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DIET OF THE WOLF *CANIS LUPUS* (LINNAEUS, 1758) IN THE BIESZCZADY MOUNTAINS, POLAND

Dieta wilka *Canis lupus* (Linnaeus, 1758) w Bieszczadach, Polska

Abstract: Analysis of diet of the wolves *Canis lupus* Linnaeus, 1758, living in the Bieszczady Mts. was made. From December 2013 to November 2014 a total of 125 wolf fecal samples were collected and subsequently analyzed in terms of the prey species composition. Generally the most frequent prey for wolves in the Bieszczady Mts. were roe deer *Capreolus capreolus*, accounting for 44.8% of the wolf diet, wild boar *Sus scrofa* at 39.2% and red deer *Cervus elaphus* at 10.4%, respectively. Altogether ungulate remains were identified in 94.4% of scat samples, which means 94.8% biomass of consumed food. Wolves successfully hunted roe deer and wild boar in all seasons of the year. The share of roe deer in their diet was smallest in the autumn (29.4%), while it was greatest in the summer (55.5%); an opposite relationship was found for wild boars (11.1% in summer and 58.8% in autumn). Remains of red deer were identified in scat samples collected during two seasons only; in the spring they accounted for 11.1%, while in the summer it was 27.7%. Moreover, fecal samples of wolves in the Bieszczady Mts. contained remains of the domestic cat *Felis catus*, least weasel *Mustela nivalis*, pine marten *Martes martes*, European hare *Lepus europaeus* and probably also the harvest mouse *Micromys minutus*. However, these mammals form a slight part of the diet of the analyzed species. No remains of farm animals were found in the tested scat samples.

Key words: wolf, *Canis lupus*, diet, the Bieszczady Mts.

Introduction

The wolf *Canis lupus* is one of the three large predators, next to the brown bear *Ursus arctos* and the lynx *Lynx lynx*, living in Poland. From among these three the wolf is found most frequently and in the largest number. It inhabits large forest complexes both in the east and west of Poland and its population is presently estimated at approximately 1000 animals (Nowak and Mysłajek 2011; Mysłajek and Nowak 2014).

The first reports of damage caused by wolves in the Polish territory may be found in the archives of the administration of the Grand Duchy of Posen in the first half of the 19th century (Okarma 2015). They include information concerning losses among farm animals caused by wolves, as well as cases of wolf attacks on humans. In the 19th century the wolf was included in the register of game species, as it was commonly considered at that time as a pest. Initially culling of wolves was an obligation of both peasants and gentry, while later monetary awards were also introduced for killing this predator. As a consequence of these actions the wolf population was gradually decreasing. During WWI the number of wolves increased again; however, immediately after the war culling of wolves started again. During WWII a territorial expansion of wolves was observed, as the animals crossed the Vistula. In the early 1950s the population of wolves was estimated at c. 1000 animals; however, already in 1959, after a period of wolf extermination, approximately 250 animals remained and in the early 1970s there were only about 100 individuals (Nowak and Mysłajek 2011; Okarma 2015). In 1998, after an extensive campaign of non-governmental environmental organizations, the wolf was granted the status of a protected species throughout Poland. It is a species included in the Polish Red Book of Animals and it is also included in the Appendix on strictly protected species of the Bern Convention. It is a priority species of the Habitat Directive (Appendixes II and IV) and trade in their trophies is regulated by the Washington Convention (Nowak and Mysłajek 2011).

Despite the passage of time the wolf continues to be a species raising many controversies. This phenomenon is particularly evident among farmers as well as meat and milk producers, seeing wolves as bringing losses in cattle and sheep rearing.

