JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, January 2011, Vol. 56, No. 1
doi: 10.1111/j.1556-4029.2010.01539.x
Available online at: interscience.wiley.com

PAPER

PATHOLOGY/BIOLOGY

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Comparison of Decomposition Rates and Faunal Colonization of Carrion in Indoor and Outdoor Environments

ABSTRACT: Decomposition and insect colonization of pig (*Sus scrofa* L.) carcasses were observed over a 42-day period inside and outside a house in a suburban region of Edmonton, Alberta. Three freshly killed pig carcasses were placed outdoors on grass and three carcasses were placed in separate rooms inside a house in a suburban residential area. The carcasses were examined and sampled regularly. Outside carcasses were colonized rapidly by *Calliphora vicina* (R-D), *Lucilia sericata* (Meigen), *Lucilia illustris* (Meigen), *Eucalliphora latifrons* (Hough), *Cynomya cadaverina* (R-D), *Phormia regina* (Meigen), and *Protophormia terraenovae* (R-D). There was a delay of 5 days before inside carcasses were first colonized but all species except *E. latifrons* and *L. illustris* readily colonized at this time. Many more insects colonized the outside carcasses, and these were rapidly skeletonized. Inside, much fewer insects were present and decomposition was slowed and colonization extended. Dispersal patterns of postfeeding larvae inside the house on hard substrate were greatly expanded compared with those from carcasses on grass.

KEYWORDS: forensic science, forensic entomology, blow flies, Calliphoridae, elapsed time since death

Carrion provides a rich but ephemeral nutrient source for arthropods and supports a dynamic and diverse fauna over time. The value of understanding arthropod assemblages associated with carrion to estimate the elapsed time since death of a homicide victim has been known for centuries (1–3) and has been used commonly worldwide in the last 30 years or more (4–6). Forensic entomology is the study of insects in relation to legal matters. Medico-criminal entomology is a subset of forensic entomology, involving specifically the study of insects involved in criminal matters, primarily homicides, although it can include other criminal issues, such as neglect and abuse. Insects associated with dead bodies can be used to assist in understanding many factors about the death, such as elapsed time since death, presence or absence of drugs, poisons or wounds, and postmortem disturbance or movement (4). This medicocriminal usage of entomology has resulted in a consequent surge in research on carrion communities in various geographic areas, habitats, seasons, and scenarios in North America (e.g. [7–21]). This has resulted in a much greater understanding of carrion ecology, as well as providing valuable evidence in court.

The majority of the research on carrion ecology has been conducted in rural areas, for obvious reasons. Carrion studies involve decomposing animal carcasses or meat baits that result in a strong odor, making urban research difficult. Only a few studies, therefore, have been conducted in urban or suburban areas of North America (22–24) or worldwide (25–33). It is well known that many carrion-frequenting insects are synanthropic, indicating that certain species are more likely to be found associated with human dwellings, in other words in urban or suburban areas, than others (3,34–36). As well, many homicides occur in such areas. However, little is known of the carrion ecology of urban or suburban regions, and in particular, no research has been conducted comparing decomposition rates and insect colonization patterns between carrion inside a dwelling and that found outside. Many homicides occur inside homes and victims are often not discovered for some time. In New Zealand, of 50 human cadavers studied, 37 were found inside suburban houses (36). Forensic entomology is very valuable in such cases, but little is understood about the possible delays in colonization that may result from the body being indoors, or if certain species may be less attracted to indoor remains.

As so little carrion research has been conducted in suburban or urban regions, and none inside houses, most data are anecdotal, coming primarily from case histories (34,37,38). Studies from Hawai'i and New Zealand compared the insects associated with human remains inside dwellings versus outside, again from case histories and found significant differences between the colonizing species (36,39). However, the meteorological and geographic conditions in Canada are very different from those in other regions, so these data are not applicable to Canada.

The objectives of this research, therefore, were to compare and contrast faunal colonization rates and patterns and decompositional rates between carrion inside a house and carrion outside in a suburban area of Canada.

