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Forensic Insect Succession and Carrion Decomposition in Indoor and Outdoor Habitats: Implications for Post-mortem Interval Estimation in Dhamar, Yemen

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Abstract

Forensic entomology is a branch of forensic science that utilizes insects to assist in criminal investigations. Building on the foundational principles of forensic entomology, this study investigates of entomofauna's role in decomposing rabbit carcasses (*Oryctolagus cuniculus* L.), across varied environments. Using a consistent collection and analysis protocol, we monitored the decomposition process and insect activity in three different environments in Dhamar City, Yemen. Two carcasses were outdoors: one in a botanical garden and another in an open agricultural area. The third was indoors in a laboratory at the Faculty of Agriculture at Thamar University. The research was conducted over two periods: September and November 2023, as well as October 2024. Urban environments, including both botanical gardens and controlled indoor settings, typically exhibit higher temperatures and lower humidity, which accelerates decomposition more than in agricultural sites. The dry stage was reached by day 30 in urban environments, whereas in agricultural areas, it took approximately 52 days. A total of 1270 adult insect specimens were collected, with outdoor habitats exhibiting the highest abundance. *Chrysomya albiceps* (Calliphoridae) was the dominant species at all sites in the early phases of decomposition, confirming its forensic usefulness in determining postmortem intervals (PMIs). This study describes insect succession resulting from carrion decomposition in both indoor and outdoor habitats in Dhamar City, Yemen. It establishes baseline data essential for estimating the post-mortem interval (PMI) in the locality.

Article Info

Keywords:
Forensic Insect, Carrion decomposition, Insect succession, PMI, Dhamar, Outdoor, Indoor habitat

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1. INTRODUCTION

Forensic science plays a vital role in crime investigations [1], with forensic entomology being a branch utilized in criminal cases across various countries [2], particularly in relation to upcoming legal proceedings [3], [4]. The primary role of insects in crime scene analysis is as a biological indicator to estimate the post-mortem interval (PMI) [5], [6]. [7] This involves estimating the PMI based on temperature patterns and the sequential colonization of carcasses [8], [9]. The decomposition process involves several stages, starting with the 'fresh' stage, followed by 'bloat', 'active decay', 'advanced decay', and finally 'dry' and 'skeletal' stages, where only dry tissue or bones remain [10]. Forensic indicators refer to larvae that feed and develop on carcasses, including families such as Calliphoridae *(Chrysomya albiceps)* [4], [11], Sarcophagidae (*Sarcophaga sp*) [12], [13], Muscidae, Fanniidae [14], Phoridae, and Piophilidae. These are the most relevant Diptera families and the primary insect groups involved in the early decomposition of organic matter [6], [15], along with carrion beetles from Coleoptera families such as Dermestidae, *Dermestes maculatus* [16], Staphylinidae, and Scarabaeidae [17] during the late stage of decomposition. The period of colonization by dipteran larvae in myiasis wounds or via arthropod succession on the carcasses of humans, pets, or cattle is particularly significant [18]. Comparing species found on corpses with an unknown post-mortem interval to those already identified in the same region can facilitate the estimation of the post-mortem interval, as the time required for these species to arrive at the body under similar climatic conditions is already well understood [19], [20]. Many researchers in this field have used animals, such as pigs [21], rabbits [19], and rats [22], [23] as models to simulate human decomposition. Different studies have been conducted in regions such as Egypt [24], Nigeria [15], Kuwait [25], and Riyadh [23]. An effective succession model should include information on the activity times of necrophilous arthropods, as their presence depends on their distribution [26], habitat type [24], [27], environmental conditions [28], and season. Our study underscores the importance of incorporating data on the activity times of necrophilous arthropods under various environmental conditions. This approach is particularly crucial in regions such as Yemen, where climatic conditions significantly influence the decomposition rates and insect colonization patterns. Due to the lack of studies on arthropod succession or carrion decomposition in Yemen, this study was initiated in entomology to fill this research gap by conducting a preliminary investigation into insect succession and rabbit carcass decomposition across three distinct sites in Dhamar City, Yemen. This study aimed to provide a forensic database for this biogeoclimatic region.

