Stored-Product Insects Associated with a Retail Pet Store Chain in Kansas

RENNIE ROESLI, BHADRIRAJU SUBRAMANYAM, JAMES F. CAMPBELL,[1] AND KIM KEMP[2]

Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66506

J. Econ. Entomol. 96(6): 1958–1966 (2003)

ABSTRACT The types and numbers of insect species associated with eight Kansas retail stores belonging to a pet store chain were surveyed during February to August 2001. Insects were monitored at 1–3-wk intervals using food- and pheromone-baited pitfall traps for beetles and pheromone-baited sticky traps for moths. Thirty traps of each type were placed within a store. Thirty insect species belonging to 20 families in four orders were recorded from the eight stores. The weevils, *Sitophilus* spp.; Indianmeal moth, *Plodia interpunctella* (Hübner); and merchant grain beetle, *Oryzaephilus mercator* (Fauvel), were the most common and abundant species in all stores, whereas the red-legged ham beetle, *Necrobia rufipes* (Degeer), and red flour beetle, *Tribolium castaneum* (Herbst), were abundant only in one store. The numbers of each insect species captured varied from store to store. In each of the stores, a total of 12–19 stored-product species were captured in traps, and seven of the eight stores had relatively high species diversity. With the exception of one store, the different types of insect species found among the remaining seven stores were essentially similar. The mean density of insects in infested bulk-stored and bagged pet food products removed from a store ranged from 65 to 656 adults/kg. The types and numbers of insect species captured in traps indicated that infestations were well established in the surveyed stores. Early detection and management of these infestations is critical for maintaining quality and integrity of food products sold in the pet stores.

KEY WORDS trapping, pet food, stored-product insects, community ecology

RETAIL SALES OF DOG and cat foods in the United States reached $11.1 billion in 2000 (Gurkin 2001). A majority of pet foods are sold in grocery stores, followed by mass markets and retail pet stores. Retail pet stores sell products made from dry cereal products, legumes, oil seeds, and animal byproducts in whole or processed form. These products are susceptible to a variety of stored-product insects (Haines and Pranata 1982). Stored-product insects in retail stores can cause significant economic loss by contaminating and damaging products on the shelves (Subramanyam et al. 2001). Furthermore, infested product may cause allergic reactions when handled by some sensitive individuals (Phillips and Burkholder 1985).

A limited number of surveys were conducted to determine insect species associated with retail grocery and pet stores. Loschiavo and Okumura (1979) sampled stored-product insects with food-baited traps in 33 supermarkets and six feed and pet food stores in Hawaii. They captured stored-product insects in traps at all sampled locations, and the species most commonly found were the cigarette beetle, *Lasioderma serricorne* (F.), merchant grain beetle, *Oryzaephilus mercator* (Fauvel), and red flour beetle, *Tribolium castaneum* (Herbst). Haines and Pranata (1982) catalogued insects and arachnids associated with stored products in four retail stores in Java, Indonesia. They reported a total of 53 species associated with food products in these retail stores, of which 29 were considered pest species. Species of significant economic importance were the rice weevil, *Sitophilus oryzae* (L.), maize weevil, *Sitophilus zeamais* Motschulsky, the bostrichid woodborer, *Dinoderus bifoveolatus* (Wollaston); and *T. castaneum.*

Two recent surveys in the United States provided information on possible sources of infestations and pest management practices commonly used in retail stores. Platt et al. (1998) used commercial food- and pheromone-baited traps to monitor stored-product insects in eight grocery stores in Oklahoma. They reported stored-product insects to be more common and abundant near pet food aisles compared with other areas of the store. The most common insect species captured in traps were the Indianmeal moth, *Plodia interpunctella* (Hübner), drugstore beetle, *Stegobium paniceum* (L.), and *O. mercator.* Arbogast et al. (2000) also used food- and pheromone-baited traps to mon-

This paper reports research results only. Mention of a proprietary product name does not constitute an endorsement or recommendation for its use by Kansas State University or the U.S. Department of Agriculture.

[1] USDA-ARS, Grain Marketing and Production Research Center, Manhattan, KS 66502.

[2] Nestlé Purina PetCare Company, St. Louis, MO 63164.

Table 1. Location and size of eight pet stores in Kansas surveyed for stored-product insects during 2001

Store no.	Location	Floor area (m^2)	No. visits	Sampling duration	Total no. pitfall trap samples[a]	Total no. sticky trap samples[a]
1	Overland Park	1,320	11	17 Feb–27 Aug	288	295
2	Overland Park	1,050	8	16 Feb–02 Jul	230	232
3	Overland Park	598	11	16 Feb–27 Aug	303	314
4	Overland Park	483	8	16 Feb–02 Jul	214	227
5	Wichita	924	7	20 Feb–12 Jul	174	184
6	Wichita	1,045	7	20 Feb–12 Jul	165	176
7	Topeka	960	12	05 Feb–24 Aug	345	342
8	Lawrence	800	11	05 Feb–24 Aug	299	312

[a] Number of traps per store × number of visits.

itor insects in three department stores and two pet stores. They used spatial maps of trap captures to identify infestation foci and target pesticide applications. They captured stored-product insects in all five stores. The flat grain beetle *Cryptolestes pusillus* (Schönherr), *L. serricorne, O. mercator, T. castaneum,* and *P. interpunctella* were the most common insects. In the surveyed department stores, infestations generally were associated with food products in or near the pet department. In the pet stores, infestations were generally associated with cat food, dog food, and horse feed.

The present investigation was designed to determine stored-product insect incidence and abundance exclusively in pet stores in Kansas belonging to a retail chain. Eight cooperating retail pet stores were sampled for insects between February and August 2001 with food- and pheromone-baited traps. Our objectives were to determine the types and numbers of insect species captured in traps and those found in product samples, and to characterize diversity and similarity of stored-product insects captured in traps among the eight pet stores.

