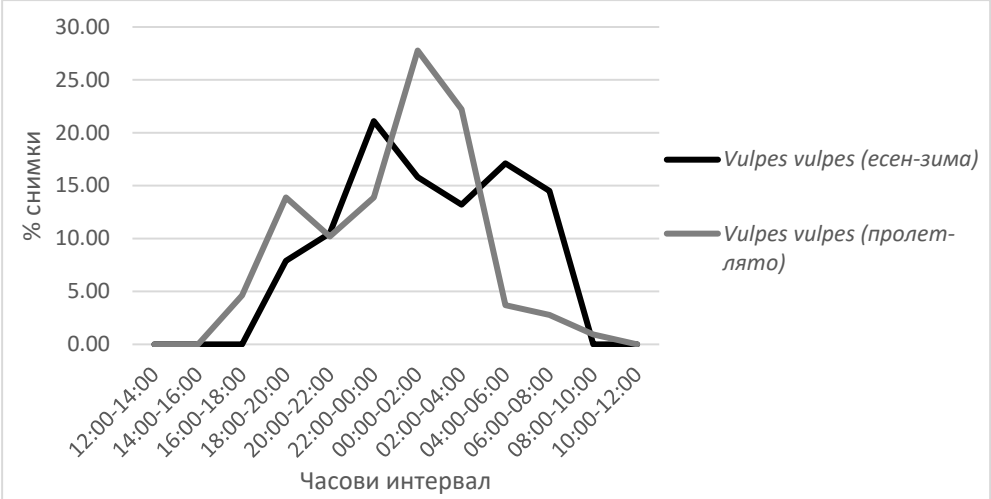

Fig. 6. *Comparison of the fox's daily activity throughout the year in the Zlatiyata Nature Reserve.*

The stone marten maintains the same peak before midnight during the spring-summer period as during the autumn-winter period, but no second peak was observed (Fig. 7).

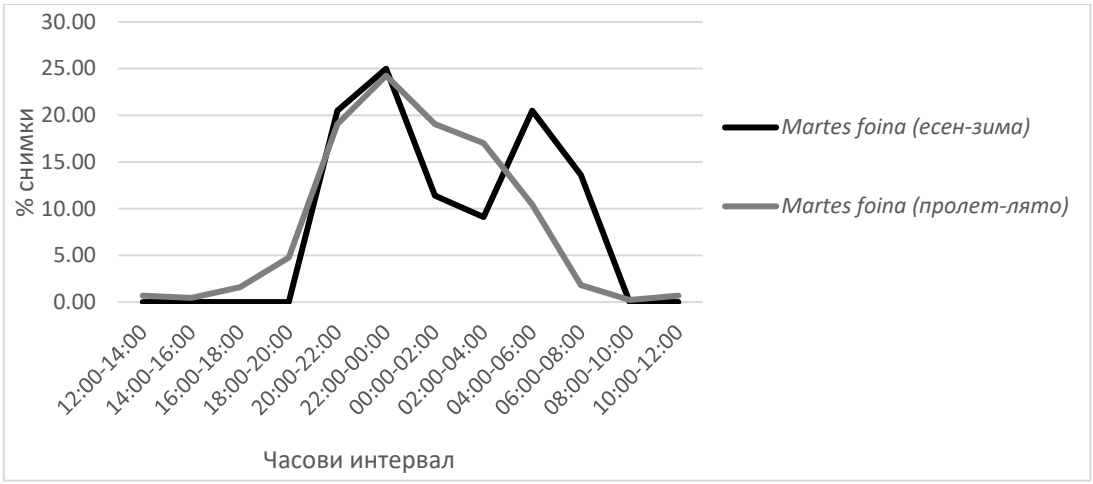

Fig. 7. *Comparison of the daily activity of the stone marten throughout the year in the Zlatiyata Nature Reserve.*

4.2.2. Activity of the fox and the stone marten in the protected area "Maritsa – Parvomay"

And during the spring-summer period the fox has one peak of activity – between 20:00 and 22:00 (Fig. 8). During the period a slight increase in activity is observed in the interval from 04:00 to 06:00.

The stone marten exhibits bimodal diurnal activity during the autumn-winter period, but during the spring-summer period its activity has only one peak – between 20:00 and 22:00 (Fig. 9).

