# Insect Colonization and Succession on Rabbit Carcasses in Southwestern Mountains of the Kingdom of Saudi Arabia

EHAB M. ABOUZIED[1,2]

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**ABSTRACT** This study describes for the first time the necrophagous insects attracted to carcasses of the European rabbit in the mountains of Al-Baha Province of southwestern Kingdom of Saudi Arabia (KSA). Twenty-four rabbit carcasses were exposed in 2010 during spring (March, April, and May), summer (June, July, and August), and autumn (September, October, and November). The calliphorid fly species, *Calliphora vicina* Robineau-Desvoidy, *Chrysomya marginalis* (Wiedemann), *Chrysomya chloropyga* (Wiedemann), *Chrysomya albiceps* (Wiedemann), and *Lucilia cuprina* (Wiedemann), the sarcophagid *Liosarcophaga babiyari* (Lehrer), and muscoid flies *Musca domestica* (L.) and *Musca stabulans* Fallén were attracted to the carcasses. Seven species of Coleoptera, the dermestid *Dermestes maculatus* (De Geer), three species of hister beetles, *Saprinus moyses* Marseul, *Saprinus ruber gemminigeri*, and *Saprinus chalcites* (Illiger), the tenebrionid *Himatismus* sp., the clerid species, *Necrobia ruficollis* (F.), and the staphylinid beetle *Creophilous maxillosus* (L.) were also attracted to the rabbit carcasses. One species of adult pteromalid fly pupal parasitoid *Nasonia* sp. was also collected. The dominant larvae on all the rabbit carcasses were *Ch. albiceps*, *L. cuprina*, and *Li. babiyari*. Insect activity caused rabbit carcasses to decompose faster during summer ($21.38 \pm 0.49$ d) compared with spring ($27.5 \pm 0.73$ d) and autumn ($30.38 \pm 0.50$ d). This study indicates that in this region of KSA, *Ch. albiceps*, *L. cuprina*, and *Li. babiyari* are species useful for estimating minimal postmortem intervals.

**KEY WORDS** insect succession, rabbit carcass, decomposition stages, mountains, Kingdom of Saudi Arabia

After death of an exposed animal, a succession of fungi, bacteria, and insects colonize the carcass under various air temperature conditions. Flies (Diptera) are among the first insects attracted to the earliest stages of decomposition (Byrd and Castner 2010). Beetles (Coleoptera) usually invade soon afterwards (Byrd and Castner 2010). These insects can mate, oviposit, and develop on the carcass producing distinctive necrophagous communities (Catts and Goff 1992). As decomposition progresses, taxa of insects disappear over time, whereas others will increase in numbers. Numerous studies of necrophagous communities have been carried out in many regions of the world, but relatively few in the Middle East (Tantawi et al. 1996, Al-Mesbah 2010, and Al-Mesbah et al. 2012).

This study is the first report of the succession of necrophagous insects using European rabbit carcasses exposed in Al-Baha Province in the southwestern mountainous region (2,221 ± 71 m a.s.l.), Kingdom of Saudi Arabia (KSA). This study documents the dominant insects that colonize European rabbit carcasses from the moment of exposure to the dry carcass stage of decomposition from March to December 2010. A timetable was constructed based on the occurrence of each insect species colonizing the carcasses.

[1] Department of Zoology, Faculty of Science, P.O Box: 63514, Fayoum University, Tawfik El-Hakeem, Al Fayoum, Faiyum, Egypt.
[2] Corresponding author, e-mail: ehabmaz@yahoo.co.uk.

## Materials and Methods

The Animal Use Committee of King Khalid University, Abha, KSA, following protocols suggested by the European Union Committee of Animal Use in Research, granted permission to use rabbits as a research animal. No specific permits were required, as rabbits are considered animals of domestic consumption.

**Study Site.** Al-Baha Province (total area 11,000 $km^2$) is situated in the southwestern KSA between Mecca and Aseer (Fig. 1). The province is divided into three distinct regions, and this study took place in the Sarah Region (20° 01′43″ N, 41° 46′19″ E, 2221.5 ± 73 m, a.s.l.). The study region is characterized by relatively high mountains with temperate weather and extensive plant cover resulting from relatively high annual rainfall. Trees averaged 1.5 m in height. Ground cover is mostly grasses after the end of winter rainfall during December, January, and February. The daily maximum and minimum air temperature, relative humidity and rainfall, were recorded using a Wireless Weather Station (La Crosse Technology, LA Crosse, WI) model 1543 XLS during the study periods.