Materials and Methods

Store Characteristics. The retail pet stores (stores 1 through 8) varied in floor dimensions and were within 140 miles from Kansas State University, Manhattan, KS (Table 1). In each store, >50% of the products sold were foods for cats, dogs, small animals (including ferrets and rabbits), and birds. These products are packaged in bags and displayed on shelves or stored in bulk in Plexiglas containers on a food display table. Wild bird foods are commonly packaged in bags, and contain single or mixed raw ingredients of whole, cracked, and/or ground cereal grains and oil seeds with or without vitamins and minerals. The ingredients of small animal and bird foods in display containers are more complex, containing a wide range of raw and/or processed ingredients, including whole, cracked, and/or ground cereal grains (wheat, corn sorghum, and millet), legumes (soybean and peanuts), oil seeds (sunflower, rape, almond, and sesame seeds), dried fruits (banana, papaya, raisin, and apples), dried vegetables (carrot, spinach, parsley, and peas), grass (Canary grass), spices (anise, caraway, and fennel), seeds, dried eggs, yeast, meat, fish meal, vitamins, and minerals. The dried dog and cat foods in bags consist of extruded products of variable size and shape. They are made of rice, corn, wheat, eggs, yeast, fat, beef, poultry, and/or fish, and are rich in animal protein (>20% by wt) and fat (>10% by wt).

Layout of products among the stores was generally similar because all stores belong to the same retail chain. The food display table was absent in two of the eight stores (stores 3 and 4). The temperature inside the stores was maintained at 20–25°C throughout the year. The temperature in store 7 was above 25°C during the month of July 2001 because of malfunction of the air conditioning system.

Insect Survey Procedures. Beetle adults and larvae were monitored with commercial pitfall traps baited with food oil and pheromone lures from Trécé, Salinas, CA (Mullen 1994). Male *P. interpunctella* were monitored with sticky traps baited with a commercial sex pheromone (Pherocon II traps, Trécé, Salinas, CA). Pitfall traps were fitted with three separate rubber septa lures containing sex pheromones for *L. serricorne/S. paniceum* and *Trogoderma* spp., and an aggregation pheromone for *Tribolium* spp.

Thirty traps of each type were placed throughout each store, primarily in locations concealed from the customer's view, such as behind products on shelves and kick plates. All traps and lures were replaced every 4–6 wk. Stores were visited every 1–3 wk for a total of 7–12 times between February and August 2001. During each visit, beetles captured in pitfall traps were collected and placed in 35 × 10-mm plastic Petri dishes (Easy Grip, Becton Dickinson Labware, Franklin Lakes, NJ). Males of *P. interpunctella* captured in sticky traps were counted on-site. Moths were removed from the sticky surface with forceps to prevent trap saturation and the consequent reduction in trap capture efficiency. Traps with ≥30 *P. interpunctella* males were replaced with new ones.

Enumerating Trap Captures. All stages of insects captured in pitfall traps were identified to species, where possible. Species that required clearing or dissection (e.g., *Sitophilus* spp. and *Cryptolestes* spp.) were identified to genus. Individuals of these species captured in traps from at least one sampling date from each store were subsampled (7–21 adults for *Sitophilus* spp. for each store and 3–16 adults for *Cryptolestes* spp. for each store) for species identification using descriptions of Whitehead (1987), Haines (1991), and Halstead (1993).

Most beetle larvae caught in traps were identified to genus using characters described by Halstead (1986) because it is difficult to identify larvae to species. Larvae of the red-legged ham beetle, *Necrobia rufipes* (Degeer), were identified using descriptions of Simmons and Ellington (1925). Nonstored product insect species caught in pitfall traps were identified, but not enumerated.

The taxa and total number of insect species captured in pitfall and sticky traps was summarized. Incidence of each insect species was calculated as the number of stores out of eight in which a species was detected between February and August 2001. The capture of beetle adults or larvae in each pitfall trap and *P. interpunctella* males in each sticky trap was expressed as numbers captured/trap/wk. Mean weekly capture of a species in traps was computed using the MEANS procedure (SAS Institute 1989). Trap captures were transformed to log $(x + 1)$ for statistical analysis. Differences among stores in mean weekly trap captures of all beetle adults or larvae and *P. interpunctella* males were determined by one-way analysis of variance. Means were separated by the Fisher protected least significant difference (LSD) test at the $\alpha = 0.05$ level (SAS Institute 1989).

Relative abundance of each species captured in a trap was expressed as a percentage using the following formula: 100 × (weekly trap catch of a species/weekly trap catch of all species). Mean relative abundance of each species was computed using the MEANS procedure (SAS Institute 1989). Percentages were transformed to angular values for statistical analysis. Differences in relative abundance of a species among stores were determined using one-way analysis of variance and Fisher protected least significant difference test at the $\alpha = 0.05$ level (SAS Institute 1989).

Species Diversity. The types of adult insect species and the total adults of all species found among stores may be related to the number of times the store was visited or the store dimensions. Therefore, the relationship between the number of insect species or the total number of adults of all species captured among stores and the number of store visits or store dimensions was determined using the CORR procedure (SAS Institute 1989). In addition, the different types of insect species captured in each store were correlated with the corresponding total number of adults found in that store.

The total numbers of adults of the 27 stored-product insect species captured in pitfall traps in each store were used to compute the Simpson's index of diversity (Simpson 1949) as:

$$1 - D = 1 - \Sigma\, (p_i)^2 \qquad [1]$$

where $(1 - D)$ is the Simpson's index of diversity, p_i is proportion of individuals of species 'i' (i = 1–27) in a store relative to the total individuals of all species. The values for the Simpson's index range from 0 to 1, where 0 indicates low diversity and 1 indicates high diversity.

Similarity of Species Composition Among Stores. Similarity of species composition among pet stores was measured using the Morisita's index of similarity and unweighted paired-group method using arithmetic average cluster analysis technique (Morisita 1959). The Morisita's index was calculated as:

$$C_\lambda = 2\, \Sigma\, X_{ij}X_{ik} / (\lambda_1 + \lambda_2) N_j N_k \qquad [2]$$

where C_λ is the Morisita's index of similarity between the adult trap captures (samples) of stores 'j' and 'k'; X_{ij} and X_{ik} are the number of individuals of species 'i' captured in stores 'j' and 'k', respectively; N_j and N_k are total number of individuals in samples 'j' and 'k', respectively. λ_1 is calculated as: $\Sigma\, [X_{ij}(X_{ij} - 1)]/N_j(N_j - 1)$. λ_2 is calculated as: $\Sigma\, [X_{ik}(X_{ik} - 1)]/N_k(N_k - 1)$. The values for the Morisita's index range from 0 (no similarity) to 1 (complete similarity).

