

RESEARCH ARTICLE

ESTIMATING THE ROLE OF ARTHROPOD SUCCESSION IN PREDICTING THE POSTMORTEM INTERVAL OF INDOOR DROWNED AND SLAUGHTERED RAT CADAVERS

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ABSTRACT

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Estimating the succession period of a carcass, or the so-called postmortem interval, is a topic that has occupied forensic arthropodologists since the nineteenth century. Arthropods are considered one of the main invertebrates for accessing and colonizing cadavers. The present study aimed to identify the arthropod succession in indoor rat carcasses. The current study considered the link between the developmental larval stages of arthropods and the postmortem interval. Fifteen female Wistar rats (*Rattus norvegicus*) were equally allotted into three experimental models based on their manner of death: group “1” (control, killing by head dislocation), group “2” (killing by drowning), and group “3” (killing by slaughtering). The abundance of related arthropods did not differ greatly between the control and the drowning groups, but there are clear differences between the two groups in the carrion's shape and color. The slaughtered group showed a large difference in the abundance of related arthropods from groups “1 and 2”. This study reported 16 invertebrates' taxa belonging to 13 Families (12 Families belonging to Phylum: Arthropoda and one to Phylum: Nematoda): *Chrysomya albiceps* (28%), *Apis* sp. (0.11%), *Musca domestica* (6%), *Sarcophaga* sp. (16%), *Wohlfahrtia magnifica* (6%), *Parasarcophaga orgyrostama* (3%), *Dermestes maculatus* (3%), *Dermestes frischii* (3%), *Saprinus* sp. (3%), *Nasonia* sp. (4%), spiders (4%), *Dermatophagoides* sp. (7%), *Cimex lectularis* (6%), *Porcellio laevis* (2%), mites (2%), nematodes (6%). In conclusion, the current study provides a basis for further studies examining arthropod succession in predicting the postmortem period of internal rat carcasses and the manner of death.

INTRODUCTION

Once death occurs, cells begin to die and enzymes inside cells start to digest in a manner known as autolysis, and the body begins to decompose. The bacteria found in the digestive system start to destroy delicate tissues to create fluids and gases (e.g. carbon dioxide, hydrogen sulfide, methane, sulfur

dioxide, hydrogen, and ammonia)^[1]. The volatile chemicals that are released at various the variables stages of body decomposition can be isolated. The isolated volatile molecules at every stage can influence the insects' behavior. Insects are attracted to substances called apeneumones that result from the decaying cadaver^[1]. It

was found that sulfur-containing compounds were initially responsible for attracting flies to the decomposing carcass, however oviposition of flies was stimulated by compounds (ammonium-rich) found on the carcass^[2]. The science of using arthropods including insects in criminal investigations is called forensic entomology^[3,4]. Carrion attracts insects or arthropods. The succession of insects helps in determining the cause and method of death, movement of the body, involvement of suspects at the death site, and the time elapsed between death and discovery of the cadaver—a measurement known as the postmortem interval (PMI)^[3,4]. Forensic entomology has become an increasingly important tool in criminal investigation in Thailand, leading to successful convictions^[5]. The most significant factor in corpse decomposition is temperature, which affects body decomposition, followed by arthropod access to the body^[6].

Forensic entomology receives great attention, as forensic medicine can find traces of evidence through insects associated with humans and their inhabitants, or insects in any field in general^[7-9]. It is interesting to note arthropod abundance and diversity, and that certain species have evolved to take advantage of the protected habitats we provide. Many arthropods are attracted to humans, such as cockroaches, house flies, bed bugs, silverfish, dust mites, and fleas. They have adapted to living in human habitations and have become integrated into human biology. Although these arthropods are not directly dependent on humans, insects like dirty flies bugs, biting midges, mites, and mosquitoes feed on human blood directly by sucking blood or consuming feces, and litter produced by humans^[7-9]. Some insects have changed their lifestyle and adapted to live inside our homes to feed and rest. For example, cereal pests, and blood-feeding insects have shifted their usual habitat around the home and become reliant on humans for survival^[7-9].

Forensic entomology is a global scientific field that integrates knowledge of insects into crime scene investigations, with un-

limited utility^[10]. One of the main limitations is insect growth, which is affected by a large number of environmental factors, such as temperature and humidity. This means that estimates of the time of death can be inaccurate, especially in cases where the body is exposed to harsh environmental climate^[11]. Ecologically, arthropods succeed over carrions; a decomposing cadaver is a microhabitat for a variety of organisms like bacteria, fungi, plants, and animals^[12]. Therefore, the current study is designed to obtain primary data about the decomposition process and to document forensically significant arthropod species associated with indoor decomposing rats. The methods of killing corpses in the current study were different (drowning and slaughtering) to investigate the association of the pattern of succession in arthropods and the manner of death.

MATERIAL AND METHODS

Experimental animals

In spring 2024 (from March 21th to May 25th), animal experiments were conducted in our lab on a total of 15 healthy female Wistar rats (*Rattus norvegicus*) obtained from the Faculty of Science, Al-Azhar University, Assiut branch, with an average weight of 280±64 g. The rats were allotted into three groups (five rats/each group) according to the manner of death as follows:

- Group “1” (control), rats were killed by head dislocation (severing the spinal cord by pulling the head without severing the head, the rats died in the moment).
- Group “2” (drowning), rats were placed in a bucket filled with water and pushed down to avoid their floating (the rats died within 2-4 minutes).
- Group “3” (slaughtering), rats were killed by cutting the throat with a sterile blade (the rats died within 1-2 minutes).

After death, within 15 minutes, rat carcasses were transferred to the investigation room in labeled cork rectangular white plates. The study area was as isolated room to limit

human interference and consumer disturbances. The carcasses were placed two meters apart from each other to prevent the overlap of arthropod succession. For the first month, the carcasses were monitored daily at 11:00 am (the time of death) and then every three days until the rats remains were completely dried (no live or active arthropod were found in the carcasses). The stages of decomposition were recorded, and a digital camera was used to photograph the cadavers until the decaying remains stage (Figure 1). The ethical committee of the Faculty of Science, Assiut University, approved the investigation protocol under number (01-2024-0012).

Isolation, handling, and preservation of invertebrates from cadavers

During the first month following the rats' deaths, the cadavers were examined

every day. Invertebrates from each rat were taken, separated, identified, and counted (Table 1). For long-term preservation, the invertebrates were placed in either 10% neutral formalin or 72% ethanol. At the end of the experiment, the percentage of each species/group was calculated based on the total number of each species in the three groups.

