

4 Biology, Behavior, and Ecology of Insects in Processed Commodities

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Most insects found in storage facilities consume commodities, but some feed on mold growing on stored products. Others may be predators and parasitoids. Insects that attack relatively dry processed commodities (those with about 10% or more moisture content at 15 to 42°C) can cause significant weight losses during storage. Insects occur in flour mills, rice mills, feed mills, food processing facilities, breakfast and cereal processing facilities, farm storages, grain bins, grain elevators, bakeries, warehouses, grocery stores, pet-food stores, herbariums, museums, and tobacco curing barns. Economic losses attributed to insects include not only weight loss of the commodity, but also monitoring and pest management costs and effects of contamination on product trade name reputation.

Life Histories

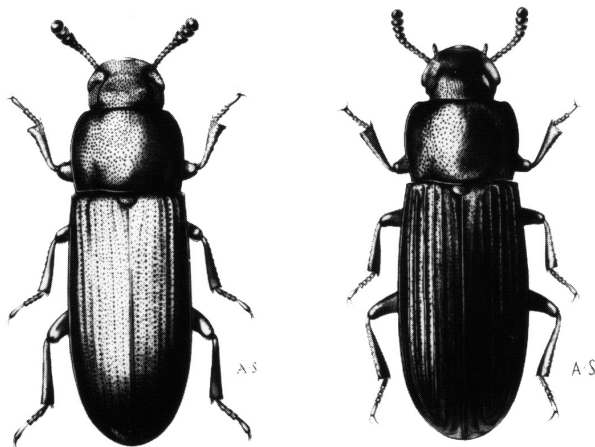


Figure 1. Red flour beetle, left, and confused flour beetle, right, each 2.3 to 4.4 mm long (from Rees 1996).

Red flour beetle, *Tribolium castaneum* (Herbst)

Red flour beetle adults (Figure 1) are reddish brown. Eggs are oblong and white. Adults show little preference for cracks or crevices as oviposition sites. Eggshells are coated with a sticky substance that aids in attaching the eggs to surfaces and causes small particles to adhere to them (Arbogast 1991). Larvae are yellowish white with three pair of thoracic legs.

Typically, there are six to seven larval instars, depending on temperature and nutrition. Larvae move away from light, living concealed in the food. Full-grown larvae move to the food surface or seek shelter for pupation. Pupae are white and exarate, which means that appendages are not fused to the body. External genitalic characters on pupae can be used to differentiate males and females (Good 1936).

Average development from egg to adult ranges from 41.8 days at 25°C to 21.7 days at 35.5°C (Hagstrum and Subramanyam 2006). Howe (1956a) found that between 35°C and 37.5°C at a relative humidity (RH) more than 70%, development is completed in 19 to 20 days (eggs in three days; larva in 12 to 13 days; pupa in four days). Males have a setiferous patch on the posterior side of the fore femur, but females do not (Bousquet 1990). Adults of red flour beetles live several months to several years. At 18°C to 29°C, the average life span of males and females ranges from 130 to 198 days. Adults are capable of lifelong reproduction. The preoviposition period is eight to 10 days. At 25°C and 70% RH, a mated female lays three to five eggs per day for the first few

days and two to three eggs per day for the rest of her life. A female, on average, can lay a total of 360 eggs during a lifetime, but egg laying decreases in females more than 100 days old (Sokoloff 1972).

Confused flour beetle, *Tribolium confusum* (Jacquelin du Val)

The confused flour beetle (Figure 1) is reddish brown and biologically similar to the red flour beetle. The two species can be distinguished by the number of segments in the club of the antenna (confused flour beetle has four or five and the red flour beetle has three) and the greater distance between the eyes of the confused flour beetle from below (Hagstrum and Subramanyam 2006). Adults of both species have well-developed wings, but only red flour beetles have been observed to fly (Arbogast 1991). The optimum, maximum, and minimum temperatures for confused flour beetle development are all about 2.5°C lower than for red flour beetle. At 32.5°C optimum temperature and 70% RH, confused flour beetle completed development in about 25 days (eggs in four days; larva in 16 days; pupa in six days) (Howe 1960). Developmental time was 20 days at 35°C and 56.2 days at 22.5°C (Hagstrum and Subramanyam 2006). Male confused flour beetles have a setiferous fovea on the posterior side of all femora; females do not (Bousquet 1990).

