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Neotropical Entomology

ISSN 1519-566X
Volume 41
Number 1

Neotrop Entomol (2012) 41:27-31
DOI 10.1007/s13744-011-0005-9

Springer

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ECOLOGY, BEHAVIOR AND BIONOMICS

Succession of Carrion Fauna in the Arid Region of San Juan Province, Argentina and Its Forensic Relevance

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Keywords

Arid zone, cadaveric fauna, decomposition process, Postmortem interval estimation

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Edited by Fernando B Noll – UNESP

Received 24 March 2011 and accepted 30 September 2011
Published online 10 February 2012

Abstract

The succession of carrion fauna and the decomposition stages were studied in the arid environment of San Juan Province, Argentina (31°32′ 34.7″ S; 68°34′39.4″ W). Two pig carcasses (*Sus scrofa*) were placed in wire mesh cages, 100 m apart from each other. Each carcass was surrounded by pitfall traps, and a modified Malaise trap was placed above. Daily samplings were carried out to collect the insects present in the carcasses and the traps, and body and environmental temperature were measured. The main colonizer species was *Chrysomya albiceps* (Wiedemann) and its larvae were dominant over other Diptera. The first adult blowflies emerged at 8.9 days. The time to reach the remains stage was 8 days shorter than for other South American sites. We recorded the early arrival of adult *Dermestes maculates* De Geer and *Dermestes ater* De Geer 2 days after the beginning of the assay, and larvae of these species were recorded 4 days after. We determined a 1.5-day error in the postmortem interval estimation using the temperatures measured in the assay and those recorded by the nearest meteorological station.

Introduction

Forensic entomology is based on the use of arthropods as evidence in criminal investigations, particularly in the case of death under doubtful circumstances (Hall 2001). The fauna associated to a corpse contributes to determining the postmortem interval (PMI) and provides useful forensic information. The PMI can be estimated by determining the degree of development of the specimens present on the corpse, particularly dipteran larvae, if the death occurred relatively recently. The succession patterns of the arthropods found, either whole individuals or their remains, as puparia, cocoons, exuviae, and feces, are studied during the final stages of decomposition (Goff 1993, Tabor *et al* 2005).

The environmental and biogeographic conditions particular to each region influence the species composition and dynamics of the carrion fauna present (Carvalho *et al* 2000, Centeno *et al* 2002, Battán Horenstein *et al* 2005). Therefore, it is necessary to conduct research at different sites, typically using the domestic pig (*Sus scrofa*) as an experimental model (Payne 1965, Goff 1993).

Forensic entomology studies in Argentina are recent, mainly consisting in studies of case histories (Oliva 1997), determination of species composition (Aballay *et al* 2008), with few studies relating the entomofauna to the decomposition stages and their relevance to legal medicine (Centeno *et al* 2002, in the Buenos Aires metropolitan area, 34°28′ S; 58°28′ W; and Battán Horenstein *et al* 2007, 2010, in the Córdoba province, 31°21′ S; 64°05′ W). These last two assays were conducted in more humid climates, and to this date there is no information available on cadaveric succession in arid regions of Argentina, which is necessary to characterize the cadaveric decomposition process and the base line for the carrion fauna (Goff 1993) in arid areas of Argentina, establishing possible differences in comparison with humid regions in order to conduct forensic investigations with experimental data from the same region.

There are great variations in temperature and relative humidity between the metropolitan areas of Buenos Aires and San Juan City (31°32′ S, 68°34′ W) in summer, mainly due to the Mediterranean situation of the latter and the influence of the Andean mountains, with San Juan exhibiting wider thermal amplitude and much higher temperatures. On the other hand, the insect fauna in San Juan is typical of the Monte biogeographic region (Cabrera & Willink 1973, Roig Juñent *et al* 2001), whereas in Buenos Aires, the insect fauna is associated to the Pampeana region (Cabrera & Willink 1973). In the present work, the results from research conducted in humid Argentina regions and other sites in South America are compared to an assay of cadaveric decomposition conducted in summer in San Juan Province with the goal of establishing the potential differences in comparison with other sites in Argentina, taking into account the effects of extreme aridity.

Material and Methods

The study was conducted in a 5-ha park belonging to the Facultad de Ciencias Exactas, Físicas y Naturales, campus of San Juan National University, Argentina (31°32′34.7″ S; 68° 34′39″ W), at 673 m.a.s.l. The assay was carried out in January (southern hemisphere summer), in a sector with *Acacia aroma*, *Prosopis strombulifera*, and *Larrea divaricata* bushes, as well as *Prosopis chilensis* and *Prosopis flexuosa*, among others. The climate is continental, arid, and dry, with wide thermal amplitude and annual mean temperature of 19°C. Mean relative humidity of 43% and scarce precipitations (110 mm annual) are concentrated in the summer season.