Statistical analysis

Experiments were run in triplicate. Using SPSS (version 16, SPSS Inc., Chicago, IL) and Prism 5 statistical software, a one-way ANOVA with Tukey's *post-hoc* test was used to assess the significance of variances among the groups. $P < 0.05$ and $P < 0.01$ were considered a significant or highly significant, respectively.

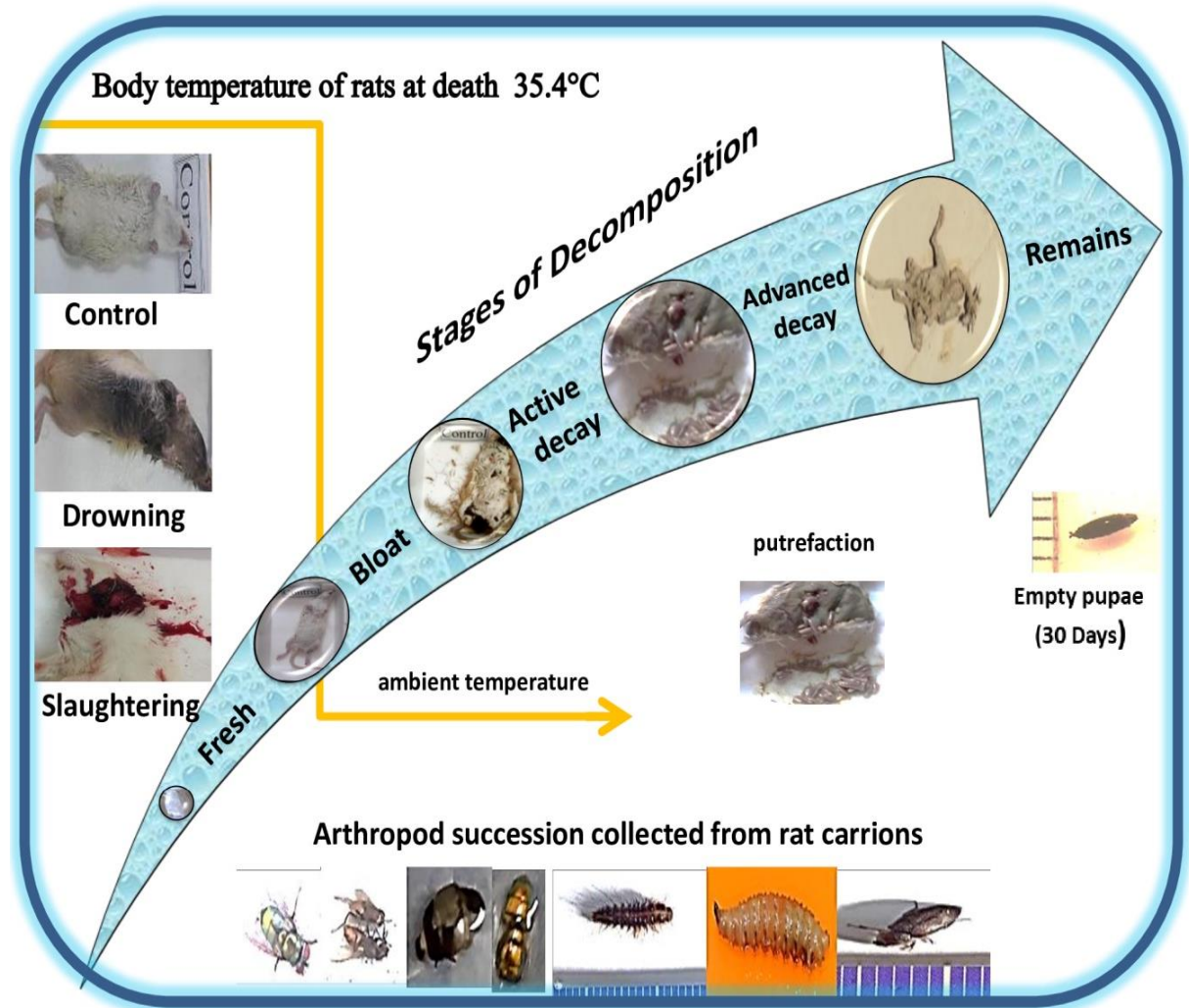


Figure 1: Diagram showing the investigation design.

Table 1: Invertebrates of forensic importance collected from rats' carrions in an indoor room over a period of 60 days postmortem.

Family	Species/Abbreviations	Adult Arthropods Numbers/Groups			Total
		Control	Drowning	Slaughtering	
Calliphoridae	<i>Chrysomya albiceps</i> /Ch (blow fly)	298	202	449	949
Apidae	<i>Apis</i> sp./Ap	0	0	4	4
Muscidae	<i>Musca domestica</i> /Mu (house fly)	15	4	16	35
Sarcophagidae	<i>Sarcophaga</i> sp./Sar (flesh fly)	218	184	272	674
	<i>Wohlfahrtia magnifica</i> /Wo	84	62	94	240
	<i>Parasarcophaga orgyrostama</i> /Pa	26	16	38	80
Dermestidae	<i>Dermestes maculates</i> /D1 (hide beetle)	35	23	52	110
	<i>Dermestes frischi</i> /D2	24	15	38	77
Histeridae	<i>Saprinus</i> sp./Sap (clown beetles)	37	25	50	112
Pteromalidae	<i>Nasonia</i> sp./Na	48	30	63	141
Lycosidae	Spider/Spi	32	25	43	100
Pyroglyphidae	<i>Dermatophagoides</i> sp./De (dust mites)	70	57	94	221
Cimicidae	<i>Cimex lectularis</i> /Ci (bed bugs)	88	60	111	259
Porcellionidae	<i>Porcellionides pruinosus</i> /Po (woodlouse)	19	11	32	62
Acaridae	<i>Sancassania berlesei</i> /Sb (mite)	11	3	13	27
Mononchidae	Nematode/Ne	68	53	90	211
Total		1073	770	1459	3302

*The abbreviations of carrions' invertebrates present in Figures "3-8" and Table "2".

