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Is Corridor Use by European Carnivores Driven by Habitat Characteristics or Food Supply?

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Annotation

This thesis is made up of introduction and conclusion in Czech and the manuscript in English. In the study, we determined if corridor structures use by carnivores is influenced by habitat features or prey quantity. We found that predator utilization of corridors are primarily driven by abundances of its principal prey rather than corridor characteristics but this relationship between prey abundance and carnivore distribution is species-specific. None of the measured habitat features affected the probability of carnivore detection.

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Bc. Eliška Padyšáková

Poděkování:

Bobe, Tominko, Peter, Eliší, Simčo, Jiříku, Blonďáku, Kamčo, Joly, Martine, Jardo, Kubo, Kepy, Piňosi, Radko, všichni opraváři a odtahovači Bertičky, kamarádi, rodino – DĚKUJI!

Obsah

Úvod

Ubývání přirozeného prostředí ve prospěch zemědělství, lidské zástavby a dopravy se stalo na mnohých místech světa velkým a často diskutovaným problémem (Lindenmayer *et al*. 2000; Fahring 2002, 2003; St-Laurent *et al.* 2009). Původní krajina se fragmentuje a ztrácí kontinuitu a prostupnost kvůli velkému množství bariér vytvořených lidmi. V krajině zůstávájí roztroušeny více či méně izolované ostrůvky vhodného habitatu obklopené nehostinným typem vegetace. Tyto ostrůvky se pak stávají jediným možným útočištěm pro mnoho druhů zvířat (Miller & Cale 2000; Drinnan 2005). Logickým důsledkem fragmentace je mnohdy výrazná změna struktury zvířecích společenstev a pokles diverzity (Fahring & Merriam 1994; Fahring 2003), často spojený i s lokální extinkcí nejvíce citlivých druhů (Zuidema *et al.* 1996; Schmiegelow & Mönkkönen 2002).

Samotná fragmentace, tj. rozpad původně velkého a souvislého celku přirozeného prostředí na menší oddělené ostrůvky (Fahring 1997), ovšem nepředstavuje největší hrozbu. Tou je úplná ztráta vhodného prostředí (Fahring 1997, 2002, 2003; Burkey 1995; Betts *et al*. 2006; St-Laurent *et al.* 2009) vedoucí k celkovému snížení zastoupení daného prvku v krajině (Schmiegelow & Mönkkönen 2002). Pokud z původní mozaiky vhodného habitatu vymizí kus území, zvýší se tím izolovanost zbývajících částí (Fahring 1997) a následně se sníží míra rekolonizace a druhová diverzita v jednotlivých fragmentech (Bolger *et al.* 2001).

Skutečný dopad negativních změn v krajině na společenstva zvířat závisí na prostorovém uspořádání jednotlivých habitatových prvků a stupni kontinuity. Schopnost dosáhnout a využít izolovaných ostrůvků je závislá nejen na meziostrůvkové vzdálenosti (Dunning *et al.* 1992), ale i na biofyzikálních vlastnostech obklopující matrice a pohybových schopnostech jednotlivých druhů zvířat (Henein & Merriam 1990). Jestliže je okolní vegetace nehostinná a pro mnohé druhy nepřekonatelná, vytvářejí se metapopulační struktury, které oslabují stabilitu a stálost populací zvířat (Gilpin & Hanski 1991).

Zmírnění izolačního efektu lze dosáhnout ponecháním koridorů, které zvyšují stupeň kontinuity prostředí (Beier & Noss 1998; Perault & Lomolino 2000; Bolger *et al.* 2001; Hilty & Merenlender 2004; Pardini *et al.* 2005). Koridory, tj. úzké lineární pásy vhodné vegetace spojující preferované, ale izolované ostrůvky habitatu (Forman & Gordon 1986), umožňují vzájemnou výměnu individuí (Bolger *et al.* 2001; Gehring & Swihart 2003; Hilty & Merenlender 2004; Pardini *et al.* 2005) či tok genů (Leung *et al.* 1993; Mech & Hallett 2001; ale viz Horskins *et al*. 2006) mezi separovanými populacemi, popřípadě mohou sloužit jako zdroje jedinců (Perault & Lomolino 2000). Koridory rovněž vytváří spojnici mezi vzdálenými částmi velkých domovských okrsků jednotlivců (Bolger *et al.* 2001) či slouží jako vhodný habitat pro život některých druhů zvířat (Bolger *et al.* 2001; MacDonald *et al.* 2004). Na druhou stranu, pokud v rámci koridorů převládne tzv. okrajový efekt (edge effect), mohou se stát i biologickou pastí pro určité druhy (Simberloff *et al.* 1992).

