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Original article

Two human cases associated with forensic insects in Riyadh, Saudi Arabia

Abdulmani H. Al-Qahtni [a], Mohammed S. Al-Khalifa [a], Ashraf M. Mashaly [b,*]

[a] Department of Zoology, College of Science, King Saud University, P.O. Box: 2455, Riyadh 11451, Saudi Arabia
[b] Department of Zoology, Faculty of Science, Minia University, El Minia 61519, Egypt

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ABSTRACT

In Riyadh, Saudi Arabia, we are reporting two cases of natural death. The two bodies showed different types of habitat, insect colonization and decomposition stage. The first case was about the body of a 65-years-old male, with mummification of the clothed body was found in an outdoor habitat. Different life stages of *Dermestes maculatus* DeGeer (Coleoptera: Dermestidae were gathered from the cadaver, and due to the advanced degree of decomposition, the PMImin was estimated to be 3 months. The second body belonging to a 40-years-old male, was found in a semi-closed apartment (indoor habitat), and the body was at the end of the bloated decomposition stage. In this case, *Musca domestica* L. (Diptera: Muscidae) larvae were collected, and the PMImin was estimated to be 4 days. The limited insect activity for the two bodies caused by the advanced decomposition stage in the first case and indoor environment in the second. Average temperatures of (23.3 ± 1.6) °C for the first body and (27.5 ± 1.7) °C2 for the second body. Habitat was the key factor to attract insects to the two cadavers. This study stressed that, for accurate estimates of time since death, knowledge of the impact of different variables on insects found over and around the carrion is essential.

1. Introduction

Forensic entomology distinguishes as the study and use of insects and other arthropods in legal investigations (Gennard, 2007). It involves the knowledge of insect taxonomy, ecology, physiology, and biology in legal matters (Hall, 2001). In addition, the insects found in the crime scenes in a specific geographical region help to answer the three most obvious questions of violent crime, namely where, when and how the incident occurred with the victim (Hall, 2008). The time of human mortality can be predicted based on the study of arthropods succession on the cadaver and knowing the development time of arthropods life stages (Introna et al., 1998). Decomposing dead carcass was considered a rich source of food for a number of arthropods (Smith, 1986).

The first phases of decomposition were governed by flies and their larvae, which eat the large part of the corpse and are responsible for the greatest decay (Schoenly and Reid, 1987). In general, insect succession on carrion was initiated by calliphoride flies followed by Muscidae and Sarcophagide (Goff, 1993). Then Coleoptera begins to appear in the late stages (Catts and Haskell, 1990). Species from at least 23 dipteran families use carrions as a food supply, the much more important of which are Calliphoridae, Sarcophagidae, Muscidae, and Fanniidae (Savage, 2002). Over the past few decades, the ecological value of necrophagous dipterans has been complemented by their use as entomological evidence in homicide cases as they provide data on the time and location of death and the existence of incriminating materials (Carvalho et al., 2001). The occurrence of *Musca domestica* L. on fresh pig carcass was confirmed by Heo et al. (2008). And it was recorded by Abouzied (2014) on the bloat stage of rabbit carcasses. In all their study habitats, Mashaly and Al-Mekhlafi (2016) recorded *M. domestica* and indicated their possibility of recovery from human bodies in forensic investigations.

Dermestide beetles are scavengers that feed on dried tissue and skin from many animals as well as dry plant tissue. They are distributed throughout the world and can be used in cases of forensic entomology (Smith, 1986; Benecke, 2015). Catts and Goff (1992)

* Corresponding author.
E-mail address: mashaly69@gmail.com (A.M. Mashaly).
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stated that they were indicators of the PMI, especially when mummified or skeletonized bodies were found (Schroeder et al., 2002). *Dermestes maculatus* DeGeer is a necrophagous species recognized as an important component of insect fauna combined with human and animal remains in various parts of the world, including Saudi Arabia (Goff, 1993; Mashaly, 2017; Zanetti et al., 2019). Some studies have shown that marks and other objects on cadaver tissues can be produced by these beetles (Holden et al., 2013; Zanetti et al., 2015).

