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Insect species colonized indoor and outdoor human corpses in Riyadh, Saudi Arabia

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ABSTRACT

The species and patterns of forensically significant insects associated with casework were documented in this study in Riyadh, Saudi Arabia. Ten cadavers naturally died were examined. Insects attracted to human corpses have been carefully collected and classified using appropriate taxonomic keys. Two cases were outdoor compared to eight cases were indoor. Age ranged from 30 to 61 years. Corpses were found at various decompositional stages. A total of 258 insect individuals were collected from the ten bodies. Larvae was the most cast collected with 253 individuals. Moreover, the outdoor corpses were colonized by different insect life stages (22 individuals) included one beetle species and three fly species. Also, the indoor corpses colonized by different insect life stages (236 individuals) included two beetle species and six fly species. Overall, 9 different species of insects were identified. Within Diptera, seven species were present in nine of the cases. Besides, four of the cadavers had beetles. *Chrysomya albiceps* Wiedemann was the only insect recorded in 7 cases (39.2%), followed by *Musca domestica* L. (19.4%) and *Dermestes maculatus* DeGeer (15.5%). Estimated minPMI was ranged from 1 to 15 days. The presence and diversity of assorted insects in cadavers may lead to the advancement of the understanding of forensic entomology and of refined estimations of the minPMI.

1. Introduction

Forensic is the use of scientific techniques to solve crimes and is used to describe the work of scientists who examine evidence in order to help the police solve crimes. Forensic entomology uses insects to assist authorities in determining origin, location, and time of death of a human (Collins, 2001). Life cycles of insects act as reliable clocks starting in minutes after death. When other methods are unsuccessful, they can be used to determine the time of death (Shepherd, 2003). These can also indicate if after death a body was moved (Catts and Haskell, 1990). As well as many others have stated that the presence and action of insects speeds up decomposition (Bass, 1997). Accessibility of a cadaver for insects plays an important role in the applicability of an entomological approach. Differences in species composition and in time of their arrival on the body have been reported from indoor and outdoor conditions. For example, the scuttle flies (Diptera, Phoridae) have been described as later colonizers of cadavers exposed in the field (Smith, 1986), whereas in the case of a dead body found indoors these flies are among the first, if not the first, colonizers (Reibe and Madea, 2010).

The carrion insects are grouped into different categories based on their food preferences (Smith, 1986); a) Sarco-saprophages: feed on decomposing flesh and imbibe in the blood and body fluids, e.g. Sarcophagidae, Calliphoridae, Muscidae and Dermestidae. b) Coprophages: are drawn to herbivores' rumen material, e.g. Scarabaeidae, Muscidae. c) Dermatophages: feed on dried skin, hair, ligament and bones, e.g. Dermestidae, Tineidae. d) Predaceous species: feed only on carrion entomofauna, especially on Dipteran larvae, e.g. Histeridae and Staphylinidae. The rate of decomposition, larval growth and rate of development may be influenced by environmental factors such as ambient temperature and geographical location (Benbow and Berg, 2013). Cloudy, rainy or windy conditions may not be suitable for the arrival of the flies to lay their eggs. Entomologists will often look at the "windows" available for insect activity and provide minimum limits for insect

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infestations. It is not known how objective the determination of the "window" is, or whether there is enough known about these species to predict behavior based on weather conditions. Indoor conditions typically limit the existence of blow flies, or at least delay their access to the remains of humans (Campobasso et al., 2001). Access to the body by insects is one of the many crucial factors that affect the rate of decomposition when investigating PMImin of bodies found indoors (Mann et al., 1990). Depending on the insect species and conditions at the scene, the rate of development can indicate a PMI from less than 1 day to more than 1 month (Smith, 1986). In the background of forensic entomology, the key indicator for PMI estimation can be the early necrophagous insect that could gain access into the colonized corpse indoors (Reibe and Madea, 2010). There are several reports on forensically significant flies in the world, for example in China (Guo et al., 2010), Australia (Meiklejohn et al., 2013), Korea (Kim et al., 2014) and Saudi Arabia (Mashaly et al., 2017). However, carcasses in mid- to late decay contain few Diptera, resulting in Coleoptera being more important in predicting PMI (Shukla, 2018).

In Saudi Arabia, few data from these types have been published but are so important for understanding the local fauna associated with casework at different geographical locations, especially when clinicians may depend on old taxonomic keys, which may not include all species local to the area. The aim of the current study was to examine forensically relevant insects associated with some casework in Riyadh, Saudi Arabia. These data will help not only to guide the identification and detection of insect species in the area, but also to guide research questions on species of importance in this geographical location. This research also makes it possible to compare patterns of insect colonization between indoor and outdoor scenes.