Míra tolerance k fragmentaci či ztrátě habitatu je v rámci čeledi šelem (*Carnivora*) výrazně druhově specifická (Crooks 2002). Mezidruhově odlišné reakce na fragmentaci jsou způsobené hlavně rozdílnými pohybovými možnostmi jedinců a jejich schopností vyhledat a zužitkovat potravní zdroje. Zejména pro menší druhy (lasice kolčava, lasice hranostaj, tchoři) jsou některé konkrétní části krajiny obtížně prostupné, zatímco větší druhy (liška obecná, kuna skalní) je nevnímají jako překážku (Gehring & Swihart 2003). Vzhledem k velikosti areálu druhů, jejich populační dynamice a etologii má zmenšování rozlohy dostupného habitatu pod kritickou hranici vliv na dlouhodobé přežívání populací. Postupem času přežívají jen druhy široce adaptované, tolerantní a hojné, čímž dochází k následné ztrátě druhového bohatství daného území. Ve fragmentované krajině, ve které jsou hojně zastoupeny těžko prostupné oblasti, je tak nesmírně důležité zachovat či obnovit přirozené spojnice mezi izolovanými lokalitami a umožnit tím pohyb zvířat krajinou (Gehring & Swihart 2003).

Populační strukturu i druhové složení zvířecího společenstva může zásadně ovlivnit člověk svým způsobem využívání krajiny. Potravní generalisté (např. liška obecná, kuna skalní) se díky své schopnosti přizpůsobit se nejrůznějšímu prostředí i široké škále potravní nabídky lépe vyrovnávají s následky fragmentace krajiny (Swihart *et al.* 2001; Virgós *et al.* 2002). Naproti tomu, potravní specialisté (např. oba druhy lasic), kteří jsou omezeni svými habitatovými a potravními nároky, jsou vůči změnám životního prostředí mnohem zranitelnější (Crooks 2002) a více podléhají populačním poklesům ve srovnání s generalisty. Z práce Virgóse *et al.* (2002), zabývající se reakcemi jednotlivých zástupců evropských šelem na fragmentaci lesa, je patrné, že nejlépe se s úbytkem přirozeného prostředí vyrovnala liška (*Vulpes vulpes*), která je schopna obývat i zemědělskou krajinu s malým podílem lesa. Další zástupci generalistů jezevec (*Meles meles*) a kočka divoká (*Felis silvestris*) se se změnami prostředí vyrovnali obdobně, nicméně oba druhy vyžadují větší podíl lesa v nejbližším okolí svého teritoria. Ačkoliv je jezevec potravním generalistou, který se rychle adaptuje na téměř jakoukoli potravu, je náročný na vlastnosti habitatu; vyžaduje vhodné lokality pro hrabání svých nor, ze kterých pak vyráží na pravidelné obchůzky teritoria.

Většina prací zabývajících se touto problematikou mapuje následky výše jmenovaných jevů u různých skupin zvířat převážně na severoamerickém kontinentě či v Austrálii (Nupp &

Swihart 1998; Laurance & Laurance 1999; Jonsen & Taylor 2000; Lindenmayer *et al.* 2000; Bolger *et al*. 2001; Betts *et al*. 2006). Srovnatelných prací z Evropy je stále nedostatek a přizpůsobivost (citlivost) evropské fauny na změny v dramaticky se měnící krajině tak není dostatečně prozkoumána (viz Virgós *et al.* 2002; Mortelliti & Boitani 2008; Šálek *et al*. 2009). My jsme se v předkladané magisterské práci zaměřili na šelmy běžně žijící ve středoevropské přírodě a snažili se tak přispět do mozaiky znalostí z této oblasti.

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Is Corridor Use by European Carnivores Driven by Habitat Characteristics or Food Supply?

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Abstract

Corridors may reduce the negative biological effects of both habitat loss and fragmentation by providing habitat linkages among preferred (but otherwise isolated) patches; or by providing an extra breeding habitat for many species, including carnivores. Here, we examine if corridor use by carnivore species is influenced by habitat characteristics or prey quantity. To detect the spatial distribution of carnivores we used the scent station method. We founded that predator utilization of corridors are primarily driven by abundances of its principal prey, rather than corridor characteristics; however, this relationship between prey abundance and carnivore distribution is species-specific. None of the habitat features measured affected the probability of carnivore detection. We believe that maintaining the corridor structures in a fragmented landscape is an essential tool for preserving the quality of the ecosystem.

Key words: fragmentation, corridors, carnivores, habitat characteristics, food supply predator-prey interaction, Europe

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Introduction

Increased habitat fragmentation and landscape usage, caused by humans, has occurred in Europe during the past decades; and it is considered as a major threat to biological diversity worldwide (Wilcove *et al.* 1998). These negative trends are primarily caused by the spread of infrastructure (highways, high speed rail corridors, etc.), expanding urbanization (residential and commercial developments), and the intensification of agricultural production (increases of intensively cultivated areas). The long-term influence of the above-mentioned human-induced practices can result in discontinuous and impermeable areas, due to significant amounts of barriers across the landscape (Miko & Hošek 2009).