A number of factors have an impact on the succession of the insect carrion, which is considered to be a complex process occurring in nature. Considering these factors helps to reduce the questions raised by the forensic entomologist during the investigations and to make the investigations easier (Sonker and Singh, 2017). Various variables of the scene such as geographical region, habitat, season and climate, and manner of death, are included. It is essential to have knowledge of the influence of all these factors on the insects found in and around the carcasses for the reasonable estimates of the PMI (Anderson, 2001). All of these factors affect the structure, richness, abundance, and diversity of the carrion insects in a specific geographic area (Heo et al., 2011). Smith (1986) stated that geographic locations influence the carcass species composition, the time of invasion and the period of colonization on the carcass. Habitat environment in which the carcass is found, such as indoor or outdoor, exposure to sun or shade, rural or urban location or submerged in water bodies also influences the level of decomposition and insect succession pattern (Bornemissza, 1957). Goff (1991) recorded that, between indoor and outdoor environments, the formation of taxa and insect succession patterns was totally different. Besides, Anderson (1995) has noted that some insect species are confined to indoor habitat, whereas some are figured only in outdoor habitat.

Case reports are very important as forensic entomology is constantly evolving and growing with their use. Numerous classical case studies have been published that show the effectiveness and usefulness of forensic entomology. Starting with 19 cases reported by Smith (1986). Then a follow-up of research began around the world such as Goff and Flynn (1991) who estimated the PMI in some case studies by analyzing the arthropod succession patterns. More recently, 132 forensic entomological studies in Belgium and France over a 36-year period were described by Dekeirsschieter et al. (2013). During medicolegal death investigations in the United States, Sanford (2017) reviewed 203 forensic entomology cases. Evidence from 25 cases from 2011 to 2014 was provided by Corrêa et al. (2019), including related organisms, new records, and correlations between current experimental data and data from species obtained from the present cases. Wang et al. (2019) presented four cases that occurred in Southern China. In Saudi Arabia, Alajmi et al. (2016) and Al-Qahtni et al. (2019) have been presented. Here we present two human cases in Riyadh, Saudi Arabia, highlighting the type of insect evidence used, considering the impact of habitat and the stage of decomposition.

2. Materials and methods

Two dead bodies were discovered in Riyadh, Saudi Arabia, and then transferred within 24 h of discovery from the scenes of death to the Institute of Legal Medicine at King Saud Hospital. From finding to autopsy, human bodies were preserved in the morgue at a mean temperature of 4 °C.

Insect samples were collected from scene or during the autopsy according to the method described by Amendt and Hall (2007). Larvae and pupae are stored in an ethanol solution of 75%, while adults were preserved in 75% ethanol solution. Samples from the corpse and the surface areas around the corpse are obtained for outdoor collections. We have made an effort to collect all obtainable insect evidence for indoor collections. Insect species have been classified using Catts and Haskell (1990) and Pont (1991) identification keys. We also had a detailed record of the corpse's state of decomposition, including gender, age, cover, habitat, finding date, and stage of decay. The entomology laboratory, College of Sciences, King Saud University will permanently preserve all entomological evidence. The temperatures of the clarified crime scene were assessed using the temperature of the nearest weather station.

With the approval of the Institute of Legal Medicine at King Saud Hospital, photos of cases at the scene of death or autopsy for legal proceedings were taken. All procedures have been carried out in accordance with the terms of the Graduate Studies and Scientific Research Committee, Department of Zoology, College of Sciences, King Saud University.

3. Results

Two case studies are described in order to show the differences related to the necrophagous insect community and the pattern of human decay. The two cases share the same manner of death (natural death). Despite this similarity, according to different exposure temperatures (daily average temperature ranging between 23.3 °C and 27.5 °C), the bodies showed two completely different patterns of decomposition and insect colonization. The features of the corpses including age, gender, decomposition stage, ambient, scene, colonized insects, average temperature were recorded (Table 1). As for the stage of decomposition, one corpse was in the mummified stage and the other was in the bloated stage. The age for both cases was 40 and 65 years. At the time of discovery, all corpses were clothed. The manner of death in the two cases was natural death. One case was reported in December and the other case was documented in March. Case one was an outdoor case, but the other was an indoor case. In the two forensic cases, twelve dead insect samples were taken along with 3 adults, 7 larvae and 2 pupae. Specimens collected belong to *Dermestes maculatus* DeGeer (Coleoptera: Dermestidae) and *Musca domestica* L. (Diptera: Muscidae). Beetles were recorded in the outdoor case; besides, the flies were recorded in the semi-closed indoor case.

