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The importance of natural habitats to Brazilian free-tailed bats in intensive agricultural landscapes in the Winter Garden region of Texas, United States

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Abstract

The conversion of natural lands to agriculture is a leading cause of the worldwide loss of biodiversity. In particular, cropland monocultures alter insect abundance and diversity compared to adjacent natural habitats. While agricultural lands can provide large numbers of insect pests as prey items to predators such as bats, insect pest population size vary greatly throughout growing seasons. This study assesses the importance of land use and corn earworm moth availability as spatial and temporal drivers of bat activity. We quantified spatial variation in land use patterns at fifteen sites located within the Winter Garden region in south central Texas and used bat detectors and insect pheromone traps to monitor nightly bat activity and corn earworm moth abundance across the landscape and throughout most of the year. Our temporal analyses show that bat activity was positively correlated with moth abundance, but only early in the growing season when moth abundance is at its peak. The key result from this study is a positive relationship between bat activity and natural habitat cover during late summer months, corresponding to periods of low moth abundance and a peak in bat activity. During the late summer period, bats were more active at sites containing a larger percentage of natural habitats than those containing a larger percentage of agricultural land. Our results strongly suggest that intensive agricultural practices create systems providing bats with inconsistent resource supply, but the persistence of natural habitats provides consistency in food supply though time. Taken together, these findings illustrate the importance of protecting and restoring natural habitats for the conservation for bats and the pest-suppression services they provide in agricultural ecosystems.

Introduction

Agricultural landscapes exist as mosaics of monocultural croplands and remaining fragments of variously intact natural habitat. The conversion of natural habitats into agricultural land alters the abundance and interactions of native species, and land conversion, largely for agriculture, is recognized as the most important threat to biodiversity worldwide (Dale et al., 1994, Myers et al., 2000, Foley et al., 2005, Morton et al., 2006). Bats are predators of insects in agricultural landscapes and are known to contribute valuable economic services through consumption of insect pests (Kunz et al., 2011). However, many studies to date on bat habitat use within agricultural landscapes demonstrate that bats prefer remaining woodland, corridor and riparian habitats and avoid arable and agricultural lands (e.g. Walsh and Harris, 1996, Vaughan et al., 1997, Razgour et al., 2011). Studies also indicate that the abundance, diversity and activity of bats decline in parallel with the intensity of agricultural development (Russo and Jones, 2003, Wickramasinghe et al., 2003).

Apart from their intrinsic conservation value, the loss of bats is of concern because they provide several crucial ecosystem services worldwide, including pollination (Bumrungsri et al., 2008, Cox et al., 1991) and seed dispersal (Cox et al., 1991, Moran et al., 2009). Insectivorous bats can act as biological control agents and significantly reduce populations of agricultural insect pests (Cleveland et al., 2006, Federico et al., 2008).

Agricultural habitats alter the insect resource base available to bats. Reductions in plant diversity as occurs in agricultural landscapes is associated with a parallel decrease in insect diversity (Crutsinger et al., 2006, Haddad et al., 2009, Genung et al., 2010), and prey availability (Krebs et al., 1999, Benton et al., 2003, Racey and Entwistle, 2003, Tsitsilas et al., 2006). In addition, observations that bat activity and insect abundance are significantly higher on organic farms than on conventional farms (Wickramasinghe et al., 2004, Wickramasinghe et al., 2003), provides further support for the idea that preservation of natural and semi-natural habitats within agricultural landscapes is important for the conservation of bat populations. Further, non-crop habitat becomes even more crucial in periods of decreased quality of crop habitat; i.e. when crops are in senescence and no longer provide an ample insect source (Wickramasinghe et al., 2004).