Disintegration of a more-or-less homogenous area leads to reduced habitat patch sizes and their subsequent isolation or loss (Fahring 1997). The loss of a particular habitat from the original mosaic of suitable patches in the landscape increases the isolation of the remaining patches (Fahring 1997). These remnants then become the only area of suitable habitat to occupy, surrounded by an unfavourable habitat type, containing low advantages in terms of mortality and movement rates (Fahring 1998). Consequently, this may lead to decreased population survival, or even the local extinction of sensitive species (Wilcove *et al.* 1998; Jager *et al.* 2006; St-Laurent *et al.* 2009).

The negative biological effects of habitat loss and fragmentation can be reduced by the maintenance of natural connections among these isolated patches (Taylor *et al.* 1993, Schmiegelow *et al.* 1997). Wildlife corridors (*i.e.* linear strips of suitable vegetation linking preferred, but shredded, habitat patches (Forman & Gordon 1986)), can provide this role (Beier & Noss 1998; Perault & Lomolino 2000; Bolger *et al.* 2001; Hilty & Merenlender 2004; Pardini *et al.* 2005; but see Horskins *et al.* 2006). Corridors particularly serve as habitat linkages among preferred, but otherwise isolated, patches in a single home range (Bolger *et al.* 2001), or as extra breeding habitat for certain species (Bolger *et al.* 2001; MacDonald *et al.* 2004). Corridors may also increase (or at least maintain) the levels of inter-patch exchange of individuals (Bolger *et al.* 2001; Gehring & Swihart 2003; Hilty & Merenlender 2004; Pardini *et al.* 2005) and gene flow (Leung *et al.* 1993; Mech & Hallett 2001; but see Horskins *et al.* 2006) among populations in residual patches - and thus serve as important conservation tools for maintaining connected populations. Facilitating the movements of animals and genes among otherwise isolated populations may lead to a decrease in their inbreeding depression (Aars & Ims 1999). Finally, in some cases, they can serve as demographic sources of individuals (Perault & Lomolino 2000).

The degree of toleration to habitat loss and fragmentation varies markedly among carnivores (Crooks 2002). Their interspecific response differences to fragmentation result from the animal's ability to move and obtain suitable food among jumbled patches (Gehring & Swihart 2003). In a fragmented landscape, generalist predators benefit from their high adaptability to various food items and wide-ranging food searches (Jager *et al.* 2006), and thus they are at a marked advantage related to specialists (Swihart *et al.* 2001; Jager *et al.* 2006). Specialists which are restricted in their habitat and food preferences are more vulnerable to the environmental disturbances (Crooks 2002), and are thus more highly subject to population declines. Thus, the species composition and population structures may be highly influenced by the anthropogenic changes in land use (Crooks & Soulé 1999; Crooks 2002).

Despite the long-term scientific interest in corridors worldwide, as far as we know, there has only been one study monitoring the use of corridors by carnivores in Europe. Šálek *et al.* 2009 tested carnivore presence within corridors versus hayfield matrix. Their findings clearly demonstrated an animal preference to use corridors, compared to the surrounding matrix. Additionally, they did not find any of the habitat characteristics tested to have affected the probability of corridor visits by the carnivores.

The predator-prey system within a fragmented landscape has been tested to examine the effects of habitat destruction on the dynamics between prey and its predator (Bascompte & Solé 1998; Swihart *et al.* 2001). Strictly specialist predators (small mustelids *Mustela erminea*, *M.nivalis*), with rodents comprising 77 - 85% of their diets (Erlinge 1981; Martinoli *et al.* 2001; Elmeros 2006; Lanszki & Heltai 2007), were more sensitive to environmental disruptions than were the prey. Nevertheless, many carnivore predators are not obligate specialists, with the proportion of small mammals in their diets varying between 25 - 70% (Goszczyński 1986; Prigioni & Marinis 1995; Genovesi *et al.* 1996; Goldyn *et al.* 2003); however, they are capable of using alternative food resources in the case of low quantities of their principal prey (Swihart *et al.* 2001). Corridor-like structures were shown to host the highest small mammal prey biomass for predators across agriculturally-intensified landscapes (Michel *et al.* 2006). Since most European carnivores depend upon a small mammal prey base (Jedrzejewski & Jedrzejewska 1992; Michel *et al.* 2006), we determined if a higher abundance of small mammal species caused any associated higher attendance of the carnivores along the corridors within the fragmented landscape.

The purpose of this study was to find the general patterns of corridor use by native carnivore species living in the highly fragmented Central European landscape, interwoven by a number of corridor-like structures. From the previous study (Šálek *et al.* 2009) we knew that carnivores were almost completely lacking in hayfields. Therefore, we focused on linear structures crossing the agricultural landscape, as well as their characteristics in terms of habitat and nutritive rates.

