



Short Note

Winter diet of wolf (*Canis lupus*) after the outbreak of African swine fever and under the severely reduced densities of wild boar (*Sus scrofa*)

Harri VALDMANN*, Urmas SAARMA

Tartu University, Department of Zoology, Vanemuise Str. 46, 51014 Tartu, Estonia

Keywords:wild boar
ASF
scat analysis
wolf diet**Article history:**

Received: 14 February 2020

Accepted: 14 August 2020

Acknowledgements

This work was supported by grant (PLTOM20905) of the Institute of Ecology and Earth Sciences, University of Tartu, Estonia. We also thank Andrus Dräbitsinski for his help.

Abstract

The outbreak of the African swine fever (ASF) in Estonia in 2014 resulted in heavy hunting pressure on wild boar, issued by authorities to stop further spread of the virus. As a consequence, local wolf prey base changed abruptly. To investigate the effects of this change to wolf diet, we collected 121 wolf scats from November to April in 2017–2018 from five Estonian counties and compared the results with the wolf dietary data from 1998. To eliminate possible dog scats from the material collected from areas close to settlements, genetic analysis was used. We found that ungulates still formed the bulk of the wolf diet, however, the occurrence of moose, wild boar, small rodents and hares has dropped considerably. The proportion of the roe deer and mammalian predators has increased from 51% to 55% and 4% to 10%, respectively. Moreover, plants, being totally absent in the previous study, were found in 25% of scats, in many cases representing the only food item. Food niche breadth has widened from 1.54 to 2.3. While roe deer was found to be a highly preferred, moose was still an avoided prey species.

The grey wolf (henceforth “wolf”) is one of the most important apex predators and keystone species in Europe and in many other parts of the World (Krofel et al., 2017; Beschta and Ripple, 2016; Mech and Boitani, 2004). Being a major source of human-carnivore conflict, the welfare of the wolf depends strongly on policies that facilitate coexistence of humans and wolves in changing environments (van Eeden et al., 2018; Treves and Bruskotter, 2014). However, such policies should be based on scientific evidence, of which dietary data are among the most critical.

Wolf diet has been studied at local scales in several countries in Europe (Sidorovich et al., 2016; Llana and López-Bao, 2015; Meriggi et al., 1996), including the Baltic States (Žunna et al., 2009; Valdmann et al., 2005; Kübarsen and Valdmann, 2003; Valdmann et al., 1998). As a generalist predator, wolf diet is largely shaped by the prey availability (Baudrot et al., 2016). In Europe, their diet consists mainly of large- and medium-sized wild ungulates such as roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), moose (*Alces alces*) and red deer (*Cervus elaphus*), but also of livestock and other anthropogenic foods, if available (Newsome et al., 2016; Zlatanova et al., 2014; Meriggi and Lovari, 1996). In areas where beaver (*Castor fiber*) is abundant, it can also form a significant portion of wolf diet (Sidorovich et al., 2016; Andersone and Ozolins, 2004).

In Estonia wolf is spread all over the country, having recently also recolonized the two largest islands, Saaremaa and Hiiumaa (Plumer et al., 2018). The number of wolf packs in Estonia has ranged around 25 (150–160 wolves) in recent years and the numbers of legally killed wolves were 67 (2018/19), 104 (2017/18) and 114 (2016/2017) (Estonian Environment Agency). In 1998 official wolf numbers in Estonia were about 300 (Estonian Ministry of Environment). Wolf predation on livestock, mainly on sheep, has been a major source of human-wolf conflicts in Estonia and understanding wolf food habits is crucial to de-

velop effective strategies for wolf conservation and management, and for mitigation of wolf-human conflicts.

The most comprehensive previous wolf diet study in Estonia (Valdmann et al., 1998) demonstrated that while the roe deer is the major item in wolf’s diet (50.9%), the preferred prey was the wild boar, albeit its frequency of occurrence was considerably smaller (16.8%). Moose was also consumed (11.8%), but according to the analysis was avoided.

On the 6th of September 2014, for the first time, the African swine fever (ASF) was diagnosed in Estonia.