RESULTS

Carrion's decomposition pattern

In the present study, all three groups exhibited the matching pattern, which involved five stages from the fresh stage to the skeletal stage (Figures 1 and 2). Rats in group "1" died instantly, while rats in groups "2 and 3" died within 1-4 minutes. Corpses are usually intact and free of arthropods in the autolysis (fresh) stage (0-12 hours, Figure 3). Corpses decompose as they lose body temperature until reaching the environmental temperature surround the

corpse. Corneal clouding, rigor mortis, or temporary stiffness of the limbs occur in the muscles due to chemical changes in the body, and rigor mortis results in the accumulation of blood on the side closest to the ground without swelling in the body. No putrid odors or discoloration of the skin were noticed in group "1", but in group "2" we observed blackening of the carcass from the ventral side and some arthropods species flying around the carrions especially in group "3" (Figure 3).

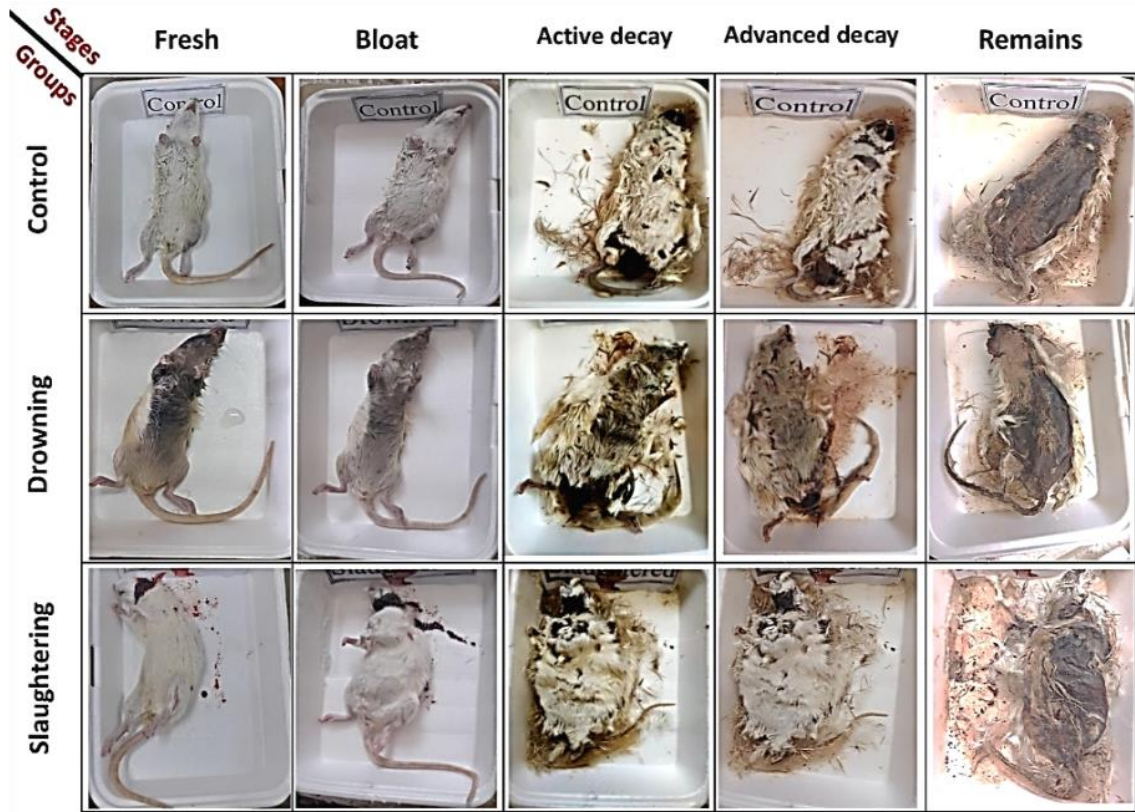


Figure 2: Overview showing the decomposition stages of rat carrions.

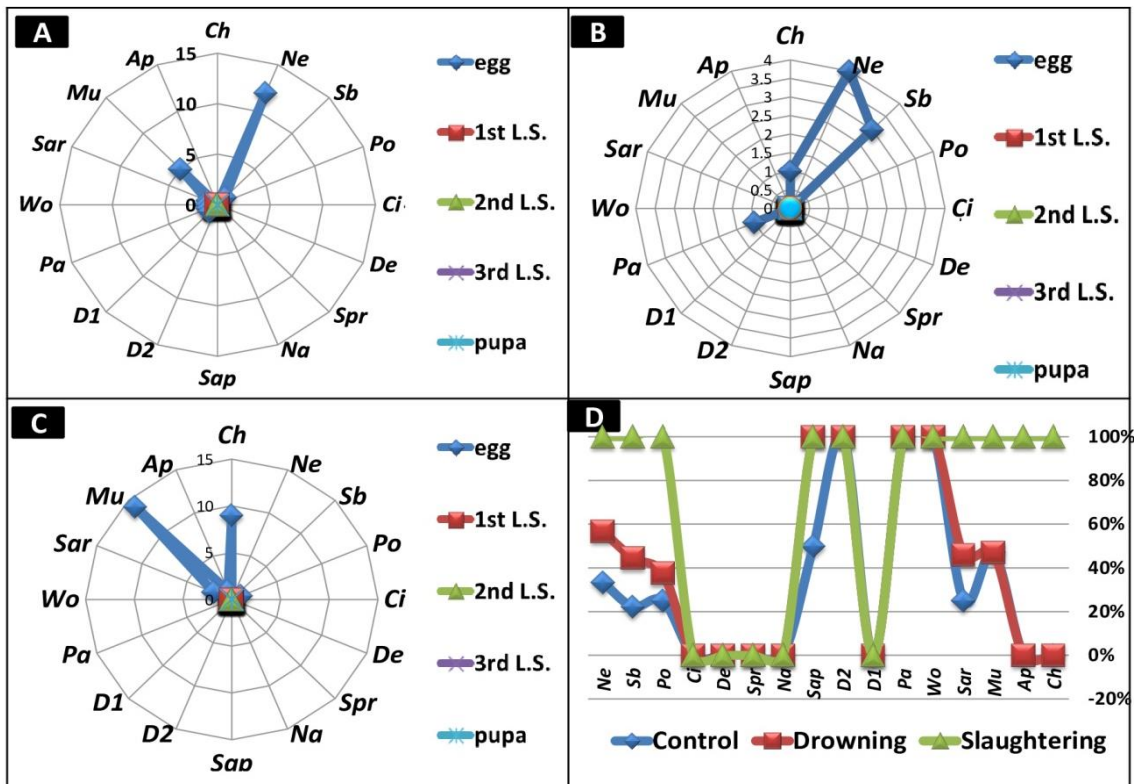


Figure 3: Number of arthropods from rat carrions in all groups in fresh stage. (A) Group “1”: control group, (B) group “2”: drowning group, (C) group “3”: slaughtering group, and (D) adult species in all three groups. L.S: Larval stage.