Methods and study design

Study area

Our study area comprises 300 km^2 of fragmented agricultural landscape in the north-western portion of the České Budějovice basin (48.57 N, 14.28 E), Doudlebia, Czech Republic. This region is dominated by intensively cultivated agricultural land (66%), with a high share of forest (14%). The area has a gently rolling topography with altitudes ranging from 400 to 450 m.a.s.l. The climate has an unstable terrestrial character; with a mean annual rainfall of 600 - 750 mm. July is the hottest month (mean temperature 17 - 18°C), with the maximum above 30°C. Winters are characterized by cold temperatures (mean -1°C to 1°C), and has about 40 days of snow cover. The region is characterized by a diverse mosaic of agricultural land with cultivated crop fields, grasslands, exclusive-use pastures, an extensive variety of fish ponds, and dense rural developments. The highly fragmented forest consists of small patches of secondary coniferous or mixed forest embedded within agricultural areas. The agricultural land is characterized by extensive arable fields, as well as hayfields which are occasionally used as pasture. The hayfields are entirely drained and reseeded with species such as *Lolium sp*., *Phleum sp*., *Festuca sp*., or *Dactylis sp.*; and these are mowed once or twice a year. The whole landscape is criss-crossed by numerous corridors which often bisect some of the agricultural or hay fields.

The corridors in our area are strips of vegetation varying in widths from 3 - 30 m wide and their spatial structure (drainage ditches, woody or herbaceous strips/rows). The vegetation within the herbaceous corridors was formed from dense long-stemmed grasses *Calamagrostis sp., Festuca sp*., *Arrhenatherum sp*., and *Phalaris sp*., with a maximum height of the hayfield vegetation. Shrubs were dominated by either *Prunus spinosa* or various species of *Salix* spp. in the mesic and more humid habitats, respectively. The woody corridors were formed by tree species such as *Quercus sp*., *Pinus sp.* or *Alnus sp. Calamagrostis epigejos*, *Festuca rubra*, *Arrhenatherum elatius*, and *Geum urbanum* were typical understorey species in mesic corridors. *Filipendula ulmaria*, *Lysimachia vulgaris*, and *Scirpus sylvatica* were the dominant species forming the understorey layer among more humid shrubs.

Mammal surveys

We conducted the study during the spring (May - June) and autumn (September - October) of both 2008 and 2009. Fifty-seven corridors were chosen for the evaluation of mammalian predators, as well as the abundances of their principal prey, which are small mammals (one scent station and trapping transect for small mammals was established per corridor). All of our corridors connected habitat patches potentially used by carnivores. The corridors were chosen based on digitized aerial ortho-photomaps (1:5000) using a geographical information system (GIS; ArcView 3.2a, Environmental Systems Research Institute, Inc. 2000). These were independently positioned spatially, and did not overlap. The minimum distance between neighbouring localities was 500 m, in order to achieve the independence of the replicate sites (*e.g.*, Gehring & Swihart 2003).

To assess the spatial distribution of carnivores in our study we used the scent station method. These stations are widely used in North America for the monitoring of scent-sensitive carnivore populations (*e.g.* Travaini *et al.* 1996; Zielinski & Stauffer 1996; Crooks & Soulé 1999; Gehring & Swihart 2003). Station positions were prepared by clearing 1 m^2 plots of debris and grass. Each scent station consisted of a 1 x 1 m square of black garden foil, fully covered with a 2 cm layer of fine-grained masonry sand, and a lure placed at the centre. A microcentrifuge tube containing 1.5 ml of liquid domestic rabbit urine was attached to a wooden stick about 15 cm above the sand. The animals left their foot prints in the sand when they came to sniff the stick. The urine was topped up every control day (if necessary). We used rabbit urine as a mild attractant (Linhart & Knowlton 1975), in order to avoid tempting predators from greater distances; since our intention was to analyse their use within the immediate vicinity's spatial elements, in which the station was located.

Carnivores were identified based upon the footprint's dimensions and shape characteristics (Anděra & Horáček 2005). The visitation of an individual species at the scent station was treated as one observation of that species during the whole exposure time. We excluded from the dataset the footprints of domestic dogs (*Canis lupus familiaris*, six cases), as well as any tracks which we were not able to determine to the genus level (four cases); these deletions did not qualitatively affect the results. We calculated all martens only on the genus level (*Martes* sp.), as we were not able to distinguish between the tracks of the pine marten *Martes martes* and stone marten *Martes foina*.

During each activated period, stations were inspected daily for 5 consecutive rainless days, resulting in a total of 1140 station-days. If raining occurred, we considered the day as a missing observation, and the stations were reactivated when conditions improved (the next available day).

In order to detect the food supply, *i.e.* patterns of composition and abundance of small mammal communities within the corridors, we used a standardized method consisting of a

150 m line of 30 baited traps (wheat flour, margarine and bacon mixture, with a piece of wick), spaced every 5 m along the corridor (Adams 1984; Korpimäki *et al.*, 2005; Heroldová *et al.*, 2007). In accordance with ethical standards for animals, the capture of small terrestrial mammals was permitted by the Department for Animal Protection of the Ministry of Education, Youth, and Sports (permit reference number 9690/2006-30/300). The distributions and abundances of small mammals were determined in the same corridors as were used for the carnivore monitoring. The traps were exposed for one night during each sampling period, resulting in a total of 6840 trap-nights. The trapped animals were counted and determined as to species (Anděra & Horáček 2005). All of these were pooled into a single category "small mammals" within each study corridor in the analysis; as they can equivalently serve as food sources.

