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SHORT COMMUNICATION

Postmortem interval estimation with *Dermestes maculatus* (Coleoptera: Dermestidae) and *Chrysomya albiceps* (Diptera: Calliphoridae) in Colombia

Yardany RAMOS-PASTRANA[1,α*], Noelia I. ZANETTI[2α*], Eric CÓRDOBA-SUAREZ[1]

[1] Universidad de la Amazonia, Grupo de Investigación en Entomología Universidad de la Amazonia –GIEUA–, Florencia, Caquetá, Colombia

[2] Instituto de Ciencias Biológicas y Biomédicas del Sur (INBIOSUR, CONICET/UNS), Departamento de Biología, Bioquímica y Farmacia, Provincia de Buenos Aires, Argentina

[α] These authors contributed equally to the article.

* Corresponding author: ya.ramos@udla.edu.co; nzanetti@criba.edu.ar ; https://orcid.org/0000-0002-3193-6659

ABSTRACT

Insects attracted to cadavers can be used to estimate postmortem interval (PMI). In this study, inmature stages and adults of *Dermestes maculatus* and *Chrysomya albiceps* were collected in association with a human cadaver in a closed aquatic environment in Caquetá, Colombia, and analyzed to determine the PMI. We also conducted an experiment with a pig carcass to estimate the emersion time, which began three days after carcass submersion. The minimum PMI was 481.5 hours. Time of death, time of emersion and period of insect activity matched the actions of the murder suspects, who confessed to murdering the victim 25 days prior to the discovery of the body.

KEYWORDS: forensic entomology, submerged cadavers, dressed cadavers, closed environments

Estimación del intervalo post mortem con *Dermestes maculatus* (Coleoptera: Dermestidae) y *Chrysomya albiceps* (Diptera: Calliphoridae) en Colombia

RESUMEN

Los insectos atraídos a cadáveres pueden ser usados para estimar el intervalo post mortem (IPM). En este estudio, una muestra de estados inmaduros y adultos de *Dermestes maculatus* y *Chrysomya albiceps* fueron recolectados en asociación con un cadáver humano en un ambiente cerrado y acuático en Caquetá, Colombia, y analizada para determinar el IPM. Además, se condujo un experimento con un cadáver porcino para estimar el tiempo de emersión, que comenzó tres días después de la sumersión del cadáver. El IPM mínimo fue 481.5 horas. El tiempo de muerte, tiempo de emersión y el periodo de actividad insectil coincidieron con las acciones de los sospechosos del crimen, quienes confesaron haber asesinado a la víctima 25 días antes del descubrimiento del cadáver.

PALABRAS CLAVES: entomología forense, cadáveres sumergidos, cadáveres vestidos, ambientes encerrados

Forensic entomology is the application of insect studies in cases of legal nature, in any of its three components: urban, stored products and medico-criminal (Hall and Huntington 2010). Within the latter component, the main application of forensic entomology consists in determining the postmortem interval (PMI) of a human or an animal cadaver (Anderson 1999).

Dermestes maculatus De Geer, 1774 (Coleoptera, Dermestidae) is a cosmopolitan beetle and has been associated with decomposing remains at different stages of decomposition, even early ones (Zanetti *et al.* 2015). It is able to colonize, feed and reproduce on fresh tissues soon after death and is found associated with cadavers located indoors or outdoors (Gunn 2018; Zanetti *et al.* 2019). Like other insects, the presence and development of *D. maculatus* are influenced by different factors, namely temperature, which can affect the number of dermestid instars (Zanetti *et al.* 2016).

Chrysomya albiceps Wiedemann, 1819 (Diptera, Calliphoridae) has worldwide distribution and feeds on human feces and decomposing animal tissue, although it can predate other dipteran larvae (Al-Shareef and Al-Qurashi 2016). It can be a first colonizer on cadavers and, like dermestids, it can be found indoors or in open environments and the development duration of its immature stages decreases with increasing temperatures (Ramos-Pastrana *et al.* 2014).

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Here we describe the use of *D. maculatus* and *C. albiceps* attracted to a human cadaver in an aquatic environment in Colombia to determine time of death.

On 9 May, 2020, at 16:00 pm, an adult male cadaver of approximately 90 kg was found in the urban zone of Florencia city, Colombia (1º37′26.5′′N, 075º35′59.07′′W) (Figure 1). The dressed body was found inside a lidded plastic tank filled with 800 L water. Additionally, the body was wrapped in a woolen blanket and tied to a stone of 19.2 kg. The cause of death was an abdominal stab wound caused with a sharp weapon. The hands were tied with a rope on the back of the body. The head, hands and feet were partially skeletonized and the rest of the body was ending the active decomposition stage. The Attorney General's Office informed that the crime suspects indicated in their confession that approximately 2 L hypochlorite were added to the water in the tank. The police investigation confirmed that the man had been seen last by neighbors on 14 April.