At the bloat stage (12 hours-3 days), resident microorganisms found in the digestive tract start to digest body tissues, excrete gases that cause swelling of the trunk and extremities, and produce foul-smelling chemicals including putrescine and cadaverine (Figure 4). The tissues break down and release hydrolytic enzymes, and the outer layer of skin becomes loose, causing the skin to slip. Digestive decomposition results in a dark, foul-smelling liquid

known as “purge fluid”, which is expelled from the nose and mouth due to gas pressure in the intestines. Bacteria changed from aerobic to anaerobic. The first arthropods to arrive at cadavers were: *Chrysomya albiceps*, *Musca domestica*, *Sarcophaga* sp., *Wohlfahrtia magnifica*, and *Parasarcophaga orgyrostama*. Besides the cadavers, beetles, isopods, ants, and spiders were also noticed. Groups “1 and 3” were more bloated than group “1” (Figure 4).

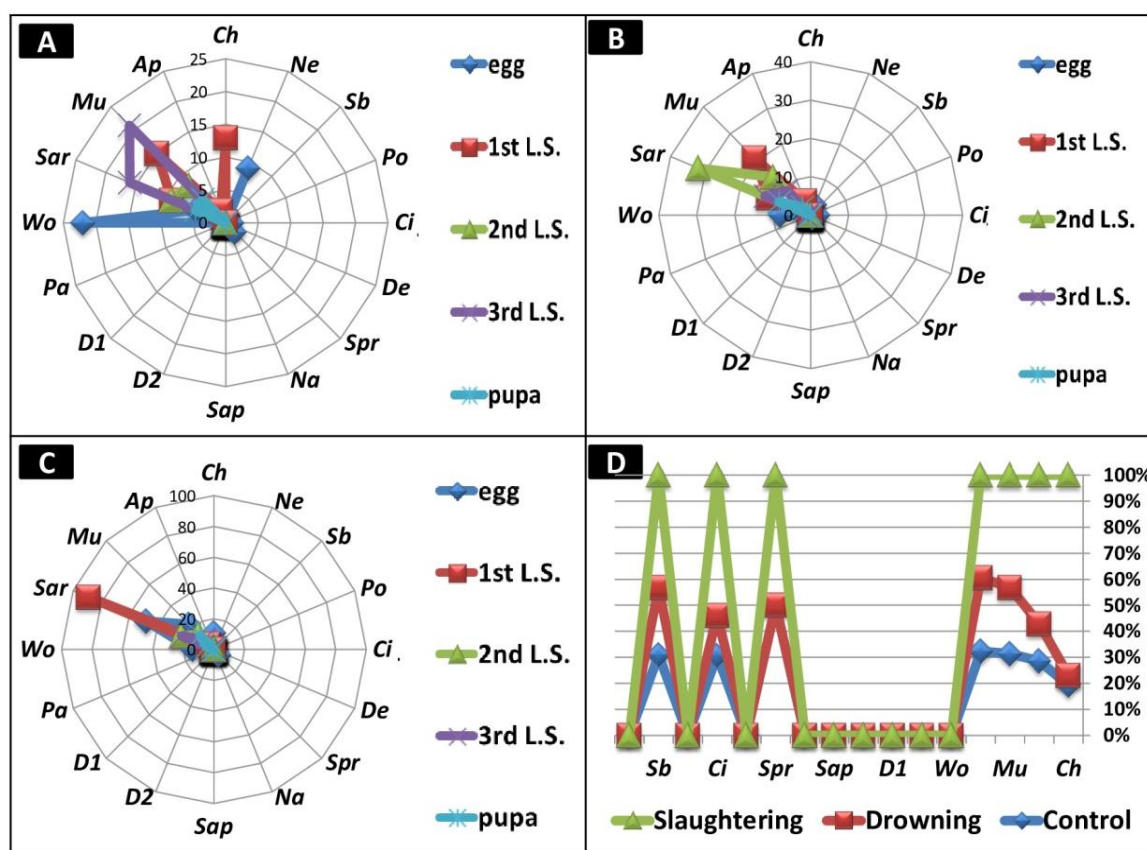


Figure 4: Number of arthropods from rat carrions in all groups in bloat stage. (A) Group “1”: control group, (B) group “2”: drowning group, (C) group “3”: slaughtering group, and (D) adult species in all three groups. L.S: Larval stage.

In the active decay stage (4-6 days), the tissues start to liquefy, while the skin begins to turn black (Figure 5). Blowflies target early decomposing corpses, through specific odor receptors, and lay their eggs in holes and exposed wounds. In group “1”, a black color in the mouth and anus was noticed. A large hole in the posterior region appeared in group “2”, while in group “3” the arthropods were markedly increased in the

wound. Tallow, or corpse wax, may form, preventing further decomposition (Figure 5). During the advanced decay stage (7-29 days), most of the remains change color and often turn black (Figure 6). Decay, where tissues and cells decompose and liquefy as the body decomposes, was almost complete causing changes in the chemistry of the surrounding soil (Figure 6). When the bloating stops, the soft tissue of the remains usually collapses