Corridor characteristics

All experimental corridors were surrounded by hayfields or a matrix of arable lands. We avoided placing scent stations immediately adjacency to highways, large water bodies, or cities; as these can be perceived as movement barriers by animals. Each corridor segment (300 m) was characterized by a series of environmental factors that could influence the presence of carnivores and small mammals. We measured the local habitat's attributes by optical observations at the site, including: the proportion of shrub cover (height < 5 m); proportion of corridor length covered by woody vegetation; and the width of the corridor which was calculated by averaging the initial, middle, and final widths within the 300 m corridor segment. Specific habitat attributes seem to play an important role in corridor selection by carnivores and small mammals (Hilty & Merenlender 2004; Sinclair *et al.* 2005).

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Statistical analysis

We treated the occurrence of mammals observed as a binary response variable (the presence or absence) of a specific carnivore species during the 5 exposure days in the analysis, in order to avoid multiple detections of the same individual at any particular scent station during the exposure period.

We separately considered each carnivore species in the analysis, since their ecological requirements are quite different (Anděra & Horáček 2005). Corridors could therefore represent a large proportion of small mustelid territory (MacDonald *et al.* 2004) or an opportunistically exploited landscape structure of the larger species. To analyse the impact of the habitat's characteristics and food supply upon the individual carnivore species visitations, we performed six separate analyses using a Linear and Nonlinear Mixed Model (NLME), implemented with the software R 2.10.0. (http://cran.r-project.org). The same analysis was subsequently repeated for the sum of carnivores (*i.e.* the total number of all carnivore species detected at a specific scent station) because we attempted to detect the response of the whole carnivore assemblage to corridor quality. These findings may later be useful for the planning, management, and conservation of wildlife corridors. Corridor identity was treated as a random effect. Corridor width, the proportion of corridor length covered by woody vegetation, the proportion of shrub cover, as well as the abundance of small mammals were included as fixed effects within the model.

Results

In total, we recorded 137 detections of 8 carnivore species during 1140 station-nights. The average detection rate at scent stations was 8.4 detections per night. We registered the greatest number of carnivore records in the spring of 2008 (n=47); conversely, the least detections were recorded during the following spring 2009 (n=18). The number of records from the autumn periods were quite similar (n=38 in 2008 and n=32 in 2009, respectively). Nevertheless, the differences in the number of carnivore observations between the two periods were not significant.

The domestic cat *Felis catus* and the European polecat *Mustela putorius* were the most common species; and respectively accounted for 28% (n=37) and 21% (n=28) of the numbers of carnivores detected. Further, we also recorded the least weasel *Mustela nivalis*, stoat *Mustela erminea*, marten *Martes sp.*, and red fox *Vulpes vulpes* (Fig.1).

The Eurasian badger *Meles meles* was excluded from the subsequent analysis because of the small visitation rate in our study corridors (n=2). Similarly, we excluded records of domestic dogs, which usually follow the trajectory movements of their owners.

Small mammal abundances (276 in total) differed considerably among study sites as well as in periods. We recorded 113 individuals in both periods of 2008. We detected a strong decrease of small mammal abundances in the next year (2009), with only 23 and 27 trapped individuals in spring and autumn, respectively. The most common trapped species was mouse *Apodemus* sp. 70% (n=192), followed by: the common vole *Microtus arvalis* 18% (n=50), field vole *Microtus agrestis* 5% (n=15), bank vole *Clethrionomys glareolus* 5.6% (n=16), insectivores common shrew *Sorex araneus* 0.4% (n=1), and the white-toothed shrew *Crocidura suaveolens* 1% (n=3).

In the course of further analysis we tested whether the distribution of carnivores was determined by the local corridor's characteristics (shrub, woody level, width) or the population densities of the small mammals. The significant relationship between the sum of carnivores and small mammal community; and non-significant relationship between the measured corridor characteristics and carnivores (Table 1) indicates the use of corridors as a consequence of sufficient food supplies; rather than of habitat features, regardless of the species identity. The above results were partially affirmed when evaluating special analyses for levels of individual species (Table 1). There appears to be a close association between food resources and the occurrences of both the weasel and marten, apart from the carnivores getting along with the habitat attributes of landscape structure (Table 1). The statistical nonsignificance of the relationship between the measured habitat features and carnivore visitations was consistent in all analyses of the individual species (Table 1).

