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Habitat use and diet of the red fox *Vulpes vulpes* in an agricultural landscape in Poland

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1 Introduction

The red fox *Vulpes vulpes* Linnaeus, 1758 is known to be one of the most important predators in farmland areas (Lloyd, 1980; Newton, 1998; Tryjanowski, 2000). During the last decade a rapid increase of the fox abundance was observed in Western Poland (Bresiński and Panek, 2000). Moreover changes in fox habitat preferences took place. Foxes expanded their habitat from mid-field afforested areas to adjacent open arable fields, often in the vicinity of human settlements (Panek and Bresiński, 2002). Along with habitat shift some modification in fox ecology occurred. There is some evidence that foxes reduced their fear of humans, started to use artificial structures as shelters and included garbage and poultry into their diet (Panek and Bresiński, 2002). The adaptation of red fox to intensively used farmland is still in process and may differ according to local conditions. Red fox is definitely an omnivore species, with behavioural plasticity (Lloyd, 1980; Lariviere and Pasitschniak-Arts, 1996), so we expected it should easily adapt to new open farmland habitats. Therefore, surveys involving simultaneous studies of fox diet and habitat selection in the agricultural landscape are of particular importance.

Dens have a crucial meaning for foxes, not only as breeding places, but also as a shelter for adults during the whole year (Meia and Weber, 1993). Their location may be related to the distribution of food resources (Macdonald, 1983; Weber, 1985) or the presence of adequate habitats (Meia and Weber, 1992, 1993). On the other hand, both habitat and trophic condition regulate population dynamics. In this work we study the abundance, den site and diet of the red fox in an intensively cultivated area. Potential ecological consequences of habitat shift of the species are also discussed.

2 Materials and methods

2.1 Study area

Studies were conducted between October 1998 and February 2001 near Poznań, Wielkopolska province, western Poland (52°27'N, 16°57'E). The study area was 15 km^2 of farmland, where mainly cereals, oilseed rape and sugar beets were cultivated. Patches of marshes, meadows and drainage ditches occupied approximately 4% of the area. Marsh area (N = 57) varied between 0.01 and 9.8 ha. Most of the marshland did not dry completely throughout the year. Ditches (total length 11.4 km) were up to 6 m deep and contained water only periodically. The dominant vegetation in marshes and ditch banks were reed *(Phragmites communis)* and herbaceous plants. No forests or woodlots occurred in the study area. Single trees and bushes, mainly willows *(Salix sp.)*, grew on the edges of ditches and marshes.

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Urbanised areas and roads constituted 5% of the study area. In the middle of the study area a city dump site was located.

2.2 Fox abundance

For estimation of fox number and abundance den searching and snow tracking were used (PRIKLONSKY, 1965). The dens were mapped and controlled at last once a month. For each den, location and entrance exposure were recorded. Non-breeding individuals also dig dens and use them with different intensity (GOSZCZYŃSKI, 1985; MEIA and WEBER, 1993). For this reason, in 1999 more controls were performed to distinguish among three types of dens, viz. breeding dens, non-breeding permanent dens, and non-breeding temporary dens. Classification was based on observations of tracks, scats and food remains left at the den entrances. During other seasons, dens were categorized only as either used or abandoned. Dens not used in a particular year were excluded from analysis. The number of adult foxes (N) was calculated using the equation N = (2*BD) + PD, where BD = number of breeding dens, PD = number of non-breeding permanent dens. This formula was based on the assumption that two adult foxes (a male and a female) inhabit each breeding den, while the other den types are occupied by solitary individuals. Dens visited by foxes irregularly (non-breeding temporary dens) were probably used as additional shelters. These were excluded in the calculation to avoid overestimation of the population size.

Snow tracking was performed during the winters 1999/2000 and 2000/2001. Each winter, 40 random transects (0.5–1.5 km) were walked, not later than 24 h after new snow had fallen. All fox tracks crossing the transect line were counted. The number of tracks was converted into the number of tracks per 1 km of transect line per day. The mean penetration index (n tracks km^{-1} d^{-1}) was calculated and used for estimating the abundance of foxes, according to the following formula by PRIKLONSKY (1965): A = 1.57*P/DMD, where A = mean abundance, P = mean terrain penetration index, DMD = daily movement distance. A daily movement distance of 12.5 km, considered typical for a fox under mild winter conditions in a farmland (GOSZCZYŃSKI, 1985), was used for abundance estimation.