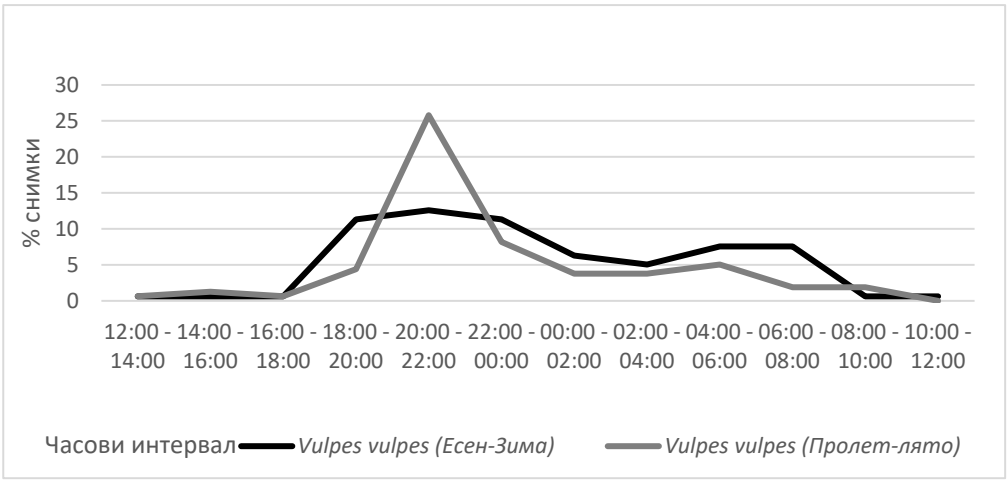

Fig. 8. *Comparison of the daily activity of the fox throughout the year in the Maritsa-Parvomai Nature Reserve.*

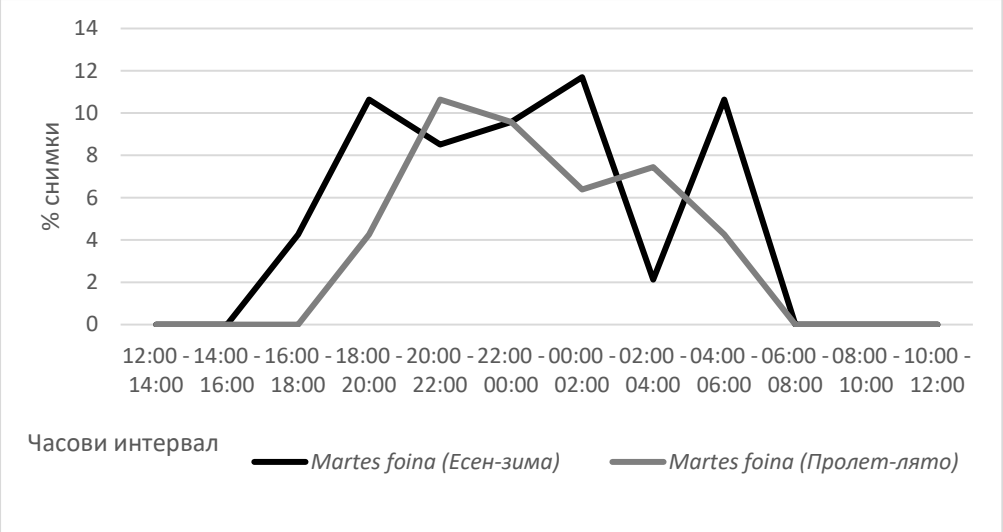

Fig. 9. *Comparison of the daily activity of the stone marten throughout the year in the Maritsa-Parvomai Nature Reserve.*

4.2.3. Activity of the fox and the stone marten in a mountainous area

The fox exhibits unimodal diurnal activity with a single peak in the interval 18:00 – 20:00 during the autumn-winter period in a mountainous area (Fig. 10), and in the spring-summer period – bimodal diurnal activity, with an increase in activity observed even in the daylight hours.