Since then the ASF has spread all over Estonia excluding the relatively isolated island Hiiumaa and the outbreak reached its peak in 2015–2017 (Borklund et al., 2018). As a result of ASF, high wild boar hunting quotas were introduced to diminish the effects of ASF, resulting in very low numbers of wild boar.

Several scenarios could be predicted locally if ungulate species composition will abruptly change. We hypothesise that under the limited availability of wild boar, the proportion of other ungulate species in wolf diet will increase, especially of the roe deer, as its densities have been quite stable. Alternatively, wolves may take advantage of fox- or coyote-type foraging behavior (Newsome et al., 2016) including intraguild predation. We also hypothesise that as a result of reduced wolf packs (Valdmann et al., 2004), caused by ongoing wolf hunting, moose may be continuously avoided.

To address these questions, we performed a scat analysis to investigate the effects of changes in local prey base to wolf diet and compared the results with the previous study (Valdmann et al., 1998). To ensure that all scats belonged to wolf, particularly the scats collected in close proximity of settlements, a genetic analysis was conducted to discriminate between wolves and dogs.

For the study 121 wolf scats were collected from the hunting grounds in the Central- and South-East Estonia (Nov–Apr. 2017–2018) with very low densities of wild boar (<1.5 ind/1000 ha). Scats were collected along forest roads and all samples were frozen at –80 °C. To obtain results comparable with previous wolf diet study in Estonia, scats were

*Corresponding author

Email address: harriva@ut.ee (Harri VALDMANN)

Table 1 – Comparison of frequency of occurrence (FO) of main prey categories between two studies: Valdmann et al. (1998) and this study (2018).

Prey category	1998 FO	2018 FO
Wild ungulates:		
Moose	11.8	<1
Wild boar	16.8	4
Roe deer	50.9	55
Mammalian predators	3.3	10
Plant material (apples and hay)	-	25
Small rodents	10.2	4
Lagomorphs	5.8	1

collected from approximately the same area (Valdmann et al., 1998), and during early spring as in the previous study (we did not compare summer diets).

To identify food items, the scat samples were processed according to standard laboratory procedures (Ciucci et al., 2015; Reynolds and Aebischer, 1991). Non-mammal remains recovered in wolf scats were identified by comparison with reference materials and mammal remains by examining the cuticular pattern and the medulla of the hairs using a reference manual (Teerink, 1991) and hairs collected from hunted animals.

Scat contents were divided into five prey categories: ungulates, small rodents, mammalian predators, plant material, lagomorphs (*Lepus* sp.) and quantified by the frequency of occurrence (FO) of prey species in scats. To compare the proportions of ungulate prey in scats with the proportions of their numbers in the study area, chi-square test was used (Statistica, 2004). Ivlev's electivity indices (Krebs, 1997) were calculated for each ungulate prey species. The densities of moose (≈ 3.2 ind/1000 ha) and roe deer (≈ 16 ind/1000 ha) were obtained from yearly estimations of hunting clubs from study area. Food niche breadth was calculated after Levin (1968). To obtain estimates of confidence limits for niche breadths we used bootstrap procedure ($n=10000$) (Krebs, 1997; Efron, 1982), employing the statistical package R.

Scats of wolves and free-ranging dogs are sometimes difficult to distinguish and to avoid mixing the data of both species, we conducted a genetic analysis according to Plumer et al. (2018) for three scat samples that we could not assign and also for 21 samples collected from close proximity of settlements that we identified as wolf scats. The length of the final alignment was 245 bp and the dataset was further aligned with homologous wolf and dog sequences from Estonia (Plumer et al., 2018; Hindrikson et al., 2012). Molecular identification of species was possible due to specific nucleotide characters that distinguish between wolves and dogs in Estonia (see Plumer et al., 2018). Out of the three analysed samples that we could not assign to species (wolf or dog) with confidence, two belonged to wolf and one to dog. All 21 samples that we identified as wolf scats (based on morphology, smell and content) were assigned by the genetic analysis also as wolves. The dog data was excluded from further analyses and thus the final number of wolf scats was $n=120$.