2.3 Den sites

We tested relationships between den location and three habitat parameters. For each den, distances to the nearest building, major road and other den were measured. The same measurements were performed in 103 control points located randomly in the areas studied.

2.4 Food composition

Fox scats were collected between September 1999 and October 2000, along random transects and frozen for later analysis. They were then soaked in water, crumbled and inspected for macroscopic remains (mainly bones and teeth) to identify prey species. Fur and feather remains found within scats were identified using a light microscope (HAUSMAN, 1920; DZIURDZIK, 1973). Identified food remains were classified into the following eight categories: rodents, lagomorphs, birds, plants, fruits, trash, Coleoptera. Birds preyed by fox were divided in 3 groups: small birds (in the size of sparrow), medium sized (starling – pigeon) and large birds (mainly poultry and game birds). The frequency of each food type was expressed as percentage of the total number of scats. Birds preyed by foxes were determined additionally on the basis of remains of fox meals, like feathers, bones and carrion.

2.5 Statistical analyses

Standard statistical methods were used to describe and analyze the data (ZAR, 1999). Calculations were conducted using the SPPS for Windows package (NORUSIS, 1986). Differences in the location between occupied and random sites (presence/absence binary data) were analysed using backward-stepwise logistic regression (HOSMER and LEMESHOW, 1989). The significance of each variable included in the model was based on the Log Likelihood ratio.

Because most of dens were located in steep slopes, we tested for fox preferences of exposure. We compared the ratio of dens dug in slopes of eight main exposures with expected values using χ^2 for circular distribution test. Most slopes in area studied were linear (e.g. banks of ditches and marshes). Thus, expected values were calculated in relation to the ratio of slope with a given exposure in a total slope length in the study area.

All statistical tests were two-tailed. We considered $P < 0.05$ as the minimum level determining significance.

3 Results

3.1 Abundance

Fox abundances in 1999–2000, determined by winter tracking were 2.1 and 1.79 individuals/km^2 respectively. During the study period, a total number of 76 fox dens were found. Each year some of dens were abandoned, mainly as a result of anthropogenic or natural destruction. At the same time new dens were established as well. There were 32 dens occupied by foxes in 1998, 38 in 1999, 44 in 2000, and 27 in the beginning of 2001. In 1999, evidence of offspring were found in 5 dens. In the same year, 23 fox dens were visited exceptionally often, suggesting that they were in "permanent" use. Another 10 dens (26%) were used only as an alternative hide and therefore classified as "temporary". Fox density in 1999 estimated on the basis of den counts was 2.2 individuals/km^2. In 1999, there was no significant difference between the numbers of foxes estimated based on snow tracking and on den searching (χ^2 test with Yates correction, $\chi^2 = 0.01$, df = 1, $p = 0.93$).

3.2 Den location

92% of dens were situated on slopes (N = 70). Banks of drainage ditches (N = 39), marsh banks (N = 14) and boundary strips between fields (N = 9) were the most frequent den locations. Dens were randomly distributed in ditches and other slope habitats, as marsh banks and boundary strips between fields (χ^2 test with Yates correction, $\chi^2 = 0.05$, df = 1, $p = 0.82$). Eight dens were placed in trenches and piles of soil. Six were dug in completely flat ground, five in maize fields and one in a dry meadow.

Dens were not randomly distributed among slopes of various exposures ($\chi^2 = 19.62$, df = 7, $p = 0.006$). Foxes showed significant preferences for southern exposure, where most dens were dug (Figure). Number of dens located in western slopes was markedly lower in proportion to the available length of slope of that exposure (Figure).

There were significant habitat differences between den and control sites ($\chi^2 = 11.02$, df = 2, $p = 0.004$). Foxes selected more sites farther from buildings ($\chi^2 = 4.71$, $p = 0.03$). Distances between adjacent dens were markedly lower than between dens and control points ($\chi^2 = 3.10$, $p = 0.08$). Distance to nearest road did not affect den distribution.

