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Higher bat and prey abundance at organic than conventional soybean fields

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ABSTRACT

Studies that have compared biodiversity at organic and conventional farms have generally found that there are more species in greater abundances at organic farms. One widespread problem with previous studies is that most do not control for differences in field structure and landscape composition at organic and conventional farms. Thus, the effects observed may be due to factors other than organic farming practices. We addressed this problem by selecting matched organic-conventional pairs of soybean fields such that in each pair the soybean fields were similar in size, hedgerow length, and surrounding landscape composition within 1 km, 2 km and 3 km of the fields. At each of our 16 field pairs (32 sites), we measured relative differences in bat species richness and abundance using acoustic bat recorders, and bat prey availability using black-light traps. We predicted that organic soybean fields would have greater bat species richness, bat abundance and bat prey abundance than conventional soybean fields due to the prohibition of synthetic pesticides and longer more diverse crop rotations in organic fields, both of which should benefit bat insect prey. We found that organic soybean fields had higher bat species richness, bat abundance and bat prey abundance than conventional fields, after controlling for the effect of differences in soybean height between conventional and organic fields. Our results suggest that the management practices used at organic farms benefit bats at least in part by providing greater bat prey availability.

1. Introduction

The use of agro-chemicals - pesticides and fertilizers - threatens biodiversity. Declines in plants (Geiger et al., 2010), invertebrates (Benton et al., 2002; Geiger et al., 2010) and vertebrates (Köhler and Triebskorn, 2013) have been attributed to agro-chemical use, which can have direct effects, through toxicity, or indirect effects. One indirect mechanism that is thought to have caused declines in insectivores is the reduction of invertebrate prey (Benton et al., 2002). Insecticides can target invertebrate prey directly, and herbicides can limit invertebrate host plants growing in fields or along field margins (Boatman et al., 2004). In locations where agro-chemicals are in greater use, there may be less invertebrate prey available to insectivores, resulting in lower abundance of insectivores in those areas.

Studies that compare biodiversity in organic versus conventionally farmed fields are often taken as support for the impacts of agro-chemicals on biodiversity. Organic farming prohibits the use of synthetic agro-chemicals, and organic farms have longer more diverse crop rotations than those under conventional farming (OMAFRA, 2009). While more studies have found greater biodiversity at organically farmed fields than conventionally farmed fields (Lichtenberg et al., 2017), there are large differences in results among and within taxonomic groups (Wickramasinghe et al., 2004; Fuller et al., 2005; Pocock and Jennings, 2008), among agricultural crop species or sampling locations within a farm (Wickramasinghe et al., 2003; Batáry et al., 2010), and among landscape contexts (Lichtenberg et al., 2017).

However, in most comparisons of biodiversity in organic versus conventional fields, the organic fields tend to be smaller (Freemark and Kirk, 2001; Norton et al., 2009), have more vegetated field margins (Wickramasinghe et al., 2003; Fuller et al., 2005), and are surrounded by more diverse landscapes (Norton et al., 2009; Winqvist et al., 2012) than the conventional fields. This raises the question whether lower reported biodiversity in conventional than organic fields is in fact due to the agro-chemical use in the conventional fields or to differences in field and landscape attributes between organic and conventional farming systems. Thus, if the goal is to uncover the effects of organic farming practices on animal abundance and diversity, substantial care is needed in site selection to avoid confounding these effects with other potentially influential variables.

Insectivorous bats are an important group in agricultural systems because they provide pest control services. Lactating bats have been found to eat approximately 75% to more than 100% of their

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bodyweight in insects per night (Kunz et al., 2011), and their ability to forage opportunistically (Clare et al., 2009) allows them to target insect pest species that may be highly abundant for discrete periods of time (Davidai et al., 2015). Bats can suppress insect pest populations (Kunz et al., 2011), which should limit crop damage. In fact, bat agricultural pest control services have been estimated to be worth $3.7 to $53 billion per year in the United States (Boyles et al., 2011). Thus, farmers benefit from conservation actions that increase bat abundance in agricultural areas.

Our objective was to measure relative bat diversity and abundance and the abundance of their insect prey at organic and conventional fields, using a study design that controlled for potentially confounding field and landscape attributes. Specifically, we predicted that 1) the number of bat species and bat abundance, and 2) the number of nocturnal aerial insects, would be higher at organic fields than conventional fields in matched organic-conventional pairs selected to control for field and landscape attributes. Since we hypothesized that bats would be more abundant at organic fields than conventional fields because of their higher bat prey availability, we also predicted that 3) there would be a strong positive relationship between bat activity and the abundance of insects.

