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Composition of the wolf's *Canis lupus* L. diet in the Wigry National Park

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Abstract. The diet of wolves *Canis lupus* L. was assessed in the Wigry National Park in North-Eastern Poland, which overlaps with the Natura 2000 site "Ostoja Wigierska". The content of a total of 149 scat samples was collected in 2017 and analysed in order to determine dietary composition. Wolves primarily feed on wild ungulates, which make up 75.4% of food biomass. Despite the fact that wild boar *Sus scrofa* L. and red deer *Cervus elaphus* L. dominate in the ungulate community in the study area, the primary prey species was observed to be roe deer *Capreolus capreolus* L. with 39.6%, while red deer and wild boar only constituted 18.7% and 8.3% of the food biomass, respectively. Additionally, beaver *Castor fiber* L. was found to be an important prey (10.9%) as well and livestock accounted for 15.1% of all biomass consumed. The livestock eaten by wolves also included carcasses of domestic animals illegally disposed of in the forest. We therefore conclude that decisions on the management of the wolf's food base within protected areas, such as national parks or Natura 2000 sites, should be preceded by intensive local studies.

Keywords: wolf diet, prey selection, wild ungulates, beaver, livestock

1. Introduction

Wolves *Canis lupus* L. prey mostly on large ungulates (Newsome et al. 2016) but, regionally, may specialise in other food sources (Darimont et al. 2003; Dalerum et al. 2018). Moreover, wolves display seasonal and multiannual dietary shifts depending on the dynamics of population numbers of their potential prey (Sidorovich et al. 2003; Meriggi et al. 2011). Therefore, when planning actions to protect wolves in national parks (Jamrozy 2015) or in Natura 2000 sites (Diserens et al. 2017), the knowledge of not only the distribution, numbers and demographic parameters of populations but also the species 'foraging pattern' is necessary (Jędrzejewski et al. 2010).

The wolf's diet composition has been extensively studied in Poland (Jędrzejewski et al. 1992; Śmietana and Klimek 1993; Nowak et al. 2005, 2011). The major prey are large wild ungulates (on an average, 86.6% of the food biomass consumed), including red deer *Cervus elaphus* L. in the first place, followed by roe deer *Capreolus capreolus* L. and wild boar *Sus scrofa* L. In some areas, however, beavers *Castor fiber* L. are also intensively hunted by wolves (Nowak et al. 2011; Jędrzejewski et al. 2012).

The wolf population inhabiting the Augustów Forest is one of the best recognised populations in terms of food composition. However, the north-western edge of the forest, protected in the Wigry National Park (WPN) and the 'Ostoja Wigierska' (PLH200004) Natura 2000 site, has not been investigated (Harmuszkiewicz 2011; Jędrzejewski et al. 2012). At the same time, the area, mainly due to a large share of lakes, differs considerably from the remaining tracts of the Augustów Forest with respect to both topography and habitats.

The aim of this work was to determine the wolf's diet composition as well as the pattern of prey selection from the ungulate mammal community in the WPN.

2. Study area

The WPN (54°02'56''N; 23°04'20''E), designated in 1989, covers an area of 150.8 km^2 with a further 118.2 km^2 forming its buffer zone. About 94% of the park land over-

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laps with the special area of conservation 'Ostoja Wigierska' covering 160.7 km^2. The area is considered a wetland of international importance under the Ramsar Convention and is also encompassed by the special bird protection area 'Puszcza Augustowska' (PLB200002).

The National Park is located in the north-western part of the Augustów Forest in the Podlaskie voivodeship. The park is largely a forested area (63%). Scots pine *Pinus sylvestris* L. stands prevail in the forests (80%), whilst in smaller forest expanses, there dominates either Norway spruce *Picea abies* L., black alder *Alnus glutinosa* Gaertn., birch *Betula* spp. L. or pedunculate oak *Quercus robur* L. (Łoziński 2002). The remaining portion of the park consists of water bodies (19%) and non-forest communities (18%). The area remains under the influence of continental climate characterised by long winters, which usually last from the third decade of November to the first decade of April. The average annual temperature is 6.3 °C, and the average annual precipitation is 589 mm (data for the years 2002–2016, provided by the 'Wigry' Integrated Environmental Monitoring Station in Sobolewo).

About 19 species of large- and medium-sized mammals have been recorded in the WPN, including four species of wild hoofed mammals, such as red deer, roe deer, European elk and wild boar (Jamrozy 2015). Lynx *Lynx lynx* Kerr. is another large predatory mammal, next to wolf (Jędrzejewski et al. 2002b; Niedziałkowska et al. 2006). Monitoring performed using camera traps and genetic analyses backed up by the DNA microsatellite markers provided evidence that the WPN area overlaps with the fragments of territories of the three wolf packs (Romański et al. 2018).

