

TECHNICAL NOTE

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The Black Soldier Fly *Hermetia illucens* (Diptera: Stratiomyidae) As a Potential Measure of Human Postmortem Interval: Observations and Case Histories

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ABSTRACT: The black soldier fly, *Hermetia illucens* (L.), has been shown to be a ubiquitous inhabitant of both surface and buried human remains throughout the southern, central and western United States and Hawaii. Unlike most other species of forensically important Diptera, this species frequently dominates bodies in the dry/post decay stage of decomposition. Adults of the black soldier fly appear to initiate oviposition (egg laying) 20 to 30 days postmortem. Even at warm temperatures (27.8°C), subsequent completion of the life cycle can require an additional 55 days. Life history data for *H. illucens*, when used in combination with data for other cohabiting arthropod species and viewed in the context of local environmental conditions, can provide medicolegal investigators with valuable parameters for estimating the postmortem intervals for badly decomposed remains.

KEYWORDS: forensic science, forensic entomology, black soldier fly, postmortem interval, diptera, stratiomyidae, insect invasion, time since death

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Memorial Prologue

Following his retirement from Clemson University, Ted Adkins developed an avid interest in the newly emerging field of forensic entomology in this country. As with previous endeavors, he pursued forensic entomology with diligence and vitality. Ted brought both knowledge and a refreshing sense of humor to a discipline that dwells on human tragedy. He quickly earned the respect and esteem of the forensic colleagues with whom he routinely collaborated. In forensic entomology circles, he is sorely missed.

Introduction

The potential usefulness of terrestrial, aquatic, and marine invertebrates in interpreting time, location, and cause/manner of death is well documented in both entomological and forensic literature [1–6]. While decomposing remains are recycled by a wide variety of organisms ranging from microbes to scavenging mammals, insects generally constitute the most conspicuous and forensically important element in terrestrial habitats [7].

Currently, there are two basic approaches to the application of entomological data to estimation of the postmortem interval (PMI) [8]. During early decomposition, entomological estimates of the PMI are rooted in analyses of the time period required for the insect species represented to develop to the growth stage encountered at the death scene. Most often, fly larvae (maggots) in the families Calliphoridae (blow flies) and Sarcophagidae (flesh flies) predominate. These flies currently provide the most accurate entomological indicators of PMIs. Because of their relatively short developmental cycles, blow flies and flesh flies are typically useful only during the first three to four weeks following death. The second entomological approach to PMI determination is applicable to remains in the more advanced stages of decomposition. In these cases, an analysis of insect community structure as it relates to expected successional patterns forms the template for dating the remains. This latter approach is far more difficult and less accurate than analyses of fly development. Forensic entomologists are constantly searching for longer ranging, developmentally based insect indicators for the PMI.

The family Stratiomyidae consists of small to fairly large flies (5 to 15 mm in length) usually encountered as adults around flowers or vegetation [3]. Members of this family are commonly referred to as soldier flies because of the conspicuous spines present on the thorax of some species. The immature stages of terrestrial species are found in rotting wood, in dung, in lavatories, within compost heaps, and associated with a wide variety of decaying animal and plant materials. Dunn [15] recorded larvae feeding in large numbers upon the body of a man found in the jungle of the Panama Canal Zone. No other larvae were reported associated with these remains.

The black soldier fly, *Hermetia illucens* (L.) (Figs. 1 & 2), has been shown to be a ubiquitous inhabitant of both surface and buried human remains throughout the southern United States and Hawaii [16]. Unlike most other Diptera species of forensic importance, *H. illucens* frequently dominates remains in the drier, post decay stage of decomposition. Adult *H. illucens* appear to initiate oviposition (egg laying) approximately 20 to 30 days postmortem. Once eggs are laid, hatching requires approximately 4 days [11], and larval development requires between 14 days at 30°C [14] and 31 days at 27.8°C [12]. Egg to adult development requires between 38 and 41 days [12–14]. It should be noted that *H. illucens* development can be prolonged for up to 5 months if food supplies are depleted or environmental conditions are adverse [14]. Available developmental data from literature are presented in Table 1. Adult *H. illucens* reportedly become active during morning hours when temperatures reach 25°C and have been observed sunning themselves on exposed, sunlit surfaces as early as 0830 [11]. Mating occurs near breeding sites in full

