Saudi Journal of Biological Sciences 30 (2023) 103706

HOSTED BY

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Beetles associated with buried carcasses: potential forensic importance in Riyadh, Saudi Arabia

Osama Al-Zahrani [a], Mohammed S. Al-Khalifa [a], Fahd A. AL-Mekhlafi [a,*]

[a] Department of Zoology, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia

ARTICLE INFO

Article history:
Received 1 May 2023
Revised 4 June 2023
Accepted 9 June 2023
Available online 15 June 2023

Keywords:
Buried carcasses
Forensic entomology
Insect succession
Coleoptera

ABSTRACT

Burial has a special influence on carrion fauna, which may change the rate of decomposition and so affect postmortem estimates. This study aimed to identify species and succession of beetles on buried remains. From 28 January to 31 May 2021, we examined the Coleoptera on buried and exposed rabbit carcasses, on the campus of the University of King Saud in an area measured around 175 m by 250 m. The area is almost entirely devoid of flora, except for a few acacia trees and some common wild herbs. It is about 1 km away from residential neighborhoods. In total, 165 specimens belonging to 4 families were collected. The Tenebrionidae was the most abundant family, where it formed 52% at a depth of 20 cm and 78% at a depth of 40 cm in the buried carcasses, while the family Dermestidae was the most abundant in the surface carcasses, as it formed 53% of the insects sampled. Type *Mesostena puncticollis* Solier, 1835 (Tenebrionidae) predominated at exposed carcasses as well as at depths of 20, 40 cm and while type *Dermestes frischii* Kugelann, 1792 (Dermestidae), predominated at depth of 40 cm and exposed carcasses, and type *Saprinus chalcites* (Illiger, 1807) (Hisiteridae) at depth of 20 only. These findings are possibly useful in forensic investigations involving buried bodies in Riyadh, Saudi Arabia.

1. Introduction

Forensic entomology is the study of insects and other arthropods discovered on a carcass and are used to solve crime especially in medico legal cases (Byrd and Tomberlin, 2019; Haskell and Williams, 2009). Succession is the action of proceeding sequentially or in order. until a stable peak community is achieved, one dominant insect species or community in an ecosystem is gradually replaced by another While decomposition is a continuous process that is typically broken down into different stages, such as fresh, bloated, advanced decay, and decay stage. Decomposing carcasses is an appealing resource to many species of necrophagous, opportunistic and occasional insects (Byrd and Tomberlin, 2019; Haskell and Williams, 2009).

Insects and other arthropods are used by forensic entomologists as a source of information while conducting investigations into legal matters (Catts and Goff, 1992; Keh, 1985). However, prior knowledge of the fauna present and connected with carcasses is necessary for this discipline. It is also feasible to calculate the postmortem interval [PMI], or the period of time between death and cadaver finding, using biological elements (such as development time) and species succession patterns (Lord, 1990; Smith, 1986).

Three of the most important factors that could affect the decomposition process are temperature, access insect and burial depth (Mann et al., 1990). Temperature and humidity have a significant impact on both the rate of decay and the presence of arthropods on the body. Rapid body decomposition is caused by higher humidity and temperature levels', whereas slower decomposition is instigated by the opposite conditions (Monteiro-Filho and Penereiro).

Buried carcasses' patterns of decomposition differ from those of exposed carcasses in this regard. Larval growth is hindered because the soil temperature is often lower and less changeable than the ambient temperature (VanLaerhoven and Anderson, 1996). Moreover, the type of soil slows down aerobic bacterial activity (Bornemissza, 1957).

A prominent class of insects of forensic value is the Coleoptera. Numerous investigations of pig and rabbit carcasses, as well as

* Corresponding author at: Department of Zoology, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia (F.A. AL-Mekhlafi).

E-mail addresses: 441105606@student.ksu.edu.sa (O. Al-Zahrani), mkhalifa@ksu.edu.sa (M.S. Al-Khalifa), falmekhlafi@ksu.edu.sa (F.A. AL-Mekhlafi).

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2023.103706
1319-562X/

buried human corpses, have revealed a variety of Coleoptera species, including Athetini *sp*, *Oxytelus insignitus* Gravenhorst, Anotylus *sp*, *Aleochara spp*, *Philonthus spp*, and *Emus hirtus* (L.), Histeridae (*Saprinus furvus* Erich, Leiodidae, Carabidae, and Silphidae (Arnaldos et al., 2005; Corrêa et al., 2014; Payne et al., 1968; VanLaerhoven and Anderson, 1996; VanLaerhoven and Anderson). Nonetheless, all of this knowledge was derived from studies done in Europe and America. There are no records on Coleoptera successional patterns and community composition on buried carcasses in Saudi Arabia.

The major goal of this study was to identify the species composition of Coleoptera discovered in buried carcasses in Riyadh due to the significance of these insects for forensic entomology and the paucity of studies on these insects in buried tombs in Saudi Arabia.

2. Materials and methods

The experiment was carried out between 28 February to 31 May 2021 in the University of King Saud's campus" (43°24′N, 46°36′E) Diriyah - Riyadh - Saudi Arabia (Fig. 1). Warm temperate environment with a scorching summer best describes the local climate. The temperature ranged throughout the study period from 18 to 39.2°c.

Twenty-four mature rabbits *Oryctolagus cuniculus* L. (Lagomorpha: Leporida), were buried., Their weight ranges between (1400–2200 g). The animals were sacrificed by chloroform. The use of rabbits was approved by the Research Ethics Committee, AL-Imam Muhammad Ibn Saud Islamic University project number (35–2021). To simplify removal and stop scavenging by other animals, the rabbits were placed on top of chicken wire-covered holes with a mesh size of 25 mm. and buried in a grave, 60 × 30 cm in 20, 40 cm deep. In accordance with the technique employed by (VanLaerhoven and Anderson, 1996).

All the graves were at least 10 m from each other and placed in a metal cage measuring 60 by 50 by 30 cm3 to deter scavengers. A probe (EM50G data logger, Ecotone, Gdynia, Poland) was buried next to the grave at the same depth to measure the soil's temperature and humidity. And were programmed to take a temperature and humidity reading every hour.

