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Morphological and Diagnostic Study of Forensically Important Insects Associated with Carcasses and Their Role in Postmortem Interval Estimation

A Thesis

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿ فَلَمَّا قَضَيْنَا عَلَيْهِ الْمَوْتَ مَا دَلَّهُمْ عَلَى مَوْتِهِ إِلَّا
دَابَّةُ الْأَرْضِ تَأْكُلُ مِنْسَأَتَهُ فَلَمَّا خَرَّ تَبَيَّنَتِ الْجِنَّ أَنْ
لَوْ كَانُوا يَعْلَمُونَ الْغَيْبَ مَا لَبِثُوا فِي الْعَذَابِ الْمُهِينِ ﴾

صدق الله العلي العظيم

سورة سبأ / الآية 14

Dedication

To the guide and savior of this nation,

the master of all creation and the finest of humanity,

**The Chosen Prophet Muhammad, peace and blessings be upon him and his
family,**

and to his pure household, from whom Allah has removed all impurity and purified
thoroughly,

**and especially to the gate of hope and refuge of the perplexed, the awaited
Imam Al-Hujjah ibn Al-Hassan Al-Mahdi, may Allah hasten his noble
reappearance...**

To the soul of my martyred father,

who departed and watered the soil of this beloved homeland with his pure blood,
and to the souls of Iraq's righteous martyrs who spared nothing of what was most
precious to them...

To the one who taught me patience and boundless generosity,

to the beloved of my heart and soul, my dearest mother...

To my brothers and sisters, companions on this path and people of loyalty...

To my support in life and the source of my strength and pride,

my dear husband, who stood by my side every step of the way...

To the blossoms of my heart and the joy of my soul, my beloved children...

To all of these, I dedicate the fruit of my effort and the culmination of my years.

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Summary

The present study aimed to document the succession of forensically important insects, identify insect species associated with animal carcasses, and estimate the postmortem interval (PMI) under different environmental conditions in Al-Diwaniyah Province, Iraq. Field experiments were conducted at two contrasting sites, namely an agricultural area and a human cemetery in Al-Daghara District, using dog carcasses with weight (30–40 kg) and wild boar carcasses with weight (60–120 kg) placed under two burial conditions (surface and buried). The study was carried out from 25 June 2025 to 6 April 2026. Insect specimens were identified using morphological characteristics and standard taxonomic keys, while statistical analyses were restricted to the most abundant and forensically significant species. The results of the study can be summarized as follows:

First: Eight species belonging to the order Diptera were identified: *Calliphora vicina*, *Lucilia sericata*, *Chrysomya megacephala*, *Chrysomya albiceps*, *Chrysomya putoria*, *Musca domestica*, *Sarcophaga vagans*, and *Sarcophaga haemorrhoea*. Members of the family Calliphoridae were the first insects to colonize the carcasses and predominated during the early stages of decomposition, whereas members of the families Muscidae and Sarcophagidae appeared progressively as decomposition advanced.

Second: Eight species belonging to the order Coleoptera were identified: *Dermestes frischii*, *Dermestes maculatus*, *Dermestes ater*, *Dermestes peruvianus*, *Necrobia rufipes*, *Saprinus subnitescens*, *Euspilotus richteri*, and *Mesostena puncticollis*. These beetles were primarily associated with the advanced and skeletal stages of decomposition, with members of the families Dermestidae and Cleridae becoming increasingly abundant as the carcasses dried.

Summary

Third: Three species belonging to the order Hymenoptera were identified: *Cataglyphis livida*, *Camponotus xerxes*, and *Messor syriacus*. These species were observed during different stages of decomposition, and their occurrence was mainly associated with the surrounding environmental conditions rather than with a specific stage of decomposition.

Fourth: Carcass decomposition proceeded through five distinct stages: the fresh stage, bloated stage, active (wet) decay stage, advanced (dry) decay stage, and skeletal stage. The duration of decomposition ranged from approximately 1.10 to 37.00 days. Burial depth was the principal factor influencing decomposition rate, with buried carcasses requiring significantly longer to decompose than surface carcasses, averaging 53.09 days compared with 20.92 days, respectively.

Fifth: Significant effects of carcass type, study environment, and burial condition on insect succession and species abundance were observed. Differences in the arrival time and composition of insect communities were evident among the different treatments, while burial delayed insect colonization and reduced insect abundance compared with surface-exposed carcasses.

Sixth: Statistical analyses were limited to the most abundant and forensically important species, namely *Calliphora vicina*, *Lucilia sericata*, *Musca domestica*, *Chrysomya megacephala*, *Chrysomya albiceps*, *Sarcophaga vagans*, *Dermestes frischii*, *Dermestes maculatus*, and *Necrobia rufipes*. These species exhibited significant differences in abundance and succession patterns according to carcass type, study environment, and burial condition.

Seventh: The postmortem interval (PMI) was estimated using third-instar (L3) larvae by applying two complementary approaches: the Accumulated Degree Hours (ADH) method and a statistical model based on larval length. The estimated PMI differed significantly according to carcass type, study

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environment, and burial condition, highlighting the importance of incorporating these variables into PMI estimation models under hot environmental conditions.

Eighth: This study represents one of the forensic entomology investigations conducted under environmental temperatures exceeding 40°C. It provides the first comprehensive dataset from Al-Diwaniyah Province, southern Iraq, on insect succession and postmortem interval estimation for both surface-exposed and buried carcasses. In addition, the study presents taxonomic identification keys for the recorded insect species, thereby establishing a valuable regional reference database for forensic entomology and supporting future medico-legal investigations in hot arid environments.

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List of Abbreviations and Symbols

Symbol / Abbreviation	Meaning
PMI	Post-Mortem Interval
PAI	Pre-Appearance Interval
TOD	Time of Death
ADH	Accumulated Degree Hours
LDT	Lower Developmental Threshold
LSD	Least Significant Difference (statistics)
DNA	Deoxyribonucleic Acid
L3	Third-Instar Larva
sp. / spp.	Species (singular / plural)
AOS	Accessory Oral Sclerite
SS	Sutural Stria
°C	Degrees Celsius
%	Percent
±	Plus / minus
* / **	Significant ($P \leq 0.05$) / highly significant ($P \leq 0.01$)
kg / g	Kilogram / gram
Km	Kilometre
mm / cm	Millimetre / centimeter
H	Hour

Contents

Table of Terminology

A glossary of the principal technical terms used in this dissertation.

Term	Definition
Forensic entomology	The application of the study of insects and other arthropods to legal investigations, principally to estimate the post-mortem interval.
Post-mortem interval (PMI)	The elapsed time between death and the examination or discovery of the remains.
Decomposition	The progressive breakdown of soft tissues after death, divided into successive stages (fresh, bloated, active decay, advanced decay, skeletal).
Insect succession	The predictable sequence in which different insect taxa colonise a carcass as decomposition proceeds.
Carrion / carcass	Dead animal remains that serve as the substrate for decomposition and insect colonisation.
Oviposition	The laying of eggs by adult insects on or near the remains.
Larval instar	A developmental stage of an insect larva between moults; the third instar (L3) is the largest larval stage used in PMI estimation.
Accumulated Degree Hours (ADH)	The cumulative thermal energy (temperature $\times$ time) required to reach a given developmental stage, used to back-calculate PMI.
Lower Developmental Threshold (LDT)	The minimum temperature below which insect development effectively ceases.
Pre-Appearance Interval (PAI)	The interval between death and the first appearance of a given insect taxon on the remains.
Pupariation / puparium	The process by which a mature fly larva forms a hardened puparium before the pupal stage.
Calliphoridae (blow flies)	A dipteran family of primary forensic importance, usually the first colonisers of fresh remains.
Dermestidae (skin / hide beetles)	A coleopteran family characteristic of the later, drier stages of decomposition.
Entomological evidence	Insect specimens and developmental data collected from remains and used as physical evidence in legal contexts.

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Chapter One

Introduction

1.1 Introduction

Forensic entomology is the scientific discipline concerned with applying knowledge of insect biology and ecology to legal investigations, particularly the estimation of the postmortem interval (PMI). The colonization, succession, and development of insects on decomposing remains provide important information concerning the time, location, and circumstances surrounding death. In addition to PMI estimation, insect evidence can assist in determining whether a body has been relocated, identifying antemortem injuries, and detecting toxic substances through entomotoxicological analysis (Matuszewski *et al.*, 2024a; Bambaradeniya *et al.*, 2024).

The reliability of forensic entomology is strongly influenced by environmental conditions. Insect succession and developmental rates vary considerably according to local climatic and ecological factors, making region-specific datasets essential for reliable forensic interpretation (Matuszewski *et al.*, 2024b; Bambaradeniya *et al.*, 2024). Temperature is particularly important because necrophagous insects are poikilothermic organisms whose metabolic activity, developmental rate, and life-cycle duration are directly regulated by the surrounding thermal environment (Roe & Higley, 2023). Most forensically important blowfly species develop optimally between approximately 16 and 35°C; however, temperatures exceeding 40°C can markedly alter insect activity, survival, and developmental timing. Extreme heat may reduce survival in some species while accelerating decomposition and favoring thermotolerant species in others (Kandowangko *et al.*, 2024; Matuszewski *et al.*, 2024a).

Decomposition generally progresses through five recognized stages: fresh, bloated, active decay, advanced decay, and skeletal (Kandowangko *et al.*, 2024). Elevated temperatures can substantially accelerate this process. For example, pig carcasses exposed to an ambient temperature of 39.7°C completed

the bloated stage within two to three days and the active decay stage within three to five days, demonstrating the limited applicability of temperate-derived PMI models to hot environments (Abbasi, 2025). Consequently, insect colonization and succession must be evaluated under the specific climatic conditions in which forensic investigations are conducted.

Insect colonization of decomposing remains follows an ecological succession that changes with decomposition stage and habitat characteristics (Kandowangko *et al.*, 2024; Abbasi, 2025). Three insect orders are of primary forensic importance. Diptera are generally the most important, particularly the family Calliphoridae, which includes genera such as *Chrysomya* and *Lucilia*. These flies commonly represent early colonizers of decomposing remains and can develop rapidly under suitable environmental conditions (Roe & Higley, 2023). Muscidae and Sarcophagidae are also frequently associated with decomposing remain and contribute to colonization during different stages of decay (Kandowangko *et al.*, 2024). Coleoptera, including carrion-associated and predatory families such as Silphidae and Staphylinidae, become increasingly important during active and advanced decomposition (Deshpande *et al.*, 2024). Hymenoptera, particularly Formicidae, may occur throughout decomposition and can act as scavengers or predators of fly eggs and larvae (Kandowangko *et al.*, 2024).

Under high-temperature conditions, thermotolerant insect species may become more prominent and their developmental rates may differ substantially from those observed in temperate regions. For example, *Chrysomya megacephala* has been reported to complete its life cycle in approximately 9–10 days at 34°C, compared with 14–21 days under temperate conditions (Roe & Higley, 2023). Such differences demonstrate the importance of obtaining

locally derived developmental and succession data rather than relying exclusively on models developed under different climatic conditions.

The use of animal carcasses as substitutes for human remains has long been an important component of decomposition research in forensic entomology (Miles *et al.*, 2020). Domestic pigs (*Sus scrofa domestica*) have been widely adopted as experimental models because of their anatomical and physiological similarities to humans, including comparable skin characteristics and general body composition. Entomological investigations have also demonstrated similarities in the colonization and succession of major necrophagous insects on pig and human remains (Matuszewski *et al.*, 2020; Miles *et al.*, 2020). The use of animal models additionally provides greater experimental control and reproducibility than human cadaver studies.

Carcass biomass may also influence decomposition and insect succession; however, its precise effect remains unresolved. Previous studies have reported differing relationships between carcass mass and decomposition rate, indicating that additional controlled investigations are required to clarify the influence of biomass on decomposition and insect colonization (Miles *et al.*, 2020). Therefore, comparison of carcasses with different body masses may provide useful information concerning the interaction between carcass characteristics, decomposition, and insect succession.

The present dissertation investigates medium-sized dog carcasses with weight 30–40 kg and wild pig (*Sus scrofa*) carcasses with weight 60–120 kg. The wild pig was selected as the principal experimental model because of its established anatomical, physiological, and entomological similarities to humans, while the inclusion of dog carcasses provides a comparative model for evaluating differences in decomposition and insect colonization associated with carcass type and biomass.

Despite the considerable development of forensic entomology internationally, regionally specific data remain limited in Iraq. Most available PMI models have been developed under temperate climatic conditions and may therefore have limited applicability to the extreme heat characteristic of Iraqi summers, when ambient temperatures frequently exceed 40°C. Furthermore, baseline information concerning insect succession associated with vertebrate carcasses under hot-arid Iraqi conditions remains limited. The absence of locally validated data represents an important gap in the practical application of forensic entomology to medico-legal investigations in Iraq.

The present dissertation addresses this gap by providing forensic entomological data from Al-Diwaniyah Province, southern Iraq. It investigates insect succession and decomposition of buried and surface-exposed dog and wild pig carcasses under the high-temperature conditions characteristic of the region. In addition, the study provides experimental data on the use of wild pig (*Sus scrofa*) carcasses in forensic entomological research in Iraq, contributing to the establishment of a regional reference framework for future forensic and medico-legal investigations.

1.2 Objectives of the Study

The present study aims to:

1. To identify the successive stages of decomposition and determine their durations for buried and surface-exposed dog carcasses with weight 30–40 kg and wild pig (*Sus scrofa*) carcasses with weight 60–120 kg under high-temperature conditions exceeding 40°C in Al-Diwaniyah Province, southern Iraq.
2. To catalogue and identify insect species colonizing and attracted to each carcass type in two forensic environments, an agricultural field and a human

cemetery, and to determine which species are capable of completing their life cycles under these environmental conditions.

3. To develop a region-specific mathematical model for postmortem interval (PMI) estimation under hot-climate conditions based on larval length, ambient temperature, larval developmental stage, and carcass mass.
4. To test the hypothesis that certain necrophagous insect species are unable to survive at temperatures exceeding 40°C and to identify locally adapted species capable of persisting under extreme heat stress.
5. To compare the findings of the present study with those reported from temperate and hot-climate regions and to evaluate the influence of climate, carcass mass, and geographic location on insect succession and decomposition patterns.

Chapter Two

Literatures Review

2. Literature Review

2.1 Forensic Entomology: Definition and Scope

Forensic entomology is a specialized branch of forensic science that applies the study of insects and other arthropods associated with decomposing remains to legal investigations. It plays a crucial role in estimating the postmortem interval (PMI), identifying body relocation, detecting ante-mortem injuries, and assisting in forensic toxicology through the analysis of insects feeding on human or animal remains. Recent advances in molecular biology, including DNA barcoding and molecular identification techniques, have significantly improved the accuracy of insect species identification and the reliability of forensic interpretations. Despite these advances, insect succession and development remain strongly influenced by environmental and geographical conditions, emphasizing the need for region-specific forensic entomological data. (Deshpande, 2024).

Postmortem interval (PMI) estimation represents one of the principal applications of forensic entomology. By analyzing the developmental stages and succession patterns of insects associated with decomposing remains, forensic entomologists can estimate the minimum time since death with greater accuracy than many conventional methods during the later stages of decomposition. Beyond PMI estimation, forensic entomology contributes to determining whether a body has been relocated, detecting ante-mortem injuries, identifying insect-associated toxins or drugs, and supporting victim identification through molecular analyses. Recent advances in DNA barcoding, molecular genetics, and artificial intelligence have further enhanced the accuracy and reliability of insect identification and forensic interpretation. (Amendt *et al.*, 2021).

2.2 Forensic Entomology Through Time

The history of forensic entomology dates back to the thirteenth century during the Chinese Song Dynasty. The earliest documented application is attributed to Song Ci (Sung Tz'u), who described the famous "sickle murder case" in his book *Xi Yuan Ji Lu* (The Washing Away of Wrongs) published in 1247. In this case, flies were attracted to traces of blood remaining on a sickle that had been cleaned, enabling investigators to identify the murder weapon and obtain the offender's confession. This case is widely recognized as the first recorded application of insect evidence in a criminal investigation and marks the foundation of modern forensic entomology. Since then, the discipline has evolved substantially, integrating entomology with molecular biology, ecology, and forensic science to improve the estimation of the postmortem interval (PMI) and support criminal investigations (Benecke, 2001; Byrd & Castner, 2010; Deshpande, 2024).

Early clues can be traced in the way insects grow; they do not appear out of thin air but go through their stages. Around 1850 in France this kind of thing made its way into a courtroom. Workmen had been digging and came across the mummified remains of an infant. The insects around it told the story: the child was long dead, much earlier than anyone thought, and so the tenants were exonerated. Bergeret wrote of it some years on. Nowadays, Yovanovich and Megin are often mentioned together when discussing the tracking of bugs on a body over a matter of weeks or months.

The process is simple once the heart has stopped and the blood no longer runs. Rotting flesh gives off gases and the blowflies are there first to mark the beginning of decomposition. Beetles will follow in due course, working their way from the damp tissue to what is dry. And when they have done their part,

all that is left is the skeleton. A researcher named Smith sorted creatures found on dead bodies into four groups back in 1986

Burrowing into dead flesh, these bugs survive by eating what others avoid. Their presence marks a stage few creatures can handle.

Some creatures stalk the insects feeding on dead matter. Others live by invading them from within.

Some wasps, ants, plus certain beetles feed on both flesh and the creatures already living within it. They do not pick sides when eating.

Certain species just end up being found on the ground. They are not hunters; they just happen to come by cruising along. Springtails and then spiders join in. The spiders do not announce their presence, and there is no trace of their arrival. They merely see a body and think of it as just another stick or log for them to sit on. Small "creatures" who have come to sit still while they are there.

Flies and beetles are the leading species of insects that provide evidence at the scene of a crime. Insects are the primary source of almost all evidence at a crime scene. The arrivals of flies and beetles give timing clues concerning the time of death. However, experts continue to have differences of opinion regarding when one stage of decay ends and another begins. The number and variation of insects in Africa are astounding. More than 300 species from at least 40 families have been identified (Payne, 1965; Smith, 1986); and the numbers of species and families are similar to northern continents and tropical regions (Carvalho and Mello-Patiu, 2008; Almeida and Mise, 2009).

There is great difficulty in distinguishing between two different subspecies of insects in portions of Sub-Saharan Africa. In Nigeria, for example, there are few publications that document the adult form of insects

(i.e., flies), while there are almost no publications that provide photographs of larvae (i.e., immature form). As a result of these limitations, larvae often develop to the adult stage before they can be identified; therefore, before larvae reach maturity, many of them die from lack of ability to identify them.

At the same time, laboratories across nations such as the United States and the UK apply DNA analysis effective at any age, including embryos, firmly connecting immature phases to their grown counterparts. This difference leads to a central issue: relying only on visible features without gene-based techniques makes forensic judgments weaker, more uncertain, less dependable.

2.3 The Latest Approved Classification of Subfields 2025–2026

1. Medico-legal Entomolog: is the principal branch of forensic entomology concerned with the application of insects and other arthropods in criminal investigations involving human and animal remains. Its primary role is the estimation of the postmortem interval (PMI) based on insect succession and developmental stages. In addition, it assists investigators in determining whether a body has been moved after death, detecting ante-mortem or post-mortem injuries, and identifying the presence of drugs or toxic substances through forensic entomotoxicology. Accurate interpretation of insect evidence requires consideration of environmental factors, geographical location, and species-specific developmental patterns. (Matuszewski *et al.*, 2024a; Deshpande, 2024; Byrd & Castner, 2010).

2. Stored Product Entomology: Although, consumer law businesses are not criminals but the concern is who takes the blame when a product that has been bought becomes bugged. Situations like wheat that is rotten and was bugged before purchase and the loss of crops due to insects could be the basis of an action or claim. It is just as important to know how the bug was there as it is to know who caused the problem, and the issue of how the product was bugged

now takes the forefront as time now becomes of the utmost importance since who and how it happened can become just as legally important (Byrd & Castner, 2010).

3. Urban Entomology: Urban entomology is a major branch of applied entomology concerned with arthropods associated with human-built environments, including residential buildings, hospitals, hotels, schools, commercial facilities, and other urban infrastructures. It focuses on insects and other arthropods that affect public health, damage structures, contaminate food, or create economic losses. As global urbanization continues to increase, urban entomology has become an essential discipline that integrates research, pest management, environmental health, and public education to improve the quality of urban living and protect human health and property (Rust *et al.*, 2024).

4. Medical and Veterinary Entomology: Medical and veterinary entomology is the branch of entomology that deals with arthropods of medical and veterinary importance, including species responsible for disease transmission, myiasis, allergic reactions, envenomation, and other conditions affecting humans and animals. In recent years, forensic entomology has become an integral component of this discipline because it applies insect evidence to legal investigations. According to Kotze *et al.* (2023), recent advances in molecular biology, integrative taxonomy, and analytical techniques have greatly enhanced the accuracy and reliability of forensic entomology, expanding its applications beyond postmortem interval estimation to include species identification, entomotoxicology, body relocation investigations, and other medico-legal analyses.

2.4 Uses of Forensic Entomology

Forensic entomology is an important branch of forensic science that utilizes insects and other arthropods associated with decomposing remains to provide valuable medico-legal evidence. Its primary application is the estimation of the postmortem interval (PMI) through the analysis of insect succession and developmental stages (Rivers & Dahlem, 2022; Amendt *et al.*, 2023). In addition, forensic entomology assists in determining whether a body has been moved after death, identifying the location of death, detecting ante-mortem or post-mortem injuries, and supporting forensic toxicological investigations through the analysis of drugs and toxins accumulated in necrophagous insects (Tomberlin & Benbow, 2023; Rivers & Dahlem, 2022). Recent advances in molecular identification techniques, including DNA-based analyses, have further improved the accuracy and reliability of forensic entomological investigations (Amendt *et al.*, 2023)

1. Time since death can be estimated

Estimation of the postmortem interval (PMI) is the primary application of forensic entomology. Necrophagous flies are usually the first insects to colonize a corpse, depositing eggs or larvae shortly after death. The developmental stage of these insects, together with environmental variables such as temperature, humidity, and species-specific developmental rates, provides reliable information for estimating the minimum postmortem interval (minPMI). In addition, the analysis of insect succession can improve the accuracy of PMI estimation, particularly during advanced stages of decomposition (Amendt *et al.*, 2023; Rivers & Dahlem, 2022; Tomberlin & Benbow, 2023).

2. Original crime scene can be identified

In forensic investigations, insect evidence can assist in determining whether a corpse has been moved from its original location. Because many insect species exhibit specific habitat preferences and predictable geographical distributions, the assemblage of insects recovered from a body may indicate that death occurred in an environment different from where the body was discovered. According to Bernhardt *et al.* (2023), the ecological characteristics and succession patterns of necrophagous insects provide valuable information for reconstructing crime scenes and identifying postmortem body relocation, thereby supporting forensic investigations and improving the interpretation of medico-legal evidence.

