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A preliminary study of forensic entomology in Medellín, Colombia

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Abstract

This is the first report of an ongoing study of insect succession on carrion carried out in Medellín, Colombia, using pigs (*Sus scrofa*) as a model to determine the insect sequence over 207 days. During this period, 2314 insects belonging to the following orders and families were collected: Diptera: Calliphoridae, Muscidae, Piophilidae, Sarcophagidae, Syrphidae, Otitidae; Hymenoptera: Apidae, Formicidae, Halictidae, Mutilidae, Vespidae; Coleoptera: Staphylinidae, Histeridae, Carabidae, Scarabaeidae, Silphidae, Dermestidae, Cleridae, Nitidulidae; Dermaptera: Forficulidae; Hemyptera: Gelastocoridae, Coreidae; Lepidoptera: Hesperiidae.

Five decomposition stages were observed (fresh, bloated, active decay, advanced decay, and dry remains) and four insect ecological categories (necrophagous, predators, omnivorous, and incidental). During the fresh stage, the first insects that appeared were flies of the families Sarcophagidae and Muscidae and specimens of Formicidae (Hymenoptera). During the bloated period, species of Calliphoridae (Diptera) were predominant and the first to oviposit. During the third and fourth stages (active decay and advanced decay), the most abundant families were Calliphoridae and Muscidae, although Staphilinidae (Coleoptera) also stood out. During the last stage (dry remains), the dominant family was Formicidae (Hymenoptera) followed by Dermestidae (Coleoptera) with a large number of immature insects.

Keywords: Forensic entomology; Insect succession; Carrion entomofauna

1. Introduction

Forensic entomology is the scientific discipline of interpreting information concerning a death, using insects as silent witnesses in order to provide data not available by using the normal methods of classic pathology [1].

Forensic entomology is inexorably related with the fields of medical entomology, taxonomy, and forensic pathology [2], and is used mainly to estimate the time of death or postmortem interval (PMI) based on the developmental rates and the successional ecology of specific insects that feed on carcasses. The period of 72 h after death is usually the most important time, and often the only period to accurately estimate the time of death. These methods may be used to determine if a body has been moved from one locality to another, and may provide information about the site of death itself, because of the relatively defined diversity of insects that exists in specific geographical areas. Insect species found on a decomposing body that do not correspond with species normally found in the area can be a good indicator that the body in question was moved from one area to another [1,3,4]. Forensic entomology can be used also in cases that involve possible sudden deaths, such as traffic accidents without obvious causes and the criminal abuse by use of drugs and poisoning. Larvae that are found consuming a body may ingest, incorporate, and bioaccumulate chemical metabolites of drugs from the corpse into their own tissues such as barbiturates, cocaine, amphetamines, and even poisons. These insect tissues can be analyzed to detect those substances, and this process is important in cases in which the body is in an advanced state of decomposition or when it lacks blood and it is not possible to carry out toxicological routine analysis [1,5,6].

Insects and other invertebrates feed on carrion in a successional manner dependent on the state of decomposition. The recognition of the species involved, the pattern and time of arrival at the scene of the adults, and subsequently

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the eggs and larvae, together with a knowledge of their development rates can give an indication of the time of death. As observed in the studies indexed by Smith [7], in 1894 Mégnin reported eight periods of activity of cadaverous fauna, also called waves of insects [8]. Other authors reported a different number of waves: Fuller, three waves [9]; Howden, two waves [10]; Jiron and Cardin, in their study with dogs reported four waves [11]; Johnson, four waves in small mammals [12]; Rodriguez and Bass, four waves [13]; Utsumi, with dogs and rats described two waves [14]; Payne, six waves [15]; Lord and Burger, five waves [16]; Bornemissza, five waves [17]. In more recent studies, five phases settle down during the postmortem interval associated to the insects' activities [6,18,19].