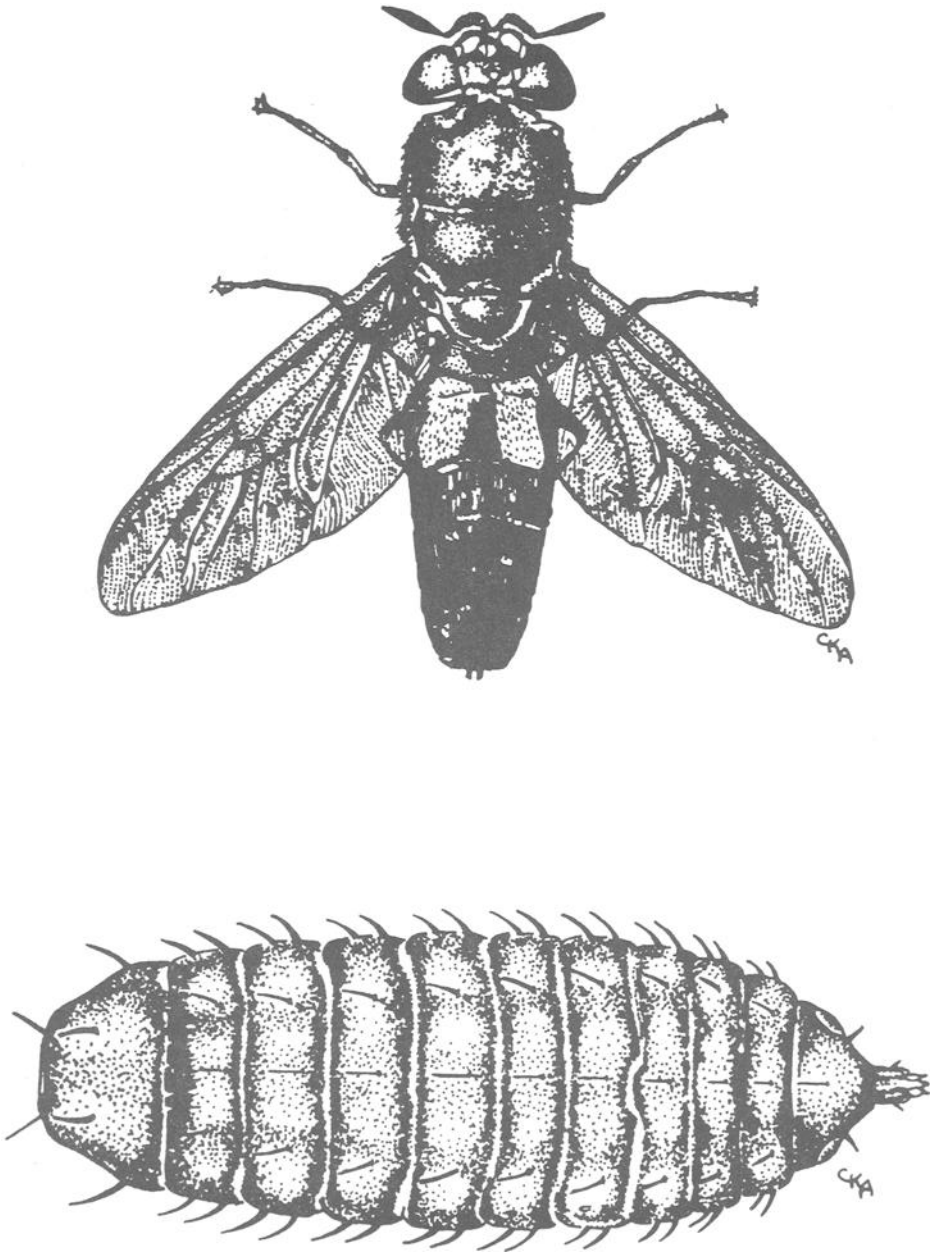


FIG. 1—Diagrammatic representation of the adult and mature larva of *Hermetia illucens* (L.).