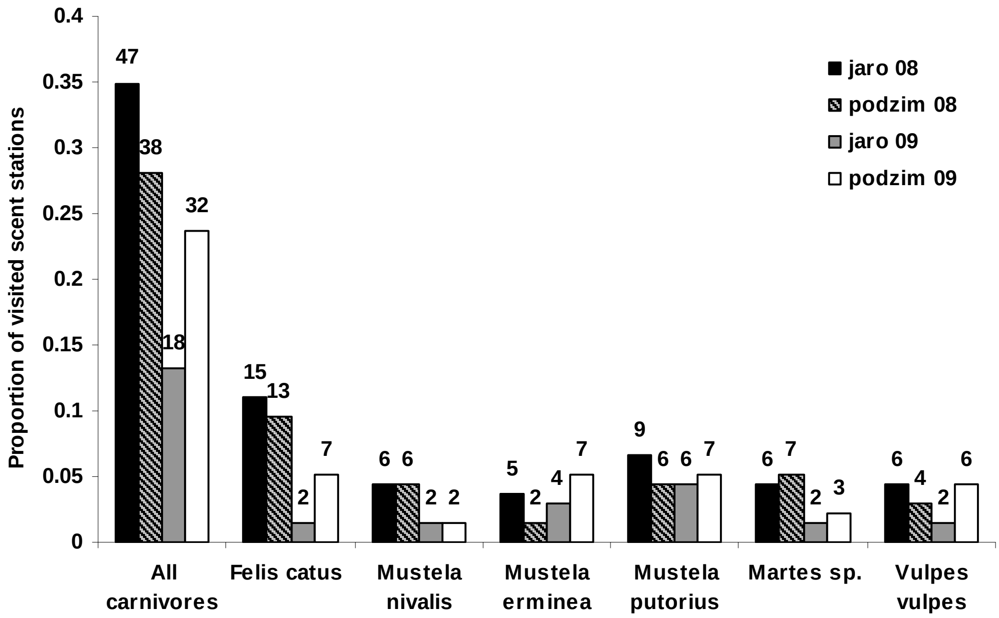

Fig. 1. The proportion of scent stations visited by a particular carnivore species during each activated period of the experiment (multiple visit of the same carnovire species was not taken into account). The numbers above the bars represent the total number of visits for individual species and their sum.

Table 1. Results of NLME (binominal error, random effect: corridor identity). Significance values are in bold print. Indicative levels of significance are in italic and bold print. Width - average width of corridor; woody level - proportion of corridor length covered by woody vegetation; shrub cover - proportion of shrub cover; small mammals –abundance of trapped small mammals within corridor. All carnivores – total number of all carnivore species detected at a concrete scent station.

Species	Fixed effects	d.f.	t-value	p-value
All carnivores	Width	53	0.2	0.82
	Woody-level	53	0.6	0.58
	Shrub cover	53	1.4	0.18
	Small mammals	170	2.2	**0.03**
Felis catus	Width	53	0.2	0.82
	Woody-level	53	-0.2	0.88
	Shrub cover	53	1.3	0.20
	Small mammals	170	1.9	***0.05***
Mustela erminea	Width	53	0.6	0.56
	Woody-level	53	1.2	0.23
	Shrub cover	53	0.3	0.73
	Small mammals	170	-0.7	0.50
Mustela nivalis	Width	53	-0.4	0.67
	Woody-level	53	1.7	0.10
	Shrub cover	53	0.1	0.92
	Small mammals	170	3.2	**< 0.01**
Mustela putorius	Width	53	0.9	0.40
	Woody-level	53	-1.0	0.30
	Shrub cover	53	-0.2	0.82
	Small mammals	170	1.6	0.11
Martes sp.	Width	53	0.4	0.73
	Woody-level	53	-0.7	0.50
	Shrub cover	53	1.7	0.10
	Small mammals	170	2.8	**< 0.01**
Vulpes vulpes	Width	53	-0.3	0.78
	Woody-level	53	1.1	0.29
	Shrub cover	53	1.4	0.18
	Small mammals	170	1.0	0.32

Discussion

Corridors, which provide important habitat for many species (Downes *et al.* 1997) or the role of landscape connectivity, allowing for the maintenance of links among otherwise separated populations (Bolger *et al.* 2001; Hilty & Merenlender 2004) are thus important tools for the conservation of many species within fragmented landscapes. Although the benefits of corridors are known for many animal taxa such as invertebrates (Schlee & Stump 1995), butterflies (Haddad 2000), small rodents (Perault & Lomolino 2000), and birds (Spackman & Hughes 1995); we still lack sufficient data about its significance for carnivores, which are primarily the drivers of ecosystem function and stability. Our observations highlight the importance of corridors for the persistence of European carnivores within the agricultural landscape in Central Europe. We founded that predator utilization of corridors are primary driven by the abundances of its principal prey, rather than the corridor's characteristics.

Predators concentrate their foraging activity on those habitats with high densities of feeding sources (*e.g.* Macdonald 1983; O'Donoghue *et al.* 1998; Jepsen *et al.* 2002; Sidorovich *et al.* 2007; Zub *et al.* 2008). Corridors leading through human-modified landscapes have previously been reported as important habitats for small mammals (Tattersall *et al.* 2002; Michel *et al.* 2006), where they may achieve high diversity and densities, when compared to the unfavourable habitat matrix (Rondinini *et al.* 2006). Although carnivores have many and varied opportunistic feeding strategies, small mammals represent the most important prey species for most carnivores inhabiting Central European agricultural landscapes (Jedrzejewski & Jedrzejewska 1992; McDonald *et al.* 2000; McDonald 2002). In line with our expectations, and based on a complex model of all species detected, carnivore occurrences in the corridors were closely associated with the abundances of small mammals (Table 1). Similarly, these results are in concordance with previous research from the same study area, which had demonstrated that the distribution of mammalian predators around habitat edges (such as both the corridors' and forest-farm edges) are driven by the gradient of small mammal abundances (Šálek *et al.* unpubl. manuscript.). Preferential carnivore occurrences in prey-rich corridor habitats were detected elsewhere for the stone marten (Rondinini & Boitani 2002), polecat (Rondinini *et al.* 2006), and least weasel (Macdonald *et al.* 2004).