We followed the standard methods used in decomposition assays with porcine models (Goff 1993). Two pigs (*S. scrofa*) weighing approximately 13 kg each were killed and placed in wooden framed cages covered with wire mesh (120×100×150 cm), over 5 cm of loose dirt, previously stirred. Within each cage, a modified Malaise trap was placed over the carcasses, consisting of a fine-meshed cloth arranged in an inverted funnel shape, with a 5-L plastic recipient placed in the vortex, which was extracted for collection of insects and replaced in every sampling date. The trap was placed between 10 and 15 cm above ground level in order to allow entrance to insects. Six pitfall traps were placed at a distance of approximately 40 cm from the carcasses, and other six pitfalls were placed at 15 m as controls. The control traps were used to differentiate the local epigeic fauna from the fauna associated to the carcass (Centeno *et al* 2002). These traps consisted in 500 cm^3 plastic recipients containing 10% anti-freezing solution. Both cages were separated by a 100-m distance.

Each carcass was sampled twice a day for 20 days from 1:00 to 4:00 p.m. (diurnal sampling), which was the time in which adult dipterans exhibited their greatest activity, and from 8:00 to 11:00 p.m. (nocturnal sampling), which served the purpose of recording the presence of adult coleopterans. After the 20th day, diurnal sampling was conducted daily for 7 days, then twice a week for 15 days, and finally, once a month until skeletonization of the carcasses. In nocturnal samplings, only adult coleopterans were collected. In diurnal samplings, the cadaveric entomofauna caught in the modified Malaise traps was collected in addition to insects from the pitfall traps. Manual collection of dipteran and coleopteran larvae and adults was carried out over, within and around the carcasses. Part of the dipteran larvae was reared in the laboratory until adult emergence to facilitate their identification; the rest were killed using water at 70–80°C and kept in 70% ethanol. In each sampling date, we recorded air temperature, temperature of the mass of dipteran larvae, and the relative humidity. We recorded two body temperatures. Internal body temperature was measured rectally, and external body temperature was measured at the inguinal region. Adult arthropods were killed using chloroform and then placed in entomological boxes until their identification, following Oliva (1997, 2002), Mariluis and Schnack (2002), and Domínguez (2007). The material collected was placed in the collection of Instituto and Museo de Ciencias Naturales (IMCN UNSJ) and the Catedra de Zoología I (ZI UNSJ) of the Facultad de Ciencias Exactas, Físicas y Naturales, San Juan National University.

Results and Discussion

Following Payne's classification (1965), we distinguished five decomposition stages: fresh, bloated, active decay, advanced decay, and remains. The average local temperature and humidity conditions recorded for the sampling site during the entire decomposition process were 37.5°C and 44.1% RH, respectively. Variations in mean temperature from four daily recordings from the carcass (internal and external), mass of larvae, and environment, as well as maximum and minimum temperatures recorded in the Pocito San Juan (INTA) meteorological station are also described (Fig 1). The length of the decomposition stages as well as the succession of the cadaveric entomofauna recorded and their developmental stage (egg, larva, pupa, adult, puparium, or exuvia) and each decomposition stage with their associated entomofauna are shown in Table 1.

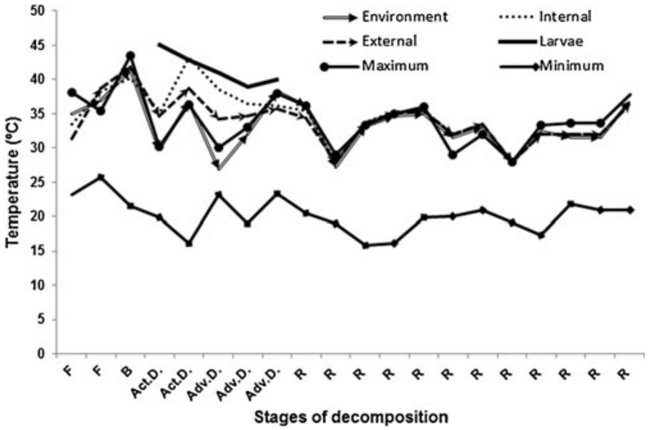

Fig 1 Mean temperatures (in degrees Celsius) recorded during the decomposition process at: *Environment* air temperature; *internal* inside the body; *external* body surface; *larvae* larvae mass; *maximum* and *minimum* from nearby weather station. Stages of decomposition: *F* fresh, *B* bloated, *Act. D.* active decay, *Adv. D.* advanced decay; *R* remains (The temperature of larvae mass of the first day of active decay was only recorded for C2. The record of larvae mass in last day of the advanced decay stage was only for C1.).