Natural enemies – Several predators, parasitoids, and pathogens attack red and confused flour beetles. An anthocorid predatory bug, *Xylocoris falvipes*, parasitic wasps *Holepyris sylvanidis*, and number of pathogens, including bacteria, fungi, and protozoa, are known to damage flour beetles (Arbogast 1991; Hagstrum and Subramanyam 2009).

Commodities infested and nature of the damage – In nature, red flour beetles have been found in bee nests, longitudinally split acorns, and bark habitats. They feed on organic material and fungi under tree bark (Linsley 1944). Red flour beetles feed on a wide variety of plant and animal products, and large populations are associated with stored food and feed grains, oilseeds, nuts, dried fruits, spices, pulses, beans, cacao, cottonseed, and forest products. Both larvae and adults feed on seed embryos, grain dust, and broken kernels and tend to prefer floury materials (Arbogast 1991). Red flour beetles do not develop on sound kernels (Anonymous 1986).

Larval and adult tunnels are common in infested flour, appearing as trails on dusty surfaces in food-processing facilities and grain elevators. In heavy infestations of red or confused flour beetles, food may be discolored, have a disagreeable odor and often may contain life stages of the insect, exuviae, and fecal matter. The odor is attributed to chemicals secreted from insects' thoracic or abdominal glands (benzoquinones). The chemicals are heat stable and impart a disagreeable odor to food, which is not removed by cooking (Hodges et al. 1996).

Facilities infested – Both red and confused flour beetles are found in many parts of the world. Red flour beetles inhabit warmer climates, and confused flour beetles are found in cooler climates. These beetles primarily occur in flour mills, feed mills, warehouses, retail grocery stores, boxcars, semolina mills, and bakeries (Cogburn 1973b; Bousquet 1990; Trematerra et al. 2007). Beetles also occur in empty cargo containers, farm grain bins, farm storages, grain elevators, peanut shelling plants, residences, and pet stores (Hagstrum and Subramanyam 2009).



Figure 2. Sawtoothed grain beetle, 1.7 to 3.2 mm long (from Rees 1996).

Sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.), and Merchant grain beetle, *Oryzaephilus mercator* (Fauvel)

Sawtoothed (Figure 2) and merchant grain beetles share similar life histories. Eggs usually are deposited singly in crevices of coarse grain but are also laid in finely ground material. Oviposition often

begins during the first week of adult life and peaks the second or third week. Average fecundity is about 280 eggs per female. An average of two to four larval instars occurs, depending on nutrition and temperature, but there are typically three larval instars. When the larva reaches maturity, it constructs a crude pupal cell by cementing together food particles. Before pupating the larva fastens its caudal extremity to a solid object. Adults are reddish brown, slender, flat, and about one-tenth of an inch long. Adults have six sawtooth-like projections on each side of the thorax. Adults live six to 10 months. The population growth rate of sawtoothed and merchant grain beetles depends on temperature, humidity, and food type. Adults and larvae are somewhat resistant to cold and capable of withstanding three weeks of exposure to cold temperatures of between -1°C to 1°C (Arbogast 1991).

Sawtoothed grain beetle and the merchant grain beetle can be distinguished by the relative lengths of eye and temple and by male genitalia. Distinguishing features in the male genitalia are that sawtoothed grain beetle has several setae along the posterior edge of sternite VIII, while merchant grain beetle has only three setae on each side near the lateral margin of the posterior edge. In the median genitalia orifice, sawtoothed grain beetle has eight strengthening chitinous rods, merchant grain beetle has 16 rods (Howe 1956b).

