Mammalian Biology 79 (2014) 176–182

Contents lists available at ScienceDirect

Mammalian Biology

journal homepage: www.elsevier.com/locate/mambio

Original Investigation

Forest-edge utilization by carnivores in relation to local and landscape habitat characteristics in central European farmland

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ARTICLE INFO

Article history:
Received 30 April 2013
Accepted 19 August 2013
Available online 17 September 2013

Keywords:
Carnivores
Farmland
Forest-edge utilization
Landscape characteristics
Local characteristics

ABSTRACT

Rapid changes in agricultural landscape structure and composition affect many different farmland biotas, including carnivores, which are a key element of ecosystem stability, yet little is known about their distribution and habitat use. In this study, we evaluated how habitat characteristics on two different spatial scales (local and landscape scale) affected the forest-edge utilization by small and medium-sized carnivores in fragmented central European farmland. Based on an indirect method for detecting carnivores (scent stations), we sampled 212 forest fragments of different sizes (1–7864 ha) during April to May from 2006 to 2009. Our results indicate that carnivore utilization of forest-edge habitats was driven by landscape rather than local characteristics even though the overall extent of explained variation was small. The most important factors that determined response of the carnivore community were the area of farmland and that of urban land on a landscape scale. The corridor connectivity between small forest fragments and other spatial elements played a crucial role in the occurrence of red fox. Our results suggest that comprehensive studies on multi-species carnivore assemblage using scent station might be useful in evaluating species-specific response to habitat characteristics, especially if large numbers of stations visited by carnivores are available.

Introduction

Increasing human activities associated with agricultural intensification and urban expansion lead to a massive habitat loss or fragmentation and these factors are recognized to be one of the most serious threats to farmland biodiversity (Faaborg et al., 1993; Robinson and Sutherland, 2002). Carnivores inhabiting intensively used agricultural landscape are fundamental elements of ecosystem structure, function and diversity despite their low densities across fragmented landscapes (Jędrzejewska and Jędrzejewski, 1998; Gittleman et al., 2001). Although carnivores' response to habitat fragmentation is species-specific, they are ultimately affected by degradation of natural habitats and other human activities (Crooks, 2002). In fragmented landscapes the populations of area-sensitive specialist carnivores tend to be decreasing which has resulted in many of them being classified as endangered species (Schadt et al., 2002; Anděra and Červený, 2009). Contrarily, generalist carnivores seem to be tolerant or even benefit from agricultural and suburban development (Crooks and Soulé, 1999; Gehring and Swihart, 2003; Šálek et al., 2010a). The knowledge of distribution and factors affecting habitat utilization of carnivores is the first step to their conservation and management.

Local and landscape habitat characteristics are important factors that influence carnivore diversity and distribution in fragmented agricultural ecosystems (Virgós et al., 2002; Gehring and Swihart, 2003). Different local and landscape scale habitat characteristics allow co-occurrence of more carnivore species due to species-specific resource utilization at different spatial scales (Crooks, 2002). Landscape composition determines the spatial distribution of different biotic (e.g. prey) and abiotic resources and can serve as an indicator of local population densities of carnivores. Similarly, landscape utilization can also depend on the structure, configuration and size of forest fragments. For example, larger and more heterogeneous forest fragments are able to maintain higher number of carnivore territories, which could be important for the conservation of forest-dwelling species. However, smaller forest fragments might be more suitable for generalist carnivores due to relaxed agonistic interactions with area-sensitive top predators

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1616-5047/$ – see front matter
http://dx.doi.org/10.1016/j.mambio.2013.08.009

(i.e. "mesopredator release hypothesis", Crooks and Soulé, 1999). Alternatively, some generalist species may benefit from greater areas of disturbed habitats surrounding small forest fragments because food availability and diversity is often higher in areas associated with open farmland, urban residences, or other human-related resources (Tellería et al., 1991; Austen et al., 2001). The level of utilization of individual landscape fragments also depends on connectivity, which enables animal movement among different patches and thus increases exchange of individuals or gene flow among separated populations (Mech and Hallett, 2001; Gehring and Swihart, 2003). Moreover, carnivores inhabiting fragmented landscape tend to occupy large reticular home ranges, with a significant proportion of unsuitable habitat matrix (e.g. Rondinini and Boitani, 2002) and thus the corridor connectivity may diminish the negative effects of fragmentation (Hilty and Merenlender, 2004; Šálek et al., 2009). Local habitat characteristics are related to food availability and other vital resources, such as shelter or den sites. Although carnivores are able to forage in variety of different habitats, their activity in agricultural landscape is predominantly focused on prey-rich edge structures (Larivière and Messier, 2000; Winter et al., 2000; Šálek et al., 2010a; Červinka et al., 2011; Svobodová et al., 2011; Červinka et al., 2013), which could result in an increase of direct and indirect interactions, thus affecting spatial distribution of individual species (Polis et al., 1989; Creel and Creel, 1996; Palomares and Caro, 1999; but see Šálek et al., 2013).

The main aim of this study was to investigate the impact of habitat characteristics on two spatial scales on carnivore forest-edge utilization in intensively used agricultural landscape. Particularly we examined species-specific response to local and landscape characteristics as important precursors of carnivore habitat use and diversity. To the best of our knowledge, our results bring first detailed information about multiple-species carnivore distribution and habitat associations in the central European farmland, applicable for local landscape planning and for carnivore conservation management.