In the fresh stage, the scarce abundance of *Lucilia sericata* (Meigen) (Diptera: Calliphoridae) (*N*=3) could be a consequence of the high temperatures recorded. In the Buenos Aires region, this species was very abundant in mid-spring and was considered as poorly tolerant to very high temperatures (Centeno *et al* 2004). On other hand, the occurrence of *Musca domestica* (L.) (Diptera: Muscidae) was remarkable given that it is commonly considered coprophagic and rarely recorded in forensic situations (Oliva 1997). We only collected them as adults due to predation by larvae of *Chrysomya albiceps* (Wiedemann) (Diptera: Calliphoridae).

When the carcasses reached the bloated stage, we recorded eggs 42 h after death. These eggs hatched by the end of that sampling day. First instar larvae belonged to *C. albiceps* and *Cochliomya macellaria* (Fabr.) (Diptera: Calliphoridae), but we were not able to determine which one of these species was the first to lay eggs on the carcass. Thus, even when *C. albiceps* was one of the first species to arrive on the carcass, we cannot ascertain that it was the first to colonize it at the larval stage. We did not observe a clear "arrival order" or "wave" during carcass colonization in our study. This disagrees with Oliva (1997), who distinguished *C. albiceps* as a species belonging to the "second wave", maybe based on the predatory trait of these larvae and their effect on *C. macellaria* (Wells 1992; Faria *et al* 1999, Grassberger *et al* 2003, Centeno *et al* 2004).

In addition, the presence of Dermestidae larvae from the sixth and seventh day on both carcasses must be highlighted, with records of adults on the second day of the assay. Centeno *et al* (2002) recorded adults on the tenth day, while Oliva (2001) reported them as frequent between the 25th and 35th day after death. In Ipeúna, Brazil (22°23′ S, 47°40′ W), Gomes *et al* (2009) collected larvae after the 22nd day of the beginning of decay, and in Medellín, Colombia (6°29′ S, 75°54′ W), Pérez *et al* (2005) recorded larvae on the 27th day. Considering that in these sites the climate is much more humid, whereas in San Juan the relative humidity was 43%, it is likely that the rapid desiccation of the carcasses due to the dry conditions provided larvae with dry tissue (skin and skin appendages) soon after death, thus speeding their occurrence. This should be taken into account when estimating PMI in a forensic investigation involving a corpse in an arid climate and with the presence of Dermestidae.

In active decay stage, we collected *Polybia ruficeps* Schrottky (Hymenoptera: Vespidae), which was recorded preying on adults of *C. albipes* in the modified Malaise trap. In forensic terms, the possibility that *P. ruficeps* might influence the colonization of the carcass by dipterans, decreasing their abundance or eliminating the older stages should be considered as these species are usually employed to determine the PMI.

In the remains stage, the carcasses were reduced to hairs, bones, and dry leather fragments. Here, the emergence of adults of *C. albiceps* occurred 9.8 days (carcass 1) and 8.9 days (carcass 2) after death. At this point, we want to observe a fact: when estimating PMI, it is frequent to use the temperatures recorded by the meteorological station closest to the site where the corpse was found. In San Juan, that value was 28.2°C during the first 9 days of decomposition. Thus, if that temperature had been used to determine the PMI, based on the *C. albiceps* life cycle from Grassberger *et al* (2003), we would have obtained a PMI of 10.4 days, whereas the actual death had occurred 9 days before, meaning that our estimation would have had a 1.5-day error. Based on these results, we consider it important to establish the potential differences between the temperature of the site of finding and that recorded by the meteorological station of the area.

The most notorious difference with Centeno *et al* (2002), Gomes *et al* (2009), and Pérez *et al* (2005) is the length of the decomposition process, since in San Juan the remains stage was reached 8 days after death, whereas in the above-mentioned articles, this stage was reached on day 22. This difference may be attributed to the extremely arid environment of San Juan, determining the rapid desiccation of the carcass, as detailed above. The dry tissues are not suitable as a food source of blowflies larvae; that could be the cause for the early occurrence of dermestids larvae and other species-associated carcass remains. This results in an acceleration of the successional pattern.

The data collected represent the first contribution to the knowledge of cadaveric succession in arid regions of Argentina and will help to establish the base line of carrion fauna

Table 1 Succession of the cadaveric entomofauna related to the decay stages in pig carcass 1 (PC1) and 2 (PC2).