3. Rape and sexual assault can be revealed

A perpetrator's DNA may be discovered from the victim's genitals even when no semen is present (Amendt, 2010). After eating tissue that semen has come into contact with, larvae may contain a source of usable DNA, and when examined correctly, prove valuable when relating suspects to crime scenes (Chamoun *et al.*, 2020).

4. Causes of death can be deduced

Entomotoxicology is a branch of forensic entomology that involves the detection and analysis of drugs, poisons, and other xenobiotics in necrophagous insects feeding on decomposing remains. When conventional toxicological specimens such as blood or internal organs are unavailable or unsuitable because of advanced decomposition, fly larvae can serve as alternative biological samples for toxicological analysis, thereby providing valuable information that may assist in determining the cause of death. (Hodecek, 2020).

5. Neglected children, elderly or pets

Children left unattended for days will be unable to be looked after, similarly elderly and even pets, when left unassisted, often develop in conditions which reveal signs of their neglected state.

Maggots, which are naturally associated with dead bodies, can also infest wounds present on the bodies of living humans. Therefore, if live children are found to have insects present in them, along with evidence that there has been no care provided to wounds present on their bodies it is possible they may have been neglected (Benecke *et al.*, 2004).

6. Road accident cases can be determined

Occasionally when accidents involving vehicles occur such as trucks or cars traveling off road, a possible cause may be a driver stung by a bee or wasp while driving, which would affect their ability to safely control their vehicle. points this toward vehicle occupants of cars stung mid journey Byrd & Castner. (2019).

7. Terrorist activities can be identified

Cruz (2007) reported that blowfly larvae may retain explosive residues, allowing laboratory analysis to assist in identifying explosive compounds used in bombing investigations.

8. Suicide and sudden death

The presence of certain insects is an indicator of where individuals may have inflicted harm to themselves, because of the larvae tend to appear at such injuries and it's in the abdomen of the larva which they obtain the nutrients that individual has consumed (Amendt *et al.*, 2021).

9. Perpetrator can be identified

DNA recovered from necrophagous insects and their larvae has become an important source of forensic evidence. Blowfly larvae feeding on decomposing tissues may contain human DNA that can be successfully extracted and analyzed to assist in victim identification and, in some cases, provide investigative leads related to criminal events. Advances in molecular techniques have significantly improved the reliability of insect-derived DNA in forensic investigations (Amendt *et al.*, 2021; Wells & Skaro, 2023).

10. Narcotics can be traced to the original supplier.

Forensic entomotoxicology examines drugs, poisons, and other toxic substances accumulated in insects feeding on decomposing remains. The detection of narcotics in larvae or pupae can provide valuable information when conventional human tissues are unavailable or highly decomposed. In addition, insect-derived toxicological evidence may support the interpretation of drug-related deaths and contribute to forensic investigations involving illicit substances (Amendt *et al.*, 2021; Aly *et al.*, 2023).

11. Detection of explosives.

Honeybees have emerged as promising biological detectors of explosive materials because of their highly developed olfactory system and their ability to learn specific odors through classical conditioning. After training, honeybees can recognize explosive compounds such as TNT and other energetic materials with high sensitivity, making them a valuable complementary tool for security screening and humanitarian demining. Recent studies by Sahoo *et al.* (2025) highlighted that advances in conditioning techniques, automated monitoring systems, and biosensor technologies have significantly improved the practical application of honeybees for explosive detection in forensic and security investigations.

2.5 The Decay of Human Remains

Human decomposition occurs as a result of many chemical processes over time, being broken down by tiny living organisms that eat away at the body tissues. Factors such as heat and humidity, and the weight of the individual, will all impact on how long the decomposition process takes and several other less obvious factors (Erzinclioglu, 2003). There are five distinct stages within the decomposing body that will give witness to the process of decay:

1. The Fresh Stage

By day two, the exterior of the body has cooled, and the temperature of the surrounding area is also beginning to decrease. Blood will have moved from the surface down to the parts of the body that are lowest. Blowflies will also find their way to the body during this time, depositing eggs in the vicinity of an area of the body that has not been disturbed (Erzinclioglu, 2003).

2. The Bloating Stage

Approximately 72 hours following death, gases produced by the body will be beginning to accumulate at an accelerated rate and will have produced bloating of the body. *Musca domestica* (the housefly) and *Chrysomya albiceps* (green blowfly) will just be starting to appear (Reddy, 2011).

3. The Active Decomposition Stage

During the active decomposition stage, accumulated gases are released as body tissues rupture, resulting in a marked reduction in body mass. This stage is characterized by intense insect activity, particularly by necrophagous flies belonging to the families Calliphoridae, Sarcophagidae, and Muscidae. Large numbers of larvae actively feed on soft tissues, accelerating

decomposition and providing valuable evidence for estimating the postmortem interval (Byrd & Castner, 2019; Rivers & Dahlem, 2022).

4. Post-Active Decomposition:

During the post-active decomposition stage, most soft tissues have been consumed, leading to a decline in fly abundance and an increase in beetle populations, particularly members of the families Dermestidae, Cleridae, and Histeridae. These insects feed on dried tissues, skin, and remaining organic materials, making them important indicators of the later stages of decomposition (Byrd & Castner, 2019; Amendt *et al.*, 2021).

5. Skeletal Dry Stage

The skeletal dry phase represents the final stage of decomposition, during which most of the soft tissues have been removed, leaving primarily bones, cartilage, hair, and small amounts of dried skin. At this stage, the decomposition odor is minimal, and necrophagous flies are largely absent, while dermestid beetles and other insects capable of feeding on dried tissues and keratinized materials become more prevalent. According to Sharma *et al.* (2025), the duration of the skeletal dry phase varies considerably depending on environmental conditions, including temperature, humidity, insect activity, and carcass exposure, rather than occurring within a fixed number of days.

2.6 Order of Medically & Forensically Important Insects Found on Human cadavers

Upon the decay of the body, blow flies can often be found to have arrived first on a body. Flesh flies soon follow behind blow flies once conditions are ripe for their life style to continue. With a distinct succession pattern, these insects are important in establishing time of death of a victim. As Smith listed over 850,000 species linked to the crime scene, there are four most distinct

groups found on the body; these are Muscidae, Calliphoridae, and Sarcophagidae. There have been over 60 identified species of insect found on decomposing tissue and each is found to alter the pace of the decay process in some aspect. This time order of succession of insects will offer crucial insight into the time and location that a body has been found.

Flies are perhaps one of the largest orders of insects and one that often proves crucial in the findings that can be gained in the crime scene, where over 120,000 species have been named; there are many that can be used for crime scene analyses. Al-Ashbal, (2020), detailed the major families of flies that were important to the crime scene. Blow flies land upon the body in the initial stage of a body's decomposition and are of primary importance in a vast majority of real-life case analyses, with over 1,500 species found in approximately 150 families of various fly species found thriving in decaying matter. However, out of all blow fly species, one is noted time and again; the green blow fly is one of the first to arrive at the scene of death, therefore contributing heavily in the time of death estimates. As if out of nowhere, house flies (part of the Muscidae family) possess around 200 species of importance for forensic and medicinal contexts (Grzywacz *et al.*, 2017). Flesh flies (part of the Sarcophagidae family) have over 850 documented species, the reason why these flies are commonly found in investigations are due to the location in which they are often found (Buenavena & Pupe, 2017).

Beetles are thought to have the largest variety of species compared to other insects (Byrd & Castner, 2010). There are four species of beetle that are typically found at a crime scene, first is Silphidae, then Staphylinidae, Cleridae, followed by Dermestidae. There is one particular species of beetle, *Dermestes maculatus*, which is frequently encountered at crime scene investigations due to its opportunistic nature (Zanetti *et al.*, 2015). Ants, wasps, moths can all be

found at a scene; however, their results are much less fruitful (Amendt *et al.*, 2007).

2.7 Factors Affecting Insect Succession on Corpses (Physical and Chemical Factors)

Many elements will dictate how flies and other insects populate a body and eat away at the body; some examples include moisture, heat, deceased weight, and the chemicals inside the body. These elements may lengthen or shorten the time it takes flies and other insects to become established, therefore muddying the estimates of the time of death of the body being investigated (Amendt *et al.*, 2010). If the body is disturbed, however, the evidence for the original time of death fades rapidly. For instance, by moving the body to an unmarked grave, placing the body into an indoor location, or wrapping the body in something, the arrival of flies and other insects is delayed and the remaining evidence is compromised (Gennard, 2012). Changes in the above-mentioned factors are responsible for the vast majority of the evidence being destroyed.

1. Burial

Burial is one of the most important factors influencing insect colonization of human remains. Soil acts as a physical barrier that restricts the access of necrophagous insects to the corpse, resulting in delayed colonization, altered insect succession, and increased difficulty in estimating the postmortem interval (PMI). The extent of these effects depends on burial depth, soil characteristics, temperature, and moisture. Sharma *et al.* (2025) demonstrated that buried carcasses exhibited significantly slower decomposition and delayed insect colonization compared with exposed carcasses, emphasizing the importance of considering burial conditions during forensic entomological investigations.

2. Physical barriers

such as clothing, plastic wrapping, bags, containers, or enclosed environments can delay or alter insect access to human remains. These barriers influence the timing of insect colonization, modify insect succession patterns, and may affect the estimation of the minimum postmortem interval (PMI). Sharma *et al.* (2025) reported that barriers restricting insect access significantly influence decomposition dynamics and should always be considered during forensic entomological investigations.

3. Burning

Burning can substantially alter the decomposition process and insect succession on human remains. Heat exposure changes the physical characteristics of tissues, affects the attractiveness of the remains to necrophagous insects, and may delay or modify colonization by certain insect groups. McIntosh *et al.* (2017) demonstrated that burned pig carcasses exhibited altered insect succession and significant differences in colonization compared with unburned carcasses, emphasizing the need to consider burning when estimating the postmortem interval.

4. Insecticide Application

Other offenders take it a step on and douse the remains in insecticide to fend the arthropods off. One Saudi study proved the point: on treated bodies, the ordinary succession simply never began (Gennard,2012).

5. Chemical Substances from Suicide

Kianoush *et al.* (2022) used rabbit carcasses loaded with Aluminium phosphate, diazinon and nortriptyline as proxy for death by poisoning. Those chemicals changed succession by a measurable amount. The work suggests that toxicology must ride alongside the entomology, never follow it.

2.8 Previous Studies in Iraq

Forensic entomology research in Iraq has developed gradually since 2006, providing valuable baseline information on carrion-associated insects and their forensic applications.

Abdul Rassoul *et al.* (2010), University of Baghdad, conducted one of the first forensic entomological studies in Iraq. The research investigated insect succession on rabbit and fish carcasses in Baghdad between February 2006 and January 2007. Nineteen Dipteran species belonging to four families were identified, with *Musca domestica* and *Chrysomya megacephala* being the most abundant. The study also examined third-instar larvae of Calliphoridae and Sarcophagidae and documented the seasonal occurrence of beetles, with *Saprinus* spp. being the dominant taxon, while *Dermestes maculatus* and *Necrobia rufipes* were less abundant.

Augul *et al.* (2015), University of Baghdad, reported the first record of the rove beetle *Creophilus maxillosus* (Coleoptera: Staphylinidae) in Iraq after recovering it from larvae of *Chrysomya albiceps*.

Al-Moussawi (2015), University of Kufa, carried out a seasonal survey of forensically important insects in Najaf Province and recorded ten species belonging to seven families within three insect orders. Diptera represented 60% of the collected fauna, followed by Orthoptera (30%) and Hymenoptera (10%).

Al-Boshabaa and Al-Moussawi (2015), University of Kufa, experimentally demonstrated that temperature and relative humidity significantly affect the rate of arthropod colonization on animal carcasses.

Augul and Al-Saffar (2015), University of Baghdad, investigated insect succession on rabbit carcasses in Baghdad and recorded 18 species belonging

to three orders. The study also documented *Dermestes frischii* as a new record for the Iraqi insect fauna.

Al-Shabbani (2015), University of Al-Qadisiyah, investigated several biological aspects of forensically important insects in Al-Diwaniyah Province. The study identified forensic insect species, evaluated insect succession on animal carcasses under different environmental conditions, and assessed the effects of diet and selected drugs on the growth and development of blowflies, providing important baseline information for forensic investigations in Iraq. Al-Mufraji (2018), University of Kerbala, surveyed forensically important insects in different habitats of Karbala Province. Eight insect families belonging to three orders were recorded, and the study concluded that suburban habitats supported fewer carrion-associated insect species than agricultural habitats.

Al-Ashbal (2020), University of Kerbala, conducted a comprehensive taxonomic survey of forensic insects in Karbala Province and added fifteen species to the Iraqi fauna, including ten species of Diptera and five species of Coleoptera, together with diagnostic identification keys.

Zangana (2022), University of Sulaimani, surveyed Diptera associated with carrion in Sulaymaniyah Province and recorded eleven species belonging to seven families, including the first record of *Hydrotaea cyrtoneurina* in Iraq.

2.9 Using the third-instar stage to estimate the Postmortem Interval (PMI)

Estimation of the postmortem interval (PMI) is one of the major subjects of interest in forensic entomology. Blowflies (Calliphoridae) lay their eggs on a corpse, and the flies proceed through three larval instar stages, following a process of pupation and emergence. As the third instar is the most developed, lasting for 25–57% of the time of development, it is also the most useful of the four larval stages for insect-based estimation of time of death (Matuszewski &

Mdra-Bielewicz, 2024a). The underlying principle is obvious. The time that has elapsed to reach the oldest third-instar on the corpse is the postmortem interval, as long as there was not a significant lapse between death and oviposition. When to use the third instar Larval development progresses through three instar stages. All three instar stages have forensic applications in determining the PMI; however, as the first two stages are much more limited in time and more similar in size and form to one another, it is much harder to determine the PMI from these than the third instar, despite the great variation in the growth of this instar (Matuszewski, 2021).

2.10 Ways to Assess the Age of a Third Instar Larva

1. Length and Weight

One of the methods used by professionals is to measure a larva against a chart based on temperature in degrees Celsius and its appropriate growth for that species over time. Size can help to estimate the larva's age - because the amount of time from larva to pupation is faster when the temperature is warmer than the amount of time at colder temperatures. This principle can be combined with other methods of estimating age.

In the isomegalen graph, the x-axis represents the elapsed time (number of days) from the mid-third stage of the larval period to pupation; the y-axis represents the temperature (degrees Celsius) of the environment in which the larva is growing; and the curved lines of the graph show the growth from mid-third instar larva to pupation for different species of insects (Ngando *et al.*, 2024). From the values along the y-axis, the age of a larva can be quickly determined according to the amount of time it has been growing in the environment where it is located based on the temperature the larva had while growing. The logistic growth model allows an estimate of the age of a larva based on the size of the larva, regardless of either the environmental

temperature the larva has been growing in or the estimated time elapsed. The logistic growth model and estimating age based upon the size of a larva can be easily used in digital applications (Gao *et al.*, 2024). The other common method is based on weighing.

All examples given contain one issue - from late third instar onto pupation, growth slows before reversing; now that the third-instar larva has settled into its final growth period, any estimate of age can be made with a high degree of confidence just based on the measurement of the third instar larva's length using measurement of the larval body weight to assess age will not be reliable because of the size/weight relationship (Matuszewski & Mądra-Bielewicz, 2025).

2. Sex-Based Estimation

Sex-related differences in larval development can improve the accuracy of forensic age estimation. Picard *et al.* (2013) demonstrated that male and female third-instar larvae of *Lucilia sericata* exhibit significantly different growth trajectories, with males completing their development earlier than females. Consequently, incorporating larval sex into developmental models can reduce error and improve the estimation of the minimum postmortem interval (PMI_{min}).

3. Laboratory Rearing Method

The laboratory rearing method is widely used in forensic entomology to estimate the minimum postmortem interval (PMI_{min}). Immature insects collected from a corpse are reared under controlled laboratory conditions until they reach the adult stage, allowing accurate species identification and age estimation. Matuszewski *et al.* (2021) emphasized that maintaining appropriate temperature, humidity, and feeding conditions during rearing is essential for

obtaining reliable developmental data and improving the accuracy of PMI estimation.

4. Pre-Appearance Interval (PAI)

The pre-appearance interval (PAI) is the period between death and the first appearance of a particular insect species on human remains. This interval varies among species and is strongly influenced by environmental conditions, particularly temperature. Matuszewski *et al.* (2021) emphasized that incorporating species-specific pre-appearance intervals into forensic analyses can improve the accuracy of postmortem interval (PMI) estimation, especially during the early stages of decomposition.

2.11 Forensically Important Insect Families

Order Diptera

Wherever people are, flies are, the world over, and they are nearly always the first arthropods onto a body (Benecke, 2001; Greenberg & Kunich, 2002). Holometabolous in their metamorphosis, they pass through visibly separate stages: egg, three larval instars, pupa, adult. Diptera make up close to 60% of everything recovered off cadavers, and in the early going their taste runs plainly to moist remains (Gennard, 2012).

1. Family Calliphoridae (Blowflies)

The family Calliphoridae comprises some of the most forensically important flies because they are usually the first insects to colonize exposed remains. Adult blowflies are strongly attracted to decomposing tissues, where females rapidly oviposit, initiating the first stage of insect succession. Their predictable developmental pattern, consisting of egg, three larval instars, pupa, and adult, makes them valuable indicators for estimating the minimum postmortem interval (PMI_{min}). Williams and Villet (2017) emphasized that

accurate identification and developmental data of blowflies are fundamental for reliable forensic entomological investigations.

2. Family Sarcophagidae (Flesh Flies)

Warmth suits the flesh flies, and they breed for the most part in the tissue of dead animals, a few turning parasitic and capable of myiasis. Over 3,100 species stand described in the family (Aspoas, 1994; Gillott, 1995). Their tight bond to decaying matter is what makes Sarcophagidae good for PMI estimation and for placing a scene both (Campobasso *et al.* (2001) turned up their colonies on rabbit carcasses buried 10–20 cm down in spring; Al-Ashbal (2020) logged six of the family's species on Iraqi cadavers.

3. Family Muscidae (Houseflies)

Muscidae is one of the few fly families that thrive in unprecedented numbers, because they feed off of both faeces and the remains of dead animals regardless of preference. The species have a tendency to colonise a deceased organism after Calliphoridae and Sarcophagidae but play an extremely important role in the decomposition process after the abdominal cavity has opened (Smith, 1986). Tullis and Goff (1987) recorded several species of Muscidae that were found during and after the decay of monkeys in the Hawaiian rainforest and found that *Musca domestica* was the most prevalent. The extensive geographic distribution of Muscidae and their close association with the human lifecycle increase the application of these fly families within forensic science (Byrd & Castner, 2020). Adult Muscidae are attracted to the fluids of decedents, and prefer to oviposit via natural openings, open wounds or moistened soft goods; once the larvae have developed, they will feed directly of the decedent (Byrd & Castner, 2020).

Within their examination of farming lands, Heo *et al.* (2008a) documented that Muscidae are able to lay eggs in surfaced and buried cadavers.

In addition to *Synthesiomyia nudiseta* (Van Der Wulp, 1883), a species associated with human remains in tropical and subtropical environments, in the bloated stage of decay (Byrd & Castner, 2020), the larvae of this species are predaceous and prefer to consume *Chrysomya rufifacies* larvae (Nazni *et al.*, 2008). *Ophyra* is a genus of approximately 20 species located in warm climates worldwide and is also a forensic taxon; the larvae tend to be found on cadavers in the wet stages of decomposition (Byrd & Castner, 2001). *Ophyra spinigera* Stein, 1910 has played a part in many cases examining human remains in Malaysia (Lee *et al.*, 2004).

4. Family Fanniidae (Lesser Houseflies)

Originally Fanniidae lived within the Muscidae; Fanniidae is now a separate entity and does provide real forensic significance. An example, one of the most widely cited species, *Fannia canicularis* was recovered from a case of child neglect in Germany (Benecke, 2001) with larvae that offer relatively drier conditions for pupation; it is morphologically similar to the dung-breeder, *Fannia scalaris* (Fabricius) (Byrd & Castner, 2010).

5. Family Piophilidae (Cheese Flies)

Small, glossy, black, 4–5 mm long, the Piophilidae range worldwide and on into cold country (Byrd & Allen, 2001). A broken wing vein is the diagnostic mark. *Piophila casei* is the one most often on cadavers, at the wet stage and the dry.

Order Coleoptera

The order of insect with the richest groups is Coleoptera and has colonized almost all terrestrial habitats excluding the poles and highlands and is very much richer in the tropics than any other parts of the world. The majority of the groups are less affected by cold than the flies, and in cold countries it is

the beetles which dominates carrion fauna rather than the flies, in a forensic investigation these groups will be mostly encountered in later stages of decomposition (Midegle & Villet, 2009).

1. Family Staphylinidae (Rove Beetles)

Short elytra give a rove beetle away, baring over half the abdomen; in size the family stretches from small to large. Predators make up most of the forensically useful species, lured to a body by the fly larvae rather than the flesh. Of the predatory genera, *Creophilus* shows up most on animal remains (Centeno *et al.*, 2002). Early to arrive, Staphylinidae can linger a good while, wrapping up their life cycle in 7–10 days (Rasmi & Jisr, 2015).

2. Family Histeridae (Clown Beetles)

Small, hard, glossy and black, oval and compact, the Histeridae carry elytra cropped short to expose the abdomen's tail end. Clubbed or elbowed antennae, flattened legs. They arrive at decomposing matter to hunt fly larvae and other insects, and they keep nocturnal hours; come daylight they slip under the body or inside it. Best documented of them forensically is *Saprinus*, with a taste for fresh pupae (Gennard, 2007; Szelecza *et al.*, 2017).

3. Family Silphidae (Carrion Beetles)

Around 12 mm is the usual size for adult Silphidae, flattened in build, the head looking undersized, the antennae clubbed, the short elytra leaving the abdomen's rear on show (Gennard, 2007; Scott, 1998). Brood care falls to both parents, the males seeing off rival arthropods. Adults tend to make a body inside 24 hours, feeding on just-hatched dipteran eggs and young larvae (Anderson & Peak, 1985). Through the fresh and bloating stages, they are present, and choosy about carcass size, certain species sticking to the larger remains only (Rasmi & Jasra, 2015).

4. Family Dermestidae (Hide Beetles)

Latecomers, the Dermestidae, arriving in terminal decay once the flies have stripped most of the soft tissue. What is left is their fare: dried skin, connective tissue, bone. They span 1.5 to 10 mm, oval to elongate, antennae clubbed, and want 20 to 50 days to develop, temperature depending. Their giveaway behavior is thanatosis, a feigned death on being touched, jolted, or lit, run off the heavy setae down their flanks and rear (Gennard, 2007; Rasmi & Jasra, 2015).