Wolves are territorial animals, living in family groups (packs). A pack consists of the breeding pair and their progeny. The diet of these predators consists primarily of large ungulates, mainly the red deer *Cervus elaphus*, roe deer *Capreolus capreolus* and the wild boar *Sus scrofa* (Jędrzejewski et al. 2012). The latter do not seem to be favorite prey of wolves, since they may be dangerous and aggressive opponents, especially in the breeding season. In the case of a mosaic of forest and meadows occasionally also farm animals (mainly sheep, cattle and goats) were preyed on by wolves. The wolf's diet may be supplemented with predators, rodents (including beavers), amphibians, reptiles, birds, as well as carrion and plant food (Jędrzejewska and Jędrzejewski 2001; Jędrzejewski et al. 2012). The species composition of prey and their percentage in the wolf diet depend on many factors, such as habitat type, richness and availability of individual animal groups, as well as the season of the year (Jędrzejewski et al. 2012).

All predators killing their prey have a major impact on prey populations. Depending on the size of prey population predation by wolves can be a regulating factor for some populations or may significantly reduce their size. Wolves

select both, weak and unhealthy individuals as well as strong animals in good condition. Besides the direct impact on the size of prey population, wolves have also an indirect effect on ecosystem. Ungulates killed by wolves are usually big individuals that are very important food for many carrion feeders. The presence of wolves changes also the behavior of the prey and their physiological reactions (Okarma 2015).

The last comprehensive studies on the diet of wolves living in the Bieszczady Mts, covering all vegetation seasons, were conducted over two decades ago (Śmietana and Klimek 1993). It seems that in the twenty-year period, particularly in view of changes continuously taking place in the environment, as well as changes in the management both for the population of wolves and their potential prey, habits and dietary preferences of these predators may have changed. For this reason the aim of this study was: (1) to determine the diet of wolves living in the Bieszczady Mts and (2) to specify the effect of the season of the year on the composition of the diet for this predator.

Material and methods

Analyses were conducted in mountainous areas, in large forest complexes of the Bieszczady Mountains, located in south-eastern Poland (Fig. 1). Most samples were collected from areas at a lower altitude (550–816 m a.s.l.), between Lipie, Polana, Ustrzyki Górne and sources of the river San. The number of samples collected in each season is given in Table 1. The area of the study included areas inhabited by three packs of wolves (Pirga 2014) (Fig. 1, Tab. 2).

The other mammals occurring in the area are wild ungulates – red deer *Cervus elaphus*, roe deer *Capreolus capreolus*, wild boar *Sus scrofa*, European bison *Bison bonasus* and carnivores – brown bear *Ursus arctos*, lynx *Lynx lynx* and wildcat *Felis silvestris*.

The experimental material comprised wolf scat (125 samples) collected seasonally throughout the year, starting from the December 2013 to the November 2014. Collected samples were frozen to be prepared after thawing. For this purpose feces were soaked for 24 h in water with a detergent. Next, they were washed with running water on a small-mesh sieve until only animal bones and hair remained. Rinsed material was dried first at room temperature on plastic dishes and then for 2 days at 45°C in a laboratory drier. Such prepared samples were weighed on a laboratory balance. Feces were analyzed for the presence and percentage shares of different animal species using conventional methods developed by Lockie (1959) and Goszczyński (1974). Prey species were identified based on hair, bones and hooves (Pucek 1984; Teerinka 1991).

Results provided by the conventional method were verified using a scanning microscope. Adequately cut mammalian hairs prepared from feces were attached