2. MATERIALS AND METHODS

2.1. Study site

The study was conducted from 2023 to 2024 in Dhamar City, located approximately 100 km south of Sana'a, the capital. It lies between latitudes $14°–15°$N and longitudes $43.30°–44.5°$E. The terrain varies from plateaus and plains to $2400\,\mathrm{m}$ above sea level. During 2023-2024, the City of Dhamar experienced above–average rainfall, peaking in August, with scattered rain in November, and an annual average precipitation ranging from 109 to 326 mm. Thamar University, which hosts the Faculty of Agriculture, is situated on the main campus at $14.5794°$N and $44.3789°$E. The College of Agriculture is located approximately 200 m from the main street. The road was only 10 m from the Botanical Garden, which is close to a residential area (Fig. 1).

Conflict of Interest declaration: The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

Author Contributions: AB and MJ contributed to the design and implementation of the research, JK to the analysis of the results and to the writing of the manuscript. VK conceived the original and supervised the project.

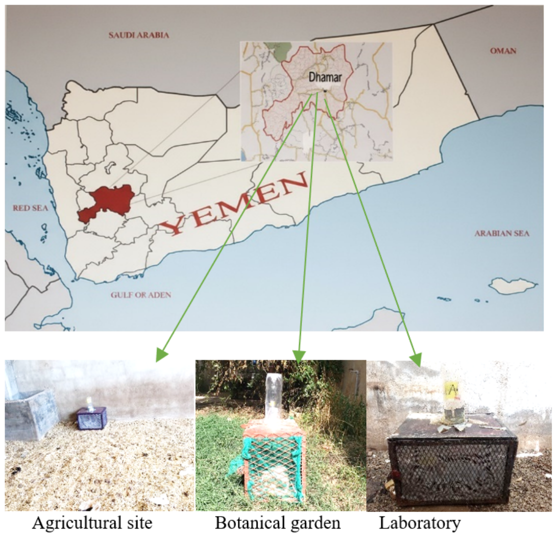

Figure 1. The map of Yemen shows Dhamar City and the Location of the Study sites.

2.2. Carcasses

The rabbits used in this study were treated in accordance with the regulations of the Animal Research and Ethics Committee of Biological Sciences, Sana'a University (Ethics Code: BAHSS 103). Additionally, rabbits were chosen because pigs were not permitted for use in the experiments in Yemen. Three mature live rabbits (*Oryctolagus cuniculus* L.) were used, with an average body weight of 1.33 ± 0.29 kg (n=3).They were obtained locally and euthanized with chloroform to prevent injuries that could affect the results. The three rabbits were assigned to three areas: the botanical garden, agricultural site, and the laboratory habitat. The carcass decomposition stages were classified as fresh, bloated, decaying, and dry.

2.3. Rabbit Cages:

The rabbit carcasses were carefully positioned in solid steel cages with a 2 cm mesh, measuring 50 cm × 40 cm × 25 cm (length × width × height). To keep scavengers away from them, they were topped with a layer of wire screening that allowed insects to enter but prevented them from escaping the traps. A wooden plate at the bottom of the cage was used to observe the insects that visited and to prevent them from sticking to the surface of the carcass.

2.4. Environmental Data

According to Mashaly (2020) [29], a thermo-hygrometer was employed at each site to measure both the temperature and humidity by recording the ambient temperature and relative humidity hourly throughout the experiment (Tables 1 and 2).

2.5. Sampling and Identification

The experiment was conducted over three months: September, October 2023, and November 2024. At each research site, three rabbit carcasses were euthanized by chloroform inhalation. Adult insects were collected daily from 9:00 a.m. to 12:00 p.m. using a plastic bottle trap placed above the cage, following the methodology outlined by ALMesbah (2010) [25] and AlDakhil (2020) [30]. Diptera, Hymenoptera, and Coleoptera adults were meticulously selected using forceps, preserved in 70% ethanol, and labeled with the corresponding dates and times. All specimens were identified to the order, family, genus, and species levels using suitable keys [31–34].

2.6. Statistical Analysis

SPSS software version 21 was used for analysis. Differences in the mean temperature and insect sampling among habitats were evaluated using the Kruskal-Wallis (H) and chi-square tests, which are non-parametric methods for comparing independent samples. Statistical significance was set at $p \leq 0.05$.

3. RESULTS:

3.1. Climatic conditions(temperature and humidity).

The temperature and relative humidity were recorded daily using a Max-Min Thermo Hygrometer [TA318 credits Imagine Instruments LLC], and the data are shown in Tables 1 and Fig. 2. The minimum and maximum temperatures at the first outdoor location (botanical garden) ranged from 9 to 28 °C, with an average relative humidity of 30% to 92%, recorded from day 2 postmortem through day 30 postmortem. At the second outdoor site (agricultural site), the minimum and maximum temperatures ranged from 1 to 29 °C, with an average relative humidity ranging from 72% to 99%,recorded from day 7 postmortem to day 52 postmortem. (Table 2; Fig. 2) In contrast, indoor temperatures (laboratory) ranged from 1 to 28 °C, with an average of relative humidity ranged from 38% to 66% and was recorded from day 2 to day 30.

