Crop Protection 108 (2018) 1–11

Contents lists available at ScienceDirect

Crop Protection

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

Impact of field-edge habitat on mammalian wildlife abundance, distribution, and vectored foodborne pathogens in adjacent crops

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ARTICLE INFO

Keywords:
Field-edge habitat
Foodborne pathogens
Food safety
Lagomorph
Mammalian wildlife
Rodents

ABSTRACT

Field-edge habitat is important for enhancing biodiversity and associated ecosystem services on farms for long term agricultural sustainability. However, there is some concern that this habitat will increase wildlife activity and damage to adjacent crops. Wildlife incursion into production areas may also pose food safety risks. A two-year study in walnut orchards and processing tomato fields in the Sacramento Valley, California, documented variable use of farm fields by mammalian wildlife. This depended on field-edge habitat (restored hedgerows versus conventionally managed field edges where vegetation was mostly controlled), wildlife species present, season, and crop monitored. In walnut orchards, deer mice (*Peromyscus maniculatus* Wagner, 1845) were found throughout the orchard, while house mice (*Mus musculus* Linnaeus, 1758) exclusively used hedgerows. In tomato fields, deer mice were more common in field interiors during spring, but used field-edge habitats more during summer; the opposite was true for house mice. In general, deer mice preferred more open sites, while house mice were most numerous in areas with thick cover. Both desert cottontails (*Sylvilagus audubonii* Baird, 1858) and black-tailed jackrabbits (*Lepus californicus* Gray, 1837) showed affinity to hedgerow portions of fields, although this association was stronger for cottontails. Overall, we documented greater mammalian species richness and abundance associated with hedgerows. However, this increase in diversity did not generally lead to greater wildlife incursion into adjacent crops. In walnut orchards, *Salmonella* and non-O157 STEC were detected from 2 (1%) and 4 (2%) individual rodents, respectively ($n = 218$); no detections occurred in tomato fields. A subset of fecal samples ($n = 87$) from rodents captured in walnut orchards were positive for *Giardia* (25%) and *Cryptosporidium* (24%) but prevalence was not associated with field-edge habitat type. Overall, there does not appear to be a substantially greater risk of crop loss or contamination of foodborne pathogens in crops bordered by hedgerows in our study in the Sacramento Valley, although potential damage could vary by the stage and type of crop and wildlife species present.

1. Introduction

A challenge in the 21st century is to produce food for our growing population, while at the same time, protecting and sustaining our natural resources (Millennium Ecosystem Assessment, 2005). The planting of robust field-border habitats (e.g., hedgerows) is a management practice that has been gaining popularity for enhancing biodiversity on farmlands (Long et al., 2017). These narrow strips of vegetation, often referred to as hedgerows, are planted along crop edges so that no land is taken out of production (Long and Anderson, 2010). Benefits of hedgerows include enhanced pollination and arthropod pest control in adjacent crops, water quality protection, and habitat for birds (Zhang et al., 2010; Morandin et al., 2016; Rusch et al., 2016; Heath et al., 2017). There is significant policy support behind these plantings through funding from the United States Department of Agriculture (NRCS, 2017; USDA, 2017). However, despite the benefits of hedgerows and financial support, few landholders (growers and landlords) adopt bio-diverse field edges. One reason is the perceived risk of increased damage from wildlife (especially rodents) using these habitat plantings and the potential for transfer of zoonotic enteric foodborne pathogens

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https://doi.org/10.1016/j.cropro.2018.02.005
Received 6 December 2017; Received in revised form 3 February 2018; Accepted 5 February 2018

to human food crops by rodent fecal contamination (Jay-Russell, 2013; Karp et al., 2015a; Garbach and Long, 2017). As a result, some landholders have removed habitat on their farms to try to reduce food safety risks, especially following a nationwide outbreak of *Escherichia coli* O157:H7 associated with baby spinach grown in the California Central Coast (Beretti and Stuart, 2008). Since that time, the leafy greens industry and others have adopted a "co-management" strategy to balance food safety and conservation goals during produce production (Bianchi and Lowell, 2016). However, it still remains unclear how habitat modification, including use of hedgerows, may impact food safety risks from wildlife using these agricultural areas.

Mammalian wildlife can be serious agricultural pests, causing millions of dollars in crop losses (Witmer and Singleton, 2010; Gebhardt et al., 2011). Rodents, including mice, voles, and ground squirrels, are some of the most troublesome, as they feed on crops, causing significant yield and quality losses. They also burrow into fields and levees and chew on drip irrigation lines, disrupting and destroying irrigation systems (Baldwin et al., 2014b). Other wild mammals, including wild pigs (*Sus scrofa* Linnaeus, 1758), deer (*Odocoileus* spp.), jackrabbits (*Lepus* spp.), and cottontails (*Sylvilagus* spp.), can likewise either feed on and/or tear up crops, further reducing yields (Baldwin et al., 2014b; Anderson et al., 2016). Mammalian wildlife are also known to be vectors of foodborne pathogens that can cause severe human disease outbreaks (Jay et al., 2007; Laidler et al., 2013). Two groups of pathogens, Shiga toxin-producing *E. coli* (STEC) and *Salmonella enterica,* are responsible for the majority of the bacterial outbreaks in fresh produce (Doyle and Erickson, 2008). Both pathogens are carried by domestic animals (e.g., cattle) and wildlife. However, whereas *S. enterica* is readily isolated from many wildlife hosts (Winfield and Groisman, 2003; Gorski et al., 2011), STEC is generally more prevalent in cattle than in wildlife (Cooley et al., 2013). Other pathogens shed by mammalian wildlife that are more associated with waterborne exposure include the parasites *Giardia* spp. and *Cryptosporidium* spp. (Kilonzo et al., 2013). These may be a concern, particularly when fields are close to streams or irrigation canals.