3.1. Case report 1

On December 27, 2016, a man's corpse (Fig. 1) was found on the roof of house under the sunlight in Al-Oud district of southern Riyadh. The corpse was lying on his back. The deceased was wearing a long black pants and long-sleeved blouses on the upper body. The revised temperatures averaged 23.3 ± 1.6 °C over the previous three months (Fig. 2), according to the nearest weather station. The body was in the Mummified stage of decomposition, and it was unknown the last time he was seen. The mummification was obviously shown by the skin's desiccation, which was closely spread across anatomical prominences. Brown to black discoloration of body flesh was found with a leathery appearance of skin and adherence to bones. Also, noticeable skin slippage was found on the hands, which resulted in "glove shape" along with some epidermal feet maceration.

Crime scene investigators collected 7 different insect life stages (3 adults, 2 larvae and 2 pupae) were found attached to the clothes of the corpse, then the samples were sent to the Entomological Laboratory of King Saud University. According to the identification key, the samples were identified as *D. maculatus*. The beetle larvae were at the third larval stage and the maximum length of the larvae was 11 mm. According to the pathologist report from the Insti-

Table 1
Most appropriate data on human cases and their colonized insects with number and life stage; A: Adult L: larvae; P: Pupae.

Case no.	Age (yr)	Gender	Decay stage	Ambient	Scene	Colonized insects (number and life stage)	Finding month	mPMI Estimation
1	65	Male	Mummified	Outdoor	Roof of an old house	*Dermestes maculatus* (7; 3 A, 2 LIII, 2 P)	December, 2016	3 months
2	40	Male	Bloated	Indoor	Semi-closed apartment	*Musca domestica* (5; LIII)	March, 2017	4 days

Fig. 1. Mummified corpse in the morgue.

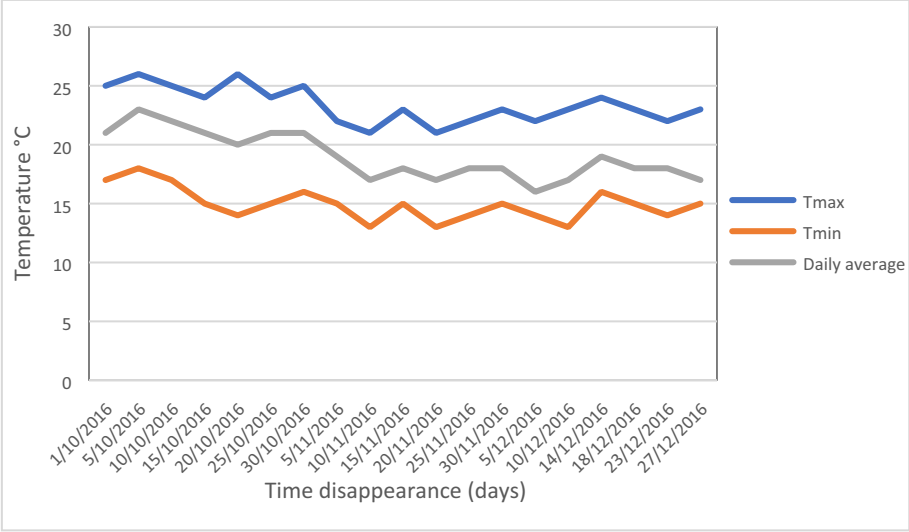

Fig. 2. Temperatures recorded by the weather station for the three months before the discovery of the body.

tute of Legal Medicine at King Saud Hospital, the PMImin estimated at 3 months as the body has reached an advanced state of decay.