Each of the arthropod species has a unique developmental behavior rate, which is modified by climatological variables such as temperature and humidity. Another variable to take into account is the ''invasion'' type pattern of the corpse, since some insect species are always present, while others disappear and later reappear. It is important to observe that not all the invertebrates found near a corpse are feeding on it, and based on this, four ecological categories have been recognized for the insect community found around corpses: (1) necrophagous species (they constitute the most important category to establish the time of death), (2) predadors and parasites of necrophagous species, (3) omnivorous species, and (4) adventitious species that use the cadaver like an extension of their ecological niche [7]. The study of the entomofauna associated with cadavers has been an extremely effective tool to clarify numerous cases of homicides, sexual abuses, and traffic of organs [2,20,21].

It is important to note that although the application of the forensic entomology has been strongly criticized for years, it is now gaining acceptance in many countries and offers a great potential of contribution to the legal profession in legal proceedings in Latin America [1].

In a city such as Medellín, where the number of unsolved deaths related to violent acts is very high, it is of great interest to apply the field of forensic entomology as a component of forensic sciences. It is important to look for new alternatives that complement existing techniques and permit the collection of additional data that will allow a more precise estimation of the time of death. In view of the fact that forensic entomology has provided excellent results in other countries, a first step should be taken to include these methodologies with the purpose of refining strategies and tools that may be used subsequently in legal proceedings.

The main objective of this work was to study the entomofauna of a cadaver of a white pig (*Sus scrofa*), the period of invertebrate activity with relation to the different phases of decomposition, to determine the number of these phases present under natural conditions of temperature and humidity in the metropolitan area of the city of Medellín, and to prepare a reference collection of insects from this region for subsequent studies. The pigs are especially adapted for this type of study, because they resemble human beings in the quantity of body hair, size of the back, and process of decomposition [18].

2. Methodology

The present study was carried out in the city of Medellín, in a bioclimatic area designated (bh-P) according to Holdridge (bh-P) [22]. The region is located at 1450 m above sea level with an average temperature between 18–24°C and an average rainfall of 1409 mm [23].

2.1. Field sampling

One pig of 17.7 kg was used as model for human decomposition [3,18]. It was sacrificed at 16.45 h at the study site consisting of an empty lot in the metropolitan area of Medellín. The pig was shot twice with 38 gauge bullets, one in the head and the other in the thorax, from a distance of 3 m. The pig was immediately placed in a metallic cage, 61 cm × 50 cm × 39 cm, which allowed the access of insects at the corpse, but prevented the corpse being disturbed by carnivorous vertebrates.

We carried out daily observations for a period of 7 months, collecting the mature insects that flew near the cadaver or settled on it, and subsequently samples of immature stages (eggs and larvae) from natural apertures (eyes, mouth, nose, ears) and of the bullet holes. We also lifted the cage to collect the insects present in the part of the cadaver that was contacting the ground within 10 cm. Some of the collected immature insects were fixed in 70% ethanol and others raised to adults for taxonomic identification.

2.2. Methodology of laboratory

The larvae and eggs were maintained under the same conditions of temperature and humidity as the field site they were collected from and maintained in wide-mouthed containers covered with muslin and fed with raw meat. The resulting adults were killed using ethyl acetate, and mounted with entomological pins for subsequent taxonomic evaluation [24–26]. The larvae that were in ethanol were cleared and mounted in Canada balsalm [27].

3. Results and discussion

A total of 2314 individuals were collected (larvae and adults) belonging to seven orders and 25 families: Diptera (Calliphoridae, Sarcophagidae, Muscidae, Piophilidae, Syrphidae, Otitidae), Hymenoptera (Vespidae, Apidae, Formicidae, Halictidae, Mutilidae), Coleoptera (Staphylinidae, Histeridae, Carabidae, Dermestidae, Scarabaeidae, Silphidae, Cleridae, Nitidulidae), Hemiptera (Gelastocoridae, Coreidae), Dermaptera (Forficulidae), Lepidoptera

Table 1
Entomofaunal succession attracted to the various stages of pig carcass[a]

