Impact of IPM practices on insect populations in retail pet stores

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Abstract

Stored-product insect infestations in retail pet stores cost pet food manufacturers millions of dollars annually, but there are no studies documenting the effectiveness of pest management practices in pet stores. Our study was designed to determine species associated with eight pet stores in Kansas and to evaluate the impact of chemical and non-chemical intervention on insect populations. Food and pheromone-baited traps were used to estimate numbers of stored-product beetles and the Indian meal moth, *Plodia interpunctella* (Hübner). Traps were placed in a grid pattern in each store, and trap catches were recorded every 1–3 weeks. Spatial analyses of trap catch data were used for monitoring infestations and for evaluating effectiveness of pest management measures. Measures used against pests included sanitation (sweeping, vacuuming and/or discarding infested products) or sanitation in combination with an insect growth regulator, hydroprene 9% EC, or a pyrethroid, cyfluthrin 20 WP. Each treatment (sanitation or sanitation plus pesticide application) was replicated in two stores. Two stores that were left untreated served as the control. Traps in the stores captured a total of 41,266 adults and 3032 larvae of 36 insect species belonging to 23 families and 7 orders. Infestations were generally associated with birdseed, small-animal foods, or spilled food. Sanitation in conjunction with hydroprene or cyfluthrin applications on targeted floor areas reduced beetle numbers but did not greatly affect Indian meal moth numbers. The significance of these findings is discussed.

Keywords: Pet specialty stores; Spatial analysis; IPM intervention

Introduction

The manufacture and distribution of pet foods is a major industry in the United States. Retail sales of dog and cat foods in 2000 were estimated at US$11.1 billion (Gurkin, 2001). The majority of pet foods sold in retail grocery stores or retail pet stores are susceptible to a variety of stored-product insects, which can cause significant economic losses by contaminating and damaging products on the shelves (Subramanyam et al., 2001). Significant losses to product manufacturers occur due to removal, return or disposal of infested products. Frequent infestations may result in decreased consumer confidence, and in a small number of cases, infested products when handled may cause allergic reactions in some sensitive people.

Two recent surveys (Platt et al., 1998; Arbogast et al., 2000) focused on stored-product insect infestations in retail stores. They reported stored-product insects to be common and abundant in stores, although the species found varied between the surveyed stores. Both Platt et al. (1998) and Arbogast et al. (2000) reported capturing more stored-product insects near petfood aisles, compared to other parts of the store.

In this paper, we report on the stored-product insect species found in eight retail pet stores in Kansas. In addition, we evaluated the impact of chemical and non-chemical pest management practices on insect populations.

Materials and methods

Eight retail stores, belonging to a retail chain and differing in dimensions and pet products sold (Table 1), were monitored for insects. Beetles were monitored with pitfall traps (Flite-Trak or Dome traps, Trécé, Inc., Salinas, California) baited with food oil and pheromone lures. Three commercial lures, one each for the cigarette beetle *Lasioderma serricorne* (F.)/ drugstore beetle *Stegobium paniceum* (L.), *Trogoderma* spp., and *Tribolium* spp., were used with the food-baited traps. Males of the Indian meal moth, *Plodia interpunctella* (Hübner) were monitored with sticky traps baited with a commercial sex pheromone (Pherocon II traps, Trécé, Inc., Salinas, California).

Thirty pitfall and sticky traps were placed throughout the store in a loosely arranged grid pattern, primarily in locations concealed from the customer's view. Trap locations were marked on the store's planogram (shelf and product layout map), so that the traps could be retrieved easily during site visits. The *x* and *y* coordinates of each trap location were measured using a hand-held DISTO™ meter (Leica Geosystems, Heerbrugg, Switzerland).

During each visit, beetles captured in traps were collected and placed in 35 mm × 10 mm plastic dishes for further identification and enumeration in the laboratory. Males of *P. interpunctella* captured in traps were counted on site and removed from the sticky surface with forceps to avoid a decrease in trap catch efficiency due to trap saturation. Traps

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Table 1. Characteristics of retail pet stores surveyed in Kansas, and specifics of pest management measures applied in each store

Store no.	Location	Store floor area (m²)	No. visits	Intervention applied	Application time	Total treated area (%)
1	Overland Park	1320	11	Sanitation – hydroprene	4th visit	30
2	Overland Park	1050	8	No intervention	–	0
3	Overland Park	598	11	Sanitation – hydroprene	4th visit	80
4	Overland Park	483	8	No intervention	–	0
5	Wichita	924	7	Sanitation – cyfluthrin	3rd visit	30
6	Wichita	1045	7	Sanitation – cyfluthrin	3rd visit	30
7	Topeka	960	12	Sanitation only; Sanitation – cyfluthrin	5th visit; after 10th visit	40
8	Lawrence	800	11	Sanitation only; Sanitation – cyfluthrin	5th visit; after 9th visit	40

with ≥30 *P. interpunctella* were replaced with new ones. Stores were visited every 1–3 weeks.

Trap captures were expressed as number of insects/trap/week (z coordinate). The x, y and z-coordinate data from each store were entered into the Surfer® program to generate contour maps of trap capture data (Keckler, 1995; Brenner et al., 1998; Arbogast et al. 2000). Contour maps showing distributions of trap captures facilitated identification of infestation foci and precision targeting of pest management measures.

After three to five initial visits to stores, four pest management intervention treatments were applied. These were: (1) sanitation only, such as vacuuming, sweeping spilled food and removal of severely infested products; (2) sanitation followed by an application of hydroprene 9% EC at the labelled rate; (3) sanitation followed by higher labelled rate application of cyfluthrin 20 WP; and (4) no intervention. Details on selected stores that received each pest management intervention are presented in Table 1.

