Agriculture, Ecosystems and Environment 211 (2015) 24–31

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Pest-removal services provided by birds on small organic farms in northern California

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ARTICLE INFO

Article history:
Received 19 November 2014
Received in revised form 4 March 2015
Accepted 18 April 2015
Available online 3 June 2015

Keywords:
Farmland birds
Ecosystem service
Pest removal
Organic farming
Field margin

ABSTRACT

Many studies have established that birds may provide a pest removal service on farms, although few studies have taken place in temperate row crop agriculture. Wildlife-friendly agricultural practices such as organic farming and the use of hedgerows can in turn provide needed habitat for birds in developed landscapes. In this study, we examined how pest removal provided by birds varies within and between "wildlife-friendly" organic row-crop farms in northern California, USA. We used point counts to assess bird diversity on 29 small organic farms and simulated lepidopteran pest outbreaks on each farm using sentinel pest experiments. We measured how the probability of pest removal varied with local habitat characteristics within the farm, and with bird diversity parameters between farms. We also used exclosure experiments to determine whether birds provide a significant pest removal service in organic row-crop agriculture. In the sentinel pest experiments, birds depredated between 0 and 80% of caterpillar presentation stations within 7 h, with a mean of 24% depredation per farm; the probability of pest removal was higher in areas close to uncultivated shrubby field margins ("hedgerows"). There was only weak evidence that the probability of pest removal was higher on farms with higher avian insectivore richness, and no evidence that pest removal varied with species diversity or abundance. Exclosure experiments on kale crops showed no significant effects of bird exclosure treatment on arthropod abundance or crop yield. However, natural caterpillar densities were relatively low during the exclosure experiment (approximately one caterpillar/m^2). These results suggest that birds may be more helpful in responding to pest outbreaks than in controlling pests at non-irruptive densities on organic row crop farms in this study system. The prevention of pest outbreaks is an essential ecosystem service on any farm, and the rapid response of birds to pest outbreak conditions is an indicator of resiliency in the agroecosystem. Therefore, the retention of uncultivated shrubby field margins in this system may benefit both birds and farmers.

1. Introduction

Agriculture currently uses over 40% of the land area worldwide (McLaughlin, 2011). Global food demand is expected to double by 2050 in response to both a rising human population and a shift in dietary preferences and habits, prompting greater pressure to convert additional land to agricultural use and increase yields on lands already in production (Balmford et al., 2012; Green et al., 2005; McLaughlin, 2011; Tilman et al., 2011). Agricultural land conversion is one of the greatest threats to birds, as well as to numerous other taxa (Chamberlain et al., 2000; Donald et al., 2001; Sotherton, 1998). Therefore, many scientists argue that that wildlife-friendly farming, which encourages biodiversity within the farm (and often makes use of diversity on the landscape level), is key to conserving global biodiversity even if some crop yield is sacrificed (Fischer et al., 2008; Perfecto et al., 2009). Others argue that by increasing crop yield (often by increasing farming intensity), land may be spared for nature (Phalan et al., 2011; Trewavas, 2002). Researchers have noted that resolving this debate hinges on understanding the relationship between yield and biodiversity, the likelihood of land being spared, and external consequences of practices raising yield, such as agrochemical run-off (Grau et al., 2013; Green et al., 2005; Phalan et al., 2011). However, en
couraging wildlife that deliver ecosystem services and enhance production may enable high yield and wildlife-friendly farming strategies to be pursued simultaneously (Railsback and Johnson, 2014).

Organic farmers vary in their approach to pest control, and simply being organic does not necessarily directly lead to higher

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http://dx.doi.org/10.1016/j.agee.2015.04.023

levels of biological pest control on the farm (Letourneau and Bothwell, 2008). One approach organic farmers may take to increase both their yield and the biodiversity within the farm is to encourage pest-eating songbirds on and around farms. Many studies have established that birds provide a valuable pest removal service on farms, both by regulating existing pest populations and by potentially stopping pest outbreaks from occurring (i.e., Greenberg et al., 2000; Jedlicka et al., 2011; Johnson et al., 2010; Perfecto et al., 2004; Van Bael et al., 2007). However, relatively few of these studies have taken place in temperate row-crop agriculture (see Triplett et al., 2012 for some examples), and many have taken place in agricultural systems that produce luxury goods such as coffee, wine, and chocolate. In this study, we examined the potential for pest control by birds in temperate row-crop vegetable farms.