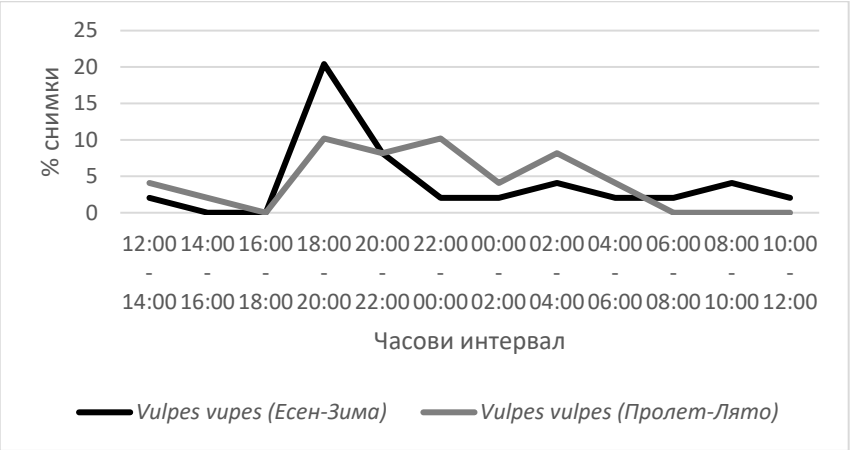

Fig. 10. *Comparison of the fox's daily activity throughout the year in the mountainous region.*

The stone marten exhibits bimodal nocturnal activity during the autumn-winter period (Fig. 11) as well as during the spring-summer period. In both cases, activity peaks in the dark part of the day.

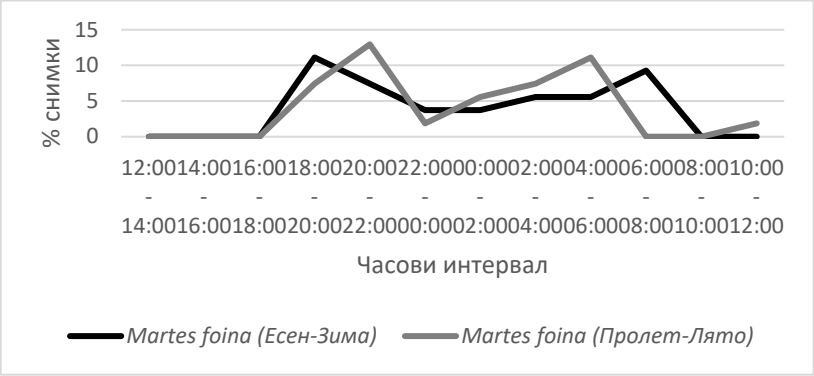

Fig. 11. *Comparison of the daily activity of the stone marten throughout the year in a mountainous area.*

Our results are similar to those of other authors investigating the activity patterns of the same species in Bulgaria (Dudin & Georgiev, 2015; Georgiev et al., 2015; Peeva, 2016; Dudin, 2017). Nocturnal but unimodal activity for both species was described by Tsunoda et al. (2020) for Central Bulgaria.

The studied predators show peak activity during darkness and twilight, which is common for areas with strong anthropogenic influence (Fig. 8; 9). Similar results were also reported by Dudin & Georgiev (2015); Peeva (2016); Dudin (2017) and Tsunoda et al. (2022).

In the present study, there are differences in the diurnal activity shown in the agricultural areas of Southern Bulgaria (Georgiev et al., 2015) and the high mountain areas (Petrov et al., 2016) in other studies.

Compared to the mountainous area (Petrov et al., 2016; Tsunoda et al., 2020), both predators in the studied agricultural areas show similar, mainly nocturnal activity during the spring-summer period. While the activity of the fox reaches two peaks in the mentioned habitats, the stone marten exhibits unimodal activity in the agricultural area during the studied period, different from the bimodal pattern in the mountainous area.

Other predators inhabiting the same territories as the fox and stone marten were also identified on the camera traps. Among them, the golden jackal (*Canis aureus*), the badger (*Meles meles*), the wild cat (*Felis silvestris*), the weasel (*Mustela nivalis*), etc. stand out.

5. CONCLUSIONS

1. Both species have a broad food niche, including a variety of food components of plant and animal origin.

2. Although both species belong to the order Carnivora, their food spectrum shows that they behave mainly as opportunistic and omnivorous, using the resources of the habitat, i.e. generalists.

3. The fox shows a higher tendency to hunt when obtaining food, judging by the higher percentage of rodents used during the study period.