Managing mammalian vertebrate pests in agricultural systems can include trapping, baiting, shooting, frightening, fencing, and the removal of non-crop habitat around farms (Van Vuren and Smallwood, 1996; Fall and Jackson, 1998; Baldwin et al., 2014b). Although these practices can be effective depending on the vertebrate pest and situation, habitat removal is controversial and with questionable efficacy for several reasons. First, vegetation is critical for providing ecosystem services on farms; filter strips, for example, help protect water quality from pathogens and other sediment associated pollutants (Atwill et al., 2006; Tate et al., 2006; Long et al., 2010). Without habitat, our natural resources degrade, leading to questions about long-term farm sustainability (Tilman, 1999; Hobbs, 2007; Geertsema et al., 2016). Second, wildlife may provide crop protection benefits from arthropod pests. For example, Kross et al. (2016) found greater insect pest control by bird species in alfalfa fields when complex field-edge habitats were present; bats likewise prey on many agricultural pests (Boyles et al., 2011). Third, there is limited information indicating a positive impact of managing habitat for controlling food pathogens. For example, Karp et al. (2015b) found an increase in food pathogens when habitat was reduced on farms. Speculation for this increase included the importance of vegetation for filtering foodborne pathogens, a better breakdown of pathogens in diverse environments, and that removing vegetation may not deter wildlife from entering farm fields.

In this study, we investigated the association between field-edge habitat, mammalian wildlife, and foodborne pathogens in orchard and row crops. Our objectives were to determine: 1) if mammalian wildlife abundance and richness in crops is influenced by field-edge habitat, 2) if certain habitat features influence the occurrence of mammalian wildlife, and 3) if foodborne pathogen prevalence in rodents is impacted by field-edge habitat. These results will provide much needed information to inform the agricultural industry about the potential impact of field-edge habitat plantings on wildlife and associated food safety concerns, hopefully allowing producers to balance their ability to maintain biodiversity on farmlands with the need to limit wildlife crop damage and food safety risk.

2. Materials and methods

2.1. Study area

This study was conducted in Yolo and Solano County in California's Sacramento Valley. The study area was intensively farmed, primarily with tree crops such as almonds and walnuts, as well as rotational field crops such as wheat, processing tomato, alfalfa, and seed crops including sunflower. The average size farm in these counties was about 182 ha with a market value of products sold averaging $400,000. There were 860 farms in Solano County and 1011 farms in Yolo County (Garbach and Long, 2017). This region was characterized by hot, dry summers and cool, wet winters (i.e. Mediterranean climate).

Our study sites included 4 walnut orchards and 5 processing tomato fields with each site approximately 32 ha in area. One side of each field had a hedgerow of California native shrubs and perennial grasses that was approximately 7 m wide × 448 m in length and 10–20-years old. The shrubs mainly included California buckwheat (*Eriogonum fasciculatum* var. *foliolosum* Nutt.), California lilac (*Ceanothus griseus* [Trel.] McMinn), California coffeeberry (*Rhamnus californica* Eschsch.), coyote brush (*Baccharis pilularis* DC.), elderberry (*Sambucus nigra* L.), and toyon (*Heteromeles arbutifolia* [Lindl.] M. Roem.). The other three sides of the fields were conventionally managed for weed control by discing, mowing, and/or the use of herbicides. The field edge on the opposite side of the hedgerow served as our control (minimum of 400 m from the hedgerow). The fields were generally surrounded on all four sides by other crop fields, but for a few sites (2 in walnuts, 1 in tomatoes), a creek ran along one side of the fields. These creeks were located on a field edge perpendicular to the hedgerow and control field edges, equilibrating any potential impact the creeks may have had on mammal response to hedgerow and conventionally managed field edges. Within the crops, weeds were managed similarly to the conventionally managed field edges. Vine training, to open the furrows for harvest, occurred once in each of the tomato fields. No active management for vertebrate species occurred during our study period.

2.2. Small rodent and lagomorph sampling

We monitored small rodent (deer mouse [*Peromyscus maniculatus* Wagner, 1845], house mouse [*Mus musculus* Linnaeus, 1758], western harvest mouse [*Reithrodontomys megalotis* Baird, 1858], California vole [*Microtus californicus* Peale, 1848], Norway rat [*Rattus norvegicus* Berkenhout, 1769], and roof rat [*Rattus rattus* Linnaeus, 1758]) activity seasonally in both walnut orchards (summer, autumn, winter, spring; July 2013 through May 2014) and tomato fields (spring and summer; May through July 2015) with Sherman live traps (HB Sherman Traps, Inc. Tallahassee, Florida, USA; Fig. 1). Trap transects were set at 0, 10, 75 and 175 m from both the conventional and hedgerow field-edge treatments into the adjacent crops. We placed two transects of 10 traps at each distance interval with traps spaced at 10-m intervals; all transects within each distance category were separated by a minimum of 30 m to minimize the likelihood of capturing the same rodent in paired transects. We baited all traps with peanut butter and rolled oats, and we added cotton bedding to provide nesting material and to capture fecal pellets voided during nesting. To minimize daytime exposure, we set traps in the evening before sunset and checked and closed all traps early the following morning for 5 consecutive nights per field site. We identified species, sexed, weighed, and ear tagged (Model 84FF, Salt Lake Stamp Co. Salt Lake City, Utah, USA) all trapped rodents to differentiate between unique and recaptured individuals; all rodents were released at the point of capture.