Insects were inspected in the soil above the buried bodies before excavation began. The bodies were placed into different plastic bags after the grave's soil was carefully removed during

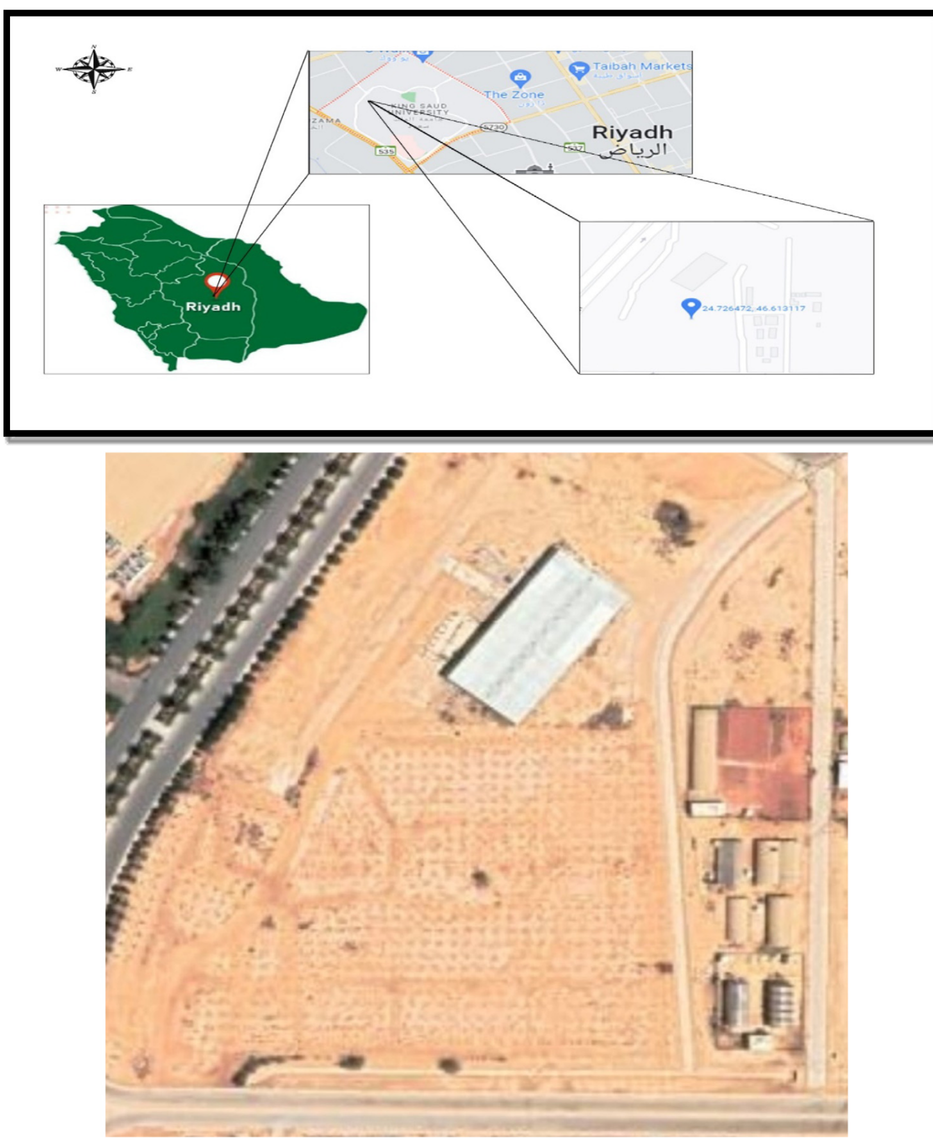

Fig. 1. Study site.

the exhumations to reveal the body. In addition to the rabbit's carcass, insects were also extracted from the layers of soil cover and the exposed soil at the bottom of the hole using forceps and brushes. Forceps were used to capture larval specimens, Fifty percent of which were then stored in 70% ethanol, and to help with identification, Fifty percent of beetles larvae were reared to adulthood. According Martín-Vega et al (2017) larvae was placed into a small plastic container (10 × 10 × 8 cm) containing apiece of rabbit skin (c. 5 × 5 cm), and tissue paper as a refuge for pupation.The plastic container was placed in an incubator under the temperature 30°c. In addition, adults and larvae were regularly collected from the surface of exposed carcasses using the abovementioned methods. Using the literature that was accessible, the insects were identified (Almeida and Mise, 2009; Fikáček and Boukal, 2004; Mazur, 2001; Navarrete-Heredia et al., 2002).

2.1. Analysis of data

To ascertain the statistical differences in the number of Coleoptera groups in buried and surface carcasses at various depths. The mean and standard deviation was calculated using IBM SPSS Statistics 28.0.0.0.

3. Results

3.1. Thermodynamics and humidity

The daily average air temperature varied between 18 and 38°-during the experiment. At 40 cm, the daily average soil temperature varied between 21.4 and 39.2 °C; at 20 cm, it varied between 21.5 and 36.5 °C (Fig. 2). It was found that there were differences in the surface (ambient) air humidity and the soil humidity of the graves at various depths. Soil humidity varied less at both depths than the surrounding air humidity (Fig. 3).

3.2. Decay rate

The decomposition rate of carcasses above-ground was 30 days, whereas for buried bodies it was 120 days. Both types of carcasses went through four decomposition stages. The stages for above-ground carcasses were fresh, bloated, decay, and dry. In contrast, buried carcasses went through the stages of fresh, bloated, decay/advanced decay, and dry. The dry stage was observed in buried carcasses after 60 days, while exposed carcasses reached this stage within 14 days (Fig. 4).

3.3. Families Collected.

In total, 165 specimens belonging to 4 families were collected. The Tenebrionidae was the most abundant family, where it formed 52% at a depth of 20 cm and 78% at a depth of 40 cm in the buried carcasses, while the family Dermestidae was the most abundant in the surface carcasses, as it formed 53% of the insects sampled (Fig. 4). The dominant species at depth 20 were *M. puncticollis* and *S. chalcites*, at 40 cm were *M. puncticollis* and *D. frischii*. Also, *D. frischii* and *M. puncticollis* were predominant in the surface carcass (Fig. 5).

3.4. Succession Pattern.

M. puncticollis and *S. chalcites* were collected from carcasses buried in both depths and surface; *N. eremita* at a depth of only 20 cm; *D. frischii* at a depth of only 20 cm and the surface carcasses; and *Adesmia stoeckleini* and *Adesmia cothurnata* only from surface carcasses Table 1.