Materials and Methods

A single story house with basement was made available in Edmonton, Alberta. The house utilized in these experiments was a single, detached house, approximately 50 years old and 55 m^2 (600 ft^2). The house was situated in a residential region of Edmonton, Alberta, and was one of many houses being removed or

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Received 10 June 2009; and in revised form 25 Aug. 2009; accepted 23 Oct. 2009.

demolished in the near vicinity. At the time of the experiment, some houses had already been removed, but many remained and some were still occupied. The house consisted of a living room, a kitchen, two bedrooms, and a bathroom. The basement was below ground and unfinished. The flooring throughout the house was hardwood, linoleum, and concrete.

Within this residential area was a large fenced section of trees, grass, and a large parking lot, where vehicles and houses were stored prior to sale. A large office building was part of the complex. This fenced area was within the residential area, close to the research house, close to a major road and buildings, yet out of sight and access from the public. This served as the outside site.

Six freshly killed domestic pig carcasses (*Sus scrofa* L.) were obtained and placed at the research sites on 26 May. The pigs were killed by pin-gun and were not exsanguinated. The carcasses weighed between 43 and 56 kg, with an average of 42.2 kg. Each carcass was clothed identically in a pair of women's panties and a man's shirt. Pig carcasses are commonly used in decomposition studies as human models (40). Three carcasses were placed in the house: one on the hardwood floor of the rear bedroom, one on the hardwood floor of the living room, and one in the bathtub. The front and back doors of the house were closed. Two of the windows were opened to give an opening of approximately 10 cm but were screened with an insect-proof screen, so allowed some air flow but did not allow insects to access the house. The rest of the windows were closed. In the front bedroom, which did not contain a carcass, two holes were cut in the window screen to allow insects' access to the house. These holes were approximately 6.5 × 14 cm and 6.5 × 23 cm. All inside doors were open.

Three carcasses were placed at the outside site directly on grass and covered with a light 2.5-cm mesh cage to prevent vertebrate access. The carcasses were separated by approximately 7–10 m (distance limited by fenced area available). Two ACR SmartButton® dataloggers (ACR Systems Inc., Surrey, B.C. Canada) were used to determine inside and outside temperatures. One button was placed in the central hall of the house and the other was pinned to a tree trunk at the outside site. The outside logger failed during the first 2 weeks, so these temperatures were taken from the nearest Environment Canada Weather Station (Edmonton Municipal Airport, <3.5 km from the research site).

Both inside and outside carcasses were examined regularly (normally every 3–4 days). Sampling times are given in Table 1. At each examination time, still and video photography was taken, written notes were made, and samples of insects were collected. Samples of both immature and adult insects were collected from each carcass. Eggs and larval Calliphoridae were collected from several areas on each carcass; half of the insects collected were placed in 90% ethanol and the other half were placed on beef liver and raised to adulthood. Representative samples of other Diptera and Coleoptera were placed in alcohol for later examination. The surrounding area (flooring or grass and soil) were examined and sampled for migrating larvae, pupae, and puparia. Outside, the grass and soil were examined surrounding the carcasses. Inside the house, wandering third instar, pupae, and puparia could easily be seen on the surfaces of the floor. The sampling procedure followed the normal procedure used at a crime scene (41).

The experiment began on 26 May and was terminated on 6 July, 42 days later.

Results

Temperature during the 42 days of the experiment fluctuated greatly at the outside site, ranging from 4 to 43°C, with a mean of 16.4°C. Inside the house, the fluctuations were, in general, much less, staying closer to the mean of 17.8°C, although at extremes ranged from 11.5 to 40°C.

In general, the outdoor carcasses were colonized much faster by insects and decomposed much faster than those indoors. Although development rates were similar, the inside carcasses started with many fewer insects, slowing and extending the decomposition period.

Adult blow flies (Diptera: Calliphoridae) were attracted to all three outside carcasses immediately after they were placed at their sites (Day 0). Eggs of *Calliphora vicina* (R-D), *Lucilia sericata* (Meigen), and *Lucilia illustris* (Meigen) were laid shortly afterward (Table 1). By Day 2, eggs and larvae of *Eucalliphora latifrons* (Hough) and *Cynomya cadaverina* (R-D) were present, with some ants (Family: Formicidae) attracted.