Insects associated with retail pet stores

All stages of insects captured in traps were identified to species. Species that required clearing or dissection (e.g. *Sitophilus* spp. and *Cryptolestes* spp.) were identified to genus and counted. Beetle larvae caught in traps were identified only to genus, using characteristics given by Halstead (1986). We used descriptions by Simmon and Ellington (1925) to identify larvae of the red-legged ham or copra beetle, *Necrobia rufipes* (De Geer). *Plodia interpunctella* were captured in both types of trap. Large numbers of adult males were captured in sticky traps. Pitfall traps captured both larvae and adults in small numbers. Non-stored product insect species caught in pitfall traps were identified, but not enumerated. In stores, some species were captured before our scheduled intervention, and others after intervention.

Impact of pest management intervention on trap captures

To evaluate the impact of pest management intervention, mean numbers of insects/trap/wk in each store throughout the survey period were plotted against time to observe population fluctuations. Sequential contour maps also provided an additional source of information for gauging effectiveness of treatments applied in stores.

Results

Insects associated with pet stores

A total of 36 adult insect species belonging to 23 families and 7 orders were captured in both types of trap across the stores. Larval stages of five species were captured in pitfall traps (Table 2). A total of 41,266 adults were captured in both trap types throughout the survey; 26% of them belonged to *Sitophilus* spp. complex, 25% were *P. interpunctella*, 23% were red flour beetle, *Tribolium castaneum* (Herbst), 10% were merchant grain beetle, *Oryzaephilus mercator* (Fauvel), 5% were laemophloeid beetles, *Cryptolestes* spp., 4% were *S. paniceum* and 4% were *N. rufipes*. Adults of the remaining 29 species were captured on few occasions in very small numbers. A total of 3032 larvae were captured in the pitfall traps. Nearly 60% of them were *N. rufipes*, 26% were *Oryzaephilus* spp., 10% were *P. interpunctella*, 4% were *Cryptolestes* spp., and <1% were *T. castaneum*.

Adult and larval numbers captured in traps varied among stores. Store 7 had the highest trap captures followed by store 1 (Fig. 1). Store 3 had intermediate numbers of beetles and low numbers of moths, whereas store 5 had intermediate moth numbers but low beetle numbers.

Impact of pest management intervention on trap captures

Insect numbers in pitfall traps in the untreated stores 2 and 4 remained low throughout the survey period (Fig. 2a), but moth numbers in June 2001 gradually increased, especially in store 2 (Fig. 3a). Focal points of beetle infestation were near the south-central area of the store 2 (Fig. 4a). A few moths were captured in sticky traps in store 2 initially, and captures were concentrated near the northwest area of the store (Fig. 4b). By the end of the survey, focal points of moth captures were near the south-central area (Fig. 4b). Infestation foci of beetles in store 4 were inconsistent (Fig. 5a), whereas moths were concentrated near the northeast area of the store (Fig. 5b).

Three months after sanitation and hydroprene application, beetle numbers in stores 1 and 3 were reduced to low levels (Fig. 2b). Moth numbers in store 1 fluctuated greatly after sanitation and hydroprene application, and were high at the end of our survey (Fig. 3b). In store 1, moth numbers were low throughout the survey (Fig. 3b). Immediately before intervention in April 2001, beetle infestation foci were near the south, centre and northeast areas of the store (Fig. 6a). Infestation foci near the south were associated with wild-bird

Table 2. Insect species captured in Kansas pet stores

Order/Family	Species	Total no. insects		Incidence (No. stores out of 8)
		Adults (n = 41,266)	Larvae (n = 3,032)	
Coleoptera				
Anobiidae	*Lasioderma serricorne* (F.)	61		6
	Stegobium paniceum (L.)	1,768		8
Cleridae	*Necrobia rufipes* (Degeer)	1,692	1,806	6
Curculionidae	*Sitophilus* spp.	10,702[a]		8
	Sitophilus granarius (L.)			
	Sitophilus oryzae (L.)			
	Sitophilus zeamais Motschulsky			
Dermestidae	*Anthrenus verbasci* (L.)	21		5
	Anthrenus scrophulariae (L.)	2		1
	Attagenus sp.	1		1
	Dermestes lardarius L.	23		3
	Trogoderma sp.	12		7
Laemphloeidae	*Cryptolestes* spp.	1,960[a]	123[a]	8
	Cryptolestes pusilloides (Steel and Howe)			
	Cryptolestes pusillus (Schönherr)			
Languriidae	*Cryptophilus* sp.	3		2
Lathridiidae	*Cartodere constricta* (Gyllenhal)	8		2
	Corticaria sp.	11		4
Mycetophagidae	*Typhaea stercorea* (L.)	1		1
Nitidulidae	*Carpophilus* sp.	1		1
Ptinidae	*Gibbium psylloides* (de Czenpinski)	19		1
Rhizophagidae	*Monotoma* sp.	2		2
Silvanidae	*Oryzaephilus mercator* (Fauvel)	4,296	789[a]	8
	Oryzaephilus surinamensis (L.)	811		8
	Ahasverus advena (Waltl)	4		4
Staphylinidae	Not identified	11		6
Tenebrionidae	*Alphitophagus bifasciatus* (Say)	4		2
	Tribolium castaneum (Herbst)	9,562	13	7
	Tribolium confusum du Val	2		2
Collembola	Not identified	Plenty in few stores		
Diptera	Not identified	Occasional		8
Orthoptera				
Gryllidae	Not identified	Occasional		8
Hymenoptera				
Bethylidae	*Cephalonomia* sp.	Frequent		2
Braconidae	*Habrobracon* sp.	Frequent		2
Pteromalidae	*Lariophagus* sp.	Frequent		8
Lepidoptera				
Pyralidae	*Plodia interpunctella* (Hübner)	290[b] + 9,983[c]	301	8
Psocoptera				
Liposcelididae	*Liposcelis* sp.	5		3
Fm. not identified	Sp. not identified (winged)	11		2

[a] Total numbers represent all species in the indicated genus.
[b] Total number of *P. interpunctella* adults captured in pitfall traps.
[c] Total number of *P. interpunctella* adults captured in sticky traps.