**Animal Model.** The European rabbit, *Oryctolagous cuniculus* (L.) (mean weight 1.5 ± 0.44 kg) was used as the animal model. Pigs are typically used for similar studies, but this animal is not allowed in KSA because of Islamic Law. Rabbits have been used previously in studies of insect-mediated decomposition (Tantawi et

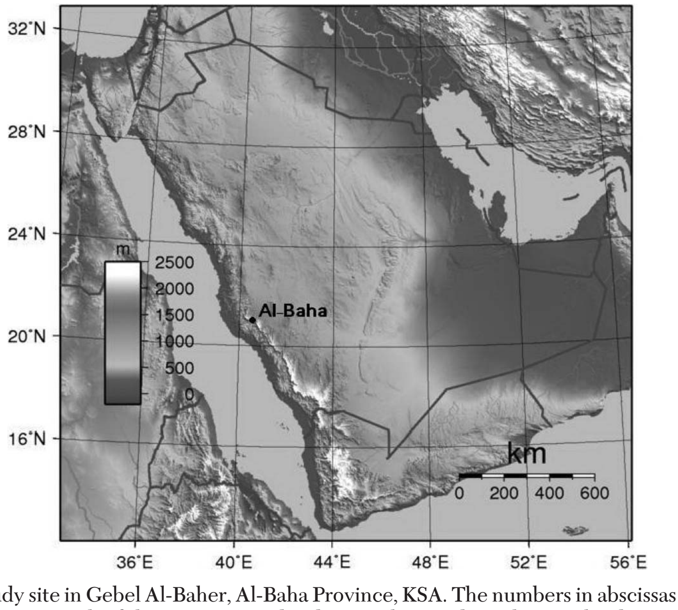


**Fig. 1.** Location of study site in Gebel Al-Baher, Al-Baha Province, KSA. The numbers in abscissas (latitude as the angular distance, in degrees, of a point north of the Equator) and ordinates (longitude as the angular distance, in degrees, of a point east of the prime [Greenwich] Meridian) are used to identify locations.

al. 1996, Bourel et al. 1999, Al-Mesbah 2012). Rabbits were killed by direct inhalation of diethyl ether for a few minutes. Care was taken to avoid injuring or producing any external wounds, as bleeding can facilitate attraction of adult flies. For each experiment, four rabbits were used.

Each rabbit was placed on its side, inside a screened cage. Each mesh cage, 1.0 by 1.5 by 0.5 m was fitted with a plastic bottom. The direct exposure of the carcass was not feasible because of the presence of dogs and wolves. The substrate below the cages was composed of firmly compacted layers of rocks of all sizes, with almost no loose soil, typical of the region. Little or no insect burrowing activity was observed (E.M.A., unpublished data). The plastic bottom of the cage prevented escape or lack of detection of fly larvae allowing for more accurate enumeration. Cages were located 500 m from each other. Each experiment continued until the animal remains were completely dry and no active or live insects were detected in any of the cages. My experiment was conducted twice during each of the three seasons of this region of KSA, spring (March, April, and May), summer (June, July and August), and autumn (September, October, and November) for a total of 24 rabbits.

**Insect Collections.** At least 50 live larvae representing instars 1–3 (if present) were removed daily with fine forceps from each cage. Approximately half of these larvae were preserved in 70% ethanol in vials labeled with the date, time of collection, area of carcass infested, and stage of the decomposition at the time of collection. All specimens were identified to the lowest possible taxonomic level by the author. Larvae were identified using Zumpt (1965) and Szpila (2010).

The other half of each larval sample was reared on rabbit meat until adult emergence in an insectary located in the Department of Essential Sciences, Community College, Al-Baha University, KSA, for confirmation of species identification. Air temperature and humidity were maintained in the insectary as measured at each carcass location throughout the study period. Emerged adults were allowed to sclerotize and then were appropriately curated. Adult flies were identified using Zumpt (1965).

Daily observations of the adult fly activity began at the first day of exposure of each rabbit carcass. Observations were made every 3 h beginning at 7:00 a.m. and continued until 4:00 p.m. daily, through 21 d of the experiment. Inside each cage, a yellow plastic sticky trap was used to collect adult flies visiting the carcasses. Additional adult flies were collected using a standard 30.5-cm-diameter aerial insect net at each cage. Beginning on day 21 of the experiment, rabbit carcasses and sticky traps were checked once daily, three times weekly. The adult insects collected were labeled by date, hour of collection, sorted into families and pinned. Representative specimens of adult calliphorids were sent to Dr. Knut Rognes (Stavanger University, Norway) for verification. Adult muscid and sarcophagid specimens were identified by Dr. John Deeming and Dr. Hassan Dawah (National Museum of Wales, Cardiff, United Kingdom).

Adult beetles were collected by fine moistened brushes or by using forceps inside the cage of each carcass. Outside the cages, beetles were caught by pitfall traps. Ten white plastic pitfall traps (250 ml) placed in two concentric circles around each cage. Each pitfall trap was separated by at least 5 m from each other. Each circle was also separated by 5 m. Adult beetles were killed in cyanide killing bottles and preserved in 70% ethanol until identification. Beetles were pinned for identification. Adult beetles were

