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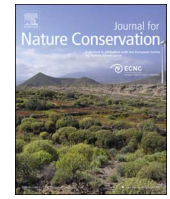

The importance of small-scale structures in an agriculturally dominated landscape for the European wildcat (*Felis silvestris silvestris*) in central Europe and implications for its conservation

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ABSTRACT

The European wildcat (*Felis silvestris silvestris*) is a threatened and elusive species that was previously considered to be forest-bound in central Europe. For the first time, we caught and radio-collared wildcats outside heavily forested habitats to investigate their habitat utilization pattern. We used a generalized linear modelling framework to test our hypotheses that sex and season influence habitat selection in addition to habitat variables. Our results reveal a gender difference in habitat selection: Females were more restricted to areal shelter habitats and avoided the areas near roads more than did males. Males used more linear shelter habitats such as watercourses or hedges and avoided the proximity to settlements more than did females. The probability of wildcat occurrence far from shelter habitats was higher in summer than in winter, probably due to high coverage and shelter provided by crops. The same pattern applied to the proximity to roads. We concluded that shelter habitats are one of the key factors for the occurrence of wildcats in agriculturally dominated landscapes. We recommend a management strategy that enhances structural heterogeneity in the agricultural landscape by conserving small-scale structures such as copses, hedges and wide field margins. Other species, such as the gray-partridge (*Perdix perdix*) and the common quail (*Coturnix corturnix*), can also benefit from these habitat recommendations. Additionally, this management strategy simultaneously creates habitat connectivity.

1. Introduction

Increasing agricultural intensification, urban expansion and the enlargement of transport routes have all led to massive habitat losses and habitat fragmentation (Foley et al., 2005; Metzger, Rounsevell, Acosta-Michlik, Leemans, & Schröter, 2006). Woodland species are especially threatened by these habitat changes (Gibson et al., 2013; Turner, 1996), but carnivores that use large areas are also affected. Some generalist carnivores, however, seem to tolerate or even benefit from agricultural and urban development (Gehring & Swihart, 2003; Salek, Cervinka, Pavluvcik, Polakova, & Tkadlec, 2013). In general, these are species with broad dietary and habitat requirements like foxes (*Vulpes vulpes*) or common raccoons (*Procyon lotor*) (McKinney, 2002). In addition, habitat edges in an agricultural landscape can provide high prey abundance for mammalian predators (Salek et al., 2013). The sensitivity of mammals to fragmentation is related to their ability to move through the landscape, and this ability is related to body size and behavioral responses to varied habitat types (Gehring & Swithart, 2003).

The knowledge of how species respond to changing environmental conditions is crucial for species conservation and management. Habitat selection analysis is one approach to determine how species react to their changing environment.

The elusive and threatened European wildcat (*Felis silvestris silvestris*) is a medium-sized carnivore and is considered a forest-bound species in central Europe (Brio, Szemethy, & Heltai, 2005; Hartmann, Steyer, Kraus, Segelbacher, & Nowak, 2013; Klar et al., 2008; Piechocki, 1990). The once widespread population in Europe decreased radically at the end of the 20th century due to habitat loss and persecution (Piechocki, 1990; Sunquist & Sunquist, 2002). As consequence from mid till the end of the 20th century, wildcat distribution in Germany was limited to some widespread forests in low montane regions, such as Harz, Eifel, Hunsrueck and Palatine Forest. To date, the species is mainly threatened by road mortality (Birlenbach et al. 2009; Hartmann et al., 2013; Klar, Herrmann, & Kramer-Schadt, 2009). In the last few decades, however, the German population has slowly recovered, and an

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expansion of the species range has been observed (Birlenbach et al., 2009; Steyer et al., 2016). Moreover, recent studies have confirmed the presence of resident wildcats in an agriculturally dominated landscape in Central Europe (Jerosch, Götz, & Roth, 2017; Streif et al., 2016). Klar et al. (2008) described a general wildcat habitat model based on wildcats in large forest habitats. Thus, it is not possible to extrapolate their model to data from an agricultural landscape. Applying Klar et al.′s modelling approach to our study area would offer one potential home range centre patch of 229 ha, but according to the previous findings of home range size this is too small to inhabit at least one wildcat (Appendix A).

Our aim was to determine the habitat requirements of the species in an agricultural landscape to provide recommendations for habitat improvement. We hypothesize that gender and season will influence habitat selection in an agricultural landscape. We assumed that shelter vegetation is crucial for the European wildcat. In an agricultural landscape this is strongly linked with season or rather growing crops. Carnivores show gender-specific differences in social behaviour and space use pattern, especially during mating season and rearing of cubs (Burt, 1943; Gittlemann, 1989; Sandell, 1989; Wilson, 1975). Female carnivores are due to their parental care more anxious to minimize predation risk as well as energy costs than males (Bissett & Bernard, 2006), while male carnivores are less affected by human activities or competitors than females (Bissett & Bernard, 2006; Bunnefeld, Linnell, Odden, van Duijn, & Andersen, 2005).