5. Family Scarabaeidae (Dung Beetles)

Plenty of Scarabaeidae go underground, tunneling the galleries that thread their life history. An urban Brazilian study set them second for abundance on pig carcasses, trailing only *Chrysomya albiceps* (Calliphoridae); on the record there were *Deltochilum brasiliensis*, *Eurysternus parallelus*, and *Coprophanaeus ensifer* (Carvalho *et al.*, 2000). Members of the family Scarabaeidae are occasionally associated with animal carcasses, particularly during the later stages of decomposition. Although they are less abundant than Calliphoridae, several necrophagous scarab species have forensic importance and may contribute valuable information for postmortem interval estimation in specific environments (Vasconcelos & Araujo, 2012).

6. Family Trogidae

Medium-sized and pale brown, the Trogidae wear a roughened back, sometimes hairy elytra, front legs cut out for digging, and antennae flattened at the ends. They appear on remains deep into decomposition, taking fur, feathers, and the dried residue ringing the body. Disturb or handle them and, like Dermestidae, they play dead (Gennard, 2007; Rasmi & Jasra, 2015).

7. Family Cleridae (Ham Beetles)

Members of the family Cleridae, particularly *Necrobia rufipes*, are commonly associated with the advanced and dry stages of decomposition. Both adults and larvae are predatory, feeding on fly larvae and other insects colonizing carrion, making them valuable indicators during the late postmortem interval (Byrd & Castner, 2019; Gennard, 2012).

Order Hymenoptera

Carrion is no obligation for Hymenoptera. The order runs to carrion feeders and predators alike, and ants and wasps especially have been caught eating dipteran larvae in the early going (Byrd & Castner, 2019).

For PMI work that is a genuine nuisance. Should something thin the larvae out before the investigator turns up, the stages still on the body at collection can make a death read fresher than it truly is.

2.12 Mock Crime Scenes

Mock scenes have settled into the standard kit of forensic-entomology training. The idea is plain enough: set animal carcasses out as stand-ins for human remains, then study how the local conditions bend the succession and rehearse the turn from insect data to PMI (Schoenly *et al.*, 1996).

2.13 Environmental and Climatic Factors Affecting Insect Succession and Development on Corpses

Any death inquiry leans on understanding how a body decomposes and what steers the process. Campobasso *et al.* (2009) showed those same steering forces either ushering the forensically important insects in or shutting them out, with all that implies for the time-of-death figure downstream.

1. Geographic Region

The colonization pattern is, for the most part, uniform at the family level. At the genus or species level, however, that uniformity vanishes, owing to the particular biogeographical and climatic make-up of the area (Payne 1965; Early and Goff 1986). The pace of succession and development is another matter; it will differ from one country to the next, or even between districts in the same country, as a function of the climate and microclimate as well as the landforms. One cannot simply take data from one place and apply it to another without first making an on-the-ground inspection to account for the local variables. Then there is the question of where the body has been left. That alone dictates the rate of decomposition and which insects are going to be on the scene and when they show up (Kaaka, 2011). Such nuances put the finishing touches on the whole process. As MacGregor (1999) puts it, it is all about the interplay of “the vegetative setting, topography, type of soil, the local climate” in driving those decomposition rates.

The differences between region are an actual difference in what the scene offers. The original invaders to the islands of Hawaii included *Chrysomya megacephala* (Macquart, 1844), *Ch. Rufifacies*, *Sarcophaga haemorrhoidalis* (Wiedemann, 1824), and *Sarcophaga occidua* (Fabricius, 1794) (Early & Goff, 1986), whereas *Phormia regina* (Meigen, 1826) and *Lucilia* (Meigen, 1826) are the earliest colonizers in Tanzania, and *Cochliomyia macellaria* (Fabricius, 1794), a calliphorid, are the first colonizers to a carcass on the coast of South Carolina (Payne, 1965).

Of course, it isn't just flies. The beetles come in shortly after the flies have arrived, but while beetles will colonize the carcass 3-10 days after death in Hawaii, they will not colonize a pig carcass until 43 days after the pig's

demise, at which time they will arrive in extremely large numbers in British Columbia (Anderson & vanlaerhoven, 1996).

2. Temperature and Humidity

Very little affects bug development and oviposition as strongly as temperature and humidity, and temperature weighs more heavily at every stage than any of the other variables. Although heat significantly speeds the growth of the larvae to full length as Reiter (1984) witnessed, it can only speed it to a certain point. Any temperature above 30C and there is a failure to complete development, pupation cannot take place and the larvae simply perish. For most of these insects, optimal temperatures are between 15C and 30C. Sunlight is important and also whether the body is left out in the open or is contained within a closed space (Keh, 1985).

Tantawi *et al.* (1996) demonstrated a direct relationship: increased temperature accelerated tissue degradation, cold retards degradation. Extremely high temperatures reduce activity and rates of development, as do wet conditions and rainfall (Anderson & vanlaerhoven, 1996) with microbes working the body to themselves (Gill, 2005). Nelson *et al.* (2008) found that only above 4 C are the eggs of the *Calliphora* blowfly ready to hatch, although above 6-7 C they develop normally to larval stage.

Medication in the body, combined with extremely wet and dry conditions, has a tendency to confuse PMI estimates due to their effect on the larval development and hatching, although combining factors, taking into account local fauna, will determine a fairly accurate figure (Anderson, 2010). Seasonal effects will pull the factors around. Wet and warm weather has large amounts of flies, beetles, ants, and wasps visiting bodies whereas drier periods lead to spiders and scorpions being attracted. Even a severe drought, although reducing insect life overall, can lead to increased attention of carrion by insects

that have survived and even increase visitation by large fly populations due to the mild heat in the late summer/ early autumn (Tembe & Mukaratirwa, 2020).

3. Season

All the rates of decay, count of the body, and flight pattern are seasonal thus altering the assemblage on a seasonal basis. An imposter set in the spring would be much more attractive than an imposter set in the winter. Many more beetles could be recovered than flies (Goddard & Lago, 1985). Blowfly turnover is quite well defined by now; throughout spring and summer in Maryland *Phormia regina* is found but *Calliphora vicina* (Hall, 1948), *Calliphora livida* and *Lucilia illustris* (Meigen, 1826) were only found in spring and *Lucilia sericata* only during the summer months (Introna *et al.*, 1989). Blowfly numbers on a body also fluctuate in a given year indicating seasonality even at a given location. In a study of 117 human corpses *Calliphora vicina* was found to be present year-round, but the assemblage still exhibited seasonal differences (Schroeder *et al.*, 2003).

4. Cause of Death

Also, the mode of death influences rate of decay and consequently, sequence of arthropod species on a carcass. Lethal doses of phenobarbital delayed insect development, a finding in a study by Beyer *et al* (1980). If there is death by poison, drugs, narcotics, insecticides and staging of decay periods, they do not arrive on time because the procession is slightly altered, in which the initial stages will appear out of synchronisation Lord & Stevenson (1986). The extent of influence is well elaborated in Avila & Goff (1998) who correlates the causes of death with number, density and developmental timing of the decomposition stages.

Unique too are the charred remains. A burnt corpse can be more susceptible to attract arthropods; the cracked charred skin readily can accept

the egg mass on its surface to be laid. Although in certain conditions burning can deter arthropods (Vanin & Huchet, 2017).

5. Condition and Placement of the Carcass

Typically, a corpse on the ground is decomposed in 4-6 stages as literature indicates. Pig carcasses buried to a depth of 50-100 cm and observed for 5 months, from July to November, progressed through 5 stages: fresh decomposition, bloating on the 5 th day of interment, wet decomposition on the 10 th day of interment, dry decomposition on the 25 th day of interment, skeletonisation on the 80 th day of interment (Payne, 1965). It is always found that buried bodies decompose slower than surface-exposed bodies regardless of conditions (Rodriguez & Bass, 1985). What is particularly interesting is that a British study on rural burial and insect access throughout the year still found that even in burials, a percentage of Muscidae were found alongside Calliphoridae (VanLaerhoven & Anderson, 1999). The depth to which a body is interred, soil type, sub-soil humidity and sub-soil atmospheric composition can all contribute to when a buried body begins to be colonized (Forbes, 2008).

6. Suspension and Air Exposure

Hanged Body: Suicide, homicide, or staged. This body will decompose and begin developing its own colonies because it is elevated off the ground. Goff *et al* (1994) reported that a hanged body in Hawaii had development and behavior very different than a body lying on the ground. Soil arthropods were excluded because there were not many paths for them to access the carcass. Another study showed that the rate of decay was slower for hanged bodies than for ground-level bodies even with additional heat generated from feeding insects (Shalaby *et al.* 2000).

Because there is more air moving around a hanged body it will lose moisture more quickly, limiting access for larvae to a wet environment for

feeding. During later stages of decomposition, the fluid will drain away and gather below the body; this is where scavengers and arthropods are more likely to collect, they may not be in the carcass anymore. Flying insects will still arrive first at a hanged body, but there are significantly fewer species and a much lower density of arthropods than a ground-level body (Goff 2000).

Chapter Three

*Materials and
Methods*

3. Materials and methods

Diwaniyah city is found in the southern region of Iraq, which is part of the Middle Euphrates region. It is located along the east side of the Diwaniyah River, about 180 km to the south of Baghdad. Diwaniyah has been known to have an abundance of fertile agricultural land, as well as being located in such an important location connecting Baghdad and the southern regions of Iraq Figure 3.1.

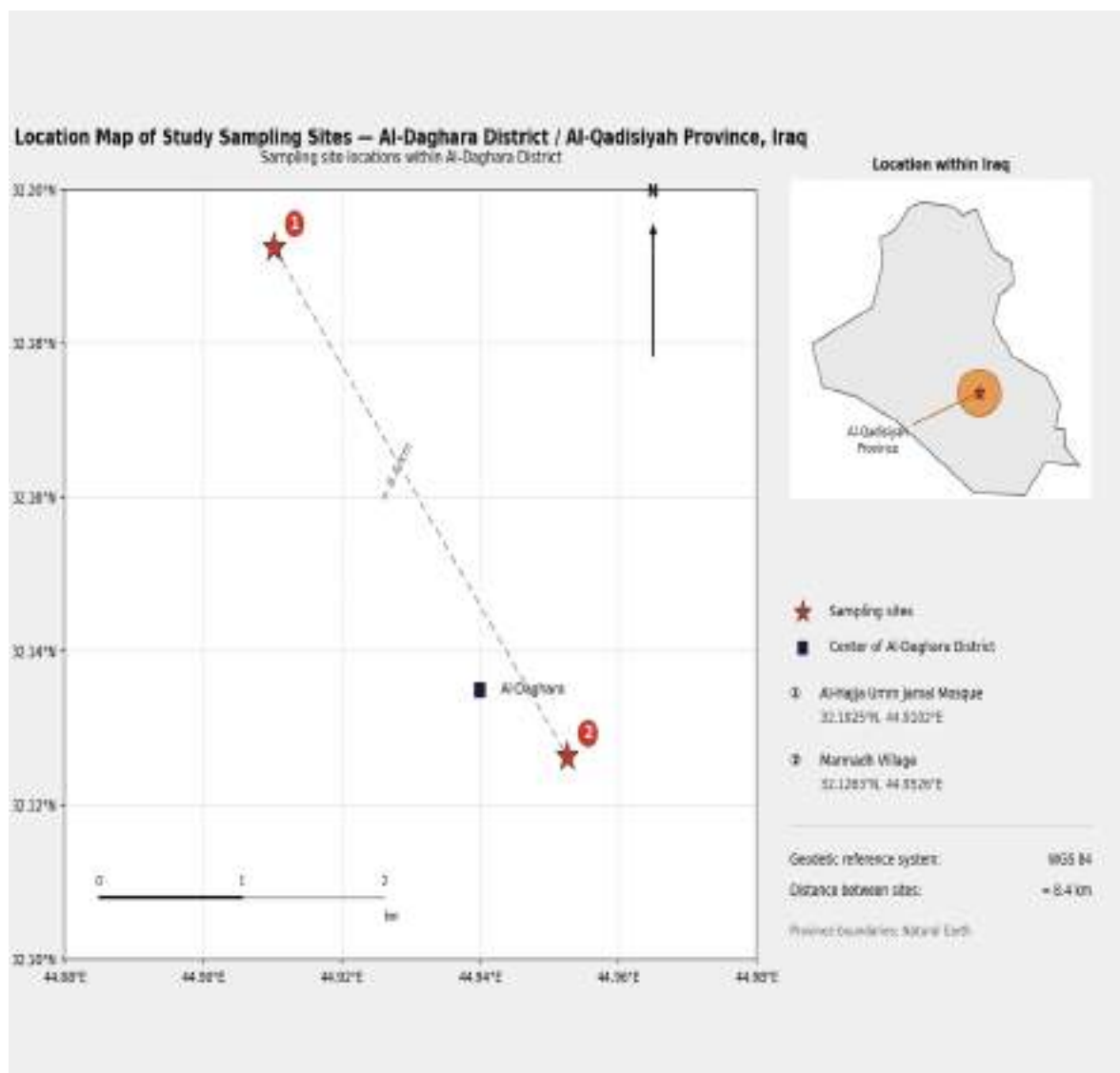


Figure (3.1): Location map of the study areas in Diwaniyah City, southern Iraq

3.1 Description of the Study field Areas

The study was conducted in two different environmental locations on the outskirts of the city, described as follows:

- **The Agricultural Area:** This area was selected in the Al-Daghara district, Marmad village, south of the city center of Al-Diwaniyah. It is characterized by the presence of dense vegetation cover, including fruit trees and vegetables, and by the presence of animals such as sheep, cows, and dogs Figure 3.2.



Figure (3.2): The agricultural study area in Al-Daghara district, Diwaniyah

- **The Cemetery Area:** It is situated in Al-Daghara district and its distance is 3000m from Al-Hajja Umm Jamal Mosque Figure 3.3. This area consists

of a number of human tombs, a sandy nature which contains insects which play an important role in the decaying of the corpses. Fieldwork at both study sites was conducted under official task-facilitation and approval letters obtained from the relevant authorities in Al-Diwaniyah Governorate (Appendix D).



Figure (3.3): The cemetery study area in Al-Daghara district, Diwaniyah

3.2 Animals Used in the Study

Two types of vertebrate animals were used as surrogates for human cadavers to achieve the objectives of the study, these animals were identified by the Natural History Research Center and Museum, University of Baghdad.

Experimental Animals

1. Dog *Canis lupus familiaris*.
2. Wild boar *Sus scrofa* Pig (See Figure 3.4: A, B)



Figure (3.4): (A) Wild pigs and (B) Dogs used in the field experimental study

3.3 Investigative Study: Methodology of Field Experiments

This field experiments occurred throughout the summer of 2025 in the city of Diwaniyah (specifically in Al-Daghara District). For this experiment, two groups of vertebrate animals (dogs versus wild pigs) were studied from 25 June 2025 through 6 April 2026. To carry out this field experiment, firearms were used to kill the selected animal specimens at both of the locations divided across the respective 1,000 square meter areas being studied.

In total, 24 animal carcasses (12 dogs and 12 wild pigs) were studied with equal distribution between the agricultural site as well as the cemeteries. Each set of carcasses had two different types of burial locations depending on which level they were subjected to experimentally:

- Burial - carcasses were buried 50 cm underground using wood boards as a cover material with 10 cm of topsoil.
- Surface Burial - carcasses were left above ground and housed within cage fencing. Dogs were housed in cages measuring (150 x 100) cm while wild pig carcasses were housed in cages measuring (200 x 150) cm and all animals were replicated three times per animal analysed during this experiment.

3.4 Determining Insect Species Associated with Remains

Excellent study sites had to be monitored regularly (every 24 hours) for each replicate of each experimental carcass; this was done from the time that the carcass died until the experiment ended. All sites were measured according to the methodology of Chin *et al.*, 2007 and Service, 1980. A standard insect net or fly roll was used to collect and record all insect species that were drawn to the carcass, whether they [the insects] were flying or crawling (Al-Mesbah, 2010).

When collecting larvae-beetles/adults; the researcher used small brushes/spoons/tweezers that were varying sizes. The larvae collected were put into 5-ml wax tubes while the adult beetles collected were placed into 20-ml wax tubes and marked accordingly to the repository (either taken on/after death) at each research visit. The following information was documented for each carcass: collection location, date of collected specimen, carcass type (i.e., fresh, dehydrated, etc.), all information regarding samples that were brought back to the lab for preservation.

In order to clean all collected specimens (larvae) of previous damage caused by improper storage, they were cleaned with distilled water (to eliminate residue), then boiled in water prior to storage in either 70% ethyl alcohol or 95% ethyl alcohol. Boiling removes moisture and prevents distortion of larval specimens, which if preserved in 70% ethyl alcohol or 95% ethyl alcohol allow

the researcher to confirm the taxonomic status of organisms collected through identification by personnel at the Natural History Research Centre via Dr. Razzaq and Assistant Dr. Hanaa Hani Al-Saffar. The official specimen-identification correspondence and reports issued by the Iraq Natural History Research Center and Museum, University of Baghdad, are provided in Appendix E.

After identification, samples were transferred to the Entomology Laboratory at the College of Sciences, University of Al-Qadisiyah, for counting and imaging using a Dino-Lite Digital Microscope (3.5: A). During the field experiment, ambient temperature and relative humidity at the study site were recorded using a digital thermometer (3.5: B).



A



B

Figure (3.5): (A) Dino-Lite Digital Microscope used for imaging; (B) Digital thermometer used for recording temperature and humidity at the study site

3.5 Collection Methods

3.5.1 Adults Collected by sweeping Net

A sweeping net was used to collect adult insects present on carcasses in both field study areas. Collected specimens were preserved by pinning or by storage in labeled vials see Fig (3.7).

3.5.2 Yellow Sticky Traps

Yellow sticky traps were employed to attract adult insects (Figure 3.6). Traps were mounted on wooden boards supported by wooden stands and positioned on the cages containing the carcasses in both field study areas. Readings were recorded daily.



Figure (3.6): Yellow sticky trap deployed on a wire mesh cage over a surface carcass

3.5.3 Collection of Larvae samples Directly

The larvae were directly collected from the research field area using forceps, transferred to plastic containers, killed in boiling water at temperature degree 80 C for one minute, and then placed into tubes containing 10 ml of 80 % ethanol (Service, 1980) to be taxonomically identified.



Figure (3.7): Equipment and materials used for insect sample collection and preservation during the study

3.5.4 Culture of Fly Larvae

Larva samples of each species were collected (first, second, and third instars) from the field study site within the general area of the study for all species of Diptera. Specimens were collected from the body of experimental animals and face, or from the mouth, eye, and ear, and from wounds. Larvae were placed in a plastic container lined with felt, with damp fish mixed with soil and sawdust for pupation Figure (3.8). Collection information included container number, date of collection, and area of collection (Al-Mufraji, 2018).



Figure (3.8): Larval rearing containers used in the study

3.5.5 Culture of Beetle Larvae

Beetle larvae were reared on pieces of fish in wooden containers filled with sawdust mixed with soil for pupation. Moisture retention was maintained

throughout the entire rearing time; both larvae were grown at ambient temperatures of (25 ± 2) C and relative humidity of (80 ± 5) %. Adults obtained were used for taxonomic comparison (Coombs, 1978).

3.6 Morphological Studies

3.6.1 External Morphology and Internal Anatomy of Larvae samples

Larvae samples were examined under a Binocular Dissecting Microscope (with $40\times$ magnification) to determine larval external morphology, the location of spiracles (anterior and posterior), and the arrangement of spines on body segments. Larvae were placed in a watch glass, processed through a series of graded ethyl alcohol solutions, and placed into xylene for (2) minutes to clarify.

If the mouthparts are to be examined, the larvae are processed through graded concentrations of ethyl alcohol and placed into xylene for 1 min to clarify. The larvae are then placed on a glass slide and immersed in Canada Balsam, covered with a coverslip, and allowed to dry before examination and imaging (Zumpt, 1965).

3.6.2 External Morphology of Adult samples

Adult samples (males and females) were described by complete examination under a Dino-Lite Digital Microscope following killing and pinning. Morphological characteristics (head, antennae, legs and wings) were recorded. Permanent slides were prepared by mounting (xylene clarified) and dry mounting with Canada Balsam, and coverslip. The remaining slides of antennae, wings and legs were prepared for viewing under a microscope using a Dino-Lite microscope mounted on a stand and connected to a computer and monitor. The thorax and abdomen then were imaged directly on a cork board after removal from the cork board.

3.7 Diagnostic Keys

3.7.1 Diptera

Identifying adult specimens of diptera was done by using various taxonomic keys and diagnostic descriptions based on the following references: Van Emden (1954), Rosemarie (1964), Zumpt (1965), Spradbery (1991), Blackith *et al.* (1997), Pont & Meier (2002), Castrezana (2010), Chen & Kameneva (2007), Carvalho & Mello-Patiu (2008), Pinto *et al.* (2011), Meiklejohn (2012), Pont (2013), Drake (2013), Domínguez (2014), Ivorra *et al.* (2014), Morgulis & Freidberg (2014), Salmela & Kaunisto (2015), Pimsler *et al.* (2016), Paiero (2017), El-Ahmady & Taha (2018), and Pragae (2019).

3.7.2 Hymenoptera

Identification of hymenoptera specimens was done through the use of taxonomic keys developed in accordance with the following authors: Collingwood (1996), Radchenko (2004), Mohamed *et al.* (2001), Ionescu-Hirsch (2009), Blaimer (2010), Rad (2011), Abdul-Rassoul *et al.* (2013), Karaman & Aktaş (2013), Ward *et al.* (2015), Sharaf *et al.* (2016), and Salata *et al.* (2018).

3.7.3 Coleoptera - Adult Specimens

Identification of adult specimens was completed using morphological keys along with taxonomic diagnosis from Kulshrestha & Satpathy (2001), Háva (2004, 2019), Ferrer (2009), Day (2010), Velázquez *et al.* (2011), Aballay *et al.* (2013b, 2016), Silvestro & Flores (2013), Brendell (2013), Almeida & Mise (2014), Keshavarzi *et al.* (2015), Nabozhenko & Keskin (2015), Price (2016), Sawaby *et al.* (2016), Aalbu *et al.* (2017), Keshavarz (2017), Bonfanti *et al.* (2018), and Chigray *et al.* (2018).

3.7.4 Coleoptera – Larval stage

Larvae were identified by the use of the dichotomous keys of: Rees (1943), Zumpt (1965), Spradbery (1991), Blackith *et al.* (1997), Oliveira *et al.* (2007), Szpila (2009), Amendt *et al.* (2010), Mendonca *et al.* (2012), Grzywacz (2013), Rezende *et al.* (2014), Riva *et al.* (2015), Szpila *et al.* (2015), Chakraborty *et al.* (2015), Grzywacz *et al.* (2015, 2017), Abdel-Reheem (2016), Demirel-Kaya *et al.* (2016), Singh *et al.* (2017), Fakoorziba *et al.* (2017).