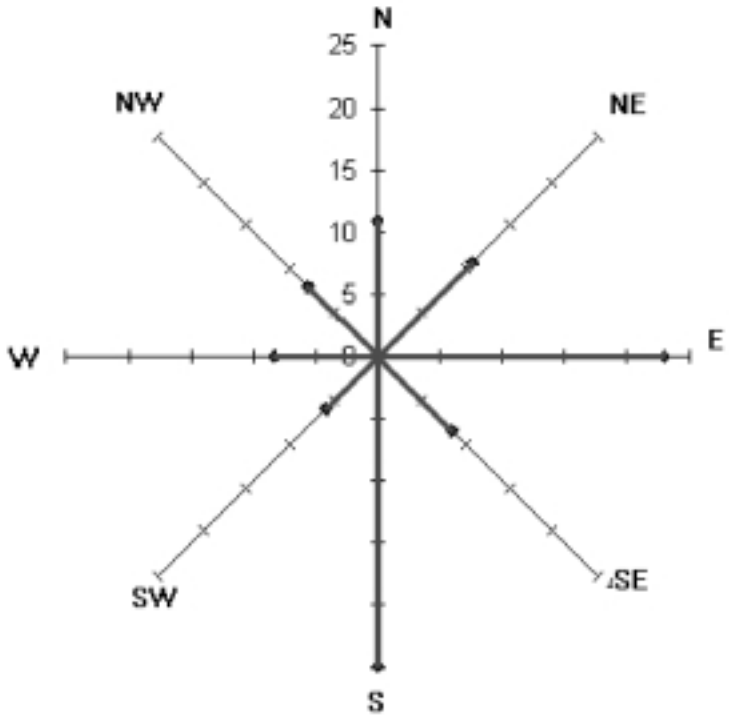

Figure. Ratio of dens [%] located in slopes with various exposures.

3.3 Diet composition

A total of 163 scats were collected. Food composition is shown in the table. The main food items were rodents of the genus *Microtus*, especially *M. arvalis*, while medium and big sized species dominated among birds. Hare remains occurred only in a small number of scats, whereas plant fragments and anthropogenic food items were quite frequent. In addition, two egg fragments and one freshwater snail *(Anisus sp.)* were found.

Remains of 22 birds preyed by foxes were found in the study area. Most of them were domesticated species: feral pigeons (*Columba livia,* N = 12), hens (*Gallus gallus,* N = 3) and turkeys (*Meleagris gallopavo,* N = 2). Following species were represented by a single specimen: mute swan *Cygnus olor*, greylag goose *Anser anser*, mallard *Anas platyrhynchos*, buzzard *Buteo buteo*, quail *Coturnix coturnix*, wood pigeon *Columba palumbus*, magpie *Pica pica*, rook *Corvus frugilegus*, yellowhammer *Emberiza citrinella*, reed bunting *E. schoeniclus*.

4 Discussion

Red fox densities established for the same area often vary depending on the applied census method (Beltrán et al., 1991). For example, breeding den counting conducted near Czempiń (Western Poland), gave twofold lower results than snow tracking (Panek and Bresiński, 2002). Similarly, Goszczyński (1999) obtained 30% higher densities by using

Table. **Percentage occurrence of different food types in the total sample of scats of red fox (N = 163).**

Food type	Occurrence %	Number of scats
Microtus sp.	67.5	110
Arvicola terrestris	1.8	3
Apodemus sp.	1.8	3
Other rodents	18.4	30
Small bird species	9.8	16
Medium bird species	16.0	26
Large bird species	22.1	36
Lagomorpha	15.3	25
Coleoptera	9.2	15
Plants	19.6	32
Fruits	7.4	12
Trash	16.0	26
Eggs	1.2	2

