Agriculture, Ecosystems and Environment 183 (2014) 11–20

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Responses of predatory invertebrates to seeding density and plant species richness in experimental tallgrass prairie restorations

Kristine T. Nemec[a,*], Craig R. Allen[b], Stephen D. Danielson[c], Christopher J. Helzer[d]

[a] Nebraska Cooperative Fish and Wildlife Research Unit, University of Nebraska, 422 Hardin Hall, 3310 Holdrege Street, Lincoln, NE 68583, USA
[b] U.S. Geological Survey-Nebraska Cooperative Fish and Wildlife Research Unit, University of Nebraska, 423 Hardin Hall, 3310 Holdrege Street, Lincoln, NE 68583, USA
[c] Department of Entomology, University of Nebraska, 212 Entomology Hall, Lincoln, NE 68583, USA
[d] The Nature Conservancy, Eastern Nebraska Project Office, P.O. Box 438, Aurora, NE 68818, USA

ARTICLE INFO

Article history:
Received 13 May 2013
Received in revised form 10 October 2013
Accepted 17 October 2013
Available online 16 November 2013

Keywords:
Grassland restoration
Tallgrass prairie
Predatory invertebrates
Natural enemies
Plant richness
Ecosystem services

ABSTRACT

In recent decades, agricultural producers and non-governmental organizations have restored thousands of hectares of former cropland in the central United States with native grasses and forbs. However, the ability of these grassland restorations to attract predatory invertebrates has not been well documented, even though predators provide an important ecosystem service to agricultural producers by naturally regulating herbivores. This study assessed the effects of plant richness and seeding density on the richness and abundance of surface-dwelling (ants, ground beetles, and spiders) and aboveground (ladybird beetles) predatory invertebrates. In the spring of 2006, twenty-four 55 m × 55 m-plots were planted to six replicates in each of four treatments: high richness (97 species typically planted by The Nature Conservancy), at low and high seeding densities, and low richness (15 species representing a typical Natural Resources Conservation Service Conservation Reserve Program mix, CP25), at low and high seeding densities. Ants, ground beetles, and spiders were sampled using pitfall traps and ladybird beetles were sampled using sweep netting in 2007–2009. The abundance of ants, ground beetles, and spiders showed no response to seed mix richness or seeding density but there was a significant positive effect of richness on ladybird beetle abundance. Seeding density had a significant positive effect on ground beetle and spider species richness and Shannon–Weaver diversity. These results may be related to differences in the plant species composition and relative amount of grass basal cover among the treatments rather than richness.

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1. Introduction

Predatory invertebrates play an important role in regulating insect pest populations within agroecosystems. Natural regulation of agricultural pests by invertebrate predators and parasites is an ecosystem service estimated to provide 5–10 times more control of pest species than industrially produced pesticides (Pimental et al., 1992) and is valued at $4.5 billion annually in the United States (Losey and Vaughan, 2006). Invertebrate predators that may reduce the densities of herbivorous insects in cropland include spiders (Araneae) (Laub and Luna, 1992; Lang et al., 1999; Maloney et al., 2003), ground beetles (Coleoptera: Carabidae) (Lang et al., 1999; McCravy and Lundgren, 2011), ants (Hymenoptera: Formicidae) (Way and Khoo, 1992; Choate and Drummond, 2011), and ladybird beetles (Coleoptera: Coccinellidae) (Obrycki and Kring, 1998).

In the Midwestern United States, there is a positive relationship between crop pest abundance and the proportion of cropland in a county (Meehan et al., 2011). Because patches of natural or semi-natural non-crop habitats (e.g., hedgerows, field margins, grassland and woodland) are recognized to be important sources of food, shelter, and overwintering habitat for predatory invertebrates in agroecosystems, restoring habitats on former cropland can increase local habitat heterogeneity, the abundance of predatory invertebrates, and the provision of pest control within an agroecosystem (Bianchi et al., 2006; Rusch et al., 2010; Pywell et al., 2011). One of the rarest habitats within North American agroecosystems is native (unplowed) northern tallgrass prairie, which since the late 1800s has been largely converted to cropland and covers less than 3% of its pre-settlement extent (Samson and Knopf, 1994). Thousands of hectares of tallgrass prairie have been restored in the central United States in the last few decades using mixtures of native grasses and forbs, with a focus on restoring ecosystem services such as soil retention, improved water quality, and

* Corresponding author at: USDA-ARS, North Central Agricultural Research Laboratory, 2923 Medary Avenue, Brookings, SD 57006, USA. Tel.: +1 605 693 5251
E-mail addresses: kristinenemec14@gmail.com (K.T. Nemec), callen3@unl.edu (C.R. Allen), sdanielson1@unl.edu (S.D. Danielson), chelzer@tnc.org (C.J. Helzer).

0167-8809/$ – see front matter. Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.agee.2013.10.024

provision of habitat for wildlife such as birds, butterflies, mammals, and herpetofauna (Dunn et al., 1993; Packard and Mutel, 1997). The predatory invertebrate communities of these restorations have received less attention even though restorations may provide a valuable ecosystem service of pest control.

Initial studies indicate tallgrass prairie can provide valuable habitat for some predatory invertebrates such as ground beetles. In a comparison of ground beetle assemblages in six different habitats (tallgrass prairie, oats, corn, soybean, old-field, and woods) at four sites in northeastern Iowa, tallgrass prairie hosted a significantly more diverse assemblage of ground beetles than was found in the other habitats (Larsen et al., 2003). Prairie also had a higher percentage of habitat specialists in its assemblage than did the less stable agricultural habitats, which were dominated by generalists.