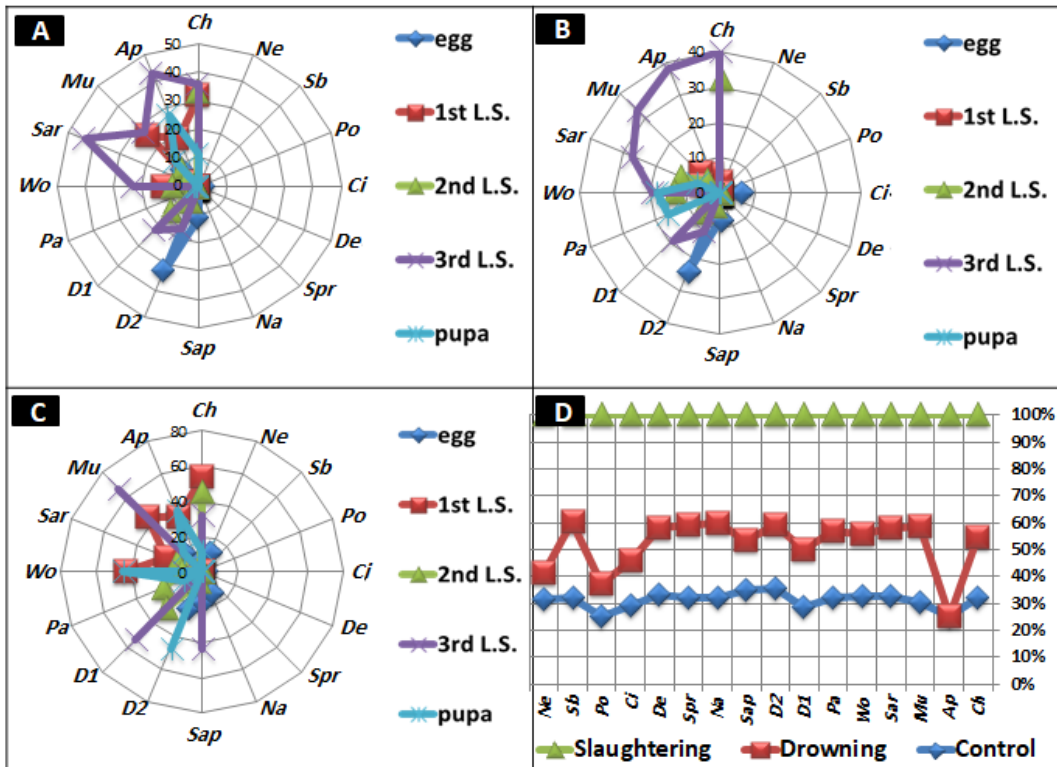


Figure 5: Number of arthropods from rat carrions in all groups in active decay stage. (A) Group “1”: control group, (B) group “2”: drowning group, (C) group “3”: slaughtering group, and (D) adult species in all three groups. L.S: Larval stage.

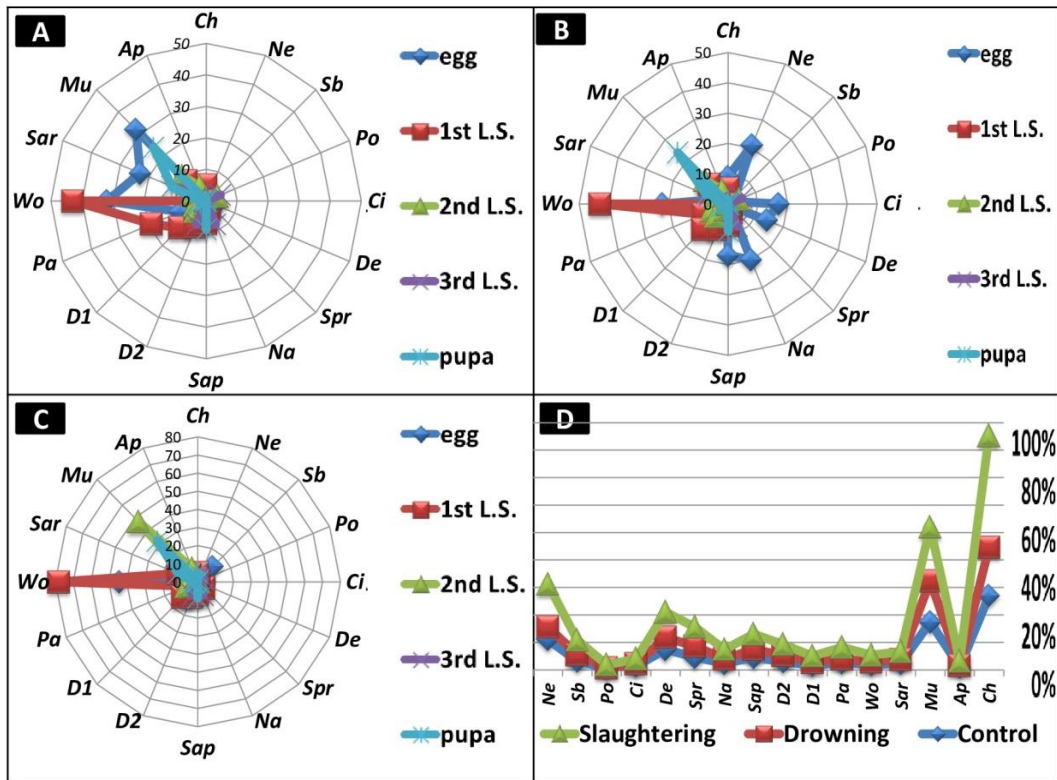


Figure 6: Number of arthropods from rat carrions in all groups in advanced decay stage. (A) Group “1”: control group, (B) group “2”: drowning group, (C) group “3”: slaughtering group, and (D) adult species in all three groups. L.S: Larval stage.

in on itself. In the active decomposition stage and at the dry/skeletonized stage (30-60 days), the remains often dry out. Fewer

specimens were found from Calliphoridae, Muscidae, and Sarcophagidae in the three groups (Figure 7).