Natural enemies – The anthocorid bugs, *X. flavipes* and *X. cursitans*, regulate sawtoothed and merchant beetle populations by predation (Arbogast 1991, Hagstrum and Subramanyam 2009). Some ectoparasitoids such as *Cephalonomia tarsalis* and the entomopathogenic fungus, *Beauveria bassiana* are effective in controlling these beetles (Lord 2001). The Bethyridae wasp, *Holepyris sylvanidis*, also is effective in controlling sawtoothed and merchant grain beetles (Arbogast 1991).

Commodities infested and nature of the damage – Sawtoothed grain beetle and the merchant grain beetle feed on stored grain, cereal products, dried fruits, nuts, animal feed, and oilseeds. Sawtoothed grain beetle is more often associated with cereal grains and cereal products while merchant grain beetle is more common in oilseed and high-oil processed foods. Sawtoothed grain beetle cannot develop on food that contains few or no carbohydrates and is unable to attack perfectly sound grain. This beetle attacks grain with small lesions

in the bran layer over the germ, then feeds on the germ. Sawtoothed grain beetles occasionally supplement vegetarian diets by feeding on eggs and dead adults of stored-product moths. On the other hand, merchant grain beetles primarily feed on oilseeds and derivatives and processed cereals with a high oil content (Arbogast 1991; Hagstrum and Subramanyam 2009).

Facilities infested – In nature, sawtoothed grain beetles are reported to occur beneath tree bark. This is essentially a crevice-dwelling species that commonly occurs in cracks and crevices of food storage facilities (Linsley 1944). Sawtoothed grain beetles are found in farm storage, grain elevators, flour mills, warehouses, railroad cars, and pet stores. The merchant grain beetle occurs in similar facilities as the sawtoothed grain beetle, but also prevails in feed stores, grocery stores, grocery warehouses, and kitchens.



Figure 3. Mediterranean flour moth, 9 to 11 mm long (from Michelbacher 1953).

Mediterranean flour moth, *Ephestia kuehniella* Zeller

The Mediterranean flour moth (Figure 3) has a wingspan of slightly less than an inch. Forewings are a pale leaden gray with transverse wavy black markings. Hindwings are dirty white. Adults are nocturnal, emerging late afternoon and evening, apparently in response to changes in light intensity and temperature. Female moths produce a sex pheromone. Within 24 hours of emergence, the female becomes stationary on a suitable surface and assumes the calling posture in which the abdomen is lifted between the wings and scent glands are extruded. Adults mate and lay small white eggs at dusk the next day. Larvae move away from light before pupation. The larva spins a silken thread and mats together food particles it is eating. When fully grown, larvae are whitish or pinkish and about one-half inch long. Inside the

silken cocoon, the full-grown larva transforms to a reddish-brown pupa. Larval diapause is important in overwintering. Egg to adult development ranges from 69.1 days at 20°C and 38.2 days at 30°C (Cox and Bell 1991; Anonymous 1986). Under 12 hours of light and 12 hours of dark conditions, adult moths can live for about 9.2 days and lay an average of 241 eggs (Cymborowski and Giebultowicz 1976).

Natural enemies – Mites such as *Cheyletus eruditus* and *Blattisocius tarsalis* prey on eggs and early instars. Most important of the 21 species of parasitoids are Hymenoptera, especially braconid, ichneumonid, and trichogrammatid wasps that often parasitize eggs or larval populations. Five species of Hemiptera prey on Mediterranean flour moth. Like other Lepidoptera, Mediterranean flour moths are susceptible to attack by the spore-forming bacterium, *Bacillus thuringiensis*. Other pathogenic microorganisms such as polyhedrosis and granulosis viruses also can attack these moths (Cox and Bell 1991; Hagstrum and Subramanyam 2009).