3.2. Case report 2

On March 07, 2017, an adult male (Fig. 3) was found dead in a semi-closed apartment in Al-Manfuha district of southern Riyadh. The corpse was found in a room where the windows were partially closed. The body lay on the floor and the clothes were heavy long-sleeved spring clothes, long-sleeved sports pants and short underwear. The decomposition stage was in a late of bloated stage, while some characteristics of the decomposition process on the body are visible, such as unpleasant smell, marked increase in abdominal size, and greatly increase the face and neck, with eye and tongue protrusion. According to police investigation, last time seen was 4 days before the discovery of the corpse. An overall mean temper-

Fig. 3. The body of man at the end of the decaying stage of decomposition.

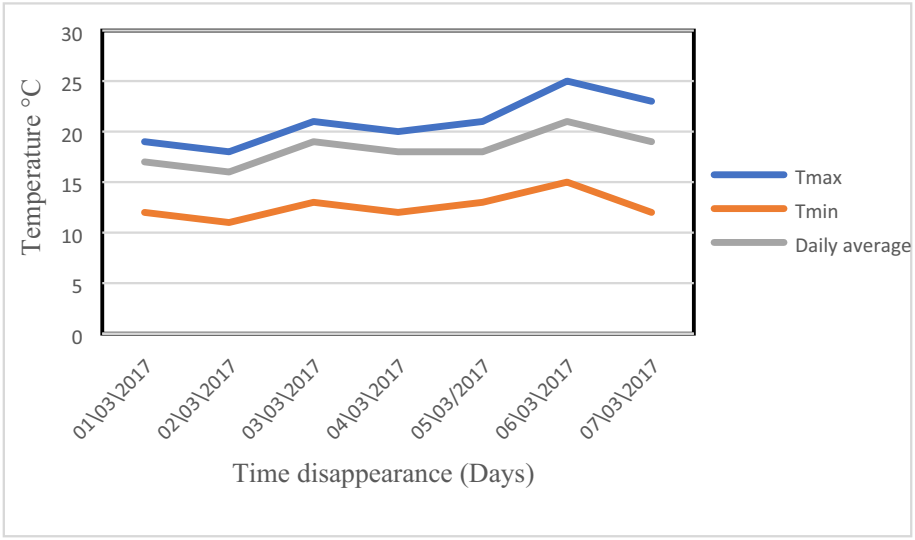

Fig. 4. Temperatures recorded by the weather station for the seven days before the discovery of the body.

ature of (27.5 ± 1.7) °C was recorded by the nearest weather station to the death scene (Fig. 4), for the week before the discovery of the body.

Insect activity was only noticeable on the face where few Diptera larvae were recovered. Using the identification keys, insect samples were identified as larvae of *M. domestica* (LIII, post-feeding 10 mm, N = 5). PMI was estimated to be 4 days from the Pathologist report and entomological data.

4. Discussion

It is important to collect data on the nature and patterns of local necrophage arthropod communities in the area where the crime occurred for the successful use of entomology in criminal investigations (Smith, 1986). In addition, death-related incidents may be characterized by differences in carrion insect cast.

Two insect species were collected in the current study, *M. domestica* from flies and *D. maculatus* from beetles. *Musca domestica* is the most widespread fly species. Flies are searching for worm places that offer enough sites for production and food to serve the lifecycle of the flies (Kettle, 1995). This fly has been collected in many cases of forensic entomology around the world, such as Sanford (2017) in the USA, Bonacci et al. (2017) and Corrêa et al. (2019) in Italy, Bernhardt et al. (2018) in Germany and Al-Qahtni et al. (2019) in Saudi Arabia. For forensic cases where the body has already been left by Diptera and only beetles can be especially useful (Centeno et al., 2002). Early and Goff (1986) noted that *D. maculatus* is the dominant species of insects combined with later decompositional stages. This beetle has been reported around the world in many cases such as, Alajmi et al. (2016) in Saudi Arabia, Talebzadeh et al. (2017) in Iran, Sanford (2017) in the United States, Sharma et al. (2018) in India, Wang et al. (2019) in China and Corrêa et al. (2019) in Italy.