3.2. Decomposition patterns

3.2.1. Outdoor vs. Indoor Decomposition Rates

As shown in Table 3 and Figure 5, the first stage of rabbit carcass decomposition began at death and ended when the dry stage began. Fig 4 shows that the first stage of decomposition (the fresh stage) lasted 48 h after death for each rabbit carcass placed outdoors (in a botanical garden) and indoors (in a laboratory) (Fig. 4A). Fig. 3 indicates that this stage lasted from day 0 to day 7 postmortem, for rabbit carcasses placed outdoors (at an agricultural site) (Fig. 3A). The started bloated stage (Fig. 4B) occurred on day 3 of the postmortem for both rabbit carcasses placed outdoor (botanical garden) and indoor rabbit carcasses. This stage began on day 8 of postmortem for the carcasses placed outdoors (at an agricultural site) (Fig. 3B). The end of the bloated stage and the start of active decay were marked by liquefaction, which first appeared on day 11 postmortem for rabbit carcasses placed outdoors (botanical garden) and indoors (Fig. 4C). Conversely, liquefaction was first observed on day 16 postmortem for a carcass placed outdoors (at an agricultural site) (Fig. 3C). The advanced decay stage begins when the flesh detaches from its extremities of the body. such as the head, limbs, and anus, the odor decreases to a moderate level, tissues become dehydrated, and bones become exposed at the extremities. This stage was reached on day 17th the carcasses placed outdoors (in a botanical garden) and indoors (in a laboratory) (Fig. 4D). However, for carcasses placed outdoors (at an agricultural site), this stage was reached on day 35 postmortem (Fig. 3D). The final stage of decomposition was the dry stage, characterized by no odor, mummified or hardened skin, and remaining whitish-gray tissues (Fig. 4D). This stage was reached on day 30 postmortem for the rabbit carcasses placed outdoors (in a botanical garden) and indoors (in a laboratory). For carcasses placed outdoors (at an agricultural site), this stage was reached on day 52 postmortem (Fig. 3D).

3.3. Insect fauna associated with rabbit carcasses

Based on the findings shown in Table 4 and Figure 6, the number of adult specimens obtained from rabbit carcasses placed indoors (in the laboratory) was lower than that collected from outside (in the botanical garden and agricultural region). A total of 1143 adult insect specimens representing six families were collected from outdoor rabbit carcasses, whereas 127 adult insect specimens representing five species were collected from indoor rabbit carcasses. Diptera (*Chrysomya albiceps*, *Musca domestica*, *Sarcophaga sp*, *Fannia scalaris*), Coleoptera (*Garreta azureus*, *Dermestes maculatus*, *Creophilus maxillosus*), and Hymenoptera (*Monomorium pharoensis*) accounted for 15.17%, 14.72%, and 12.11%

Table 1. Decompositional stages of rabbit carcasses outdoors in (September and November 2023).

Decompositional stages	Habitat	Days postmortem	Temp. (°C)			R.H.% (Average)
			Max.	Min.	Average	
Fresh	A botanical garden	0–2	27	16	22	35
	Agriculture site	0–7	24	4	14	72
Bloated	A botanical garden	3–5	24	16	20	92
	Agriculture site	8–15	22	4	13	95
Active decay	A botanical garden	6–10	26	14	20	50
	Agriculture site	16–34	25	1	13	99
Advanced decay	A botanical garden	11–16	28	10	19	40
	Agriculture site	35–45	29	2	16	77
Dry	A botanical garden	17–30	25	9	17	30
	Agriculture site	46–52	26	5	16	95

Table 2. Decompositional stages of rabbit carcass indoor laboratory (October 2024).