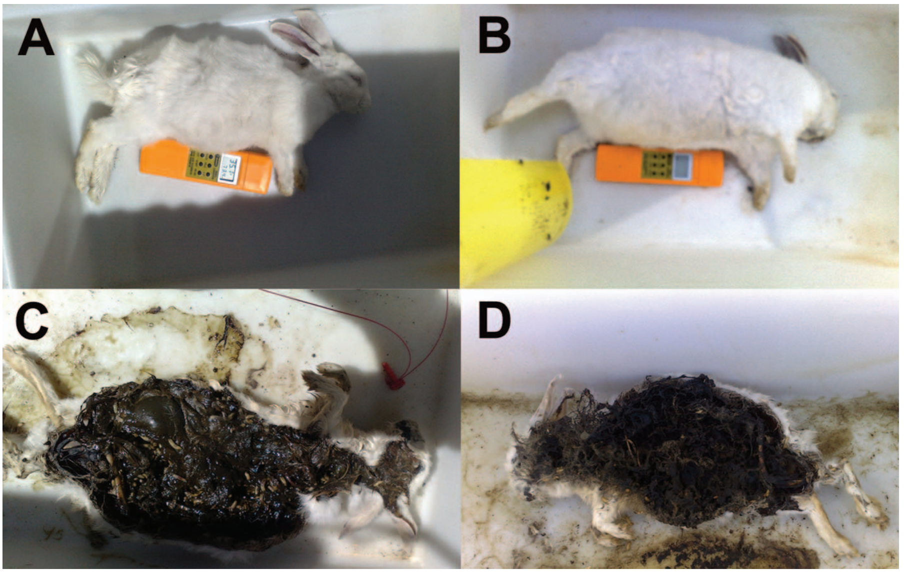


**Fig. 2.** Stages of rabbit carcass decomposition at Gebel Al-Baher, Al-Baha Province, KSA. (A) Fresh stage, (B) bloat stage, (C) active decay stage, and (D) dry decay stage. (Online figure in color.)

identified by Prof. Mahmoud S. Abdel-Dayem (Entomology Department, Cairo University, Egypt).

The adult pteromalid *Nasonia* was identified to the genus level using Graham (1969).

**Stages of Decomposition.** Four stages of decomposition were recognized following Payne (1965) and Gennard (2007): fresh stage (A), bloating stage (B), active decay (C), and dry carcass (D; Fig. 2). Photographs were taken daily with a Canon *PowerShot, S5IS* (12× optical zoom, 8 megapixels) until the end of the experiment.

**Statistical Analysis.** The climatic factors (temperature, relative humidity, and rainfall) were tested separately during spring, summer, and autumn. One-way analysis of variance (ANOVA) was applied followed by a post hoc test for comparison of each groups' mean. ANOVA followed by Bonferroni correction was carried out to compare separately between the mean durations of each decomposition stage (fresh, bloat, active decay, and dry carcass) during spring, summer, and autumn. SPSS software (Version 15; SPSS, Chicago, IL) was used for statistical analyses. A significance level at $P < 0.05$ was used in all tests.

## Results

The highest daily temperature at Al-Baha was during the summer (30.10 ± 0.25°C; $F = 28.17$; df = 2, 97; $P < 0.05$) as compared with both the spring and autumn. During the spring, the relative humidity was highest (37.95 ± 2.46% RH; $F = 21.65$; df = 2, 97; $P < 0.05$). Precipitation during the spring season (1.26 ± 0.57 mm) did not differ significantly from that of the summer season.

Daily collections and observations during the study periods revealed the attraction of 16 species of insects to the rabbit carcasses during the three periods of exposure. Included were five calliphorid species, *Calliphora vicina* Robineau-Desvoidy, *Chrysomya marginalis* (Wiedemann), *Chrysomya chloropyga* (Wiedemann), *Chrysomya albiceps* (Wiedemann), and *Lucilia cuprina* (Wiedemann); one sarcophagid species, *Liosarcophaga babiyari* Lehrer, and two muscoid flies *Musca domestica* L. and *Musca stabulans* (Fallén) (Tables 1–3). Seven Coleoptera species were observed, including one dermestid species (*Dermestes maculatus* DeGeer), three species of histerid beetles, *Saprinus moyses* Marseul, *Saprinus ruber gemminigeri* Marseul, and *Saprinus chalcites* (Illiger), one tenebrionid species, *Himatismus* sp. Haag-Rutenberg, one clerid species, *Necrobia ruficollis* (F.), and one staphylinid beetle *Creophilous maxillosus* (L.). One species of adult pteromalid pupal parasitoid *Nasonia* sp. also was collected (Tables 1–3).

The decomposition of the rabbit carcasses at Gebel Al-Baher was significantly more rapid in the summer months (21.4 ± 0.49 d; $F = 61.47$; df = 2, 21; $P < 0.05$) compared with spring and autumn. During spring exposure, rabbit carcasses persisted significantly longer (3.6 ± 0.18 d; $F = 182.3$; df = 2, 21; $P < 0.05$) in the fresh stage. The bloating stage in summer was reached more rapidly (1.9 ± 0.13 d; $F = 50.81$; df = 2, 21; $P < 0.05$). There was a longer duration of the active decay stage during autumn (7.8 ± 0.16 d; $F = 107.87$; df = 2, 21; $P < 0.05$). The dry carcass stage in both the spring (15.6 ± 0.26 d) and autumn (15.5 ± 0.33 d) was significantly longer in duration than that recorded during the summer months (13.6 ± 0.26 d; $F = 15.34$; df = 2, 21; $P < 0.05$).