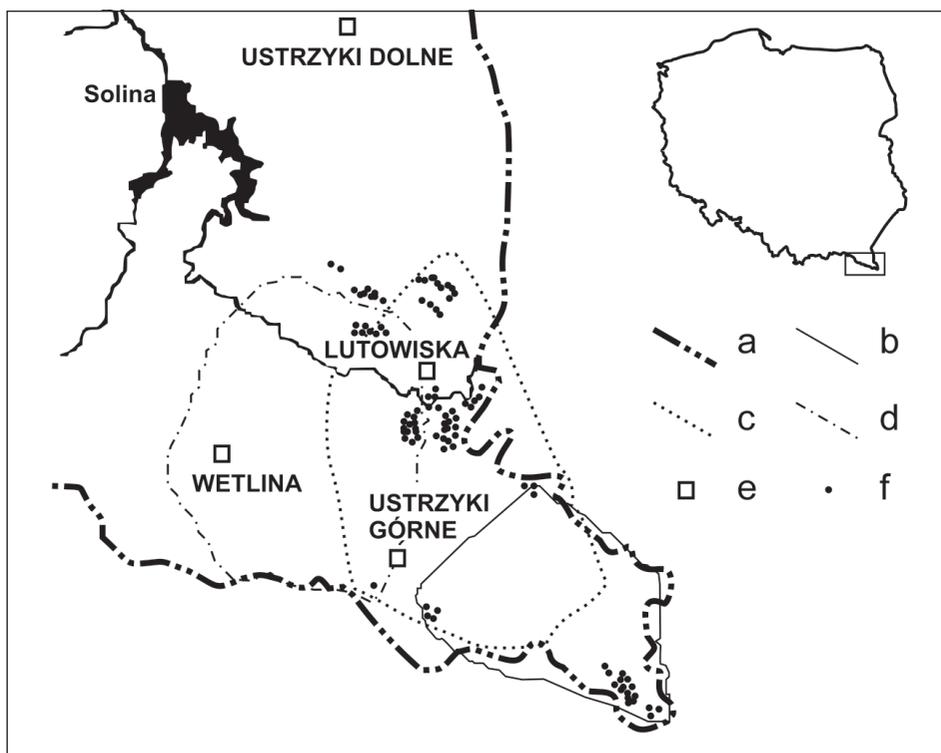


Fig. 1. Study area with locations of samples collection.

Ryc. 1. Obszar badań z miejscami zbioru prób.

a – state border / granica państwa; b – range of Negryłowska pack / terytorium watahy negryłowskiej; c – range of Stuposiańska pack / terytorium watahy stuposiańskiej; d – range of Ruska pack / terytorium watahy ruskiej; e – village / wieś; f – place of sampling / miejsce poboru prób.

using an adhesive carbon tape to aluminum microscope stubs. These stubs were placed in an Edward Scancoat Six sputterer and sputtered with gold for 8 min. Next, they were placed under a Zeiss EVO LS15 scanning microscope. Images of hairs were taken at a 400x and 2000x magnification. The hair scale patterns were analyzed, which facilitated identification of prey species (Teerinka 1991). Prey hairs contained in each sample were isolated. On their basis prey species were identified.

The following parameters were analyzed: (1) frequency of prey of a given species, expressed in the percentage of feces containing their remains in relation to all the collected fecal samples ($n=125$); (2) the percentage share of biomass of a given food type (a given species) in relation to total food biomass. Biomass of a given food type was determined by multiplying the mass of food remains

Table 1. The number of samples collected in each seasons.**Tabela 1.** Liczba prób zebranych w poszczególnych sezonach.

<i>Season</i> Pora roku	<i>Winter</i> Zima 2013/2014	<i>Spring</i> Wiosna 2014	<i>Summer</i> Lato 2014	<i>Autumn</i> Jesień 2014
<i>Number of samples</i> Wielkość próby	28	27	36	34

Table 2. The size of packs and their territories used in our study (Pirga 2014).**Tabela 2.** Liczebność watah objętych badaniami i wielkość ich terytoriów (Pirga 2014).

<i>Name</i> Nazwa	<i>Size of territory</i> Wielkość terytorium	<i>The number in the season 2013/2014</i> Liczebność w sezonie 2013/2014
Ruska	276 km ²	9 – 11
Stuposiańska	311 km ²	7 – 8
Negryłowska	161 km ²	5

detected in feces by digestibility indexes (e.g. rodents at 23, medium-sized mammals, e.g. the hare, badger, fox at 50, ungulates at 118, birds at 35, plant material at 4) (Jędrzejewska and Jędrzejewski 2001); (3) the food niche width estimated by the method proposed by Levins (1968) following the formula:

$$B = 1/\sum p_i^2$$

where: p_i denotes the share of each prey group (from Table 3) in the total consumed food biomass.