4. Despite the negative attitude towards the studied predators as pests, the low percentage of consumption of poultry and agricultural mammals shows that they are not a preferred food.

5. Throughout the year, the most frequently used food resource by both species in the studied areas are various fruits and insects of the order Coleoptera, which highlights their importance as an important complementary food resource, especially during the warm part of the year.

6. Different food sources were observed in both habitats. The food components of the high mountain regions include plants and animals typical of the mountains (blueberries, rusty wood vole), and in the studied agricultural regions, fruits and rodents typical of them.

7. Both species, with their feeding behavior, contribute significantly to agriculture and forestry, regulating the population of several rodent species and spreading the seeds of the plants they feed on.

8. Both species are active mainly during the dark and twilight part of the day.

9. In the mountainous regions, with weaker anthropogenic influence, increased activity of the fox and the stone marten is observed during the daylight hours compared to the more populated areas of the lowlands of the country.

10. In the studied agricultural regions, the fox and the stone marten strive to avoid confrontation with humans, shifting their activity more towards the dark part of the day.

11. The high overlap of food niches and the close diurnal activity are prerequisites for competition for food resources and territory between the studied predators.

6. CONTRIBUTIONS

6.1. Original contributions

1. For the first time, a year-round study has been conducted, combining comparisons of the food spectrum and diurnal activity during different seasons between the two species in two different habitats.

2. For the first time in Bulgaria, strong food competition between the studied species has been established both in mountainous and agricultural areas.

6.2. Confirmatory contributions

1. The benefit of both species for agriculture and forestry as regulators of rodent populations and the spread of plants through endozoochory is confirmed.

2. The established nutritional composition in the food of the fox and the skunk confirms the results of a number of previous studies that both species cause negligible damage to livestock.

3. The generalist-opportunistic feeding behavior of the two predators with high fruit consumption is confirmed.

7. PUBLICATIONS ON THE TOPIC OF THEDISSERTATION

1. Petrov A., 2022. On the Circadian Activity of Red Fox (*Vulpes vulpes*) and Stone Marten (*Martes foina*) in Agricultural Landscape of Northwestern Bulgaria During Spring-Summer Period. Ecologia Balkanica, 14(2), pp. 205-208. **Q4.**

2. Petrov A., Kirilov K., Tincheva D., 2022. Circadian activity of the Red fox (*Vulpes vulpes*) and the Stone marten (*Martes foina*) in agricultural landscape of Northwestern Bulgaria during autumn-winter period. ZooNotes 209, pp. 1-4.

3. Petrov A., 2024. Seasonal and circadian activity patterns of two sympatric carnivores in an agricultural habitat, Southern Bulgaria. ZooNotes 232, pp. 1-4.

4. Petrov A., Peeva S., Mollov I., 2024. What's for dinner? Diet and trophic niche overlap in two sympatric carnivores in agricultural and near-natural habitats in Bulgaria. Ecologia Balkanica, 16(1), pp. 21-29. **Q4.**

5. Petrov A., Pancheva E., 2024. Summer diet of the red fox (*Vulpes vulpes* Linnaeus, 1785) in agricultural areas in South-Eastern Bulgaria. Ecologia Balkanica, 16(1), pp. 153-156. **Q4.**

8. PARTICIPATION IN SCIENTIFIC CONFERENCES WITH MATERIALS ON THE TOPIC OF THE DISSERTATION

1. Presented a report on the topic “Food spectrum of the red fox (*Vulpes vulpes*) and the stone marten (*Martes foina*) in agricultural areas of the Upper Thracian Lowland during the autumn-winter period” for the conference “Ecology – a way of thinking 14” in the city of Plovdiv on 21.05.2022

2. Presented a report on the topic “Circadian activity patterns of the Red fox (*Vulpes vulpes*) and the Stone marten (*Martes foina*) in protected area "Zlatiyata" (Northwestern Bulgaria) during autumn-winter period” for the conference “Scientific conference with intrantional participation “Agricultural sciences and Business” in the city of Stara Zagora on 26.05.2022

3. Presented report on the topic “Seasonal and diurnal activity of the fox (*Vulpes vulpes*) and the stone marten (*Martes foina*) in the “Zlatiyata” protected area (Northwestern Bulgaria)” at the “Young Scientists Conference on Biology” conference, 01.11.2022, Plovdiv.