During spring experiments, adults of *C. vicina* first appeared at days 3–5 after carcass exposure (Table 1). Adults of *L. cuprina, Ch. albiceps, M. domestica,* and *Li. babiyari* were first caught on day 6. The adult activity of *Li. babiyari* was of longer duration, extending to day

**Table 1. The appearance and progression of the necrophagous insects observed on rabbit carcasses from field observation and laboratory rearing during spring experiments (March–May 2010), Gebel Al-Baher, Al-Baha, KSA**

| Family | Species | Fresh | | | | Bloat | | | | Active decay | | Dry carcass | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10–13 | 14–15 | 16–17 | 18–19 | 20–21 | 22–25 | 26 | 27 | 28–29 | 30 | 31 | 32 |
| *Calliphoridae* | *Calliphora vicina* | – | – | A | A | A | – | – | – | LL' | LL' | LL' | PP' | PP' | PP' | PP' | M | M | F | – | – | – |
| | *Chrysomya albiceps* | – | – | – | – | – | A | A | A | LL' | LL' | LL' | PP' | PP' | M | F | – | – | – | – | – | – |
| | *Chrysomya chloropyga* | – | – | – | – | – | A | A | A | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Chrysomya marginalis* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Lucilia cuprina* | – | – | – | – | – | A | A | A | LL' | LL' | LL' | PP' | PP' | P M | PF | P | P | M | F | F | |
| *Sarcophagidae* | *Liosarcophaga babiyari* | – | – | – | – | – | A | A | A | A,LL' | A,LL' | A,LL' | A,PP' | PP' | PP' | PP' | PP' | PP' | PP' | M | M F | F |
| *Muscidae* | *Musca domestica* | – | – | – | – | – | A | A | A | A | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Muscina stabulans* | – | – | – | – | – | A | A | A | | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pteromalidae* | *Nasonia sp.* | – | – | – | – | – | – | – | – | – | – | – | – | A | A | A | – | – | – | – | – | – |
| *Dermestidae* | *Dermestes maculatus* | – | – | – | – | – | A | A | A | A | A | A | A | – | – | – | – | – | – | – | – | – |
| *Histeridae* | *Saprinus moyses* | – | – | – | – | – | – | – | – | A | A | A | – | – | – | – | – | – | – | – | – | – |
| | *Saprinus ruber* | | | | | | | | | | | | | | | | | | | | | |
| | *Saprinus chalcites* | | | | | | | | | | | | | | | | | | | | | |
| *Tenebrionidae* | *Himatismus sp.* | – | – | – | – | – | A | A | A | A | A | A | A | – | – | – | – | – | – | – | – | – |
| *Cleridae* | *Necrobia ruficollis* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Staphylinidae* | *Creophilus maxillosus* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

A, adult stage; L, larval stage; L', larva reared in lab; P, pupal stage; P', pupation in lab; M, newly emerged males in lab; F, newly emerged females in lab; –, not observed.

Numbers in column header refer to days spent within each decomposition stage (Fresh, 1–4; Bloat, 5–8; Active decay, 9–13; Dry carcass, 14–32).

17. Adults of *Ch. chloropyga* and *M. stabulans* were caught during days 6–8, but only during the spring exposure (Table 1). However, in the summer (Table 2) and autumn (Table 3), *L. cuprina, Ch. albiceps,* and *M. domestica* were initially attracted to the rabbit carcasses on day 1, followed by *Li. babiyari* on day 2. Adults of *Ch. marginalis* were attracted to the rabbit carcasses on day 1 during the autumn (Table 3) as compared with adults of this species arriving at the carcasses in summer on day 2 (Table 2).

Larvae of three species *Ch. albiceps, L. cuprina,* and *Li. babiyari* were present on the carcasses during spring, summer, and autumn (Tables 1–3). Larvae of *C. vicina* were found on the rabbit carcasses only during the spring season (Table 1). In the spring experiment, larvae of *L. cuprina* removed from the carcasses and returned to the laboratory produced two peaks of adults, the first peak were all males (days 20–21 and days 28–29) and the second were all females (days 22–25 and days 30–31, Table 1). Larvae of *Li. babiyari* were present during the summer exposure on days 4–6 (Table 2), days 3–8 in the autumn (Table 3), and on days 9–15 during the spring exposure (Table 1).

Adult *D. maculatus* were common at the rabbit carcasses in the spring (from days 6–17), summer (from days 2–21), and during autumn (from days 2–29; Tables 1–3). Larvae of *D. maculatus* were present in large numbers at the dry carcass stage during summer (days 10–21, Table 2) and autumn (days 23–29, Table 3). Adults of the rove beetle *Cr. maxillosus* were observed in the summer only on day 3 and in autumn from days 5–7 (Tables 2 and 3). Adult hister beetles *S. moyses, S. r. gemminigeri,* and *S. chalcites* were commonly collected from the rabbit carcasses during spring, summer, and autumn. During spring, they were abundant from days 9–15 (Table 1). In autumn, hister beetles persisted on the carcasses from the bloated

