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Insect fauna visiting carrion in Southwest Virginia

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Abstract

Successional patterns of insect fauna on pig carcasses were studied in southwest Virginia. The objective was to identify and qualitatively assess the major taxa of forensic importance in this region. Studies were conducted in spring and summer 2001 and 2002, and fall 2002. Over 50 taxa were collected and identified. *Phormia regina* was the dominant fly species in the spring (>90%) and co-dominant with *Phaenicia coeruleiviridis* in the summer. *Phaenicia sericata*, *Lucilia illustris*, and *Calliphora* spp. were collected in spring and summer, but less frequently. Eleven species of Sarcophagidae also were collected with *Sarcophaga utilis* and *Helicobia rapax* the most common. In the fall, the dominant fly species were *Calliphora vomitoria*, *L. illustris*, and *P. coeruleiviridis.* The primary beetle species collected in spring and summer included three Staphylinidae (*Creophilis maxillosus*, *Platydracus maculosus*, and *Aleochara lata*) and three Silphidae (*Oiceoptoma noveboracense*, *Necrodes surinamensis*, and *Necrophila americana).* No beetles were collected in the fall.

Keywords: Forensic entomology; Successional pattern; Carrion insects; Postmortem interval

1. Introduction

The major focus of medicolegal forensic entomology is on the use of insects to assist in criminal investigations, particularly in cases of unexplained or criminal death. These investigations attempt to answer questions that pertain to the cause and place of death, and also to the postmortem interval (PMI) or time that elapsed since death [1].

There are essentially two main methods for estimating PMI using information on the insects that visit a corpse. The first method is development-based in which the development stage of the flies on the corpse is used to indicate the time since death. Flies usually are the first insects to lay eggs on a body, sometimes within minutes in many cases of unattended death [2]. Once the first colonizing species have been identified, PMI can be estimated by comparing the degree of development of the eggs, larvae, or pupae with laboratory data on their development times under a temperature regime similar to that of the period leading up to the discovery of the corpse.

A second method for estimating the PMI uses succession-based studies to gather information on the faunal progression or successional patterns of carrion-arthropods. By this method, the PMI is estimated by comparing the composition of taxa found on human remains at the time of discovery (corpse fauna) with the composition of insects obtained under controlled conditions at different time intervals on an animal model (baseline fauna) [3]. The type and composition of taxa that are attracted to a carcass usually change in a predictable pattern as decomposition progresses through

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the different stages [4]. Also, the pattern of succession of insects is specific to the location and environmental conditions in which a carcass occurs [5]. Because taxa can vary greatly with locale, it is important for precise estimation of the PMI to identify the forensically important insects that are specific to an area [6].

Studies of carrion arthropods have been conducted in several regions of the world to determine species composition and their successional patterns [5,7–10]. However, there are no published data on the forensically important insects in southwest Virginia. This paper reports on a qualitative assessment of the major insect taxa visiting and/or colonizing carcasses of domestic pigs during specific periods in spring, summer, and fall in southwest Virginia.

2. Materials and methods

Studies on the occurrence of carrion-arthropods were conducted in Blacksburg (37°11′N, 80°25′W) in southwest Virginia. The area is ~608 m above sea level and has average temperatures of 15, 20.7, and 15.5 °C in the spring, summer, and fall, respectively; average annual rainfall and snowfall are 102 and 71 cm, respectively [11]. Four studies (spring: April–June and summer: July–August, 2001 and 2002) were conducted at Kentland Farm, an agriculture research facility of the Virginia Polytechnic Institute and State University (Virginia Tech). A fifth study was conducted in fall (October–November) 2002 at a second farm located ~16 km from Kentland Farm.

