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Distribution, abundance, and seasonal patterns of stored product beetles in a commercial food storage facility

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ABSTRACT

A three-year monitoring study was performed using pitfall traps baited with pheromone lures and food oil to assess seasonal prevalence of selected stored product beetle species inside a large community food storage warehouse located in the Midwestern United States. The four predominant species captured were *Tribolium castaneum*, *Lasioderma serricorne*, *Oryzaephilus surinamensis*, and *Trogoderma variable*. During the first year, *T. castaneum* was the dominant species, comprising 79% of all beetles caught in the traps. This species declined the next year to 2% of the total and *L. serricorne*, *O. surinamensis*, and *T. variable* were the dominant species. During the final year total numbers of these three species declined, but they were still the primary species caught in the traps. Few or no beetles of any species were trapped between November and June in any year, most likely because of lower temperatures inside the warehouse during that time. Beetle captures among trap locations varied considerably during the study, probably due to movement of food products into and out of the warehouse, and movement of products and beetle populations within the warehouse. All four primary species were also consistently caught in traps placed in zones within the warehouse where no food products were stored. Specific traps and zones within the warehouse were identified as primary activity sites based on comparisons among trap locations and contour mapping of the yearly and total infestation patterns. Results show how monitoring data could be used to identify those areas within a food storage site that are most vulnerable to insect infestation.

1. Introduction

Stored product beetles can be important economic pests of packaged food products in warehouses, distribution centers, retail stores, and consumer pantries. The red flour beetle, *Tribolium castaneum* (Herbst), a ubiquitous pest of flour mills, is also found in food production facilities and storage warehouses (Campbell et al., 2002; Campbell and Arbogast, 2004). Another major pest species of packaged food products is the sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.). This species responds to food odors emanating from packages, and both adult and immature stages can invade packages by entering through flaws or openings in the packages (Mowery et al., 2002, 2004). The cigarette beetle, *Lasioderme serricorne* (F.), is a major pest of stored tobacco, but has a broad host range and also infests packaged foods. Like *O. surinamensis*, this species has been demonstrated to respond to odors emanating from different food sources (Mahroof and Phillips, 2007, 2008). The warehouse beetle, *Trogoderma variable* (Ballion), is another species that can often be found in and around food production and warehouse facilities (Campbell et al., 2002; Campbell and Mullen, 2004; Larson et al., 2008).

Stored product beetles vary in flight ability so monitoring using traps that target walking beetles can be more representative of insect abundance and diversity (Campbell et al., 2002). Adult *O. surinamensis* do not fly, but are capable of walking and climbing (Rees, 2004). Historically, *T. castaneum* has been considered a weak flyer with limited dispersal capability; however, recent studies indicate a strong tendency to fly under certain conditions (Perez-Mendoza et al., 2011a,b) and in long range dispersal (Ridley et al., 2010). *Lasioderma serricorne* is a strong flyer and highly mobile, and has been postulated to disperse from food storages to other habitats in the field (Shinoda and Fujisaki, 2001). *Trogoderma variable* is another highly mobile species; mark-recapture trapping studies show capability for extensive dispersal within and around facilities (Campbell et al., 2002; Campbell and Mullen, 2004). Monitoring programs often incorporate the use of pitfall traps

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placed on a flooring surface. Adult beetles have to climb on a roughened surface to enter the trap, which can be baited with lures impregnated with either a sex or aggregation pheromone, depending on the insect species. Kairomone attractants are also often used, either as a solid or oil and these can act as a general attractant. Lures that contain synthetic female sex pheromones to attract males are commercially available in the US for both *L. serricorne* and *T. variable*. Males of *T. castaneum* produce aggregation pheromone that attract both sexes, and lures are commercially available, although the attractiveness of this aggregation pheromone can be limited (Campbell, 2012). Commercial pheromones are not available for *O. surinamensis*, so the kairomone attractant is important for increasing capture of this species (Pierce et al., 1990).

We previously described results from a monitoring program for *Plodia interpunctella* (Hübner), the Indianmeal moth, inside a food storage warehouse (Arthur et al., 2013). Aerial wing traps baited with female sex pheromone were placed at 52 positions, and adult males were trapped throughout the warehouse, including in locations where there was little or no stored food products. Although infestation foci were difficult to determine because of nearly constant movement of foods into and out of the site, and also within the site, specific high-risk locations were identified. Beetle infestations are hypothesized to be more localized, and pitfall traps are expected to attract adults from a more limited area compared to the flight traps for adult moths. Optimal placement of pheromone traps for sampling stored product beetles in a food warehouse is often based on recommendations by manufacturers, similar to instructions for deployment of traps for *P. interpunctella*. However, analysis of trends in *P. interpunctella* captures indicated that an optimal trap density and placement could be identified. Here we took a similar approach in evaluating beetle captures in the same warehouse facility over the same multi-year period as described in Arthur et al. (2013). The objectives of this study were to: 1) determine distribution of *T. castaneum*, *L. serricorne*, *O. surinamensis*, and *T. variable* inside a food warehouse, 2) determine if consistent infestation foci could be identified during a multi-year trapping period, and 3) determine feasibility of a targeted program for beetle trapping inside a food storage facility.

