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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.

1. 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

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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, 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, 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, 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.

2. Methods

2.1. 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 not cultivated and include native oak trees, brush, forbs and grasses, as well as invasives (Stevens and Richmond, 1976). The presence of ranches and small towns result in interspersed buildings and light sources in and around the study sites. Within the study region, there are three known major bat roosts, Frio Cave, Ney Cave, and Seco Creek Bridge (Fig. 1). The colonies of Brazilian free-tailed bats in Frio and Ney Caves are among the largest in North America (McCracken, 2003; Cleveland et al., 2006). Although historical counts estimated peak summer populations to be around ten million bats in each of these caves (Davis et al., 1962), more recent estimates show present colony sizes to be approximately one million bats per cave (Betke et al., 2008). Colony size at Seco Creek Bridge is estimated to be around 250,000 bats (Kunz, personal communication). Although other species of bats forage over this landscape, Brazilian free-tailed bats are by far the most abundant species, and earlier analyses of echolocation call characteristics showed that the calls of Brazilian free-tailed bats comprise >95% of bat calls recorded in the vicinity at ground level (Gillam and McCracken, 2007).

Monitoring sites were located 5–100 km from the three major bat roosts in the region and within the over 100 km nightly foraging range of the Brazilian free-tailed bats roosting at one or more of these sites (Best and Geluso, 2003; G.F, McCracken, unpublished). To assess the effects of habitat type on bat activity, sites were selected to encompass surrounding vegetation ranging from full cropland to full natural habitat. Sites also were selected based on distance to the roosts to ensure a range of distances that include monitoring sites both near and far from the three major bat roosts (Best and Geluso, 2003).