Two stages of decomposition, bloating and mummifying stages have been documented in our study. Decomposition is a process which varies widely from body to body, environment to environment, depending on whether the body is dressed or nude, the circumstances of death, the location of the body, the weather, etc.

Upon death, most un-mummified bodies would quickly begin to putrefy and liquefy in a while, leaving only the skeleton. However, others may go through some of the processes of destruction that will finally lead to skeletonization. Bloating is swelling of body parts in any body area that is anatomically appropriate, including organs and soft tissues, due to accumulation of microorganism-generated decompositional products (Gebhart et al., 2012). Bloating usually occurs at the abdomen and then extends gradually to other parts of the body, including the genital and facial protrusion of the eye and tongue (Dekeirsschieter et al., 2009). Besides, Mummification is a natural or artificial conservation process consisting of tissue dehydration and exsiccation (drying process) (Saukko et al., 2004). It is characterised by dryness and brittle, broken skin on the bony protrusions (cheeks, forehead, back sides, and hips), usually coloured brown. Mummification is expected to occur in hot, ventilated conditions (Knight, 1996; Clark et al., 1997) and usually, but not always, in warm places where the body loses liquid by evaporation (Knight, 1996; Di Maio and Di Maio, 2001).

PMI calculation is one of legal medicine's most controversial and difficult issues. Two approaches to estimating the PMI are complementary in forensic entomology, i.e. developmental data and successive insect data found on the cadaver (Abell et al., 1982). The investigator must, however, determine which model is appropriate to use. During the early decomposition stage, when the immature stages of the dipteran colonizers are present, the use of development data is most applicable. Whereas succession data is used when no more early colonizers and the remains are populated by predators of fly maggots such as beetles (Smith, 1986; Tabor et al., 2004). In our study, according to the pathologist, the PMI was calculated to be about 3 months for the mummified body (first case). As shown by Saukko et al. (2004), due to the long periods that usually occur before the body is discovered, the time needed to mummify is not well documented. It definitely takes some weeks (Gordon et al., 1988). Di Maio and Di Maio (2001) stated that, in cases of natural death of people living alone, mummification can be found. In this case, the scene was an outdoor environment in a house roof that was not protected from the weather effects except for the presence of clothing, leading to dehydration and mummification of the corpse. In this type of environment, dry corpse would be ideal for colonization and reproduction of *D. maculatus*. Kulshrestha and Satpathy (2001) reported that, *D. maculate* is a necrophagous insect that colonizes remains that are skeletonized and mummified. Since we did not have the sequence of this beetle on a corpse in Riyadh, so we depend on the pathological report. The local insect succession data on bodies were needed in order to accurately estimate PMI using entomological methods, since the sequence of species on bodies differs between the region and local climate (Benecke, 2001).

Second case was at the end of the bloating stage, and *M. domestica* larvae were reported on the body. PMI was estimated as 4 days according to the pathologist report and police investigation (refer to the last time seen). In this case, the scene was an indoor environment with semi-closed apartment, and the cadaver wearied clothes. Ramos-Pastrana et al. (2014) reported that tissue consumption dominated from the bloated to the advanced stage of *M.* domestica. The presence of *M. domestica* larvae was notable during the decomposition process, as it could be considered an incidental visitor, according to Abouzied (2014) and Mashaly and Al-Mekhlafi (2016), who reported this fly on rabbit carcasses at various stages of decomposition. Based on relevant developmental data published *M. domestica* larvae took 4 days to reach the third instar at 27.5 °C. Bharti (2009) stated that it takes four days for *M. domestica* to reach the larvae of the third instar at 28° C. Therefore, based on forensic pathology, the PMI derived from entomological data agreed with the PMI estimation.

5. Conclusion

Two case studies, including an outdoor and an indoor case, have been reported in Riyadh, Saudi Arabia. Only two species of insects were collected from the cadavers, *Dermestes maculatus* and *Musca domestica*. PMImin ranged from 4 days to three months. Insect attraction has been affected by the cadaver habitat.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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