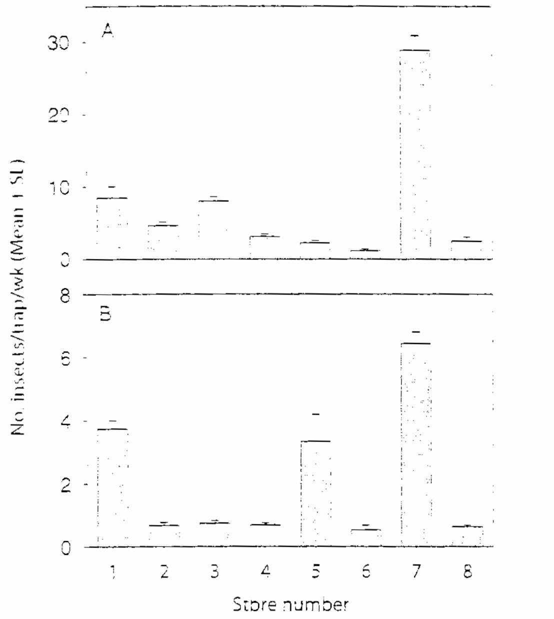

Fig. 1. Mean insects captured in traps in eight retail pet stores: (A) beetle captures of pitfall traps; (B) Indian meal moth captures in sticky traps.

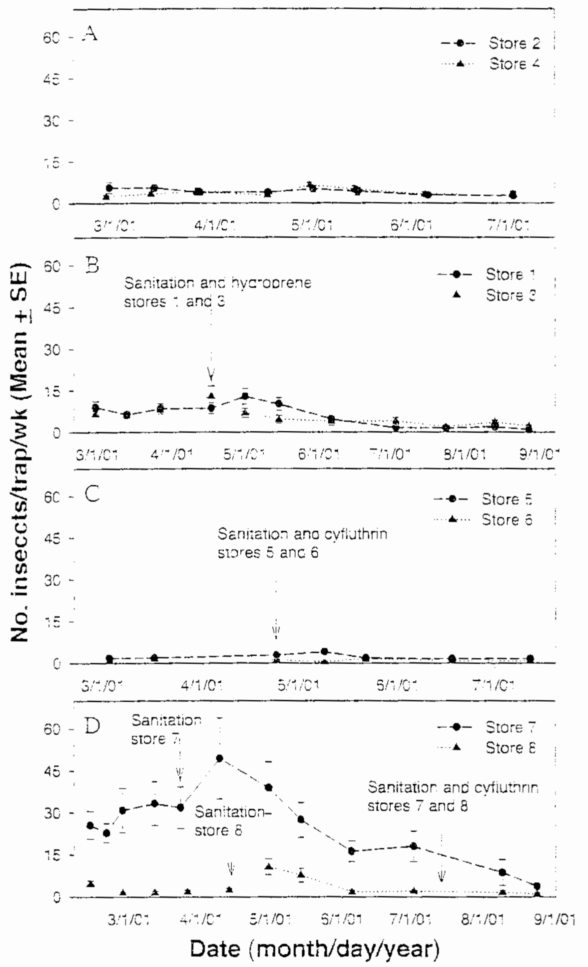

Fig. 2. Mean number of insects captured in pitfall traps throughout the survey period: (A) no intervention; (B) sanitation plus hydroprene application; (C) sanitation plus cyfluthrin application; (D) first sanitation and second sanitation plus cyfluthrin application.

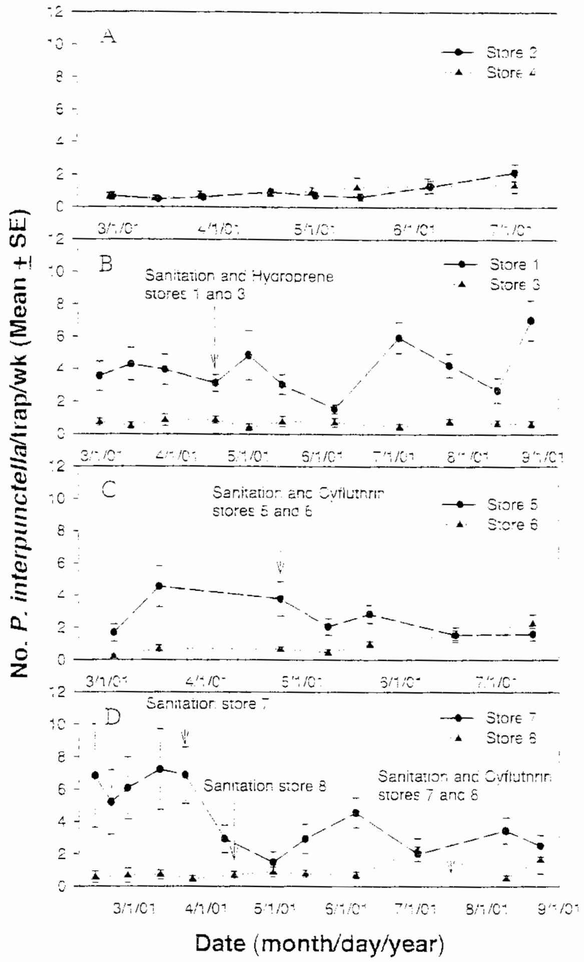

Fig. 3. Mean number of Indian meal moths captured in pitfall traps throughout the survey period: (A) no intervention; (B) sanitation plus hydroprene application; (C) sanitation plus cyfluthrin application; (D) first sanitation and second sanitation plus cyfluthrin application.