**Table 2. The appearance and progression of necrophagous insects observed on rabbit carcasses through field observations and laboratory rearing during summer experiments (June–August 2010), Gebel Al-Baher, Al-Baha, KSA**

| Family | Species | Bloat | | Active decay | | | | Dry carcass | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4–5 | 6 | 7 | 8 | 9 | 10 | 11–13 | 14–15 | 16 | 17–21 | 22 |
| *Calliphoridae* | *Calliphora vicina* | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Chrysomya albiceps* | A | – | LL' | LL' | L, PP' | L, P P' | P, M | PF | – | – | – | – | – | – |
| | *Chrysomya chloropyga* | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Chrysomya marginalis* | – | A | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Lucilia cuprina* | A | – | – | L L' | L P P' | L P P' | L P P' | P M | P F | P | P | P | – | – |
| *Sarcophagidae* | *Liosarcophaga babiyari* | – | A | A,LL' | L,L' | L,P L'P' | L, P'P | PP' | PP' | PP' | P P' | M,F | – | – | – |
| *Muscidae* | *Musca domestica* | A | A | A | – | – | – | – | – | – | – | – | – | – | – |
| | *Muscina stabulans* | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pteromalidae* | *Nasonia sp.* | – | – | – | – | – | – | A | A | A | – | – | – | – | – |
| *Dermestidae* | *Dermestes maculatus* | – | A | A | A | A | A | A | A | A,L | A,L | A,L | A,L | A,L | – |
| *Histeridae* | *Saprinus ruber* | – | – | A | – | – | – | – | – | – | – | – | – | – | – |
| | *Saprinus chalcites* | | | | | | | | | | | | | | |
| | *Saprinus moyses* | | | | | | | | | | | | | | |
| *Tenebrionidae* | *Himatismus sp.* | – | – | A | – | – | – | – | – | – | – | – | – | – | – |
| *Cleridae* | *Necrobia ruficollis* | – | – | A | – | – | – | – | – | – | – | – | – | – | – |
| *Staphylinidae* | *Creophilus maxillosus* | – | – | A | – | – | – | – | – | – | – | – | – | – | – |

A, adult stage; L, larval stage; L', larva reared in lab; P, pupal stage; P', pupation in lab; M, newly emerged males in lab; F, newly emerged females in lab; –, not observed. Numbers in column header refer to days spent within each decomposition stage (Bloat, 1–3; Active decay, 4–10; Dry carcass, 11–22).

**Table 3. The appearance and progression of necrophagous insects observed on rabbit carcasses through field observations and laboratory rearing during autumn experiments (September–November 2010), Gebel Al-Baher, Al-Baha, KSA**

| Family | Species | Bloat | | | | | Active decay | | | | | | | Dry carcass | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10–11 | 12–13 | 14 | 15 | 16 | 17 | 18 | 19 | 20–27 | 28–29 | 30–31 |
| *Calliphoridae* | *Calliphora vicina* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Chrysomya albiceps* | A | A | A | – | – | – | L | L L' | L L' | L L' | L P P' | P P' | P P' | P P' | M | M,F | F | – | – | – |
| | *Chrysomya chloropyga* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Chrysomya marginalis* | A | A | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Lucilia cuprina* | A | A | A | – | – | – | L L' | L L' | P P' | P P' | P P' | P P' | P P' | P P' | M | M,F | F | – | – | – |
| *Sarcophagidae* | *Liosarcophaga babiyari* | – | A | A | A | A | A | A,L L' | A,L L' | AP P' | P P' | P P' | P P' | P P' | P P' | P P' | P P' | P P' | P P' | M | F |
| *Muscidae* | *Musca domestica* | A | A | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | *Muscina stabulans* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pteromalidae* | *Nasonia sp.* | – | – | – | – | – | – | – | – | – | – | – | A | A | – | – | – | – | – | – | – |
| *Dermestidae* | *Dermestes maculatus* | – | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A,L | A,L | – |
| *Histeridae* | *Saprinus moyses* | | | | | | | | | | | | | | | | | | | | |
| | *Saprinus ruber* | – | A | A | A | A | A | A | A | A | A | A | A | A | A | – | – | – | – | – | – |
| | *Saprinus chalcites* | | | | | | | | | | | | | | | | | | | | |
| *Tenebrionidae* | *Himatismus sp.* | – | – | – | – | – | – | – | A | A | A | A | A | A | A | A | A | A | A | A | A |
| *Cleridae* | *Necrobia ruficollis* | – | – | – | – | – | – | A | A | A | A | A | A | A | A | – | – | – | – | – | – |
| *Staphylinidae* | *Creophilus maxillosus* | – | – | – | – | – | – | A | A | A | A | A | A | A | – | – | – | – | – | – | – |

A, adult stage; L, larval stage; L', larva reared in lab; P, pupal stage; P', pupation in lab; M, newly emerged males in lab; F, newly emerged females in lab; –, not observed. Numbers in column header refer to days spent within each decomposition stage (Bloat, 1–5; Active decay, 6–14; Dry carcass, 15–31).

stage (day 2) to day 16 (dry decay stage, Table 3). During the summer, hister beetles were detected only on day 3 (Table 2). Adults of *N. ruficollis* were observed only on day 3 in the summer season (Table, 2). During autumn experiments, *N. ruficollis* was collected on days 7–16 (Table 3). Adults of the tenebrionid *Himatismus* sp. were collected only on third day in the summer (Table 2), but were active for long periods during the spring (days 6–17, Table 1) and from days 8–30 during the autumn (Table 3).

Adults of the fly pupal parasitoid *Nasonia* sp. were collected from cages on days 14 and 15 during autumn experiments (Table 3). In the spring experiment, adults of *Nasonia* sp. were collected on days 18–25 during the dry decay stage (Table 1) and from days 8–10, during the summer experiment (Table 2).