A separate model for individual carnivore species revealed significant relationships between food abundance and the distributions of martens, least weasel, and the domestic cat. Although we were not able to distinguish between the two marten species (stone marten

Martes foina and pine marten *M. martes*), we assumed that most of the records belonged to stone martens, which are characteristic inhabitants of fragmented agricultural landscapes or human settlements (Libois & Waechter 1991; Virgós *et al.* 2000; Rondinini & Boitani 2002; Mortelliti & Boitani 2008; Šálek *et al.* 2005). In contrast, pine martens are strictly forest-dwelling species, living in largely homogeneous forests; and further seem to be sensitive to human-related activity and concomitant fragmentation (Červený *et al.* 2003). Rondinini and Boitani (2002) showed that linear structures, such as field verges or shrubby vegetation along watercourses (in contrast to arable land) were preferred habitats in territories of radio-tracked stone marten in agricultural regions. The European polecat also inhabits similar habitats, but its foraging activity is concentrated more intensively toward aquatic habitats, such as riparian vegetation or pond banks (Rondinini *et al.* 2006). However, these medium-sized mustelids are both considered to be opportunistic predators; and we assume that small mammal densities did not affect the distribution of the polecat, because of its concentration into patches with a high potential abundances of their preferred aquatic prey (Lodé 2000) such as anurans (Weber 1989), especially in the spring.

The small mustelid species (least weasel, stoat) are typical carnivores of open agricultural landscapes, and their foraging activity is mainly determined by the local abundances of small mammals (Johnson *et al.* 2000). In Central Europe the proportion of small mammals is roughly comparable (77 - 85%; Martinoli *et al.* 2001; Elmeros 2006; Lanszki & Heltai 2007); however, stoats are known as more opportunistic hunters for prey such as logomorphs or birds (Elmeros 2006). Although we had expected that the distribution of small mustelid carnivores would be the most connected with prey distribution, we only documented a significant predator-prey interaction for the least weasel. Least weasels seem to be more efficient small mammal hunters, since stoats' larger body sizes should inhibit from entering into rodent burrows (Macdonald *et al.* 2004). Similarly the higher dietary plasticity of stoats, in contrast to that of weasels, should lead to a shift toward alternative prey. Telemetry research has revealed that linear habitats, hedgerows, and other habitat edges are essential features of the home ranges of the least weasel (Macdonald *et al.* 2004) and stoat (King 1983). Moreover, the corridors should be essential habitat features for the persistence of these species within an agricultural mosaic. Since small mustelids should suffer from considerable predation by both avian and mammalian predators (Korpimäki & Norrdahl 1989), weasels avoid open spaces and prefer dense vegetation to reduce this predation risk. However, our data did not reveal preferences for more shrubby cover or woody strips in the monitored corridors (see below). On the other hand, vegetative cover composed of dense long-stemmed grassland vegetation should be sufficient to enhance the protection against predation pressures.

It was presumed that the domestic cat's presence depended upon prey abundances, since its foraging activities are mainly concentrated in the vicinity to human settlements (where their resting sites mainly occurred), and thus the corridor characteristics should only play a marginal importance in its distribution. Nevertheless, our supposition was only partially confirmed in the subsequent analysis (Table 1). The domestic cat was the species most often detected in our study. These results are in accord with the findings of Gehring and Swihart (2003) who demonstrated that the occurrence of the domestic cat was correlated with the corridor's presence within an agricultural landscape.

Red foxes and European badgers are both generalist mesopredators of similar sizes, but of different food and habitat requirements. The rare occurrence of badgers at the study site may have been caused by its high need for the proper soils in which to dig setts, which are more likely available in those forest fragments of considerable size and heterogeneity (Virgós *et al.* 2002). Most of our observed corridors were probably too narrow and insufficiently heterogeneous to correspond with the badger's behavioural needs. The presence of the red fox was neither closely associated with some of the corridor characteristics nor with the abundances of small mammal species (Table 1). As a highly vagile mammal, the red fox seems to perceive the landscape as a homogenous area where the matrix does not participate as a movement barrier (Gehring & Swihart 2003). The fox has been shown to move relatively freely across fragmented landscapes, and thus to exploit all elements within its broad niche during its foraging for food items (Gehring & Swihart 2003). Although, small mammals are the principal prey in its diet, the fox is capable of compensating for the absence of rodents by substituting other components from within its broad food spectrum (Padial *et al.* 2002) with for example: beetles, earthworms, molluscs, or carcasses (Anděra & Horáček 2005).

