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Wild, native bees and managed honey bees benefit from similar agricultural land uses

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A B S T R A C T

Although both managed and unmanaged bees are important pollinators of crops and wild plants, efforts to address questions about landscapes that best support pollinators often focus on either wild pollinators or honey bees. This study examined if there was concordance between the success of wild bee communities and managed honey bee colonies at sites varying in floral availability and disturbance level in a predominantly agricultural landscape. We also determined which agricultural land uses best supported wild bee communities. The study area in the state of North Dakota in Northern Great Plains in North America is home to understudied native bee communities as well as over ¼ of U.S. commercial honey bee colonies during the summer months. There is an assumption that honey bees can do well in agricultural areas but that wild bees need natural areas to thrive. We compared wild bee community success with health and survival of managed honey bees (data obtained from a related study) at six apiary locations over three years. We examined wild bee communities and surrounding land uses at 18 locations, three of which were spatially associated with each of six apiary locations. Wild bee abundance and species diversity were positively correlated with honey production, a measure of honey bee success, indicating that locations supporting successful honey bee colonies also supported successful wild bee communities. Grasslands, bee-forage crops, wooded areas, and wetlands were associated with increased abundance, species diversity, or functional diversity of wild bee communities. Crops not providing forage for bees, predominantly soybean, corn, and wheat, were associated with decreased functional diversity, decreased above-ground nesting bees and bees with shorter active season durations, and decreased honey bee survival. Pollinator conservation efforts retaining and enhancing grasslands, wooded areas, wetlands, and crops providing bee forage will likely support the growth, reproduction, and survival of diverse wild bee communities and the success of managed honey bees in areas dominated by intensive agriculture.

1. Introduction

Both wild and managed bees rely on resources provided by the landscape within their foraging range. Because of this, the success of bees may be considered a reflection of the quality of their surrounding landscape. There is mounting evidence of decline in some wild bee populations (Biesmeijer et al., 2006; Burkle et al., 2013; Senapathi et al., 2015), while honey bees and beekeepers continue to be faced with numerous interacting factors such as parasites, nutrition, pesticides, and socioeconomics (Lee et al., 2015; vanEngelsdorp and Meixner, 2010). Efforts to address questions about landscapes that best support pollinators often focus on either wild pollinators (Hinners and Hjelmroos-Koski, 2009; Hopfenmüller et al., 2014; Loos et al., 2014; Lowenstein et al., 2012; Winfree et al., 2011) or honey bees (Couvillon et al., 2014; Gallant et al., 2014). However, large-scale land-use trends resulting in decreased forage and nesting habitat pose threats to all pollinators (Otto et al., 2018; Thogmartin et al., 2017; Wright and Wimberly, 2013). Such concerns about broadly-occurring pollinator population and health declines highlight the importance of identifying landscapes that contribute to the success of all bees, native and non-native, wild and managed.

The Northern Great Plains (NGP) of North America is an important region for both managed and wild pollinators (Koh et al., 2016; Smart et al., 2016b) and is a major area of agricultural production (USDA-NASS, 2013) with 90% of private land in agricultural use (Rashford et al., 2011). North Dakota is the top honey producing state in the U.S. with approximately 485,000 honey bee colonies producing over 17 million kilograms of honey, valued at $70 million in 2016 (USDA-NASS,

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2017). Many of these honey bee colonies are transported throughout the country for crop pollination in late winter and early spring. North Dakota is also home to many wild bees with historical records suggesting the presence of over 300 bee species (Stevens, 1948).

In recent years, agricultural land-use features and crops thought to be supportive to bees have decreased due to shifts toward row crops grown for biofuel production, raising concerns about the fate of associated effects on pollinators (Gallant et al., 2014; Otto et al., 2016; Smart et al., 2016a). The decreasing land uses include semi-natural lands (Alaux et al., 2017; Hopfenmüller et al., 2014; Le Feon et al., 2010; Öckinger and Smith, 2006; Riedinger et al., 2015; Smart et al., 2016b; Sponsler and Johnson, 2015; Steffan-Dewenter et al., 2002; Westphal et al., 2003), crops providing bee forage (Ayers and Harman, 1992; Holzschuh et al., 2013; Riedinger et al., 2015; Rollin et al., 2013; Scheper et al., 2014; Westphal et al., 2003; Zou et al., 2017), wooded areas (Carré et al., 2009; Jha and Kremen, 2013; Morandin and Kremen, 2013; Moroń et al., 2014), and wetlands (Koh et al., 2016). Because of the pre-eminence of agriculture and the important role of pollinator habitat in the NGP, it is crucial to identify bee-utilized habitat within agricultural lands that provides broad support for both wild and managed bees, while also allowing for a productive agricultural economy. Maintaining and increasing acreage in land-use features supporting bees could help conserve wild bee communities and ensure the availability of honey bees for pollination service delivery throughout the country.