FIG. 2—Mature larvae of *Hermetia illucens* (L.) in laboratory culture. Specimens were recovered from the badly decomposed remains of an unidentified male.

sun when temperatures reach 27°C. Oviposition peaks during early to mid-afternoon (1200 to 1700), when temperatures range between 27.5 and 37.5°C [11].

Hermetia illucens life history data, when used in combination with data for other cohabiting arthropod species and viewed in the context of local environmental conditions, have the potential for providing investigators with valuable parameters for estimation of postmortem intervals in cases of advanced decomposition. The following case studies will serve to illustrate this potential.

TABLE 1—Developmental duration (days) for immature stages of *Hermetia illucens* (L.) and calculated accumulated degree day^a (ADD) standards.

Author (Date)	Rearing Temperature (C)	Developmental Duration (Days)				Calculated ADD Standards ^b
		Egg	Larva	Pupa	Total	
Booth & Shepard (1984)	24.0	4.3	—	—	—	—
May (1961)	27.8	—	31	9/10	40/41	1125.90
Tingle (1975)	29.3	—	—	—	38	1113.40

^aAccumulated degree days (ADD) = Duration (Days) × Rearing Temperature (C). For example, a period of 5 days at a temperature of 24 C would result in a value of 120 ADD.

^bOverall average = 1119.65 ADD.

Case 1

On 16 Aug. 1987, the Aiken County Coroner requested entomological assistance in estimating the postmortem interval of a body discovered in a wooded area of Aiken County, South Carolina. The body was skeletalized, disarticulated, and scattered about in a scrub oak/pine woods. Insect larvae were recovered from the remains and reared to the adult stage in an entomological laboratory in Clemson, South Carolina. The predominant insect larvae collected were *H. illucens*. No puparia were observed on the remains. The first adult *H. illucens* emerged from laboratory cultures on 17 September 1987.

Climatic records were obtained from the nearest weather station to the recovery site and an overall mean temperature of 21.7°C was calculated. Using this mean temperature as an exposure index, oviposition on the remains by adult *H. illucens* was estimated to have occurred approximately 52 days prior to emergence of the adult flies. Since remains do not become attractive to *H. illucens* adults for approximately 20 to 30 days following death, the victim's demise was estimated to have occurred in late June or early July 1987.

Upon identification of the remains, the decedent was discovered to have been a 56-year-old female who had wandered away from an institution in early July 1987. She was a known diabetic, who could survive no longer than three days without medication. It was theorized that she became disoriented, lost in the woods, and died on or about 5 July 1987. Her death was ruled accidental by the coroner.

Case 2

The remains of an unidentified male were recovered from the Jackass Ginger area off the Pali Highway on the island of Oahu, Hawaii. The remains were hanging by the neck from a tree and a presumed suicide. Five families of Coleoptera were recovered from the body and associated clothing: Cleridae [adults of *Necrobia rufipes* (DeGeer)], Dermestidae (larvae of *Dermestes maculatus* DeGeer), Histeridae (larvae), Hydrophilidae (adults of *Dactylosternum hydrophiloides*), and Staphylinidae (adults of *Creophilus maxillosus* L. and *Thyreocephalus albertisi* Fauvel). There were adults and nymphs of *Sphingolabis hawaiiensis* (Bormans) (Dermaptera: Labiidae) and the larva of an unidentified Noctuidae (Lepidoptera). Four families of Diptera were also present: Calliphoridae [empty puparia of *Chrysomya megacephala* (Fabricius) and *Chrysomya rufifacies* (Macquart)], Piophilidae [larvae of *Piophila casei* (L.)], Sarcophagidae (3rd instar larvae), and Stratiomyidae (larvae of *H. illucens* measuring 20 to 32 mm in total length).