Order	Family	Genus	Stage										
			Fresh (0–1 days)	Bloated (2–6 days)			Active (7–12 days)			Advanced (13–51 days)		Dry (52–207 days)	
			A	E	I	A	E	I	A	I	A	I	A
Diptera	Calliphoridae	*Chrysomya* sp.				×		×	×	×	×		
		Chrysomya albiceps						×		×			
		Cochliomyia sp.							×		×		
		Cochliomyia macellaria			×	×		×	×	×	×		×
		Lucilia sp.			×	×		×	×	×	×		
		Not identified		×	×		×	×					
	Muscidae	*Fannia* sp.							×		×		×
		Morellia sp.	×										
		Ophyra sp.				×			×	×	×	×	×
		Not identified				×			×	×	×	×	×
	Piophilidae	*Piophila casei*							×	×	×	×	×
	Sarcophagidae	*Oxisarcodexia* sp.							×		×		×
		Not identified	×		×	×		×	×	×	×		×
	Syrphidae	*Pseudodoros* sp.									×		×
		Not identified							×		×		×
	Otitidae	Not identified							×		×		×
Coleoptera	Carabidae	Not identified									×		
	Cleridae	*Necrobia rufipes*								×	×	×	×
	Dermestidae	*Dermestes* sp.								×	×	×	×
	Histeridae	*Hister* sp.							×		×	×	×
	Nitidulidae	Not identified									×		
	Scarabaeidae	*Coprophanaeus* sp.									×		
	Scarabaeidae	Not identified									×	×	
	Silphidae	*Oxelytrum* sp.							×		×	×	
	Staphylinidae	*Hipotelus* sp.									×		
		Lispinus sp.									×		
		Megalopinus sp.									×		×
		Pseudopsis sp.									×		×
		Spedophilus sp.									×		
		Stenus sp.?									×		
		Not identified							×		×	×	×
Dermaptarea	Forficulidae	Not identified							×	×	×	×	×
Hemiptera	Coreidae	Not identified									×		
	Gelastocoridae	Not identified								×	×		×
Hymenoptera	Apidae	*Epichaiis* sp.				×							
		Eulaema sp.				×			×		×		
		Partamona sp.							×		×		×
		Apis sp.									×		
	Formicidae	*Camponotus* sp.											×
		Linepithema sp.				×			×		×		×
		Neivamyrmex sp.											×
		Odontomachus sp.				×			×		×		×
		Pheidole sp.									×		×
		Pseudomyrmex sp.				×			×		×		×
		Solenopsis sp.	×										×
	Halictidae	Not identified									×		
	Mutilidae	Not identified											×
	Vespidae	Not identified				×			×		×		×
Lepidoptera	Hesperiidae	*Urbanus* sp.							×				
Blattodea	Blattidae	Not identified											×

[a] A, adult; E, egg; I, immature.

(Hesperiidae), Blattodea (Blattidae), and other arthropods such as Arachnida (including Acari) and Diplopoda.

According to the ecological categories of Smith [7], the entomofauna was classified as follows.

1. Necrophagous: Calliphoridae, Sarcophagidae, Muscidae, Silphidae, Dermestidae, Scarabaeidae, Formicidae.
2. Predators and parasites: Syrphidae, Staphylinidae, Forficulidae, Gelastocoridae, Histeridae, Carabidae, Vespidae, Cleridae, Silphidae.
3. Omnivorous: Vespidae, Formicidae, Blattidae, and some Coleoptera.
4. Incidental: Hesperiidae, Coreidae, Passalidae, Nitidulidae, Halictidae.

We observed five phases of decomposition and the appropriate succession of entomofauna that differ according to the body temperature of pig and the physical changes manifested such as the fresh, swollen, active decomposition, advanced decomposition, and dry remains (Table 1).

Five phases of decomposition were determined. In the first phase of fresh decomposition (0–1 days), the first insects to arrive were ants (15 min), attracted specifically to the blood and the pelvic region. Within the following 30 min, the first flies of the families Sarcophagidae and Muscidae arrived.

After 2–6 days of death (bloated phase), species of Calliphoridae were the first to oviposit on the cadaver in nose and eyes (Table 1).

In active decomposition phase (7–12 days), when a strong odor was noted, eggs and larvae observed were of Calliphoridae, collected from ears and the wounds. Among the total of insects stages, we noted the great abundance of Calliphoridae (41.8%), Muscidae (24.0%), Sarcophagidae (10.2%), and associated with this phase was the arrival of the predators, mainly Vespidae (6.6%) and Staphylinidae (3.6%) attracted by the availability of Dipteran larvae (Table 2).