2. Material and methods

2.1. Study area

The province of Riyadh is in the center of Saudi Arabia. It has a hot desert climate with low relative humidity and high average temperatures. Hot season (summer) is between April and October. August is the warmest month and January is the coolest. The average maximum annual temperature is 32.0 °C and 20.0 °C is the minimum. Climate data were collected from the closest meteorological stations to the death scenes.

2.2. Collection of the corpses and autopsy

Ten human cases involving insect specimens collected and analyzed during medical enquiry of death by the Institute of legal medicine at King Saud hospital, for the period from January 2017 through April 2018 in Riyadh, Saudi Arabia. Corpses then moved from the death scenes to the Institute of Legal Medicine. From finding to autopsy, bodies were preserved in the morgue at a mean temperature of 4 °C. The existence of any insects was carefully examined by a medical entomologist during the autopsy. Scene conditions such as place of the body with respect to shade indoors or sun outdoors were also reported. Medical or scientific evidence other than entomological data such as decomposing stage, body color, decay of various organs has been used to estimate PMIs of the corpses. With the approval of the Institute of legal medicine, a variety of photos of cases at the scene of death or autopsy for legal proceedings were taken. All activities 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.

2.3. Collecting and identifying insects

All the cases mentioned here included the collection of insect samples at the scene or during autopsy and occasionally at both locations. The procedures for collecting specimens were based on several texts and publications relating to the insect collection, preservation and analysis (Haskell and Williams, 2008). Briefly, it involves the collection of representative insect samples from the body and the scene representing the supposed oldest recorded life stages attracted to the body. The number of samples varies depending on the number of insect's present. The specimens were collected by the medical examiner. All insects collected have been transferred to the Entomology Laboratory of the Department of Zoology, College of Sciences, King Saud University. The samples collected were dead and preserved by 70% ethanol. The identification of immatures and adults is then mixed to provide as clear a picture as possible of the colonizing insect species. The identification of specimens was based on life-stage morphology and the taxon of appropriate taxonomic keys and literature, where Pont (1991) and Setyaningrum and Al Dhafer (2014) were used for flies and Catts and Haskell (1990) for beetles.

2.4. Data analysis

Statistics are determined for the location of the scene (indoor or outdoor), the temperature of the ambient scene and the prevalence of insect species collected for each case.

3. Results

A total of 10 human bodies with arthropod specimens have been referred to the Institute of Legal Medicine at King Saud Hospital. The cause of death was natural in all the cases under study as reported by the medical examiner. Description of the human cadavers collected have been shown in Table 1. The age distribution of the bodies concerned was between 30 and 61 years old. Only case no. 8 for a female, while the other cases for males. Of the 10 cases analyzed, two were from outdoor scenes and 8 were from indoor scenes. Cases were found at different stages of decomposition, ranging from fresh to the remaining stage. One corpse was at the fresh stage, four of them were in the bloated stage, three were in the dry stage, one was in the skeletal stage, and one was found as remains. All except corpse 10 was wearied clothes at the time of discovery. Flies were recorded in nine cases, while beetles were recorded four cases. Multiple stages of the life of the insects (larvae, pupae and adult) have been detected in the collected cadavers. Average temperature in each scene was indicated in Table 1. PMIs were estimated by the Forensic pathologists based on gross external changes in a dead body after death, where PMIs ranged from one to 15 days for the ten bodies. For some cases, image samples have been demonstrated (Figs. 1–4).

Only one insect was recorded in some cases, other cases attracted two or three insect types. Three cases (3, 7, 10) were attracted the highest number of insect species, in which case 3 attracted three insect species including two fly species and one beetle species represented by 102 insects (39.5% from the collected samples), case 7 attracted again two fly species represented by 44 samples (17.1%) and case 10 attracted one fly species (28 sample, 10.9%). Followed by cases (1, 6, 8, and 9) which attracted 15, 14, 18 and 18 insects, respectively. Three cases (1, 6 and 10) attracted one insect species, all of which attracted fly species (Table 1). The occurrence of the commonly found species, *Chrysomya albiceps* Wiedemann (Diptera, Calliphoridae), either as single colonies or mixed infestations in human corpses. It is clear they found as a single species on one corpse and with the house fly *Musca domestica* L.

Table 1
Most appropriate data about the natural murder cases and their colonized insects with number and life stage; A: Adult L: larvae; P: Pupae.