Decompositional stages	Days postmortem	Temp. (°C)			R.H.% (Average)
		Max.	Min.	Average	
Fresh	0–2	26	11	19	59
Bloated	3–5	25	12	19	43
Active decay	6–10	24	9	17	66
Advanced decay	11–16	27	1	14	60
Dry	17–30	28	7	18	38

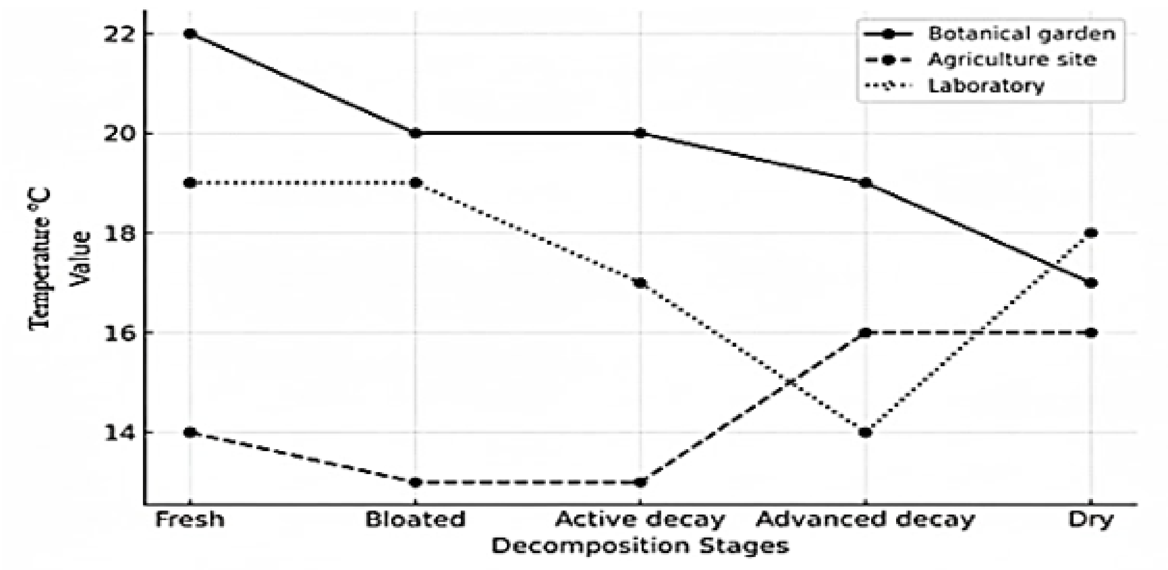

Figure 2. Temperature data for the study period in different decomposition stages and habitats.

of the insects recovered from both outdoor and indoor rabbits(botanical garden, an agriculture site, laboratory), respectively. *C albiceps* of the Calliphoridae family, representing the order Diptera, is the most abundant adult species found on rabbit carcasses both outdoors and indoors. The highest and lowest numbers of adult fly specimens within these families in the three areas (botanical garden, agriculture sites, laboratory) were as follows: Calliphoridae (*C. albiceps*) with 895, 5, and 94; Muscidae (*M domestica*) with 78, 5, and 30, and Sarcophagidae (*Sarcophaga sp*) with 2, 2, and 1, respectively. *F scalaris* of the Fanniidae family had the fewest adult specimens, with one per site. Three families represent the order Coleoptera, which is represented by three families: Scarabaeidae (*G azureus*), Dermestidae (*D maculatus*), and Staphylinidae *C. maxillosus*. Seven adult Scarabaei-

Figure 3. Decompositional stages of a rabbit carcass outdoors in an agricultural site, November. (A)Fresh, (B) Bloated, (C) active decay,(D) advanced decay, and Dry.

dae were found only on a rabbit carcass in a botanical garden. Dermestidae (*D maculatus*) specimens were collected from outdoor rabbit carcasses, totaling two and five individuals, respectively. One adult of the species *C. maxillosus* (Staphylinidae) was collected from an indoor rabbit carcass, In Hymenoptera, 140 mature adults from outdoor (agriculture site) rabbit carcasses were identified as belonging to the Formicidae family, specifically *M. pharoensis*.