At the scene, larvae, pupae and puparium were collected from the body and coverings and fixed in 96% ethanol. Adults were pinned and identified as *Dermestes maculatus* and *Chrysomya albiceps* with the help of keys (Flores and Wolff 2009; Díaz-Aranda *et al.* 2018). The oldest larval stage of *D. maculatus* was determined by measuring its head width and total length with an Olympus SZ61 stereomicroscope. All the specimens were photographed using a camera LEICA DFC450 attached to a stereomicroscope Leica M205A. The entomological material (LEUA-41619 to LEUA-41622) was deposited in the collection of the Entomology Laboratory of Universidad de la Amazonia, Colombia.

The method of accumulated degree days (ADD) was used based on temperature data supplied by Instituto de Hidrología, Meteorología y Estudios Ambientales (Colombia). The daily average temperature from 14 April to 9 May was 29 °C (range 25 - 32 °C). The minimum temperature thresholds and other insect development data, such as the duration of each stage of insect development, were used for estimations of ADD and PMI following Zanetti *et al.* (2016), Vélez and Wolff (2008) and Marchenko (1985). *Dermestes maculatus* needed an average 24.5 days to reach L6 (451.78 ADD) at 30 ºC (Zanetti *et al.* 2016). *Chrysomya albiceps* needed 14 days (360.53 ADD) to reach emergence at 25.3 ºC (Vélez and Wolff 2008).

To estimate the emersion time of the body, an assay was conducted by placing the carcass of a pig (*Sus scrofa domesticus* L.) weighing 20 kg under the same conditions that the human cadaver was exposed. This assay was authorized by the Ethics and Bioethics and Animal Welfare Committee (CEBBA) of Universidad de la Amazonia, was under protocol # CEBBA–131. Water and air temperatures were recorded inside the tank every four hours and were exactly equal to each other, ranging from 35 to 42 °C. The average between these temperatures and external environmental temperatures was calculated per day, as well as the total average (34 °C), for the analysis. This procedure was used because *D. maculatus* has an optimal development temperature range from 30 to 35 °C (Howe 1965). Its upper temperature threshold is likely about 35 ºC, as its survival drops rapidly at that temperature (Martin-Vega *et al.* 2017), mortality is 100% at 38 ºC (Raspi and Antonelli 1996), and dermestid larvae evade temperatures above 39 °C (Osuji 1975).

We identified third instar larva, pupa, and puparium of *C. albiceps* (Figure 2a-c), and larval instar six and adult specimens of *D. maculatus* (Figure 2d-e) collected on the

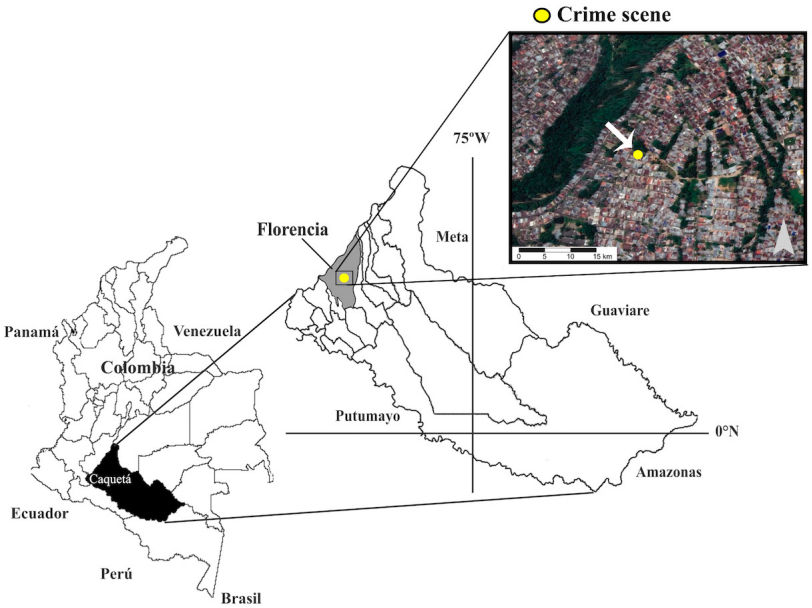

Figure 1. Geographical location of the crime scene in Caquetá, Colombia. This figure is in color in the electronic version.

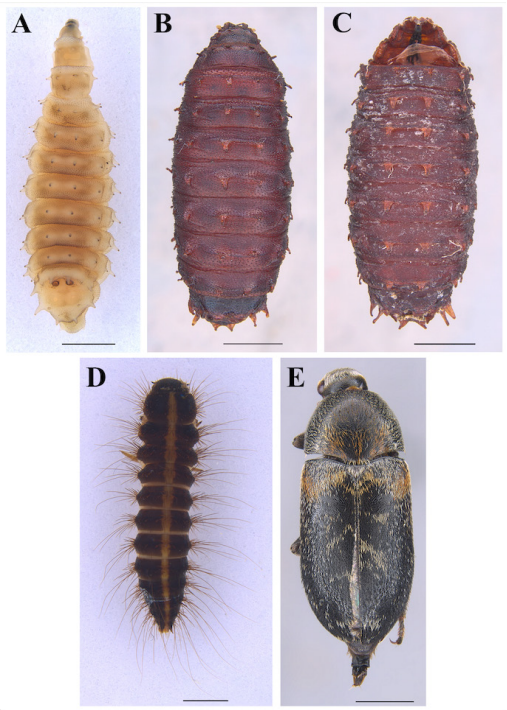

Figure 2. Entomofauna found on a human cadaver in Caquetá, Colombia. A-C – *Chrysomya albiceps* third larval instar, pupa and puparium, respectively; D-E – *Dermestes maculatus* larval instar six and adult, respectively. This figure is in color in the electronic version.