In what is naturally a semi-arid ecosystem, the irrigated croplands of the Winter Garden agricultural region in southwest Texas annually produce billions of noctuid moths (*Lepidoptera*: *Noctuidae*) and other crop pests (Wolf et al., 1990, Westbrook et al., 1997). These insects provide valuable resources to the large numbers of Brazilian free-tailed bats (*Tadarida brasiliensis*) that inhabit the region (Kunz et al., 2011, Lee and McCracken, 2002, Lee and McCracken, 2005, McWilliams, 2005). The insects infesting the region's crops, including adult corn earworms (*Helicoverpa zea*), fall armyworms (*Spodoptera frugiperda*) and other members of the noctuid pest clade are among the most abundant pests in the region and an important part of the bats' diet (Lee and McCracken, 2005, McCracken et al., 2012). Corn earworm are among the world's most destructive agricultural pests (King and Rogers, 1986, Williams, 2014) and by consuming them, bats perform valuable ecosystem services such as decreasing damage to crops and reducing the need for pesticide use (Cleveland et al., 2006, Federico et al., 2008, Lopez-Hoffman et al., 2014).

Populations of Brazilian free-tailed bats roosting in the caves of south-central Texas may be the largest, densest aggregations of mammals on earth (McCracken, 2003), and the activity levels of foraging bats in the Winter Garden region are among the highest recorded in the literature (McCracken et al., 2008). Because of

the substantial resource base that is needed to sustain these large bat populations (Kunz et al., 2011), and because croplands provide a breeding ground for insect pests (Wolf et al., 1990, Westbrook et al., 1997), it has been speculated that these huge bat populations may exist because of the insects made available by intensive agriculture (Russell et al., 2011). However, this hypothesis remains largely untested.

Land development could affect bat populations directly by altering habitats and indirectly through effects on insect prey populations. Some studies suggest that bats avoid agricultural lands. Specifically, agricultural and human developments have the greatest impacts on bats with lower wing-loading and more specialized habitat requirements. Woodland and riparian species are most affected (Walsh and Harris, 1996, Wickramasinghe et al., 2004, Duchamp and Swihart, 2008, Razgour et al., 2011), whereas more generalist species with typically higher wing-loading appear to be less at risk from anthropogenic impacts, including agricultural intensification (Duchamp and Swihart, 2008). Species with higher wing-loading typically forage in uncluttered habitats above canopy and exploit a higher diversity of insect prey than species with lower wing-loading. These traits define Brazilian free-tailed bats which have among the most diverse diets reported for any insectivorous bat species (Lee and McCracken, 2002, Lee and McCracken, 2005) and are known to forage from ground level to several 1000 m above the ground where they opportunistically exploit swarms of insects and localized insect emergences (McCracken et al., 2008). When assessing extinction risks for bats, studies concur that species with the constellation of traits possessed by Brazilian free-tailed bats are less vulnerable to human impacts (Duchamp and Swihart, 2008).

We tested the hypothesis that the abundance of insect pests was a better predictor of spatial variation in Brazilian free-tailed bats' foraging activity than land use type. First, we examined how land-use type relates to bat activity by relating the proportion of man-altered versus natural habitats to spatial variation in the number of recorded bat calls across sites. Then, we examined the relationship between the abundance of agricultural insect pests (adult moths) detected in pheromone traps and the number of bat calls. Finally, we monitored bats and insects pests over a period of nine months to assess temporal variability in those spatial associations. Based on previous studies (McCracken et al., 2012), we predicted that insect pests would be the main predictor of bat activity patterns across sites and throughout the study period.

Section snippets

Study area

We monitored bat activity nightly from March until November 2007 at fifteen sites within the Winter Garden agricultural region in south central Texas. At least 8 km, usually more, separated monitoring sites. The four-county study region (Uvalde, Frio, Zavala and Medina) covers approximately 2500 km^2 (Fig. 1) with land use dominated by agriculture and ranching. Whereas, croplands are cultivated annually for corn, cotton and sorghum (USDA-NASS, 2002), what we term here as "natural habitats" are…