Commodities infested and nature of the damage – Mediterranean flour moth is surpassed in importance only by red flour beetle as a serious pest of stored grain products. This moth prefers cereal products, especially flour, and feeds on a variety of stored commodities including cereals, nuts, dried fruits and vegetables, oilseeds and products, and dried citrus pulp (Cox and Bell 1991).

Facilities infested – Mediterranean flour moth seems more adapted to the temperate region, or Northern Hemisphere, and is less common in the United States than in Europe. It is excluded from the tropics because it cannot tolerate long exposures to high temperature. Facilities infested with Mediterranean flour moths include farm storage, grain bins, grain elevators, flour mills, feed mills, bakeries, warehouses, and tobacco curing barns. Webbing from heavy infestations can choke flour mill machinery.

Behavior

The behavior of stored-product insects is important to their survival and the ability to manage these pests. Insect mobility is important in locating food, a suitable living environment, and mating and oviposition sites. Mobility enables insects to avoid natural enemies and insecticide-treated areas and determines the number of insects caught in traps.

Many red flour beetles leave infested commodities (Hagstrum and Gilbert 1976). Few adults leave bags of flour before mating and laying eggs. The number of adults observed leaving increased from 0.4 to 24 per day as the population grew over time.

Red flour beetles actively search for feeding and oviposition sites (Campbell and Hagstrum 2002, Romero et al. 2010). Adults move an average 5.6 inches per minute after leaving flour but are moving only 26% of the time. They can travel an average of 175 feet per day. Researchers found the majority of adults in residual flour piles (62%) or seeking shelter near walls (32%). The remaining 6% of the adults moved among the piles of flour, laying eggs in 78% of the piles.

Searching for mates, male almond moths flew nearly 0.2 mile during an average 10-minute flight (Mankin and Hagstrum 1995). Females sat on the walls and released sex pheromones. Flight behavior changed as a male flew closer to a female and detected increasingly higher concentrations of sex pheromone. The male landed a short distance from the female, walked toward the female, and mated. Extensive male flight activity is evident. These insects are frequently seen flying.

Hagstrum (1984) observed that almond moth females can find residual peanuts for oviposition in an empty peanut warehouse or shelling plant. Only 8% to 20% of offspring from eggs laid on the peanuts survived. Population growth rates were low because females laid too many eggs at some locations and did not lay any eggs at others. Population growth decreased from seven- to threefold as the number of locations with peanuts increased. Female moths found only a small amount of the food during each generation, supporting population growth for several generations.

Ecology

Although insect ecology has been studied in several types of mills, more research is needed to fully understand it. The following review summarizes knowledge about species composition, abundance, seasonal trends and distribution in stored product environments. This information can be used to improve pest management programs.

Species composition – A few insect species were abundant, and many species were less common in feed, barley, semolina, and flour mills (Table 1). Feed and barley mills tended to have more species than semolina and flour mills. Thirty-one species were found in four or more of 15 mills and another 88 species of stored-product insects were found at three or fewer of these mills. The average number of species per mill was 23. Confused and red flour beetles were most prevalent and most abundant, and another 11 species were most abundant in one or more of the mills. In addition to the most abundant species listed in Table 1, warehouse beetles, *Trogoderma variabile* Ballion, and a psocid, *Liposcelis entomophilus* (Enderlein), were most abundant in Midwestern feed mills. The Mediterranean flour moth was reported in Europe, Asia, North Africa, Canada, and Wisconsin, but not in most other U.S. studies. Natural enemies were reported in six of the 15 studies.

Traps were used more frequently than visual inspection or commodity samples to study feed mills, and visual inspection or commodity samples were used more frequently than traps in flour mills. Eight or more feed mills were sampled more often (studies three through six) than eight or more flour mills (studies 13 and 14). The numbers of species found may have been influenced by sampling method and the number of facilities included in a study.

Density estimates, seasonal phenology, and population growth rate – Red flour beetle trap catches ranged from 0.2 to 2.2 beetles per trap per day at the time of fumigation (Campbell and Arbogast 2004). Numbers sharply declined after fumigation, and then increased until the next fumigation at rates of 0.002 beetles per trap per day in November and 0.004 to 0.005 from June to August.