Table A.1
Diptera identified from specimens collected from pig carcasses in southwest Virginia in spring and summer 2001 and 2002, and fall 2002

Family[a]	Genus/species	Study periods[b]		
		Spring	Summer	Fall
Calliphoridae[1,8][14]	*Phormia regina* Meigen	A, I	A, I	A
	Phaenicia coeruleiviridis Macquart	A, I	A, I	A, I
	Phaenicia sericata Meigen	A, I	A, I	A, I
	Lucilia illustris Meigen	A, I	A, I	A, I
	Cochliomyia macellaria Fabricius		A, I	
	Calliphora vomitoria Linnaeus	A, I		A
	Calliphora vicina Robineau-Desvoidy	A		A
	Pollenia rudis Fabricius	A	A	
Sarcophagidae[8][15]	*Helicobia rapax* Walker	A	A	
	Sarcophaga Meigen	A	A	A
	Sarcophaga sinuata Meigen	A		
	Sarcophaga houghi Aldrich	A		
	Sarcophaga utilis Aldrich	A	A	
	Sarcophaga mimoris Reinhard		A	
	Sarcophaga bullata Parker	A, I	A, I	
	Ravinia Robineau-Desvoidy	A	A	
	Boettcheria Parker	A		
	Boettcheria cimbicis Townsend	A		
	Macronychia aurata Coquillett	A		
	Blaesoxipha Loew	A	A	
	Amobia oculata Zetterstedt	A		
	Spirobolomyia flavipalpis Aldrich	A		
	Oxysarcodexia ventricosa Wulp	A		
	Oxysarcodexia Townsend		A	
Muscidae [16]	Unidentified Muscidae	A	A	A
	Musca domestica Linnaeus	A	A	
	Hydrotaea leucostoma Weidemann	A	A	
Sepsidae[6] [17,18]	*Sepsis neocynipsea* Melander and Spuler	A	A	
	Sepsis flavimana Meigen	A	A	
	Sepsis punctum Fabricius	A	A	
	Meroplius minutus Wiedemann	A	A	
Piophilidae[4] [19]	*Stearibia nigriceps* Meigen	A	A	A
	Prochyliza xanthostoma Walker	A	A	A
Sphaeroceridae[4] [20]	*Lotophila atra* Meigen	A		

[a] Superscripts following family names refer to taxonomic specialists listed in Appendix. Numbers in square brackets refer to taxonomic keys listed in references, which were used for the initial identification of taxa.

[b] An "A" indicates that the species was collected as an adult; an "I" indicates that the immature stage (eggs and/or larvae) were collected.

Table A.2
Coleoptera identified from specimens collected from pig carcasses in southwest Virginia in spring and summer 2001 and 2002

Family[a]	Genus/species	Study periods[b]	
		Spring	Summer
Staphylinidae[3]	*Creophilus maxillosus* Gravenhorst	A	A
	Platydracus maculosus Gravenhorst	A	A
	Ontholestes cingulatus Gravenhorst	A	A
	Aleochara lata Gravenhorst	A	A
	Philonthus sericans Gravenhorst	A	A
Silphidae[5] [21–23]	*Oiceoptoma* Leach	A	A
	Oiceoptoma noveboracense Forster	A	A
	Necrodes surinamensis Fabricius	A	A
	Nicrophorus marginatus Fabricius	A	
	Nicrophorus orbicollis Say	A	
	Nicrophorus tomentosus Weber		A
	Necrophila americana Linneaus	A	A
Cleridae[7]	*Necrobia rufipes* De Geer	A	A
	Necrobia ruficollis Fabricius	A	A
	Necrobia violacea Linneaus	A	
Trogidae	*Trox* Fabricius	A	
Dermestidae	*Dermestes* Linnaeus	A	A
Histeridae[2]	*Hister abbreviatus* Fabricius	A	A
	Hister coenosus Erichson		A
	Euspilotus assimilis Paykull	A	A
	Margarinotus foedatus LeConte	A	A
	Margarinotus Marseul	A	

[a] Superscripts following family names refer to taxonomic specialists listed in Appendix. Numbers in square brackets refer to taxonomic keys listed in references, which were used for the initial identification of taxa.
[b] "A" indicates that the species was collected as an adult.

Two pig carcasses from the Virginia Tech Swine Center were used in each study. Carcasses used in the spring studies were generally larger (41–45 kg) than those in the summer and fall studies (23–27 kg). The pigs were put down via electrocution and were transported immediately to the field sites. Each carcass was placed inside a cage constructed of 2.54 cm steel-welded tubing enclosed with 1.27 cm mesh hardware cloth. Cages were open on the bottom so that the carcasses were in direct contact with the ground. Cages also were staked to the ground to prevent disturbance of the carcasses by vertebrate scavengers.