In advanced decomposition phase (13–51 days), which is characterized by the absence of odor and the removal of a great part of the soft tissues, a high number of larvae of Muscidae and Piophilidae were observed (Table 3), and adults of Coleoptera arrived, principally Scarabaeidae, Cleridae, Dermestidae, Histeridae, Silphidae, and Staphylinidae, and the presence of incidental families was noted (Table 1).

Decomposition finishes with the dry remains phase (52–207 days) and during this stage we found for the first time

Table 2
Total percentage of families attracted to the stages of decay on pig

Order	Family	Stage				
		Fresh	Bloated	Active	Advanced	Dry
Diptera	Calliphoridae	0	59.5	41.8	10.4	0.3
	Muscidae	25	11.6	24.0	23.5	7.2
	Otitidae	0	0.0	2.0	1.3	0.4
	Piophilidae	0	0.8	3.6	11.0	4.4
	Sarcophagidae	75	9.9	10.2	11.4	6.2
	Sciaridae	0	0.0	0.0	0.1	0.0
	Syrphidae	0	0.0	0.5	0.5	0.2
Coleoptera	Carabidae	0	0.0	0.0	0.1	0.0
	Cleridae	0	0.0	0.0	0.9	8.5
	Dermestidae	0	0.0	0.0	6.3	16.2
	Histeridae	0	0.0	1.0	1.6	4.3
	Nitidulidae	0	0.0	0.0	0.2	0.0
	Scarabaeidae	0	0.0	0.0	0.6	0.4
	Silphidae	0	0.0	1.0	0.6	0.1
	Staphylinidae	0	0.0	3.6	9.6	5.6
Hemiptera	Coreidae	0	0.0	0.0	0.1	0.0
	Gelastocoridae	0	0.0	0.0	1.3	0.3
Hymenoptera	Apidae	0	1.7	2.0	2.1	0.5
	Formicidae	0	10.7	2.6	9.6	35.2
	Halictidae	0	0.0	0.0	0.1	0.0
	Mutilidae	0	0.0	0.0	0.0	0.3
	Vespidae	0	5.8	6.6	1.6	0.5
Blattodea	Blattidae	0	0.0	0.0	0.0	0.1
Dermaptera	Forficulidae	0	0.0	0.5	7.4	9.4
Lepidoptera	Hesperiidae	0	0.0	0.5	0.0	0.0

Table 3
Days, stage of decomposition and larvae succession on pig carcass

Order	Family \ Days	Bloated		Actived	ADVANCED					DRY							
		2--3	4--6	7--12	13-17	18-24	25-31	32-42	43-51	52-60	61-70	71-76	77-88	89-99	100-110	111-118	119-207
Diptera	Calliphoridae																
	Muscidae																
	Piophilidae																
	Sarcophagidae																
Coleoptera	Cleridae																
	Dermestidae																
	Histeridae																
	Scarabaeidae																
	Silphidae																
	Staphylinidae																
Dermaptera	Forficulidae																

larvae of Histeridae and Scarabaeidae as an well as an abundance of Dermestidae and adults of Forficulidae, Sarcophagidae, and Cleridae. The larvae of these families feed on hard dry tissues with a very low humidity (skin and cartilage possibly) (Table 3).

The complete process of decomposition lasted a total of 207 days, shorter than the 270 days reported by Anderson and Sherah [6] using the same model in summer time in Hawaii. The size of pigs was similar, 22 and 17.6 kg in this work, and it is known that the type and size of cadaver can cause effects in the rate of decomposition and in the succession of insects.

The family Calliphoridae seems to be the main one devoring soft, humid tissues with little degree of decomposition. As reported by Anderson and Mégnin [6,8], the first insects that placed their eggs on the cadaver were flies of the genus *Lucilia* (Calliphoridae).