3. Materials and methods

The wolf's diet in the WPN was assessed through the analysis of 149 scats collected in 2017, including 101 scats sampled during the autumn–winter season (from 1 October to 15 April) and 48 scats sampled in the spring–summer season (from 16 April to 30 September). The scats were gathered across the entire national park (Fig. 1), within the territories of three packs of wolves (Romański et al. 2018). The location of every scat sample was positioned using the GPS receiver. Faeces were placed in paper envelopes, dried out and stored until the time of analysing. Dry scats were weighed and rinsed on a dense mesh, then dried up again and weighed. The prey species consumed by wolves were identified based on the washed food remains such as bones, hair, hooves, claws and teeth (Lockie 1959; Goszczyński 1974). The prey species were identified to species and/or genus with the aid of identification guides (Dziurdzik 1973; Debrot et al. 1982; Pucek 1984; Teerink 1991; De Marinis and Asprea 2006) as well as of the authors' own comparative materials. In case of doubt, the microscope hair preparations were made.

The food composition was expressed as (1) percentage of proportion of scats containing respective food categories in the total number of all the scats collected and (2) percentage of biomass of individual diet items in relation to the total biomass of food consumed by wolves. The biomass was determined by multiplying the dry mass of a given category of food remains by the following digestibility coefficients: medium-sized mammals, 50; ungulates, 118; and plant material, 4 (Jędrzejewska and Jędrzejewski 1998). The Levins formula (1968) was used to calculate the breadth of food niche:

$$B = \frac{1}{\Sigma pi^2},$$

where

pi is the percentage of proportion of every prey category in the total biomass of food consumed.

The Levins index assumes the values from 1 (when only one food item is consumed) to 3 (when an animal evenly uses all food categories). The prey was grouped into the following categories for the purpose of calculations: (1) wild ungulate mammals, (2) domestic animals, (3) small wild mammals.

The food selectivity was calculated based on the Jacobs formula (1974):

$$D = \frac{r - p}{r + p - 2rp},$$

where

r is the proportion of a given prey species in the total number of wild ungulate mammals killed by wolves and p is the proportion of a given prey species in the wild ungulate community.

D index assumes the values from 1 (full preference) to −1 (complete avoiding). The share of respective ungulate mammal species in the wolf's diet was evaluated based on their frequency in scats. If cervids could not be identified to species, the contribution of respective prey species in scats was evaluated based on the species proportion found in those samples where it was evaluated. Data on the species composition of wild ungulate mammals in the WPN was received from camera traps recordings. In the present study, we used recordings from 54 camera traps available from 52 locations over the entire national park area; the details of camera traps installation were reported by Romański et al. (2018). The total material embraced 10,254 camera-traps-days, collected from January to September 2017, which contained 5,119 recordings (2,933 independent events) with 6,149 wild ungulate mammals registered.

4. Results

The analysis of scat content revealed that the food niche of wolves in the WPN was relatively narrow ($B = 1.67$). They are