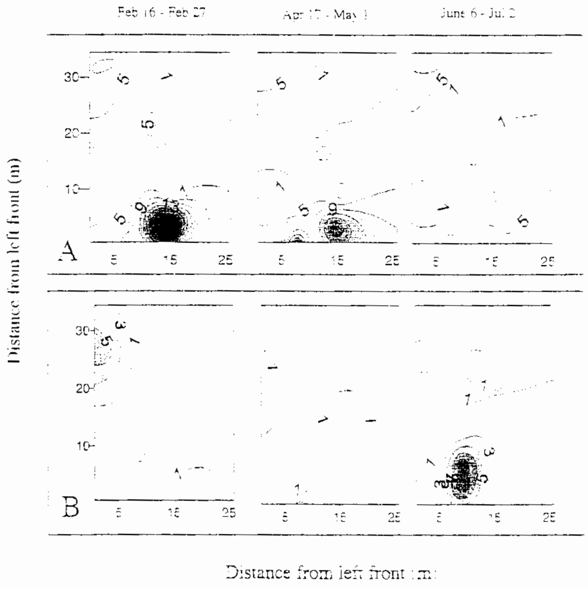

Fig. 4. Distributions of insects in store 2 during indicated trapping periods: (A) beetles; (B) Indian meal moth.

and small-animal foods kept in bags on shelves and in bulk containers on a display table. High trap captures in the middle of the store were associated with dog and cat dry foods. The northeast area of the store was near the back room, where food products are brought in and damaged products are temporarily stored. After intervention, distribution and number of beetles in targeted areas were reduced, and by the end of August 2001 very few beetles were caught in this area (Fig. 6a). Moth infestations were generally near the same area reported for beetles. After intervention, moth numbers in targeted areas were still high and new moth infestation foci developed in different store areas. In store 3, beetle infestation foci were near the centre of the store, where wild-bird and small-animal foods were kept. Immediately after intervention, beetle captures in traps increased (Fig. 7a), but diminished about four months later. Focal points of moth infestation were also near the centre of the store, but at the end of the survey another focal point was found in a different area of the store (Fig. 7b).

Before intervention, beetle trap captures in stores 5 and 6 and moth captures in store 6 were low. Moth captures in store 5 were moderately high (Fig. 1). After sanitation and cyfluthrin application, beetle captures in stores 5 and 6 remained low for the rest of the survey period (Fig. 2c). Moth captures in store 5 dropped slightly, whereas those in store 6 increased gradually (Fig. 3c). Before intervention, focal points of beetle and moth infestations were near the west and centre areas of the store (Figs. 8a and 8b), where wild-bird and small-animal foods were kept on shelves and the display table. Immediately after sanitation and cyfluthrin application in store 5, beetle trap captures near targeted areas did not show a decrease (Fig. 8a). Three months after intervention, beetle captures near most areas of store 5 were reduced, except near the west area of the store (Fig. 8a), where wild-bird foods were stored in big paper bags. Moth captures in store 5 were reduced slightly after intervention (Fig. 8b). All traps in store 6 had low beetle captures throughout the survey (Fig. 9a). Initially, moth captures in store 6 were low, but at the end of the survey two additional moth infestation foci developed (Fig. 9b).

Trap captures of beetles and moths were highest in store 7. In store 8, both the beetle and moth captures were low (Fig. 1). Immediately after sanitation, beetle captures in both stores increased, but decreased to low levels two months

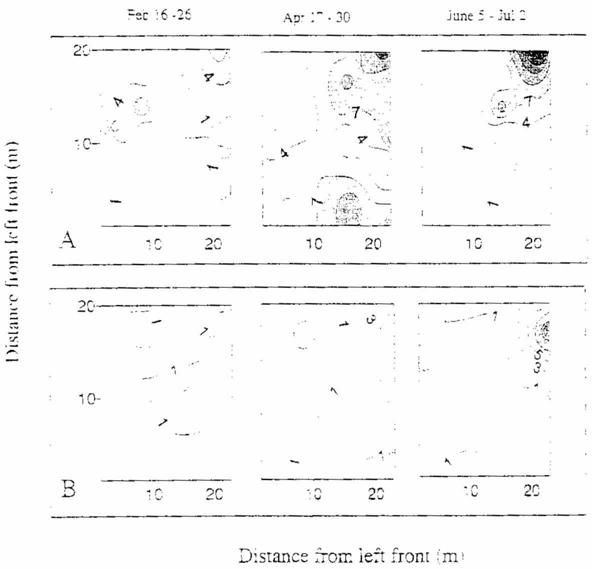

Fig. 5. Distribution of insects in store 4 during indicated trapping periods: (A) beetles; (B) Indian meal moth.