No insects were attracted to the inside carcasses until Day 5, indicating the length of time that it took for decompositional odors to penetrate outside and for adult Calliphoridae to enter through the openings in the window screen (Table 1). By Day 7, large numbers of adult flies were found throughout the house, with eggs of *Phormia regina* (Meigen) and *Protophormia terraenovae* (R-D) found in the mouth and head area. The carcasses were still bloated and putrefaction was marked. Outside, the carcasses were in active decay, with maggots throughout the head and genital region (Table 1). *Phormia regina* was also collected outside. Much of the tissue from the head had been removed, and the clothes had been displaced by insect activity, pushed up toward the neck and down toward the hocks.

By Day 10, very large numbers of adult Calliphoridae were present throughout the house, with many adult flies dead, possibly because of the lack of water in the house. Although very large numbers of adult Calliphoridae had been attracted, there were low numbers of immature insects on the remains with eggs, 1st, 2nd, and a few 3rd instar larvae of *P. regina, Pr. terraenovae* as well as *C. vicina, L. sericata,* and *Cy. cadaverina*. Larval activity was only present in the head region and anus. The remains still showed some signs of bloat with the internal organs exposed. Outside, large maggot masses were present on the remains, and much of the tissue had been removed by insect activity. Much greater numbers of larvae were seen on the outside carcasses.

By Day 15, the inside carcasses were in active decay, although they were still primarily intact. First through 3rd instar larvae were present but in much lower numbers than those on the outside carcasses, although very large numbers of eggs were still being laid. The clothing was displaced. In contrast, the outside carcasses were in advanced decay, with partial skeletonization, and foam present from larval activity. *Protophormia terraenovae* larvae were also present on the outside carcasses by this time. Adult Phoridae and Formicidae were also present.

By Day 17, larvae began to migrate from both indoor and outdoor carcasses, although the outdoor carcasses were much further decomposed, with the majority of the biomass removed. Inside carcasses were in active decay, and the underwear was pushed down the legs. The outside carcasses were partially skeletonized and what remained was dry and black.

By Day 24, the inside carcasses supported large masses of larval Calliphoridae, and although much of the head tissue was removed, tissue still remained in other areas of the body. Pupae were present in clothing and on the floor throughout the house. Migrating maggots in the bathtub had been unable to exit the tub so, after wandering for some time, pupated directly in the tub. Outside, very few larvae were present on the carcasses as very little tissue remained, except on one carcass. Adult beetles, *Hister* sp. (Family

TABLE 1—*Comparison of decomposition and insect colonization between pig carcasses inside a house and those outside.*