the latter method. In our study, fox densities in 1999 derived from two different census methods were virtually the same. Such a small bias probably resulted from the precise analysis of den use by foxes. In most studies, the majority of dens are used as breeding places and two adult foxes are assumed to live in each (e.g., GOSZCZYŃSKI, 1999; PANEK and BRESIŃSKI, 2002). In our study area, breeding dens constituted only about 13 % of all dens. Moreover, dens were arranged in clumps, each with one breeding site (see Results; GOŁDYN, 2001). This type of den distribution indicates that the studied foxes lived in clans. This social system is common especially among populations in areas under strong human pressure (BAKER at al., 1998). In each clan, there is only one dominant, breeding *alpha pair*, few female helpers, and at least one non-helping female (VON SCHANTZ, 1981; CAVALLINI, 1996; MEIA and WEBER, 1996). Most of the non-breeding dens found in the study area probably belonged to solitary members of clans. Each fox usually uses few or even several dens (GOSZCZYŃSKI, 1985; MEIA and WEBER, 1993). However, one to three of them are used more intensively than others (MEIA and WEBER, 1993). For this reason we distinguished the category of "temporary" dens and did not take them into account. It is important to notice that the number of additional dens is negatively correlated with vegetation cover (MEIA and WEBER, 1993). Foxes may dig especially many dens in farmland lacking woods or even woodlots where alternative resting-places are scare.

Red fox density in the study area is one of the highest in Poland. However it is important to notice that, compared with previous studies, the study area was relatively small, which might have led to an overestimation of the population. On the other hand, the presented results were obtained by using two different methods. Moreover, in cases where a high fox density is expected, more detailed population estimations performed in smaller areas may provide more reliable results.

The high densities obtained in the study area reflect the rising trend in red fox population size observed in Poland over at least the last 20 years (GOSZCZYŃSKI, 1985, 1990; PANEK and BRESIŃSKI, 2002). Corresponding high densities (1.63 individuals/km^2) were previously also estimated in farmland area of 66 km^2 (PANEK and BRESIŃSKI, 2000).

Several factors are regarded to be responsible for the high number of foxes in the study area as well as the whole western part of the country. The most important are i) the intensive oral vaccination against rabies, ii) a reduction in the intensity fox hunting, iii) fox adaptation to new anthropogenic conditions, e.g. the use of garbage as additional food source (BRESIŃSKI and PANEK, 2000; TRYJANOWSKI, 2000; PANEK and BRESIŃSKI, 2002).

In farmland areas, wood edges and woodlots are virtually exclusive habitats where fox dens are situated (LARIVIERE and PASITSCHNIAK-ARTS, 1996). In an area with 21% forest coverage, only 2% of all dens were located in open habitats (GOSZCZYŃSKI, 1985). Similar results were obtained by other authors in the 1970s (PIELOWSKI, 1976; STUBBE, 1980). Even

in a farmland with only 6% forest coverage, the tendency to breed in wooded areas was still significant (PANEK and BRESIŃSKI, 2002). In our study area, where wood cover was lacking, foxes successfully adapted to completely different conditions, reaching high densities. Most den sites were located in open habitat patches like banks of ditches or marshes. Steep slopes give favourable possibilities to dig dens and are preferred by foxes also in woodlands (GOSZCZYŃSKI, 1999). Deep and narrow ditches however, offer better opportunity to hide den entrances. Apart from providing breeding habitats, the ditches were probably used as ecological corridors, enabling foxes to penetrate their territories unseen by people. Dens dug in midfield ditches were found also near Czempiń (W Poland) where they constituted ca. 6% of all shelters (PANEK and BRESIŃSKI, 2002). It is worth to emphasise, that some of dens were dug in open area of crops. This phenomenon, unknown in the 1970s and 1980s (PIELOWSKI, 1976; GOSZCZYŃSKI, 1985), shows that foxes became partially independent of any marginal habitats in a farmland. PANEK and BRESIŃSKI (2002) also found a significant proportion of fox breeding sites located in this type of habitat.

Previous surveys on fox habitat selection did not reveal any uniform preference for slope exposure. In Switzerland (FUCHS, 1973), most den entrances were oriented north, northwest or west, whereas in Germany (BEHRENDT, 1955; HALTENORTH and ROTH, 1968) southeastern, southern and south-western exposures dominated. Such variability suggests that exposure choice strongly depends on local microclimatic conditions. Magnitude of western winds in Wielkopolska region (WOŚ, 1999) explains the avoidance of western exposures as a den entrance. Southern exposure gives additional possibility to warm the den throughout the whole day. In a forest, where dense vegetation prevents any draughts, foxes exhibit no preferences for certain den entrance exposures (ROMAN, 1984).