3.8 Statistical Analysis

The field experiment was designed as factorial experiments with three factors and each treatment replicated with three replications in Randomized Complete Block Design (R.C.B.D.). Data were Statistically analyzed by using the (ANOVA) tables Analysis of Variance the Significant Difference were tested by using Least Significant Difference (LSD) at (0.05) for showing result significantly (Al-Sahuki and Wuhayb, 1990), using the statistical software Genstat 2010.

The minimum post-mortem interval was estimated by rearranging the thermal-summation relationship: $PMI_{\min} = ADH \div (T - T_0)$. Under the present conditions the thermal excess ($T - T_0$) equalled 33 degree-hours per hour for both surface ($45 - 12$) and buried ($43 - 10$) carcasses; estimates are reported in hours and converted to days (hours $\div$ 24). Because they date colonisation rather than death itself, larval estimates represent minimum intervals. The following statistical formula was applied to estimate the post-mortem interval from larval-length data (Byrd & Castner, 2001):

$$T = \frac{y - \mu_t}{\sqrt{\sigma_t^2 + Var(\mu_t)}}$$

Where:

T = the statistical test value used to estimate the post-mortem interval;

y = the measurement of the unknown specimen (larval length collected from the carcass);

μ_t = the reference mean larval length at time t , derived from developmental reference data;

σ^2_t = the variance of measurements at time t from the reference developmental dataset;

$Var(\mu_t)$ = the variance of the mean estimate, calculated as:

$$Var(\mu_t) = \hat{\sigma}_t^2 \sum_{i=1}^k \frac{a_{ti}^2}{n_t}$$

k = the number of independent reference samples;

n_t = the number of individuals in the sample at time t .

Chapter Four

*Results and
Discussion*

4 Results and Discussion

4.1 Decomposition Stages

The mean number of days associated with each decomposition stage, partitioned by carcass type, burial environment and burial level, is presented in Table (4.1) and illustrated in Figure (4.1). The grand mean rose progressively through the sequence, from 1.0988 days at the fresh stage to 4.471 (bloated), 18.12 days (active/wet decay), 28.01 days (advanced/dry decay) and 37.00 days at the skeletal stage. Burial level generated the largest and most consistent contrast at every stage: carcasses buried at (50) cm recorded substantially higher day values than surface carcasses, and the level effect was highly significant at all five stages (Table 4.2). Carcass type was the second influential factor, pig carcasses generally exceeding dogs, with the type effect highly significant at every stage. The burial environment (cemetery vs agricultural) exerted a smaller, stage-dependent influence: it was significant at the fresh stage but non-significant at active/wet decay. Coefficients of variation were low across all stages (2.7–6.9%), indicating high reproducibility.

These results suggest that, under the high summer temperatures of southern Iraq, burial depth was the dominant control on decomposition timing, carcass type was secondary, and the cemetery-versus-agricultural setting was comparatively minor. The marked retardation of buried carcasses is consistent with the well-documented effect of burial in restricting insect access, buffering and lowering the temperature experienced by the remains, and limiting oxygen and gas exchange; recent comparative work has shown that decomposition slows progressively with increasing depth and that the colonising fauna becomes more restricted below ground (Sharma *et al.*, 2025). The tendency for pig carcasses to decompose more slowly through the gross stages than dogs may reflect their greater body mass, thicker subcutaneous fat and different

integument, which prolong the availability of soft tissue and modify the internal microenvironment of the carcass (Amendt *et al.*, 2007; Sharma *et al.*, 2025). The weak and stage-dependent environment effect is consistent with broadly similar soil exposure and microclimate at the two sites during a single summer window; site effects in carrion ecology are typically mediated by soil moisture, shade and the local faunal pool, and may become apparent only across seasons or contrasting habitats (Matuszewski, 2021; Mashaly *et al.*, 2020). The faster overall progression at the surface accords with regional studies in hot climates reporting rapid summer decomposition (Mashaly *et al.*, 2020; Albushabaa & Almousawy, 2016; Abd Al-Rasoul, 2021; Al-Ashbal, 2022; Al-Mufraji, 2018) and with Saudi observations on human and animal remains (Mashaly *et al.*, 2020; Bosly, 2021).

Forensic significance. For casework in this region, the data indicate that burial level and carcass type must be weighed explicitly when decomposition stage is used to bracket the PMI, because a buried body can present a far earlier gross stage than a surface body of identical age, and a larger carcass may lag a smaller one. Decomposition scoring alone is therefore best treated as a coarse temporal frame to be refined by entomological evidence (Sections 4.2–4.11).

4.1.1 Fresh Stage. See (Table 4-1. Fig 4-1, plate 1,2,3 and 4)

The fresh stage, characterised by the absence of visible external change and the commencement of autolysis and anaerobic microbial activity beneath an intact integument, The results of table (4-1) showed that the interaction between types of carcass and burial environmental and burial level in fresh stage. The results showed that the highest value was (2.033) days at dog carcass cemetery and buried compared with lowest value was (0.50) days at dog carcass cemetery and agricultural surface compared with pig (2.100, 0.657, 1.00) days respectively. Statistical analysis showed that significant

difference between results which founded in this table. recorded the shortest mean duration in the present study (overall grand mean 1.099 days). Surface carcasses reached bloat within approximately one day under the high ambient temperatures of southern Iraq (43–45 °C), consistent with the accelerated autolytic and microbial kinetics observed in hot-arid environments (Schotsmans *et al.*, 2024). Buried carcasses (50 cm depth) remained in the fresh stage significantly longer than surface carcasses, a pattern attributed to the combined effects of soil insulation, reduced oxygen availability, and the near-complete exclusion of necrophagous insects that would otherwise initiate surface disruption (Rodriguez & Bass, 1985; Rai *et al.*, 2022). Pig carcasses generally exceeded dog carcasses in fresh-stage duration (1.189 vs 1.008 days), and cemetery sites recorded a marginally longer fresh stage than agricultural sites (1.323 vs 0.875 days), reflecting the greater body mass and thicker adipose layer that retard the initial rise in core temperature and delay the onset of detectable surface change. These findings accord with recent controlled burial studies demonstrating that depth is the single strongest predictor of early decomposition rate in terrestrial vertebrate carrion (Rai *et al.*, 2022; Schotsmans *et al.*, 2024).

Table (4-1) Mean number of days at the fresh decomposition stage for interaction between carcass types and burial environmental and burial level

Carcass Type	Burial Environment	Burial Level		Carcass Type x Burial Environment
		Surface	Buried	
Dog	Cemetery	0.500	2.033	1.267
	Agricultural	0.500	1.000	0.750
Pig	Cemetery	0.657	2.100	1.378
	Agricultural	1.000	1.000	1.000
lsd5%		0.070**		0.049**
Carcass Type		Carcass Type x Burial Level		Carcass Type Mean
Dog		0.500	1.517	1.008
Pig		0.828	1.550	1.189
lsd5%		0.049**		0.035**
Burial Environment		Burial Environment x Burial Level		Burial Environment Mean
Cemetery		0.578	2.067	1.323
Agricultural		0.750	1.000	0.875
lsd5%		0.049**		0.035**
Burial Level Mean		0.664	1.533	
lsd5%		0.035**		

4.1.2 Bloat Stage. See (Table 4-2. Fig 4-1, plate 1,2,3 and 4) The bloat stage, during which anaerobic fermentation generates sufficient gas to distend the abdominal cavity and force fluid exudation, The result of table (4-2) showed that the interaction between types of carcasses and burial environment and Burial level in bloat decomposition stage.

The results showed that the highest value was (9.00) days at pig carcass in burial level compared with the lowest value was (3.400) days at pig Agriculture compared with dog carcass (5.233, 1.167) days respectively. Statistical analysis showed that significant difference between results which founded in this table. showed a mean duration of 4.471 days across all treatment groups. The most pronounced variation was again associated with burial level: surface carcasses entered and exited the bloat stage markedly faster than buried counterparts, as the absence of soil cover permitted volatile gas to dissipate through the skin and facilitated earlier rupture via insect activity (DeBruyn, 2021). At burial depth, the impeded gas release prolonged the bloat phase, and

the reduced insect pressure meant that skin rupture was delayed relative to surface placements. Carcass type followed the same pattern seen throughout the trial, pig carcasses recording a longer mean bloat duration than dogs (5.484 vs 3.458 days). These dynamics have practical forensic implications: a buried carcass presenting in the bloat stage is likely to have a PMI substantially longer than a surface carcass at the same gross stage, and decomposition scoring alone may severely underestimate time since death for buried remains. A cemetery microenvironment was associated with a slightly higher bloat-stage mean than agricultural land, possibly reflecting differences in soil moisture and compaction that affect gas retention. The overall pattern is consistent with experimental burial studies conducted in contrasting climatic settings (DeBruyn, 2021; Procopio *et al.*, 2020) and reinforces the need for burial-adjusted decomposition reference data in forensic casework.

Table (4-2): Mean number of days at bloat decomposition stage for interaction between carcass type and burial environment and burial level

Carcass Type	Burial Environment	Burial Level		Carcass Type x Burial Environment
		Surface	Buried	
Dog	Cemetery	1.700	5.233	3.467
	Agricultural	1.167	5.733	3.450
Pig	Cemetery	3.467	9.000	6.234
	Agricultural	3.400	6.067	4.734
lsd5%		0.376**		0.266**
Carcass Type		Carcass Type x Burial Level		Carcass Type Mean
Dog		1.434	5.483	3.458
Pig		3.434	7.534	5.484
lsd5%		0.266ns		0.188**
Burial Environment		Burial Environment x Burial Level		Burial Environment Mean
Cemetery		2.584	7.117	4.850
Agricultural		2.284	5.900	4.092
lsd5%		0.266**		0.188**
Burial Level Mean		2.434	6.508	
lsd5%		0.188**		

4.1.3 Active (Wet) Decay Stage. See (Table 4-3. Fig 4-1, plate 1,2,3 and 4)

The active (wet) decay stage was the longest of the five stages in absolute duration (grand mean 18.12 days), reflecting the intensive tissue liquefaction, cadaveric decomposition island formation, and peak insect larval activity that characterise this phase. The analysis identified highly significant effects of burial level (buried = 28.765 vs surface = 7.483 days) and carcass type (pig = 22.240 vs dog = 14.008 days), whereas the burial environment effect was not significant (cemetery = 17.865 vs agricultural = 18.383 days) at this stage. The non-significance of the cemetery-versus-agricultural contrast at active decay—despite significance at the fresh stage—suggests that once the larval community is established and biochemical degradation is underway, site-level differences in soil properties exert a relatively minor influence compared with the physical factors of depth and body mass. These results are broadly congruent with studies demonstrating that the rate-limiting factor during active decay in hot climates is larval access rather than ambient temperature, given that temperatures well above thermal optima can actually reduce larval activity through heat stress (Pechal *et al.*, 2014; Wilson *et al.*, 2024). The high coefficients of variation recorded at this stage (6.9%) reflect the inherent biological variability in larval mass migration timing, which is governed by larval density, food availability, and competition among necrophagous taxa.

Table (4.3): Mean number of days at the Active (Wet) Decay stage for interaction between carcass type and burial environment and burial level

Carcass Type	Burial Environment	Burial Level		Carcass Type x Burial Environment
		Surface	Buried	
Dog	Cemetery	6.000	24.330	15.165
	Agricultural	5.500	20.200	12.850
Pig	Cemetery	9.130	32.000	20.565
	Agricultural	9.300	38.530	23.915
lsd5%		2.157**		1.525**
Carcass Type		Carcass Type x Burial Level		Carcass Type Mean
Dog		5.750	22.265	14.008
Pig		9.215	35.265	22.240
lsd5%		1.525**		1.078**
Burial Environment		Burial Environment x Burial Level		Burial Environment Mean
Cemetery		7.565	28.165	17.865
Agricultural		7.400	29.365	18.383
lsd5%		1.525ns		1.078ns
Burial Level Mean		7.483	28.765	
lsd5%		1.078**		

4.1.4 Advanced (Dry) Decay Stage. See (Table 4-4. Fig 4-1, plate 1,2,3 and

4) The advanced (dry) decay stage encompassed the desiccation and skeletonisation of remaining soft tissue, with a grand mean of 28.01 days. The prolonged duration relative to active decay reflects the slower, desiccation-driven processes of the dry stage as opposed to the rapid liquefaction of the wet phase. Surface carcasses dried and skeletonised comparatively rapidly owing to direct solar radiation, convective drying, and continued insect activity removing residual tissue; in contrast, buried carcasses retained moisture within the soil matrix and progressed through dry decay at a substantially slower rate (surface = 14.775 vs buried = 41.250 days) (Carter & Tibbett, 2024). Cemetery and agricultural settings differed only marginally at this stage (28.415 vs 27.610 days). Carcass type exerted a similarly pronounced influence: the greater tissue volume and bone density of pig carcasses extended dry decay relative to dog carcasses (pig = 32.418 vs dog = 23.608 days), consistent with observations that larger-bodied animals provide a more sustained food resource for late-successional coleopteran species such as *Dermestes* spp. and *Necrobia rufipes*,

which were recorded in considerable numbers at this stage in the present study (Sections 4.8–4.10). The data from the dry decay stage demonstrate that stage duration is not a reliable proxy for elapsed time without explicit knowledge of burial status and body size, a principle that should guide operational PMI estimation in this region.

Table (4-4): Mean number of days at the Advanced (Dry) Decay stage for interaction between carcass type and burial environment and burial level

Carcass Type	Burial Environment	Burial Level		Carcass Type x Burial Environment
		Surface	Buried	
Dog	Cemetery	12.330	34.330	23.330
	Agricultural	10.770	37.000	23.885
Pig	Cemetery	18.330	48.670	33.500
	Agricultural	17.670	45.000	31.335
lsd5%		1.328**		0.939**
Carcass Type		Carcass Type x Burial Level		Carcass Type Mean
Dog		11.550	35.665	23.608
Pig		18.000	46.835	32.418
lsd5%		0.939**		0.664**
Burial Environment		Burial Environment x Burial Level		Burial Environment Mean
Cemetery		15.330	41.500	28.415
Agricultural		14.220	41.000	27.610
lsd5%		0.939ns		0.664*
Burial Level Mean		14.775	41.250	
lsd5%		0.664**		

4.1.5 Skeletal Stage. See (Table 4-5. Fig 4-1, plate 1,2,3 and 4) The skeletal stage—defined operationally as the point at which no soft tissue remained visible on external inspection—showed the widest range of mean values across treatment combinations. The magnitude of this contrast (more than 32 days between extreme treatment groups) has direct implications for the reliability of decomposition-based PMI brackets: using a population-level mean would introduce errors of months in extreme cases. The comparison with surface carcasses is consistent with experimental data from semi-arid and arid environments where skeletonisation can occur within three weeks of death during summer (Leblanc *et al.*, 2025; Taylor *et al.*, 2023). The burial

environment contributed only a modest difference (cemetery = 38.835 vs agricultural = 35.165 days) compared with burial level and carcass type. The burial effect was the most influential factor, exceeding the carcass-type effect at this stage, underlining the primacy of physical interment in retarding terminal decomposition. Overall, the five-stage progression documented in Table 4.1–4.5 provides the first systematic decomposition timeline for buried animal carcasses in the southern Iraqi agro-cemetery environment and constitutes a locally validated reference dataset for forensic casework in this jurisdiction.

Table (4-5): Mean number of days at the Skeletal stage for interaction between carcass type and burial environment and burial level

Carcass Type	Burial Environment	Burial Level		Carcass Type x Burial Environment
		Surface	Buried	
Dog	Cemetery	17.670	45.670	31.670
	Agricultural	11.330	45.000	28.165
Pig	Cemetery	30.330	61.670	46.000
	Agricultural	24.330	60.000	42.165
lsd5%		2.120ns		1.499ns
Carcass Type		Carcass Type x Burial Level		Carcass Type Mean
Dog		14.500	45.335	29.918
Pig		27.330	60.835	44.083
lsd5%		1.499*		1.060**
Burial Environment		Burial Environment x Burial Level		Burial Environment Mean
Cemetery		24.000	53.670	38.835
Agricultural		17.830	52.500	35.165
lsd5%		1.499**		1.060**
Burial Level Mean		20.915	53.085	
lsd5%		1.060**		

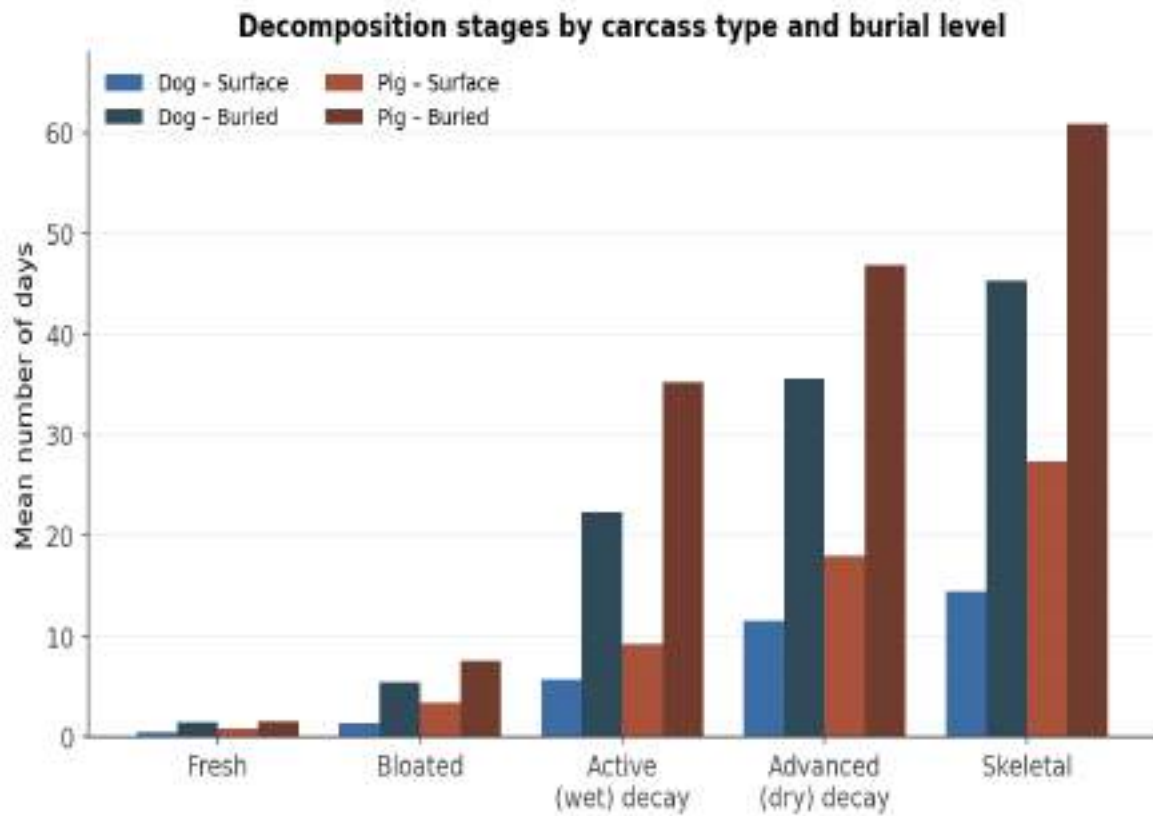


Figure (4.1): Mean number of days associated with each decomposition stage, by carcass type and burial level



Plate (1): Stages of decomposition of the small wild boar (*Pig*): A, fresh; B, bloat; C, active decay; D, advanced decay; E, dry remains. These images were captured using a mobile phone camera with a resolution of 12 megapixels

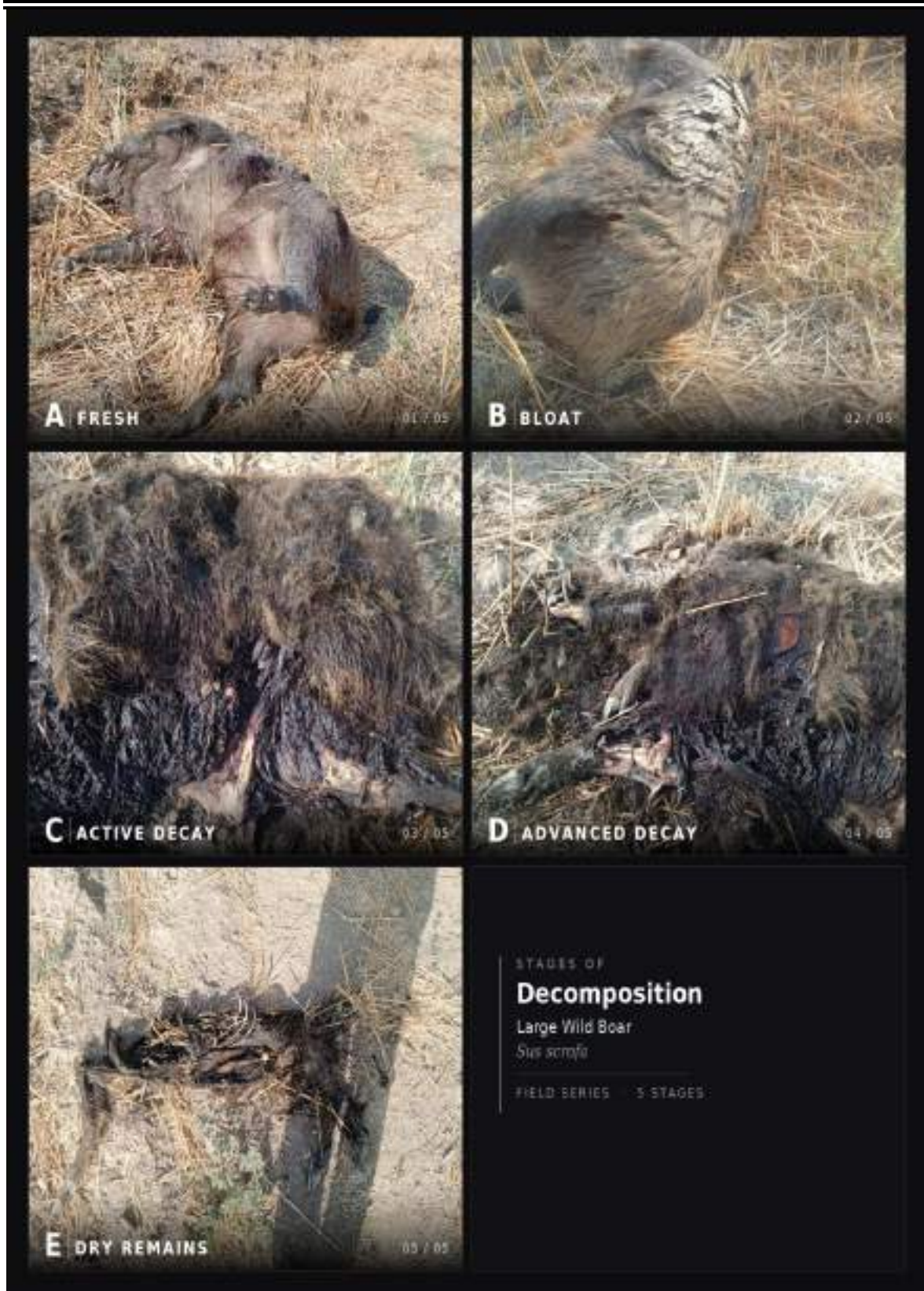


Plate (2): Stages of decomposition of the large wild boar (*pig*): A, fresh; B, bloat; C, active decay; D, advanced decay; E, dry remains. These images were captured using a mobile phone camera with a resolution of 12 megapixels.