The proportion of individuals of a species (p_i in equation 1 among stores was subjected to the unweighted pair-group method with arithmetic average cluster analysis using the CLUSTER procedure (SAS Institute 1989). The tree diagram (clusters) showing similarity in species composition (indicated by the inverse values of distance between clusters) among stores was plotted using the TREE procedure (SAS Institute 1989).

Insects in Bagged or Bulk Food Products. Infested bagged products were found in four of the stores during our visits. However, only the manager in store 7 gave us permission to bring these products to the laboratory for further study. A total of 19 bags (10 bags weighing 2.3 kg and 9 bags weighing 4.5 kg) of wild bird food from the shelves, and 10 different bulk-stored food products weighing 5.2–17 kg were brought to the laboratory for insect extraction and enumeration of both live and dead insects. Products were passed two to four times through the Boerner divider (Watson et al. 1970) to obtain a working sample. Adults of stored-product insects extracted from the working sample were expressed as numbers/kg. The insect species and numbers recovered from bulk-stored food products were compared with those from wild bird food using the Simpson's index of diversity and Morisita's index of similarity as described above.

Results

Insect Species Associated with Pet Stores. At least 30 insect species representing 20 families and four orders were captured in traps among the eight stores. These species included 24 Coleoptera, 3 parasitic Hymenoptera, 1 Lepidoptera, and 2 Psocoptera (Table 2). Across all eight stores, a total of 27 stored-product insect pests were observed, but in each store traps captured 12 (store 4) to 19 (store 3) pest species (Fig. 1).

The six stored-product insects common to all eight stores were: *Cryptolestes* spp., *O. mercator*, the saw-toothed grain beetle, *Oryzaephilus surinamensis*, *P. interpunctella*, *Sitophilus* spp., and *S. paniceum*. A pteromalid parasitoid, *Lariophagus* spp., also was found in all stores. *Trogoderma* spp. and *T. castaneum* were

Table 2. Insect taxa captured in traps

Order/Family	Species	Common name	Total no. adults	Total no. larvae	No. stores out of 8 with insects
Coleoptera					
Anobiidae	*Lasioderma serricorne* (F.)	Cigarette beetle	61		6
	Stegobium paniceum (L.)	Drug store beetle	1,768		8
Cleridae	*Necrobia rufipes* (Degeer)	Red-legged ham beetle or Copra beetle	1,692	1,806	6
Curculionidae	*Sitophilus* spp.[a]	Weevil	10,702		8
Dermestidae	*Anthrenus verbasci* (L.)	Varied carpet beetle	21		5
	Anthrenus scrophulariae (L.)	Carpet beetle	2		1
	Attagenus spp.	Black carpet beetle	1		1
	Dermestes lardarius L.	Larder beetle	23		3
	Trogoderma spp.	Warehouse beetle	12		7
Laemophloeidae	*Cryptolestes* spp.[b]	Flat grain beetle	1,960	123	8
Languriidae	*Cryptophilus* spp.		3		2
Lathridiidae	*Cartodere constricta* (Gyllenhal)	Plaster beetle	8		2
	Corticaria spp.	Fungus feeder	11		4
Mycetophagidae	*Typhaea stercorea* (L.)	Hairy fungus beetle	1		1
Nitidulidae	*Carpophilus* spp.	Corn sap beetle	1		1
Ptinidae	*Gibbium psylloides* (de Czenpinski)	Shiny spider beetle	19		1
Rhizophagidae	*Monotoma* spp.		2		2
Silvanidae	*Oryzaephilus mercator* (Fauvel)	Merchant grain beetle	4,296	789[c]	8
	Oryzaephilus surinamensis (L.)	Sawtoothed grain beetle	811		8
	Ahasverus advena (Waltl)	Foreign grain beetle	4		4
Staphylinidae	Unidentified	Rove beetle	11		6
Tenebrionidae	*Alphitophagus bifasciatus* (Say)	Two-banded fungus beetle	4		2
	Tribolium castaneum (Herbst)	Red flour beetle	9,562	13	7
	Tribolium confusum J. du Val	Confused flour beetle	2		2
Hymenoptera					
Bethylidae	*Cephalonomia* spp.	Parasitic wasp	Frequent		2
Braconidae	*Habrobracon* spp.	Parasitic wasp	Frequent		2
Pteromalidae	*Lariophagus* spp.	Parasitic wasp	Frequent		8
Lepidoptera					
Pyralidae	*Plodia interpunctella* (Hübner)	Indianmeal moth	290[d] + 9,983[e]	301	8
Psocoptera					
Liposcelididae	*Liposcelis* spp.	Psocid, book lice	5		3
Unidentified	Species unidentified (winged)	Psocid	11		2

[a] Species included the granary weevil, *S. granarius* (L.), rice weevil, *S. oryzae* (L.) and maize weevil, *S. zeamais* Motschulsky.
[b] Species included *C. pusilloides* (Steel & Howe) and the flat grain beetle *C. pusillus* (Schönherr).
[c] Larvae were identified only to genus, therefore the value may included larvae of *O. surinamensis.*
[d] Total number of *P. interpunctella* adults captured in pitfall traps.
[e] Total number of *P. interpunctella* adults captured in sticky traps.

captured in seven stores, whereas *L. serricorne* and *N. rufipes,* were captured in six stores. All other species were captured in five stores or less. Overall, *Sitophilus* spp. were captured in large numbers among the stores, followed by *P. interpunctella, T. castaneum, O. mercator, N. rufipes, Cryptolestes* spp., and *S. paniceum* (Table 2). A total of 1,806 larvae of *N. rufipes* were caught in pitfall traps in six of eight stores (Table 2); ≈92% of the total larvae were captured in store 7. The second largest number of larvae captured in pitfall traps was that of *Oryzaephilus* spp., followed by *P. interpunctella* and *Cryptolestes* spp. (Table 2).

