



Variation in the feeding pattern of red foxes in relation to changes in anthropogenic resource availability in a rural habitat of western Poland

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ABSTRACT

The feeding pattern of red foxes *Vulpes vulpes*, i.e., the composition of their diet and dietary responses to fluctuations in the abundance of common voles *Microtus arvalis* were compared in the periods before and after the limitation of anthropogenic food availability in a rural area in western Poland. During the winter seasons of 1996/97–2014/15, the diet of the foxes was estimated by analysing the stomach contents of individuals shot from November to March and the index of vole abundance was obtained by counting their burrow entrances. The major component of the fox diet over the entire study period was anthropogenic food (mainly, the remains of farm animals) that showed both the highest average proportion in the stomach content volume (53.4%) and the highest average frequency of occurrence in the stomachs (62.7%), whereas small mammals were the second important component (27.5% and 54.2%, respectively). The frequency of anthropogenic food decreased and the frequencies of wild ungulate carrion and other wild vertebrates (mainly birds) increased after the limitation of anthropogenic resources. The observed fluctuations in the index of vole abundance resulted in positive changes in the small mammal frequency and negative changes in the anthropogenic food frequency, but the course of these relationships did not significantly differ between the two periods. The frequency of hares in fox stomachs did not change significantly between these periods, but recently the occurrence of hares in the diet of foxes increased with vole abundance. This study indicated that the reduction of anthropogenic food availability for carnivorous mammals may result in their switching to other prey species and potentially may have a negative influence on the demography of such prey species.

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Introduction

The red fox *Vulpes vulpes* is an opportunistic predator that has a wide geographical range. Hence the composition of its diet shows considerable spatial diversity (Lloyd, 1980). In agricultural areas and agro-forest mosaics of temperate and northern Europe, the traditional basic components of its diet have been small rodents that are usually characterized by fluctuations in their numbers, which caused periodic changes in the consumption of both small rodents and alternative prey (Angelstam et al., 1984; Dell'Arte et al., 2007; Dupuy et al., 2009; Goszczyński, 1974, 1986; Jędrzejewska and Jędrzejewska, 1992; Leckie et al., 1998; O'Mahony et al., 1999; Sidorovich et al., 2006; Weber, 1996). For example, in agricultural

areas of Poland in the 1960s–1980s, common voles *Microtus arvalis* were the small rodents that were most often eaten by foxes (33–65% of total prey biomass) and, in the periods when the availability of these voles was low, foxes would switch to brown hares *Lepus europaeus* and birds, including gamefowls (Goszczyński, 1974, 1986). Such periodic switching of a predator to the alternative prey species may lead to fluctuations in their populations, which were mostly found in northern latitudes (Angelstam et al., 1984; Norrdahl and Korpimäki, 2000).

In the 20th century, the red fox and some other species of carnivorous mammals began to feed more intensely on food wastes from people, which was related to the expansion of urbanized areas and to the occupation of such areas by these animals, and often resulted in an increase in density and changes of spatial and social structure of their populations (Bateman and Fleming, 2012). The most important components of the diet of foxes living in urban areas are usually wastes of various kinds found in litterbins and compost piles, household animals, and at times food purposefully fed

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by people (Baker et al., 2000; Contesse et al., 2004; Doncaster et al., 1990; Harris, 1981). However, also in certain rural areas, the diet of these animals has recently been found to contain a large amount of anthropogenic food, in particular carrion and post-slaughter waste from farm animals (Bino et al., 2010; Gołdyn et al., 2003; Jankowski et al., 2008; Panek, 2013; Panek and Bresiński, 2002). In western Poland, the remains of farm animals constituted only 4.9% of the total volume of stomach content in foxes shot in the winter periods between the years 1965–1973, but it has increased up to 53.3% in the years 2001–2007 (Panek, 2013).

The increase in the consumption of anthropogenic food by foxes could coincide with changes in the importance of other prey species for this predator. For example, over the past decades, a considerable decline in the number of brown hares has been observed in Europe (Smith et al., 2005). Long-term research on the composition of the diet of red foxes in western Poland has shown that brown hares, which used to be an important food of foxes, after a distinct decrease in their density, has become an accidental prey that are caught only occasionally, thereby they are replaced with farm animals in fox diet (Panek, 2013). However, it is unknown whether the higher consumption of regularly available food from people could result in other dietary changes in foxes; for example, foxes abandoning voles as their main food and the absence of the aforementioned switching between voles and alternative food.

The restriction of anthropogenic food availability by proper waste management was proposed as an effective method for controlling overabundant populations of red foxes, because experiments showed that this significantly reduced their survival (Bino et al., 2010). Moreover, it may be expected that in such circumstances foxes would also respond functionally, i.e., by changing their feeding habits, which would be more complex than mere restriction of consuming food from people. Therefore, will a potential reduction in anthropogenic resources in rural and suburban areas in Poland and other European countries result in foxes switching back to catching hares and other species with an unfavourable conservation status?