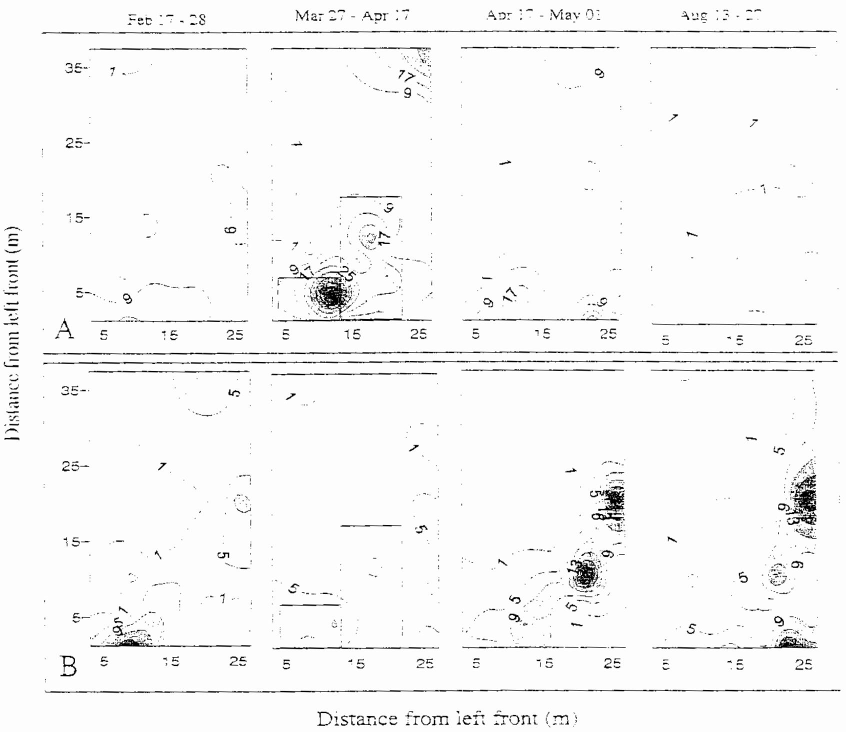

Fig. 6. Distribution of insects in store 1 before and after the first intervention and near the end of the survey period: (A) beetles; (B) Indian meal moth. Rectangular areas inside maps indicate areas targeted for pest management intervention.

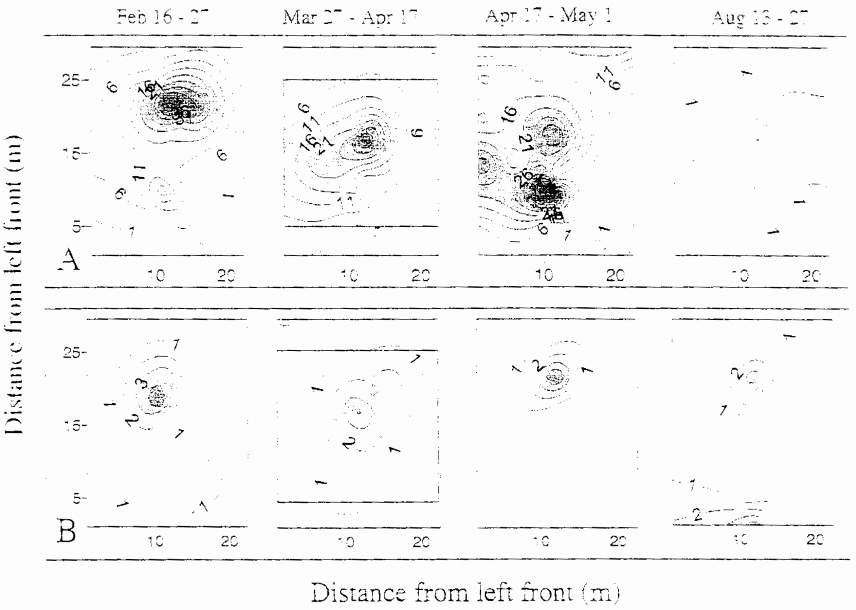

Fig. 7. Distribution of insects in store 3 before and after the first intervention and near the end of the survey period: (A) beetles; (B) Indian meal moth. Rectangular areas inside maps indicate areas targeted for pest management intervention.

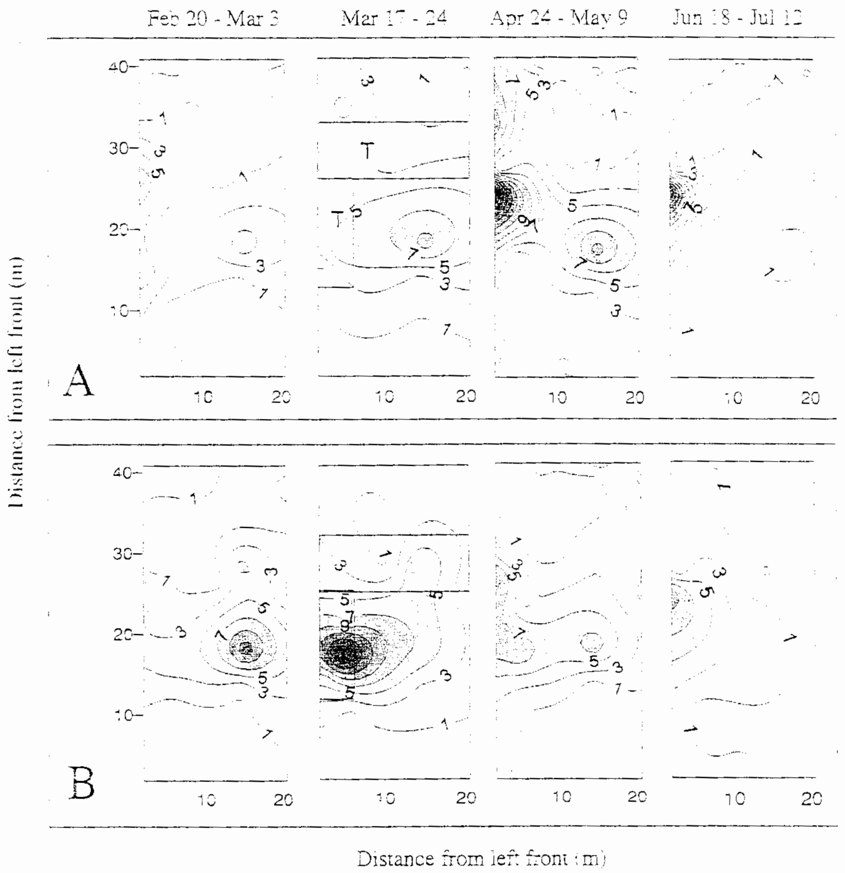

Fig. 8. Distribution of insects in store 5 before and after the first intervention and near the end of the survey period. (A) beetles; (B) Indian meal moth. Rectangular areas inside maps indicate areas targeted for pest management intervention.