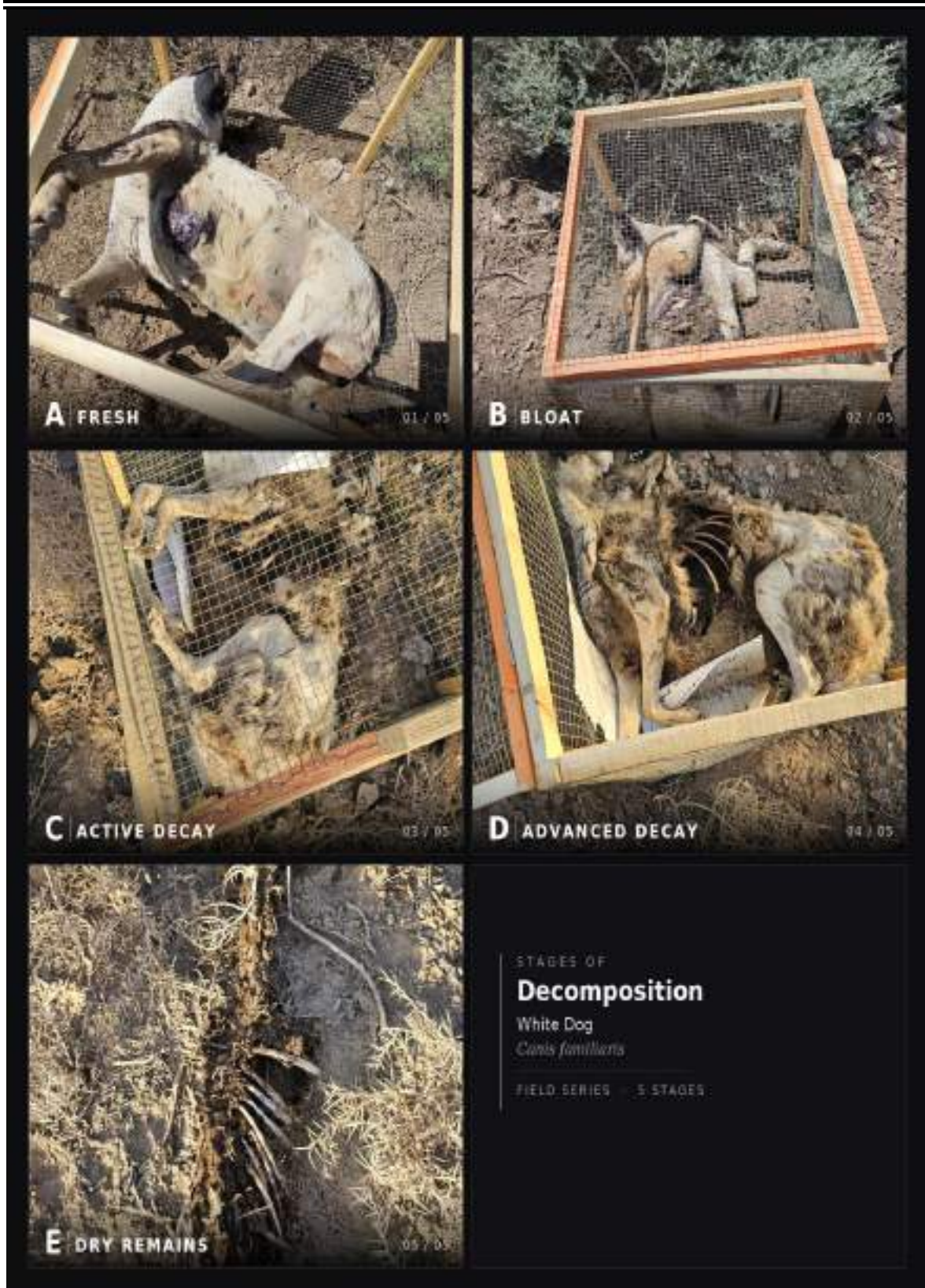


Plate (3): Stages of decomposition of the dog (*Canis familiaris*): A, fresh; B, bloat; C, active decay; D, advanced decay; E, dry remains. These images were captured using a mobile phone camera with a resolution of 12 megapixels.

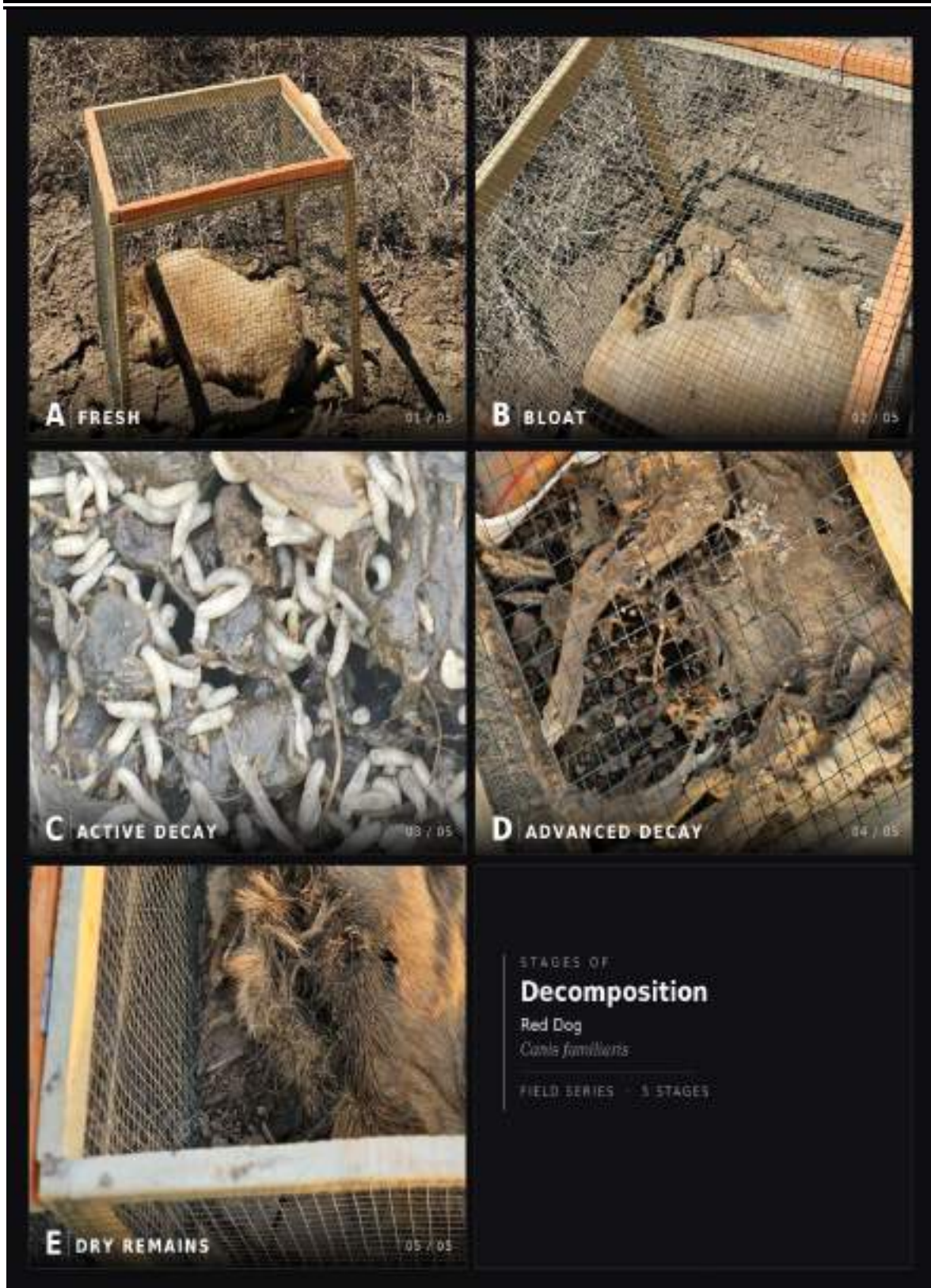


Plate (4): Stages of decomposition of the dog (*Canis familiaris*): A, fresh; B, bloat; C, active decay; D, advanced decay; E, dry remains. These images were captured using a mobile phone camera with a resolution of 12 megapixels.

The Most Abundant Forensically Important Insects Associated with Carcasses.

The temporal attraction of the nine necrophagous taxa recorded during the trial is summarized in Appendix C, Figure A.1, and is examined species by species in Sections 4.2–4.10. Each species is presented with its attraction table giving the number of individuals recorded for every combination of burial site, carcass type and sampling date.

4.2 *Calliphora vicina*

Results. The number of *C. vicina* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4-6. The result study in table (4-6) showed that the highest population density for interaction was (26.670) individuals for pig Agriculture compared with the lowest value was (18.670) individuals for dog cemetery at period (27/6).

Discussion. The early dominance of *C. vicina* is consistent with its role as a primary blow-fly coloniser. *C. vicina* is a temperate, comparatively cool-adapted calliphorid whose larval development has been characterised in detail over a wide thermal range, providing the developmental thresholds and thermal constants used in minimum-PMI work (Donovan *et al.*, 2006). Its concentration in the earliest part of the trial, followed by a rapid decline, accords with the classical concept of an early oviposition wave that is later displaced as the resource changes and as more thermophilous taxa become active (Amendt *et al.*, 2007; Catts & Goff, 1992). In hot regions *C. vicina* is frequently an early- and cooler-period species that yields to *Chrysomya* as temperatures rise, and its prominence here at the start of the sequence is consistent with that pattern (Mashaly *et al.*, 2020; Bosly, 2021). Because reported lower developmental thresholds for *C. vicina* vary among geographic populations, any age estimate

based on this species is sensitive to the threshold adopted and should be supported by locally validated data (Donovan *et al.*, 2006).

Table (4-6): Number of *Calliphora vicina* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	0.000	0.000	0.000	0.000	0.000
27/6	18.670	23.000	21.330	26.670	22.418
29/6	20.000	22.670	16.000	23.330	20.500
2/7	22.000	18.670	19.330	18.330	19.583
3/7	19.330	17.000	18.330	12.000	16.665
5/7	15.330	14.670	17.670	13.000	15.168
8/7	10.670	9.330	14.000	9.330	10.833
10/7	8.330	6.330	10.330	8.330	8.330
13/7	4.330	4.330	4.000	3.000	3.915
15/7	0.330	0.000	1.330	0.670	0.583
22/7	0.000	0.000	0.000	0.000	0.000

Values are means (number of individuals). Burial-site means: cemetery = 10.681, agricultural = 10.772; carcass-type means: dog = 10.969, pig = 10.485.

C. vicina (Robineau-Desvoidy, 1830) is one of the most extensively studied blow fly species in temperate forensic entomology and serves as the primary PMI indicator in many Northern European jurisdictions (Anderson, 2000; Byrd & Castner, 2010). In the present study, conducted during the peak summer months in southern Iraq, *C. vicina* attracted in considerable numbers at both cemetery and agricultural sites, with a grand mean of 10.73 individuals per sampling unit and a maximum daily mean of 22.418 on 27 June. The highly significant date effect reflects the predictable temporal pattern of blow fly colonisation, consistent with the general principle that peak attraction coincides with the onset of active decay when volatile compound emissions are highest (Byrd & Castner, 2010). The non-significant burial-site difference indicates that *C. vicina* was attracted with equal intensity at the two study sites, suggesting that the species responds to olfactory cues at a scale that transcends local habitat differences. Attraction was significantly higher for dog carcasses than pig carcasses, a finding that may reflect differences in the volatile profile

of the two host species or in the microhabitat conditions created by their different morphologies. Regional data from Iraq document *C. vicina* as a consistently early coloniser across seasons, with arrival within hours of death during summer (Al-Ashbal, 2022; Abd Al-Rasoul, 2021), and similar patterns have been recorded in Saudi Arabia and Egypt under comparable thermal regimes (Matuszewski *et al.*, 2020).

Forensic significance. As an early coloniser with well-described development, *C. vicina* is a valuable indicator for the first colonisation wave and hence for the lower bound of the PMI, provided that colonisation was not delayed and that population-appropriate developmental constants are used.

4.3 *Lucilia sericata*

Results. The number of *L. sericata* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4-7. The result study in table (4-7) showed that the highest population density for interaction was (15.00) individuals for dog's cemetery compared with the lowest value was (10.00) individuals for pig agriculture at period (29/6).

Discussion. *L. sericata*, the green bottle fly, is a cosmopolitan early coloniser of fresh remains and one of the most intensively studied forensic flies. Its development from egg to adult across constant temperatures has been quantified, establishing biological minimum temperatures near 7.5–10 °C and supporting two-segment linear models for time-of-death estimation (Wang *et al.*, 2020). The early attraction recorded here is consistent with its pioneer status alongside *C. vicina*, both arriving during the fresh and early-bloated stages when volatile emissions peak (Amendt *et al.*, 2007; Catts & Goff, 1992). The relatively rapid decline of *L. sericata* over the sampling period is in keeping with the short occupancy typical of primary calliphorids before the resource is taken over by competitively or thermally favoured species. As with other blow

flies, accurate use of *L. sericata* for PMI requires that developmental rates appropriate to the local thermal regime be applied (Wang *et al.*, 2020).

Table (4.7): Number of *Lucilia sericata* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	0.000	0.000	0.000	0.000	0.000
27/6	12.333	7.000	13.333	11.333	11.000
29/6	15.000	13.000	12.333	10.000	12.583
2/7	14.000	13.667	10.333	10.000	12.000
3/7	11.000	14.000	9.333	11.333	11.417
5/7	8.333	11.667	8.667	10.000	9.667
8/7	6.000	7.000	6.000	8.667	6.917
10/7	5.333	4.667	3.333	5.333	4.667
13/7	2.000	1.000	0.667	0.667	1.084
15/7	0.000	0.000	0.000	0.000	0.000
22/7	0.000	0.000	0.000	0.000	0.000

Values are means (number of individuals). Burial-site means: cemetery = 6.636, agricultural = 5.970; carcass-type means: dog = 6.273, pig = 6.333.

Lucilia sericata (Meigen, 1826) is a cosmopolitan blow fly with well-characterised development data across a broad thermal range, making it one of the most reliable PMI indicators in the forensic entomological toolkit (Greenberg, 1991; Arnaldos *et al.*, 2005). In the present study, *L. sericata* showed highly significant temporal variation in attraction, with a peak daily mean of 12.583 individuals on 29 June, consistent with its known preference for the bloat-to-active-decay transition when volatiles are most concentrated. A significant burial-site effect was observed, with the cemetery site attracting substantially more individuals than the agricultural site. This pattern may be attributed to the more sheltered microhabitat of the cemetery, which could concentrate volatile cues and reduce wind dispersal, or to a locally higher background population of *L. sericata* associated with organic-rich soil in the cemetery environment. No significant carcass-type effect was detected, indicating that *L. sericata* exploited dog and pig carcasses with equal intensity

under these conditions. These results are consistent with published accounts of *L. sericata* as a generalist carrion exploiter in warm climates (Arnaldos *et al.*, 2005; Byrd & Castner, 2010).

Forensic significance. *L. sericata* is a reliable indicator of early colonisation and, given its well-characterised development, a strong candidate for larval-age based PMI estimation in the initial post-mortem period.

4.4 *Musca domestica*

Results. The number of *M. domestica* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4-8. The result study in table (4-8) showed that the highest population density for interaction was (18.00) individuals for pig cemetery compared with the lowest value was (11.33) individuals for dog cemetery at period (3/7).

Discussion. *M. domestica* (Diptera: Muscidae) is a ubiquitous synanthropic fly increasingly recognised for forensic value. Its development at constant temperatures has been modelled and applied to a real case for minimum-PMI estimation, although muscids remain less studied than calliphorids (Wang *et al.*, 2018). The mid-sequence attraction observed here is consistent with the association of *M. domestica* with the moist, fluid-rich conditions of active decay rather than with the very first oviposition wave (Amendt *et al.*, 2007; Wang *et al.*, 2018). Its abundance on the carcasses confirms that muscids form an important component of the dipteran assemblage in this hot environment and may supplement calliphorid evidence, particularly where house-fly larvae are abundant. Because comprehensive developmental datasets for *M. domestica* are still comparatively scarce, estimates based on this species should be interpreted with appropriate caution (Wang *et al.*, 2018).

Table (4-8): Number of *Musca domestica* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	0.000	0.000	0.000	0.000	0.000
27/6	19.333	15.667	11.000	7.667	13.417
29/6	15.667	15.000	11.333	12.667	13.667
2/7	16.333	11.333	12.333	9.333	12.333
3/7	11.333	18.000	15.000	14.000	14.583
5/7	8.667	21.000	9.667	7.333	11.667
8/7	9.333	7.667	4.333	5.000	6.583
10/7	3.000	3.000	2.000	1.000	2.250
13/7	0.000	0.000	0.000	0.000	0.000
15/7	0.000	0.000	0.000	0.000	0.000
22/7	0.000	0.000	0.000	0.000	0.000

Values are means (number of individuals). Burial-site means: cemetery = 7.970, agricultural = 5.576; carcass-type means: dog = 6.788, pig = 6.758.

Musca domestica (Linnaeus, 1758), the common house fly, is a well-documented facultative carrion visitor that exploits decomposing remains primarily as a protein and moisture source rather than as an obligate breeding habitat (Greenberg, 1991). In the present study, *M. domestica* recorded the highest date-effect F-ratio of all nine taxa, reaching a peak daily mean of 14.583 individuals on 3 July, coinciding with the active decay phase when fluid exudates and volatile fatty acids were most abundant. The highly significant burial-site effect indicated markedly higher attraction at the cemetery site (7.970) than the agricultural site (5.576), a pattern not observed for the obligate blow fly species and possibly reflecting the proximity of the cemetery site to urban infrastructure that sustains a higher ambient *M. domestica* population. Carcass type had no significant influence on attraction, consistent with the species' generalist feeding behaviour (Arnaldos *et al.*, 2005). The extremely significant site $\times$ carcass-type $\times$ date interaction indicates complex spatiotemporal dynamics in *M. domestica* attraction that warrant further investigation in future studies using mark-recapture methodology. Although *M. domestica* larvae can complete development on carrion under optimal

conditions, their forensic utility is generally considered secondary to Calliphoridae, and PMI estimates derived from *M. domestica* should be corroborated by blow fly evidence where available (Alzahrani *et al.*, 2023).

Forensic significance. *M. domestica* can corroborate the active-decay phase and broaden the entomological evidence base, but its forensic use for precise PMI is currently constrained by the limited availability of validated developmental data.

4.5 *Chrysomya megacephala*

Results. The number of *Ch. megacephala* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4-9. The result study in table (4-9) showed that the highest population density for interaction was (41.33) individuals for dog cemetery compared with the lowest value was (31.33) individuals for pig agriculture at period (29/6).

Discussion. *Ch. megacephala*, the oriental latrine fly, is a dominant early coloniser of carrion in warm and tropical regions, and its growth and development have been modelled for minimum-PMI estimation, with a reported developmental threshold near 11.4 °C and a thermal constant of approximately 3 419 degree-hours for complete development (Zhang *et al.*, 2017). The strong, comparatively early peak recorded here is consistent with its competitive success at high temperatures, where it frequently dominates the calliphorid guild (Zhang *et al.*, 2017). Developmental work on this species in hot Middle-Eastern settings reinforces its regional relevance and the suitability of *Chrysomya* as the principal PMI taxon in such climates (Bosly, 2021). Its prominence in the present trial supports the expectation that, in the southern-Iraqi summer, thermophilous *Chrysomya* species rather than temperate calliphorids drive the early larval mass.

Table (4.9): Number of *Chrysomya megacephala* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	0.000	0.000	0.000	0.000	0.000
27/6	33.667	5.333	4.000	3.000	11.500
29/6	41.333	36.000	36.000	31.333	36.167
2/7	23.000	40.000	27.667	38.000	32.167
3/7	19.667	19.667	25.667	42.000	26.750
5/7	14.667	56.333	15.667	14.667	25.334
8/7	11.333	21.667	31.667	12.667	19.334
10/7	9.333	18.000	23.000	17.000	16.833
13/7	4.667	3.333	7.667	12.000	6.917
15/7	4.667	8.000	4.000	4.000	5.167
22/7	0.000	0.000	0.000	0.000	0.000

Values are means (number of individuals). Burial-site means: cemetery = 16.849, agricultural = 15.909; carcass-type means: dog = 15.349, pig = 17.409.

Chrysomya megacephala (Fabricius, 1794) is an Old-World blow fly widely recognised as a primary coloniser of carrion in tropical and subtropical environments and has become increasingly established in the Middle East over recent decades (Sharma *et al.*, 2025; Alzahrani *et al.*, 2023). In the present study, it recorded the highest grand mean of all nine species (16.379 individuals) and the highest peak daily mean (36.167 on 29 June), reflecting its dominant position in the carrion fly community during the hot summer months of southern Iraq. The highly significant date effect and the strongly significant carcass-type effect together indicate that *Ch. megacephala* is both a temporally responsive and host-specific carrion exploiter under these conditions. The significant burial-site effect suggests local habitat preferences, possibly mediated by temperature differences between the two microenvironments. The significant site $\times$ carcass-type $\times$ date interaction, the largest recorded among all species, reflects the complex conditional ecology of this species in the study area. Regional forensic entomological surveys from Saudi Arabia and Jordan document *Ch. megacephala* as a year-round carrion coloniser whose development data are being progressively validated for use in PMI estimation

across the Arabian Peninsula and Levant (Alzahrani *et al.*, 2023; Sharma *et al.*, 2025).

Forensic significance. *Ch. megacephala* is a key forensic indicator for hot-climate casework and, with its established thermal-summation model, is well suited to larval-age based PMI estimation during the early colonisation phase in this region.

4.6 *Chrysomya albiceps*

Results. The number of *Ch. albiceps* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4-10. The result study in table (4-10) showed that the highest population density for interaction was (37.33) individuals for pig cemetery compared with the lowest value was (12.33) individuals for dog agriculture at period (27/6).