The two cages used in each study were located ~91 m apart at the edge of an open field bordered by a thickly wooded area. Although both cages received direct sunlight during most of the day, one of the cages was more shaded during the afternoon. Two pitfall traps were dug ~8 cm from the abdomen of each carcass and a plastic cup filled with water and a few drops of liquid soap were placed in each trap to capture crawling insects.

Because decomposition of the carcasses progressed at different rates during the spring, summer, and fall studies, the sampling protocol was adjusted accordingly for each period. Sampling was conducted daily (between 1200 and 1500 h) until the carcasses reached advanced decay. This state of decay corresponded to 21 days in the spring studies and 8 days in the summer studies, in the fall, sampling was conducted at irregular intervals for ~4 weeks.

Sampling of adult insects was conducted with aerial net sweeps above and around the carcass, pitfall traps, and by taking specimens directly off the carcass to qualitatively assess species occurrence. An assessment was also made of the relative abundance of taxa (family) based on visual observations and collected specimens. Fly eggs and maggots were collected, when they were present, and reared to the adult stage for species identification. Beetle larvae were not collected at regular intervals, nor were efforts made to identify them.

Most of the specimens were identified to genus or species. Specimens were also sent off to taxonomic specialists for verification (see Appendix) and vouchers were placed in the Museum of Natural History at Virginia Tech [12].

Other data recorded at the time of sampling included ambient temperature (using a digital thermometer), maggot mass temperature (using a meat thermometer), and rainfall (using a rain gauge). A weather station near the research farm provided additional hourly temperature and rainfall data [13].

3. Results

Over 50 insect taxa were collected and identified from decomposing pig carcasses during the spring, summer and fall studies (Tables A.1 and A.2). Taxonomic composition was similar in spring and summer, but slightly more taxa were collected in the spring. The tables also show the species that were collected as adults (A), and/or egg or larvae (I), and provide references to the taxonomic keys [14–23] that were used for the initial identification of taxa.

Visitation of the carcasses by insects occurred within the first two days of each study, with the earliest arrivers being dipterans in the families Calliphoridae, Sarcophagidae, and Muscidae (Figs. 1–2). Six families of flies were observed visiting or colonizing the pig carcasses in the spring and summer (Table A.1). Calliphoridae was represented by seven species in the spring, and six species in both the summer and fall. *Phormia regina* was the dominant dipteran species in the spring comprising >90% of the specimens that were collected. However, *P. regina* was co-dominant with *Phaenicia coeruleiviridis* in the summer. Other blow flies (*Phaenicia sericata*, *Lucilia illustris*, *Calliphora* spp.) were found less frequently compared with the two dominant species. Sarcophagidae was represented by 14 taxa in the spring, 8 species in the summer and 1 species in the fall, with *Sarcophaga utilis* and *Helicobia rapax* the most frequently collected species. *P. regina*, *P. sericata*, and *Sarcophaga bullata* were also identified from adults, which were reared from eggs or maggots collected from the carcasses in the spring. Similarly, *P. regina*, *P. sericata*, *L. illustris*, and *Cochliomyia macellaria* were identified from reared specimens in the summer.

Some of the muscids collected in the spring and summer were not identified beyond family. These are listed as ''unidentified muscids'' in Table A.1. This group of unidentified specimens, however, was thought to contain at least three additional species of muscids.

Six families of beetles were collected (Table A.2). The dominant species collected in the spring and summer included three staphylinids (*Creophilis maxillosus*, *Platydracus maculosus*, and *Aleochara lata*), three silphids (*Oiceoptoma noveboracense*, *Necrodes surinamensis*, and *Necrophila americana*) and two histerids (*Euspilotus assimilis* and *Hister abbreviatus*).