2. Methods

2.1. Overview

We estimated bat species richness and abundance and nocturnal aerial insect abundance in 16 pairs of soybean fields. Each pair contained an organic and a conventional field. The fields were selected to isolate the effects of farming practices (organic vs. conventional). We did this by selecting a conventional field that matched each organic field in terms of field size, length of hedgerows/treelines around the field, local habitat around the sampling equipment, and surrounding landscape composition measured as the proportion of the landscape in agriculture, forest and shrubland, water, and urban cover within 1, 2 and 3 km of the field. At each field we sampled bats using automated bat recorders, and we sampled insects using black-light traps. Bat activity (number of bat passes recorded) was used as an index of bat abundance. We performed generalized linear mixed modeling (GLMM) for bat species richness, total bat activity, individual bat species activity or presence/absence, total insect abundance, insect abundance in separate size classes, and insect abundance in separate Orders as response variables, and field type (organic versus conventional) as our predictor variable of interest. Presence/absence was used for the two least common bat species.

2.2. Study region

We conducted our study in the regions of eastern Ontario (29 fields) and Montérégie, Quebec (3 fields) in Canada (mean latitude: 45.23, mean longitude: −75.17, Fig. 1). Our study area covered a latitudinal span of ~65 km and a longitudinal span of ~160 km. Organic farming is relatively uncommon in this area with 1.7% of farms in Ontario and 4.4% of farms in Quebec that are certified organic or are transitioning to certified organic (Statistics Canada, 2016a). The dominant crops in Ontario and Quebec are corn (17.4% and 20.0%, respectively), hay (15.1% and 36.0%, respectively) and soybean (20.8% and 16.9%, respectively) (Statistics Canada, 2016b). Pesticide applications to conventionally farmed soybeans include treatment of seeds with neonicotinoids (imidacloprid, clothianidin or thiamethoxam), and direct application of pesticides to fields. The latest information available in Ontario indicates about 50% of soybean seeds are treated with neonicotinoids (Statistics Canada, 2016b; Government of Ontario, 2017), and about 1.8 kg of active ingredient of pesticides are applied per hectare of soybean, of which 98.8% is herbicide (Farm and Food Care Ontario, 2015).

2.3. Site selection

We identified farmers growing certified organic soybean, and quantified the attributes of the fields where they planned to grow soybean in the 2017 growing season. We chose soybean because it is commonly grown both organically and conventionally in our study area. We found organic soybean farmers through web directories, an organic seed seller, and through other organic soybean farmers. Using the most recent and detailed imagery we could find (MNR, 2014; 50-cm resolution), we delineated the sizes of the fields and the length of the hedgerows/treelines around the fields. We calculated the proportions of agriculture, forest and shrubland, water and urban cover within 1, 2 and 3 km of each field (Table A.1. and AAFC, 2017).

To identify a suitable conventional field to pair with each organic field, we first identified areas with similar land cover to that surrounding the organic field of interest. The conventional field was within 6 to 18 km of the organic field. We targeted areas that were at least 6 km from the organic field to ensure spatial independence, i.e. so that it was unlikely that the same individual bats would commute to both fields (Brigham, 1991; Henderson and Broders, 2008; Elmore et al., 2005; Sparks et al., 2005). Commuting distances of bats are not well known. One study found that the hoary bat (*Lasiurus cinereus*), likely the most mobile species in our area, commutes distances greater than 6 km for foraging (Barclay, 1989), but its mean commuting distance was estimated at 3.4 km in another study (Bonaccorso et al., 2015). We used a maximum distance of 18 km so that the fields would be in the same general region. We then created uniform points approximately 600 m apart in the 6 to 18 km area from each organic field, and calculated the proportions of agriculture, forest and shrubland, water and urban cover within 1, 2 and 3 km of each point (AAFC, 2017). We then identified points that shared similar proportions of land cover at the 1, 2 and 3 km radius landscape extents to the organic field of interest. Within this set of candidate areas we then identified fields of similar size and length of hedgerows/treelines around the field to the organic field of interest, and that were either soybean or corn the previous year (AAFC, 2017), because soybean and corn are commonly rotated on fields in Ontario. For each organic field, we followed this process of identifying potential paired conventional fields, and then ranked the potential conventional fields from the strongest match to the weakest match based on their similarity in land cover within 1, 2 and 3 km of the field, field size and hedgerow/treeline length. Ideally we would have also matched the paired fields based on hedgerow/treeline height (see Wickramasinghe et al., 2003), but this information was not available. For one organic field, we redid the selection process to consider areas farther from the organic field of interest (see directly below) after finding few options for potential matched conventional fields within 18 km. All spatial analyses were performed in ArcGIS 10.4.1 (ESRI, Redlands, California).

Starting with the top-matched candidate conventional field for each organic field, we first confirmed it would be planted with soybean in 2017 using conventional practices, and then requested permission to access the field for bat and insect surveys. The resulting conventional fields in each matched pair were in our top 4 candidate choices (mean = 2.4). The resulting pairs were between 6.6 and 25.4 km apart (mean = 12.7 km). No significant differences were detected in the field structure and landscape composition between the matched pairs (Fig. A.1 and Table A.2).

2.4. Field data collection

2.4.1. Acoustic sampling for bats

We selected two sampling locations on the edges of each field (A and B). These locations were paired in the matched organic-conventional field pairs based on the vegetation immediately surrounding the survey equipment (hedgerow/treeline versus open), and the land cover type adjacent to the field at the sample location (forest versus agricultural field, Fig. 2). The A and B survey locations at each field were at