conditions, priority effects and exclusion mechanisms can affect the decomposition pattern and determine whether the decomposing remains will be colonized by dermestids (Charabidze *et al.* 2014; Magni *et al.* 2015). In woodland and desert environments, *D. maculatus* colonization occurred prior to that of calliphorids (Magni *et al.* 2015). Kumara *et al.* (2009) reported an infestation and the unusually rapid arrival of *Dermestes ater*, De Geer, 1774 in Malaysia, most likely due to the warm climate.

It should be noted that the estimation of *C. albiceps* development obtained from literature is based on a temperature that is 8.7 times lower than the average temperature registered inside the crime-scene tank. This difference probably overestimated ADD of *C. albiceps* in our case, as the determination of ADD at 30 or 35 °C will likely result in shorter periods (Grassberger *et al.* 2003) and the body. Estimations indicated that dermestid larvae had a minimum development time of 481.5 hours, while the calliphorids completed their development to adult stage in at least 15 days (Figure 3). The collection of *C. albiceps* third larval instar specimens and younger *D. maculatus* larval instars indicate a second colonization wave. The data suggest a first colonization by *D. maculatus* ovipositing on 19 April, and a later oviposition by *C. albiceps* on 24 April (Figure 3).

Emersion time of the pig carcass was three days after submersion, suggesting the cadaver immersion was probably 17 April.

Our estimates indicate that the period of insect activity (PIA) was shorter than PMI. The time of death, time of emersion and PIA estimated through the pig experiment and the insects collected on the body matched the actions of the suspect perpetrators, who confessed to murder the victim on 14 April. PIA could be related to delayed insect access while the body was submerged (Amendt *et al.* 2007). Submersion in water, enclosure, presence of clothes or toxins can alter the decomposition process of cadavers, including the colonization and succession by necrophagous fauna (Magni *et al.* 2015; Al-Khalifa *et al.* 2020). The fact that the body was in a dark environment within the closed tank and initially submerged probably influenced the colonization by insects, particularly primary colonizers such as Diptera. Dermestids usually first consume the head, hands, and feet of human cadavers, perhaps due to tissue composition or to that these body parts dry more rapidly than other body parts. Additionally, the colonization of natural orifices can be attributed to dipterans and dermestids, while hands and feet are colonized only by dermestids (Amendt *et al.* 2007; Charabidze *et al.* 2014). Intrinsic factors associated with cadaver decomposition should be considered as well, such as age, constitution, integrity of the corpse and cause of death, as they often cause the overlap of several decomposition stages on different parts of the cadaver (Campobasso *et al.* 2001).

Dermestids may visit decomposing remains during all decomposition stages, including fresh corpses, but tending to favor older desiccated remains (Gunn 2018). The cases in which dermestids were found on fresh remains could be related to inter-specific competition between decomposing insects rather than food preference (Gunn 2018). Environmental

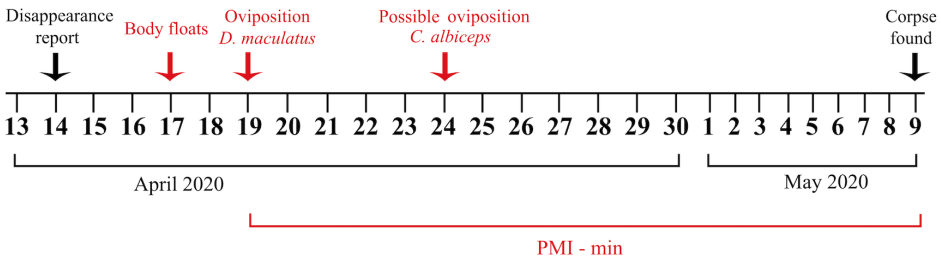

Figure 3. Time line showing the events related to the case. The events marked with black refer to facts, red color to estimates. This figure is in color in the electronic version.

colonization by these flies would have occurred later than here indicated. The time of adult emergence of *C. albiceps* could also be different from our estimation as no pupa was reared until adult hood and no intrapuparial analysis was performed.

Based on our estimations, the earliest floating stage would have set in on 17 April, and the cadaveric fauna would be present from that moment on, beginning colonization by *D. maculatus* on 19 April 2020. Based on the negative phototaxis of dermestids (Zanetti 2013) and the local duration of daylight, the colonization would have occurred at approximately 6:30 pm.

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