Captures inside were higher than those outside the flour mill, and outside trap catch also declined after fumigation. Only red flour beetles generally were recovered in product samples from mill equipment and trash buckets. Over the sampling period, the number of beetles captured in traps was correlated with the number of live insects in product samples. Indianmeal moth and warehouse beetle are considered less important to the milling industry than red flour beetle. On average, fumigation reduced Indianmeal moth trap catches 4.4% and warehouse beetle by 16.7%. Trap catches of Indianmeal moth (16.1 vs 0.7) and warehouse beetle (12 vs 0.05) were higher outside than inside flour mills, and catches inside

tended to follow seasonal trends for captures outside. Release recapture studies showed that some Indianmeal moths entered the warehouse from outside. An additional 10 species of stored-product insect pests and parasitoids were captured in traps.

In English flour mills, the Mediterranean flour moths resting on the outside of centrifugal sifter increased from early in the year until fumigation during the summer in at least one of three years at all three mills studied (Dyte 1965). Substantial numbers of larvae were found in residue samples from centrifugal sifters at one mill, but few or none were found in these residues at the other two mills. *Venturia cansescens* (Grav.), a common parasite of Mediterranean flour moths, was present in all three mills.

Over three years in two Danish flour mills, Mediterranean flour moths increased exponentially from late April or early May until mid-August (Skovgard et al. 1999). Population density in one mill was five to 10 times that in the other mill. Seasonal phenology was determined primarily by temperature and incidence of larval diapause. Trap catch approached zero during winter, but at least one moth was caught on 58 out of 61 trappings. A simulation model indicated that 95% of larvae break diapause between June 11 and September 12 and that moths realized only 1% to 3% of reproductive potential.

Distribution of insects within a facility – In an Italian feed mill, confused flour beetles and red flour beetles were most abundant in the raw-grain weighing room, the processing and bagging room, and the storage room for bagged feed (Trematerra and Sciarretta 2004). *Attagenus brunneus* Faldermann was found mainly in the processing and bagging room. Sawtoothed grain beetle and rice weevil were found most often in the raw-grain receiving area and the storage room for bagged feed. Drugstore beetle was most often found in the processing and bagging room, but some drugstore beetles were found in the raw-grain receiving area and the storage room for bagged feed. In Canada, confused flour beetles and larder beetles were collected throughout a feed mill, but more confused flour beetles were collected in the warmer grinding and tallow rooms, and more larder beetles were collected in undisturbed areas of the mixing and pelleting room and near pallets in the warehouse (Mills and White 1993).

Average numbers of insects per sample varied from 9.0 for the patent flour rebolt reel stream to 61.3 for

the low-grade flour elevator boot (Good 1937). The patent and clear flour rebolt reel streams contained fewer insects because insects are sieved out. Red flour beetle was the dominant species. Lesser grain borer and rice weevil were abundant in wheat and wheat screenings but almost absent after the third or fourth break. White-shouldered house moth, *Endrosis sarcitrella* (L.), was generally found in the grain cleaning area of the mill, but less frequently in the milling area (Dyte 1965). Brown house moth, *Hofmannophila pseudospretella* (Stainton), and common clothes moth, *Niditinea fuscella* (L.), were found in the mill, but there was no evidence of them breeding in machinery.

Granary weevil eggs do not survive milling of wheat into semolina, and females do not oviposit on semolina, but females introduced into a factory will oviposit on macaroni while it is drying, and offspring can complete development (Chapman 1923).

Variation in number of species among mills and years

– The number of insect species found at feed mills in five Midwestern states ranged from seven to 21 (Larson et al. 2008). Of the 30 insect species, only five occurred in every feed mill in this study. These species were foreign grain beetle, hairy fungus beetle, red flour beetle, the warehouse beetle and Indian meal moth. Two genera, *Cryptolestes* spp. and *Anthicus* spp., were captured in seven mills. The granary weevil was trapped in six of the eight mills. The remaining species were found in one to five mills. In a winter survey of eight feed mills, Rillett and Weigel (1956) found between one and 13 species per mill.