D. frischii and *M. puncticollis* appeared in the decay/advanced decay stage on day 30 and continued throughout the dry stage until day 90 in buried carcasses. While, *D. frischii* appeared only in the decay stage and *M. puncticollis* in the dry stage in surface carcasses. *S. chalcites* was recorded on the 40 day in the decay/advanced decay stage and continued to the 70 days in the dry stage on buried carcasses, While it appeared in the decay stage only on surface carcasses. As for *N. eremita* it appeared only in the stage of putrefaction on corpses buried at a depth of 20 cm, and *A. cothurnata* and *A. stoeckleini* appeared only on surface carcasses in the stage of bloated and decayed, respectively (Tables 2 and 3). Fig. 6 shows all species recorded in this study.

4. Discussion

The observed decay rates of carcasses above-ground and buried bodies provide valuable insights into the decomposition process. Both types of carcasses, undergo four distinct decomposition stages. Carcasses progress from the fresh stage, where the carcass

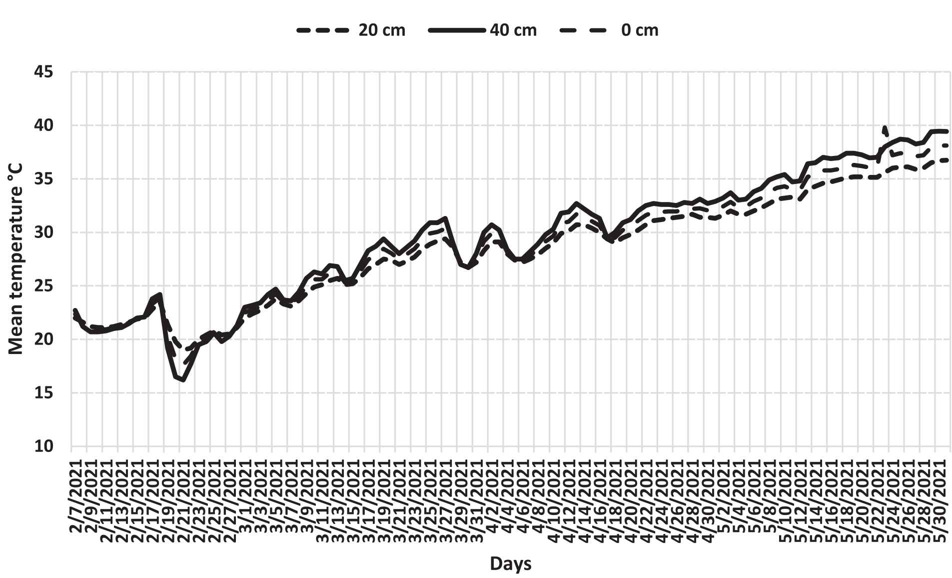

Fig. 2. Ambient air and soil temperatures on a daily basis for 120 days at 20, 40 cm.

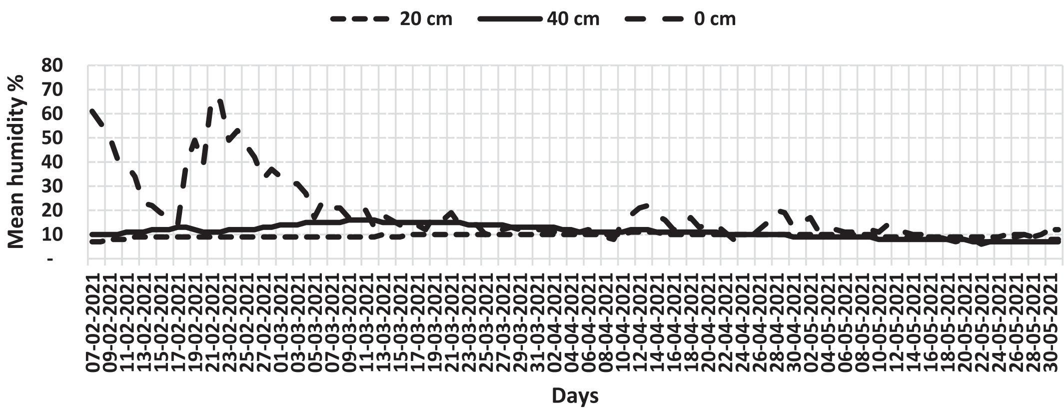

Fig. 3. Average daily humidity of ambient air and soil for 120 days at 20, 40 cm.