The aim of this study was to a) describe the composition of the diet of red foxes, b) calculate relationships between the frequencies of different prey categories in foxes' food, c) estimate the dietary responses of these predators to the fluctuations in the number of voles in two periods: when the anthropogenic food was abundantly available and once when this food was limited. We used changes in anthropogenic resources resulting from government regulations concerning the disposal of farm animal carrion in the country (introduced in order to adapt national sanitary rules to the principles of the European Union) as a semi-experimental study design.

Material and methods

Study area

The study was conducted in the years 1996–2015 in an area of 100 km² located near Czempin, south of Poznań, in western Poland. This area was mostly an agricultural landscape with predominant arable land. The owners of agricultural land were either large agricultural companies whose area was divided into crop fields of 10–100 ha (60% of the agricultural area) or smaller family farms with fields that were hardly larger than 10 ha (40%). Cereals were the main crop, but oilseed rape, maize, beets, potatoes, and alfalfa were also cultivated. During the study period, no clear changes in the composition of crops were observed. For example, the proportion of cereals remained at the same level (1996–57.1%, 2013–56.3% of the crop area; data of the Central Statistical Office). The animal production in this region (mostly pigs, cattle, and poul-

try), on the other hand, increased considerably during the study period (1996–31.0 t/km², 2013–47.4 t/km², in post-slaughter warm weight; data of the Central Statistical Office). Built-up places covered 9% of the study area and they included the town of Czempin and 23 small villages, which constituted clusters of residential and farm buildings. The distance from the nearest buildings did not exceed 1.7 km at any point from the study area. Forest patches ranging from 70 to 270 ha covered 7% of this area, while clumps of trees (from <1 to 15 ha) and strips (roadsides, ditches, border lines) with wild herbaceous vegetation, bushes, and trees occupied 3% of the agricultural landscape.

The spring density of red foxes in the study area amounted to about 0.2 individuals per km² in the 1960s and 1970s, but it started to increase in the early 1990s and reached 0.9–1.1 individuals per km² in the second half of 1990s (Panek and Bresiński, 2002). However, their abundance decreased at the turn of the century (probably due to intensification of culling by the hunters in the late 1990s) and fluctuated between 0.4 and 0.8 individuals per km² in the years 2002–2015 (M. Panek, unpubl. data from spotlight counts). Foxes' food and its dependence on the availability of prey have been studied in the same area since the 1960s (Goszczyński, 1974; Panek, 2013; Panek and Bresiński, 2002; Pielowski, 1976; Ryszkowski, 1982).

The numbers of common voles showed distinct fluctuations in this region in the previous decades (Ryszkowski, 1982). The autumn density of brown hares in the years 1999–2006 ranged from 4.4 to 8.1 individuals per km², and the mean for this period (6.7) was 7 times lower than the average for the 1960s and 1970s (Panek, 2013). In the years 2007–2015 the population of hares continued to fluctuate on such low level, i.e., between 3.3 and 6.1 individuals per km² in spring (M. Panek, unpubl. data from spotlight counts). The roe deer was the most common ungulate species: its average spring density increased from 8.0 individuals per km² in the years 1997–1999 to 11.5 individuals per km² in the years 2013–2015 (M. Budny, unpubl. data from total counts in the whole study area). According to the local hunting statistics, populations of other ungulates, i.e., red deer, fallow deer and wild boar, also increased during the study period, particularly in the case of the last species (mean spring densities in the years 1997–1999 and 2013–2015 in individuals per km² for the three species respectively: 0.1–0.4, 0.4–1.0 and 0.2–1.1; M. Budny, unpubl. data).

Farmers in Poland, including our study area, often collect the manure in prisms placed in crop fields. They regularly collect the manure and leave it to be used as a fertilizer during tillage. The prisms typically measure 5–20 m in diameter and 2–3 m in height, and contain mainly cereal straw and farm animal faeces. Various food and animal wastes can be sometimes found in those prisms, both from farms and households, including carrion of farm and household animals. However, since 2008, a government regulation became effective in Poland (Journal of Laws of the Republic of Poland, 2007) establishing the principles of collecting dead farm animals from farmers and their disposal. After the implementation of this regulation the number of dead animals disposed in our region increased considerably and next showed slow growing trend at least until 2014 (unpubl. data of the regional office of The Agency for Restructuring and Modernisation of Agriculture). This should reduce the availability of farm animal carrion for foxes.

Data collection

The winter diet of red foxes was studied by analysing the stomach contents of individuals shot in the study area from November to March. During 18 winter seasons from 1996/97 to 2014/15 (excluding 2002/03 when data could not be collected), 939 stomachs were checked, and in 672 of them (27–70 stomachs per season) some food items were found. In each stomach with such content, the

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