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Spatio-temporal distribution of stored-product insects around food processing and storage facilities

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ABSTRACT

Grain storage and processing facilities consist of a landscape of indoor and outdoor habitats that can potentially support stored-product insect pests, and understanding patterns of species diversity and spatial distribution in the landscape surrounding structures can provide insight into how the outdoor environment can be more effectively monitored and managed. The spatial and temporal distribution of stored-product pests was assessed at three food processing facilities using two types of traps and the influence of landscape features on their outside distribution was evaluated. For corrugated traps, targeting walking individuals, placed both inside and outside facilities, the predominant groups, accounting for 59% of captures, were *Cryptolestes* spp. (Coleoptera: Laemophloeidae), *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) and *Sitophilus* spp. (Coleoptera: Curculionidae). Numbers captured in outside corrugated traps tended to be less than captures inside structures, and while level of species diversity was similar fungal feeding species were more common in outside traps. In outside corrugated traps, *Cryptolestes* spp., *Typhaea stercorea* (L.) (Coleoptera: Mycetophagidae) and *O. surinamensis* were most abundant and in outside Lindgren traps that targeted flying individuals, *T. stercorea*, *Cryptolestes* spp. and *Ahasverus advena* (Waltl) (Coleoptera: Silvanidae) were most abundant. No correlation was observed between total captures and species diversity between inside and outside traps. Distribution of stored-product insects in corrugated traps tended not to be spatially clustered (Global Moran's *I* values ranged from −0.25 to 0.22). However, Anselin local Moran's *I* indicated that at local level some traps with greatest captures had traps in the vicinity with similar values, but these specific locations were temporally variable. Landscape around each outside corrugated trap was characterized, and increased captures were associated with proximity to grain storage or processing structures, but not with presence of spillage as originally hypothesized. Overall, results support hypothesis that there is considerable movement of insects in landscape surrounding facilities, resulting in limited spatial pattern other than temporally variable hot spots inside or near structures.

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1. Introduction

Food processing facilities where grain is stored and processed after harvest are human dominated environments consisting of multiple buildings and storage structures situated within a broader urban and agricultural landscape mosaic. Both interior and exterior patches in this landscape can be populated by a diverse community of arthropods. Approximately 1660 insect species in the orders Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera and Psocoptera are associated with stored-products, including species that are granivores, fungivores, omnivores, and natural enemies (Hagstrum and Subramanyam, 2009). In general, research on monitoring and management of stored-product pests has focused on populations inside the structure of the building or grain in a storage bin. However, stored-product insects have been readily captured outside of structures (Throne and Cline, 1989, 1991; Fields et al., 1993; Dowdy and McGaughey, 1994, 1998; Doud and Phillips, 2000; Likhayo and Hodges, 2000; Campbell and Arbogast, 2004; Campbell and Mullen, 2004; Trematerra et al., 2004; Kučerová et al., 2005; Campbell et al., 2006), and immigration of insects into facilities

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can have a significant impact on monitoring and pest management programs (Campbell and Arbogast, 2004; Toews et al., 2006).

Sources of stored-product insects recovered outside can be individuals dispersing from other structures containing stored-products, either short-range dispersal from other structures on site or long-range dispersal from other locations, or food material accumulations in the landscape surrounding structures. Grain spillage and residues inside grain elevators are exploited by stored-product pests (Kučerová et al., 2003; Reed et al., 2003; Arthur et al., 2006), and while it is likely that they also exploit outside spillage the evidence is more limited (Kučerová et al., 2005). Examples of outside spillage include whole grain accumulations near unloading areas, dust and other excess material from processing that is blown out of facilities and accumulates in areas outside, trash containers and excess equipment stored outside which contains residual food material. The persistence of these outside food accumulations and their quality as resources for specific stored-product pest species is likely to be highly variable. These outside food patches can be exploited by stored-product insects as locations for reproduction or provide food and shelter for dispersing adults and thus attract dispersing adults into the proximity of structures. The potential importance of sanitation programs to eliminate these outside food accumulations has been widely acknowledged in food industry pest management programs, but the association of stored-product insects with spillage accumulations or other features of the landscape outside of structures has not been evaluated.