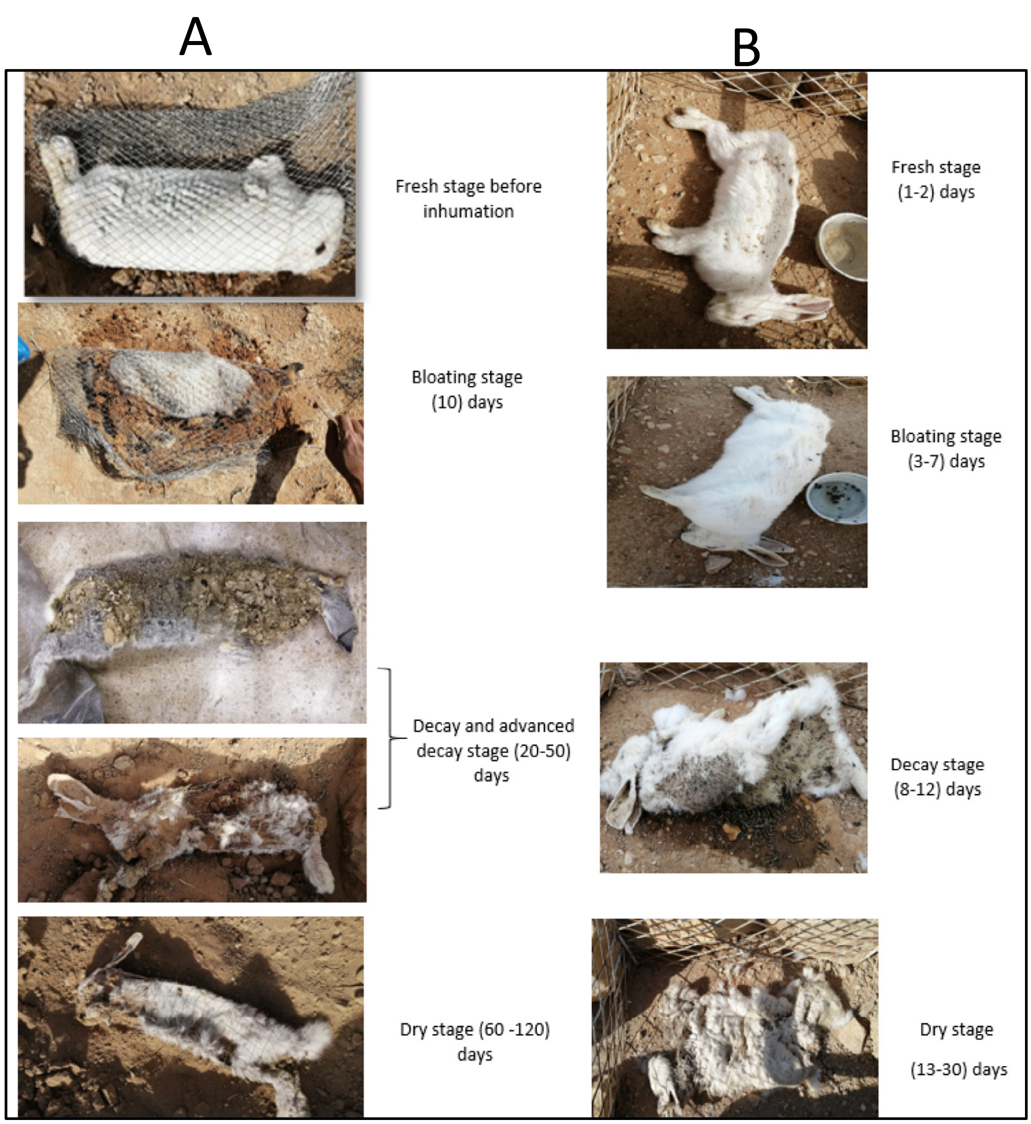

Fig. 4. Stages of decomposition of buried rabbits carcass (A) and carcass above the surface of the soil (B).

is newly deceased, to the bloated stage, characterized by the accumulation of gases and bloating of the body. This is followed by the decay stage, where the carcass starts to break down and undergo biological decomposition. Finally, the carcass reaches the dry stage, indicating a state of advanced decomposition where only skeletal remains and desiccated tissue are left.

The most notable disparity between above-ground and buried carcasses is the time it takes to reach the dry stage. Buried car-

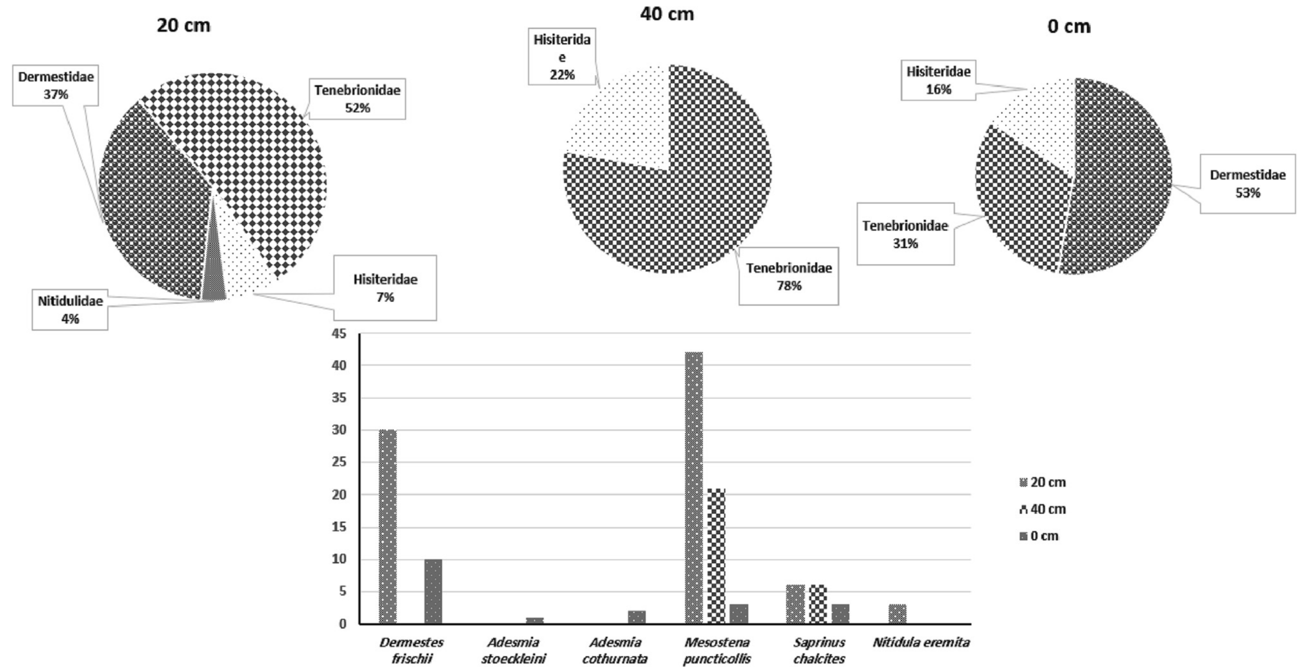

Fig. 5. Percentage of families and distribution of Coleoptera species collected from carcasses at different depths 0, 20 and 40 cm.

Table 1
A matrix showing the presence or absence of beetles at different burial depths and soil surfaces.

family	Genus and species	buried		soil surface
		20 cm	40 cm	
Dermestidae	*Dermestes frischii*	√	–	√
Tenebrionidae	*Adesmia stoeckleini*	–	–	√
	Adesmia cothurnata	–	–	√
	Mesostena puncticollis	√	√	√
Hisiteridae	*Saprinus chalcites*	√	√	√
Nitidulidae	*Nitidula eremita*	√	–	–

Beetles species presence (√) or absence (–).

Table 2
Succession and timing of species of beetles found on rabbit carcasses buried between 20 and 40 cm deep.