The results of diet analyses obtained in the present study are similar to those from other farmland studies in Central Europe (GOSZCZYŃSKI, 1974; GOSZCZYŃSKI, 1986; KOŽENÁ, 1988) and Great Britain (LLOYD, 1980; O'MAHONY et al., 1999; LECKIE et al., 1998). In all cases foxes fed predominantly on rodents and game birds, using poultry and garbage as alternative food. The high frequency of rodent remains in scats (89.6%) is related to the fact that foxes forage mainly in open habitats where this prey is most abundant (GOSZCZYŃSKI, 1985; JĘDRZEJEWSKA and JĘDRZEJEWSKA, 1998). Birds gave a high proportion of fox diet in the present study (a total 47.9% occurrence in scats). The majority of them belonged to large and middle-sized species, like feral pigeons and poultry, which dominated in prey remains eaten by foxes. Birds also formed an important part of fox diet in other agricultural areas in Czechoslovakia (KOŽENÁ, 1988) and central Poland (PRUDNICKI et al., 2000), where mainly poultry was eaten. Our results indicate that poultry constituted an important and easily available fox prey in densely populated farmland. On the other hand, such a feeding strategy can cause obvious conflicts with poultry owners (PRUDNICKI et al., 2000). This explains, why dens in the study area were located farther from settlements than control points.

Another frequent element in fox scats were garbage items (Table). The main sources of this food were a city waste dump located in the middle of study area and dustbins. Garbage is a common element in the diet of foxes living in urbanised areas in Great Britain (HARRIS and SMITH, 1987; DONCASTER et al., 1990; SAUNDERS et al., 1993). The use of garbage as food source in farmland foxes was reported from the Czech Republic, with a frequency of 5.8% in scats (KOŽENÁ, 1988). Also in fields near Czempiń (W Poland) remains of livestock, partially eaten as carrion and offal at dumping sites, constituted on average 44.4% of fox stomach content (PANEK and BRESIŃSKI, 2002). Garbage items are usually not healthy nor of high energetic value. On the other hand they are easily accessible during the whole year, independently of environmental conditions, e.g. the presence of rodents (PANEK and BRESIŃSKI, 2002). The importance of the city dump as foraging area was confirmed by field

observations. Foxes were often observed digging undercuts under the dump fence. In winter their tracks leading to the dump were up to two kilometres long.

Compared with most other studies, a smaller proportion of hare in fox diet was found. One of the possible explanations for this is the significant decline of the hare population in western Poland due to epidemic of EBHS (European Brown Hare Syndrome) (BRESIŃSKI and JĘDRYCZKOWSKI, 1999). Another possibility is that foxes partially switched from this energetically costly prey to the more available poultry and garbage. In the area of Czempiń, where foxes foraged intensively on carrion and offal, hares also constituted an only relatively small proportion of food (PANEK and BRESIŃSKI, 2002).

The presented results show that farmland populations of foxes adapt to anthropogenic conditions in a similar way than urban populations. Animals learned to use garbage and poultry as major food items, thereby making themselves partially independent from fluctuations in the availability of natural food resources. The extra food provided by people probably caused a rapid increase of fox population density in farmland areas. Favorable trophic conditions caused the foxes to switch from traditional den habitats to new ones. Our results further provide some evidences that foxes reduced their fear of people and human infrastructure.

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Summary

Red fox *Vulpes vulpes* density, diet and den site selection were studied in a unwooded farmland of western Poland. During years 1999–2000 snow tracking was performed, and in 1999 dens were counted. Estimated population densities based on snow tracking were 2.1 and 1.79 individuals/km² respectively, while den counts gave a value of 2.20 individuals/km². Almost all dens were located on steep slopes, mainly on banks of drainage ditches (51%) and marsh banks (18%). Foxes markedly preferred southern exposure, while western slopes were avoided. The relatively high number of dens, their clumped distribution and the small number of breeding dens show that the studied population was organised in 5 clans. 26% of the dens were used only temporarily indicating that some of individuals use more than one den. Scat analyses revealed a high frequency of rodents, birds (mainly poultry) and garbage items in fox food (65.6, 47.9, 16.0% occurrence in scats, respectively). Fox adaptation to anthropogenic food sources and change in den site selection are discussed as main factors responsible for the occupation of farmland and in consequence, for the increase of fox densities in Poland.