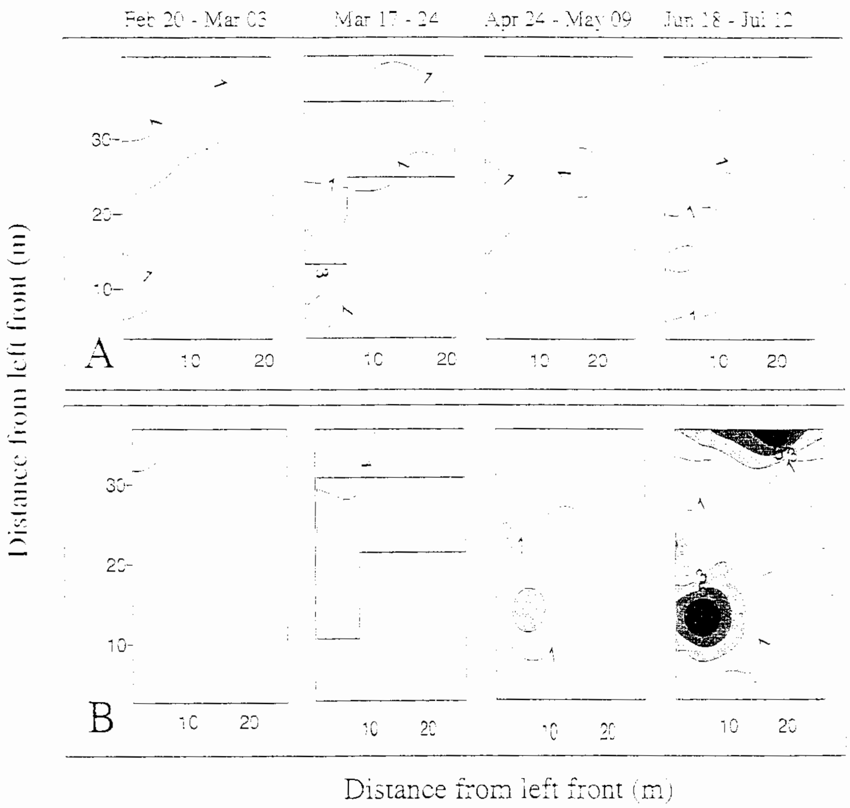

Fig. 9. Distribution of insects in store 6 before and after the first intervention and near the end of the survey period: (A) beetles; (B) Indian meal moth. Rectangular areas inside maps indicate areas targeted for pest management intervention.

after sanitation (Fig. 2d). Immediately after sanitation and cyfluthrin application, beetle captures in store 7 decreased and this reduction persisted until the last sampling occasion. Beetle trap captures in store 8 remained low throughout this time (Fig. 2d). Moth captures in stores 7 and 8 fluctuated after the first and second interventions (Fig. 3d). In store 7, beetle infestation foci were near the northeast area of the store where wild-bird foods in bags were displayed on shelves (Fig. 10a). Moth infestation foci were present in different store areas (Fig. 10b). Immediately after sanitation in store 7, beetle captures near targeted areas increased, but decreased three months after sanitation (or immediately before the second intervention). At this time, a new focal point of beetle infestation developed near the northwest area of the store (Fig. 10a). This new infestation was dominated by *Necrobia rufipes*. During sanitation activities, decomposing carcasses of two mice were found under a kickplate. The carcasses were covered with adults and larvae of *N. rufipes*. These mice, along with the beetles, were removed and discarded. Immediately after a second sanitation and cyfluthrin application, the focal point of beetle infestation previously found near the northwest area of store 7 disappeared, but a new focal point of beetle infestation developed near the east side of the store (Fig. 10a). This new focus was not found in subsequent sampling. In store 7, moth distribution and captures were reduced following the first sanitation as well as after the second sanitation and cyfluthrin application (Fig. 10b). Although beetle numbers in store 8 were low before sanitation, beetle infestation foci near the northeast and southeast areas of the store (Fig. 11a) were associated with wild-bird and small-animal foods. Immediately after sanitation in store 8, beetle captures increased, but gradually decreased thereafter (Fig. 11a). The focal point of moth infestation near the southwest area of store 8 (Fig. 11b) was also associated with wild-bird food stored in large bags that were placed on the top shelf. Therefore, sanitation or pesticide application to target areas on the floor did not affect the moth infestation.

Discussion

The large number of different insect species captured in retail pet stores reflects the diversity of products carried and the suitability of these products to stored-product insects. Pet food products contain ingredients that are favourable for supporting stored-product insect infestations. For example, pet foods are generally made up from single or mixed raw ingredients of whole, cracked and/or ground cereal grains and oilseeds, with or without vitamins and minerals. Small-animal and bird foods in display containers consisted of raw and processed ingredients, including whole, cracked and/or ground cereal grains (wheat, corn sorghum and millet), legumes (soybean and peanut), oilseeds (sunflower, rape, almond and sesame), dried fruits (banana, papaya, raisin and apple), dried vegetables (carrot, spinach, parsley and pea), grass (Canary grass), spices (anise, caraway and fennel), other seeds, dried eggs, yeast, meat, fishmeal, vitamins and minerals. Dog and cat foods in bags are extruded products consisting of rice, corn, wheat, eggs, yeast, fat, beef, poultry and/or fish, and are rich in animal protein (>20% by weight) and fat (>10% by weight).