Days	family	Genus and species	D. stage	20 cm	40 cm
10	–	–	Bloated	–	–
20	–	–	Decay/ advanced decay	–	–
30	Dermestidae	*Dermestes frischii*		A3	–
	Tenebrionidae	*Mesostena puncticollis*		A6	–
40	Dermestidae	*Dermestes frischii*		A12/L6	–
	Tenebrionidae	*Mesostena puncticollis*		A3	–
	Nitidulida	*Nitidula eremita*		A3	–
	Hisiteridae	*Saprinus chalcites*		A3	–
50	Tenebrionidae	*Mesostena puncticollis*		A12	–
Total				45	0
Mean				6.42 ± 0.70	0 ± 00
60	Dermestidae	*Dermestes frischii*	Dry	A6	–
	Tenebrionidae	*Mesostena puncticollis*		A15	A6
	Hisiteridae	*Saprinus chalcites*		–	A3
70	Hisiteridae	*Saprinus chalcites*		A3	A3
	Tenebrionidae	*Mesostena puncticollis*		–	A15
80	–	–		–	–
90	Tenebrionidae	*Mesostena puncticollis*		A9	–
	Dermestidae	*Dermestes frischii*		A3	–
100–120	–	–		–	–
Total				36	27
Mean				7.20 ± 0.74	6.75 ± 0.94

Table 3
succession and timing of the species of beetles that were gathered from exposed rabbit carcasses.

Days	Family	Genus and species	D. stage	Numbers
01-Feb	–	–	Fresh	–
03-Jul	Tenebrionidae	*Adesmia cothurnata*	Bloated	A3
8	Dermestidae	*Dermestes frischii*	Decay	A9
	Hisiteridae	*Saprinus chalcites*		A3
9	Dermestidae	*Dermestes frischii*		A9
	Hisiteridae	*Saprinus chalcites*		A6
	Tenebrionidae	*Adesmia cothurnata Glabrior*		A3
10	Dermestidae	*Dermestes frischii*		A12
	Tenebrionidae	*Adesmia stoeckleini*		A3
Nov-19	–	–		–
20	Tenebrionidae	*Mesostena puncticollis*	Dry	A3
21	–	–		–
22	Tenebrionidae	*Mesostena puncticollis*		A3
23–29	–	–		–
30	Tenebrionidae	*Mesostena puncticollis*		A3

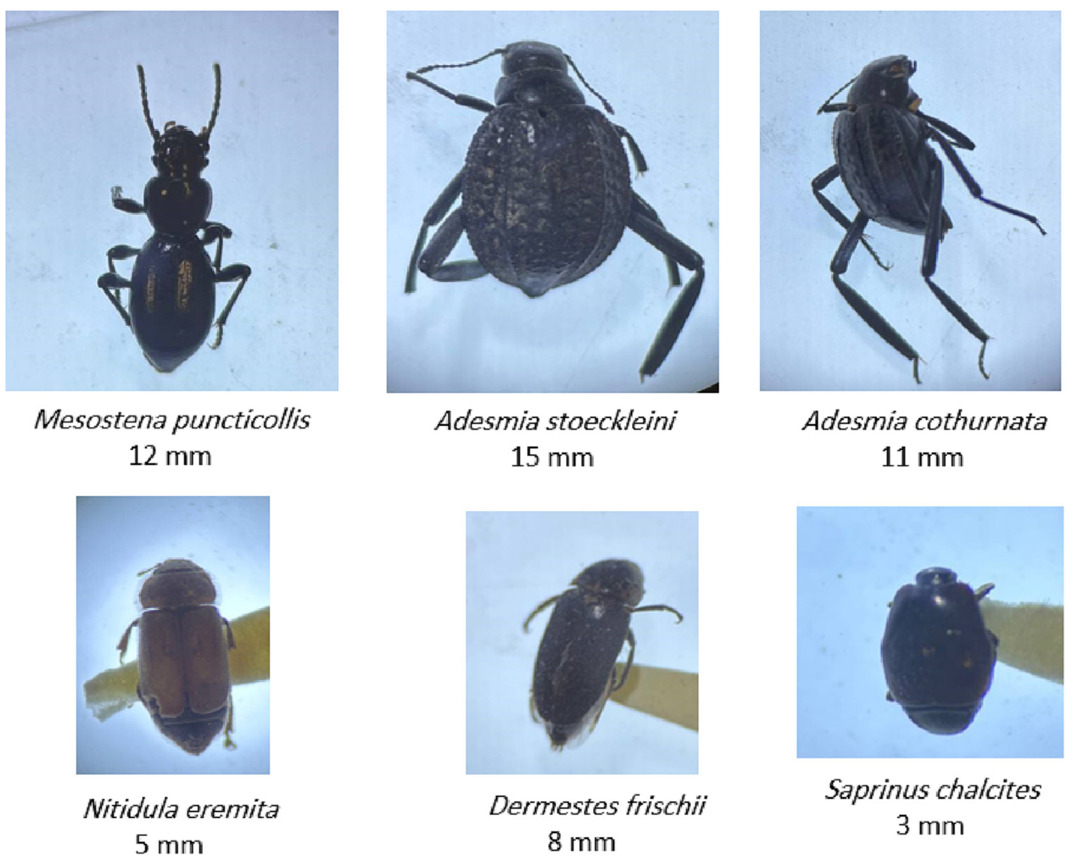

Fig. 6. Beetles collected during sampling.

casses require 60 days to reach this stage, while exposed carcasses accomplish the same state in just 14 days. This discrepancy implies that burial significantly prolongs the decomposition process, possibly due to reduced exposure to oxygen and external factors that accelerate decay (Tibbett & Carter, 2008).

Dermestidae a storage pest that consumes dry organic material predominated throughout the post-exhumation period and served as its primary defining feature. They may enter through any opening during the butyric fermentation stage or when the corpse is dry, and they frequently settle on exposed corpses. They may also be attracted to dry tissue, hair, bones, or the carcasses of dead insects, as well as the presence of fibres or fabrics (Mariani et al., 2010). Dermestids have a crucial role in the interpretation of taphonomic techniques in forensic research (Mariani et al., 2010; Oliva, 1997) and archaeological contexts, as well as in the reconstruction of historical environments (Centeno et al., 2009; Fugassa et al., 2008; Huchet and Greenberg, 2010). Since they may also cause small-scale damage to bones during mummification, their existence is very instructive (Huchet et al., 2013; Martin and West, 1995; Schroeder et al., 2002).