3.4. Insect Succession

Based on the findings presented in indoor (Tables 5 and 8), *Sarcophaga sp.* was identified during the fresh stage (0-2 days postmortem), which was the initial decay phase that attracted insects, *Chrysomya albiceps* (Calliphoridae) and *Musca domestica* (Muscidae) appeared on indoor corpses during the bloated (3-5 days), active (6-10), and advanced (11-16 days) decay stages, while *Fannia scalaris* (Fanniidae) appeared only during the bloated stage. One *Creophilus maxillosus* (Staphylinidae) was discovered during the active decay stage, and no ants (*Monomorium pharoensis*, Formicidae) were detected indoors. In (Table 6)shown that the variety and abundance of insects were higher outdoors. At the agricultural site, Diptera: Calliphoridae (*C albiceps*), Muscidae (*M domestica*), Sarcophagidae (*Sarcophaga sp.*), and Fanniidae appeared during the bloating stage (8-15 days postmortem). Calliphoridae and Muscidae persisted from the bloated to advanced decomposition stages, whereas *Dermestes maculatus* (Dermestidae) appeared in both the active and advanced stages. From the bloated to dry stages, only *M pharoensis* ants were observed. Outside carcasses in the botanical garden (Table 7) attracted more Diptera, *C albiceps,* and *F scalaris* at the fresh stage (0-2 days). *C. albiceps* remained active until the advanced decay stage, *Sarcophaga sp.* appeared only during bloating, and *Musca domestica* was present from the bloating to the advanced decay. Beetles *D maculatus* species were observed during the active decay stages, while *Garreta azureus* was observed from the fresh stage, continuing until the dry stage. Overall, outdoor rabbit carcasses supported greater insect diversity and abundance than did in an indoor habitat.

4. DISCUSSION

4.1. Stages and rate of decomposition

These results indicate that the classification of decomposition varies across different environments depending on the type of carcass and the duration of each stage. In this study, four stages of decomposition were observed, aligning with the description by Aly (2017) [24]. However, Al Mesbah (2010) [25] recorded four distinct decomposition stages in rabbit remains, which match the findings of this study. The decomposition classifications used here were based on Al Mashaly(2016) [35], a framework widely adopted by many other authors [23], [30], [36]. The most suitable description for the various decompositions appears to be Matuszewski's classification [37], which is endorsed by researchers in medicolegal entomology. The time required for rabbit carcasses to fully decompose was longer in an agricultural setting compared to a botanical garden and laboratory, consistent with a prior study conducted in Riyadh, Saudi Arabia [38]. Moreover, among three carcasses, bodies took longer to decompose in the agricultural environment than in the botanical garden and laboratory, likely due to differences in environmental conditions, insect activity, and abundance, as also noted in AL-Mekhlafi (2020) [39]. Changes in microclimate, affected by the proximity of carcasses to plants and trees, clearly influence the decomposition process [38], The higher average temperature in the botanical garden may have sped up decomposition at the site. We also observed that the rabbit carcasses in the three locations were embalmed, and this mummification could have resulted from dehydration caused by a combination of low temperature and high humidity.

4.2. Succession on carrion entomofauna

The most common species found on all corpses across the three locations in this study were *C. albiceps*, *M. domestica*, *Sarcophaga* sp, and *F. scalaris*. These species have been documented as important insects in Saudi Arabia [40], Egypt [24], and Kuwait [25] and are used to estimate the postmortem interval (PMI) in entomologi-

Table 3. Decomposition of rabbit carcasses in outdoor and indoor (September, November 2023, October 2024).

Decompositional stages	Habitat	Days postmortem	Temp. (°C)			R.H.% (Average)
			Max.	Min.	Average	
Fresh	A botanical garden	0–2	27	16	22	35
	Agriculture site	0–7	24	4	14	72
	Laboratory	0–2	26	11	19	59
Bloated	A botanical garden	3–5	24	16	20	92
	Agriculture site	8–15	22	4	13	95
	Laboratory	3–5	25	12	19	43
Active decay	A botanical garden	6–10	26	14	20	50
	Agriculture site	16–34	25	1	13	99
	Laboratory	6–10	24	9	17	66
Advanced decay	A botanical garden	11–16	28	10	19	40
	Agriculture site	35–45	29	2	16	77
	Laboratory	11–16	27	1	14	60
Dry	A botanical garden	17–30	25	9	17	30
	Agriculture site	46–52	26	5	16	95
	Laboratory	17–30	28	7	18	38

Figure 4. Decompositional stages of a rabbit carcass indoors in the laboratory site, October. (A)Fresh, (B) Bloated, (C) Active decay,(D) Advanced decay, and Dry.

Table 4. Entomofauna associated with rabbit carcass placed outdoors and indoor during September, November 2023, and October 2024.