Elapsed Time Since Death	Inside Carcasses		Outside Carcasses	
	Decomposition	Colonization	Decomposition	Colonization
Day 0	Fresh	No insect activity	Fresh	Adult blow flies and eggs of: *Calliphora vicina* *Lucilia sericata* *Lucilia illustris*.
Day 1	Rigor mortis still present. Lividity visible. Bloat beginning.	No insect activity	Rigor mortis still present. Lividity visible. Bloat beginning. Fecal material extruded from anus in one carcass.	Calliphoridae eggs in mouth, as above.
Day 2	Bloat. Lividity still visible. Skin showing some signs of internal putrefaction, but little discoloration.	No insect activity	Early bloat. Skin showing signs of internal putrefaction. Maggots and eggs mostly confined to mouth.	Eggs/larvae in mouth as above, also: *Eucalliphora latifrons* *Cynomya cadaverina*. Some ants on pigs (Formicidae).
Day 7	Bloat, putrefaction, and discoloration. Decompositional fluid leaking from mouth. Internal organs burst open in two carcasses.	Many adult Calliphoridae throughout house. Some dead. Eggs in mouth and head area: *Phormia regina* *Protophormia terraenovae* (First eggs laid on Day 5).	Active decay, some bloat remaining. Extensive putrefaction, skin discolored in places. Maggots throughout head, some in anus. Much of head tissue removed by maggots.	Eggs, 1st and 2nd instar Calliphoridae as above, with some molting to 3rd instar. Large numbers of eggs. *P. regina* eggs and larvae now present.
Day 10	Still some signs of bloat. Internal organs open. Body discolored in places.	Low numbers of eggs, 1st, 2nd, and 3rd instar Calliphoridae, as above and: *C. vicina* *Cy. cadaverina* *L. sericata*.	Active decay. Skin blackened. Much of tissue removed.	Eggs, 1st, 2nd, and 3rd instar Calliphoridae as above. Several large maggot masses in head area. Adult Braconidae on one carcass.
Day 15	Carcass blue green throughout, decompositional fluid leaking from anus and mouth. One carcass still appears bloated. Tissue in mouth breaking down. Internal organs and gut region exposed. Majority of tissue still intact. Maggot mass in mouth.	Thousands of adult Calliphoridae throughout house, many dead. Eggs to 3rd instar Calliphoridae larvae as above. Larvae and eggs in face and between legs, and gut region. Large numbers of eggs. Much fewer immature insects on remains than on outside carcasses.	Advanced decay. Bones exposed, skin black, underwear dragged off carcass by maggot activity.	Eggs, 1st, 2nd, and 3rd instar Calliphoridae. Large maggot masses. Larvae have not yet begun to migrate. *Pr. terraenovae* larvae as well as above. Adult Phoridae present. Adult Formicidae present.
Day 17	Active decay, intestines extruded. Body still mostly intact. Large quantities of decompositional fluid surrounding carcasses. Skin still pink in places.	Large numbers of adult Calliphoridae in house. Many dead. Live adult flies resting on walls, doors, and windows, rather than actively flying. Larval Calliphoridae in mouth and head area. A few larval Calliphoridae beginning to migrate from one carcass.	Head area reduced to skin and bones. Intestines dried out and black. Majority of biomass removed.	Larval Calliphoridae beginning to migrate from two of three carcasses. Large maggot masses still present. Adult Phoridae present.
Day 24	Active decay. Much of tissue on head removed. Maggot masses throughout carcasses.	Large masses of Calliphoridae on carcasses. Calliphoridae pupae found in clothing and on floor.	Remains stage. Most of body skin and bones in two carcasses. Third carcass still in late advanced decay, with intense maggot activity.	Calliphoridae pupae in surrounding area. Some 3rd instar larvae present on two carcasses, but most in prepupal or pupal stage. Third carcass still has many maggot masses. *Oiceptoma noveboracense* (Silphidae, larvae), *Hister* sp. (Histeridae, adult) *Necrobia* sp. (Cleridae, adult).
Day 29	Not checked	Not checked	Remains stage. Still some flesh and maggots on one carcass.	As above and *Creophilus maxillosus* (Staphylinidae, adult and larval).
Day 32	Advanced decay. Skin black. Body deflated, hair falling out.	Almost all adult Calliphoridae in house now dead. Large numbers of 3rd instar Calliphoridae migrating from carcasses and many pupae found around carcasses and throughout house. Some migrating 3rd instar and pupae found in basement and every room of house. Many pupae on carcasses. Larval Calliphoridae still feeding in tissue. Pupae several centimeters deep in bathtub. No teneral flies emerging yet.	Remains stage	Large numbers of teneral blow flies emerging from grass surrounding two carcasses. Phoridae adults *Creophilus maxillosus* (Staphylinidae, adult and larval) *O. noveboracense* (Silphidae, larvae) *Heterosilpha ramosa* (Silphidae, adult) *Necrobia* sp. (Cleridae, adults).