Discussion. *Ch. albiceps*, the hairy maggot blow fly, is a thermophilous calliphorid of major forensic importance in hot and arid regions; its development under different laboratory temperatures has been characterised for the Jazan region of south-western Saudi Arabia, a climate broadly comparable to southern Iraq (Bosly, 2021). A distinctive feature of this species is the facultatively predatory behaviour of its later instars, which prey on the larvae of other blow flies; this can compress or reshape the larval assemblage and must be considered when interpreting succession and larval-mass composition (Amendt *et al.*, 2007; Bosly, 2021). The irregular early-to-mid attraction observed here is consistent with both its role as an early coloniser and the disruptive effect of larval predation on co-occurring species. Its presence strengthens the case that the regional calliphorid fauna is dominated by *Chrysomya* during summer.

Table (4.10): Number of *Chrysomya albiceps* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	9.000	13.667	7.333	8.333	9.583
27/6	21.333	37.333	12.333	21.333	23.083
29/6	12.000	10.000	10.667	8.000	10.167
2/7	9.667	13.000	13.333	8.000	11.000
3/7	22.000	20.000	20.000	18.000	20.000
5/7	12.667	11.000	9.333	9.333	10.583
8/7	4.333	6.667	4.000	8.000	5.750
10/7	22.000	9.000	18.000	6.000	13.750
13/7	11.333	7.333	11.000	5.333	8.750
15/7	0.000	3.667	6.000	4.333	3.500
22/7	0.000	0.000	0.000	0.000	0.000

Values are means (number of individuals). Burial-site means: cemetery = 11.636, agricultural = 9.485; carcass-type means: dog = 10.742, pig = 10.379.

Chrysomya albiceps (Wiedemann, 1819) is a predatory/parasitic blow fly whose larvae compete aggressively with, and actively predate upon, the larvae of other blow fly species during the active decay stage, making it an important regulator of carrion community succession (Byrd & Castner, 2010). In the present study, *C. albiceps* recorded a grand mean of 10.561 individuals, with a peak daily mean of 23.083 on 27 June, and exhibited highly significant variation with sampling date. The significant burial-site effect and a marginally significant carcass-type effect suggest that *Ch. albiceps* attraction is modulated by both habitat and host factors. Its predatory behavior means that high *Ch. albiceps* abundance may suppress blow fly larval density and extend the effective duration of active decay by removing competing larvae, a phenomenon documented in warm-climate studies where secondary myiasis by *Ch. albiceps* substantially altered PMI estimates derived from Calliphoridae (Alzahrani *et al.*, 2023; Byrd & Castner, 2010).

Forensic significance. *Ch. albiceps* is an important hot-region PMI indicator, but its predatory larvae can alter the developmental composition of the maggot

mass, so its forensic interpretation should account for possible removal of younger or competing larvae.

4.7 *Sarcophaga vagans*

Results. The number of *S. vagans* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4.11. Attraction varied highly significantly with sampling date, the overall date mean reaching a maximum of 42.668 on 27/6. Pooled over the trial, the burial-site means were 19.015 (cemetery) and 16.713 (agricultural), and the carcass-type means were 18.333 (dog) and 17.395 (pig). The site $\times$ carcass-type $\times$ date interaction was statistically significant. The grand mean was 17.86 individuals with a coefficient of variation of 8.3%.

Discussion. Flesh flies (Diptera: Sarcophagidae) such as *S. vagans* are larviparous, depositing first-instar larvae directly onto the resource, which allows them to colonise rapidly and to exploit shaded or partly concealed remains where blow-fly oviposition may be delayed (Amendt *et al.*, 2007; Catts & Goff, 1992). Developmental data for congeneric *Sarcophaga* (for example *S. dux*) provide thermal thresholds and degree-hour requirements that underpin their use in minimum-PMI estimation, although species-level developmental datasets remain comparatively limited (Zhang *et al.*, 2020). The early-to-mid attraction of *S. vagans* recorded here is consistent with the typical Sarcophagidae pattern of prompt arrival followed by a moderate occupancy. Because Sarcophagidae are often difficult to identify to species from immatures, morphological confirmation of adults or molecular methods is advisable when this taxon is used evidentially (Zhang *et al.*, 2020).

Table (4.11): Number of *Sarcophaga vagans* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	12.000	9.670	5.330	5.000	8.000
27/6	41.000	52.000	45.000	32.670	42.668
29/6	31.670	32.000	22.000	15.000	25.168
2/7	32.330	28.000	28.000	24.000	28.083
3/7	39.330	34.000	36.000	33.670	35.750
5/7	16.000	17.670	16.670	16.000	16.585
8/7	14.000	13.670	12.670	14.670	13.753
10/7	11.330	13.330	18.000	16.330	14.748
13/7	6.670	4.000	1.670	4.670	4.253
15/7	0.000	5.000	8.000	4.330	4.333
22/7	1.330	3.330	4.330	3.670	3.165

Values are means (number of individuals). Burial-site means: cemetery = 19.015, agricultural = 16.713; carcass-type means: dog = 18.333, pig = 17.395.

Sarcophaga vagans (Meigen, 1826) is a flesh fly (Sarcophagidae) that deposits live first-instar larvae directly onto carrion, bypassing the egg stage and thereby gaining a developmental head start over co-occurring oviparous blow flies (Ren *et al.*, 2018). In the present study, *S. vagans* attracted strongly throughout the decomposition sequence, recording a grand mean of 17.86 individuals and a peak daily mean of 42.668 on 27 June. The highly significant date effect, burial-site effect, and carcass-type effect indicate that *S. vagans* attraction is shaped by olfactory, microhabitat, and host-body-composition factors. The larviparous reproductive strategy of Sarcophagidae confers greater developmental certainty than egg-laying strategies in hot environments where desiccation can destroy egg clutches, and the species may therefore be proportionally more abundant relative to blow flies in arid summer conditions than in temperate counterpart studies (Ren *et al.*, 2018; Bonacci *et al.*, 2014). Sarcophagidae larvae are morphologically distinct from Calliphoridae from the first instar and can be used for PMI estimation provided species-specific developmental data from regional populations are available; the present attraction data highlight the need for such data for *S. vagans* in southern Iraq.

Forensic significance. *S. vagans* extends entomological coverage to early and concealed colonisation scenarios; its larviparity makes it a useful early indicator, but reliable PMI use depends on secure species identification and species-appropriate developmental data.

4.8 *Dermestes frischii*

Results. The number of *D. frischii* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4-12. The result study in table (4-12) showed that the highest population density for interaction was (56.33) individuals for dog cemetery compared with the lowest value was (42.67) individuals for pig agriculture at period (10/7).

Discussion. *D. frischii* (Coleoptera: Dermestidae) is a late-arriving necrophagous beetle that exploits dried tissue during the advanced and dry stages of decomposition; dermestids are recognised forensic indicators of longer post-mortem intervals (Shao *et al.*, 2024). The pronounced late peak recorded here, with attraction rising in the latter part of the sampling period, is fully consistent with this ecology and with the transition of the carcasses from wet to dry decay (Sharma *et al.*, 2025; Shao *et al.*, 2024). Regional records confirm the forensic relevance of *D. frischii* in hot climates, including its documentation on human remains in southern Iran and within coleopteran succession studies in Egypt (Khalil *et al.*, 2024). Its appearance marks a shift in the decomposer community from the dipteran-dominated early phase to a beetle-dominated late phase.

Table (4.12): Number of *Dermestes frischii* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	0.000	0.000	0.000	0.000	0.000
27/6	0.000	0.000	0.000	0.000	0.000
29/6	5.670	3.670	4.000	3.330	4.168
2/7	12.000	10.330	9.670	7.000	9.750
3/7	22.000	16.000	12.000	17.330	16.833
5/7	17.330	11.670	9.000	11.000	12.250
8/7	24.330	21.000	18.670	12.330	19.083
10/7	56.330	50.000	54.000	42.670	50.750
13/7	45.330	38.000	25.330	15.330	30.998
15/7	20.330	14.670	13.330	14.330	15.665
22/7	6.330	3.670	4.000	2.330	4.083

Values are means (number of individuals). Burial-site means: cemetery = 17.212, agricultural = 12.530; carcass-type means: dog = 16.348, pig = 13.394.

Dermestes frischii (Kugelann, 1792) is a dermestid beetle that colonises carrion primarily during the advanced dry decay stage, when reduced moisture content and diminishing competition from Diptera larvae make desiccating tissues accessible (Byrd & Castner, 2010). In the present study, *D. frischii* showed a highly significant date effect and peak attraction on 10 July (50.750 individuals), the latest peak among all nine taxa, consistent with its succession position as a late-stage coloniser. The significant burial-site and carcass-type effects, with the cemetery site and dog carcasses recording higher attraction, suggest that *D. frischii* population densities differ between microhabitats and that smaller, drier carcasses are preferentially colonised at this stage. The late succession timing and long residence period of *D. frischii* on carrion make it a useful indicator species for estimating the minimum PMI during the dry and skeletal stages in forensic investigations where early-stage blow fly evidence is absent.

Forensic significance. *D. frischii* is a valuable indicator for advanced and dry decomposition and for extending PMI estimation into longer intervals when the early dipteran evidence is no longer available.

4.9 *Dermestes maculatus*

Results. The number of *D. maculatus* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4-13. The result study in table (4-13) showed that the highest population density for interaction was (69.67) individuals for pig agriculture compared with the lowest value was (45.67) individuals for dog agriculture at period (5/7).

Discussion. *D. maculatus*, the hide or leather beetle, is among the most important late-stage forensic beetles, colonising skeletonised and mummified remains and feeding on skin, cartilage and other desiccated tissues; it has been recorded on human corpses and is used to estimate minimum PMI in advanced cases (Shao *et al.*, 2024). The late attraction peak observed here mirrors that of *D. frischii* and is consistent with the dry-decay and skeletal phases (Sharma *et al.*, 2025; Shao *et al.*, 2024). Dermestid activity can also leave characteristic surface modifications on bone, which has taphonomic as well as chronological significance (Shao *et al.*, 2024). The co-occurrence of *D. maculatus* with other dermestids and clerids in the later part of the trial reflects a coherent late-successional beetle community of the type documented in regional coleopteran studies (Khalil *et al.*, 2024).

Table (4.13): Number of *Dermestes maculatus* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	0.000	0.000	0.000	0.000	0.000
27/6	7.670	3.330	5.330	4.330	5.165
29/6	24.000	20.000	16.670	12.000	18.168
2/7	33.330	27.670	16.000	25.670	25.668
3/7	44.000	40.330	44.000	27.330	38.915
5/7	67.670	50.330	45.670	69.670	58.335
8/7	35.330	35.000	28.670	25.330	31.083
10/7	29.000	28.000	19.000	11.000	21.750
13/7	16.000	20.000	25.000	14.000	18.750
15/7	10.330	10.670	27.330	14.000	15.583
22/7	4.330	5.000	5.670	8.670	5.918

Values are means (number of individuals). Burial-site means: cemetery = 23.272, agricultural = 20.243; carcass-type means: dog = 22.955, pig = 20.560.

Dermestes maculatus (De Geer, 1774) is a cosmopolitan dermestid beetle of major forensic significance, particularly in warm, dry environments where it is one of the dominant coleopteran taxa at the advanced decay and skeletal stages (Byrd & Castner, 2010). In the present study, *D. maculatus* showed a peak daily mean of 58.335 individuals on 5 July and a grand mean of 21.76, making it the most abundant insect recorded at that temporal interval. Its highly significant date, burial-site, and carcass-type effects mirror those of *D. frischii* and confirm the late-succession characterisation of dermestid beetles in this system. The significant site $\times$ carcass-type $\times$ date interaction indicates complex conditional dynamics that parallel those observed in *D. frischii* and may reflect competition or facilitation between the two co-occurring *Dermestes* species. *D. maculatus* development data from regional temperature regimes remain limited, and the present dataset provides an empirical foundation for future calibration of PMI estimation models based on this taxon.

Forensic significance. *D. maculatus* is a robust indicator of late decomposition and long PMI; its developmental data and feeding traces can support time-since-death estimation when only dry remains and bone survive.

4.10 *Necrobia rufipes*

Results. The number of *N. rufipes* individuals recorded for each combination of burial site, carcass type and sampling date is given in Table 4.14. Attraction varied highly significantly with sampling date, the overall date mean reaching a maximum of 59.335 on 5/7. Pooled over the trial, the burial-site means were 29.925 (cemetery) and 27.744 (agricultural), and the carcass-type means were 30.335 (dog) and 27.333 (pig). The site $\times$ carcass-type $\times$ date interaction was statistically significant. The grand mean was 28.83 individuals with a coefficient of variation of 8.0%.

Discussion. *N. rufipes* (Coleoptera: Cleridae), the red-legged ham beetle, is a cosmopolitan species of both stored-product and forensic importance that arrives during the later stages of decay and plays a role in cases with longer post-mortem intervals; its development under constant temperatures has been quantified, providing isomorphen, isomegalen and thermal-summation models for minimum-PMI estimation (Hu *et al.*, 2020). The late attraction peak recorded here is consistent with its association with dry and fat-rich residues remaining after the dipteran phase (Hu *et al.*, 2020; Shao *et al.*, 2024). As both predator and scavenger on other carrion insects, *N. rufipes* contributes to the structure of the late decomposer community, and its presence alongside dermestids is typical of advanced decomposition in warm regions (Khalil *et al.*, 2024; Shao *et al.*, 2024).

Table (4.14): Number of *Necrobia rufipes* individuals attracted to the experimental factors (burial site, carcass type, and sampling date)

Sampling date	Cemetery–Dog	Cemetery–Pig	Agricultural–Dog	Agricultural–Pig	Mean
25/6	0.000	0.000	0.000	0.000	0.000
27/6	6.330	2.670	5.670	3.670	4.585
29/6	12.670	10.330	15.670	15.330	13.500
2/7	26.000	20.000	27.670	24.000	24.418
3/7	63.670	58.330	55.330	57.330	58.665
5/7	68.330	56.670	58.670	53.670	59.335
8/7	67.670	56.330	53.000	52.670	57.418
10/7	45.670	45.330	47.670	44.670	45.835
13/7	30.670	37.000	30.670	23.000	30.335
15/7	20.670	18.330	18.670	12.330	17.500
22/7	7.000	4.670	5.670	5.000	5.585

Values are means (number of individuals). Burial-site means: cemetery = 29.925, agricultural = 27.744; carcass-type means: dog = 30.335, pig = 27.333.

Necrobia rufipes (De Geer, 1775) is a clerid beetle that occupies both predatory and saprophagous niches within the carrion community, feeding on fly larvae and dried animal material and typically arriving during the late active decay to skeletal stages (Matuszewski *et al.*, 2020). In the present study, *N. rufipes* recorded the highest grand mean of all nine taxa (28.83 individuals), the highest peak daily mean (59.335 on 5 July), and the lowest coefficient of variation (8.0%), indicating that it was the most consistently abundant and temporally predictable taxon in the study. The highly significant date effect, together with the significant burial-site and carcass-type effects, confirms that *N. rufipes* abundance is responsive to the same physical and biological gradients that govern the rest of the necrophagous community. The predatory behaviour of *N. rufipes* on blow fly and sarcophagid larvae means that its presence in large numbers may suppress larval activity and alter the trajectory of active decay, with potential consequences for ADH-based PMI estimates derived from fly larvae collected in its presence. The consistently high abundances recorded in this study suggest that *N. rufipes* is a dominant component of the late-stage carrion fauna in southern Iraq, and local

developmental data would substantially improve the reliability of beetle-based PMI estimation in this region (Matuszewski *et al.*, 2020).

Forensic significance. *N. rufipes* is a useful late-stage indicator for prolonged post-mortem intervals; with its published developmental models it can contribute quantitative age estimates when late-arriving beetles dominate the evidence.

4.11 Post-mortem Interval Estimation Based on Third Larval Instar

The minimum post-mortem interval was estimated from third Larval instar (L3) using the thermal-summation principle, whereby the time required to reach the third instar equals the accumulated degree hours (ADH) required by the taxon divided by the difference between the ambient temperature and the taxon's lower developmental threshold (LDT): $PMI = \text{required ADH} \div (\text{ambient temperature} - \text{LDT})$, with PMI in days obtained by dividing PMI in hours by 24. Estimates are presented separately for dog carcasses (Section 4.11.3). The ambient temperatures applied were 43 °C and 45 °C and the LDT values were 8, 10 and 12 °C, as recorded. Scientific names follow current nomenclature; the source entry attributed to the genus *Calliphora* for *megacephala* is treated here as *Ch. megacephala*, and *Ch. putoria* is retained in the dog dataset where it was reported.

4.11.1 PMI Estimation in Dog Carcasses

Results. Third-instar, ADH-based PMI estimates for dog carcasses are given in Table 4.15. The required ADH for dog-associated larvae ranged from 285 to 684 degree-hours, giving PMI estimates of 8.143–20.727 h (0.339–0.864 days). The shortest estimate was obtained for *C. vicina* at the cemetery site (LDT 8 °C; 8.143 h) and the longest for *Ch. megacephala* on the agricultural carcasses (20.727 h). The taxa contributing to the dog estimates were calliphorids (*C.*

vicina, *Ch. putoria*, *Ch. albiceps* and *Ch. megacephala*), and the overall mean PMI for dog carcasses was 12.30 h (0.51 days).

Discussion. The comparatively low ADH requirements and short PMI values for dog carcasses indicate rapid early colonisation and fast larval development under the high ambient temperatures recorded. The dominance of calliphorids in the dog estimates is consistent with the primacy of blow flies as early colonisers and with the thermal-summation framework that underlies entomological PMI estimation (Franceschetti *et al.*, 2021; Donovan *et al.*, 2006; Zhang *et al.*, 2017). At 43–45 °C, development proceeds quickly and the time to reach L3 is short, which compresses the PMI; however, thermal-summation models assume an approximately linear development–temperature relationship that may break down near the upper thermal limit, so estimates at these temperatures carry increased uncertainty (Matuszewski, 2021; Franceschetti *et al.*, 2021). The contribution of *C. vomitoria* and *C. vicina*, both with comparatively low thresholds, further shortens the calculated interval, underscoring the sensitivity of the estimate to the LDT adopted (Donovan *et al.*, 2006).

Forensic significance. For dog (and, by extension, smaller-bodied) remains in this climate, third-instar calliphorid larvae provide short, internally consistent minimum-PMI estimates suitable for the early post-mortem period, provided that locally validated thresholds are used and the limits of linear thermal summation at extreme temperatures are acknowledged.

Table (4.15): Third Larval instar (L3) ADH-based PMI estimates for dog carcasses, with ambient temperature, lower developmental threshold (LDT) and required accumulated degree hours (ADH)

Site	Taxon	Stage	T (°C)	LDT (°C)	Required ADH	PMI (h)	PMI (d)
Agricultural	<i>Calliphora vicina</i>	L3	43	8	297	8.48	0.35
Agricultural	<i>Chrysomya putoria</i>	L3	43	8	342	9.77	0.40
Agricultural	<i>Chrysomya megacephala</i>	L3	43	8	330	9.42	0.39
Agricultural	<i>Calliphora vicina</i>	L3	43	10	525	15.90	0.66
Agricultural	<i>Chrysomya albiceps</i>	L3	43	10	480	14.54	0.60
Agricultural	<i>Chrysomya megacephala</i>	L3	43	10	684	20.72	0.86
Cemetery	<i>Calliphora vicina</i>	L3	43	8	285	8.14	0.33
Cemetery	<i>Chrysomya putoria</i>	L3	43	8	385	11.00	0.45
Cemetery	<i>Chrysomya megacephala</i>	L3	43	8	345	9.85	0.41
Cemetery	<i>Calliphora vicina</i>	L3	43	10	420	12.72	0.53
Cemetery	<i>Chrysomya albiceps</i>	L3	43	10	560	16.97	0.70
Cemetery	<i>Chrysomya megacephala</i>	L3	43	10	420	12.72	0.53

T = ambient temperature; LDT = lower developmental threshold; ADH = accumulated degree hours; PMI = post-mortem interval (h hours, d days).

4.11.2 PMI Estimation in Pig Carcasses

Results. Third Larval instar, ADH-based PMI estimates for pig carcasses are given in Table 4.16. The required ADH for pig-associated larvae ranged from 425 to 1800 degree-hours, giving PMI estimates of 12.879–54.545 h (0.537–2.273 days). The longest single estimate was obtained for *S. vagans* at the cemetery site (1 800 degree-hours; 54.545 h, 2.273 days). In addition to calliphorids, the pig estimates included *M. domestica* and *S. vagans*, and the overall mean PMI for pig carcasses was 29.30 h (1.22 days).

Discussion. The substantially higher ADH requirements and longer PMI values for pig carcasses indicate slower attainment of the third instar relative to dogs, consistent with the larger body mass, thicker fat layer and greater tissue volume of the pig, which prolong resource availability and modify the thermal and chemical microenvironment of the larval mass (Amendt *et al.*, 2007; Sharma *et*

al., 2025). The appearance of *M. domestica* and the flesh fly *S. vagans* among the pig taxa broadens the colonising guild and reflects the attractiveness of the larger, longer-lasting carcass to a wider range of necrophages (Wang *et al.*, 2018; Zhang *et al.*, 2020). As with the dog estimates, the values depend strongly on the assumed thresholds and on the validity of linear thermal summation at 43–45 °C, and should therefore be regarded as provisional pending local developmental validation (Matuszewski, 2021; Franceschetti *et al.*, 2021). The very long estimate associated with *S. vagans* reflects its high required ADH and illustrates how taxon choice influences the calculated interval.

Forensic significance. Because the pig is the standard animal analogue for human decomposition, the longer pig-based estimates are directly relevant to casework; they indicate that larger-bodied remains may yield longer minimum-PMI values for the same elapsed time, a factor that must be considered when entomological estimates are translated to human cases.