Analysis of subsamples showed that all *Sitophilus* specimens from stores 1, 3, 4, 5, and 6 were *S. oryzae.* Approximately 17% of the specimens from store 7 and 10% from store 8 were *S. oryzae;* the rest were *S. zeamais.* All specimens from store 2 were granary weevils, *Sitophilus granarius* (L.). All *Cryptolestes* specimens from stores 1 through 7 were *Cryptolestes pusilloides* (Steel and Howe). However, in store 8, 50% of the specimens were *C. pusilloides* and 50% were *C. pusillus.* All *Tribolium* specimens were that of *T. castaneum,* with the exception of two. These two specimens were identified as confused flour beetles, *Tribolium confusum* (Jacquelin duVal).

The number of insect species or the total number of adults captured in traps was not related ($P > 0.05$) to the size of the store or the number of store visits (Table 3). Similarly, there was no correlation ($P > 0.05$) between the total number of adults captured in a store and the number of species found in that store.

The greatest number of adults (of both beetles and moths) in pitfall traps was captured in store 7 (16,710

Table 3. Correlation coefficients (*P* values) showing relationship between five paired variables

	No. store visits	Store dimension	Total no. adults
No. species[a]	0.329 (0.426)[b]	−0.003 (0.995)[b]	−0.119 (0.778)[b]
Total no. adults	0.665 (0.072)[b]	0.080 (0.851)[b]	

Each correlation was based on $n = 8$ paired observations.
[a] Includes only adult trap capture data.
[b] All correlations (ρ) were not significant (H_o: $\rho = 0$, $P > 0.05$).

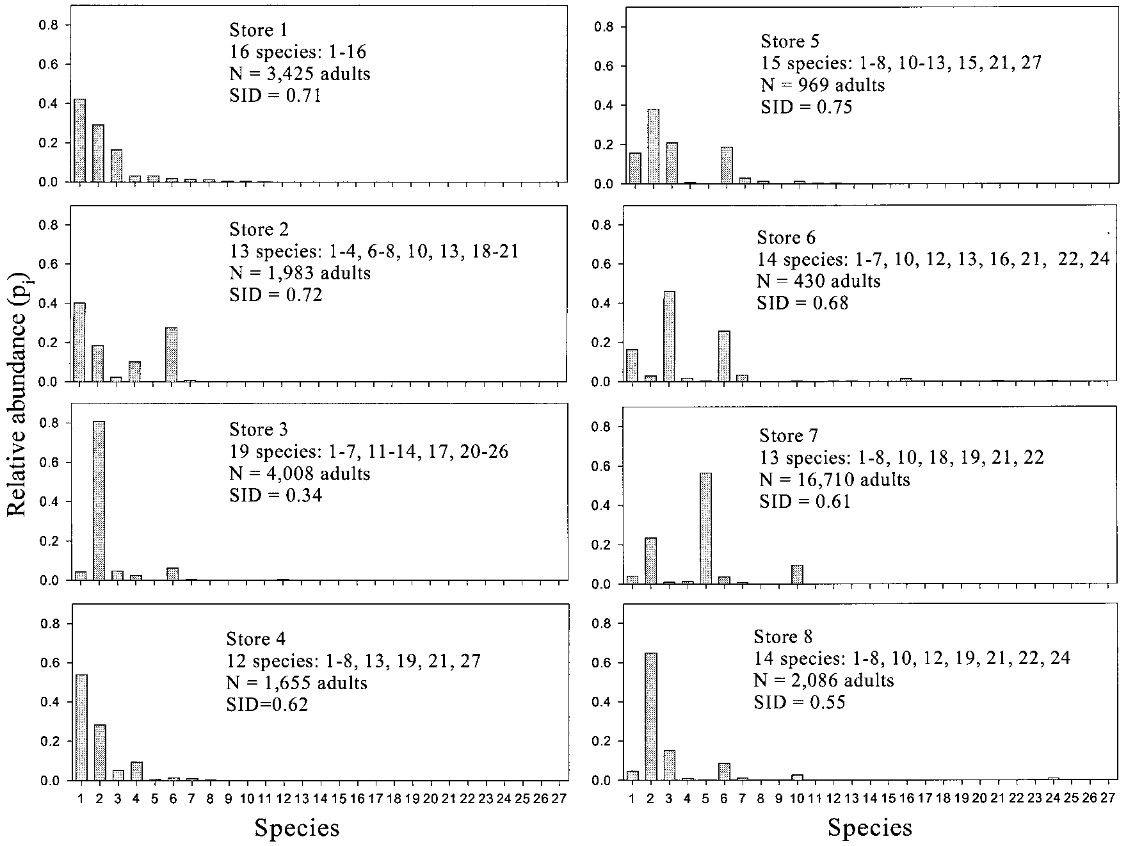

Fig. 1. Relative abundance [expressed as a proportion of the total (N) captured] of adults of stored-product insect species and Simpson's index of species diversity (SID) in each of the eight pet stores. The species numbered in the graphs are: 1, *O. mercator*; 2, *Sitophilus* spp.; 3, *S. paniceum*; 4, *O. surinamensis*; 5, *T. castaneum*; 6, *Cryptolestes* spp.; 7, *P. interpunctella;* 8, *L. serricorne*; 9, *G. psylloides*; 10, *N. rufipes*; 11, Psocoptera (winged); 12, *A. verbasi*; 13, Staphilinidae; 14, *A. bifasciatus*; 15, *T. confusum*; 16, *C. constricta*; 17, *A. scophulariae*; 18, *Cryptophilus* spp.; 19, *A. advena*; 20, *Monotoma* spp.; 21, *Trogoderma* spp.; 22, *Corticaria* spp.; 23, *Attagenus* spp.; 24, *D. lardarius*; 25, *Carpophilus* spp.; 26, *T. stercorea*; and 27, *Liposcelis* spp.

individuals), while the fewest number of adults was captured in store 6 (430 individuals). Mean trap captures of adults and larvae of stored-product insects varied among the stores ($F = 28.45$; df = 7, 232; $P = 0.0001$ for adults, and $F = 9.94$; df = 7, 232; $P = 0.0001$ for larvae). Mean captures of *P. interpunctella* were different among the stores ($F = 18.18$; df = 7, 232; $P = 0.0001$). The highest mean capture of beetle adults and larvae and males of *P. interpunctella* occurred in store 7 (Table 4). The second highest trap captures of *P. interpunctella* males were observed in store 1, and captures of this species between stores 1 and 7 were not significantly different ($P > 0.05$) from another. Mean trap captures of *P. interpunctella* males in store 5 were lower ($P < 0.05$) than captures in stores 1 and 7 but higher than captures in the remaining stores.