## Discussion

The taxa composition of carrion entomofauna attracted to the rabbit carcasses at Gebel Al-Baher at the family and genus level is similar to what has been reported in previous studies (i.e., Payne 1965, Anderson and VanLaerhoven 1996, Bourel et al. 1999, Grassberger and Frank 2004, Al-Mesbah et al. 2012). In this study, 16 insect species were identified that were directly attracted to the rabbit carcasses throughout the course of the study. The regional biodiversity of known necrophagous species was well represented in my study (Al-Ahmadi and Salem 1999, Dawah and Abdullah 2009; El-Hawagry et al. 2013 in KSA). Similar taxa were reported in Egypt by Tantawi et al. (1996).

Several factors may have influenced the total number of insect taxa found during this study. The geographical location and altitude of Gebel A-Baher (2221 ± 73 m a.s.l.) may have resulted in a smaller "pool" of available taxa and more obvious, the relative small size of the rabbit carcasses (1.5 ± 0.44 kg) attracting fewer taxa. Simmons et al. (2010) and Spika et al. (2011) reported that the carcass mass can affect the rate of decomposition with smaller carcasses decomposing more rapidly. Simmons et al. (2010) concluded that when comparing numerous studies of insect-mediated decomposition from many different environments and temperatures, a secondary influential factor is the carcass size, with small carcasses decomposing faster than large carcasses. Hewadikaram and Goff (1991), however, indicated that carcass size is not important in terms of the sequence of arthropod succession patterns.

As with my study, Battán et al. (2012) reported that insect-mediated decay rates of exposed carcasses were significantly faster in the summer than during other seasons. These authors correlated the more rapid decomposition to the invasion of the carcasses by calliphorid, sarcophagid, and muscid larvae due to favorable ambient air temperatures as compared with the other seasons. Shean et al. (1993) postulated that maximum temperatures probably influenced decomposition more than minimum temperatures. This typical pattern has also been reported by other authors such as Tantawi et al. (1996), Wang et al. (2008), and Al-Mesbah et al. (2012). Campobasso et al. (2001) showed that air temperature has a direct influence on the putrefaction processes, but several studies have suggested a strong negative relationship between ambient temperature and the time necessary for the onset of the bloating stage (Voss et al. 2009, Matuszewski et al. 2010). In this study, in the spring and autumn, the bloating stage of the rabbit carcasses took longer as compared with summer. Similarly, in Europe, Matuszewski et al. (2010) found that the bloating stage of pig carcasses lasted longer in spring than in summer and autumn. The decrease in the relative humidity during the summer accelerated the drying of the rabbit carcass in this study.

It is noted that the lack of direct exposure of the rabbit carcasses to the natural substrate because of the cage design may have influenced decomposition. At the study site, the soil composed mostly of rocks was extremely hard packed and dry. The relatively small size of the rabbit carcasses and regional high air temperatures resulted in almost no decomposition fluids being released during the active decay process (E.M.A., unpublished data). This may have limited microbial activity.

*C. vicina* was the only blow fly species attracted to the fresh stage of the rabbit carcasses, but only in the spring experiment. Other authors have also reported this species as a first colonizer (Arnaldos et al. 2005, Ortloff et al. 2012). My spring experiments indicated no clear sequence of species except for *Calliphora.* In the summer and autumn, adults of *L. cuprina, Ch. Albiceps,* and *M. domestica* were initially attracted to the rabbit carcasses at the bloat stage followed by the *Li. babiyari* as a secondary colonizer, arriving one day later. Adults of *Ch. albiceps* were common in the three seasons of the study, reaching peak abundance during the summer and autumn (Tables 2 and 3). Adults of *Ch. chloropyga* were active during the bloat stage of the spring experiment. In both summer and autumn, adults of *Ch. marginalis* were recorded in fewest numbers during the first days (first for summer and second for autumn) of the bloating stage. Similarly, Voss et al. (2009a) reported other species of *Chrysomya* as secondary colonizers of the bloat stage.

Adults of *M. domestica* were attracted to the bloat stage of the rabbit carcasses in the spring, summer, and autumn experiments. However, no larvae of *M. domestica* were found on the rabbit carcasses during this study. Arnaldos et al. (2005) reported adults of *M. domestica* as the dominant fly during the summer period from the first day of carcass exposure. Voss et al. (2009a) reported that adult *M. domestica* would regularly visit carcasses, although oviposition was rare. Adults of *M. stabulans* visited the rabbit carcasses only during the bloating stage during spring experiment. Arnaldos et al. (2005) reported that adults of *M. stabulans* showed no clear seasonal preference and were found throughout the year.

Larvae collected directly from the rabbit carcasses during the spring, summer, and autumn were primarily *Ch. albiceps, L. cuprina,* and *Li. babiyari.* As indicated previously, larvae of *C. vicina* were collected from carcasses only during the spring season. Larvae of *Li. babiyari* appeared inside the rabbit carcasses during the active decay stage (in summer and autumn) and lasted to the beginning of the dry carcass, during spring. In comparison, Voss et al. (2009a) reported that sarcophagid larvae were present during the early bloating stage, but not during the active decay stage.