Dermestes frischii is a species widely distributed all over the world. Lefebvre and Gaudry (2009) report that the dermestids arrive to animal carcasses in the third wave, during the advanced decay stage. in Riyadh recorded *D. frischii* on rabbit carcasses during winter and autumn. In Al-Ahsaa, Shaalan et al. (2017) recorded Dermestidae on rabbit carcasses during winter, summer, and autumn. In our current study, it was recorded in the decay stage in the winter and spring on the exposed carcasses and at a depth of 20 cm on the buried carcasses in our current study. it has been found on pig carcasses buried 60 cm deep in southern Italy (Bonacci et al., 2017), and collected in Turkey on rabbit carcasses in the soil at a depth of 30 cm (Kekillioğlu and Başar, 2019), and on carcasses of pigs buried at a depth 40 cm (Leşinin and Bölgesinden, 2018). It was only recorded on exposed Saudi Arabian corpses (Al-Khalifa et al., 2020; Al-Shareef and Al-Mazyad, 2017; Mashaly et al., 2019; Shaalan et al., 2017).

Few investigations have been done to determine the importance of Nitidulidae for forensic entomology (Byrd and Castner, 2009). Although they feed on dried skin at around the same time as the Dermestidae during the dry stage of decomposition, larvae and adults prefer skin with more moisture (Payne and King, 1970). reported Martinez et al., (2017) that all nitidulids found on pigs in Colombia occurred 13–51 days after death, and were all at an advanced stage of decay. in our study *N. eremita* was collected at a depth of 20 cm in Decay/advanced decay, and as far as we know, this species was not recorded on corpses, but other species belonging to the Nitidulidae family were recorded. Collected Nitidulidae sp and *Omosita colon* (L.) (Nitidulidae) in exhumations at a depth of 30 (Corrêa et al., 2014; Pastula and Merritt, 2013). and they were collecting *Carpophilus hemipterus* (Nitidulidae) from exposed carcasses (Abd El-Bar et al., 2016). In Brazil, exposed corpses of three more species and *Carpophilus* sp. were collected. (Mise et al., 2007). Moreover, in Colombia, Turkey, Canada, and China, Nitidulidae has been connected to carrion (Özdemir and Sert, 2009; VanLaerhoven and Anderson, 1996; Wang et al., 2008; Wolff et al., 2001).

The Histeridae mostly feed on insect eggs and larvae, most of which inhabit animal carcasses, rotting plant materials, and manure. In the early stages of decomposition, many species can be found in carcasses, where they feed on fly larvae (Baviera and Vienna, 2019; Mazur, 2007). Histeridae are frequently seen in exposed carcasses (Almeida and Mise, 2009), *S. chalcites* the only one collected in this study. It was collected in many areas of Saudi Arabia from the surface carcasses, in Al-Baha in all seasons except winter (Abouzied, 2014), in jeddah in autumn and winter (Al-Shareef and Al-Mazyad, 2017), in Al-Ahsaa Oasis in all seasons (Shaalan et al., 2017). other species belonging to the family Histeridae were recorded, such as *S. splendens*, *S. semistriatus*, *S. moyses, S. ruber* and *S. semipunctatus* in Saudi Arabia on exposed carcasses (Abouzied, 2014; Mashaly et al., 2020; Mashaly et al., 2018). In contrast, the *Saprinus* sp. species was collected from the carcasses of rabbits buried at a depth of 30 cm in Turkey (Kekillioğlu and Başar, 2019). Record *Euspilotus assimilis*, *Saprinus pensylvanicus* and *Saprinus sp*. (Histeridae) on pork piece buried at a depth of 30 cm in India (Bala and Kaur, 2014). *Operclipygus subterraneus* Caterino and Tishechkin, 2013 (Coleoptera: Histeridae) is the only Histeridae species collected in buried carcasses in South America (Corrêa et al., 2012).

Numerous forensic entomology studies have discovered tenebrionid beetles on the remains (Aballay et al., 2016; Santos et al., 2014; Zanetti et al., 2015). These taxa, however, have been regarded as incidental on cadavers (Corrêa et al., 2014; Özdemir and Sert, 2009). *M. puncticollis* was recorded on exposed rabbit carcasses in Egypt (Hamdy et al., 2022; Sawaby et al., 2009).

Trophic interactions refer to the feeding relationships between different organisms in an ecosystem. Beetles, being a diverse group of insects, participate in various trophic interactions depending on their specific ecological niche and feeding habits (Schoenly et al 1991). Dermestidae beetles play an important ecological role in the decomposition process, breaking down animal carcasses and other organic matter (von et al 2011). Histeridae beetles are often found in habitats with decaying organic matter, dung, or carrion (Shayya and Lackner 2020). Some nitidulidae species are scavengers, consuming decaying plant and animal matter (Nadeau et al 2015). Many species within Tenebrionidae family are detritivores and feed on decaying organic matter like dead plants and animals. They play an important role in the decomposition process (Aballay et al., 2016).

Overall, Each family plays a unique role in trophic interactions, contributing to nutrient cycling and the overall functioning of ecosystems.

5. Conclusions

The current study gives the first record of Coleoptera associated with buried carcasses in the Riyadh, Saudi Arabia. and the data acquired reveal intriguing variations in the beetles gathered, demonstrating their applicability to the interpretation of cases involving remains in comparable circumstances. It also demonstrates the importance of conducting studies in different regions, which would add to the body of knowledge for forensic entomology. Further biochemical and molecular research upon beetles that are collected from buried carcasses may be needed.

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.

Acknowledgements

The authors express their sincere appreciation to the Researchers Supporting Project number (RSP2023R104), King Saud University, Riyadh, Saudi Arabia.

Funding

This project was funded by Researchers Supporting Project number (RSP2023R104), King Saud University, Riyadh, Saudi Arabia.

References

Aballay, F.H., Flores, G.E., Silvestro, V.A., Zanetti, N.I., Centeno, N.D., 2016. An illustrated key to, and diagnoses of the species of Tenebrionidae (Coleoptera) associated with decaying carcasses in Argentina. Annales Zoologici. BioOne, 703–726.