The relative abundance of each of the eight economically important stored-product insects varied among the stores (F, range among species = 4.15–113.66; df = 7, 229; $P < 0.0003$) (Table 5). For example,

Table 4. Weekly captures (mean ± SE) of stored-product insects in commercial pitfall and sticky traps

Trap type/ Insects	Store no.							
	1	2	3	4	5	6	7	8
Pitfall trap								
Adults[a]	4.8 ± 0.7bc	3.8 ± 0.8cd	5.7 ± 0.9b	3.2 ± 0.5cd	2.0 ± 0.5e	1.1 ± 0.4f	23.9 ± 4.9a	3.1 ± 0.7de
Larvae[a]	0.5 ± 0.1b	0.4 ± 0.2bc	0.1 ± 0.1c	0.5 ± 0.3bc	0.2 ± 0.1c	0.1 ± 0.1c	2.1 ± 0.5a	0.2 ± 0.1c
Sticky trap								
Moths[a]	3.9 ± 0.5a	0.9 ± 0.12c	0.7 ± 0.2c	0.9 ± 0.2c	2.4 ± 0.5b	1.0 ± 0.2c	4.4 ± 1.1a	0.9 ± 0.2c

Each mean is based on $n = 30$ traps.
[a] For adults, larvae, or moths, means among stores followed by different letters are significantly different ($P < 0.05$; Fisher's protected LSD).

Table 5. Relative abundance (%mean ± SE) of eight economically important stored-product insect adults captured in commercial pitfall traps

Store	Species[a,b]								
	CSP	LS	NR	OM	OS	SSP	SP	TC	OSP[c]
1	2.3 ± 0.9cd	2.3 ± 1.0a	1.5 ± 1.0cd	31.7 ± 4.5bc	2.7 ± 0.5b	27.4 ± 3.5d	24.1 ± 2.7a	3.4 ± 1.1b	5.0 ± 1.2ab
2	19.3 ± 4.3a	0.1 ± 0.1b	0.1 ± 0.1d	50.1 ± 4.4a	8.2 ± 1.2a	17.1 ± 2.4e	3.2 ± 1.1d	0.0 ± 0.0c	0.8 ± 0.6c
3	6.4 ± 1.6bc	0.0 ± 0.0b	0.0 ± 0.0d	6.9 ± 1.5d	2.8 ± 0.7b	69.7 ± 4.1a	10.4 ± 2.1bc	0.3 ± 0.2c	3.6 ± 0.8b
4	1.3 ± 0.6d	0.1 ± 0.1b	0.0 ± 0.0d	38.2 ± 4.4b	9.9 ± 1.8a	41.0 ± 3.8c	4.5 ± 1.2cd	1.6 ± 1.6c	3.5 ± 1.5bc
5	11.9 ± 3.2ab	0.7 ± 0.5b	3.5 ± 1.8bc	14.8 ± 2.7d	1.1 ± 0.8c	47.7 ± 5.0bc	13.5 ± 3.1b	0.1 ± 0.1c	6.8 ± 2.0b
6	21.6 ± 4.9a	0.0 ± 0.0b	0.5 ± 0.5cd	27.3 ± 5.7c	3.1 ± 1.4bc	4.6 ± 1.7f	28.7 ± 6.2a	0.9 ± 0.9c	13.2 ± 4.3a
7	3.0 ± 0.7bcd	0.2 ± 0.2b	21.2 ± 3.7a	5.8 ± 0.8d	1.7 ± 0.2b	27.9 ± 2.9d	2.7 ± 1.0d	35.4 ± 3.2a	2.2 ± 1.1bc
8	7.1 ± 2.1bc	0.4 ± 0.4b	4.6 ± 1.7b	7.9 ± 2.5d	0.7 ± 0.3c	51.3 ± 3.9b	20.5 ± 2.6a	0.3 ± 0.2c	5.6 ± 2.2b

Each mean is based on $n = 30$ traps.

[a] For each species, means among stores followed by different letters are significantly different ($P < 0.05$; Fisher's protected LSD).

[b] CSP, *Cryptolestes* spp.; LS, *L. serricorne;* NR, *N. rufipes;* OM, *O. mercator;* OS, *O. surinamensis;* SSP, *Sitophilus* spp.; SP, *S. paniceum;* TC, *T. castaneum.*

[c] OSP includes other species that varied from store to store. Store 1: *A. bifasciatus, A. verbasci, C. constricta, G. psylloides, T. confusum, P. interpunctella,* Psocoptera, and Staphilinidae. Store 2: *A. advena, Cryptophilus* spp., *Monotoma* spp., *Trogoderma* spp., *P. interpunctella,* and Staphilinidae. Store 3: *A. bifasciatus, A. scrophulariae, A. verbasci, Attagenus* sp., *Carpophilus* spp., *Corticaria* spp., *D. lardarius, Monotoma* spp., *P. interpunctella,* Psocoptera, Staphilinidae, *Trogoderma* spp., and *T. stercorea.* Store 4: *A. advena, Liposcelis* spp., *P. interpunctella,* Staphilinidae, and *Trogoderma* spp. Store 5: *A. verbasci, Liposcelis* spp., *P. interpunctella,* Psocoptera, Staphilinidae, *T. confusum,* and *Trogoderma* spp. Store 6: *A. verbasci, Corticaria* spp., *D. lardarius, P. interpunctella,* Staphilinidae, and *Trogoderma* spp. Store 7: *A. advena, Corticaria* spp., *Cryptophilus* spp., *P. interpunctella,* and *Trogoderma* spp. Store 8: *A. advena, A. verbasci, Corticaria* spp., *D. lardarius, P. interpunctella,* and *Trogoderma* spp.