Key words: Vulpes vulpes, red fox, farmland, habitat utilisation, diet composition, predation

Zusammenfassung

Habitatnutzung und Nahrung des Rotfuchses in einem landwirtschaftlichen Gebiet Polens

Untersucht wurden Populationsdichte, Nahrung und die Lage der Baue von Rotfüchsen in einem unbewaldeten Agrargebiet in Westpolen. In den Jahren 1999–2000 wurden Fährtenzählungen im Schnee und 1999 eine Bauzählung durchgeführt. Die auf der Basis der Fährtenzählungen geschätzten Popluationsdichten betrugen 2,1 beziehungsweise 1,79 Individuen/km², während die Bauzählung einen Wert von 2,20 Individuen/km² ergab. Nahezu alle Baue befanden sich an steilen Hängen, hauptsächlich von Entwässerungsgräben (51 %) und Randzonen von Sumpfgebieten. Die Füchse bevorzugten

deutlich südexponierte Hänge, während Westhänge gemieden wurden. Die relativ große Zahl von Bauen, ihre Zusammenballung in bestimmten Gebieten und die geringe Anzahl von Wurfbauen zeigen, dass die Population in fünf Familienverbänden organisiert war. 26 Prozent der Baue wurden nur zeitweise benutzt, was darauf hinweist, dass einige Individuen mehr als einen Bau benutzen. Kotanalysen ergaben hohe Anteile von Nagetieren, Vögeln (hauptsächlich Hausgeflügel) und Abfall in der Nahrung (Häufigkeiten von 65,6, 47,9 beziehungsweise 16,0 % in den Kotproben). Als Hauptfaktoren für die Besiedlung von Agrargebieten durch den Rotfuchs und die daraus resultierende Zunahme der Fuchsdichte in Polen werden die Anpassung der Füchse an anthropogene Nahrungsquellen und Veränderungen in der Wahl des Baustandortes diskutiert.

Schlüsselwörter: Vulpes vulpes, Rotfuchs, Agrargebiet, Habitatnutzung, Nahrungszusammensetzung, Prädation

Résumé

Utilisation de l'habitat et régime alimentaire du Renard roux Vulpes vulpes dans un paysage agricole en Pologne

Densité du Renard roux *Vulpes vulpes,* régime alimentaire et sélection des terriers ont été étudiés dans une région agraire de l'Ouest de la Pologne. Au cours des années 1999 et 2000 un relevé des traces à la neige a été effectué et en 1999 les terriers ont été dénombrés. Les densités de population estimées à partir des traces relevées dans la neige atteignent respectivement 2,1 et 1.79 individus par km² tandis que le dénombrement des terriers donnait une valeur de 2.20 individus par km². La plupart des terriers étaient situés sur des pentes raides, le plus souvent sur des talus de fossés de drainage (51 %) et sur des bancs situés en limite de marécages (18 %). Les renards marquaient une nette préférence pour les expositions sud, les expositions ouest étant évitées. Le nombre relativement élevé de terriers, leur répartition groupée («en amas») et le petit nombre de terriers occupés par des nichées montrent que la population étudiée était organisée en 5 clans. 26 % des terriers n'étaient utilisés que temporairement, laissant entendre que certains individus utilisaient plus d'un terrier. Les analyses de fèces ont révélé une fréquence élevée de rongeurs, d'oiseaux (de la volaille le plus souvent) et de résidus alimentaires (occurrence de respectivement 65.6, 47.9 et de 16.0 % dans les fèces). L'adaptation du Renard aux ressources alimentaires anthropogènes et le changement dans la sélection des terriers sont considérés comme étant les principaux facteurs responsables de l'occupation de l'espace agraire et, en conséquence, de l'augmentation des densités du Renard en Pologne. Trad.: S. A. DE CROMBRUGGHE

Mots clefs: Vulpes vulpes, Renard roux, espace agraire, utilisation de l'habitat, régime alimentaire, prédation.

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