Order	Families	Genus and species	STAGES OF DECOMPOSITION																																		
			F	B	Act.D.		Adv. D.			Remains																											
Diptera		*Chrysomya albiceps* (Wiedemann)	A	AE	A	A	A	A	A		A	A	A	A	A	A	A							A													
		Chrysomya albiceps (Wiedemann)			L	L	L	L	L	L																											
		Chrysomya albiceps (Wiedemann)							P	P	P	P	P	P	P	P																					
		Chrysomya albiceps (Wiedemann)										Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu	Pu
		Cochliomyia macellaria Fabricius		AE	A																																
		Cochliomyia macellaria Fabricius			L																																
	Calliphoridae	*Lucilia sericata* (Meigen)	A	A																																	
		Sarconesia chlorogaster (Wiedemann)									A																										
	Sarcophagidae	*Sp. 1*		A	A	A	A	A	A	A						A	A	A	A	A			A	A		A					A				A	A	
	Sarcophagidae	*Sp. 2*		A	A	A	A								A		A																				
		Musca domestica Linnaeus	A	A	A	A	A	A	A		A						A		A			A		A				A		A		A					
		Ophyra sp. Robineau-Desvoidy				A	A																														
	Muscidae	*Muscina stabulans* (Fallén)				A																															
	Fanniidae	*Fannia femoralis* (Stein)				A																															
	Fanniidae	*Fannia fusconotata*(Rondani)		A		A	A										A																				
	Anthomyiidae	*Sp.*			A									A			A	A	A	A																	
	Piophilidae	*Sp.*	A	A	A																																
Coleoptera	Dermestidae	*Dermestes maculatus* De Geter		A	A	A	A	A	A	A		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
	Dermestidae	*Dermestes ater* De Geer		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
		Dermestes spp.						L	L	L	L	L	L	L	L		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
	Cleridae	*Necrobia rufipes* De Geer			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Xerosaprinus (S.str) diptychus (Marseul)		A		A	A	A	A	A	A	A	A				A			A																	
		Euspilotus (Hesperosaprinus) pavidus (Erichson)		A	A	A	A	A	A	A	A	A	A																								
	Histeridae	*Euspilotus (Hesperosaprinus) modestus* (Erichson)						A	A	A																											
		Euspilotus (S.str) lacordairei (Marseul)			A	A	A	A	A																												
		Euspilotus (Hesperosaprinus) parenthesis (Schmidt)					A					A																									
		Euspilotus (S.str) ornatus (Blanchard)						A																													
	Staphylinidae	*Creophilus maxillosus* (Linnaeus)			A		A																												A		
	Staphylinidae	*Philonthus longicornis* Steph			A	A																															
		Salax lacordairei Guérin M-éneville	A	A	A		A												A	A		A								A	A	A		A	A		
	Tenebrionidae	*Trichoton roigi* Ferrer & Moragués	A	A	A		A												A				A		A		A				A	A					
		Hylithus tentyroides Lacordaire	A									A		A				A												A							
	Trogidae	*Omorgus suberosus* (Fabricius)				A					A										A		A								A						
	Scarabaeidae	*Ataenius sp.* Harold							A	A		A		A													A										
Hymenoptera		*Camponotus mus*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
		Camponotus punctulatus a Mayr	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A			A	A	A			A	A	A	A	A	A	A	A	A	A	A	A	
		Camponotus punctulatus b Mayr	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A		A	
		Pheidole bergi Mayr	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
		Pheidole triconstricta Forel			A	A		A	A	A	A			A		A		A	A	A	A			A	A	A	A	A			A	A	A	A	A	A	
	Formicidae	*Solenopsis sp.* Westwood	A	A		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A		A		A	A	A	A	A	A	A	A	A	A	A	A	
	Vespidae	*Polybia ruficeps* Schrottky			A						A			A	A	A	A		A	A																	
	Cabronidae	*Rubrica masuta* (Christ)															A																				
TIME	SAMPLING		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
	POS MORTEM INTERVAL IN DAYS		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	31	34	38	40	46	54	95

E eggs, *L* larvae, *P* pupae, *A* adults, *Pu* puparium, *F* fresh, *B* bloated, *Act. D.* active decay, *Adv. D.* advanced decay.

Highlighted squares indicate the species coinciding in time in both carcasses studied; squares not highlighted indicate species present in one carcass or the other.

that will allow the use of insects as forensic evidence. Further studies are needed in this type of environment where desiccation of corpses is fast, which determines the early onset of the dry stage, narrowing the time window in which dipteran larvae can be found in the corpse.

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