Sitophilus spp. was most abundant in store 3 and constituted 70% of all individuals captured. This species was least abundant in store 6 (5%) (Table 5). *Oryzaephilus mercator* was most abundant in store 2 (50%). *Lasioderma serricorne* was captured in low numbers (≤2%) only in six of the eight stores. *Necrobia rufipes* and *T. castaneum* were generally scarce (≤5%) or absent in some stores, but were most abundant only in store 7 (≥21%).

Species Diversity. The relative abundance (p_i) of the 27 insect species found among stores is shown in Fig. 1. Seven of the eight stores had relatively high species diversity (Simpson's index >0.50), with the exception of store 3, which had a low species diversity (Simpson's index = 0.34). Store 5 had the highest species diversity index (Simpson's index = 0.75).

Similarity of Species Composition Among Stores. Values for the Morisita's index among the eight pet stores ranged from 0.08 to 0.97 (Table 6). The Morisita's index between store 7 and each of the other stores was low, indicating that the species composition in this store was not similar to those found in the other stores. Species were most similar between stores 1 and 4 (Morisita's index = 0.96) and between stores 3 and 8 (Morisita's index = 0.97). A similar trend was apparent from the tree diagram (Fig. 2). For example, the narrowest distance (indicating highest similarity) was observed between stores 1 and 4, followed by the distance between stores 3 and 8. Generally, distances between clusters were not relatively large, although store 7 appeared to be most distant from the other stores.

Insects in Pet Food Products. Five stored-product insect species were recovered from the bagged bird food and seven from the bulk food products (Table 7). *Sitophilus* spp. and *Cryptolestes* spp. were found in large numbers in bird-food products. In the bulk food products, *Oryzaephilus* spp. and *Cryptolestes* spp. were common. The mean ± SE density in bagged food products was 655.7 ± 143.0 adults/kg, whereas in the bulk food products it was 65.3 ± 51.1.

Species diversity was greatest in the bulk-stored food products (Simpson's index = 0.75), when compared with diversity in bird-food products (Simpson's index = 0.22) (Fig. 3). Furthermore, both the bulk and bird-food products shared little similarity in species composition (Morisita's index = 0.23) (Fig. 3).

Table 6. Matrix of Morisita's indices showing similarity of species composition among the eight pet stores

Store no.	1	2	3	4	5	6	7	8
1	1.00	0.82	0.55	0.96	0.80	0.53	0.31	0.63
2		1.00	0.40	0.85	0.72	0.53	0.21	0.45
3			1.00	0.49	0.74	0.15	0.37	0.97
4				1.00	0.66	0.37	0.24	0.52
5					1.00	0.66	0.33	0.86
6						1.00	0.08	0.32
7							1.00	0.39
8								1.00

A value of 0 indicates no similarity whereas 1 indicates complete similarity.

Table 7. Relative abundance (%mean ± SE) of adults of seven stored-product insect species recovered from infested pet food products in store 7

Species	Bulk[a]	Bagged[b]
Cryptolestes spp.	26.7 ± 8.3	22.1 ± 7.0
N. rufipes	2.9 ± 1.6	0.1 ± 0.1
Oryzaephilus spp.	31.4 ± 5.5	0.2 ± 0.1
P. interpunctella	3.4 ± 1.4	–[c]
Sitophilus spp.	19.0 ± 6.9	76.2 ± 6.9
S. paniceum	3.3 ± 1.7	–[c]
T. castaneum	13.4 ± 4.9	1.4 ± 0.6

[a] Mean relative abundance values are based on a mean ± SE ($n = 10$) of 65.3 ± 51.1 adults.

[b] Mean relative abundance values are based on a mean ± SE ($n = 19$) of 655.7 ± 143.0 adults.

[c] Not present.

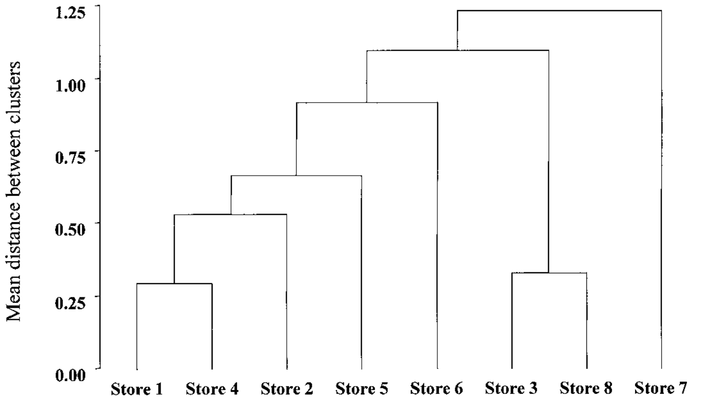

Fig. 2. A tree diagram with mean distances showing similarity of species composition among the eight pet stores.

Discussion

The large numbers of *O. mercator* adults and *P. interpunctella* males captured in our study were similar to those reported by Platt et al. (1998) and Arbogast et al. (2000) from department, grocery, and pet stores. Males of *P. interpunctella* were captured in sticky traps in all eight pet stores. Platt et al. (1998) and Arbogast et al. (2000) reported captures of male *P. interpunctella* from all retail grocery and pet stores they sampled. Therefore, *P. interpunctella* appears to be a common stored-product pest in retail environments in the United States. Larvae of *P. interpunctella* have a high preference for dried fruits, nuts, cereals, and oilseeds and products; a medium preference for cereal products, cocoa, and carobs; and a low preference for dried vegetables and pulses (Williams 1964, Cox and Bell 1991). These preferred foods were prevalent in the retail pet stores we surveyed and may explain the presence of *P. interpunctella* in all stores.