In the fall, visitation and colonization of the carcasses by insects was minimal during the first two weeks (Fig. 2). *Calliphora vomitoria*, *L. illustris* and *P. coeruleiviridis* were the first and most dominant fly species to visit the carcasses, with only a few specimens of P. *regina*, *P. sericata*, *P. vicina*, and *Sarcophaga* spp. *Phaenicia coeruleiviridis*, *P. sericata*, and *L. illustris* also were identified from specimens that were reared. During the third and fourth weeks no adult insects

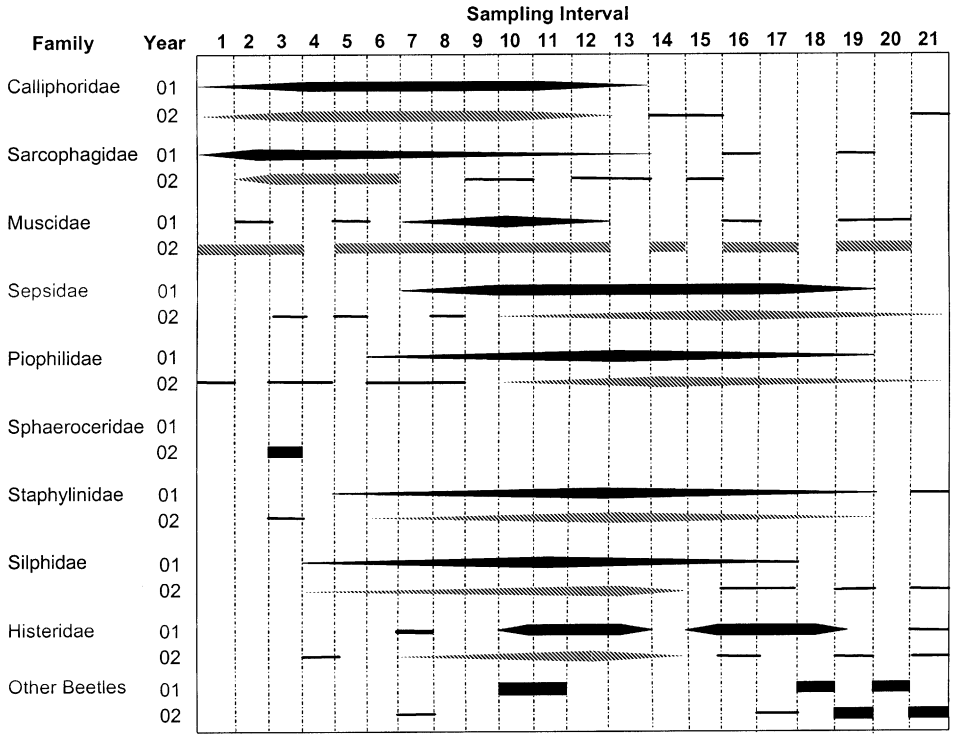

Fig. 1. Occurrence and relative abundance (indicated by the thickness of bands) of families of insects found on pig carcasses in spring 2001 and 2002 in southwest Virginia. Sampling interval is one day.

