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Seasonal activity patterns of European bats above intensively used farmland

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A B S T R A C T

Bats are top insect predators on farmland, yet they suffer from intensive farmland management. Here, we evaluated the seasonal activity patterns of European bats above large, arable fields and compared these patterns between ecologically distinct bat species. Using repeated passive acoustic monitoring on a total of 93 arable fields in 2 years in Brandenburg, Germany, we surveyed the activity of different bat species between early spring and autumn. We then used generalized additive mixed models to describe and compare the seasonal bat activity patterns between bat categories, which were build based on the affiliation to a functional group and migratory class, while controlling for local weather conditions. In general, the affiliation to a bat category in interaction with the season in addition to cloud cover and ambient air temperature explained a major part of bat activity. The season was also an important factor for the foraging activity of open-space specialists such as *Nyctalus noctula* but showed only a weak effect on species such as *Pipistrellus nathusii* which are adapted to edge-space habitats. Across the seasons, habitat use intensity was high during the period of swarming and migration and low during the energy demanding period of lactation. Seasonal patterns in foraging activity showed that open-space specialists foraged more intensively above agricultural fields during the migration period, while edge-space specialists foraged also during the energy demanding period of lactation. We conclude that the significant seasonal fluctuations in bat activity and significant differences between bat categories in open agricultural landscapes should be taken into consideration when designing monitoring schemes and management plans for bat species in regions dominated by agriculture. Also, management plans should be directed to improve the conditions on arable land especially for bat species which would be classified as narrow-space foragers such as *Myotis* species.

1. Introduction

Over past decades, global food production has increased fourfold (Robinson and Sutherland, 2002), with currently one-third of global primary production being routed to human consumption (Krausmann et al., 2013). The constantly rising demand for food leads to drastic land use changes, which can be roughly summarized as conversion of previously pristine habitats into farmland and an expansion and intensification of agricultural land use in developed countries (Tilman et al., 2001). In addition insecticides, herbicides and industrial fertilizers, which influence the local and also the global nitrogen cycle (Canfield et al., 2010), are applied on arable fields using heavy machinery (Robinson and Sutherland, 2002). All these changes have altered the prospects of plant and animal populations on agricultural land resulting in a biodiversity loss on farmland (Stoate et al., 2001) across multiple taxa and on a range of spatial scales from local to landscape level (Benton et al., 2002; Vaughan et al., 2003). More than 21% of Europe's land area is currently used by agriculture of which about 59% is arable land (FAO, 2011) a number predicted to increase in the near future (Tilman et al., 2001, 2011).

A variety of factors potentially affect populations of birds, invertebrates and mammals on farmland such as the land use intensity (Allan et al., 2014), the crop type or management schemes (Tapper and Barnes, 1986; Wickramasinghe et al., 2003, 2004) and

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the landscape structure and composition of landscape elements surrounding arable fields (e.g., Hendrickx et al., 2007; Fuentes-Montemayor et al., 2011). The pronounced climatic change over the year (hereafter seasonality) is yet another very important factor, as it shapes the availability of food and the suitability of roosts (winter and summer roosts) and the habitat use of mammals (Morrison et al., 2012). However, information on seasonal variation in activity of nocturnal bats (*Chiroptera*) on intensively used arable fields is largely missing.

Here, we investigated the seasonal changes of bat activity on arable fields and contribute to the knowledge of how the endangered (Mickleburgh et al., 2002) and protected (Der Rat der Europäischen Gemeinschaften, 1992) group of bats use agricultural landscapes.

Since bats in the temperate zone adjust their foraging and activity levels according to their annual reproductive life cycle (Mackie and Racey, 2007), we predicted to find changes in activity levels across the seasons. In particular, we expected an increase in activity in spring and a further increase in summer after weaning of juveniles and the beginning of dispersal from their natal colonies. We further predicted higher activity levels in autumn when adult bats search for mates and move between summer habitats and hibernacula sites (Kunz et al., 2003). Also, we expected to observe decreased activity in late autumn when bats prepare for hibernation.

In addition, we grouped bat species according to their migratory capacity and their predominant foraging space (narrow, edge and open space; Schnitzler and Kalko, 2001) into bat categories to elucidate potential differences in seasonal activity patterns within and between these groups. We expected that migrating bat species are more active during migration periods in spring or autumn compared to non-migrating species. Further, we expected bat species which are adapted for fast flight in open space to be more active on arable fields than bat species predominantly foraging along edge structures like forest edges or hedgerows. In turn, we expected edge specialists to be more active on arable fields than bat species which are adapted to forage in narrow-space habitats such as forests. In summary, our study serves to identify seasonal activity patterns and quantify the use of large arable fields by different functional bat groups during important stages of their reproductive life cycle. Especially in a landscape strongly dominated by intensive agriculture, this knowledge is valuable for bat species conservation, as all bat species interact with this type of habitat to some extent either due to their high mobility or in order to reach more suitable habitat patches. Furthermore, our study provides important basic knowledge for future studies related to e.g., ecosystem services bats might provide by feeding on phytophagous insects (Kunz et al., 2011) in landscapes dominated by farmland.