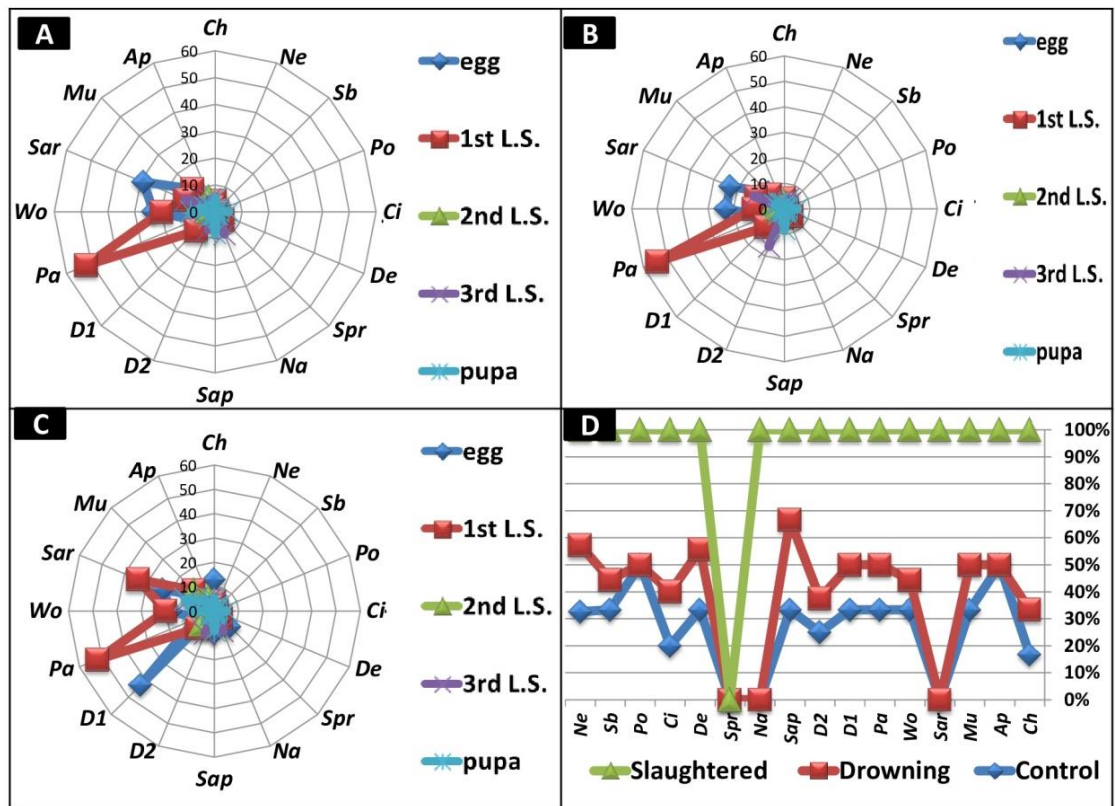


Figure 7: Number of arthropods from rat carrions in all groups in skeletonize (Dry) stage. (A) Group “1”: control group, (B) group “2”: drowning group, (C) group “3”: slaughtering group, and (D) adult species in all three groups. L.S: Larval stage.

Arthropods differentiated between the manners of death

Sixteen taxa and 13 Families of invertebrates were collected from rat cadavers as follows (Table 1): Family: Calliphoridae included *Chrysomya albiceps* (31.4%, 21.3%, and 47.3%), Family: Apidae included *Apis* sp. (0%, 0%, and 100%), Family: Muscidae included *Musca domestica* (42.9%, 11.4%, and 45.7%), Family: Sarcophagidae included *Sarcophaga* sp. (32.3%, 27.3%, and 40.4%), *Wohlfahrtia magnifica* (35.0%, 25.8%, and 39.2%), and *Parasarcophaga orgyrostama* (32.5%, 20.0%, and 47.5%), Family: Dermestidae included *Dermestes maculatus* (31.8%, 20.9%, and 47.3%), *Dermestes frischi* (31.2%, 19.5%, and 49.4%), Family: Histeridae included *Saprinus* sp. (33.0%, 22.3%, and 44.6%), Family: Pteromalidae

included *Nasonia* sp. (34%, 21.3%, and 44.7%), Family: Lycosidae included spider (32.0%, 25.0%, and 43.0%), Family: Pyroglyphidae included *Dermatophagoides* sp. (31.7%, 25.8%, and 42.5%), Family: Cimicidae included *Cimex lectularis* (34.0%, 23.2%, and 42.9%), Family Porcellionidae represented by *Porcellio laevis* (30.6%, 17.7%, and 51.6%), Family: Acaridae included *Sancassania berlesei* (mites, 40.11%, 11.1%, and 48.1%), and Family; Mononchidae (nematodes; 32.2%, 25.1%, and 42.7%) of groups “1, 2, and 3”, respectively (Figure 8). However, group “3”, the slaughtering group, showed a significant increase ($P<0.0001$) in the number of arthropods compared with the other two groups.