Based on a complex, as well as single species model, we did not uncover any relationship in either the carnivore distribution or corridor characteristics; and thus we can confirm the previous research results from agricultural landscapes (Šálek *et al.* 2009). The corridors widths, as well as the proportion of shrub cover and woody levels did not explain the observed patterns of carnivore utilization among individual corridors. Our results are contrary to those of Hilty and Merenlender (2004) who founded a higher prevalence of mammalian predators in wider (360 - 1450 m wide) vineyard corridors, as opposed to narrow ones. However, based on the conditions of our study of an agricultural landscape we could not compare the utilization of corridors, because all of the monitored linear structures are not wider than 30 meters. The monitored corridors have an average width of 9 m, but some of them were ≤ 5 m (n=19). Moreover, the narrowest ones (3 m wide) were primarily formed by shrubs or dense long-stemmed grasses, where only a minor proportion of the corridor length was covered by trees. We presume that the width of the corridors should be considered under the necessary threshold for the effect of width for individual carnivore species (see also Šálek *et al.* 2009).

Conclusions and management implications

Corridor conservation has been widely accepted as an effective tool with which to maintain carnivore populations within highly fragmented landscape (Rosengberg *et al.* 1997; Crooks 2002; Šálek *et al.* 2009). Particular corridors should play a vital role in the conservation of some endangered European carnivore species, such as the European and steppe polecats (*Putorius putorius*, *P. eversmanni*) inhabiting agriculture landscapes (Anděra & Hanzal 1996). Favourable conditions of agricultural practices and suburban developments can lead to strong increases in population densities of generalist mesopredators, which derive benefits from their dietary and habitat plasticity. Corridors may then serve them as travel lanes or breeding habitats. Similarly, the heightened abundance of potential prey, such as small mammals or birds in the corridors may lead to higher predator abundances, in turn influencing predator-prey interactions. Narrow corridors should increase nest predation rates and lower fledgling success; and may act as an ecological trap by attracting birds to habitats with higher predation risks (Gates & Gysel 1978; Weldon 2006), resulting in seriousness impacts for many declining farmland birds.

Planning corridor structures should play a determinative role in management and conservation of target wildlife species; however, it should differ in the dependence of species-specific ecological features. Since narrow strips of linear vegetation are useful structures for carnivore movement and foraging (Downes *et al.* 1997; Perault & Lomolino 2000; Šálek *et al.* 2009), wider and more heterogeneous corridors should minimalize the negative consequences of predators; due to the reducing search efficiency in highly structured habitats (Ratti & Reese 1988; Suarez *et al.* 1997; Bowrnan & Harris 1980; Martin 1993). Similarly, a variety of shrub and tree covers can provide higher vertical or horizontal micro-patch diversity, and offer higher quantities of food, shelters, and other life requirements for the entire spatio-temporal corridor community. Despite some negative effects of corridor structures, we consider that the maintenance of corridors in a fragmented landscape is an essential feature in order to preserve ecosystem quality. However, we need more information to meticulously reveal the predator-prey interactions and ecology of particular species, in order to have the important tools for future planning and construction of corridors which can lead to an enhancement of their conservation benefits.

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Závěr

Koridory, zvyšující propojenost fragmentované krajiny či poskytující vhodné životní prostředí, jsou považovány za velmi důležité součásti ochrany některých druhů zvířat (Downes *et al.* 1997; Bolger *et al.* 2001; Hilty & Merenlender 2004). Naše pozorování potvrdila, že koridory jsou nesmírně cenným a šelmami (*Carnivora*) hojně využívaných prvkem ve fragmentované krajině střední Evropy. Dle výsledků celkového modelu je jasné, že výskyt šelem v koridorech je ovlivňován hustotou jejich primární kořisti nikoli vlastnostmi daného prostředí. Výsledky individuálních modelů pro konkrétní sledované druhy ukazují na blízký vztah mezi potravní nabídkou a výskytem kun (*Martes martes* a *M. foina*), lasice kolčavy (*Mustela nivalis*) a kočky domácí (*Felis catus*) v koridorech.

Nejčastěji zaznamenaným druhem v naši studii byla kočka, která je vázaná na lidská obydlí. Dle předpokladů byl její výskyt v koridorech úzce spjat s množstvím drobných savců a zcela nezávislý na vlastnostech koridorů.

Žádná z měřených vlastností koridorů (šířka koridoru, procentuální zastoupení dřevin v délce koridoru a pokryvnost keřového patra) významně neovlivňovala výskyt šelem v koridorech. Zejména u šířky je toto zjištění pro nás dost překvapivé, vzhledem ke studiím z jiných zemí (Hilty & Merenlender 2004). Je to zřejmě způsobeno tím, že velice malé rozdíly v šířce koridorů v rámci celé studijní plochy jsou pod prahem vnímání tohoto jevu u jednotlivých druhů šelem.

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