2. Material and methods

2.1. Study area

Within the framework of the “Agricultural Landscape Laboratories” (AgroScapeLabs, www.scapelabs.org), we conducted our study from May to September 2012 and March to June 2014 to additionally sample the onset of the seasonal activity of bats. The study region covers about 291 km^2 and is located in the catchment area of the Quillow stream (53°20′ North, 13°42′ East) in the Uckermark region (Brandenburg, Germany). This area is one of the least populated regions in Germany with a population density of 17 inhabitants per km^2. Over a full year cycle, ambient temperature averages 8.6±0.2 °C (mean ± one standard deviation, data from 1981 to 2010) with an annual precipitation of 480 mm to 620 mm per year (DWD, 2015). Changes in land use over the past 50 years and a collectivisation of formerly small farms in the region of our study area during the socialist period resulted in a homogeneously structured landscape with an estimated average field size of about 20–75 ha (Katzschner, 2011). Accordingly, the study area is mainly characterized by arable fields (66%). Grasslands (10%) and remnant forest patches (13%) represent a minor feature of the landscape, as well as water bodies (6%) and urban areas (5%). Hereby, water bodies are mainly represented by numerous small post-glacial ponds, so-called kettle holes, but also larger lakes and rivers. The following bat species are known to regularly occur in the study region: *Nyctalus noctula, N. leisleri*, *Eptesicus serotinus*, *Vespertilio murinus*, *Pipistrellus pipistrellus*, *P. pygmaeus*, *P. nathusii*, *Plecotus auritus*, *Barbastella barbastellus*, *Myotis myotis*, *M. nattereri*, *M. brandtii* and *M. daubentonii* (LFA M-V, 2014).

2.2. Study design

We repeatedly monitored bat activity on 53 arable fields from May to September 2012 and on 40 newly selected fields from March to June 2014 (N = 93 in total). Arable fields were at least 1 km apart from each other and cultivated with the locally prevailing crop types corn (N = 27), canola (N = 34) and wheat (N = 32). We used a passive acoustic monitoring approach to assess the relative activity of bat species on arable fields (Batcorder, EcoObs GmbH, Nuremberg, Germany). Prior to sunset, we randomly selected 6 sites (2 sites per crop type) and monitored bat activity on all 6 sites simultaneously by setting up one Batcorder per site. Hereby, each Batcorder was mounted on top of a 3 m pole. To exclude direct influences of nearby dominant landscape structures (forest edges, hedges, water, urban areas) on bat activity (e.g., reported in Kelm et al., 2014; Heim et al., 2015), we kept a distance of at least 150 m between the Batcorder and the described structures. During any given night, we monitored 3.5 h of first bat activity after sunset which includes the first peak of nocturnal bat activity (Rydell et al., 1996). We continued the monitoring until all sites were monitored once in a given month. The recording was conducted one week before and after new moon with a break of 2 weeks between recordings to avoid effects of moonlight on our results. Batcorders, which record in real time and a sample rate of 500 kHz (16 bit), were set to record only incoming sound with a minimum sound pressure level of −36 dB and a critical frequency of more than 16 kHz. These settings allow the recording of even silent bat calls, while non-bat calls below 16 kHz would not trigger a recording. Post-trigger time was set to 800 ms. Once triggered, the recording would last for 800 ms and continue for additional 800 ms if the sound pressure and frequency level of the ultrasound signals remained above the sound pressure level and frequency thresholds.

To avoid a large influence of climatic conditions on our data, we recorded bat activity only during nights with no rain, and with wind speed below 11 $^{m}/_{s}$. As we conducted our monitoring also during spring, we could not avoid low ambient air temperatures (range: 4–20 °C) and thus controlled for potential effects of temperature in addition to humidity and cloud cover in our statistical models.

2.3. Bat species identification

In order to avoid potential misidentifications of bat species, we decided to use a manual instead of an automatic approach for bat species identification (Russo and Voigt, 2016). We identified bat species based on the ultrasonic recordings by measuring frequencies of at least two echolocation calls per recording using Avisoft SASLab Pro (version 5.1.0, Avisoft Bioacoustics, Berlin Germany; settings: Hamming window, FFT = 512, overlap = 93.75%; time resolution = 0.064 ms, frequency resolution = 0.977 kHz) and