Sitophilus spp. was not reported from Oklahoma grocery stores (Platt et al. 1998). Arbogast et al. (2000) reported that *S. oryzae* constituted 1.5% of the total insect numbers captured in pet stores. In our survey, *Sitophilus* were the most abundant species found in pitfall traps and bird-food products. Bird-food products are generally made up of different types of whole cereal grains, and *Sitophilus* spp. feed and reproduce in whole cereal grains such as barley, maize, rice, and wheat (Haines 1991). Additional work is needed to determine whether the bird-food products were already infested with *Sitophilus* spp. before they were brought into the store or became infested on the shelves from residual populations within the store.

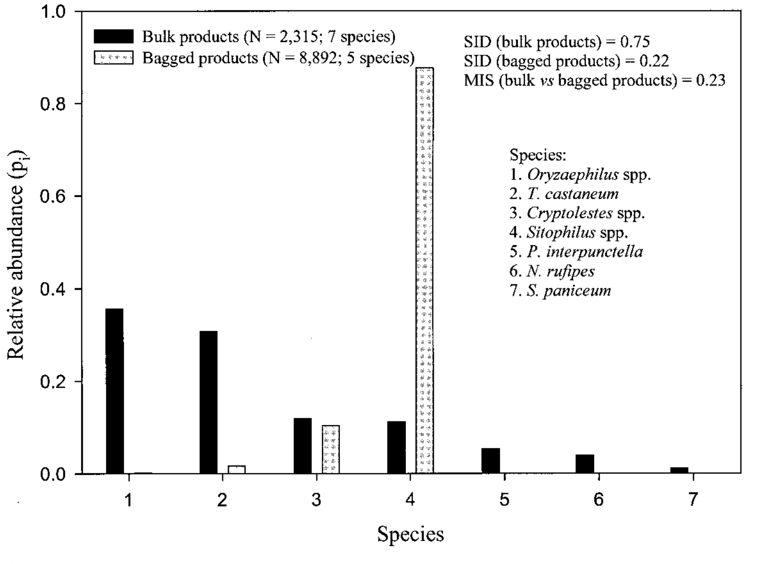

Fig. 3. Relative abundance [expressed as a proportion of the total (*N*) individuals] of adults of stored-product insect species, Simpson's index of species diversity (SID), and Morisita's index of species composition similarity (MIS), in bulk-stored and bagged bird-food products from store 7.

Platt et al. (1998) and Arbogast et al. (2000) did not report *N. rufipes* from retail stores. Both larvae and adults of *N. rufipes* cause considerable damage to stored copra (dried coconut), ham, cheese, dried fish, and other products rich in protein content (Simmons and Ellington 1925, Gonzales et al. 1957, Ashman 1963). Dog food, cat food, and pig ears within the pet stores were some of the products rich in protein. *Necrobia rufipes* infestations may have been associated with these foods, and a cursory examination of these products showed presence of *N. rufipes* larvae and adults. *Necrobia rufipes* is also a facultative predator and preys on larvae of *L. serricorne, O. mercator,* and the corn sap beetle, *Carpophilus dimidiatus* (F.) (Simmons and Ellington 1925, Ashman 1963). Larvae of *Oryzaephilus* spp. were frequently captured in pitfall traps in the stores, suggesting that suitable prey for *N. rufipes* was available in the stores. Furthermore, *N. rufipes* can breed on animal carcasses (De Souza and Linhares 1997). We captured 450 *N. rufipes* larvae in a pitfall trap in store 7 that was placed behind a kick plate. Apparently, the trap was near a dead cadaver of a mouse, and the mouse cadaver was completely covered with *N. rufipes* larvae and adults.

The number of stored-product insects reported from the eight retail pet stores we surveyed were greater than those reported by Platt et al. (1998) and Arbogast et al. (2000). For example, we reported 27 pest and 3 beneficial insects associated with stored products, whereas Arbogast et al. (2000) reported eight stored-product beetles in pitfall traps and *P. interpunctella* males in sticky traps. Platt et al. (1998) captured 13 insect species in pitfall traps and 31 species in sticky traps; approximately one third of the species in sticky traps and one half those in pitfall traps were stored-product insects. Differences in species composition and trap captures among the three studies may be a result of the types of food products held in the stores and the level of sanitation and pest management practiced.

The number of adult insect species and total number of adults of all species found in stores were not related to store dimensions or number of store visits. This suggested that factors other than these were responsible for number of insect species or total number of adults found among stores. Differences among the eight stores in the types and numbers of insects found may be related to how the food products were inspected and managed, and these aspects were beyond the scope of our study. Some of the inspection and product management practices include inbound inspection of products for infestation, maintaining a clean stock (back) room, rotating stocks on a "first-in and first-out" basis, removal of spillage under shelves, behind kick plates, and on shelves, removing and discarding torn or insect-infested bags from shelves, use of insect monitoring devices, and application of approved insecticides as needed.

The diversity in the types of pet food products present in stores coupled with patchy distribution of spilled food products on the shelves and behind kick plates may explain the diversity and similarity of species composition found in the stores. Simpson's diversity index suggested that the pet store ecosystem had many insect species. Morisita's indices and the narrow distances obtained among clusters in the tree diagram indicated a high degree of species composition similarity among seven of the eight stores. However, store 7 was different from the other stores because *T. castaneum* constituted 56% of total captured adults. In all other stores, *T. castaneum* was either absent or constituted <5% of total insects captured. The reasons for abundant captures of *T. castaneum* in store 7 are unknown. Store 7 was different from the other stores because it also had a high proportion (10% of total trap captures) of *N. rufipes.* The high degree of similarity in species composition among seven of the eight stores is not surprising, because all stores belonged to the same retail chain, were located in the same geographical area (state of Kansas), and received products from the same distribution center.

There were differences in the insect species composition in infested bulk-stored food products and bagged bird food products sampled from store 7. The wild bird food contained a mixture of whole cereal grains, and hence the number of species found was small and predominantly included *Sitophilus* spp. that are capable of exploiting whole cereals. The bulk-food products included a variety of ingredients and therefore the species found were more diverse. The high density of insect found in food products suggests that infested products were overlooked for an extended period of time.