Hypothesis testing on habitat preferences of animals based on high-resolution location data obtained from biologging is usually done in the framework of resource selection functions (e.g., Manly, McDonald, & Thomas, 1993). To this end, the hypotheses of how animals make use of the available landscape composition can be formulated in so-called candidate models that can be ranked by their importance in an information-theoretic approach (Johnson & Omland, 2004). This approach allows greater understanding of the system in question (Greaves, Sanderson, & Rushton, 2006) and is a common tool in habitat selection analysis (see Grilo, Molina-Vacas, Fernandez-Aguilar, Rodriguez-Ruiz, & Ramiro, 2018; Stillfried, Belant, Svoboda, Beyer, & Kramer-Schadt, 2015).

We set up candidate models for the occurrence of wildcats in an open agricultural landscape guided by four main hypotheses and specified by sex:

(1) Wildcats need shelter habitats including habitat types other than forest.
(2) Wildcat occurrence is linked to prey availability.
(3) Wildcats avoid the areas near human activities.
(4) Season and sex determine the proximities to foraging sites, shelter habitats and human activities.

To define global habitat requirements in an agricultural landscape we created a combined model out of the four hypotheses. The results are helpful to fulfil the requirements of the ongoing national strategies for wildcat conservation aiming for large-scale habitat connectivity (Action plan, Birlenbach et al., 2009), which is also demanded by the European Habitats Directive in articles 3 and 10 (Council of Europe, 1992).

2. Materials and methods

2.1. Study area

The study area in Central Germany was located in a landscape unit called the “Goldene Aue”, which is situated between the woodlands of the Lower Harz Mountains (Saxony-Anhalt) to the north and Kyffhäuser Mountain (Thuringia) to the south. The linear distance between the forests is 7–10 km (Fig. 1). Both woodlands have still stable wildcat populations (Thüringer Landesanstalt für Umwelt und Geologie (TLUG, 2009) with a supposed regular exchange of individuals (Piechocki, 1990).

The “Goldene Aue” is located at 150 m a.s.l. and is thought to be a suboptimal habitat for the European wildcat due to its intensive agricultural utilization, which involves the cultivation of rapeseed and different cereal crops. The countryside is marked by high structural diversity, including hedges, copses and old orchards. A 122 ha patch in the centre of the study area represents the largest forest. Overall, only 2% of the study area is forest, whereas 70% of the area is farmland, which represents the dominant land use type. The mean annual temperature is 8 °C, and the average annual precipitation is 490 mm.

The study area is intersected by the motorway A38 in an east-west direction. The motorway is partly fenced with an unbridgeable fence for wildcats and has underpasses which make the motorway permeable for wildlife on some segments. The traffic volume of the motorway within the study area was 27.542 vehicle/24 h (BASt), which is low compared to other traffic volume on motorways around the populated area Harz. The road density in the study area ranged between > 0.30–0.50 km/km^2 (Schumacher & Walz 2000)..Wildcat data

The wildcat data are based on 7327 locations from 11 individuals (6 females; 5 males) from 2451 tracking days between 2010 and 2013 (Table 1). Genetic analysis confirmed that all captured wildcats were genetically purebred without any signs of interbreeding with domestic cats (Senckenberg Institute, Gelnhausen). The average observation period of the individuals was 7 months ± 5.5 (1–26 months). . Female wildcats were fitted with VHF collars, and in the second investigation year, males were fitted with GPS collars. The research was approved by the local animal welfare officer and by the state administrative office of Saxony-Anhalt and the Environment Agency of Saxony-Anhalt (AZ: 42502-2-982 Uni DD). All ethical criteria concerning research on animal wildlife were met. We estimated the VHF wildcat locations by car and on foot using triangulation, as described by Kenward (2001) and White and Garrott (1990). Wildcat positions were obtained using 3 or more fixes collected within less than 15 min, with angles between consecutive bearings around 40°, and angles between the 2 outermost bearings around 145°. This was done by one person. All wildcats were located at least once a day approximately five times per week and one to six fixes by night time at least twice per week. The GPS-collars were programmed to acquire two fixes by day and six fixes at night (Table 1). The estimated maximum radio-tracking error was 50 m. All monitored wildcats were located within the study area during the observation period. Thus they established their home ranges in an agricultural landscape (Jerosch et al., 2017). To avoid temporal autocorrelation, we selected only locations separated by at least six hours. This selection resulted in a database of 3869 locations ranging from 250 to 1188 locations per cat.

2.2. Landscape variables

We used environmental vector data from the German information system for cartography and topography (Authoritative Topographic-Cartographic Information System, ATKIS). Due to the detailed vegetation mapping, data from the state agency for environmental concern Saxony-Anhalt (Biotope- and Usage Mapping, BTNT) and Thuringia (Open country Biotope Mapping, OBK) were also used. We extracted four land-use types (waterbodies (D_wat), settlements (D_set), paved roads (D_roa), and single houses (D_sh) from ATKIS and seven land-use types (forest (D_for), arable land (D_a), pasture (D_mea, shrubs, fallows habitat types with tall-grown herbaceous vegetation hedges and tree rows) from the vegetation state map. In addition, two new land-use types were created from the vegetation state map: We merged the forest, shrubs and fallows habitat types with tall-grown herbaceous vegetation to create a new type called shelter habitat (D_shh). Following this, we created an ecotone feature by pooling tree rows,