2. Materials and methods

This study was conducted in a warehouse, with four distinct areas, Areas 1, 2, 3, and 4 (Fig. 1), with layout and trap locations previously described in Arthur et al. (2013). Briefly, this was a large stored food warehouse that served a network of community food banks in a Midwestern metro area. Monitoring began on 22 June of 2005 and concluded on 4 April 2008. Beetles were monitored using Dome™ traps (Trece, Adair, OK, USA). These traps have three prongs on the underside of the top surface for attachment of pheromone lures. During the first year of monitoring, 48 traps were placed in the facility. Briefly, 12 traps were placed in Area 1. Traps 1–8 were evenly placed on the floor adjacent to the side walls, while traps 9–12 were adjacent to the side walls but more aggregated due to the presence of stacked goods in the vicinity. In Area 2, 18 traps were placed on the floor underneath the bottom shelf about 0.3 m from the aisle at the approximate same positions as described for the *P. interpunctella* traps, while traps 16 and 17 were adjacent to the side wall (Fig. 1). In Area 3, eight traps were placed underneath first level shelves, about 0.3 m from the aisle. In Area 4, there were no shelves, so nine traps were placed on the floor adjacent to the side walls. Four additional traps were added in years 2 and 3, and these traps were also adjacent to the side wall.

The Dome traps were baited with approximately 300 mg of food oil bait, and commercially available pheromone lures for

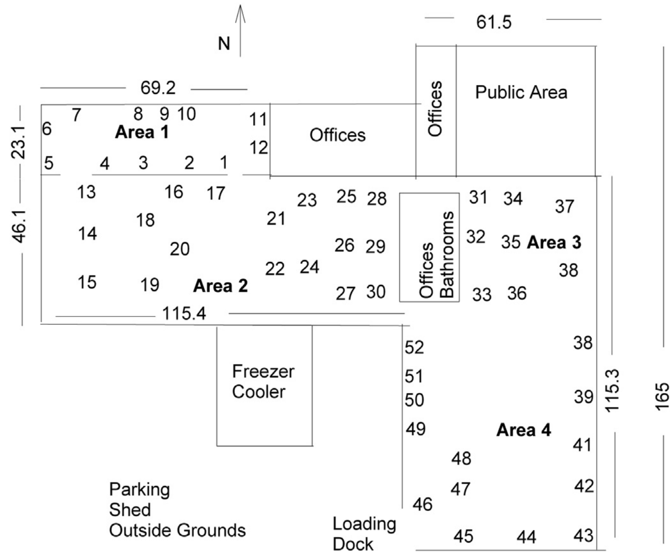

Fig. 1. Location of approximate trap positions, dimensions (m), and delineations of Areas in the food warehouse.

T. castaneum, *T. variable*, and *L. serricorne* (Trece, Adair, OK, USA). Each of these pheromones was impregnated on a separate rubber septa, and attached to the prongs on the underside of the Dome trap lid. Although the food oil bait was primarily placed in the traps to attract *O. surinamensis*, other species could have been attracted as well. The lures were replaced approximately every 6 weeks from late spring to early autumn, and every 8 weeks during rest of year. A duplicate set of trap bottoms was prepared in the laboratory at the Center for Grain and Animal Health Research, Manhattan, KS and when traps were sampled, the bottom of the trap was replaced with a reconditioned bottom with fresh food oil.

During the warmer months of the year, traps were checked every one to two weeks, during autumn the traps were checked about every three weeks, and during the winter traps checked about every six weeks. In the laboratory, adults of the three species monitored by the pheromones, and also adults of *O. surinamensis*, were removed from the food oil bait, counted and recorded. In addition, adults of the following species were also identified and recorded: merchant grain beetle, *Oryzaephilus mercator* (Fauvel), drugstore beetle, *Stegobium paniceum* (L.), *Sitophilus* spp., either rice weevil, *S. oryzae* (L.) or maize weevil, *S. zeamais* Motschulski, and confused flour beetle, *Tribolium confusum* Jacqueline DuVal. All other beetles considered to be stored product beetles and not identified were classified as “other beetles”. Temperature was recorded inside the warehouse using Hobo data loggers (Onset Computers, Bourne, MA, USA), and daily average temperatures were presented in Arthur et al. (2013).

Data for beetle catch were analyzed using the Means Procedure in the Statistical Analysis System (SAS, v. 9.1, SAS Institute, Cary, NC, USA) to first summarize overall trends in trap catch for *T. castaneum*, *L. serricorne*, *O. surinamensis*, and *T. variable*. The General Linear Models Procedure in SAS was then used to determine if trap catch differed among the 52 traps for each of the three years, using the Bonferroni option to account for experiment-wise error rate at $P < 0.05$. While the Bonferroni adjustment provides a conservative method to separate among trap positions, it also provides a test to separate trap positions at the high end of the range from those at the low end of the range. Data for all sampling dates within a year were combined; however, on those dates when total catch of all 4 of these species was less than 20 for the entire warehouse, data for