Based on the inventory of ungulates, carried out in 2013 in the Bieszczady National Park and the buffer zone (red deer – 206 individuals, wild boar – 118, roe deer – 59) (Pirga 2013) and frequency of ungulates in feces of wolves (our study), selection by wolves of particular species was assessed using the selectivity index D (Jacobs 1974):

$$D = (r - p) / (r + p - 2rp)$$

where r was the fraction of a species among all wild species killed by wolves and p was the fraction of that species in the ungulate community. D ranged from -1 (total avoidance of a species) to 0 (selection proportional to occurrence) and to 1 (maximum positive selection) (Jędrzejewski et al. 2012).

In the statistical verification of results, concerning differences in the food biomass in individual seasons, the non-parametric Kruskal-Wallis test was applied. Normal distribution was tested using the W Shapiro-Wolf test. In the statistical tests the significance level of ≤ 0.05 was adopted. Calculations were performed using the Statistica 10 (StatSoft. Inc. 2011).

Results

Analysis of wolf feces in terms of the species composition of prey showed a marked predominance of ungulates: roe deer, wild boars and red deer among their prey (Tab. 3).

The most common prey of the analyzed packs were roe deers (frequency – 44.8%, percentage share of biomass at 47%) and wild boars (frequency – 39.2%, percentage share of biomass at 44.1%). In the Bieszczady wolves hunted red deer much less often. Such remains were found in 10.4% of samples and its total biomass comprised only 3.7% of consumed food. The frequency of ungulates in feces of wolves was 94.4% and ungulate remains accounted jointly for 94.8% of biomass.

The value of the selectivity index D for roe deer was 0.63, for wild boar 0.18

Table 3. Diet of wolves in the Bieszczady Mts in years 2013–2014. %F – frequency of occurrence in feces, %B – percent of food biomass, + - part below 0.05%.

Tabela 3. Dieta wilków w Bieszczadach w latach 2013–2014. %F – procent frekwencji w odchodach, %B – procent biomasy pokarmu, + - udział poniżej 0,05%.

Food items Pokarm	%F	%B
Roe deer / Sarna <i>Capreolus capreolus</i>	44.8	47.0
Wild boar / Dzik <i>Sus scrofa</i>	39.2	44.1
Red deer / Jeleń szlachetny <i>Cervus elephus</i>	10.4	3.7
Ungulates (in total) Kopytne (w sumie)	94.4	94.8
Domestic cat / Kot domowy <i>Felis catus</i>	1.6	0.7
Least weasel / Łasica łąska <i>Mustela nivalis</i>	1.6	0.1
Pine marten / Kuna leśna <i>Martes martes</i>	0.8	0.1
European hare / Zając szarak <i>Lepus europaeus</i>	0.8	0.7
Plant material Materiał roślinny	25.6	+
Number of droppings/food biomass [kg] Liczba odchodów/biomasa pokarmu [kg]	125.0	277.2
Food niche width B Szerokość niszy pokarmowej B	2.33	

and for red deer -0.82. It means that among ungulates wolves preferentially prey on roe deer and avoid red deer. Wild boar seemed to be taken more than expected from their relative abundance, but it wasn't a preferred species of prey.

The second group of prey, represented in the analyzed samples in markedly lower numbers, consisted of the so-called small and medium-sized mammals. These included the pine marten, least weasel, European hare and the domestic cat. In this group of mammals remains of cats and weasels were found with identical frequency – 1.6%. However, due to the difference in size of these species obviously their biomass percentage shares in the total biomass were lower (Tab. 4). In the case of two other prey species, the hare and marten, their percentage shares in feces were insignificant (Tab. 4).