The objectives of this study were to determine if wild bees and managed honey bees were successful in the same landscapes and to describe how agricultural land use may best support wild bee communities. We addressed the following two questions: 1) Are wild bee community metrics (abundance, species richness, species diversity, and functional trait diversity) associated with honey bee metrics (honey production and colony survival)? and 2) What land-use types are associated with successful wild bee communities? Our study is timely and informative, providing evidence on how pollinator habitat management efforts may be prioritized in agricultural areas.

2. Methods

2.1. Study sites and land use quantification

We chose six apiary sites existing across an agriculture-grassland gradient based on GIS analysis of the areas surrounding each apiary site (Smart et al., 2016b). Wild bee survey locations were located between 1 and 2.5km of apiary sites. These survey locations were at least 1km from each other. The minimum distance of 1km from apiary sites and other wild bee survey locations was chosen to decrease potential foraging overlap (Fig. 1). We chose exact wild bee survey locations based on land access, the presence of floral resources on which to find foraging bees, and variability in the presence of potential wild bee habitat, such as wooded areas and grasslands (Table S1). Survey locations primarily occurred along roadside ditches where floral resources were predominantly located.

Methods for quantifying land use are detailed in Smart et al., 2016b. To summarize, land use was determined via visual observation and supplemented with data obtained from the National Agricultural Statistics Survey Cropland Data Layer (NASS CDL). Final quantification was done via GIS analysis (ArcGIS v.10), which provided the square meters of various land-use types within a 3.2km radius around each apiary site (Fig. 1). The distance of 3.2km was chosen as a realistic total area (approx. 32km^2) over which honey bee colonies at a given site would be expected to forage (Beekman and Ratnieks, 2000; Visscher and Seeley, 1982). We grouped land uses into the following categories based on similarities in floral abundance and disturbance: wooded, wetlands, open water, grasslands, non-alfalfa hay-land, pasture, crops providing potential bee forage, crops not providing significant bee forage, and ruderal land (Table 1). Survey locations varied widely in the amount of land use in these categories (Table S1). Casual observations found no wild bee visitation and low frequency of honey bee visitation to soy and corn at all study sites so we grouped these crops with the other crops not providing bee forage (wheat and oats). This observation was corroborated by analysis of honey bee-collected pollen from apiaries at these study sites (Smart et al., 2016b).

We examined land use surrounding each wild bee survey location at scales of 1500m, 700m, and 300m (Fig. 1). These scales were chosen to encompass varying flight ranges for different groups of bees and their different uses of the surrounding landscape (Greenleaf et al., 2007; Steffan-Dewenter et al., 2002). At the 1500m scale some survey locations overlapped. However, we assumed this overlap did not bias observed relationships as the overlapping area was a small proportion of the total area examined and the majority of bees from collections at the central collection site would not be foraging near the edge of the 1500m buffer.

2.2. Wild bee community sampling and characterization

In 2010, we chose two wild bee survey locations near each of the six apiary sites, resulting in twelve bee survey locations. In 2011, we added an additional survey location around each apiary site to better encompass landscape variability, resulting in eighteen bee survey locations for 2011 and 2012. We sampled wild bees between May and September, once every three weeks in 2010, for a total of six sampling rounds per survey location, and once every four weeks in 2011 and 2012, for a total of five sampling rounds per survey location. Logistic constraints led to the compromise between the number of survey locations and sampling frequency, resulting in less frequent sampling at more sites in 2011 and 2012. We sampled all sites within three to four days during each sampling round using two different sampling methods: sweep netting and bowl traps. Although bowl traps are both efficient and unbiased in terms of observer bias (Westphal et al., 2008), they have other potential biases (Jean, 2010). We included both sampling methods to maximize the number of species caught and to compensate for variable performance of each individual sampling method.

2.2.1. Sweep netting

We visited each survey location twice for sweep netting during each sampling round, with one sample between 10 a.m. and 1 p.m. and another between 1 p.m. and 6 p.m. Sampling took place when there was no precipitation and the temperature was greater than 15 °C. In 2010, we spent thirty minutes of sweep time, with two 15 min samples, at each survey location per sampling round with the survey effort focused on patches of blooming flowers. In 2011 and 2012, we reduced sampling time to twenty minutes per sampling round per site, due to the increase in survey location number. Sweep netting took place along a meandering transect with observers walking at a consistent pace while constantly sweeping through vegetation, covering approximately 100m^2 in ten minutes with the transect path varying to encounter patches of blooming flowers. All bees were collected from sweep nets with the exception of honey bees and other readily-identifiable bees, primarily bumble bees, which were identified to species, counted, and released.

2.2.2. Bowl trapping

In 2010, we set up thirty-six bowl traps for approximately twenty-four hours at each survey location during each sampling round along two orthogonal lines when possible, or along one straight line, with 5 m between bowls, along roadside ditches or other open areas. The traps consisted of 200ml plastic cups painted either fluorescent blue, fluorescent yellow, or white (Guerra Paint and Pigment, New York, NY) filled with a 2% soap solution (Dawn dish soap, Procter & Gamble, Cincinnati, OH) attached to bamboo stakes elevating the traps slightly above vegetation height to ensure visibility. Due to the increase in the number of survey locations in 2011 and 2012, the number of cups was