Case no.	Age (yr)	Gender	Decay stage	Ambient	Colonized insects (number and life stage)	Average Temperature (°C)	mPMI Estimation (days)
1	30	Male	Fresh	Outdoor	*Sarcophaga dux* (15; L)	16.1 ± 2.3; min 10.0; max 24.0	1
2	61	Male	Dry	Outdoor	*Chrysomya albiceps* (2; L) *Musca domestica* (4; L) *Dermestes maculatus* (1; A)	22.3 ± 1.6; min 14.0; max 28.0	4
3	50	Male	Dry	Indoor	*Chrysomya albiceps* (54; L) *Physiphora alceae* (15; L) *Dermestes maculatus* (33; L)	18.5 ± 1.3; min 8.0; max 22.0	7
4	50	Male	Bloated	Indoor	*Chrysomya albiceps* (1; L) *Wohlfahrtia nuba* (2; P) *Dermestes maculatus* (3, L)	30.4 ± 2.7; min 22.0; max 38.0	5
5	50	Male	Skeletal	Indoor	*Dermestes maculatus* (4; L) *Dermestes frischii* (2; L)	30.4 ± 2.7; min 22.0; max 38.0	13
6	57	Male	Remains	Indoor	*Chrysomya albiceps* (14; L)	16.7 ± 1.2; min 10.0; max 22.0	15
7	44	Male	Bloated	Indoor	*Chrysomya albiceps* (14; L) *Musca domestica* (30; L)	25.8 ± 2.1; min 18.0; max 30.0	3
8	47	Female	Bloated	Indoor	*Chrysomya albiceps* (8; L) *Musca domestica* (6; L) *Sarcophaga argyrostoma* (4; L)	17.3 ± 1.8; min 15.0; max 20.0	7
9	40	Male	Dry	Indoor	*Chrysomya albiceps* (8; L) *Musca domestica* (10; L)	27.6 ± 1.9; min 23.0; max 32.0	5
10	33	Male	Bloated	Indoor	*Megaselia scalaris* (28; L)	27.7 ± 2.6; min 21.0; max 33.0	3

Fig. 1. Corpse of the outdoor case 2 in the morgue indicating some insect larvae (Arrow).

Fig. 2. Corpse revealed the high number of insect larvae on the head of the corpse after transferring to the morgue (case 3).

and the beetle, *Dermestes maculatus* DeGeer in 4 and 3 of the corpses, respectively (Table 2).

The two outdoor cases attracted four insect species included one beetle species and three fly species represented by 22 individuals (8.5%). The fly species, *Sarcophaga dux* Thomson was found on case 1 with 15 individuals. Also, case 2 attracted three insect species with 7 individuals. On the other hand, the eight indoor cases attracted 8 insect species included two beetle species and 6 fly species with 236 individuals (91.5%). Beetle species were attracted to three cases of the indoor cases, from which *D. maculatus* was recorded on the three cases, while *D. frischii* Kugelann was recorded on only one case. Two of the indoor cases attracted only one insect species (fly species). Another three attracted two insect species. From these three cases, case 5 attracted two beetle species and the other two cases (7 and 9) attracted the same two fly species, *Ch. albiceps* and *M. domestica.* The rest three indoor cases attracted three insect species, in which case 3 and 4 attracted two fly species and one beetle species, while the case 8 attracted three fly species. Also, it was shown that one of the indoor cases (case 4) was in an apartment with an open window, but the rest had a closed window (Table 1, Fig. 5).

A total of 258 insects were collected from the ten bodies, along with 3 adult, 253 larvae and 2 pupae. The identified insects belonged predominantly to the orders of Diptera and Coleoptera. They included six families, seven genera and nine different species. Larval samples made up about 98.1% of the samples retrieved from

Fig. 3. A corpse with a huge number of insect larvae on the back and head of the corpse (case 9).

Fig. 4. Scene of corpse number 10 showing a lot of waste materials in the apartment.

these corpses. Results show that, majority of cadavers were found in all season months except summer. Some bodies attracted a high number of insect species and number such as case 3 which discovered in January 2017 attracted the 3 species and 102 insects (39.5%), and the two cadavers found in March 2018 (cases 7 and 8) again attracted 3 species and 62 insects (24%). Case 9 and 10, which were discovered in April 2018, attracted 3 species with 46 insects (17.8%). Each of the corpses 4 and 5, which discovered in October 2017 recorded the lowest occurrence of insects (6 insects: 2.3%) (Table 2).