Additionally, in three samples coming from the winter season, apart from remains of the above-mentioned mammals, bone fragments probably belonging to the harvest mouse *Micromys minutus* were also found. Remains of farm animals were not found in the scat samples.

Plant material was detected in 25.6% of analyzed samples. Its biomass accounted for as little as 0.006% of consumed food. The predominant volume of plant food consisted of fir *Abies* sp. needles and undigested fragments of grasses *Poaceae*.

Table 4. Per cent of frequency (F) and food biomass (B) of prey species in the diet of wolves from Bieszczady Mts in different seasons, + - part below 0.05%.

Tabela 4. Procentowa frekwencja (F) i biomasa (B) poszczególnych gatunków ofiar w diecie wilków z Bieszczadów z uwzględnieniem sezonu badawczego, + - udział poniżej 0,05%.

Food items Pokarm	% B				% F			
	Winter Zima	Spring Wiosna	Summer Lato	Autumn Jesień	Winter Zima	Spring Wiosna	Summer Lato	Autumn Jesień
Roe deer Sarna	48.1	28.1	67.1	42.2	50	44.4	55.5	29.4
Wild boar Dzik	51.1	61.0	12.6	54.7	46.4	44.4	11.1	58.8
Red deer Jeleń szlachetny	-	10.2	17.8	-	-	11.1	27.7	-
Domestic cat Kot domowy	-	-	2.5	-	-	-	5.5	-
Least weasel Łasica łąska	-	-	-	0.2	-	-	-	5.8
Pine marten Kuna leśna	-	-	-	0.3	-	-	-	2.9
European hare Zając szarak	-	-	-	2.6	-	-	-	2.9
Plant material Materiał roślinny	+	+	+	+	25	25.9	27.8	23.5

Analyses showed that, depending on the season of the year, the total biomass and the percentage shares of prey in the diet of wolves varied (Tab. 4).

In the winter period 50% of the wolf diet was composed of roe deer (48.1% biomass in that season) and 46.4% – wild boars. Despite lower frequency, the wild boar biomass was greater and amounted to 51.1%. Plant material was found in 25% of samples and the mean value of biomass was very low (0.07%) (Tab. 4).

In the spring the percentage shares of roe deer and wild boar in the diet were identical (44.4%). In that season the biomass was greatest in the case of the wild boar and the smallest in the roe deer. Also spring is the season when new species, the red deer, appeared in wolves feces. Plant material was identified in about quarter of samples and its biomass was extremely low (0.01%) (Tab. 4).

In the summer wolves hunted all the three ungulate species. In that season roe deers predominated in their diet at a frequency of 55.5% (67.1% biomass). Moreover, wolves hunted red deers (27.7% frequency, 17.8% biomass) and less frequently – wild boars. Additionally, in the summer remains of the domestic cat were detected in two samples. Plant material was present in 27.8% of samples and its biomass was the same as in spring (Tab. 4).

The autumn turned out to be the richest season in terms of prey diversity (number of prey species). In the case of ungulates wild boar remains were recorded in 58.8% of samples (54.7% biomass), while in 29.4% of samples roe deer tissues were detected (42.2% biomass). Very few samples contained remains of two predatory mammalian species, the weasel and marten, and one lagomorph, i.e. the European hare. Plant material was recorded in 23.5% of samples and the mean biomass value was very low (0.01%) (Tab. 4).

Based on the results the food niche width was calculated. The value of index *B* was 2.33.

Discussion

Studies conducted in Bieszczady Mts on the diet of wolves indicated that in the period from December 2013 to November 2014 roe deer was the most common prey of these predators, followed by wild boars, with red deer being the least frequent ungulate prey. The share of other mammals (small and medium-sized) in the wolf diet was markedly lower.