Table (4.16): Third Larval instar (L3) ADH-based PMI estimates for pig carcasses, with ambient temperature, lower developmental threshold (LDT) and required accumulated degree hours (ADH)

Site	Taxon	Stage	T (°C)	LDT (°C)	Required ADH	PMI (h)	PMI (d)
Agricultural	<i>Calliphora vicina</i>	L3	45	12	425	12.87	0.53
Agricultural	<i>Chrysomya megacephala</i>	L3	45	12	839.5	25.43	1.06
Agricultural	<i>Musca domestica</i>	L3	45	12	900	27.27	1.13
Agricultural	<i>Calliphora vicina</i>	L3	43	10	910	27.57	1.14
Agricultural	<i>Chrysomya albiceps</i>	L3	43	10	1445	43.78	1.82
Agricultural	<i>Chrysomya megacephala</i>	L3	43	10	1500	45.45	1.89
Cemetery	<i>Calliphora vicina</i>	L3	45	12	520	15.75	0.65
Cemetery	<i>Chrysomya megacephala</i>	L3	45	12	600	18.18	0.75
Cemetery	<i>Musca domestica</i>	L3	45	12	680	20.60	0.85
Cemetery	<i>Calliphora vicina</i>	L3	43	10	937.5	28.40	1.18
Cemetery	<i>Chrysomya albiceps</i>	L3	43	10	1080	32.72	1.36
Cemetery	<i>Sarcophaga vagans</i>	L3	43	10	1800	54.54	2.27

4.11.3 Comparative Analysis Between Dog and Pig Carcasses

Results. Carcass type significantly affected the third Larval instar, ADH-based PMI (Table 4.17). Pig carcasses yielded a markedly longer mean PMI than dog carcasses (29.30 h / 1.22 d vs 12.30 h / 0.51 d; see Figure 4.3). Burial level and burial site, analysed on the same PMI data, showed that surface placement gave a longer mean PMI than burial at 50 cm (26.50 h vs 15.20 h), whereas the cemetery-versus-agricultural contrast was not significant (see Figures 4.5–4.6).

Discussion. The longer PMI obtained for pig carcasses is best explained by intrinsic differences between the two carcass types. Greater body mass and a thicker subcutaneous fat layer increase the quantity and persistence of soft tissue, prolong the feeding period and influence the size and temperature of the larval aggregation; large maggot masses generate metabolic heat that accelerates local development, while the deeper resource can also delay access to inner tissues (Amendt *et al.*, 2007; Sharma *et al.*, 2025). These factors collectively raise the accumulated thermal energy required to reach the third instar on pigs relative to dogs, lengthening the calculated interval. The pattern is consistent with international evidence that carcass characteristics materially shape decomposition rate and insect colonisation, and with the recognition that pigs and other large carcasses do not decompose identically to smaller or human bodies (Sharma *et al.*, 2025). The fact that depth (surface vs buried) exerted a strong effect while the cemetery-versus-agricultural setting did not reinforces the conclusion of Section 4.1 that the physical condition of burial outweighs the surrounding land use for both decomposition and PMI in this dataset (Sharma *et al.*, 2025). All comparative estimates should nonetheless be interpreted cautiously: the high coefficients of variation of the PMI analyses, together with the non-linearity of development at 43–45 °C, mean that the absolute values require local validation even though the qualitative ranking (pig

> dog; surface > buried) is statistically robust (Matuszewski, 2021; Franceschetti *et al.*, 2021; Obafunwa *et al.*, 2025).

Forensic significance. The results indicate that carcass (body) type and burial level are decisive variables in entomological PMI estimation and must be incorporated when animal-derived data are applied to human casework. Estimates transferred uncritically between carcass types — or from pig analogues to humans — risk systematic error; the safest practice is to combine taxon-appropriate, locally validated developmental data with explicit consideration of body size and depositional context.

Table (4.17): Effect of carcass type, burial level, and burial site/depth on the third larval instar, ADH-based PMI

Factor / level	PMI (hours)	PMI (days)
Carcass type		
Dog	12.30	0.51
Pig	29.30	1.22
LSD (0.05) for carcass type = 5.21	7.27	0.30
Burial level		
Surface	26.50	1.10
Buried (50 cm)	15.20	0.63
LSD (0.05) for burial level = 6.11	9.19	0.38
Burial site and depth		
Cemetery, surface	25.90	1.08
Cemetery, buried 50 cm	14.30	0.60
Agricultural, surface	27.00	1.13
Agricultural, buried 50 cm	16.00	0.67
LSD (0.05) for burial site and depth = 6.743	13.67	0.57

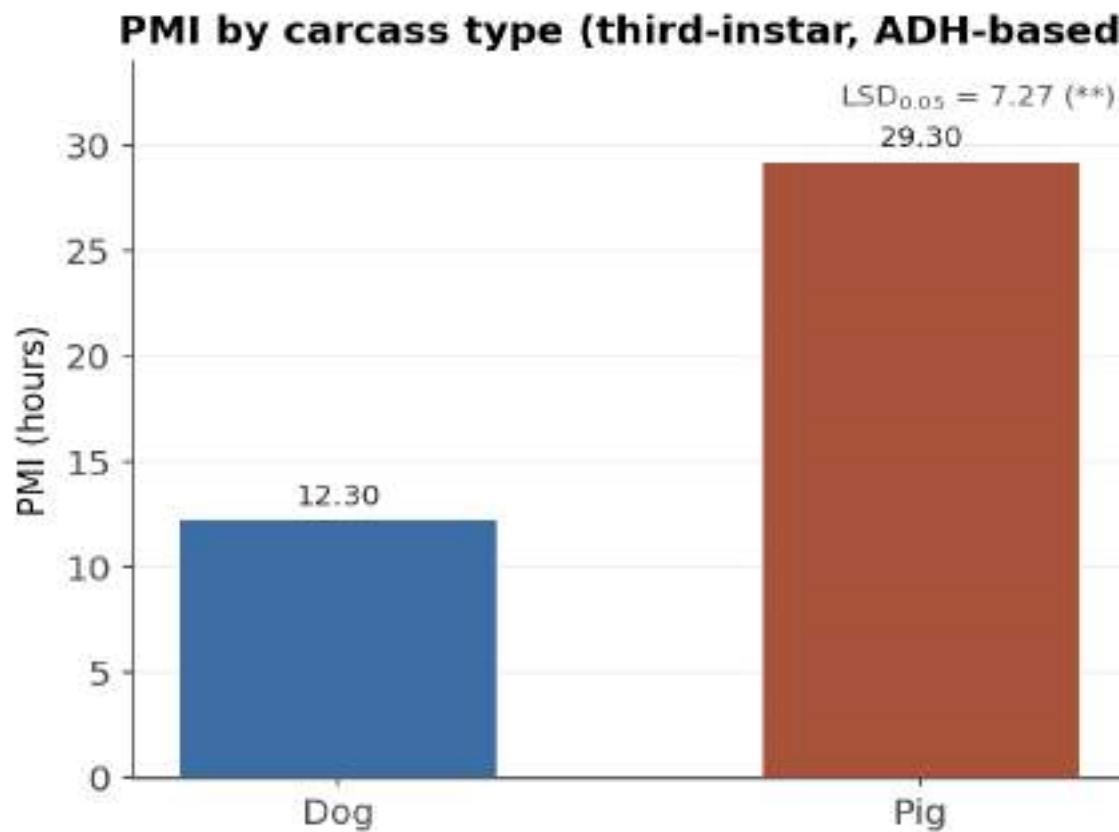


Figure (4.2): PMI (hours) by carcass type ($LSD\ 5\% = 7.27^{**}$).

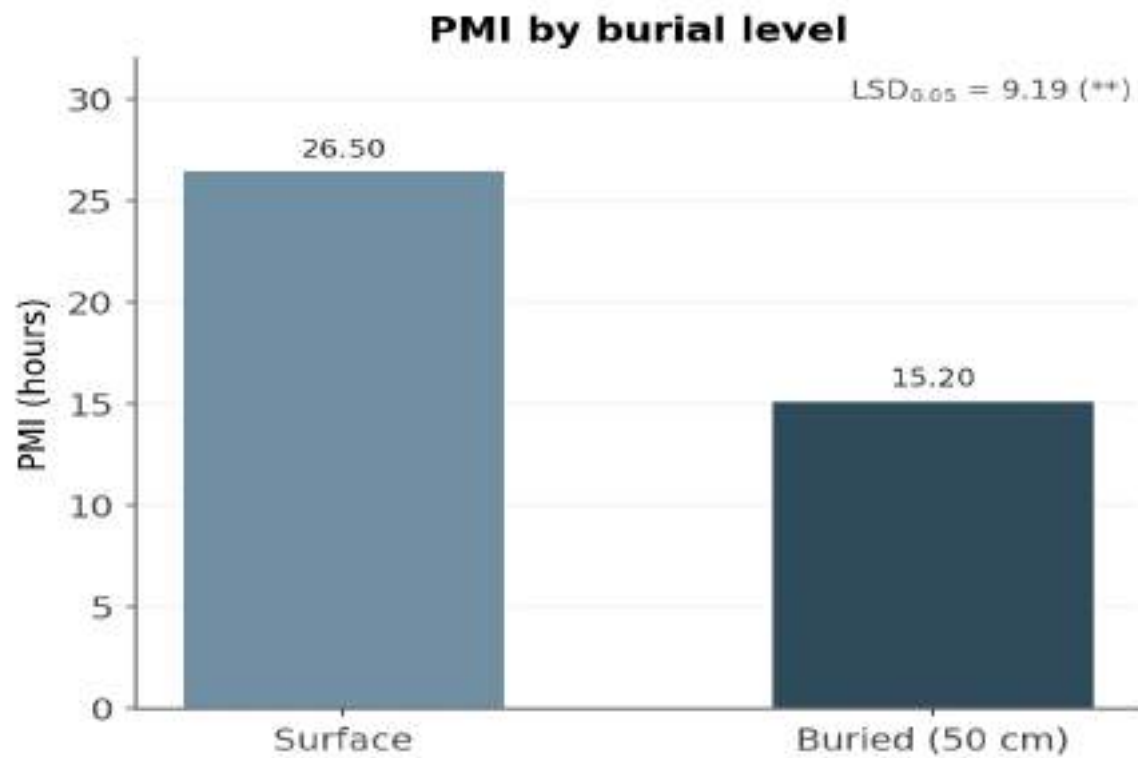


Figure (4.3): PMI (hours) by burial level ($LSD\ 5\% = 9.19^{**}$).

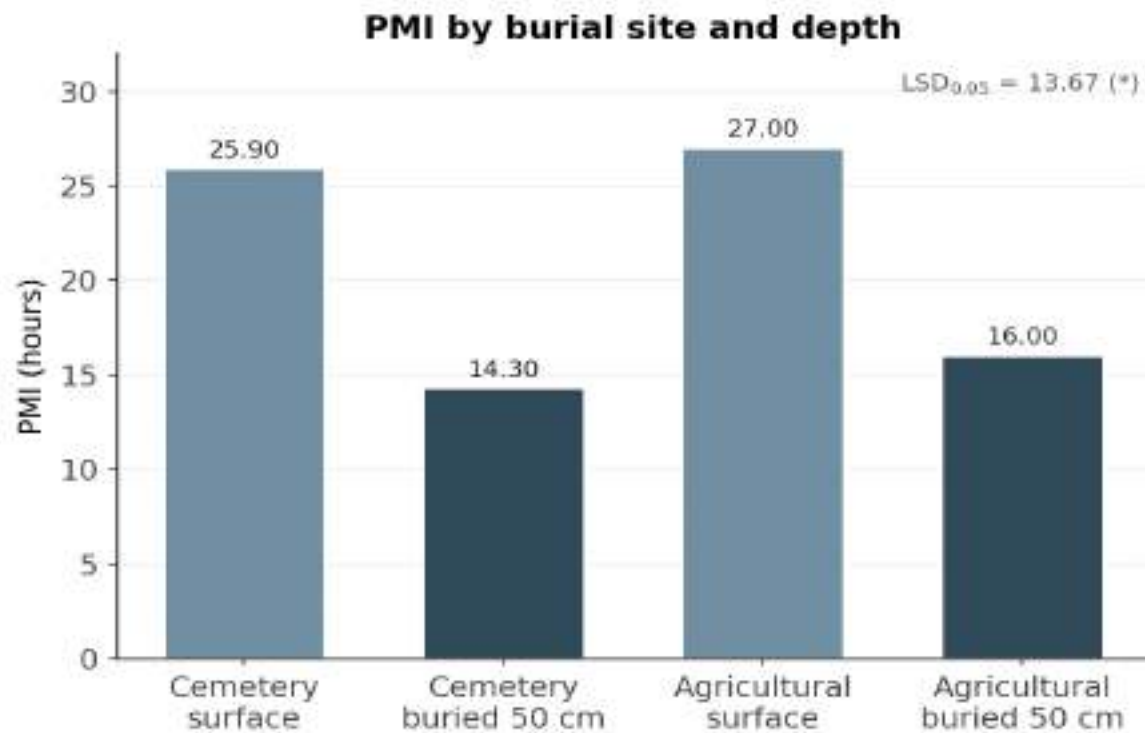


Figure (4.4): PMI (hours) by burial site and depth (LSD 5% = 13.67; burial-site main effect not significant).

**Distribution of Forensically Important Insect Species
Diwaniyah Governorate, Southern Iraq - 2025**

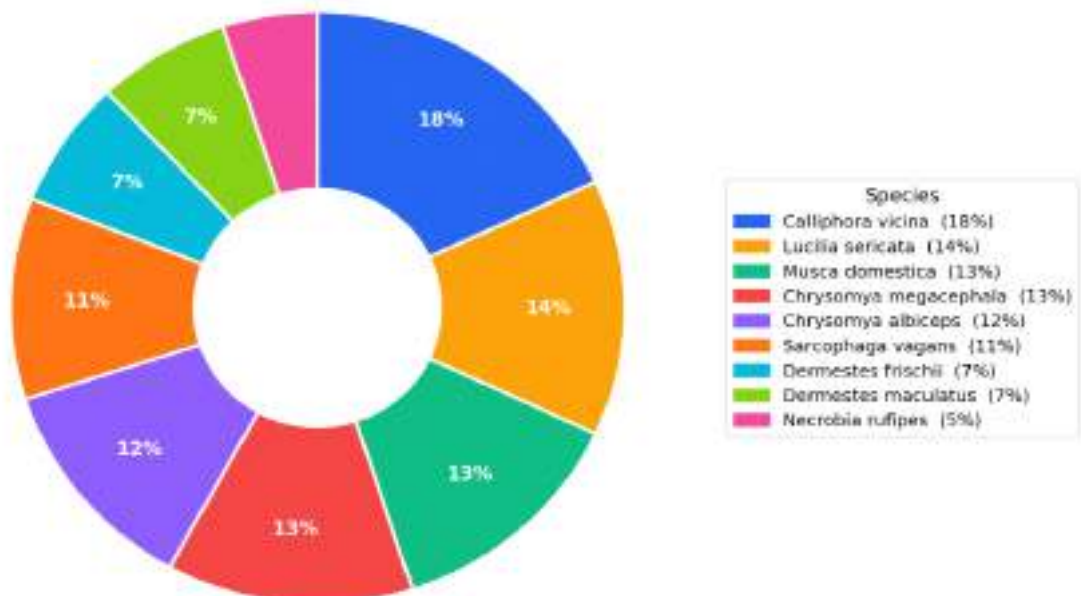


Figure (4.5): Percentage distribution of the nine forensically important insect species recorded across all sampling occasions at the study sites in Diwaniyah Province, southern Iraq

Figure 4.5 showed that the relative contribution of each of the nine forensically important species to the total catch pooled across all sampling occasions, sites, carcass types and burial levels. *Necrobia rufipes* was the single most abundant taxon, accounting for approximately 5% of all individuals recorded, followed by *Dermestes maculatus* (7%) and *Sarcophaga vagans* (11%). *Chrysomya megacephala* (13%), *Dermestes frischii* (7%), *Calliphora vicina* (18%) and *Chrysomya albiceps* (12%) each contributed moderate shares, while *Musca domestica* (13%) and *Lucilia sericata* (14%) were the least abundant of the nine species. Grouped by order, the three coleopteran taxa (*Dermestes frischii*, *Dermestes maculatus* and *Necrobia rufipes*) jointly accounted for approximately 48.8% of all individuals despite comprising only three of the nine species, whereas the six dipteran taxa together made up the remaining 51.2%. This pattern indicates that, although Diptera (Calliphoridae, Sarcophagidae and Muscidae) colonise carcasses earlier and are individually more numerous during the fresh, bloat and active-decay stages, the late-arriving Coleoptera accumulate a comparable or greater overall share of the total catch because the advanced-dry and skeletal stages that they dominate persist for a much longer period (Sections 4.1.4-4.1.5; Table 4.1-4.5). *Necrobia rufipes* and *Dermestes maculatus* in particular were recorded consistently across nearly all treatment combinations (Sections 4.9-4.10), underscoring their reliability as late-stage forensic indicators in this hot-climate setting. Species-specific attraction patterns, broken down by burial site, carcass type and sampling date, are presented individually in Sections 4.2-4.10 and Tables 4.6-4.14.

4.12 Identification Study

4.12.1 Identification Key for Third larval instar Larvae of Forensically Important Insects

4.12.2 Glossary of Anatomical Terms Used in This Key

Terms are grouped by the taxon they are most relevant to. Where a term has a different sense in a different order, both senses are given.

4.12.3 Diptera — larval terminology

Cephalopharyngeal skeleton (cephaloskeleton): the internal, sclerotized feeding and support structure of the fly larva's head, comprising the mouthhooks and pharyngeal sclerite; the single most information-rich structure for larval identification.

Mouthhooks: the paired, pigmented, hook-shaped sclerites at the front of the cephaloskeleton that the larva uses to macerate food; may be symmetric or asymmetric between the pair.

Accessory oral sclerite: a small supplementary sclerite lying between the bases of the mouthhooks in some taxa; its presence, absence, and shape is diagnostic at genus level in several Calyptratae.

Pharyngeal sclerite (theca): the posterior part of the cephaloskeleton, formed of a dorsal cornu and a ventral cornu on each side.

Dorsal cornu: the dorsal (upper) arm of the pharyngeal sclerite; its shape, degree of sclerotization, and the presence or absence of a pale, membranous "window" (fenestra) near its tip are important diagnostic characters.

Ventral cornu: the ventral (lower) arm of the pharyngeal sclerite.

Anterior spiracles: the paired breathing structures on the first thoracic segment, each bearing a row or cluster of finger-like lobes (papillae); the

number and arrangement of lobes is diagnostic at species level in several genera.

Posterior spiracles: the paired breathing structures at the posterior (anal) end of the larva, each consisting of a peritreme (ring) surrounding a spiracular plate with respiratory slits and a central or off-centre button.

Peritreme: the sclerotized ring bordering each posterior spiracular plate; complete (closed) in some taxa, incomplete (open, with a gap) in others — a key family- and genus-level character.

Button: a small sclerotized knob at or near the centre of the posterior spiracular plate, from which the respiratory slits radiate; may be distinct, faint, or absent.

Spiracular slits: the elongate respiratory openings within the posterior spiracular plate; their number (typically two in second-instar, three in third-instar Calyptratae), shape (straight, sinuous/serpentine, or S-shaped) and orientation are diagnostic.

Spiracular (stigmal) cavity: a deep, cup-shaped depression on the posterior face of the last larval segment within which the posterior spiracles sit, recessed below the body surface; well developed in Sarcophagidae, absent in Calliphoridae.

Inter-band area: the strip of integument lying between the anterior and posterior spinose bands on a given body segment; whether it bears spines, warts, or is bare is diagnostic within Sarcophagidae.

Creeping welts / spinose bands: transverse bands of small, posteriorly directed spines encircling each larval segment, used in locomotion.

4.12.4 Diptera — adult terminology

Arista: the bristle-like terminal process of the antenna's third segment; may be bare, short-plumose, or fully plumose (feathered) along its length — a family-level character.

Ptilinal suture / lunule: a curved suture above the antennal bases marking where the ptilinum (an eversible sac used to break out of the puparium) was retracted; present in the Schizophora, absent in Aschiza (e.g., Syrphidae).

Calypters (calypteres): a pair of scale-like flaps at the base of the wing that cover the haltere; their size and whether their under-surface bears setae is diagnostic.

Meron: a sclerite on the side of the thorax above the hind coxa; the presence and arrangement of a vertical row of bristles on it separates several calyptrate families.

Stem vein (vena spuria excluded): the basal section of the wing vein system from which the radial and medial veins arise; bare or setose on its dorsal surface — used to separate Chrysomyinae from Calliphorinae.

Proepimeron / proepisternum: sclerites on the front of the thorax just above and in front of the fore coxa; presence of a single strong bristle on the proepisternal (propleural) area separates some *Chrysomya* species.

Notopleuron: a sclerite on the thorax bearing (typically) four bristles in Sarcophagidae, used as a family character.

Fronto-orbital / frontal setae: rows of bristles along the margin of the frons (forehead); their convergence or divergence below the frontal lunule is diagnostic in *Sarcophaga*.

Syntergite (tergites 7+8): the fused dorsal plate formed by the sixth abdominal visible segments in male *Sarcophaga*, whose colour is diagnostic.

4.12.5 Coleoptera terminology

Elytra (sing. elytron): the hardened, modified forewings of beetles that meet in a straight mid-dorsal line and protect the membranous hindwings and abdomen.

Pygidium: the exposed apical abdominal tergite left uncovered by the elytra in some families (notably Histeridae, Staphylinidae), used for both display and diagnostic purposes.

Prosternal process / prosternal fovea: the ventral projection of the prosternum between the front coxae; a lateral pit (fovea) on or beside it is a key generic character in Saprininae (Histeridae).

Antennal club: the expanded terminal segments of the antenna; its degree of compaction, punctation pattern, and the arrangement of sensory groups are diagnostic within Histeridae and Dermestidae.

Retorse tubercles: small, posteriorly directed spine-like tubercles on the terminal abdominal segments of dermestid larvae, whose number is diagnostic between some *Dermestes* species.

Urogomphi: a pair of pincers-like or spine-like processes at the tip of the last abdominal segment in dermestid (and some other) beetle larvae.

Hastisetae: spear-shaped, barbed larval setae characteristic of Dermestidae, used defensively and taxonomically.

Hypomeron: the deflexed lateral portion of the pronotum below the lateral pronotal ridge; whether it bears setae is diagnostic within *Saprinus*.

Sutural stria: the elytral groove running immediately alongside the elytral suture (the mid-line where the two elytra meet); its completeness and punctation pattern are used within *Saprinus*.

Tarsal formula: a shorthand (e.g., 5-5-5) giving the number of tarsal (foot) segments on the fore, mid, and hind legs respectively; useful at family level.

4.12.6 Hymenoptera (Formicidae) terminology

Petiole: the narrowed first segment of the ant's waist ("pedicel") between the mesosoma and gaster; whether its apex/node is angular, rounded, or scale-like is diagnostic between genera and species.

Postpetiole: a second, smaller waist segment present in Myrmicinae (absent in Formicinae), lying between the petiole and the gaster proper.

Gaster: the ant's "true" abdomen, i.e. the abdominal segments behind the petiole (and postpetiole where present).

Mesosoma: the fused thorax-plus-propodeum region of the ant body, bearing the legs and (in winged castes) the wings.

Propodeum: the first true abdominal segment, fused to the thorax, forming the posterior part of the mesosoma; its profile (angular, toothed, or evenly rounded) and armature (spined or unarmed) are diagnostic.

Clypeus: the sclerite forming the lower/front margin of the face, immediately above the mandibles; the position of the antennal insertion relative to its margin is diagnostic between *Camponotus* and *Cataglyphis*.