The PMI estimate for this case was based primarily on the developmental stages of *H. illucens* larvae obtained from the remains. Specimens recovered at the scene were immediately preserved and thus not available for rearing studies. Development of *H. illucens* larvae to maturity (32 mm total length) requires approximately 31 days at 27.8°C [12]. During the period of time in question, temperatures at the recovery site had a mean of 23°C. Adjusting for the lower scene temperatures, an estimated period of larval development of 37 days was calculated. When combined with the standard ovipositional delay of 20 to 30 days, to allow for the remains to become attractive to adult *H. illucens*, a postmortem interval of 57 to 67 days was suggested. This estimate coincided well with the facts developed in the case.

Case 3

The body of a male was recovered from a pineapple field in Waipio, Oahu, Hawaii. The body's physical condition was between the post decay and dry-remains stages. Four families of Coleoptera were present on the remains: Cleridae [adults of both *Necrobia*

ruficollis (F.) and *N. rufipes*], Dermestidae (adults and larvae of *D. maculatus*), Histeridae (adults of both *Atholus rothkirchi* Bickhardt and *Saprinus lugens* Erichson), and Staphylinidae [adults and larvae of *C. maxillosus*, adults of *Philonthus discoides* (Gravenhorst), *Philonthus longicornis* Stephens, and *T. albertisi*]. There were six families of Diptera associated with the body and soil beneath the body: Calliphoridae (empty puparia of *C. rufifacies*), Otitidae (3rd instar larvae measuring 12 to 13 mm total length), Piophilidae (larvae of *P. casei*), Psychodidae (larvae of *Psychoda* prob. *pseudoalternata* Williams), Sarcophagidae (3rd instar larvae measuring 15 to 16 mm total length), and Stratiomyidae (larvae of *H. illucens* measuring 10 to 14 mm total length). Adults of the cricket *Teleogryllus oceanicus* (LeGuilleu) (Gryllidae) were also present on the remains and in the soil under the remains. There were specimens of Pseudoscorpionida, Symphyla, and Gamasida (Acari) present in the soil samples taken from beneath the remains.

The PMI estimate for this case was 34 to 36 days, which fit well with the last time the victim had been seen alive, 37 days prior to discovery of the remains and collection of specimens. This estimate was based on comparisons of arthropod species recovered from the remains with results of decomposition studies conducted in similar areas on the island of Oahu. Presence of only empty puparial cases of *C. rufifacies* indicates a minimum period of 17 days. The staphylinid beetle *P. longicornis* is present on remains as adults and larvae from days 15 to 33. Presence of only adults indicates a period greater than 33 days. Larvae of *P. casei* depart remains by day 37 for pupariation, and the size of the specimens collected was consistent with those collected from decomposition studies during days 33 to 36. Otitidae larvae have been recovered from decomposition studies up to day 37. *Hermetia illucens* larvae measuring 10 to 14 mm were also consistent with this interval. A total of 436.6 ADD would be required to complete development from egg to larvae measuring 10 to 14 mm in total length (Table 1). Based on climatic data from the NOAA Weather Station at Wailaua, it would have required 16 days to complete development to this stage. This period combined with a minimum period of 20 days for the remains to become attractive for oviposition gives an interval of 36 days. Presence of both adult and larval Dermestidae and adults of two species of Cleridae was consistent with the 33 to 36 day interval, but not definitive.