Analysis of scat composition revealed that as in previous study (Valdmann et al., 1998), ungulates dominated in wolf diet, the roe deer being the main prey, the proportion of which has increased from 51% to 55%, Tab. 1. The occurrence of moose, wild boar, small rodents and hares has dropped considerably. On the other hand, the proportion of

Table 2 – Comparison of Ivlev's electivity indices for ungulate prey in previous study (Valdmann et al., 1998) and this study (2018).

Ungulate prey species	Ivlev's electivity index	
	1998	2018
Moose	-0.35	-0.90
Wild boar	0.23	-0.05
Roe deer	0.07	0.61

mammalian predators and plants has increased, especially the latter, which occurred in 25% of analysed samples in this study, while being absent in the previous one. Bias adjusted food niche breadth was 2.3 (95% confidence intervals 1.95–2.64), compared to 1.54 in the previous study. Composition of ungulate prey proportions in diet differed significantly from their availability ($\chi^2=32.75$; $df=2$; $p<0.05$). According to the Ivlev's electivity indices (Tab. 2), roe deer was highly preferred and moose was avoided, whereas wild boar was close to neutral.

Our results indicate significant shift of preferences and FO-s in local wolf diet compared to the previous study of wolf winter diet in Estonia (Valdmann et al., 1998). Also, the food niche breadth has widened considerably. As the availability of wild boar was very low in the study area, its consumption was reduced by more than 4 times, from 17% to 4%. As predicted, roe deer formed the bulk of the wolf diet (55%), although the increase compared to the 1998 data (51%) was less than expected. Roe deer was found as a preferred food item also in a study conducted in western and central parts of Poland (Nowak et al., 2011). However, in some of the other studies conducted in Europe, roe deer was avoided (Jędrzejewski, 2000; Okarma, 1995). We anticipated that wolves increase the consumption of moose, but it dropped from 12% to a mere 1%. The likely reason is the reduced wolf packs in Estonia due to high hunting pressure, legal and illegal (Valdmann et al., 2004). Moose has been an avoided food item also in other studies conducted in Europe (Jędrzejewski, 2000; Okarma, 1995).

Concerning the intraguild predation in our study ("mammalian predators" in Tab. 1), wolves exclusively fed on raccoon dog (*Nyctereutes procyonoides*). According to Paquet and Carbyn (2003), shortage of ungulate prey may increase the proportion of other predators in wolf diet. As sarcoptic mange is widespread among raccoon dogs in Estonia, weakened animal is an easy prey for wolves. As a negative effect of intraguild predation, mange will be easily transferred over to a wolf as canids are very susceptible to this parasitic infection, probably causing wolves, like other infested canids, to come closer to human settlements in their search for food. Thus, shortage of regular food (e.g., wild boar) can be detrimental to wolf population as they consume more mammalian predators, including the infected raccoon dogs. As a result, wolves get more frequently infected and getting weaker and unable to hunt for a regular prey, come closer to human settlements, posing danger to dogs. Although we did not find dog remains in wolf scats, a dog was reportedly killed by wolf in study area during this period. The health condition of a wolf was unknown, but we actually saw an infected wolf near the attack place.

Wolves may be brought closer to human settlements also by other factors. Roe deer can concentrate near settlements as a response to a very high predation pressure by wolves and also by lynx, for which roe deer has been a staple food in Estonia (Valdmann et al., 2005). The numbers wolves seen around settlements has been steadily increasing in the study area and elsewhere in the country.

Concerning the consumption of plant material, its proportion was unusually high, being found in 25% of scats, in many cases representing the only food item. Apples and hay were the most common plant items found. Although plant items are energetically not important for wolf (Jędrzejewska and Jędrzejewski, 1998), they can be used as an emergency food during a period when wolves suffer from food deficiency. As suggested by Homkes et al. (2020), plant items can be consumed more by wolves than previously believed. Another reason could be intentional consumption of grass as a self-medicating behavior against parasites. This type of behavior has been observed in several other species, including dogs and cats (Hart, 2008; Sueda et al., 2008) and raccoon dogs (Laurimaa et al., 2016).