In addition to carrying foods that are susceptible to stored-product insects, retail pet stores have many structural features in which spilled food products accumulate. Typical locations include spaces under kick plates, shelves, spaces between shelves, and flat surfaces. The varying quantities of spilled food in these "difficult-to-clean areas" provide a patchy, resource-rich environment for supporting stored-product insect infestations. Therefore, infestation risk in retail stores is directly related to the level of sanitation and pest management intervention. Simple pest management recommendations for retail environments include inbound inspection of products, sanitation, frequent stock rotation, inspection of products on shelves for insects and damage, timely removal of infested products, identification of infestation foci, and precision-targeting of pesticide applications (Brenner et al. 1998, Arbogast et al. 2000). The impact of these suggested pest management practices on insect infestation risks within retail stores warrants further investigation.

Acknowledgments

We are grateful to the retail store managers and employees for cooperating in this survey. This project was supported by funds from the Nestlé Purina PetCare Company, St. Louis, MO, and partially by funds from CSREES–USDA (RAMP) under Agreement No. 00-51101-9674. We thank Anil Menon, Liang Fang, Fangneng Huang, Muktinutalapati Laxminarayan, Yunyan Xiao, Yuyu Wang, and Zeb Larson for assistance with the retail store sampling and trapping. Carmelita Goossen, Zeb Larson, and Sarah Velasquez helped in extracting insects from pet food products. Jeff Weier and Chuck Burks reviewed an earlier version of the manuscript. This paper is Contribution No. 02-344-J of the Kansas State University Agricultural Experiment Station.

References Cited

Arbogast, T. A., P. E. Kendra, R. W. Mankin, and J. E. McGovern. 2000. Monitoring insect pests in retail stores by trapping and spatial analysis. J. Econ. Entomol. 93: 1531–1542.

Ashman, F. 1963. Factors affecting the abundance of the copra beetle *Necrobia rufipes* (Deg.) (Col., Cleridae). Bull. Entomol. Res. 53: 671–680.

Brenner, R. J., D. A. Focks, R. T. Arbogast, D. K. Weaver, and D. Shuman. 1998. Practical use of spatial analysis in precision targeting for integrated pest management. Am. Entomol. 44: 79–101.

Cox, P. D., and C. H. Bell. 1991. Biology and ecology of moth pests of stored foods, pp. 181–193. *In* J. R. Gorham [ed.], Ecology and management of food-industry pests. FDA Technical Bulletin 4. Association of Official Analytical Chemists, Arlington, VA.

De Souza, A. M., and A. X. Linhares. 1997. Diptera and Coleoptera of potential forensic importance in southeastern Brazil: relative abundance and seasonality. Med. Vet. Entomol. 11: 8–12.

Gonzales, J., J. P. Quilao, and N. C. Manalo. 1957. Study of the biology of the copra beetle. Araneta J. Agric. 4: 69–83.

Gurkin, A. H. 2001. The petfood report. Petfood Industry, November 2001: 26–32.

Haines, C. P. 1991. Insects and arachnids of tropical stored products: their biology and identification, 2nd ed. Natural Resources Institute, Overseas Development Administration, Kent, United Kingdom.

Haines, C. P., and R. I. Pranata. 1982. Survey on insects and arachnids associated with stored products in some parts of Java, pp. 17–48. *In* N. C. Teter and A. S. Frio [eds.], Progress in grain protection, Proceedings, 5th Annual Workshop on Grains Post-harvest Technology. Southeast Asian Cooperative Post-harvest Research and Development Programme, Laguna, Philippines.

Halstead, D.G.H. 1986. Keys for the identification of beetles associated with stored products. I–Introduction and key to families. J. Stored Prod. Res. 22: 163–203.

Halstead, D.G.H. 1993. Keys for the identification beetles associated with stored products. II–Laemophloeidae, Passandridae and Silvanidae. J. Stored Prod. Res. 29: 99–197.

Loschiavo, S. R., and G. T. Okumura. 1979. A survey of stored product insects in Hawaii. Proc. Hawaii Entomol. Soc. 13: 95–118.

Morisita, M. 1959. Measuring interspecific association and similarity between communities. Mem. Fac. Sci. Kyushu Univ. Series E. 3: 65–80.

Mullen, M. A. 1994. Development of pheromone-baited traps, pp. 421–424. *In* E. Highley, E. J. Wright, H. J. Banks, and B. R. Champ [eds.], Proceedings, 6th International Working Conference on Stored Product Protection, Canberra 17–23 April 1994. CAB International, Wallingford, United Kingdom.

Platt, R. R., G. W. Cuperus, M. E. Payton, E. L. Bonjour, and K. N. Pinkston. 1998. Integrated pest management perceptions and practices and insect populations in grocery stores in south-central United States. J. Stored Prod. Res. 34: 1–10.

Phillips, J. K., and W. E. Burkholder. 1985. Health hazards of insects and mites in food, pp. 280–292. *In* F. J. Baur [ed.], Insect management for food storage and processing. American Association of Cereal Chemists, St. Paul, MN.

SAS Institute. 1989. SAS/STAT® user's guide, version 6, 4th ed. Cary, NC.

Simmons, P., and G. Ellington. 1925. The ham beetle, *Necrobia rifipes* De Geer. J. Agric. Res. 30: 845–863.

Simpson, E. H. 1949. Measurement of diversity. Nature (Lond.) 163: 688.

Subramanyam, Bh., J. Campbell, and K. Kemp. 2001. It's in the detail for retail. Pest Control May: 26–28.

Watson, C. A., A. L. Hawk, P. Neffennegger, and D. Duncan. 1970. Performance evaluation of grain sample dividers. U.S. Dep. Agric. Research Service Report, ARS Special Report No. 51-38.

Whitehead, D. R. 1987. Weevils (Curculionidae, Coleoptera), pp. 223–230. *In* J. R. Gorham [ed.], Insect and mite pests in food: an illustrated key, vol. 1. U.S. Dep. Agric. Handbook No. 655, Washington, DC.

Williams, G. C. 1964. The life-history of the Indian mealmoth, *Plodia interpunctella* (Hübner) (Lep. Phycitidae) in warehouse in Britain and on different foods. Ann. Appl. Biol. 53: 459–475.

Received for publication 12 November 2002; accepted 17 August 2003.