In two recent studies, Davis and Utrup (2010) and Orlofske et al. (2011) assessed the invertebrate communities of tallgrass prairie restorations, including some predator families. Davis and Utrup found no difference in total invertebrate abundance, family richness, or richness of invertebrates between low- and high-richness plantings of varying sizes and ages in south-central Nebraska. Similarly, Orlofske et al. (2011) found no significant difference in invertebrate abundance and species richness among remnant and restored prairies in Iowa. In both studies, specimens were not identified beyond the family level. To our knowledge, no studies have compared the abundance of predatory invertebrates within experimental tallgrass restorations created with methods typically used to restore prairie in the region. Such an approach may help identify seed mixes that are most effective in attracting predatory invertebrates.

Determining the appropriate seeding density and plant species richness to use in seed mixes is important because these factors affect the plant community and soil characteristics of the restoration, which in turn influences the invertebrate community. For example, high plant species richness in grasslands has been associated with high plant biomass (Hector et al., 1999; Spehn et al., 2000) and greater diversity of plant structures, which increases the availability of microhabitats and limiting resources to invertebrates (Joern and Laws, 2013). In addition, the density of vegetation can affect the densities of invertebrates within a habitat by affecting food resources and the amount of bare ground cover, which influences microclimate (Arnan et al., 2007). Soil moisture has been found to affect oviposition, larval survival, and within-field distribution of ground beetles (Holland et al., 2007). However, the effect of the plant community on soil is not clear as studies have found no significant relationship between plant richness, soil moisture, and soil temperature in grasslands (Porazinska et al., 2003; Dias et al., 2010).

In this study we evaluated the effect of seeding density and plant species richness on grassland invertebrates. We compared the abundance and richness of predatory invertebrates in 55 m × 55 m-research plots seeded with a low richness tallgrass prairie seed mix commonly used in central Nebraska (15 species representing a typical Conservation Reserve Program (CRP) mix used by the Natural Resources Conservation Service, or NRCS, the CP25 mix), at low and high seeding densities, and a high richness mix (97 species typically planted by The Nature Conservancy), at low and high seeding densities. Although high richness seed mixes or high seeding densities can cost up to five to ten times as much as low richness or low seeding densities, little information is available on the benefits that may result from the added richness or seeding density.

We assessed the abundance and richness of four groups of predatory invertebrates: ants, ground beetles, spiders, and ladybird beetles that were identified to species or the lowest taxonomic level feasible and grouped into feeding guilds. Although both omnivorous and carnivorous invertebrates can be effective in pest control (Hunter, 2009) and are encompassed by the term "predatory invertebrates" in this paper, feeding guilds may respond differently to habitat manipulation (Harvey et al., 2008). We tested three null hypotheses: (1) the abundance of ant, ground beetle, spider, and ladybird beetle feeding guilds will not differ among the four treatments; (2) the richness and Shannon–Weaver diversity of ant, ground beetle, spider, and ladybird beetle feeding guilds will not differ among the four treatments; and (3) there is no correlation between plant community characteristics and invertebrate abundance, richness, and Shannon–Weaver diversity.

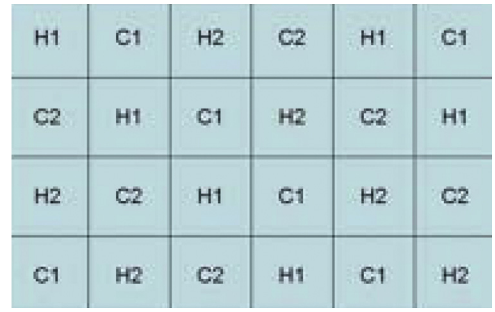

Fig. 1. Layout of the treatments applied to 55 m × 55 m plots in the study (C1 = low richness seed mix, low seeding density; C2 = low richness seed mix, high seeding density; H1 = high richness seed mix, low seeding density; H2 = high richness seed mix, high seeding density).

2. Methods

2.1. Study area

The study area lies within the central Platte River ecosystem, which includes the Platte river channel and floodplain from mid-Dawson County to mid-Hamilton County in central Nebraska (NGPC, 2005). The Nebraska Game and Parks Commission has determined the central Platte River to be a biologically unique landscape (NGPC, 2005). The region has a continental climate, with warm, wet summers and cold, dry winters. Mean annual air temperature is 10.4 °C and mean annual precipitation is 63.9 cm (High Plains Regional Climate Center, 2010).

The study site is located approximately 10 km south of Wood River, Nebraska (Hall County; 40°44′41″ N, 98°35′11″ W) on a 7.3-ha field owned by TNC. Soils at the site are of loamy alluvium or sandy alluvium parent material and include Wann loam, rarely flooded; Caruso loam rarely flooded; and Bolent–Calamux complex, occasionally flooded (NRCS, 2010). The site is bordered to the south and east by county roads and TNC prairie restorations, to the west by a cornfield, and to the north by trees and the Platte river. The study site was under cultivation in a corn–soybean rotation in the decades prior to the experiment.

2.2. Treatments and experimental design

In late March and early April 2006, the 7.3-ha field was cultivated and divided into 24, 0.30-ha plots (55 m × 55 m). The plots were seeded from an all-terrain vehicle (ATV) and a John Deere drop spreader according to a 2 × 2 factorial design, in which two levels of richness (low plant richness and high plant richness) were applied using two different seeding densities (low and high seeding rates). The experiment was arranged in a systematic design, with six columns running west to east across the field and each column containing four plots assigned to the four treatments (Fig. 1). The treatments were applied systematically instead of randomly in order to facilitate seeding with the drop spreader. Treatments consisted of: (1) a low richness CRP tallgrass prairie seed mix (CP25 mix, 15 species) used by the NRCS seeded at half the recommended