TABLE 1—*Continued.*

Elapsed Time Since Death	Inside Carcasses		Outside Carcasses	
	Decomposition	Colonization	Decomposition	Colonization
Day 39	Advanced decay	Teneral Calliphoridae emerging. Thousands of Calliphoridae pupae on and around carcasses. Many pupated on body, although some prepupal larvae migrated through house. Still a few 3rd instar larvae on carcasses. Large number of adult flies throughout the house. Windows black with adult Calliphoridae.	Remains stage	Very large numbers of teneral Calliphoridae emerging from all carcasses. Calliphoridae pupae and empty puparia. *O. noveboracense* (Silphidae, larvae), many *Necrobia* sp. (Cleridae, adults)
Day 42	Advanced decay/remains stage	Very large numbers of empty Calliphoridae puparia and pupae surrounding each carcass and throughout house. Much more than seen in outside pigs. Many thousands of adult Calliphoridae emerging from carcasses and throughout house. Carcasses still had 3rd instar and younger larvae on what remained of the tissue.	Remains stage	Large numbers of empty Calliphoridae puparia. *Necrobia* sp. (Cleridae, adults and larvae).

Histeridae) and *Necrobia* sp. (Family Cleridae) as well as larval *Oiceptoma noveboracense* (Forster) (Family Silphidae), were found on the outside remains, and 2 days later, adult and larval *Creophilus maxillosus* (L.) (Family Staphylinidae) were recovered.

By Day 32, the outside carcasses were in the remains stage and large numbers of teneral flies were present on surrounding vegetation. Inside, the carcasses were still in advanced decay, and large numbers of pupae and migrating larvae were found throughout the house. Migrating larvae and pupae were found in the basement and in every room of the house although many remained on the carcasses. Larval Calliphoridae were still present on all carcasses. The bathtub was several centimeters deep in pupae as the migrating larvae had been unable to climb the sheer walls. No teneral flies were present in the house.

By Day 39, large numbers of teneral flies were emerging from all six carcasses, with the consequent empty puparia found at both sites. Many larval Silphidae were present on the outside carcasses but only Calliphoridae were found on the inside carcasses. The inside carcasses remained in advanced decay, and some larvae were still present.

By Day 42, there were so many emerging adult Calliphoridae throughout the house that they made visibility difficult, flying into peoples' faces and obscuring windows. Inside carcasses still had a range of stages of Calliphoridae feeding on them, indicating an extended range of time over which eggs were oviposited. The entire floor throughout the house was liberally covered in pupae and empty pupal cases. Outside carcasses were reduced to bones, and large numbers of empty puparia were present as well as adult and larval Coleoptera.

Discussion

Blow flies (Diptera: Calliphoridae) were attracted to the outside remains immediately after the carcases were placed and laid eggs. However, colonization of the inside carcasses was delayed for 5 days. Colonization was not only delayed but was also much slower on the inside carcasses, with much lower numbers of larvae present, and egg laying continuing for most of the decomposition period. Tissue was removed and decomposition much more accelerated in the outside carcasses, because of the much greater number of insects present. Decomposition is known to progress much faster in the presence of insects (10) and is obviously impacted by the number of larvae present. As decomposition was slower indoors, the carcasses provided oviposition sites for much longer than the outside carcasses, so that larvae still remained 42 days postmortem. Despite this, warmer inside temperatures meant that the insects' development stages on the inside carcasses only slightly lagged behind those on the outside carcasses, and by the end of the experiment, very large numbers of flies had been attracted and laid eggs and many teneral flies emerged.

In Hawai'i, in a comparison of 35 human cases found indoors and outdoors, very different fauna were collected from the two environments (39). Of the 22 species recovered, only five were found in both situations. Initial decomposition was characterized by a much greater diversity of Diptera species indoors rather than outside. As in these experiments, the author found much greater numbers of individual species colonizing the remains outdoors. Some species were considered to be indicators of an inside death, although the author specifies that this is only for the Hawai'ian Islands (39). Indeed, at least one species considered solely indoors, *Stomoyxs calcitrans* (L.), is a common livestock pest (42), so is often recovered outdoors in other regions, although rarely on bodies.