We examined three predictions of the general hypothesis that birds provide pest control services in our study system. First, we used a sentinel pest experiment to simulate an insect irruption and tested the prediction that pest removal rate is positively correlated with insectivorous songbird species richness, abundance, and/or diversity. This prediction derives from the biodiversity-ecosystem function (BDEF) hypothesis and more recent work suggesting pest control by birds in agricultural systems is associated with species richness (VanBael et al., 2008), functional richness (Philpott et al., 2009), or predator abundance (e.g., Jedlicka et al., 2011). Second, because bird diversity and abundance on farms are often associated with hedgerows and/or woody field edges (Batary et al., 2010), we tested the prediction that sentinel pests placed closer to uncultivated habitat would have higher rates of pest removal, and that pest removal would vary with the type of uncultivated habitat surrounding the farm. Third, we used bird-proof exclosures to test the prediction that excluded crops would host higher insect pest abundances and suffer higher levels of insect damage than control plants, due to the release of insect pests from top–down bird interactions. This prediction follows from previous work showing that songbirds can significantly reduce herbivorous insects, and thereby decrease crop damage and increase productivity of a primary producer in agricultural systems through a top–down trophic cascade (e.g., Baumgartner et al., 1999; Johnson et al., 2010; Kirk et al., 1996; Terborgh et al., 2010; Van Bael et al., 2007).

2. Methods

2.1. Study system

This study took place on 29 organic farms in Humboldt County, California, USA. The farms were located along a coastal and elevational gradient, and therefore were situated across a variety of habitats. Farms ranged from approximately 1 to 47.5 km from the coast and from sea level to approximately 350 m in elevation. While not all of the farms were certified organic at the time of the study, they all strictly followed organic farming practices. Some farms occasionally received organic pest treatments such as *Bacillus thuringiensis* (Bt) spray, although only in response to the pest community and never as a regularly scheduled treatment. Each farm cultivated a variety of row crops providing similar low-structure habitat for birds; some farms grew additional crop types, such as orchard fruits, flowers, or wine grapes.

2.2. Bird point counts

Two experienced observers performed point counts on each farm once per month between May and August 2012. As all of the farms used in this study were relatively small (and often encompassed only one or two fields), we established a single point count site at each farm at a field edge (see Freemark and Rogers, 1995). We placed each point count site along the field edge closest to bird "source" habitat defined first as riparian habitat, second as forest, or third as mature hedgerow or tree line. When farms had multiple fields, we chose the field closest to bird "source" habitat as defined above. The majority of hedgerows were made up of blackberry bramble (*Rubus armeniacus*), and tree lines varied by farm and included coniferous and/or deciduous trees. All point count sites were pooled in analyses regardless of adjacent source habitat type.

Bird point counts followed the unlimited distance dependent double-observer method in order to calculate detection probability (Forcey et al., 2006; Nichols et al., 2000). The observers recorded each bird detected (either visually or aurally) as either less than or greater than 50 m from the point count site. In order to assess habitat use, we recorded whether each bird detected was in row crop, cultivated, hedgerow, natural habitat, unknown habitat, or a flyover. Cultivated habitat was defined as non-row crop cultivated land, such as orchards, vineyards, or pasture/fodder, while natural habitat was defined as any uncultivated areas including riparian and forested areas bordering the farms. If an individual bird used multiple habitat categories, we prioritized recording first whether they were in row crop or second in cultivated habitats. The observers completed the point counts for all farms within the span of six days per month, and within 3 h of dawn. All point counts were conducted on days without strong winds or rain.

We used program DOBSERV (Hines, 2000) to estimate avian abundances for each farm based on detection probabilities calculated from the double-observer point count method. We used species' proportional abundances to calculate a Shannon–Wiener diversity index for each farm for use as a predictor variable (Gotelli and Ellison, 2013). We also used these abundances to create a predictor variable describing the summed abundance of each bird species confirmed to be sentinel pest predators by motion activated camera footage ("key predator abundance").

2.3. Sentinel pest experiment

The speed and magnitude of avian response to an ecosystem change may be measured using "sentinel pest" experiments, which not only make pests more abundant, but also more available to predators. We used sentinel pest experiments to simulate the start of an lepidopteran pest outbreak to determine rate of insect removal by birds for each farm (*sensu* Perfecto et al., 2004). We performed all sentinel pest experiments within nine days at the end of June 2012, ensuring that they would all be completed within the peak bird breeding season.

We used kale (*Brassica oleracea*, Acephala Group) as a focal crop for both sentinel pest experiments and exclosure experiments as it is a widely grown row crop in our study area and may host many species of lepidopteran pests (e.g., *Pieris rapae, Trichoplusia ni, Plutella xylostella*, etc.). Kale is a specialty food crop: in 2012 kale represented only 0.1% of the total area of vegetables harvested in CA ("USDA: National Agricultural Statistics Service," 2012). However, in 2001, kale production in California brought in $9.8 million, and cultivation of kale is rapidly increasing, with a 56.6% increase in acres of kale harvested in the United States between 2007 and 2012 (USDA: National Agricultural Statistics Service, 2012).

Each pest presentation station consisted of two third or fourth instar cabbage looper (*T. ni*) caterpillars attached to the dorsal surface of a Lacinato kale (*B. oleracea*) leaf placed in a water pick (a plastic water vial used in the floral industry). The caterpillars were affixed to the leaf using a dot of cyanoacrylate adhesive at the posterior end of the abdomen, allowing the caterpillars a degree of natural movement. We placed 20 pest presentation stations on