Adult *D. maculatus* were common among the carcasses in the spring, summer, and autumn. Adults were active during the bloated stage and the first days of the dry carcass stage. Similar findings were reported by Arnaldos et al. (2005). These authors reported that adult dermestids were collected during the earliest stages of decomposition in spring and summer. In addition, Von Hoermann et al. (2005) reported that the newly emerged males of *Dermestes maculatus* were attracted by the odor of piglet carcasses during the postbloating stage (9 d after death) due to the emission of benzyl butyrate, which was considered the key compound for beetle attraction. During summer and autumn, larvae of *D. maculatus* were most active during the dry carcass stage.

The adults of the rove beetle *Cr. maxillosus,* a maggot predator, were active in summer and in autumn experiments. Similarly, the adults of *Cr. maxillosus* were recorded in late summer and the beginning of autumn on pig carcasses in Poland (Matuszewski et al. 2008). During our study adults of *Cr. maxillosus* were observed inside the cages of rabbit carcasses, during only the third day of the summer experiments. Ortloff et al. (2012) reported adults of *Cr. maxillosus* could be collected from pig carcasses from the bloating to early dry stage in the summer. Similar results have been reported for staphylinid maggot predators in other studies (Payne 1965, Early and Goff 1986, Tullis and Goff 1987, Anderson and VanLaerhoven 1996, Matuszewski et al. 2008).

Adult hister beetles, *S. moyses, S. ruber gemminigeri,* and *S. chalcites* were commonly collected from rabbit carcasses during spring, summer, and autumn. During spring, they were abundant from the active decay to the first 2 d of the dry carcass. In autumn, they persisted on carcasses from the bloat stage to the first days of the dry decay stage. During summer, they were collected during the bloat stage to the end of the dry carcass. However, Matuszewski et al. (2008) reported that the activity of *Saprinus* was limited during the active decay stage of pigs in Poland. Smith (1986), Kovarik and Centerino (2001), and Byrd and Castner (2010) have indicated that hister beetle genera *Saprinus, Margarinotus* and *Hister* are predators of dipteran larvae and eggs associated with carrion.

Adults of *N. ruficollis* were collected during both the summer and autumn experiments, similarly. In autumn experiments, *N. ruficollis* was collected from the active decay to the dry carcass stages of examined rabbit carcasses. In contrast to our results, adults of *Necrobia* in other studies occurred only during the late active decay stage (Early and Goff 1986, Tabor et al. 2004, Matuszewski et al. 2008).

In conclusion, this study presents for the first time the succession of necrophagous insects attracted to rabbit carcasses and the succession of these insects during three distinct seasons in an arid high mountain region (2,200 m a.s.l.) on the Arabian Peninsula. At this site in Gebel Al-Baher, KSA, the fly species *C. vicina, Ch. albiceps, L. cuprina,* and *Li. babiyaris* are species that may be useful for estimating the minimal postmortem interval. Al-Mesbah (2010) has made similar suggestions, that these species can be used as forensic indicators to estimate minimal postmortem intervals in the Middle East.


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## References Cited


**Al-Ahmadi, A. Z., and M. M. Salem. 1999.** Entomofauna of Saudi Arabia, general survey of insects reported in the Kingdom of Saudi Arabia. Part I: Checklist of insects. King Saud University, Academy Publisher and Press, Riyadh, Saudi Arabia.

**Al-Mesbah, H. 2010.** A study of forensically important necrophagous Diptera in Kuwait. MS thesis, University of Central Lancashire, England.

**Al-Mesbah, H., C. Moffatt, O.M.E. El-Azazyc, and Q.A.H. Majeedd. 2012.** The decomposition of rabbit carcasses and associated necrophagous Diptera in Kuwait. Forensic Sci. Int. 217: 27–31.

**Anderson, G., and S. VanLaerhoven. 1996.** Initial studies on insect succession on carrion in southwestern British Columbia. J. Forensic Sci. 41: 617–625.

**Arnaldos, M., M. Garcia, E. Romera, J. Presa, and A. Luna. 2005.** Estimation of postmortem interval in real case based on experimentally obtained entomological evidence. Forensic Sci. Int. 149: 57–65.

**Battán, H. M., B. Rosso, and M. D. García. 2012.** Seasonal structure and dynamics of sarcosaprophagous fauna on pig carcass in a rural area of Cordoba (Argentina): Their importance in forensic science. J. For. Sci. Int. 217: 146–156.

**Bourel, B., L. Martin-Bouyer, V. Hedouin, J. Cailliez, D. Derout, and D. Gosset. 1999.** Necrophilous insect succession on rabbit carrion in sand dune habitats in northern France. J. Med. Entomol. 36: 420–425.

**Byrd, J., and J. Castner. 2010.** Insects of forensic importance. pp. 39–79. *In* J. H. Byrd and J. L. Castner (eds.), Forensic Entomology. The Utility of Arthropods in Legal Investigations, CRC, Boca Raton, FL.

**Campobasso, C., G. Vella, and F. Introna. 2001.** Factors affecting decomposition and Diptera colonization. Forensic Sci. Int. 120: 18–27.