Abd El-Bar, M.M., Sawaby, R.F., El-Hamouly, H., Hamdy, R., 2016. A preliminary identification of insect successive wave in Egypt on control and zinc phosphide-intoxicated animals in different seasons. Egypt. J. Forensic Sci. 6 (3), 223–234.

Abouzied, E.M., 2014. Insect colonization and succession on rabbit carcasses in southwestern mountains of the Kingdom of Saudi Arabia. J. Med. Entomol. 51 (6), 1168–1174.

Al-Khalifa, M.S., Mashaly, A.M., Al-Qahtni, A.H., 2020. Insect species colonized indoor and outdoor human corpses in Riyadh, Saudi Arabia. J. King Saud University-Sci. 32 (3), 1812–1817.

Almeida, L.M., Mise, K.M., 2009. Diagnosis and key of the main families and species of South American Coleoptera of forensic importance. Revista Brasileira de Entomologia 53, 227–244.

Al-Shareef, L.A., Al-Mazyad, M.M., 2017. Beetles (Insecta, Coleoptera) associated with rabbit carcasses in three habitats in Jeddah, Kingdom of Saudi Arabia. Aust. J. Basic Appl. Sci. 11 (2), 139–145.

Arnaldos, M., Garcia, M., Romera, E., Presa, J., Luna, A., 2005. Estimation of postmortem interval in real cases based on experimentally obtained entomological evidence. Forensic Sci. Int. 149 (1), 57–65.

Bala, M., Kaur, P., 2014. Insect faunal succession on buried piece of pork in the state of Punjab (India): a preliminary study. J. Forensic Res. 5 (6), 1–4.