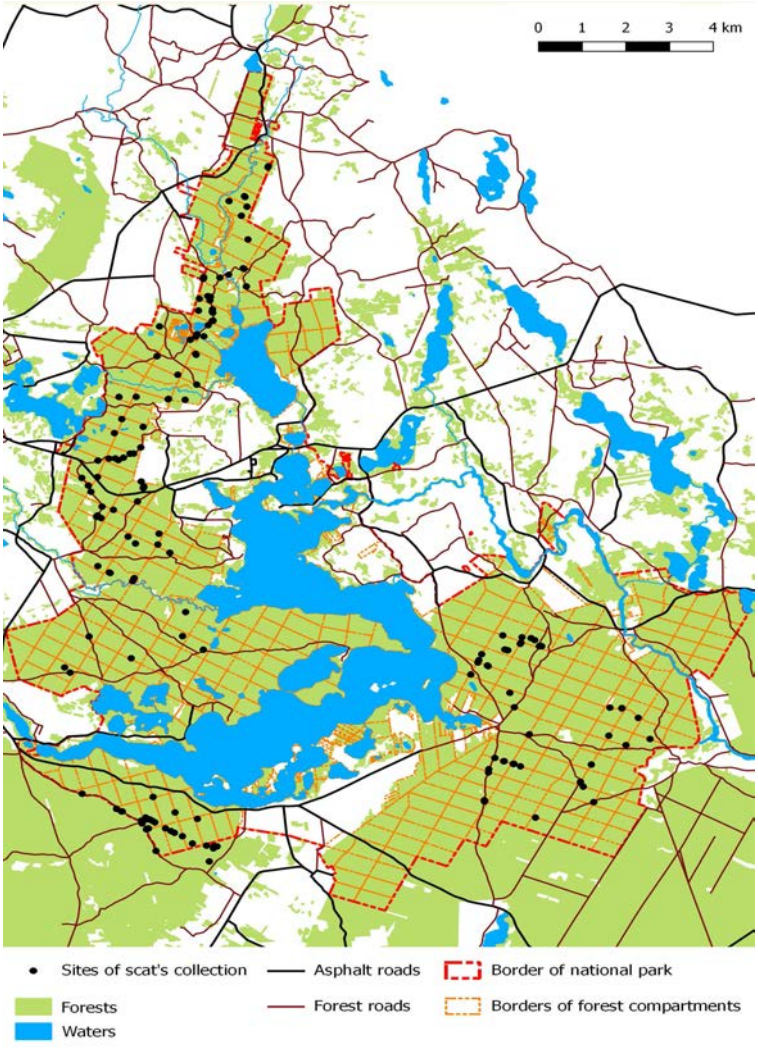

Figure 1. Area of Wigry National Park with locations of collected wolf scats

specialised in hunting wild ungulate mammals, which constituted 75.4% of the food biomass consumed. Roe deer was the most frequent prey, and its proportion in the wolf's diet was twice as high as that of red deer, 39.6% and 18.7%, respectively. Wild boar was the third most significant prey, whilst European elk was only sporadically consumed. Beavers were an important extra prey in the wolf's diet and provided for as much as 10.9% of the food biomass consumed. Hare was rarely consumed, whereas small rodents and birds were only an infrequent prey. Scats of wolves from the WPN contained remains of a cow, a goat, pigs and dogs, and their combined contribution in the food biomass was 9.5%. Tiny pieces of plastic were found in one of the scat samples (Table 1).

The wild ungulate mammal community in the WPN evaluated using camera traps recordings consists of four species. Wild boar was the most frequently recorded (n = 2,808 individuals), the second most abundant was red deer (n = 2,273) and roe deer (n=866), whilst European elk was least frequent (n = 202) (Table 2). From the above ungulate community, wolves tended to select roe deer, for which the Ivlev selection coefficient was D = 0.763. The remaining species were killed to a lesser degree than was their contribution to the prey community, what was corroborated by the negative values of the selection coefficient (Table 2).

5. Discussion

Several earlier studies provided evidence that red deer is most frequently hunted by wolves in north-eastern Poland and is a prey of preference in the wild ungulate mammal community (Jędrzejewski et al. 1992, 2000, 2002a; Okarma 1995; Jędrzejewska et al. 1997). First analyses of the wolf's diet composition in the Augustów Forest in the years 2000–2006 have also shown that red deer is the prey of pre-

Table 1. Diet composition of wolves in Wigry National Park

Food item	Total	
	B [%]	O [%]
Red deer *Cervus elaphus*	18.7	18.1
Roe deer *Capreolus capreolus*	39.6	36.9
Moose *Alces alces*	0.7	1.3
Cervids unidentified *Cervidae*	8.1	10.7
Wild boar *Sus scrofa*	8.3	13.4
Wild ungulates total	75.4	76.5
Goat *Capra aegagrus hircus*	0.5	0.7
Cattle *Bos* sp.	4.6	1.3
Domestic pig *Sus scrofa domesticus*	2.0	1.3
Domestic dog *Canis lupus familiaris*	2.3	4.7
Domestic animals total	9.5	8.1
European hare *Lepus europaeus*	4.1	6.0
Beaver *Castor fiber*	10.9	14.8
Small rodents	0.1	4.7
Small mammals total	15.1	25.5
Birds Aves	+	0.7
Plant material	+	4.7
Plastic	+	0.7
Number of scats	149	
Biomass of consumed food [kg]	138.9	
Food niche breadth B	1.67	

O – share of scats [%], B – share of total biomass consumed [%]. (+) Contribution to diet <0.05%

Table 2. Prey selection by wolves from the wild ungulate community in Wigry National Park

Species	*r*	*p*	*D*
Wild boar *Sus scrofa*	16.7	45.6	-0.614
Moose *Alces alces*	1.7	3.3	-0.327
Red deer *Cervus elaphus*	26.6	37.0	-0.237
Roe deer *Capreolus capreolus*	55.0	14.1	0.763

r – fraction of a species among all wild species killed by wolves **[%],** *p* – fraction of species in the ungulate community **[%],** *D* – selectivity index after Jacobs (1974)

ference (Jędrzejewski et al. 2012). However, a later research made with the use of a large number of scats (*n*=576), collected in the years 2005–2009, yielded results indicating that wolves in the Augustów Forest chose to prey on roe deer, which contributed to 25% of the wolf's diet (Harmuszkiewicz 2011). Our studies provide evidence that the above trend may be continued, because roe deer was also a major component of the wolf's diet in the WPN in 2017.