We are uncertain whether the high proportion of plant items in our study is the result of reduced prey availability, abundance of apples due to their rich crop during study period or an interaction of these conditions. But the remarkably high intraguild predation on raccoon dog is certainly unfavourable for local wolf population, facilitating the spread of sarcoptic mange. ☞

References

- Andersone Z., Ozolins J., 2004. Food habits of wolves (*Canis lupus*) in Latvia. *Acta Theriol.* 49: 357–367.
- Baudrot V., Perasso A., Fritsch C., Giraudoux P., Raoul F., 2016. The adaptation of generalist predators' diet in a multi-prey context: insights from new functional responses. *Ecol.* 97: 1832–1834.
- Beschta R.L., Ripple W.J., 2016. Riparian vegetation recovery in Yellowstone: The first two decades after wolf reintroduction. *Biol. Cons.* 198: 93–103.
- Borklund A., Cay B., Depner K., Földi Z., Guberti V., Masiulis M., 2018. Epidemiological analyses of African swine fever in the European Union (November 2017 until November 2018). *EFSA J.* 16: 5494.
- Ciucci P., Boitani L., Pellicioni E., Rocco P., Guy I., 1996. A comparison of scat-analysis methods to assess the diet of the wolf (*Canis lupus*). *Wildl. Biol.* 2: 37–48.
- Efron B., 1982. The Jackknife, the Bootstrap and Other Resampling Plans. CBMS-NSF Regional Conference Series in Applied Mathematics, Monograph 38, SIAM, Philadelphia.
- Hart B.L., 2008. Why do dogs and cats eat grass? *Vet. Med.* 103: 648.
- Hindrikson M., Männil P., Ozolins J., Krzywinski A., Saarma U., 2012. Bucking the trend in wolf-dog hybridization: first evidence from Europe of hybridization between female dogs and male wolves. *PLoS ONE* 7(10): e46465.
- Homkes A.T., Gable T.D., Windels S.K., Bump J.K., 2020. Berry important? Wolf provisions pups with berries in Northern Minnesota. *Wildl. Soc. Bull.* 1–3.
- Jędrzejewska B., Jędrzejewski W., 1998. Predation in vertebrate communities. The Białowieża Primeval Forest as a case study. Springer Verlag, Berlin.
- Jędrzejewski W., Jędrzejewska B., Okarma H., Schmidt K., Zub K., Musiani M., 2000. Prey selection and predation by wolves in Białowieża Primeval Forest, Poland. *J. Mammal.* 81: 197–212.
- Krebs C.J., 1997 *Ecological Methodology*. Harper & Row, New York.
- Krofel M., Giannatos G., Čirovič D., Stoyanov S., Newsome T.M., 2017. Golden jackal expansion in Europe: a case of mesopredator release triggered by continent-wide wolf persecution? *Hystrix* 28: 9–15.
- Kusza S., Nagy K., Lanszki J., Heltai M., Szabó C., Czarnomska S.D., 2018. Moderate genetic variability and no genetic structure within the European golden jackal (*Canis aureus*) population in Hungary. *Mammal Res.* 64: 63–69.
- Kübarssepp M., Valdmann H., 2003. Winter diet and movements of wolf (*Canis lupus*) in Alam-Pedja Nature Reserve, Estonia. *Acta Zool. Lit.* 34–40.
- Laurimaa L., Süld K., Davison J., Moks E., Valdmann H., Saarma U., 2016. Alien species and their zoonotic parasites in native and introduced ranges: the raccoon dog example. *Vet. Par.* 219: 24–33.
- Levins R., 1968. *Evolution in Changing Environments: some Theoretical Explorations*. Princeton University Press.
- Llaneza L., López-Bao J.V., 2015. Indirect effects of changes in environmental and agricultural policies on the diet of wolves. *Eur. J. Wildlife Res.* 61: 895–902.
- Mech L.D., Boitani L. (Eds.) 2004. *Wolves: Behavior, Ecology, and Conservation*. University of Chicago Press.