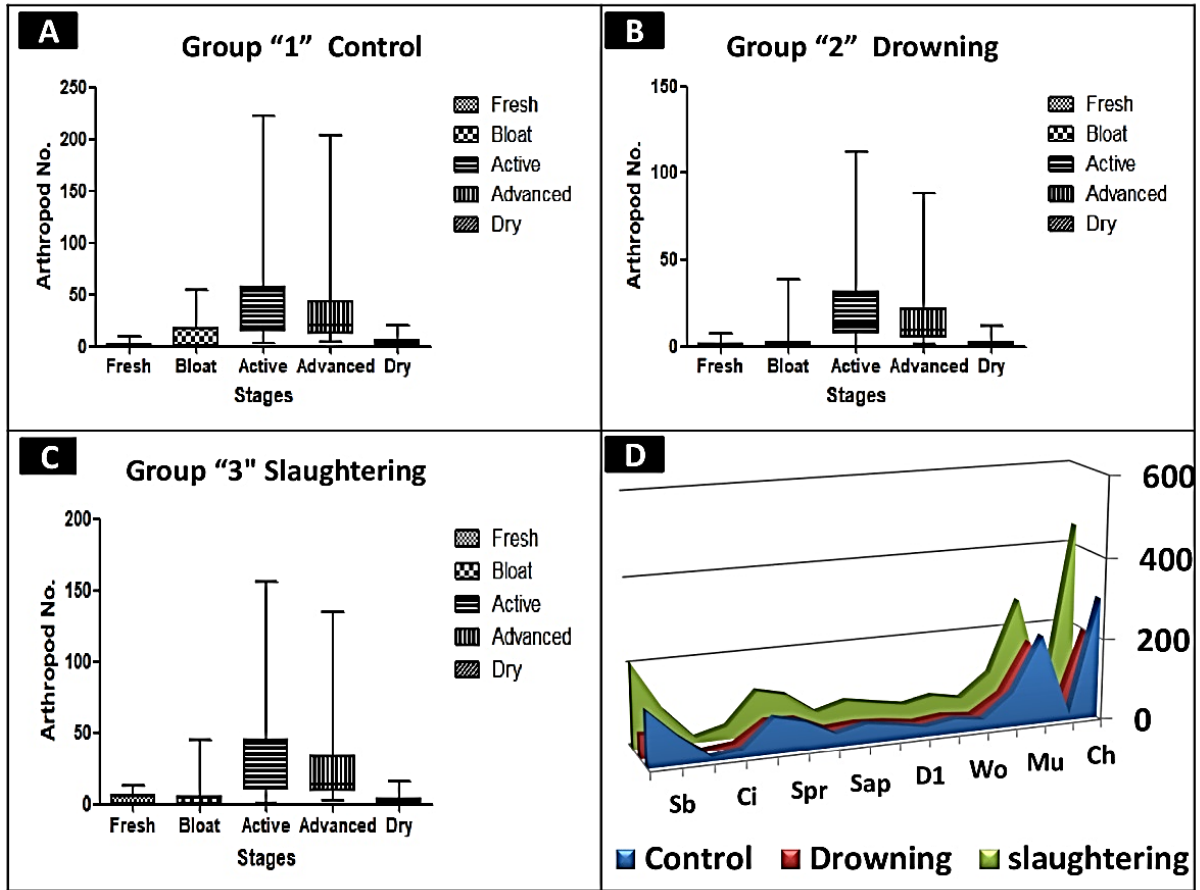


Figure 8: Number of arthropods from rat carrions in all groups in five stages of decomposition. (A) Group "1": control group, (B) group "2": drowning group, (C) group "3": slaughtering group, and (D) number of arthropods from rat carrions in all groups in the five stage of decomposition. Group "3" (slaughtering group) showed a significant increase in the number of arthropods compared with the other two groups (One-way ANOVA and Tukey's *post-hoc* test with significance set at $P < 0.0001$).

The comparison of adult species at the end of the study showed that some species had different distributions across the studied groups as follows (Table 2): Group "3" had a highly significant increase in *Chrysomya albiceps*, *Apis* sp., *Dermatophagoides* sp., and nematodes compared with groups "1 and 2". Moreover; group "2" had a significant increase in *Musca domestica* and mites, but had a significant decrease in *Wohlfahrtia magnifica*, *Dermestes maculatus*, and *Cimex lectularis* compared with groups "1 and 2". Additionally, group "2" had a highly significant decrease in *Sarcophaga* sp. compared with Group "3". An insignificant difference was observed in *Parasarcophaga* and *Dermestes frischii* among the three groups.

DISCUSSION

Forensic investigators employ the study of arthropods including insect populations to analyze the cause of death, such as poisoning, drowning, slaughtering, suicide, and electrocution^[13]. Therefore, determining the manner of death is a crucial aspect of criminal inquiry, especially when dealing with a severely decomposed body^[14]. The current study showed five phases of decomposition in rat carrions, which varied depending on the type of carcass and the duration of the stages. Farag *et al.*^[15] found four stages of decomposition in rats during the dry (remains) stage. Herein, we observed that the arthropods we gathered exhibited a greater number of taxa compared to the most previous research. Specifically, we

Table 2: Comparison of the numbers of isolated adult specimens in the studied groups throughout the entire study period.

Species Abbreviations	Control	Drowning	Slaughtering	P-value
Ch	59.6±1.3 ^b	41.0±14.3 ^b	89.8±21.5 ^a	0.001
Ap	0.0 ^b	0.0 ^b	0.8±0.4 ^a	<0.001
Mu	3.2±1.9 ^b	36.8±11.78 ^a	3.2±1.9 ^b	<0.001
Sar	43.6±22.2 ^{ab}	12.4±5.7 ^b	54.4±23.8 ^a	0.012
Wo	16.8±8.4 ^a	3.2±1.9 ^b	18.4±2.1 ^a	0.001
Pa	5.2±0.5 ^a	4.6±1.3 ^a	7.6±3.4 ^a	0.098
D1	7.0±0.0 ^a	3.0±0.0 ^b	10.4±3.9 ^a	0.001
D2	4.8±0.4 ^a	5.0±1.0 ^a	7.6±4.3 ^a	0.21
Sap	7.2±0.5 ^{ab}	6.0±1.6 ^b	10.0±2.7 ^a	0.014
Na	9.6±1.3 ^{ab}	5.0±0.0 ^b	12.6±4.8 ^a	0.004
Spi	6.4±0.56 ^b	11.4±0.9 ^a	8.6±4.8 ^{ab}	0.051
De	14.0±0.0 ^b	12.0±0.0 ^b	18.4±3.1 ^a	<0.001
Ci	17.6±1.3 ^a	2.2±0.4 ^b	22.2±15.3 ^a	0.001
Po	3.8±0.5 ^b	0.6±0.6 ^c	6.4±2.3 ^a	<0.001
Sb	2.2±0.5 ^b	10.6±1.3 ^a	2.6±2.1 ^b	<0.001
Ne	13.6±0.9 ^b	11.8±0.0 ^b	18.0±1.6 ^a	<0.001

Data are presented as mean ± standard deviation. Comparisons were performed using ANOVA test and Tukey's *post-hoc* test with significance set at *P*-value <0.05. Different superscript letters in the same row indicate statistical difference.

documented a total of 19 invertebrates' taxa; 16 taxa were recorded from the three groups. The collected arthropods belong to 12 Families and there were 3 species from three orders registered only in the study room ground (cockroaches: Blattodea, mosquitoes: Diptera, and silverfish: Thysanura); the presence of these insects only is due to the presence of carrions indoors. Forensic entomology has received great interest in the past decades^[7,8,16]. In Egypt, Aly *et al.*^[17] recorded 18 insect species on rabbits corpses in Upper Egypt; Abd El-Aziz and El Shehaby^[18] identified 13 arthropods' taxa from uncovered rat carrions in an aerated environment in the spring season in Assiut; and Farag *et al.*^[15] Collected 12 insect species from indoor rat carrions in summer. Five stages of decomposition were demonstrated in the current analysis; with few minor differences, similar observations were reported by others^[15,17,19]. It is worth

mentioning that Egyptian environmental conditions are the best for increasing arthropods richness, a fact discussed by some researchers^[20,21] who recorded that *Cimex lectularius* is more predominant in temperate weathers, where directly exposure to the sun decreases the life cycle of insects^[16]. The two factors most crucial to the breakdown of the body are temperature and arthropod access^[6]. Most researchers have noticed that there were carrions where Calliphoridae and Sarcophagidae have been found^[22,23]. Also, our results indicated that Calliphoridae, Muscidae, and Sarcophagidae flayed surround rat carrions.