Calliphoridae Colonization

Both inside and outside carcasses attracted *C. vicina*, *L. sericata*, *P. regina*, *Pr. terraenovae*, and *Cy. cadaverina*, while only the outside carcasses attracted *E. latifrons* and *L. illustris. Calliphora vicina* is often considered to be an urban species (43) and was found to characterize the urban area outside London (30). It was collected from a university campus in British Columbia (B.C.), which is an urban area surrounded by forest (44), and also in an urban area of Nova Scotia (22). It was commonly recovered from both indoor and outdoor human cases in B.C. (34), New Zealand (36), Finland (45) and from car trunks and inside houses, and within residences, in closets, bags, and under floorboards in the U.S.A. (1). *Calliphora vicina* arrived and laid eggs immediately on the outside remains, although was not the first to colonize the inside remains. *Calliphora vicina* was one of the first to colonize rodent remains in England (46), although it has been shown to prefer more decomposed remains, if given a choice (35).

Lucilia sericata is also considered an urban species (34) and has not been collected on carrion in rural regions in B.C. (19,47) or Alberta (18), although adults, but no larvae, were minimally observed in rural Saskatchewan (21). It is a common urban inhabitant of parks and gardens (48) and is often found on indoor human cases in New Zealand (36), in traps indoors in Germany and Poland (37,49), has been collected from urban garbage in Goias, Brazil (27), and is considered to typify the urban region near London (30). It was collected almost exclusively from urban areas in human cases in B.C., frequently inside residences (34), and has also been collected from bodies inside vehicles in North America (1,34).

Phormia regina is a ubiquitous and cosmopolitan species, found inside and outside and in rural and urban areas. It is commonly found indoors in human cases in B.C. (34) and the U.S.A. (1). It has been reported to be a later arriver in some regions (50–53), although it is an earlier colonizer in other regions (14,20,47,54). This species was found a few days after death on the outside carcasses, although was one of the first species to colonize the inside carcasses.

Protophormia terraenovae developed on carcasses equally on both outside and inside carcasses, although it has not been previously documented on indoor cases (34). It is more commonly considered a rural species and dominated pig carcasses nearby in a rural habitat (18) and in interior and northern B.C. (54). In recent experiments in B.C., it was captured from carrion on both exposed carcasses and those in car trunks in a rural region (55) but was not captured at baits nearby in a suburban area (56).

Cynomya cadaverina is a species that is attracted to highly decomposed carrion, as well as human feces and cured meats (57). It has been reported to be frequently found inside houses and apartments in early spring (57).

Eucalliphora latifrons and *L. illustris* were the only blow fly species collected exclusively on the outside carcasses and were not attracted to the inside remains at all, despite obviously being present in the area. *Eucalliphora latifrons* is not a common species and was not caught indoors on any human cases in B.C. (34), although it will go into enclosed areas as it was recovered from buried carcasses in northern B.C. in a rural area (20). *Lucilia illustris* has not been collected from human cases indoors (34). It is usually an early colonizer (19,20,47), and in these experiments, it was one of the first species to lay eggs on the outside carcasses.

Of the five species of Calliphoridae collected from the inside carcasses, *C. vicina*, *P. regina*, and *L. sericata* have often been reported by other authors to colonize carcasses, baits, or human homicide victims inside houses, even entering bags and closets within such enclosed areas (1,34,36). Although little is published about the habits of *Cy. cadaverina*, it has been reported to commonly enter houses (57). *Protophormia terraenovae* was the only species that was found on both the inside and outside carcasses, which has not previously been reported as a colonizer of inside carrion. However, its presence in large numbers suggests that it will willingly enter enclosed areas as well as colonize carrion in a suburb so is also not an entirely rural species. *Lucilia illustris* was not attracted to inside carcasses, confirming previous reports (19), but its presence at this urban site was somewhat surprising, as it has been reported to be a rural species (3).

Colonization by Other Families of Insects

The inside carcasses supported only Calliphoridae, whereas several other families of insects, including Phoridae, Formicidae, Braconidae, Silphidae, Cleridae, and Staphylinidae, were recovered from the outside carcasses. Although this most probably indicates flight preference in the Coleoptera, Phoridae, and Braconidae are quite mobile and have been recovered from indoor cases (58–60). Phoridae in particular are well known to enter enclosed spaces (61–65). It is possible that had the experiment been extended for longer, other species may eventually have been attracted indoors, although in a study of past forensic entomology cases in B.C., only Piophilidae, Muscidae (*Hydrotaea* sp.), and Pteromalidae (Hymenoptera: *Nasonia vitripennis* (Walker)) were recovered indoors (34). In other regions, Fanniidae and Muscidae were collected in high-rise apartments in (37,49), and Dermestidae beetles are often found indoors (66,67). In Hawai'i, a variety of Diptera species, other than those in the Calliphoridae, and one Coleoptera species were recovered on bodies found indoors from 2 to 21 days postmortem (39).