The predominant part of roe deer in the diet of the Bieszczady wolves is quite surprising. The inventory of ungulates, carried out in 2013 in the Bieszczady National Park and part of the buffer zone showed that the number of red deer during this period amounted to approx. 206 individuals, wild boar – 118, and the roe deer only 59 (Pirga 2013). It means that percentage of each species in ungulate community was 53.8, 30.8 and 15.4, respectively. During our study, the most important prey of wolves was roe deer (F – 44.8%), the 2nd was wild boar

(39%) and the 3rd – red deer (10.4%). In case of Cervids that results are in contrary to structure of ungulate community. Red deer was hunted less than expected based on their abundance. The opposite situation was observed in the share of roe deer. That species was chosen more often than expected from its prevalence in ungulate community. When we compare inventory data (2013) with data from previous years (2009–2012) a clear downward trend in the case of red deer, stable number of roe deer and high, depending on the availability of food, fluctuations in the number of wild boar can be seen (Pirga 2010, 2011, 2012). Thus, it seems that our results were affected by localization of sampling sites. The most of the samples were collected from low altitude areas (550–816 m a.s.l.), where roe deer and wild boar are more common than red deer (Jędrzejewski et al. 2012, Okarma 2015).

The diet of wolves living in the Bieszczady Mts. and adjacent areas was investigated in the past. In a study by Brtek and Voskar (1987) in the Slovak Carpathian Mts the greatest share among wolf prey was recorded for wild boars (46%), followed by red deer (23.3%), with a slight share for roe deer (5.5%). In the Bieszczady Mts. alone the diet of wolves was analyzed in the 1990s by Śmietana and Klimek (1993). Investigations conducted by those authors on 221 wolf scat samples showed the greatest biomass to be remains of deer (from 65% in the winter to 96% in the summer), with a marked predominance of red deer (95% deer biomass) and trace amounts of roe deer (5% deer biomass). Remains of wild boars were found only in winter samples, accounting for 17% of total food biomass. A recent study, conducted in the Bieszczady Mts. demonstrated that the main food components, according to their biomass were red deer (44.2%), roe deer (26.6%) and wild boar (15.1%) (Jędrzejewski et al. 2012).

In our study, the analysis of shares of individual prey species in the diet of wolves depending on the season of the year indicates that in the winter the share of deer in the prey population accounts for 50%, while that of wild boar – 46.4%, respectively. Similar share of deer (55%) in the winter diet of wolves living in the Bieszczady National Park was reported in their study by Leśniewicz and Perzanowski (1989). Those authors analyzed stomach contents of 31 culled wolves and recorded a low share of the wild boar in the diet, amounting to as little as 11%. The small share of wild boars in the winter diet of wolves is also shown by the results of a study by Gula (2004) concerning the effect of the snow cover on hunting success rate in wolves. When analyzing remains of 118 prey animals that author stated that in the winter red deer were the predominant prey animals (with remains of this species detected in as many as 81% samples), while the two other ungulate species, i.e. roe deer and wild boars, were very rarely preyed on (10% and 9%, respectively).

The ordering of wolf prey animals reported in our study (1. roe deer, 2. wild boar, 3. red deer) is consistent with the results of a study by Nowak et al. (2011), which comprised wolves from central and western Poland. In a study conducted