Order	Family	Species	A botanical garden	Agriculture site	Laboratory
Diptera	Calliphoridae	*Chrysomya albiceps*	895	5	94
	Muscidae	*Musca domestica*	78	5	30
	Sarcophagidae	*Sarcophaga sp.*	2	2	1
	Fanniidae	*Fannia scalaris*	1	1	1
Coleoptera	Scarabaeidae	*Garreta azureus*	7	0	0
	Dermestidae	*Dermestes maculatus*	2	5	0
	Staphylinidae	*Creophilus maxillosus**	0	0	1
Hymenoptera	Formicidae	*Monomorium pharoensis*	0	140	0
Total			985	158	127

***First record [48]**

cal evidence. Extensive research supports this because these early arriving species land on corpses, as recorded in previous studies, including Moemenbellah (2018) [41] and Akpa (2021) [15], which involved collections from human carcasses.

Our results revealed flies from the families Calliphoridae, Muscidae, and Sarcophagidae, indicating that a variety of species were present during the winter study period. A lower diversity of arthropods was found in rabbit carcass indoor habitats, consistent with Zeariva's (2015) study [19]. This is likely due to lower temperatures and higher levels of relative humidity. In this study, ants and Coleoptera dominated the later stages of decomposition, whereas Calliphoridae were more prevalent during the early stages. The carcasses showed signs of desiccation, resulting in fewer fly visits. Beetles (Coleoptera) were the most common during this stage, consistent with Ozdemir's (2009) study [42].

Table 5. Insect succession on a rabbit carcass placed in a laboratory indoor October 2024.

Order	Family	Species	Decompositional stages / Days postmortem					Total
			Fresh	Bloated	Active decay	Advanced decay	Dry	
			0–2	3–5	6–10	11–16	17–30	
Diptera	Calliphoridae	*Chrysomya albiceps*	0	7	67	20	0	94
	Muscidae	*Musca domestica*	0	4	16	10	0	30
	Sarcophagidae	*Sarcophaga sp.*	1	0	0	0	0	1
	Fanniidae	*Fannia scalaris*	0	1	0	0	0	1
Coleoptera	Scarabaeidae	*Garreta azureus*	0	0	0	0	0	0
	Dermestidae	*Dermestes maculatus*	0	0	0	0	0	0
	Staphylinidae	*Creophilus maxillosus*	0	0	1	0	0	1
Hymenoptera	Formicidae	*Monomorium pharaonis*	0	0	0	0	0	0
								127

Table 6. Insect succession on a rabbit carcass placed outdoors at an agricultural site in November 2023.

Order	Family	Species	Decompositional stages / Days postmortem					Total
			Fresh	Bloated	Active decay	Advanced decay	Dry	
			0–7	8–15	16–34	35–45	46–52	
Diptera	Calliphoridae	*Chrysomya albiceps*	0	1	3	1	0	5
	Muscidae	*Musca domestica*	0	1	2	2	0	5
	Sarcophagidae	*Sarcophaga sp.*	0	2	0	0	0	2
	Fanniidae	*Fannia scalaris*	0	1	0	0	0	1
Coleoptera	Scarabaeidae	*Garreta azureus*	0	0	0	0	0	0
	Dermestidae	*Dermestes maculatus*	0	0	3	2	0	5
	Staphylinidae	*Creophilus maxillosus*	0	0	0	0	0	0
Hymenoptera	Formicidae	*Monomorium pharaonis*	0	48	62	22	8	140
								158

Table 7. Insect succession on a rabbit carcass placed in a botanical garden outdoors in September 2023.

Order	Family	Species	Decompositional stages /Days postmortem					Total
			Fresh	Bloated	Active decay	Advanced decay	Dry	
			0–2	3–5	6–10	11–16	17–30	
Diptera	Calliphoridae	*Chrysomya albiceps*	2	642	231	20	0	895
	Muscidae	*Musca domestica*	0	50	18	10	0	78
	Sarcophagidae	*Sarcophaga sp.*	0	2	0	0	0	2
	Fanniidae	*Fannia scalaris*	1	0	0	0	0	1
Coleoptera	Scarabaeidae	*Garreta azureus*	1	0	4	1	1	7
	Dermestidae	*Dermestes maculatus*	0	0	2	0	0	2
	Staphylinidae	*Creophilus maxillosus*	0	0	0	0	0	0
Hymenoptera	Formicidae	*Monomorium pharaonis*	0	0	0	0	0	0
								985

Results showed that the family Scarabaeidae (Garreta azureus) was only found in botanical garden habitats, transitioning from initial to delayed decay stages, and has been rarely studied and recorded, as seen in a study in Southern Africa [43]. The family Staphylinidae (C. maxillosus) had no previously known occurrences in Yemen. However, in this study, it appeared during the active decay stage. Dermestidae (D. maculatus) was found in both the active and advanced decay stages outside the agricultural and botanical sites. These findings are consistent with those reported by Vianna (2022) [44], confirming the continued presence of M. pharoensis (Hymenoptera: Formicidae) during carrion decomposition under outdoor conditions, as supported by studies conducted in Brazil (2021). These insect succession patterns highlight the need for further research on how different habitats influence decomposition processes.