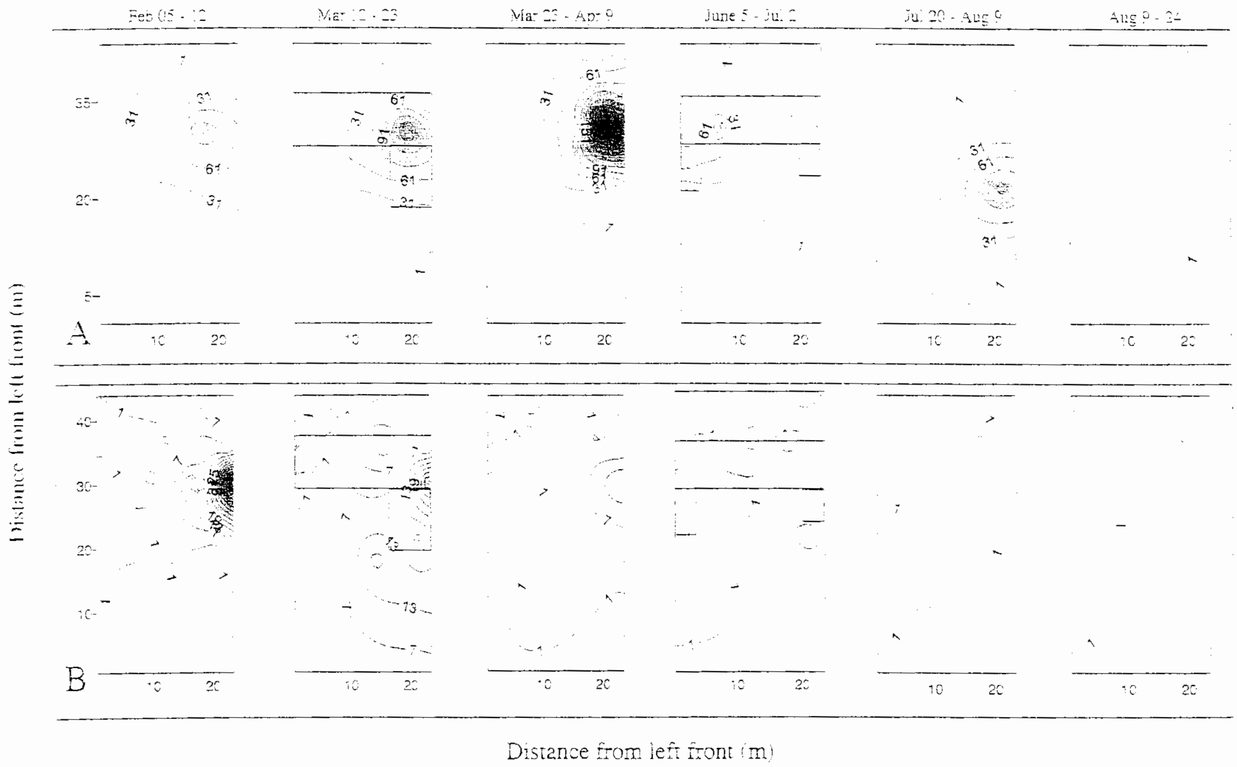

Fig. 10. Distribution of insects in store 7 before and after the first intervention and near the end of the survey period: (A) beetles; (B) Indian meal moth. Rectangular areas inside maps indicate areas targeted for pest management intervention.

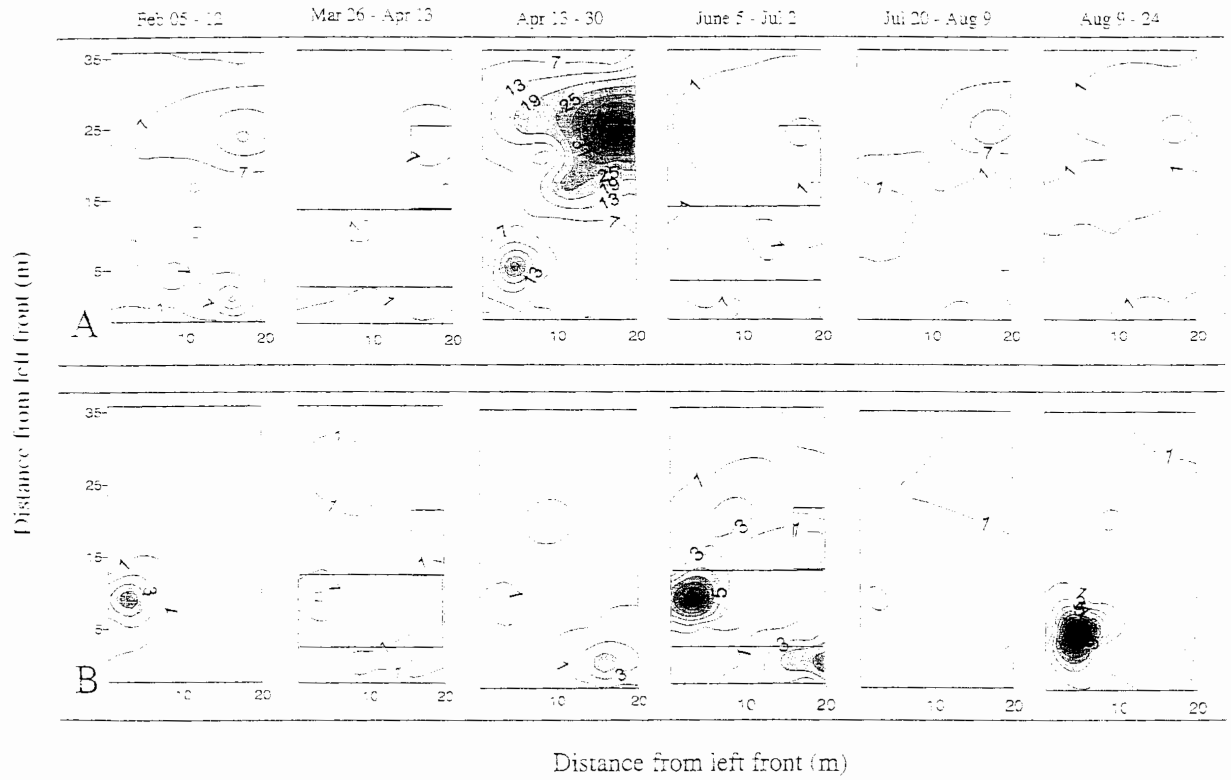

Fig. 11. Distribution of insects in store 8 before and after the first intervention and near the end of the survey period: (A) beetles; (B) Indian meal moth. Rectangular areas inside maps indicate areas targeted for pest management intervention.