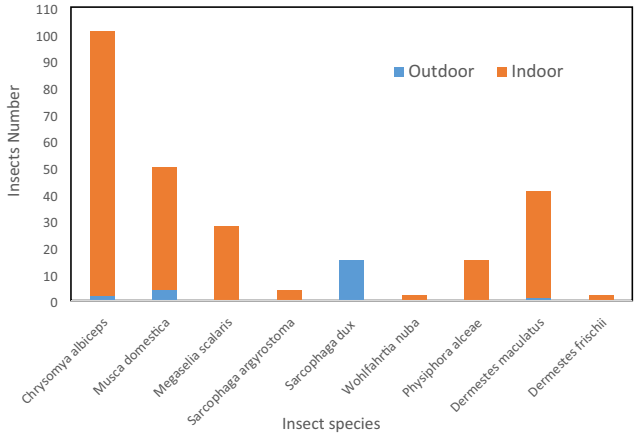

Fig. 5. Number of insects recorded on the corpses in the outdoor and indoor locations.

Chrysomya albiceps was the only insect recorded in seven cases with the highest number of 101 individuals included adults and larvae, followed by *M. domestica* (larvae) and *D. maculatus* (adults, larvae and pupae) which recorded in four cases with 50 and 41 individuals, respectively. Each of the rest species were recorded only on one case. *Wohlfahrtia nuba* Wiedemann and *D. frischii* were the fewest species recorded with 2 individuals only for each of which. The only species recorded in the adult stage were *Ch. albiceps* and *D. maculatus*. Besides, *W. nuba* was the only species which recorded in the pupal stage (Table 2).

4. Discussion

Insect selection at a crime scene can provide data on identifying potential perpetrators of a victim, suspect or third-party suspects. Insects can assess the body's whereabouts, whether the body has been relocated and what kind of crime has been committed. Insects

Table 2
Insect species list collected during medicolegal death investigations; species listed by case number, insect number and collection month during the period from January 2017 to April 2018. A: Adult L: larvae; P: Pupae.

Order: Family: Species	2017					2018				Total no. of cases; Total no of insects
	Jan	Feb - Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Diptera: Calliphoridae:	3/ L: 54		4/ L: 1		6/ L: 14		2/ A: 2	7/ L: 14;	9/ L: 8	7;
- *Chrysomya albiceps*								8/ L: 8		A: 2; L: 99
Diptera: Muscidae:							2/ L: 4	7/ L: 30;	9/ L: 10	4;
- *Musca domestica*								8/ L: 6		L: 50
Diptera: Phoridae:									10/ L: 28	1;
- *Megaselia scalaris*										L: 28
Diptera: Sarcophagidae:								8/ L: 4		1;
- *Sarcophaga argyrostoma*										L: 4
- *Sarcophaga dux*							1/ L: 15			1;
										L: 15
- *Wohlfahrtia nuba*			4/ P: 2							1;
										P: 2
Diptera: Ulidiidae:	3/ L; 15									1;
- *Physiphora alceae*										L: 15
Coleoptera: Dermestidae:	3/ L: 33		4/ L: 3;				2/ A: 1			4;
- *Dermestes maculatus*			5/ L: 4							A: 1; L: 40
- *Dermestes frischii*			5/ L: 2							1;
										L: 2
Total no of cases; Total no of insects / Month	1; L: 102		2; L: 10; P: 2		1; L: 14		2; A: 3; L: 19	2; L: 62	2; L: 46	10; A: 3; L: 258; P: 2

can affect the rate of decomposition in indoor and outdoor environments on human and animal remains. Blowflies are important because they are typically the first insects to colonize a body after death. Shortly after death, blowflies discover the remains, oviposit, and feed on the remains. The decomposing carcasses are a source of food for the larvae as they continue to develop about two to four weeks into their life stages. In the later stages of decomposition, other insects may appear that feed on skeletonized remains (Amendt and Fremdt, 2013).

In the current study, *Ch. albiceps* was the dominant species recorded from indoor and outdoor carcasses in stages of bloating, decay and advancing decay. *Chrysomya albiceps* seems to colonize both indoors and outdoors carcasses (Martín-Vega et al., 2017) and is considered one of the first insects to appear on carcasses of both humans and animals (Benbow and Berg, 2013). This also used to calculate the time of postmortem (Kosmann et al., 2011). The second dominant insect in our study was *M. domesitca,* which has been reported in many studies on animal carcasses such as bigs (Heo et al., 2008), and also on each of sheep, dog and camel carcasses (Mashaly et al., 2019a). *Musca domesitca* was also reported on indoor human body (Al-Qahtani et al., 2020).