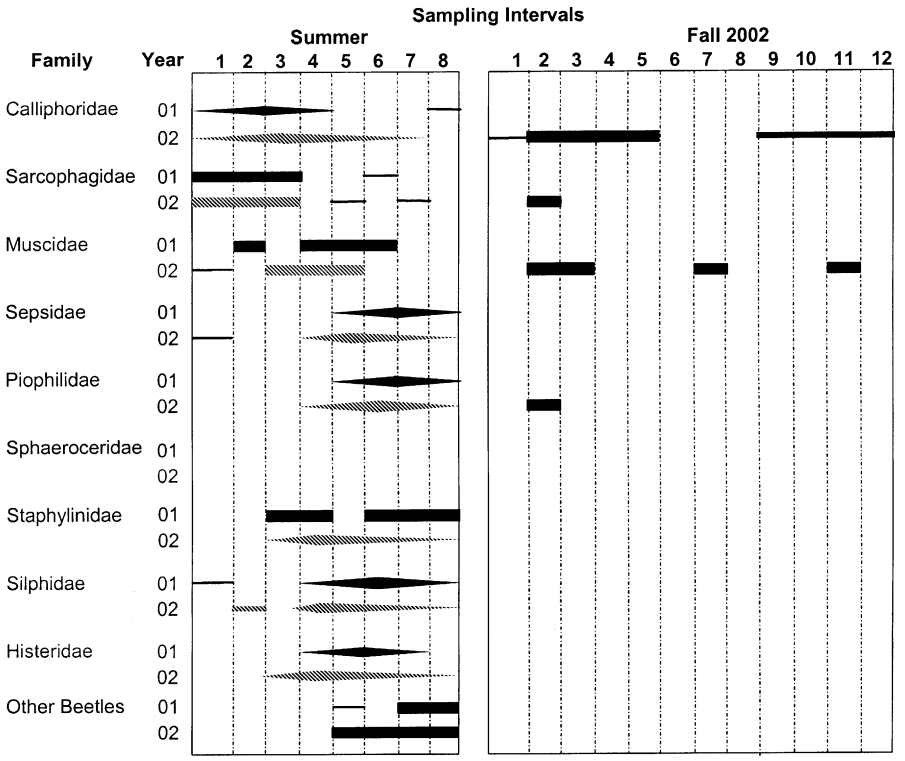

Fig. 2. Occurrence and relative abundance (indicated by the thickness of bands) of families of insects found on pig carcasses in summer 2001 and 2002, and fall 2002 in southwest Virginia. Sampling interval in the summer is one day; samples were collected at irregular intervals in the fall. The Other Beetles group includes Cleridae, Trogidae and Dermestidae.

were observed visiting the carcasses, and all of the maggots on the carcasses had died. Very few muscids and no beetles were collected in the fall.

4. Discussion

The total number of taxa reported in similar studies on vertebrate carcasses ranged from 30 to 522 [5,8,9,24–28]. Factors such as climate, sampling frequency, and number of animal models may account for the wide range of taxonomic diversity reported in these studies.

The insects and other arthropods visiting a corpse exhibit four basic relationships: Necrophagous species (taxa actually feeding on the corpse), predators and parasites of necrophagous species, omnivorous species (e.g. wasps, ants, and some beetles), and adventive species such as collembola, spiders, and centipedes, which exploit the corpse for habitat. This study reports only insect taxa falling into the first two categories.

When estimating PMI from development-based entomological data, the most significant taxa for use in PMI estimation are necrophagous species. These species develop from eggs laid on the carcass (colonizers) following death. Colonizing species of greatest importance in the early stages of decomposition usually are those from three dipteran families, Calliphoridae, Sarcophagidae, and Muscidae. These flies typically are the first to lay eggs on/in a corpse.

Flies in the family Piophilidae are sometimes collected as adults in early stages of decomposition [29,30], but are recognized mainly as late colonizers [8,25,30]. *Stearibia nigriceps* was collected on day 1 in spring 2002 and at non-consecutive intervals throughout the remainder of the study. However, in the summer studies, the earliest this species was collected was on day 4 (in 2002) and day 5 (in 2001) and, thereafter, at consecutive sampling intervals. *Piophila casei*, which occurs in southwest Virginia [12] was not collected during the studies. Possible reasons for this might be that *S. nigriceps* is dominant over *P. casei* in this area and/or the studies ended before the carcasses reached the dry remains stage of decomposition. Late-arriving insects such as dermesids and trogids were also rarely encountered.

Some insects visit but do not colonize a carcass; rather, they exploit the carcass and developing maggots as food resources. These non-colonizing insects include predators and parasites of necrophagous species, such as beetles in the families Silphidae, Staphylinidae, and Histeridae, and are useful in succession-based PMI estimations [6]. Most of the beetles that are collected during succession studies fall into this category.