Bat activity

We analyzed a total of 9552 h of recordings during 243 nights from the fifteen monitoring sites. The data include a total of 2 914 172 calls attributed to Brazilian free-tailed bats with a range of 20–129 056 calls per week (mean±SE of 1376.91±139.46 and median of 471.02). These calls were collected in a total of 278 906

files with a range of 9–7377 files per week (mean±SE of 131.68±9.35 and median of 51.2). Bat activity (calls per nightly recording session per site) was relatively low in March…

Discussion

Our results show that within an intensive agricultural landscape, the proportion of natural habitats is the best predictor of Brazilian free-tailed bat activity. These results are consistent with earlier studies showing that land use is an important predictor of bat activity (Walsh and Harris, 1996, Vaughan et al., 1997, Razgour et al., 2011) and that bats select for the presence of natural or semi-natural habitats (Walsh and Harris, 1996, Duchamp and Swihart, 2008, Razgour et al., 2011).…

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2022, Global Ecology and Conservation

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>
> …Overall, bat activity declined with increasing distance from riparian corridors (Fig. 3A). This result supports our hypothesis and corroborated findings from previous studies, indicating bat activity to be higher in agricultural landscapes when forested corridors are present (Boughey et al., 2011; Davidai et al., 2015; Kalda et al., 2015) and when habitat heterogeneity is higher in general (Frey-Ehrenbold et al., 2013; Monck-Whipp et al., 2018; Russo et al., 2018). On organic farms, greater bat activity was attributed to higher landscape heterogeneity and improved water quality when compared to conventional farms (Wickramasinghe et al., 2003)….

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2021, Ecological Indicators

> *Citation Excerpt :*

…Ecological corridors are considered important tools in farmland management because they could increase the movement of animal and plant species between habitat patches (Gilbert-Norton et al., 2010; Hofman et al., 2018). The importance of shrublands/hedgerows in farm areas for birds and bats was highlighted in several studies (Bolger et al., 2001; Russ and Montgomery, 2002; Morelli, 2012, 2013; Morelli et al., 2012; Davidai et al., 2015; Wuczyński, 2016; Cleary et al., 2017; Wilson et al., 2017; Monck-Whipp et al., 2018). Contrariwise our study predicted a decline in bird abundance and bat activity with the installation of shrubland/hedgerow corridors, probably related with the recent implementation of these structures in the studied farms (simplified and small structured vegetation)….

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2019, Agriculture, Ecosystems and Environment

Citation Excerpt :

…Numerous bat species (particularly of the Molossidae and Vespertilionidae families) are known to coexist synanthropically by exploring newly available resources. These bat families have been shown to feed on pests (Brown et al., 2015) and to select crops as preferred foraging areas especially during insect pest outbreaks (Lehmkuhl Noer et al., 2012; Taylor et al., 2013a; Davidai et al., 2015). In fact, bats tend to select foraging areas based upon the resources available (Ancillotto et al., 2017), which makes them excellent pest suppressors during seasonal insect pest outbreaks….

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…We found greater bat activity in natural areas compared to farms, highlighting the importance of conservation of natural habitat patches within intensive agricultural landscapes. This finding is consistent with previous studies in mixed annual cropping systems in the US (Davidai et al., 2015) and vineyards in North America (Kelly et al., 2016; Rambaldini and Brigham, 2011). Our finding that diversity was marginally significantly higher in natural habitat than on conventional farms may be explained by differences in local habitat features….

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…Similarly, vulnerable species in this analysis comprised three clutter species (Rhinolophus ruwenzorii, Rhinolophus guineensis and Hipposideros marisae), and their representation in priority areas decreased under the future land use scenario. Although high mobility of bats enables them to utilise natural habitat patches even in human-dominated urban

and agricultural landscapes (Duchamp and Swihart, 2008; Davidai et al., 2015), bat species exhibit high variability in dispersal abilities at the mesoscale, even within functional groups (Meyer et al., 2008; Taylor et al., 2012). Thus, our models could be markedly refined by using data on dispersal ability for individual species.…

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