In another study, only 31 Indianmeal moths were found, mainly in flour mills that were not fumigated annually (Good 1937). Longheaded flour beetles were numerous in two mills in Oklahoma, but scarce or entirely absent in all 15 of other mills. Sawtoothed grain beetles were common in only one mill in Missouri. *Palorus* spp. and *Alphitobius* spp. were found only in mills in which some of elevator boots were located in damp, dark basements.

Very small numbers of confused flour beetles were found in two of three English flour mills. A single specimen of larval or adult cadelle was found in these two mills on fewer than four occasions (Dyte 1965). Turkish grain beetle, white-shouldered house moth and broad-horned flour beetle populations each increased in a different one of the three English

mills during at least one of the three years of the study. The densities of Turkish grain beetle found in each centrifugal sifter was fairly consistent over the five years of the study. Flour mill beetle populations built up in the centrifugal sifters when the flour residues were damp.

Other food-processing facilities – In contrast to fairly extensive investigations of insect populations in mills, insect populations in food processing facilities, bakeries, peanut shelling plants, railroad boxcars, port warehouses, food distribution warehouses, groceries, and retail stores have been studied less. These inquiries also have covered species composition, insect distribution and abundance, and seasonal trends.

Cigarette beetles were trapped in 16 Japanese noodle factories, and a few drugstore beetles were trapped in nine of these factories (Suezawa et al 1987). Cigarette beetle populations peaked from May to June, in late June, in late August and in early October. None of the factories were fogged when captures were less than 25 beetles per trap, and only half of factories with higher catches were fogged. Captures were not significantly different between noodle making, drying, measuring and packing, and stock rooms. Probable sites of adult emergence were around wheat flour products and trash, and in corners of rooms and floor crevices.

Almond moth and Indianmeal moth were not uniformly distributed in a breakfast cereal factory in Australia, but were trapped more often near packing and mixing machines and conveyor belts (Rees 1999). Average trap captures ranged from 0.025 to 0.3 moths per trap per day.

Moths were abundant in only three of 35 rooms of a confectionary factory (Bowditch and Madden 1996). These rooms were used for refining chocolate and roasting nuts. High captures were near infested machinery or a result of insects being attracted to water that was present. Areas needing cleaning were readily located by inspecting around traps with high catches. Insect larvae were found in debris behind an electrical panel and two chocolate refining machines. An average of 266 days between manufacture and complaints suggest that chocolate products in Australia were stored for considerable time before being sold (Bowditch and Madden 1997). Most products were infested with one of six species of pyralids, and one was infested by the sawtoothed grain beetle.

Surveys of the factory and three distribution centers suggest that products were infested after leaving the factory.

Stored-product insect populations in bakeries in the United Kingdom included the species found in flour mills and differed by bakery section (Turner 1975, 1977, 1979). Mediterranean flour moth, confused flour beetle, broad-horned flour beetle, and Australian spider beetle, *Ptinus ocellus* Brown, were found in the dry flour section, and broad-horned flour beetle was also found in the flour silo. Moths were found in 68.5% of silos, confused flour beetles in 33%, and broad-horned flour beetle in 33%. Of sifters inspected, 68% were infested by moths, 26% by confused flour beetles, and 58% by broad-horned flour beetles. Mediterranean flour moths, confused flour beetles, broad-horned flour beetles and drugstore beetles were found in the wet dough section. Of mixers inspected, 59% were infested by flour moths, 18% by confused flour beetles, and 36.5% by broad-horned flour beetles. Provers were infested by drugstore beetles (51%), confused flour beetles (15%), broad-horned flour beetles (11%), and moths (11%). Bread coolers were infested with small numbers of shiny spider beetles, confused flour beetles and drugstore beetles. Pastry breaks were prone to moth and beetle populations under the rollers, and these species also infested cutters. Merchant grain beetles were also found in this section of the bakery. A comparison of the 1973 survey to the 1979 survey indicated there had been little reduction in insect problems during the intervening years.