Dispersal Patterns

Once 3rd instar blow fly larvae complete feeding, they enter a postfeeding dispersal stage and usually leave the carcass in search of a suitable and protected pupation site. Pupae and empty puparia associated with the outside carcasses were located within a few meters of the remains. Although exhaustive searches of the grass and soil further from each carcass were not performed, the large numbers of teneral flies resting and drying close to the carcasses suggest that the majority of puparia were located within a meter or two of each carcass. Inside the house, however, migrating pupae had wandered throughout the entire house, even entering the heating ducts and being found in large numbers in the basement. Teneral flies were found resting on surfaces throughout the house. The distance postfeeding larvae travel has been shown to depend on many parameters, such as substrate type (68), species (69,70), competition (71), predation (72,73), as well as abiotic factors (3,74) and endogenous rhythms (75). In this case, the major factor impacting dispersal distance was most notably the substrate type. Inside the house, the substrate was hardwood flooring, linoleum, or concrete, none of which offer suitable pupation media. However, outside, the carcasses rested directly on grass-covered soil, providing much closer pupation sites. Many species have been shown to only travel a short distance from the carcass when the substrate is suitable for pupation, such as loose soil (76), but will travel much further if the substrate is not suitable, such as concrete (77).

Some species are known to preferentially pupate close to or on the remains, such as *Pr. terraenovae* (35,38,78), whereas others, such as *L. sericata*, disperse much further (76,79). In the indoor experiments, large numbers of puparia were found on and associated with the clothing of the carcasses, possibly because of the lack of other suitable protected pupation sites, as well as to species preference.

As postfeeding larvae leave the remains, they may be missed by scene investigators, and the younger feeding maggots still associated with the body assumed to be the oldest insects present. This would result in a major underestimation of elapsed time since death. It is, therefore, vital to always search for postfeeding larvae, pupae, and empty puparia, either to find and identify such specimens or to search extensively enough to be able to exclude their presence and conclude that the oldest larvae have not yet left the victim. The dispersal patterns observed here are helpful in guiding investigators in where to search for such evidence depending on substrate type. Similar dispersal patterns might be expected outside if the remains were on concrete, brick, or tarmac and have been observed in human cases (unpublished data).

In both sets of carcasses, when large maggot masses developed, their actions displaced the clothing. Large aggregations of maggots have been previously shown to move clothing on pig carcasses, pushing underwear down the hind legs and upper clothing up toward the front legs, which in a human case could mistakenly suggest sexual assault (80).

In conclusion, many species of blow flies will colonize remains indoors, although a delay of several days may be expected, even when the house is not completely enclosed. Some species will readily inhabit both indoor and outdoor carcasses, although some will not enter a residence. Dispersal patterns of migrating, postfeeding larvae may be greatly extended on hard substrates, such as hard wood flooring.

Because of availability and costs, this study was only able to utilize one house. Further studies are recommended utilizing three or more houses, as well as houses of different construction materials and types.

Acknowledgments

I thank Ms. Sharon Abrams, Ms. Anne Reuse, and Ms. Janice Lacapra, Royal Canadian Mounted Police (R.C.M.P.) Forensic Laboratory, Edmonton, Alberta, for their invaluable help in collecting the insects, Inspector Bruce MacLean, Integrated Forensic Identification Services, Royal Canadian Mounted Police and Sgt. Serge Larocque, RFISS, Royal Canadian Mounted Police for assistance with placing the carcasses, and Inspector John Amerongen and Captain Ed Rostalski, of the Edmonton Fire Department, for procuring the house. I also thank Ms. Niki Hobischak for her assistance.

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