Material and methods

Study area

The research was conducted in a 1562 km^2 area of intensively used agricultural landscape in the České Budějovice basin, Doudlebia, Czech Republic (GPS: 48°59′N, 14°19′E). The study region had a flat or gently rolling landscape (altitude varies from 380 to 410 m) and was composed of a mosaic of agricultural land dominated by crop fields (45%), hayfields and pastures (15%), a variety of man-made fish ponds (5%), human settlements, gardens, orchards and non-agricultural habitats (5%). The secondary coniferous or mixed forests (30%) were dominated by the common spruce *Picea abies* and Scotch pine *Pinus sylvestris* with occasional broad-leaved tree species such as oak *Quercus* sp., birch *Betula pendula* and beech *Fagus sylvaticus*. Grasslands consisted almost exclusively of planted hayfields, which were almost completely drained and reseeded with competitive nitrogen demanding species or intensive pastures (Šálek et al., 2010b). Crop fields, with an average area of 30 ha, were mainly used for intensive cultivation of cereals, maize and legumes. The agricultural matrix consisted of relatively short (<70 cm) vegetation in the pre-harvest period. However, during the harvest season vegetation was high and dense with an average height of from 1 to 1.5 m (Šálek et al., 2009, 2010a,b).

Corridors that interlace the whole study area generally consist of shrubby vegetation and dense long-stemmed grasses linking mostly around watercourses, with widths ranging from 2 to 12 m. Forest edges are usually fringed by oak *Q. robur*, common spruce *P. abies*, *A. platanoides/pseudoplatanus*, Scotch pine *P. sylvestris* as well as European aspen *Populus tremula* and birch *B. pendula*. The shrub layer is predominantly formed by saplings of canopy trees, plus shrubs such as hazel *Corylus avellana*, blackthorn *Prunus spinosa* and willows *Salix* sp. This habitat type is characterized by dense and diverse herbaceous vegetation originating mainly from nearby hayfields, though many forest understorey species are present as well.

Carnivore survey

Carnivore utilization of forest edges was studied in 212 forest fragments of different size (1–7864 ha, mean size = 1364.5 ha, S.D. = 2505) during May and June in 2006 (43 patches), 2008 (62 patches) and 2009 (107 patches), respectively. In order to assess the spatial distribution of carnivores in our study, we used the scent station method which is the most efficient technique for carnivore sampling on large spatial scales and is also economically and logistically advantageous (Barea-Azcón et al., 2006). Previous research has shown that carnivore activity in agricultural landscapes is predominantly focused on prey-rich edge structures, such as forest edges (Šálek et al., 2010a; Červinka et al., 2011; Svobodová et al., 2011; Červinka et al., 2013). Hence the scent stations were set along the forest edges, which were clearly defined as a sharp boundary between forest and grassland habitats. We did not study carnivore occurrence on forest-crop edges because carnivore species are largely avoiding crop fields during spring period (see also Rondinini and Boitani 2002; Gehring and Swihart 2003; Baghli et al. 2005; Santos and Beier 2008; Pita et al. 2009). In small forest fragments (<15 ha) we only placed one scent station. In large forest fragments (>15 ha) we placed more stations, however we controlled a minimal spatial distance of neighbouring stations. The minimum distance between neighbouring scent stations was 500 m (average distance 3400 m) in order to achieve the independence of the sites (e.g. Gehring and Swihart, 2003; Šálek et al., 2010a; Svobodová et al., 2011). Scent stations were constructed as a 1 × 1 m square filled with a 2-cm thick layer of fine-grained masonry sand. To analyze carnivore distribution on a relatively small spatial scale, and hence to avoid alluring animals from greater distances, domestic rabbit urine was used as a mild attractant (Linhart and Knowlton, 1975). Rabbit urine was placed in a 1.5 ml microcentrifuge tube and affixed to a wooden stick, which was positioned in the centre of each scent station, approximately 15 cm above the ground. Scent stations were monitored for eight consecutive days during May and June. The presence of footprints was checked every other morning. In case of rainfall, the observation was stopped and restored scent stations were checked again after two days. In total, we monitored 212 scent stations during the whole research, resulting in 1696 scent-station nights.

Carnivore identification was based on footprint dimensions and shape characteristics (Bouchner, 2003; Anděra and Horáček, 2005). The native carnivore species occurring in our study area were small to medium-sized carnivores such as least weasel *Mustela nivalis*, ermine stoat *Mustela erminea*, European polecat *Mustela putorius*, martens (pine marten *Martes martes*, stone marten *Martes foina*), European badger *Meles meles* and red fox *Vulpes vulpes* (Bouchner, 2003; Anděra and Horáček, 2005; Padyšáková et al., 2009, 2010; Šálek et al., 2009, 2010a; Červinka et al., 2011, 2013). The footprints of domestic cat *Felis catus* were often observed in scent-stations. Because feral cats have a significant impact on native fauna (Woods et al., 2003) and knowledge of their edge utilization has important management implications, we included the domestic cats among the studied species. Based on the footprint characteristics we were not able to distinguish two marten species between themselves (stone marten and pine marten), however the stone marten is a habitat-generalist due to its capability to exploit human-related resources (Herr et al., 2009) and intensively