Table A.3
Temperature and rainfall recorded during the spring, summer, and fall studies of insect occurrence on pig carcasses in southwest Virginia

Study period	Mean (range) temperature (°C)		Total (range) rainfall (cm)
	Ambient (daytime)	Maggot mass	
Spring 2001	18.3 (1.8–28.0)	32.0 (22.0–39.0)	8.2 (0.0–4.6)
Summer 2001	22.6 (13.2–29.1)	37.0 (31.0–42.0)	2.3 (0.0–0.7)
Spring 2002	17.7 (5.5–28.3)	36.0 (21.0–43.0)	6.7 (0.0–4.2)
Summer 2002	24.5 (15.9–31.7)	40.0 (37.0–43.0)	4.2 (0.0–2.5)
Fall 2002	8.8 (−3.1–20.8)	17.0 (11.0–29.0)	15.7 (0.0–2.6)

The overwhelming majority of eggs, maggots and adult flies collected in the spring and summer were those of *P. regina.* This species is distributed widely throughout the U.S. and is considered a cold weather fly [29]. It is not surprising, therefore, that *P. regina* was the dominant species recovered in the spring. Byrd and Castner [29], reported that *P. regina* is typically not found during the hot summers of the southern United States. However, Dillon [10] noted that *P. regina* was co-dominant to *L. illustris* in spring and summer studies in British Columbia, Canada where ambient temperatures were $>35\,^{\circ}C$ on certain days. In this study, *P.regina* was collected as frequently in the summer as in the spring.

Few adult specimens of *P. regina* were collected in the fall, even though the range of temperatures for the first two weeks of that study was similar to the early period of the spring studies (see Table A.3). *P. regina* is known to enter diapause in the northeastern United States in October or November [31,32] where temperatures are generally cooler. Diapause is likely to have occurred for this species in southwest Virginia, despite the fact that this region is considered part of the south.

Interestingly, while *P. coeruleiviridis* was co-dominant with *P. regina* in the summer based on the number of adults that were collected, no individuals were identified from reared specimens. *P. coeruleiviridis* is difficult to rear under laboratory conditions compared with other blow flies [33, personal observation]. Therefore, it is likely that this species also colonized the carcasses in the summer and was collected, but not reared successfully to the adult stage for identification.

Very few insects were collected during the first two weeks of the fall study, although the carcasses were colonized by *P. coeruleiviridis*, *P. sericata*, and *L. illustris.* During the third and fourth weeks of this study, temperatures were consistently $<10\,^{\circ}C$ so adult insects disappeared and maggots that were present initially on the carcasses died before pupation.

Of the locations where succession studies have been conducted, Knoxville, TN [28] is the closest in proximity and climate to southwest Virginia. Accordingly, many of the same species were reported from carcasses in both locations, although Reed [28] reported a greater number of insect species (a total of about 217) than we report here. Several factors might account for this difference. Reed [28] used a greater number of carcasses (45 dog carcasses versus 10 pig carcasses in this study) and sampled in nine different areas (versus two for this study) throughout an entire year. In addition, Reed [28] reported incidental, omnivorous and adventive species as well as necrophagous and predators of necrophagous species. Lastly, temperatures in the winter months during the year of the Tennessee studies were much warmer than they generally are in southwest Virginia at the same time of year.

The differences between the study by Reed [28] and ours highlight the need for succession studies in different areas due to dissimilarities in species composition. Succession-based PMI estimation requires the knowledge of local carrion fauna. It provides a complementary approach to PMI estimation using development-based data, which usually results in a narrower estimate of the PMI; however, this approach can only be used when the maggots and/or pupae are still present. Analyzing succession data for PMI estimation is most useful in later stages of decomposition. Although this method results in a wider PMI, succession patterns can sometimes contribute critical clues to an investigation, such as in cases where the body has been moved from the site of death. The diversity of species, type of species, number of individuals, life stages present, and the number of individuals of each life stage all can be derived from succession studies and provide useful clues about the circumstances surrounding the death of the individual.

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Appendix

The following are a list of specialists who confirmed the identification of voucher specimens:

Dr. Jason H. Byrd (Calliphoridae), Office of the Medical Examiner, 1360 Indian Lake Rd, Daytona Beach, FL 32124, USA.

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Dr. N.E. Woodley (Sarcophagidae, Calliphoridae), Systematic Entomology Laboratory, Communications & Taxonomic Services Unit, Bldg. 005, Room 137, BARC-West, 10300 Baltimore Avenue, Beltsville, MD 20705-2350, USA

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