4.3. Variable habitat

Detailed results of the relationship between insect succession and carrion decomposition were proven in this study, which is consistent with previous studies in different environments that have been presented by other searchers, such as Sharanowski (2008) and Mabika (2014) [45], [46] In the present study found that the

Table 8. Insect succession on rabbit carcass in outdoor and indoor.

Habitat	Order	Family	Species	
A botanical garden	**Diptera**	Calliphoridae	*Chrysomya albiceps*	895
		Muscidae	*Musca domestica*	78
		Sarcophagidae	*Sarcophaga sp.*	2
		Fanniidae	*Fannia scalaris*	1
	Coleoptera	Scarabaeidae	*Garreta azureus*	7
		Dermestidae	*Dermestes maculatus*	2
Total:				**985**
A agricultural site	**Diptera**	Calliphoridae	*Chrysomya albiceps*	5
		Muscidae	*Musca domestica*	5
		Sarcophagidae	*Sarcophaga sp.*	2
		Fanniidae	*Fannia scalaris*	1
	Coleoptera	Dermestidae	*Dermestes maculatus*	5
	Hymenoptera	Formicidae	*Monomorium pharaonis*	140
Total:				**158**
Laboratory	**Diptera**	Calliphoridae	*Chrysomya albiceps*	94
		Muscidae	*Musca domestica*	30
		Sarcophagidae	*Sarcophaga sp.*	1
		Fanniidae	*Fannia scalaris*	1
	Coleoptera	Staphylinidae	*Creophilus maxillosus*	1
Total:				**127**

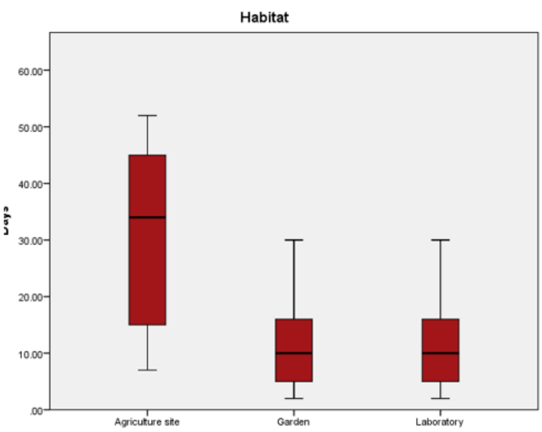

Figure 5. Variation in decomposition days of rabbit carcasses across habitats an agricultural site, a botanical garden, and a laboratory.

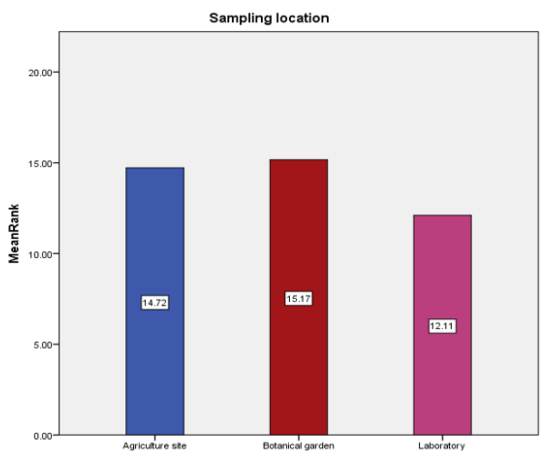

Figure 6. Mean rank of insects collected from rabbit carcasses at three sampling locations (an agriculture site, a botanical garden, and a laboratory).

temperature variation at shaded sites was less than that at exposed sites outdoor (sun-exposed) and indoor (shaded) environments were utilized, carcasses left outside decomposed faster in sun-exposed areas with abundance insects succession than in shaded areas in agricultural sites results which exhibit a high degree of similarity with studies conducted in Riyadh City, Saudi Arabia, and Qena City, in Egypt, Mashaly (2017) [47], Aly (2017) [24], as emphasized in AL Mesbah (2010) [25] in Kuwait. Furthermore, these findings align with those from multi-environmental cadaveric studies that support previous observations of porcine remains placed in shaded versus sunlit forested habitats. Taken together, these studies demonstrate that sun-exposed remains attract significantly larger taxonomic diversity and higher population densities of necrophagous insects than remains located in shaded or indoor environments.