The success of *Sitophilus* spp. in invading pet stores is due to the abundance of suitable foods, especially wild-bird foods, which are made up of different types of cereal grains and are often packaged in PVC bags that are not insect resistant. Unlike cat and dog foods, wild-bird foods are not processed under high temperatures. Therefore, infestation in raw ingredients may remain in the final product brought into the stores, and may serve as a primary source of insects.

Plodia interpunctella were found in all eight retail pet stores in large numbers. Both Platt et al. (1998) and Arbogast et al. (2000) found *P. interpunctella* to be abundant in retail stores in the south-central United States and in north-central Florida, respectively. *Tribolium castaneum* was the third most abundant insect species. Most *T. castaneum* detected in our study were from store 7. *Oryzaephilus mercator* was common and abundant in most of the stores. Arbogast et al. (2000) found both *O. mercator* and *T. castaneum* to be common in two pet stores in north-central Florida.

The presence of *Necrobia rufipes* in retail stores has not been reported previously. In our survey, this species was abundant only in store 7. The beetles were found throughout the store, including office spaces. *Necrobia rufipes* infestations in store 7 were associated with spilled cat and dog foods on the floor and under shelves, dried pigs' ears and other pet food products that were rich in protein. *Necrobia rufipes* is also reported to breed on animal (including human) carrion, and is considered to have potential forensic importance (De Souza and Linhares, 1997).

Significant differences in capture rates of beetles and moths among stores prior to intervention reflect variation in levels of infestation and pest management practices followed. Insects infesting products in bags or display containers were not often checked or noticed by store employees or management. In stores 1, 3 and 7, visible infestations (presence of adults and/or larvae sometimes in very high numbers, i.e. insect density up to 2270 insects/kg) were found in bagged products. In stores 1, 5 and 7 we found insects inside plexiglas containers that hold bulk pet food on display tables. In some stores, spillage was often found accumulating in spaces between the bottom shelves and floors. Accumulations of wild-bird foods were also found under kickplates of shelves. Product spillage often resulted from poor packaging and/or rough handling of packages, and also from rodent activities. Interestingly, live and/or dead rodents were found in stores that had high insect numbers.

Although pest management intervention was not applied to stores 2 and 4, these stores had low insect numbers. In these stores, we noticed very little spillage and little or no visible product infestation.

Temperatures inside the stores were maintained at 20–25°C throughout the year. However, during the middle of summer, monthly temperature in store 7 was >25°C due to failure of the air conditioning system. This might have contributed to high insect captures in this store.

Increase in beetle trap captures immediately after intervention in some stores, especially those receiving only sanitation, is perhaps related to disturbance-induced activity. Disturbance and removal of foods may have caused some insect species, especially *Sitophilus* spp. and *Oryzaephilus* spp. (Haines, 1991), to disperse and thus have increased their capture in traps (Cuperus et al., 1990). It took at least two months before a decrease in beetle captures was observed after sanitation, with or without a chemical application.

The first sanitation in store 7 failed to reduce beetle captures, perhaps because large numbers of beetles found inside infested bird-food product packages were reinfesting the store. During the second intervention, we removed bags with visible infestations and spillage. Sanitation and cyfluthrin application reduced beetle captures to low levels. Proper and frequent sanitation, product inspection and rotation could have prevented serious insect infestation in this store. These results suggest that if insects are allowed to proliferate in retail stores, repeated sanitation (include removal of all infested products) combined with chemical application is required to bring populations within acceptable limits.

Our intervention failed to have significant impact on *Plodia interpunctella* captures. Because larvae of this species were found in many pet foods from birdseeds to bulk materials stored in plexiglas containers, pesticide applications made to floor surfaces did not affect *P. interpunctella* infestations.

In summary, our survey showed that retail pet stores have numerous insects. *Sitophilus* spp., *P. interpunctella* and *O. mercator* were the most common and abundant species in all stores, whereas *N. rufipes* and *T. castaneum* were abundant only in one store.

Our sanitation and pesticide applications were effective in reducing beetle numbers, but not *P. interpunctella* numbers. To prevent stored-product insect infestation in retail pet stores, we recommend a thorough inbound inspection, good stockroom management, frequent stock rotation, and regular cleaning and sanitation, especially under kickplates and shelves.

We strongly recommend the use of insect monitoring devices and spatial analysis of trap capture data for identifying infestation foci and for evaluating the benefits of sanitation or pesticide application.

In our study, sanitation and/or pesticide applications were made once or twice. Further studies should attempt to verify the effects of multiple sanitation schedules and/or pesticide applications on the degree and duration of insect suppression obtained.

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References

Arbogast, R.T., Kendra, P.E., Mankin R.W., McGovern J.E., 2000. Monitoring insect pests in retail stores by trapping and spatial analysis. Journal of Economic Entomology 93, 1531–1542.

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

Cuperus, G.W., Fargo, W.S., Flinn, P.W., Hagstrum, D.W., 1990. Variables affecting capture of stored grain insects in probe traps. Journal of the Kansas Entomological Society 63, 486–489.

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

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 edition. Natural Resources Institute, Overseas Development Administration, Kent, UK.

Halstead, D.G.H., 1986. Keys for the identification of beetles associated with stored products. I—Introduction and key to families. Journal of Stored Products Research 22, 163–203.

Keckler, D. 1995. Surfer for Windows, version 6, User's Guide. Golden Software, Golden, Colorado.

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

Simmon, P., Ellington, G.W., 1925. The ham beetle, *Necrobia rufipes* De Geer. Journal of Agricultural Research 30, 845–863.

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