Basic structural characteristics of the landscape can affect species abundance and distribution (Turner, 1989; Wiens, 1997; French et al., 2004), and the abundance and distribution of stored-product insects outside food facilities is also likely to be affected by the landscape at a food facility (Trematerra et al., 2004). The landscape immediately outside of structures at a food facility can consist of a mosaic of pavement, gravel, and plantings of grass and ornamentals, surrounded in turn by a broader landscape of urban development, agricultural fields, and natural habitats. The distribution of food spillage outside and proximity to structures containing grain and processed commodities are the most likely landscape features that will impact the number and distribution of stored-product insects outside. However, where outside spillage accumulates and how rapidly the spillage is degraded are likely to influence its suitability as a resource for a given species. Degradation of food material with increased moisture and fungal growth may favor exploitation by fungivore stored-product insects and reduce exploitation by species such as *Cryptolestes* spp. and *Sitophilus* spp. often found associated with spillage inside grain elevators (Reed et al., 2003; Arthur et al., 2006). Variation in other environmental and physical features may also influence stored-product insect distribution through different mechanisms such as providing shelter and encouraging food accumulation. For example, higher temperature and flour dust accumulation have been shown to be associated with *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) distribution inside a flour mill (Semeao et al., 2012a). Different stored-product pests were shown to have different patterns of spatial distribution outside a rice storage facility (Trematerra et al., 2004). A practical benefit from knowing the distribution of the community of stored-product pests outside storage and processing facilities, and the relationship between distribution and features in the landscape is that it can help managers target outside monitoring and pest management tactics in order to reduce the risk of immigration into facilities.

One of the major pests in wheat and rice mills worldwide is the red flour beetle, *T. castaneum* (Sokoloff, 1974). The distribution of *T. castaneum*, and to a lesser extent that of *Tribolium confusum* Jacquelin du Val, inside structures such as flour mills, warehouses, and retail stores has been studied (Ho and Boon, 1995; Campbell et al., 2002; Trematerra and Sciarretta, 2004; Semeao et al., 2012a; Trematerra et al., 2007). Response of *T. castaneum* populations to structural fumigations of wheat mills has suggested that populations are relatively self-contained within individual structures (Campbell and Arbogast, 2004; Toews et al., 2006; Small, 2007; Campbell et al., 2010a,b), although the potential for movement of beetles from either outside sources or from other structures in the proximity of the facility exists. *T. castaneum* has been captured outside both in the proximity of, and far from, food facilities (e.g., Sinclair and Haddrell, 1985; Dowdy and McGaughey, 1994; Subramanyam and Nelson, 1999; Trematerra et al., 2004; Daglish et al., 2010; Ridley et al., 2011). Recent population genetic studies indicate greater potential for *T. castaneum* gene flow between facilities than previously suspected (Drury et al., 2009; Ridley et al., 2011; Semeao et al., 2012b), which suggests that a better understanding of outside activity of this species is needed.

Due to the lack of information showing patterns of spatial distribution of stored-product pests in food processing facility landscapes, the objectives of this study were: (1) evaluate the species composition and spatial and temporal distribution patterns of stored-product pests at three grain processing and storage facilities, and (2) determine which features of the exterior landscape influence outside insect distribution patterns. Two types of traps were utilized that targeted walking and flying individuals, respectively, and allowed potentially different spatial scale in movement patterns to be detected. Because the two traps were only baited with grain, with the exception of *T. castaneum* pheromone in the walking insect trap, a less biased estimation of species diversity and spatial pattern can be obtained than in previous studies that have relied on pheromone baited trapping.

2. Materials and methods

2.1. Study sites

This study was conducted at three sites (herein coded as site A, B, and C) located in the central USA (Figs. 3A, 4A, and 5A). Site A is a commercial processing facility and contains multiple buildings including a five-floor flour mill (~4531 m^3) with attached elevator with concrete silos, warehouse and packaging building, small metal three-floor feed mill, variety of office and storage shed buildings, a second grain elevator with concrete silos, one large metal bin, and two ground bunker storage locations. Surrounding these structures the landscape primarily consisted of areas of gravel and mown grass within the property line of the facility. Accumulations of food spillage consisting of wheat and corn kernels, chaff, and flour dust were observed in areas near the mill and grain elevators. The property is bordered by residential areas, a paved road and agricultural fields. Site B is small feed mill (~280 m^2) composed of one metal building used for processing animal feed which has large doors that are often open allowing for easy movement into and out of the facility. In the proximity of the feed mill, there are 20 metal bins in which either grain (primarily corn) or processed feed are stored. The landscape around the feed mill is primarily gravel and grass, with the site bordered by paved roads and an open field. Site C (Kansas State University, Hall Ross Flour Mill) is a relatively new concrete pilot-scale flour mill (2044 m^2) composed of five floors. In the proximity of the mill, there are eight metal storage bins. The facility is designed for research and education purposes and does not operate continuously. The area immediately surrounding the building is composed primarily of grass lawn, brush and open field, and paved areas.