- Meriggi A., Brangi A., Matteucci C., Sacchi O., 1996. The feeding habits of wolves in relation to large prey availability in northern Italy. *Ecography* 19: 287–295.
- Meriggi A., Lovari S., 1996. A review of wolf predation in southern Europe: does the wolf prefer wild prey to livestock? *J. Appl. Ecol.* 33: 1561–1571.
- Newsome T.M., Boitani L., Chapron G., Ciucci P., Dickman C.R., Dellinger J.A., López-Bao J.V., Peterson R.O., Shores C.R., Wirsing A.J., 2016. Food habits of the world's grey wolves. *Mamm. Rev.* 46: 255–269.
- Nowak S.R., Mysłajek W., Kłosińska A., Gabryś G., 2011. Diet and Prey Selection of Wolves (*Canis lupus*) Recolonising Western and Central Poland. *Mamm. Biol.* 76: 709–715.
- Okarma H., 1995. The trophic ecology of wolves and their predatory role in ungulate communities of forest ecosystems in Europe. *Acta Theriol.* 40: 335–386.
- Paquet P.C., Carbyn L.N., 2003. Gray wolf. In: Feldhamer G.A., Thompson B.C., Chapman J.A. (Eds) *Wild mammals of North America: Biology, management, and conservation*. John Hopkins University Press. NY. 482–510.
- Plumer L., Keis M., Remm J., Hindrikson M., Jõgisalu I., Männil P., Kübarssepp M., Saarma U., 2016. Wolves recolonizing islands: genetic consequences and implications for conservation and management. *PLoS ONE* 11(7): e0158911.
- Plumer L., Talvi T., Männil P., Saarma U., 2018. Assessing the roles of wolves and dogs in livestock predation with suggestions for mitigating human-wildlife conflict and conservation of wolves. *Cons. Gen.* 19: 665–672.
- Reynolds J.C., Aebischer N.J., 1991. Comparison and quantification of carnivore diet by faecal analysis: a critique, with recommendations, based on a study of the fox (*Vulpes vulpes*). *Mamm. Rev.* 21: 97–122.
- Sidorovich V., Schnitzler A., Schintzler C., Rotenko I., Holikava Y., 2016. Responses of wolf feeding habits after adverse climatic events in central-western Belarus. *Mamm. Biol.* 83: 247–256.
- StatSoft Inc., "Statistica", 2004. Data Analysis Software System, version 7.
- Sueda, K.L.C., Hart B.L., Cliff K.D., 2008. Characterisation of plant eating in dogs. *Appl. Anim. Behav. Sci.* 111: 120–132.
- Teerink B.J., 1991. *Hairs of west European mammals*. Cambridge University Press. Cambridge.
- Treves A., Bruskotter J., 2014. Tolerance for predatory wildlife. *Science.* 344: 476–477.
- Valdmann H., Koppa O., Looga A., 1998. Diet and prey selectivity of wolf (*Canis lupus*) in Middle- and South-Eastern Estonia. *Baltic For.* 4: 42–46.
- Valdmann H., Laanetu N., Korsten M., 2004. Group size changes and age/sex composition of harvested wolves (*Canis lupus*) in Estonia. *Baltic For.* 10: 83–86.
- Valdmann H., Andersone-Lilley Z., Koppa O., Ozolins J., Bagrade G., 2005. Winter diets of wolf (*Canis lupus*) and lynx (*Lynx lynx*) in Estonia and Latvia. *Acta. Theriol.* 50: 521–527.
- van Eeden L.M., Eklund A., Miller J.R.B., López-Bao J.V., Chapron G., Cejtin M.R., 2018. Carnivore conservation needs evidence-based livestock protection. *PLoS Biol.* 16: 395–415.
- Zlatanova D., Ahmed A., Valasseva A., Genov P., 2014. Adaptive diet strategy of the wolf (*Canis lupus* L.) in Europe: a review. *Acta Zool. Bulg.* 66: 439–445.
- Žunna A., Ozoliņš J., Pupila A., 2009. Food habits of the wolf (*Canis lupus*) in Latvia based on stomach analyses. *Estonian J. Ecol.* 58: 141–152.

Associate Editor: R. Caniglia