Baviera, C., Vienna, P., 2019. The Histeridae (Coleoptera: Histeroidea) of Sicily: new records and an updated checklist. Atti della Accademia Peloritana dei Pericolanti-Classe di Scienze Fisiche, Matematiche e Naturali 97 (2), 7.
Bonacci, T., Vercillo, V., Benecke, M., 2017. Dermestes frischii and D. undulatus (Coleoptera: Dermestidae) on a human corpse in Southern Italy: first report. Rom. J Leg Med 25 (2), 180–184.
Bornemisszа, G., 1957. An analysis of Arthropod succession in Carrion and the effect of its decomposiion on the soil fauna. Aust. J. Zool. 5 (1), 1–12.
Byrd, J.H., Castner, J.L., 2009. Insects of forensic importance. Forensic entomol. CRC Press, 39–126.
Byrd, J.H., Tomberlin, J.K., 2019. Forensic entomology: the utility of arthropods in legal investigations. CRC Press.
Catts, E.P., Goff, M.L., 1992. Forensic entomology in criminal investigations. Annu. Rev. Entomol. 37 (1), 253–272.
Centeno, N., Serrán, M., Otero, J.G., Weiler, N., 2009. An ancient assemblage of scavenger insects in Patagonia (Argentina). Entomologica Americana 115 (1), 77–80.
Corrêa, R., Moura, D., Leivas, F., Almeida, L., 2012. Operclipygus hospes (Lewis) (Coleoptera, Histeridae): a beetle of potential forensic importance for buried bodies. Neotrop. Entomol. 41, 254–256.
Corrêa, R., Almeida, L., Moura, M., 2014. Coleoptera associated with buried carrion: potential forensic importance and seasonal composition. J. Med. Entomol. 51 (5), 1057–1066.
Fikáček, M., Boukal, M., 2004. Pachysternum capense, a new genus and species for Europe, and updated key to genera and subgenera of European Sphaeridiinae (Coleoptera: Hydrophilidae). Klapalekiana 40, 1–12.
Fugassa, M.H., Martínez, P.A., Centeno, N., 2008. Examen paleobiológico de sedimentos asociados a restos humanos hallados en el sitio arqueológico Alero Mazquiarán, Chubut, Argentina. Intersecciones en antropología 9, 03–09.
Hamdy, R., El-Hamouly, H., Sawaby, R., El-Bar, A., 2022. Identification of insects colonizing carrions of tramadol-intoxicated rabbits and guinea pigs in relation to seasonal variances in Cairo. Egypt. Egyptian J. Pure and Appl. Sci. 60 (1), 34–61.
Haskell, N., Williams, R., 2009. Entomology & Death: A Procedural Guide.: Forensic Entomology 454 Partners. Clemenson, SC, USA 455.
Huchet, J.-B., Greenberg, B., 2010. Flies, Mochicas and burial practices: a case study from Huaca de la Luna. Peru. J. Archaeological Sci. 37 (11), 2846–2856.
Huchet, J.-B., Le Mort, F., Rabinovich, R., Blau, S., Coqueugniot, H., Arensburg, B., 2013. Identification of dermestid pupal chambers on Southern Levant human bones: inference for reconstruction of Middle Bronze Age mortuary practices. J. Archaeol. Sci. 40 (10), 3793–3803.
Keh, B., 1985. Scope and applications of forensic entomology. Annu. Rev. Entomol. 30 (1), 137–154.
Kekillioğlu, A., Başar, M., 2019. Adli Böceklerin (Arthropoda: Insecta) Yüzeysel Gömülerde Ekolojik Karakter Ve Kategorilerin İncelenmesi. Biyoloji Bilimleri. Araştırma. Dergisi. 12 (1), 18–21.
Lefebvre, F., Gaudry, E., 2009. Forensic entomology: a new hypothesis for the chronological succession pattern of necrophagous insect on human corpses. Annales de la Société entomologique de France (NS) 45, 377–392.
Leşinin, O.Ü.Y.S.D., Bölgesinden, D., 2018. Assessment of Entomological Remains from Soil Samples Collected from a Pig (Sus scrofa domestica) Carcass Decomposition Site after 13 Years. Turkiye Parazitol. Derg. 42 (4), 281–285.
Lord, W., 1990. Case histories of the use of insects in investigations. In: Entomology and Death: a Procedural Guide. Joyce's Print Shop, Clemson, SC, pp. 9–37.
Mann, J., Axtell, R., Stinner, R., 1990. Temperature-dependent development and parasitism rates of four species of Pteromalidae (Hymenoptera) parasitoids of house fly (Musca domestica) pupae. Med. Vet. Entomol. 4 (3), 245–253.
Mariani, R., Varela, G., Demaría, M., Rossi Batiz, M., 2010. Registro de la artropodofauna cadavérica asociada a restos humanos en situaciones forenses en la provincia de Buenos Aires. República Argentina, Libro de Resumenes XI Congreso Nacional de Criminalística, pp. 1–7.
Martin, L.D., West, D.L., 1995. The recognition and use of dermestid (Insecta, Coleoptera) pupation chambers in paleoecology. Palaeogeography, Palaeoclimatology, Palaeoecol. 113 (2–4), 303–310.
Mashaly, A.M., Al-Ajmi, R.A., Al-Johani, H.A., 2018. Molecular identification of the carrion beetles (Coleoptera) in selected regions of Saudi Arabia. J. Med. Entomol. 55 (6), 1423–1430.
Mashaly, A.M., Mahmoud, A., Ebaid, H., 2019. Influence of clothing on decomposition and presence of insects on rabbit carcasses. J. Med. Entomol. 56 (4), 921–926.
Mashaly, A., Mahmoud, A., Ebaid, H., 2020. Relative insect frequency and species richness on sun-exposed and shaded rabbit carrions. J. Med. Entomol. 57 (4), 1006–1011.
Mazur, S., 2001. Review of the Histeridae (Coleoptera) of México. Dugesiana 8 (2).
Mazur, S., 2007. On new and little known histerids (Coleoptera: Histeridae) from Taiwan with additional notes on the species composition and zoogeography. Formosan Entomologist 27, 67–81.
Mise, K.M., Almeida, L.M.d., Moura, M.O., 2007. Levantamento da fauna de Coleoptera que habita a carcaça de Sus scrofa L., em Curitiba, Paraná. Revista Brasileira de Entomologia 51, 358-368.
Nadeau, P., Thibault, M., Horgan, F.G., Michaud, J.P., Gandiaga, F., Comeau, C., Stack, C., 2015. Decaying matters: Coleoptera involved in heterotrophic systems. Beetles biodiversity, Ecol. role in the Environ., 123–174
Navarrete-Heredia, J., Newton, A., Thayer, M., Ashe, J., Chandler, D., 2002. Guía ilustrada para los géneros de Staphylinidae de México. Universidad de Guadalajara, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO).
Oliva, A., 1997. Insectos de interés forense de Buenos Aires (Argentina): Primera lista ilustrada y datos bionómicos. Museo Argentino de Ciencias Naturales" Bernardino Rivadavia" e Instituto.
Özdemir, S., Sert, O., 2009. Determination of Coleoptera fauna on carcasses in Ankara province. Turkey. Forensic Sci. Int. 183 (1–3), 24–32.
Pastula, E., Merritt, R., 2013. Insect arrival pattern and succession on buried carrion in Michigan. J. Med. Entomol. 50 (2), 432–439.
Payne, J.A., King, E.W., Beinhart, G., 1968. Arthropod succession and decomposition of buried pigs. Nature 219 (5159), 1180–1181.
Payne, J., King, E., 1970. Coleoptera associated with pig carrion. Entomologist's Monthly Magazine 105, 1265–1267.
Santos, W., Alves, A., Creão-Duarte, A., 2014. Beetles (Insecta, Coleoptera) associated with pig carcasses exposed in a Caatinga area, Northeastern Brazil. Braz. J. Biol. 74, 649–655.
Sawaby, R., Abd El-Bar, M., El-Bermawy, S., 2009. Biochemical studies of two forensically important insects in Egypt which had colonized rabbit carrions treated with organophosphorus compound. Egypt. Acad. J. biology. Sci. 1 (1), 5–11.
Schoenly, K., Beaver, R.A., Heumier, T.A., 1991. On the trophic relations of insects: a food-web approach. Am. Nat. 137 (5), 597–638.
Schroeder, H., Klotzbach, H., Oesterhelweg, L., Püschel, K., 2002. Larder beetles (Coleoptera, Dermestidae) as an accelerating factor for decomposition of a human corpse. Forensic Sci. Int. 127 (3), 231–236.
Shaalan, E.A., El-Moaty, Z.A., Abdelsalam, S., Anderson, G.S., 2017. A preliminary study of insect succession in Al-Ahsaa Oasis, in the eastern region of the kingdom of saudi arabia. J. Forensic Sci. 62 (1), 239–243.
Shayya, S., Lackner, T., 2020. Contribution to the knowledge of the clown beetle fauna of Lebanon, with a key to all species (Coleoptera, Histeridae). ZooKeys 960, 79.
Smith, K., 1986. A manual of forensic entomology. Natural History and Cornell University Press, London, Trustees of the British Museum, p. 205.
Tibbett, M., Carter, D.O., 2008. Soil analysis in forensic taphonomy: chemical and biological effects of buried human remains. CRC Press.
VanLaerhoven, S., Anderson, G., 1996. Forensic entomology: determining time of death in buried homicide victims using insect succession. Canadian Police Research Centre.
von Hoermann, C., Ruther, J., Reibe, S., Madea, B., Ayasse, M., 2011. The importance of carcass volatiles as attractants for the hide beetle Dermestes maculatus (De Geer). Forensic Sci. Int. 212 (1–3), 173–179.
Wang, J., Li, Z., Chen, Y., Chen, Q., Yin, X., 2008. The succession and development of insects on pig carcasses and their significances in estimating PMI in south China. Forensic. Sci. Int. 179 (1), 11–18.
Wolff, M., Uribe, A., Ortiz, A., Duque, P., 2001. A preliminary study of forensic entomology in Medellın. Colombia. Forensic. Sci. Int. 120 (1–2), 53–59.
Zanetti, N.I., Visciarelli, E.C., Centeno, N.D., 2015. Associational patterns of scavenger beetles to decomposition stages. J. Forensic Sci. 60 (4), 919–927.

Further Reading

Martinez, E., Duque, P., Wolff, M., 2007. Succession pattern of carrion-feeding insects in Paramo. Colombia. Forensic Sci. Int. 166, 182–189.
Monteiro-Filho, E.d.A., Penereiro, J., 1987. Estudo de decomposição e sucessão sobre uma carcaça animal numa área do estado de São Paulo, Brasil. Revista Brasileira de Biologia 47 3 289-295.
VanLaerhoven, S., Anderson, G., 1999. Insect succession on buried carrion in two biogeoclimatic zones of British Columbia. J. Forensic Sci. 44 (1), 32–43.