**Catts, E. P., and M. L. Goff. 1992.** Forensic entomology in criminal investigations. Annu. Rev. Entomol. 37: 253–272.

**Dawah, H. A., and M. Abdullah. 2009.** The Calliphoridae (Diptera: Cyclorrhapha) of south-western Saudi Arabia. Fauna Arabia 24: 359–371.

**Early, M., and M. Goff. 1986.** Arthropod succession patterns in exposed carrion on the island of O'ahu, Hawaiian Islands, USA. J. Med. Entomol. 23: 520–531.

**El-Hawagry, M. S., M. W. Khalil, M. R. Sharaf, H. H. Fadl, and A. S. Aldawood. 2013.** A preliminary study on the insect fauna of Al-Baha Province, Saudi Arabia, with descriptions of two new species. Zookeys 274: 1–88.

**Gennard, D. F. 2007.** Forensic entomology: An introduction, 2nd Ed. John Wiley-Blackwell, Hoboken, NJ.

**Graham, M. W. 1969.** The Pteromalidae of northwestern Europe. Bull. Br. Mus. (Nat. Hist.) 16: 1–908.

**Grassberger, M., and C. Frank. 2004.** Initial study of arthropod succession on pig carrion in a central European urban habitat. J. Med. Entomol. 41: 511–523.

**Hewadikaram, K., and M. Goff. 1991.** Effect of carcass size on rate of decomposition and arthropod succession patterns. Am. J. Forensic Med. Pathol. 12: 235–240.

**Kovarik, P. W., and M. S. Caterino. 2001.** 15. Histeridae Gyllenhal, 1808, pp. 212–227. *In* R. H. Arnett Jr. and M. C. Thomas, (eds.), American Beetles, Volume 1. Archostemata, Myxophaga, Adephaga, Ployphaga: Staphyliniformia. CRC, Boca Raton, FL.

**Matuszewski, S., D. Bajerlein, S. Konwerski, and K. Szpila. 2008.** An initial study of insect succession and carrion decomposition in various forest habitats of Central Europe. Forensic Sci. Int. 180: 61–69.

**Matuszewski, S., D. Bajerlein, S. Konwerski, and K. Szpila. 2010.** Insect succession and carrion decomposition in selected forests of central Europe. Part 1: Pattern and rate of decomposition. Forensic Sci. Int. 194: 85–93.

**Ortloff, A., P. Pena, and M. Riquelme. 2012.** Preliminary study of the succession pattern of necrobiont insects, colonizing species and larvae on pig carcasses in Temuco (Chile) for forensic applications. Forensic Sci. Int. 222: 36–41.

**Payne, J. 1965.** A summer carrion study of the baby pig *Sus scrofa* Linnaeus. Ecology 46: 592–602.

**Shean, B. S., L. Messinger, and M. Papworth. 1993.** Observations of different decomposition on sun exposed v. shaded pig carrion on coastal Washington State. J. Forensic Sci. 38: 938–949.

**Simmons, T., R. E. Adlam, and C. Moffatt. 2010.** Debugging decomposition data: comparative taphonomic studies and the influence of insects and carcass size on decomposition rate, J. Forensic Sci. 55: 8–13.

**Smith, K. 1986.** A manual of forensic entomology. Cornell University Press, Ithaca, NY.

**Spika, A., R. Johnson, J. Bushing, L. Highley, and O. David. 2011.** Carcass mass can influence rate of decomposition and release of ninhydrin- reactive nitrogen into grave soil. Forensic Sci. Int. 209: 80–85.

**Szpila, K. 2010.** Key for identification of Third instars of European blowflies (Diptera, Calliphoridae) of forensic importance, pp. 43–56. *In* J. Amendt, M. L. Goff, C. P. Campobasso, and M. Grassberger (eds.), Current Concepts in forensic entomology. Springer, The Netherlands.

**Tabor, K., C. Brewster, and R. Fell. 2004.** Analysis of the successional patterns of insects on carrion in southwest Virginia. J. Med. Entomol. 41: 785–795.

**Tantawi, T. I., E. M. El-Kady, B. Greenberg, and H. A. El-Ghaffar. 1996.** Arthropod succession on exposed rabbit carrion in Alexandria, Egypt. J. Med. Entomol. 33: 556–580.

**Tullis, K., and M. Goff. 1987.** Arthropod succession in exposed carrion in a tropical rainforest on O'ahu Island, Hawaii. J. Med. Entomol. 24: 332–339.

**Von Hoermann, C., J. Ruther, S. Reibe, B. Madea, and M. Ayasse. 2005.** The importance of carcass volatiles as attractants for the hide beetle *Dermestes maculatus* (De Geer). Forensic Sci. Int. 212: 173–179.

**Voss, S., H. Spafford, and I. Dadour. 2009.** Annual and seasonal patterns of insect succession on decomposing remains at two locations in Western Australia. Forensic Sci. Int. 193: 26–36.

**Wang, J., L. Zhignang, Y. Chen, C. Qiangsheng, and X. Yin. 2008.** The succession and development of insects on pig carcass and their significant PMI in south China. Forensic Sci. Int. 179: 11–18.

**Zumpt, F. 1965.** Myiasis in man and animals in the Old World. Butterworths, London, England.


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