Once the animal dies, and within a few minutes of its death, the decomposition process begins. This is due to various physiological changes that in turn lead to rot. Different insects begin to search for the corpses and attach them. Different types of insects are considered evidence of the

duration of death^[24]. In this investigation, diverse invertebrates' taxa were collected from all rat carrions groups. There were 16 invertebrates' taxa belong to 13 Families, including 12 arthropods Families (Calliphoridae, Sarcophagidae, Muscidae, Pteromalidae, Dermestidae, Histeridae, Lycosidae, Pyroglyphidae, Cimicidae, Porcellionidae, Apidae, and Acaridae) and one nematodes Family (Mononchidae). Al-Shareef and Al-Mazyad^[25] discovered a few bug species on a rabbit carcasses in an urban area in Jeddah city, Saudi Arabia: two species of Coleoptera and six species of Diptera. According to the study of Abd El-bar and Sawaby^[26], out of all the rabbit carrions that were analyzed in El-Qalyubiya Governorate of Egypt, only 16 kinds of arthropods were found. This discovery may be explained by the tiny size of the dead carcasses, which could contribute to faster decomposition and a shorter postmortem length^[27]. Another explanation is that they could also be quickly devoured by the early invader arthropods, denying any chance to later colonizer species^[28]. Additionally, the sun-exposed corpses had a far stronger scent and odor^[29]. In a similar vein, just a few kinds of insects were extracted from guinea pigs carcasses^[30], only six insect species were collected from buried rat cadavers in different types of soil^[31], and Aly *et al.*^[17] listed ten arthropod species and seven Families from rabbit and rat. Big animal carcasses typically draw a lot more species; Wang *et al.*^[32] collected 47 species from pig carcasses. In the present study, the largest number of arthropods was found on the slaughtered carrions. Ojianwuna *et al.*^[33] observed the presence of ants surrounding the strangled and killed rat cadavers without any discernible pattern from the fresh to the active decay stages. Abd Elaziz *et al.*^[34] recorded damaged *Sarcophaga* sp. (flesh fly) larvae, which feed on mice carrion killed by ZIF-8 and ZIF-L toxicity. Salim *et al.*^[35] explained the damage in development of *C. albiceps* larvae found on morphine-treated rabbit carcasses. Abd Elaziz *et al.*^[36], collected 14 species of arthropods from the

corpses of animals killed by scorpion stings and the drug digoxin, while Abd Elaziz *et al.*^[37] Studied the effect of scorpion venom and poison on arthropods collected from rabbit carcasses. In the present study, livor mortis (post-mortem tumor or post-mortem glaucoma) was observed. Livor mortis requires differentiation from a contusion or bruise, which is caused by the rupture of a blood vessel as a result of the impact of a blunt force and the depletion of blood in the surrounding tissue^[38].

There are five stages of decomposition, namely fresh, swollen, active decomposition, advanced decomposition, and skeletal stages^[18,38]. It may be difficult for forensic scientists to determine and classify the condition of the cadaver based on only one stage^[39]. There are several internal and external factors that cause these shifts, which vary from one geographical region to another and from season to season within the same region. Therefore, this has become a crucial aspect of forensic autopsy and is essential for determining the PMI or time since death. Estimating the PMI using entomological techniques involves estimating the minimum PMI based on the age of the oldest fly larvae found on decomposing remains^[40]. In this study, we observed a highly significant increase in *Chrysomya albiceps*, *Apis* sp., and nematodes in group "3" compared with groups "1 and 2". This increase can be attributed to the manner of death, as slaughtered carrions containing wound can accelerate the stages of decomposition. However, there was no significant difference in the low numbers of *Parasarcophaga* and *Dermestes frischii* among the three groups, indicating the influence of indoor environments in protecting the carcasses from certain flies and beetles. Air serves as the medium through which flies are transported to corpses^[41].

The results of the current study showed the arrival time of the first arthropods, as well as the species of arthropods, and how they related to the different phases of decomposition. In addition, the current study

indicated that the 16 invertebrates' taxa, which are of forensic significance, belong to the Phylum: Arthropod (12 Families) and Phylum: Nematoda (one Family). Therefore, arthropods may be useful for predicting the postmortem period of internal carcasses and the manner of death.

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CONFLICT OF INTEREST

The author has no conflict of interest.

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تقدير دور تعاقب المفصليات في التنبؤ بفترة ما بعد الوفاة لجثث الجرذان الغارقة والمذبوحة في الأماكن المغلقة

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يُعد تقدير فترة تتابع تحلل الجثة، أو ما يسمى بفترة ما بعد الوفاة، موضوعًا يشغل علماء مفصليات الطب الشرعي منذ القرن التاسع عشر، حيث تُعتبر المفصليات إحدى اللاقاريات الرئيسية التي تستهدف الوصول إلى الجثث واستعمارها. هدفت الدراسة الحالية إلى التعرف على تعاقب المفصليات في جثث الفئران في الأماكن المغلقة. وتتناول الدراسة الحالية العلاقة بين مراحل نمو يرقات المفصليات وفترة ما بعد الوفاة. تم تخصيص خمسة عشر جردًا (*Rattus norvegicus*) من الإناث من سلالة (Wistar) قُسمت بالتساوي إلى ثلاثة نماذج تجريبية بناءً على طريقة وفاتهم: المجموعة "1" (التحكم، القتل بخلع الرأس)، المجموعة "2" (القتل بالغرق)، والمجموعة "3" (القتل بالذبح). لم تختلف وفرة المفصليات المرتبطة بشكل كبير بين مجموعتي الكنترول والغرق، ولكن هناك اختلافات واضحة بين المجموعتين في شكل ولون الحيف. وأظهرت المجموعة "3" (المذبوحة) اختلافًا كبيرًا في وفرة المفصليات المرتبطة بها عن المجموعتين "1" و "2". وذكرت هذه الدراسة ستة عشر نوعًا من اللاقاريات تنتمي إلى 13 فصيلة (12 فصيلة تنتمي إلى شعبة: مفصليات الأرجل وفصيلة واحدة تنتمي لشعبة: الديدان الخيطية):

Chrysomya albiceps (28%), *Apis* sp. (0.11%), *Musca domestica* (6%), *Sarcophaga* sp. (16%), *Wohlfahrtia magnifica* (6%), *Parasarcophaga orgyrostama* (3%), *Dermestes maculatus* (3%), *Dermestes frischii* (3%), *Saprinus* sp. (3%), *Nasonia* sp. (4%), spiders (4%), *Dermatophagoides* sp. (7%), *Cimex lectularis* (6%), *Porcellio laevis* (2%), mites (2%), nematodes (6%).

والخلاصة، توفر الدراسة الحالية أساسًا لمزيد من الدراسات التي تتناول تعاقب المفصليات في التنبؤ بفترة ما بعد الوفاة لجثث الفئران في الأماكن المغلقة وطريقة الوفاة.