Three sarcophagid flies have been reported in our study, *S. dux*, *S. argyrostoma* and *W. nuba*. In many parts of the world, *S. dux* is a medically important flesh-flies species known to colonize decomposing human remains (Cherix et al., 2012). *Sarcophaga argyrostoma* and *W. nuba* were reported in Egypt and identified as a forensically important sarcophagid (Aly et al., 2013). With regard to the occurrence of *Ph. alceae*, our results showed the presence of the fly indoor with the *Ch. albiceps* and *D. maculatus*. The presence of *Ph. alceae* on rabbit carcasses was reported in Riyadh (Mashaly et al., 2019b). The role of scuttle flies has been reviewed in the forensic investigation, which includes the well-known tramp species *Me. scalaris*. Reibe and Madea (2010) reported that *Me. scalaris* is a common species and widely reported in indoor cases, and it can be a single marker for estimating minimum PMI in the absence of other necrophagous species. There are no reports of scuttle flies compared to previous indoor decomposition studies conducted in the Riyadh area (Al-Qahtani et al., 2020).

In forensic science, the study of beetles is important, because it can help to determine the time of death or the interval of postmortem. Gennard (2007) indicated that the Dermestid beetles were among the common beetles on the corpses. In addition, dermestid beetles are attracted to animal and human bodies during dry and skeletal stages in many geographical areas (Mashaly, 2017; Keshavarzi et al., 2015). In the present study, the larvae of two beetle species, *D. maculatus* and *D. frischii,* were recorded. *Dermestes maculatus* have been observed on an exposed human cadaver in late decomposition stage (Al-Qahtani et al., 2020). *Dermestes frischii* larvae was recorded only in one indoor case in the skeletal stage. This beetle has been documented on human and animal corpses in different parts of the world (Charabidze et al., 2014; Kökdener and Polat, 2014; Keshavarzi et al., 2015).

Environmental factors can influence the rate of decomposition, larval growth, and developmental rates (Benbow and Berg, 2013). Factors such as underground burial, submergence under water, caskets, closed vehicle, and buildings can have a major impact on the delay of colonization for long periods of time (Benbow and Merritt, 2009). We found that the indoor frequency of insect involvement is more than the outdoor frequency, presumably due to access issues and the cases location. On the other hand, observed far fewer indoor carcasses attending insects than outdoor carcasses (Anderson, 2011). Cadaveric volatile organic compounds released by outdoor corpses are likely to be more easily detected, and maybe some blow fly species females are more effective in detecting them than others (Dekeirsschieter et al., 2009). Whatever the case may be, low numbers of blow-fly females attending indoor carcasses result in low larval density feeding on carrion, resulting in a slow decomposition process (Hofer et al., 2017). A study was conducted to assess how quickly fresh carcasses are colonized by blowflies in indoor and outdoor environments. Up to 24 h later than the outdoor piglet was colonized indoor piglet. Furthermore, many different types of flies were collected, but most dominated were blowflies (Madea and Reibe, 2009). In outdoor settings, in hours or even minutes after death, blow flies are likely to locate and colonize exposed cadavers, so minPMI estimates can be very close to the actual PMI. On the other hand, oviposition may be delayed indoors as it has been noted that under this circumstance fewer females in blow fly are able to locate and access a corpse (Arnaldos et al., 2015).

It is possible to note the significance of entomological evidence as well as autopsy when calculating the PMI (Matuszewski and Szafalowicz, 2013). Forensic pathologists estimated that the PMI ranged from 1 to 15 days in the 10 cadavers surveyed in Riyadh, depending on the external changes in the dead body. Saukko and Knight (2016) reported that, various gross changes in the body after death used to give an opinion on PMI include loss of corneal reflex and eye changes, post-mortem hypostasis, rigor mortis, body cooling, decomposition and other putrefactive changes. Crucial information like when the deceased was last seen alive can suggest a maximum possible PMI, but this can only occur if he or she is found. Sometimes, if death occurred, it is the body's state itself that will inform us. Even when the cause of death is natural, death can have significant consequences for legal issues such as inheritance and insurance (Henssge et al., 1995).

Overall, the type of scene appears to play a significant role not only in the species of insects observed, but in conditions that may be met during the examination of the scene. These data represent the conditions under which these insects may be found during routine death investigations, which may be of value in understanding the conditions under which human remains are colonized by insects; the aim of the forensic entomology applied as used in caseworks.

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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