Some families can be considered as indicators of the successive periods of decomposition — fresh: with adults of Muscidae, Sarcophagidae; bloated: represented by eggs and larvae of Calliphoridae and adults of Vespidae; active: larvae of Sarcophagidae; advanced: larvae of Piophilidae; dry: larvae of Histeridae and Scarabaeidae.

Adults of the families Sarcophagidae, Muscidae, and Formicidae were collected during the whole process of decomposition, which shows the importance of these groups because of the specific needs either for their reproduction or feeding. In relation to the immature stages: Muscidae was starting from the phase of advanced decomposition until the first days of dry remains, Sarcophagidae from bloated until the first days of advanced, Piophilidae and Dermestidae from half of advanced until the end of the study, and alone Histeridae was in dry remains from its final half.

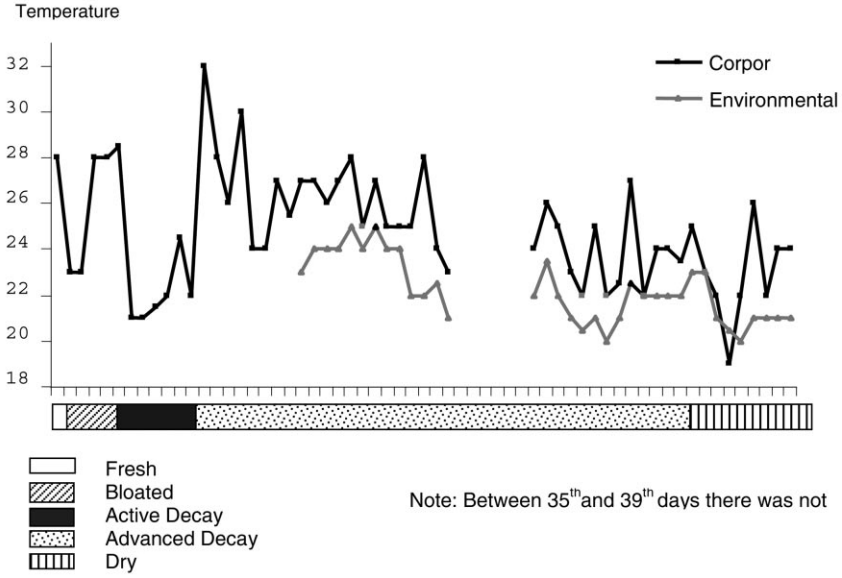

Fig. 1. Daily temperature variations related with decomposition phase.

In relation to the families Gelastocoridae and Coreidae (Hemiptera) and Hesperiidae (Lepidoptera), these are part of the local entomofauna, and they can be used to determine if the cadaver has been moved from one place to another.

A marked relationship was observed between the temperature and the phases of decomposition. In the fresh phase, there was a decrease in the temperature of the cadaver that coincides with rigid mortis. In the bloated phase, an increment was observed that can be related to the accumulation of gases generated by the metabolic activity of bacteria. In the active phase, there is a decrease in the corporeal temperature again, which coincides with the exit of gases that takes place when the skin of the cadaver tears, releasing gases. When the cadaver bursts, there is a small increase of temperature noted which may possibly be related to the great larval activity. In the phases of advanced decomposition and dry remains, the body temperature is very similar to the environmental temperature (Fig. 1).

4. Conclusions

In this work, we observed a clear succession of insects arriving at the scene; this succession is defined by two main groups: the Diptera and the Coleoptera. As was observed by Carvalho [28], the Diptera had a peak during the initial stages and Coleoptera for the advanced and dry stages. The Diptera denote the first necrophagous wave, and they are the first ones to oviposit and the first immature stages that were collected. These were followed by a second wave of predators represented by Hymenoptera and subsequently by many Coleoptera and some incidental insects, and concluded with a fourth and fifth waves, comprising immature stages of several families of Coleoptera and Dermaptera.

The study of the entomofauna associated with a cadaver, the determination of their state of biological development, the definition of the phases of decomposition, the determination of the taxonomic groups, and the relationship with the changes of temperature, are integral elements that must be studied and evaluated in order to understand the overall situation, providing valuable elements in the development and acceptance of the forensic entomology as a relevant science in Colombia.

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