The densities of insects in peanut residues at 11 shelling plants in the southeastern United States varied from 30 insects per kilogram in the winter to 580 in late summer (Payne et al. 1969). Almond moth, Indianmeal moth, red flour beetle, merchant grain beetle, and corn sap beetle made up 93% of the residual insect population, although more than 15 other species were found.

Stored-product insects were found in 81% of the railroad boxcars delivering grain products to the U.S. Gulf Coast ports, and 74% contained food residues from the previous loads (Cogburn 1973b). Red flour beetle, almond moth and lesser grain were the most abundant species.

Other parts of the marketing system –

Large numbers of cigarette beetles and almond moths were recovered from food-baited traps in four

port warehouses on the U.S. Gulf Coast (Cogburn 1973a). Almond moths and cigarette beetles were found in the food residues on the pallets in all four warehouses, with average densities of 6.14 and 2.18 per sample unit, respectively, and red flour beetles, sawtoothed grain beetles, and *Carpophilus pilosellus* Motschulsky were found in the food residues in three warehouses, with average densities of 4.83, 1.20, and 0.96 per sample unit, respectively. Insects were caught throughout the year, but catches were highest in August and September. Large numbers of *C. pilosellus* were found in two of these warehouses, and large numbers of red flour beetles were found in one. Among the four warehouses, the average overall density of all species in food residues from the pallets ranged from 9.4 to 44.4 insects per sample unit.

In food distribution warehouses, the numbers of almond moths and Indianmeal moths trapped in the vicinity of bird seed and chicken feed were significantly higher than those trapped near other commodities (Vick et al. 1986). A search around one trap with a high catch revealed a pallet of dog food infested with Indianmeal moths that was about six months out of date.

Indianmeal moths were abundant in eight Oklahoma grocery stores (Platt et al. 1998). Large numbers of merchant grain beetles and drugstore beetles were present in some stores. Beetle captures were higher in the pet food than the flour aisles. In five retail stores in north-central Florida, the most abundant insects were Indianmeal moth, cigarette beetle and merchant grain beetle (Arbogast et al. 2000). Indianmeal moth captures differed greatly among stores. Captures were highest near infested bags of sunflower seeds, birdseed, dry dog food, dry cat food or cat litter. Capture rates were essentially constant over the entire trapping period for both beetles and moths, suggesting well-established infestations.

In a survey of eight Kansas retail pet stores, 30 stored-product insect species were trapped (Roesli et al. 2003a). In each store, a total of 12 to 19 species were captured. *Sitophilus* spp., red flour beetle, and merchant grain beetle, *Oryzaephilus mercator* (Fauvel), were the most abundant. *Cryptolestes* spp., merchant grain beetle, sawtoothed grain beetle, Indianmeal moth, *Sitophilus* spp., drugstore beetle, and a pteromalid parasitoid, *Lariophagus* spp., were found in all eight stores. *Trogoderma* spp. and red flour beetle were found in seven stores, and cigarette beetle and red-legged ham beetle, *Necrobia rufipes*

(Degeer), were found in six stores. The parasitoids, *Cephalonomia* spp. and *Habrobracon* spp. were trapped in two stores. Insect densities in infested birdseed and pet food removed from the store ranged from 65 to 656 adults per kilogram. Five stored-product insect species were recovered from the bagged bird food and seven from the bulk food products.

Throughout the marketing system, temperature is a primary factor determining insect development, reproduction, and population trends. Species composition depends on which insects are introduced and varies widely between facilities and years. Within a facility, insect distribution generally is not uniform. These patterns of insect distribution and abundance can be important in developing the best pest management program.