Case 4

The remains of an unidentified male were recovered from grasses adjacent to the beach along Kamehameha Highway near Mokulea, Oahu, Hawaii. The physical condition of the remains would place them well into the post decay stage of decomposition. The skull was largely devoid of flesh and the limbs were dehydrated and partially mummified. Digits of the right hand were missing below the knuckles, possibly due to postmortem animal depredation. The trunk was intact and dry externally. There were a number of insect species associated with the remains. The Coleoptera were represented by four families: Cleridae (adult *N. rufipes*), Dermestidae (adults and larvae of *Dermestes ater* DeGeer, and *D. maculatus*), Histeridae (adults of *S. lugens*), and Staphylinidae (adults of *P. longicornis*). There were four families of Diptera present: Calliphoridae (empty puparia of *C. rufifacies*), Piophilidae (larvae of *P. casei*), Sarcophagidae (3rd instar larvae), and Stratiomyidae (larvae of *H. illucens*). By far, the predominant insect species on both the external and internal surfaces of the body were the larvae of *H. illucens* (10 to 16 mm in total length).

The PMI for this case was determined by three species: *C. rufifacies*, *P. longicornis*, and *P. casei*. The presence of these species in their respective stages of development indicated of a PMI of 34 to 36 days prior to recovery of the remains. *Hermetia illucens* was also indicative of a PMI consistent with the time interval in question. The most mature *H. illucens* larvae collected from the body were 5th instar larvae measuring 16

mm in total length. Studies by May [12] show that the 5th instar is reached 11 days following egg hatch at 27.8°C. A total of 408.8 ADD would be required for development from egg to 5th instar larvae (Table 1). May [12] also recorded 5th instar larvae measuring 17 mm in total length 12 days following egg hatch at 27.8°C, for a total of 436.6 ADD. Using weather data from the Camp Erdman NOAA Weather Station, it was determined that a period of 18 days would be required for larvae to develop to the 5th instar and 19 days to reach the 17 mm total length given by May [12]. This combined with a minimum period of approximately 20 days before the body was attractive to *H. illucens* for oviposition gives an estimated time of approximately 38 to 39 days.

Case 5

On 10 October 1986, the Greenville County Coroner requested entomological assistance in estimating the time of death of an unidentified male recovered from a gravesite near the Greenville-Spartanburg Jetport in Greenville County, South Carolina. The decedent had died from multiple gunshot wounds to the head and had been zipped into a sleeping bag prior to interment. Numerous *H. illucens* larvae were recovered from the remains, the sleeping bag, and the bottom of the grave. Specimens collected were transported to Clemson, South Carolina, and reared to adults. The first adult *H. illucens* emerged from puparia on 19 October 1986.

Climatic data from the nearby Greenville-Spartanburg Jetport National Weather Service Station for the probable time period in question gave a mean air temperature of 21°C. Using these data as a template, a minimum period for larval development was calculated of 55 days. When combined with a standard ovipositional delay period of 30 days, a minimum PMI of 85 days was suggested. The minimum nature of this estimate was emphasized, as temperature data indicative of the cooler, damp conditions within the grave were not available and the soil covering the body may have acted as a barrier to oviposition. Temperatures below 15°C may delay or curtail *H. illucens* larval development for months. Subsequently, the individuals responsible for the victim's demise provided investigators with a confession indicating that death and burial had occurred during late April 1986. This was approximately 90 days prior to the minimum PMI suggested.

Discussion

The cases detailed demonstrate the potential usefulness of *H. illucens* life history data in estimating of PMIs for individuals in advanced stages of postmortem decomposition. When used in combination with data for other cohabiting taxa and analyzed in the context of accurate local environmental conditions, *H. illucens* may provide longer range developmental estimates than other carrion-frequenting Diptera. Investigators must remain cognizant, however, of the lengthy developmental periods displayed by *H. illucens* larvae when food resources become scarce and environmental conditions become extreme. The need for detailed, regional studies of the biology, ecology, and development of *H. illucens* under varying field conditions remains paramount.

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