by those authors on wolves, the highest success rate was recorded for roe deer (42.8% biomass), followed by wild boars (22.6% biomass) and red deer (22.2% biomass). Jędrzejewski et al (2012) investigated regional variation in wolf diet in relation to species structure of ungulate communities and found significant regional differences in wolf diet. In northeastern Poland, wolves frequently hunted red deer, roe deer, wild boar, beavers and moose. In eastern Poland, roe deer dominated kills. In southeastern Poland, wolves were strongly specialized on red deer. The authors proposed that prey and habitat specialization of wolves, rather than geographic distance or topographic barriers to dispersal, are responsible for the observed ecological divergence of wolf populations, as reflected in their diet composition. Among wolf prey composed of the so-called small and medium-sized mammals in the season of 2013/2014, scat samples of the Bieszczady Mts. wolves contained remains of the pine marten, least weasel, European hare, domestic cat and probably the harvest mouse. Presence of hares, martens, weasels, and domestic cats among prey of wolves was also shown by Nowak et al. (2005) in the Eastern Carpathians, Nowak et al. (2011) in central and western Poland, and Jędrzejewski et al. (2012) in northeastern Poland. Additionally, other detected prey species include the fallow deer, fox, dog, badger, beaver, rat, mole as well as various species of birds and insects (Brtek and Voskar 1987; Śmietana and Klimek 1993; Nowak et al. 2005; Nowak et al. 2011; Jędrzejewski et al. 2012).

A very interesting finding provided by these analyses is connected with the absence of remains of farm animals in the analyzed scat samples. It is known that sheep and cattle are sometimes preyed by these predators. Almost all authors investigating the diet of wolves reported remains of farm animals in their scat irrespectively of the seasons of the year (Leśniewicz and Perzanowski 1989; Śmietana and Klimek 1993). The complete absence of farm animals in prey, recorded in our study, seems to indicate that when there is an abundance of wild animals (the systematically growing population of ungulates) wolves do not hunt farm animals (Forest Administration of Stuposiany, unpubl.). On the other hand, the wolves did not prey on livestock because our samples were collected in places where pastoral economy is underdeveloped.

The aim of this paper was to provide updated information on the diet of wolves living in the Bieszczady Mts., as well as to determine the effect of the season of the year on the diet composition. Since the latest publication, concerning the seasonality of the diet of these predators living in the Bieszczady Mts. was written over twenty years ago, it may be assumed that data presented in that paper have become at least partly outdated (Śmietana and Klimek 1993). Due to the continuous and highly dynamic changes in the environment as well as changes in game management, it is definitely advisable to conduct such studies, as obtained results may contribute insight into the biology and ecology of this valuable and threatened predator. What is more, studies on the diet of wolves should definitely be continued and their cyclic character may show whether the observed changes in the diet

are short- or long-term in character. It also seems that in areas inhabited by wolves knowledge concerning the diet of this species should be transferred to forest divisions and hunting clubs, so that the information may be included in the preparation of culling plans for the next years.

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Streszczenie

Z uwagi na to, że ostatnie kompleksowe badania diety wilków zasiedlających Bieszczady, uwzględniające wszystkie sezony wegetacyjne, przeprowadzono ponad dwie dekady temu, zasadne wydało się uaktualnienie wiedzy na ten temat. Badania przeprowadzono od początku zimy 2013 r. do końca jesieni 2014 r. Analizie poddano 125 prób wilczych odchodów, określając skład gatunkowy ofiar z uwzględnieniem wszystkich sezonów wegetacyjnych. Najczęstszymi ofiarami bieszczadzkich wilków były: sarna *Capreolus capreolus*, której udział w wilczej diecie wyniósł 44.8%, dzik *Sus scrofa* – 39.2% oraz jeleń *Cervus elaphus* – 10.4%. Udział sarny w ich diecie był najmniejszy jesienią (29.4%), a największy latem (55.5%), zaś dzika odwrotnie (odpowiednio 11.1% i 58.8%). Szczątki jelenia zidentyfikowano w odchodach pochodzących tylko z dwóch sezonów, wiosną ich udział wyniósł 11.1%, a latem 27.7%. Poza tym w odchodach wilków stwierdzono obecność szczątków innych ssaków, ich udział w diecie był jednak znikomy. Były wśród nich: kot domowy *Felis catus*, łasica łąska *Mustela nivalis*, kuna leśna *Martes martes*, zając szarak *Lepus europaeus* oraz prawdopodobnie badyłarka *Micromys minutus*. W badanych próbach nie odnaleziono szczątków zwierząt gospodarskich.