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Table 1. Stored-product insect species found in feed, barley (B), semolina (S) and flour mills.

Order ^b	Family	Species	Common name	Feed mills ^a															Tot		
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
Col.	Tenebrionidae	<i>Tribolium confusum</i> Jacquelin du Val	confused flour beetle	A	A	A	*	*	*	*	*	*	A	A	*	*	A	A	A	A	14
Col.	Tenebrionidae	<i>Tribolium castaneum</i> (Herbst)	red flour beetle	*	*	A	*	*	A	A	*	*	*	*	*	*	A	A	A	A	13
Col.	Curculionidae	<i>Sitophilus oryzae</i> (L.)	rice weevil	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	12
Col.	Silvanidae	<i>Oryzaephilus surinamensis</i> (L.)	sawtoothed grain beetle	*	*	*	*	A	*	*	*	*	*	*	*	*	*	*	*	*	11
Col.	Trogositidae	<i>Tenebroides mauritanicus</i> (L.)	cadelle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	11
Col.	Mycetophagidae	<i>Typhaea stercorea</i> (L.)	hairy fungus beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	11
Col.	Laemophloeidae	<i>Cryptolestes ferrugineus</i> (Stephens)	rusty grain beetle	*	*	*	*	A	*	*	*	*	*	*	*	*	*	A	*	*	10
Col.	Silvanidae	<i>Ahasverus advena</i> (Waltl)	foreign grain beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	9
Lep.	Pyralidae	<i>Plodia interpunctella</i> (Hübner)	Indianmeal moth	*	*	*	*	*	A	*	*	*	*	*	*	*	*	*	*	*	9
Col.	Bostrichidae	<i>Rhyzopertha dominica</i> (F.)	lesser grain borer	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	9
Col.	Curculionidae	<i>Sitophilus granarius</i> (L.)	granary weevil	*	*	*	*	A	*	*	*	*	*	*	*	*	*	*	*	*	9
Lep.	Pyralidae	<i>Ephesia kuehniella</i> Zeller	Mediterranean flour moth	A	*	*	*	*	*	*	*	*	*	*	A	A	A	*	*	*	8
Col.	Tenebrionidae	<i>Alphitobius diaperinus</i> (Panzer)	lesser mealworm	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	7
Col.	Laemophloeidae	<i>Cryptolestes pusillus</i> (Schönherr)	flat grain beetle	*	*	*	*	*	*	A	*	*	*	*	*	*	*	A	*	*	7
Lep.	Pyralidae	<i>Pyralis farinalis</i> L.	meal moth	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	7
Col.	Tenebrionidae	<i>Tenebrio molitor</i> (L.)	yellow mealworm	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	7
Col.	Laemophloeidae	<i>Cryptolestes turcicus</i> (Grouvelle)	Turkish grain beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6
Col.	Tenebrionidae	<i>Palorus ratzeburgii</i> (Wissmann)	small-eyed flour beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6
Col.	Anobiidae	<i>Stegobium paniceum</i> (L.)	drugstore beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6
Col.	Tenebrionidae	<i>Tenebrio obscurus</i> (F.)	dark mealworm	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6
Col.	Dermestidae	<i>Anthrenus verbasci</i> (L.)	varied carpet beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	5
Lep.	Pyralidae	<i>Cadra cautella</i> (Walker)	almond moth	*	*	*	*	*	*	*	*	*	*	*	*	*	A	*	*	*	5
Col.	Dermestidae	<i>Dermestes lardarius</i> L.	larder beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	5
Col.	Tenebrionidae	<i>Latheticus oryzae</i> Waterhouse	longheaded flour beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	5
Col.	Dermestidae	<i>Attagenus unicolor</i> (Brahm)	black carpet beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4
Col.	Prinidae	<i>Gibbium psyllodes</i> (de Czenpinski)	shiny spider beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4
Col.	Tenebrionidae	<i>Gnatosicus cornutus</i> (F.s)	broad-horned flour beetle	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4

continued