Beavers are a significant prey item (10.9% of food biomass) for wolves in the WPN, and this share in the wolf's diet was higher than that of the wolves living in the entire Augustów Forest. The latter share fluctuated from 4.5% to 8% of the food biomass in the years 2000–2009 (Harmuszkiewicz 2011; Jędrzejewski et al. 2012). Earlier, beaver was indicated as a prey item in the wolf's diet in numerous forests located in the whole lowland part of Poland, in both the east (Jędrzejewski et al. 2012) and the west of the country (Nowak et al. 2011). The largest contribution of beaver prey in the wolf's diet was recorded in the Romincka Forest, that is, 13.4% of food biomass, followed by the Skaliska Forest (15.4%) and the Knyszyn Forest (24.6%) (Jędrzejewski et al. 2012). Beaver is lacking only in the prey of wolves living in the Carpathians (Śmietana, Klimek 1993; Nowak et al. 2005; Jędrzejewski et al. 2012).

Domestic animals, including both livestock (cattle, goats and pigs) and pets, such as dogs, comprised 9.5% of the food biomass ingested by wolves in the WPN. The above value is lower than that reported earlier for the entire expense of the Augustów Forest, which reached from 13.7% to 15.3% of food biomass, as was determined in the years 2000–2009 by Harmuszkiewicz (2011) and Jędrzejewski et al. (2012). The scat analysis does not enable the identification of whether the prey consumed by an animal was a hunted prey or a carcass found. Wolves are known to feed on carcasses including dead livestock illegally dumped in the forest (Jędrzejewski et al. 2002a). Half pig carcasses have been recorded in the WPN (M. Romański, unpublished data). Likewise, Harmuszkiewicz (2011) reported wolves foraging on carcasses of horses, pigs and cows illegally disposed of in various parts of the Augustów Forest. The fact that residues of domestic animals were detected in wolves' scats in winter, beyond the normal grazing season, testifies to wolves foraging on carcasses of dead animals (Harmuszkiewicz 2011).

The meta-analysis of the wolf's diet over the entire range of wolf occurrence revealed the lack of relationship between the dietary diversity and the degree of anthropopressure (Newsome et al. 2016). The increased use by wolves of domestic animals and waste disposed by people was only found in the case of decreased numbers of the wild ungulate mammal populations (Sidorovich et al. 2003; Newsome et al. 2016). The food demand for wolves in Poland can be fully secured because of the increasing numbers of game animal populations including red deer, roe deer and wild boar (Borowik et al. 2013). The conflicts with livestock farming have been limited by introducing various damage prevention measures during cattle grazing (Nowak et al. 2005; Nowak and Mysłajek 2005).

This study indicates that wolves in the WPN also prey on dogs. Dogs, as domesticated predators, are known to negatively influence the local wildlife (Krauze-Gryz and Gryz 2014; Wierzbowska et al. 2016). Actions aimed at reducing the number of dogs in forests are labour-intensive and costly, whilst their physical elimination through catching or hunting encounters a substantial social opposition (Holmes et al. 2015). That is why wolves preying on dogs that penetrate the natural environment, and protected areas in particular, should be treated as providers of a desirable ecosystem service (Mysłajek 2014).

The genetic structure of wolves is correlated, in the broad geographical scale, with the prevailing environment and the prey type, which can be explained in terms of a natal habitat preference induction (Pilot et al. 2006; Carmichael et al. 2007; Musiani et al. 2007). However, differences were locally recorded in dietary composition between the adjacent packs of wolves and even amongst respective individuals (Urton and Hobson 2005; Darimont et al. 2009). Changes in the food composition of these predators may also be shaped by changes in the size of potential prey populations (Darimont and Reichmen 2002, Meriggi et al. 2011). This emphasises the significance of systematic research on the wolf's diet composition, as such studies should provide vital information necessary for managing both wolf's population and populations of their potential prey. The latter is of particular importance for the national parks and Natura 2000 sites, where conservation plans are developed by taking into account the issue of wolves, and, in parallel, hunting or reduction of wild ungulates is done.

Conflict of interests

The authors declare no competing conflicts of interests.

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Authors' contribution

R.W.M., S.N. – designed the article concept, elaborated the results and wrote the paper; M.R. – made field work; K.T.– performed laboratory work.

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