5. CONCLUSIONS

In conclusion, this study showed that habitats and seasons exhibit significantly different patterns of decomposition and insect succession, and Seasonal changes influence insect activity in Dhamar, Yemen. Decomposition rates varied with the environment and season, as did the succession patterns. In September, November 2023, and October 2024, habitat played a key role in decomposition. Carcasses in outdoor agricultural areas

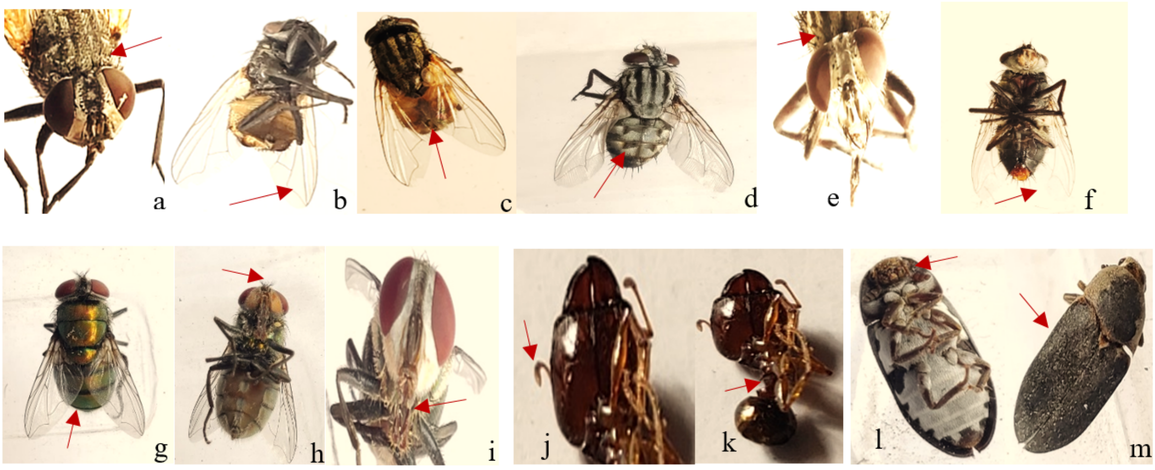

Figure 7. Morphological characteristics of Musca domestica: (a) dark grayish thorax with four longitudinal black stripes on the dorsal thorax, (b) fourth wing venation sharply angled, (c) black lines (vittae) on the dorsal abdomen. Sarcophaga sp.: (d) abdomen resembling a chessboard, (e) three longitudinal black stripes on the top of the thorax, (f) arched wing venation, and propleura without setae. C. albiceps: (g) metallic greenish color, (h) antenna with plumose arista, (i) mouthparts. M. pharoensis: (j) antennae consisting of 12 segments, ending with a three-segmented club, (k) two small nodes between the thorax and gaster. D. maculatus: (l) antennae consisting of 11 segments, ending with a three-segmented club, (m) small black spots.

decomposed more slowly and delayed insect colonization, whereas those in botanical gardens and indoor environments decomposed faster with shorter colonization periods. However, Habitat did not affect decomposition rates in botanical gardens or indoor settings, and morphological changes remained similar. Despite seasonal and environmental differences, some insect groups have arrived at a predictable succession. Specific forensic indicator species consistently appeared in habitat specific condition. *Chrysomya albiceps* (Calliphoridae) was identified in the initial stages as post-mortem interval(PMI), although *Dermestes maculatus* and Staphylinidae (*C. maxillosus*) emerged thereafter. species (*C.* maxillosus) was the first shown in this city. *G. azureus* (Scarabaeidae) was observed during the early to late degradation stages, whereas *M. pharoensis* (Formicidae) was found at nearly every stage. These findings reinforce the potential of specific insect taxa as forensic indicators of the postmortem interval (PMI) in these environments. Furthermore, this study underscores the importance of forensic entomology in Yemen, aiming to establish it as a scientific discipline, strengthen the roles of entomologists, and highlight the use of entomological data in legal investigations and court proceedings.

Ethics: The study protocol was reviewed and approved by the Animal Ethics Committee of the Biological Sciences Department, Faculty of Science, Sana'a University (Ethics Code: BAHSS105).

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