Fronto-clypeal suture: the suture marking the boundary between the clypeus and the frons (face).

Ocelli: the simple (single-lens) eyes, typically three, on the dorsal surface of the head; their presence/absence and size are diagnostic.

Antennal scrobe (antennal socket): the fossa or depression into which the antenna is inserted.

4.12.7 Third-Instar Larval Diagnostic Keys

4.12.8 Key A (larvae) — Orders of Forensically Significant Insect Larvae**1-**

1a Body bears three pairs of jointed thoracic legs; head capsule fully sclerotized and externally visible, with mandibulate mouthparts directed forward or downward Coleoptera — see below

1b Thoracic legs absent (apodous) 2

2-

2a Head reduced to an internal cephalopharyngeal skeleton, not externally visible as a sclerotized capsule; body vermiform, tapering anteriorly, truncate posteriorly Diptera — see below

2b Head capsule small but fully external, sclerotized and visible, bearing distinct mandibles and ocellar spots; body grub-like, C-shaped or straight, soft-bodied Hymenoptera: Formicidae — see below

4.12.9 Diptera — Third larval instar

Family-level separation is given first, followed by the larval couplets within each family that resolves to species in this study.

4.12.10 Key C (larvae) — Families of Diptera**1-**

1a Posterior spiracles sunk within a deep, cup-shaped spiracular cavity on the flattened terminal segment; peritreme incomplete, its button faint or absent Sarcophagidae — see below, (Figure 4.6)

1b Posterior spiracles not recessed in a deep cavity, borne flush on or only shallowly set into the terminal segment 2

2-

2a Spiracular slits sinuous or serpentine (S-shaped or tortuous); a single mouthhook Muscidae — see below

2b Spiracular slits straight or nearly so, oriented close to vertical; paired mouthhooks Calliphoridae — see below

4.12.11 Calliphoridae — Third larval instar

1-

1a Peritreme of the posterior spiracles complete (forming an unbroken ring) 2

1b Peritreme incomplete (interrupted, forming an open ring) 3

2-

2a Accessory oral sclerite present, lying between the mouthhook bases, its base pale and its tip more heavily sclerotized; anterior spiracle with 7–10 papillae *Calliphora vicina*, (Figure 4.7)

2b Accessory oral sclerite absent; body pale yellowish-white; anterior spiracle with 7–8 papillae *Lucilia sericata*, (Figure 4.8)

3-

3a Body bearing paired, tapering fleshy dorsolateral processes on abdominal segments 4–10, each tipped with a tuft of setae or spines *Chrysomya albiceps*, (Figure 4.9)

3b Body without such fleshy processes 4

4-

4a Dorsal cornu of the cephalopharyngeal skeleton with a large, distinct membranous window near its base *Chrysomya putoria*, (Figure 4.10)

- 4b** Dorsal cornu without such a window, shaped like a bird's beak, with a small pale, non-sclerotized spot near its tip rather than a true window
Chrysomya megacephala, (Figure 4.11)

Full adult diagnoses and complete species accounts for these five species (taxonomic position, differentiation, forensic importance, distribution, citations, and a figure placeholder) are given under Calliphoridae in the Diptera section that follows.

Sarcophagidae — Third larval instar

1-

- 1a** Dorsal cornu of the cephalopharyngeal skeleton bearing a large, pale-haloed window near its tip 2

- 1b** Dorsal cornu without such a window 3

2-

- 2a** Individual posterior spiracular openings clearly separated from one another; dorsal cornu brown *Sarcophaga carnaria*

- 2b** Posterior spiracular openings crowded so closely together that the individual spiracles are difficult to distinguish from one another, their combined width approximately equal to their length; dorsal cornu dark brown; anterior spiracle with more than five papillae in a single row
Wohlfahrtia nuba

3-

- 3a** Inter-band area of the thoracic and abdominal segments bearing bands of low, rounded papillae 4

- 3b** Inter-band area of the first three thoracic segments with an irregular, non-banded pattern of papillae rather than a regular transverse band
Sarcophaga (Liopygia) ruficornis

4-

4a Tip of the dorsal cornu only lightly sclerotized *Sarcophaga albiceps*

4b Tip of the dorsal cornu more heavily sclerotized than in the preceding species *Sarcophaga (Helicophagella) altitudinis*

Diagnostic Characteristics of Sarcophagidae third larval instar diagnosis:

Whitish-yellow larvae, range between 15–19 mm, (Figure 4.6: A, B). A pair of oval sensory papillae on the head. Dorsal cornu bird-tongue shaped, weakly sclerotized dorsally along most of its length, brown, apex pointed, tip only lightly sclerotized. Inter-band area of the last abdominal segments bears bands of uniform papillae. Anterior spiracle orange. Posterior spiracle width roughly doubles its length; peritreme incomplete, button absent as reported by Zumpt (1965) and Szpila *et al.* (2015).

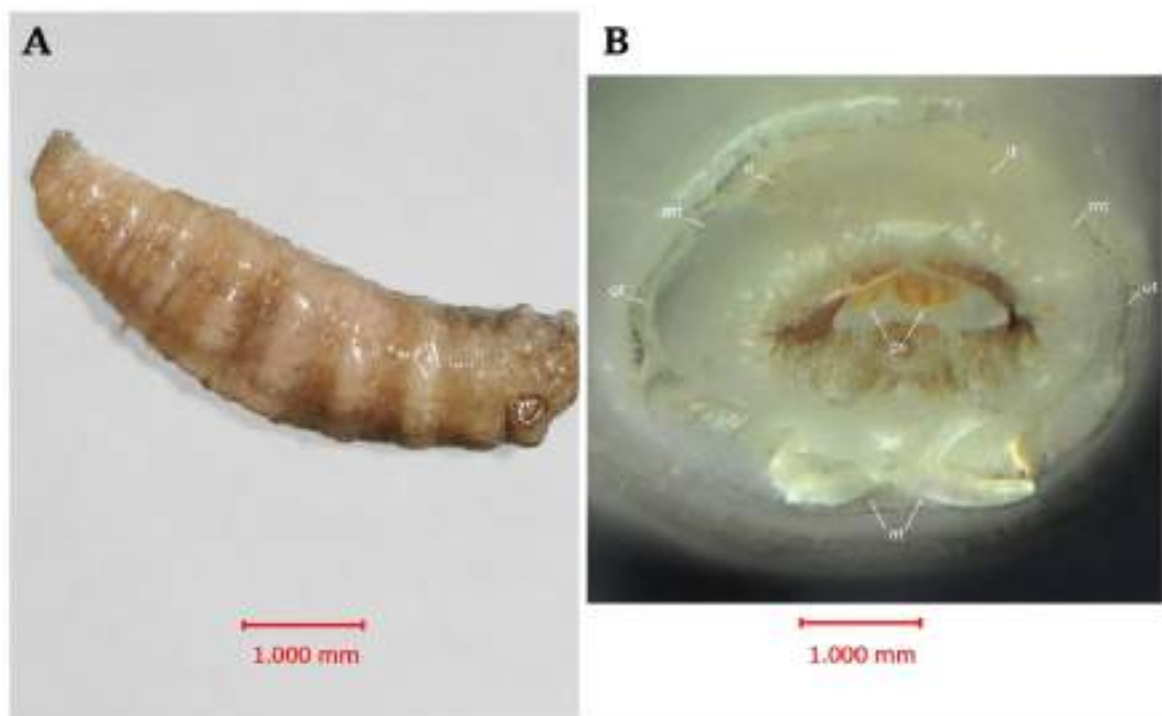


Figure (4.6): Third larval instar of Sarcophagidae. (A) General lateral view of the third-instar larva, showing the typical cylindrical, segmented body. (B) Posterior spiracles recessed within a deep, cup-shaped spiracular cavity, showing the inner peritreme (it), outer peritreme (ot), muscular tracheal trunk (mt), posterior spiracular openings (ps), anal plate (apl), and anal tubercles (at).

Diagnostic Characteristics *Calliphora vicina* Robineau-Desvoidy, 1830

Third larval instar larva diagnosis:

Body length 15–20mm, cream-white, (Figure 4.7: A, B) .A pair of oval sensory papillae on the anterior head region. Cephalopharyngeal skeleton heavily sclerotized, dark brown, with an accessory oral sclerite between the mouthhook bases (pale-based, more sclerotized apically). Dorsal cornu formed of two long fused pieces, weakly sclerotized dorsally in places, apex pointed, without a discrete window. Anterior spiracle with 7–10 finger-like papillae. Posterior spiracles rounded, orange-yellow, peritreme complete (closed), button distinct. Only one species of the genus *Calliphora* was identified during the present study. The cephalopharyngeal skeleton possesses a distinct accessory oral sclerite, which is considered a major diagnostic feature of the genus. The peritremal ring surrounding the posterior spiracles is complete and closed, while the button is clearly visible and well developed. In addition, the posterior spiracular slits are straight and nearly parallel, in agreement with the descriptions reported by Zumpt (1965) and Amendt *et al.* (2010).

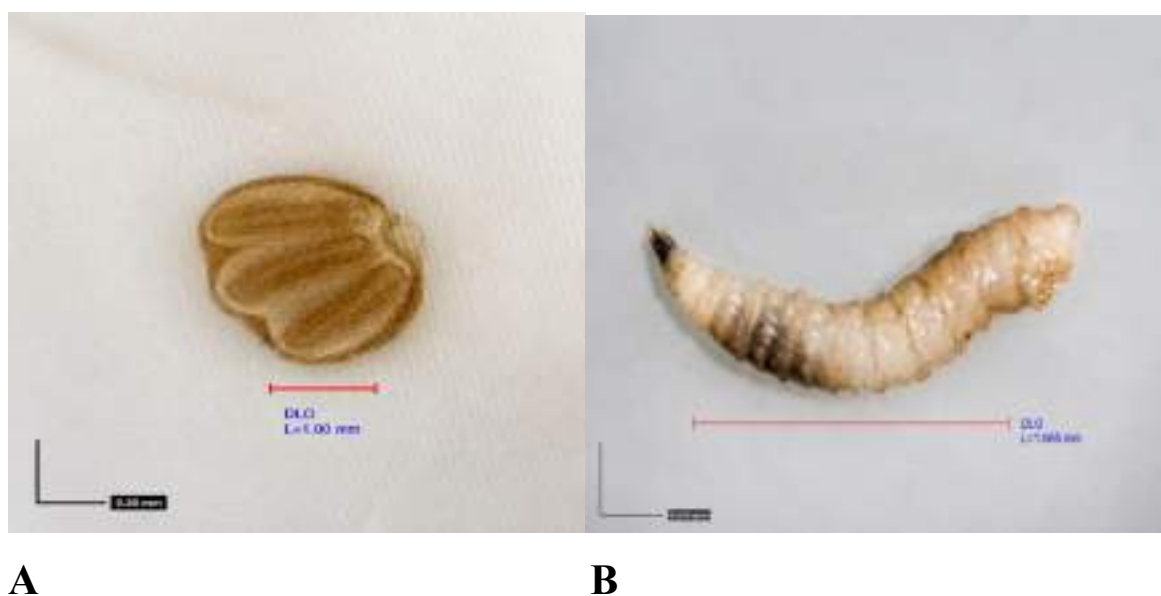


Figure (4.7): A: posterior spiracles (Pt = peritreme, Sps = spiracular slit), B: general view of the third larval instar of *Calliphora vicina*

Diagnostic Characteristics of Third-Instar Larvae of *Lucilia sericata* (Meigen, 1826)

Third larval instar larvae are creamy white to pale yellow and attain a length of approximately 16 mm (Figure 4.8: A, B). The anterior end bears a pair of oval sensory papillae. The cephalopharyngeal skeleton is heavily sclerotized and dark in color with yellowish-red regions. The mouth hooks are robust and supported by a nearly rectangular basal plate. The dorsal cornu resembles a bird wing in shape, while the posterior portion is strongly sclerotized and darkly pigmented.

Thoracic segments bear bundles of large single-pointed spines. On each side of the first thoracic segment, an orange anterior spiracle composed of 7–8 papillae are present. Similar bundles of large single-pointed spines occur on the abdominal segments. Posterior spiracles are oval to circular and surrounded by a complete peritremal ring. A darkly pigmented spiracular button is present. Spiracular slits are yellow in color with brown outer margins, and the median slit is longer than the two lateral slits, consistent with the findings of Zumpt (1965), Abdel-Reheem (2016), and Sukontason *et al.* (2018).

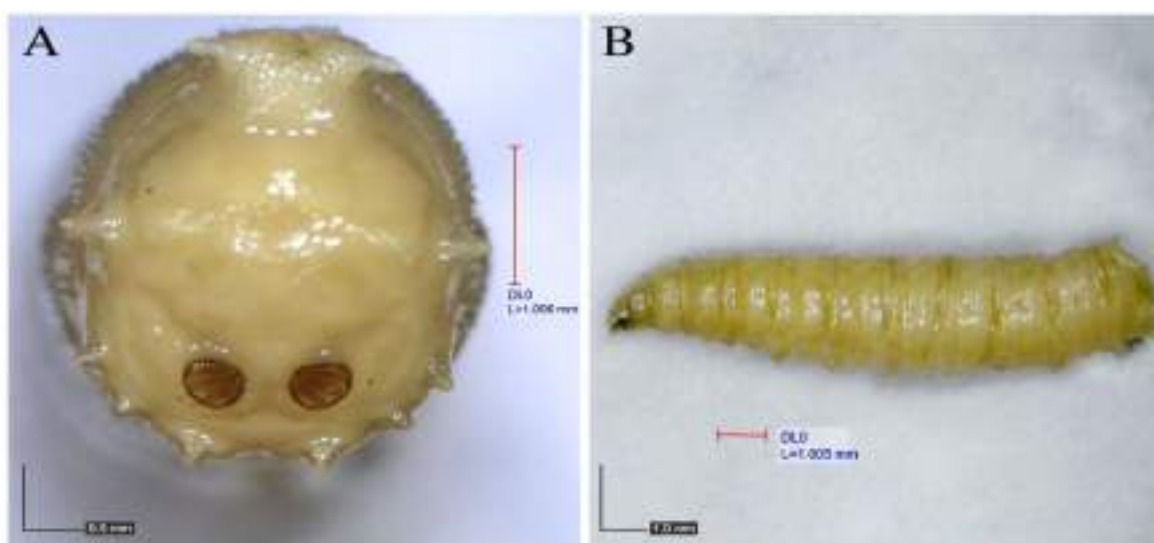


Figure (4.8): Third larval instar of *Lucilia sericata*. (A) Posterior view showing the posterior spiracles. (B) General lateral view of the third-instar larva.

Diagnostic Characteristics of Third larval instar of *Chrysomya albiceps* (Wiedemann, 1819)

Third-instar larvae are dark yellow in color and range from 13–18 mm in length. Distinct fleshy processes occur laterally and extend along abdominal segments 4–10. Body segments bear numerous small cuticular structures concentrated around the fleshy processes. The cephalic segment possesses a pair of sensory papillae, each with a small anterior lobe. The cephalopharyngeal skeleton is strongly sclerotized, black in color, and characteristically curved.

Bundles of spines are present on the fleshy processes or papillae (Figure 4.9), and the anterior spiracles are yellow, bearing 11 papillae. The dorsal surface of the abdominal segments contains numerous minute spherical cuticular structures distributed irregularly. Posterior spiracles are located within a rounded cavity, surrounded by a thick open peritremal ring. Three spiracular slits are clearly visible within the spiracular field, consistent with the descriptions of Zumpt (1965) and Sukontason *et al.* (2018).

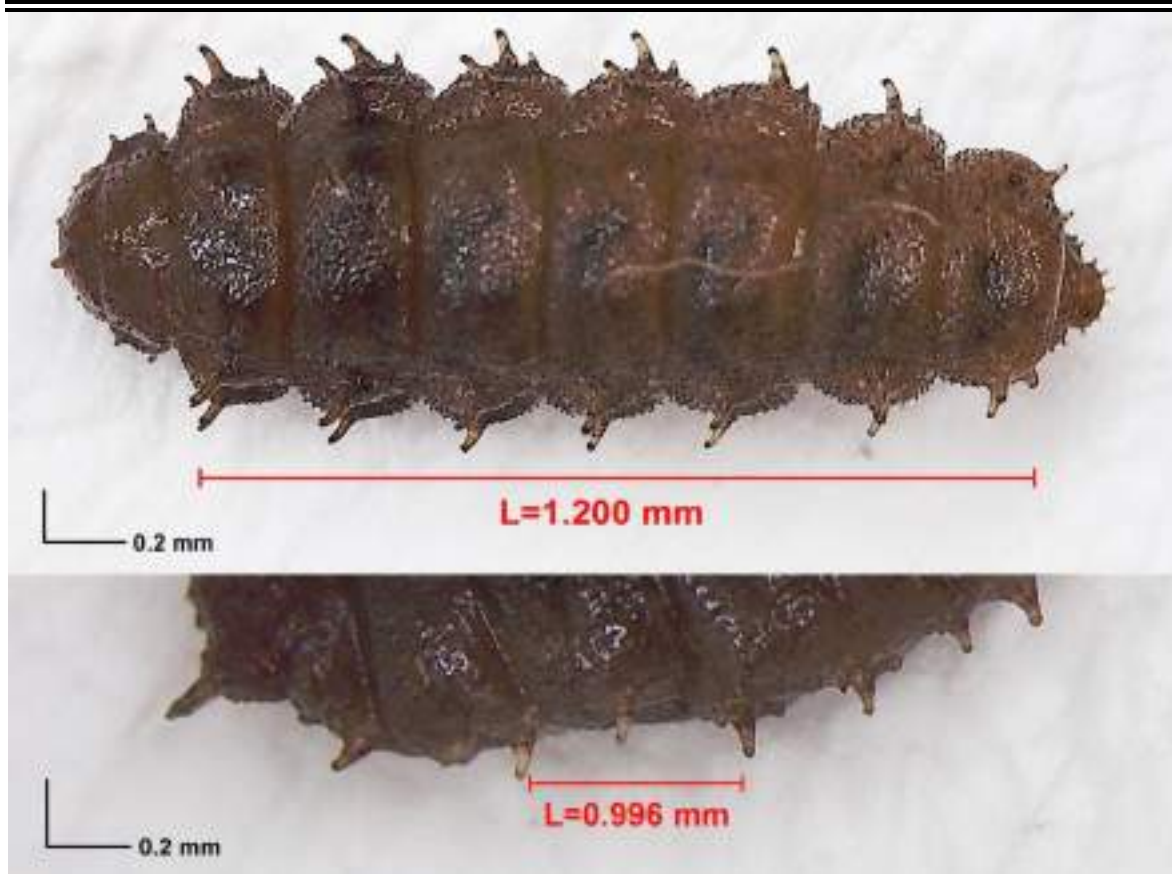


Figure (4.9): General view of the third larval instar of *Chrysomya albiceps* and body spines of the larva

Diagnostic Characteristics of Third larval Instar of *Chrysomya putoria* (Wiedemann, 1818)

Third-instar larvae are creamy white to yellowish in color and measure 15–17 mm in length (Figure 4.10, A). The cephalic segment bears a pair of sensory papillae, while the cephalopharyngeal skeleton is strongly sclerotized and dark brown in color. The mouth hooks are well developed, and the pharyngeal sclerite (Phs) or theca consists of two posteriorly divided sclerotized plates forming the dorsal cornu (Dc) and ventral cornu (Vc). The ventral cornu possesses a conspicuously large opening, whereas the dorsal cornu is elongated, strongly sclerotized, brown in color, and terminates in a pointed apex (Mendonça *et al.*, 2012).

Thoracic segments bear complete bands of fine posteriorly directed spines together with several double-pointed terminal spines (Figure 4.10, B). The first thoracic segment possesses anterior spiracles composed of 10–11 papillae. The peritremal ring surrounding the posterior spiracles is open and slightly curved dorsally. The posterior spiracles are semi-oval, pale brown in color, and lack a distinct button, in agreement with the observations of Oliveira *et al.* (2007) and Zumpt (1965).

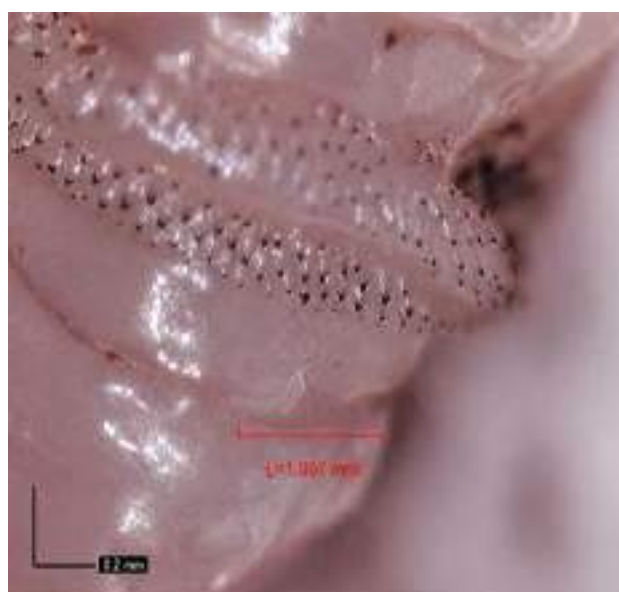
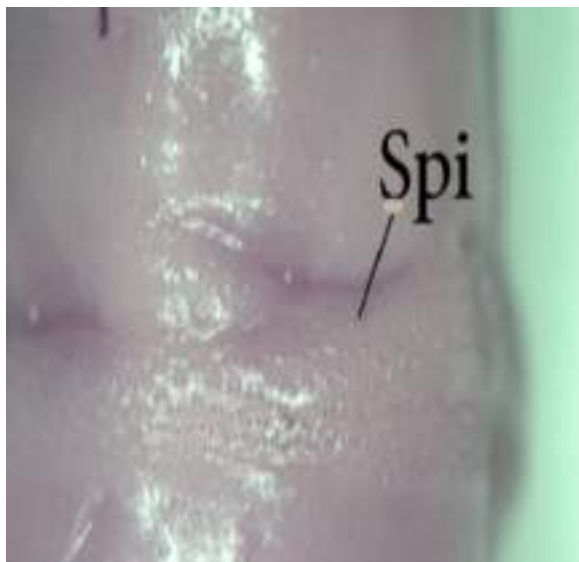
**A****B**

Figure (4.10): A: general view of the third larval instar of *Chrysomya putoria*; B, double spine bands on the larval body

Diagnostic Characteristics of Third larval Instar of *Chrysomya megacephala* (Fabricius, 1794):

Third-instar larvae are yellowish in color and measure 10–19 mm in length (Figure 4.11: A). A pair of sensory papillae is present at the anterior end of the body. The cephalopharyngeal skeleton is darkly sclerotized with reddish-brown regions, and a small weakly developed accessory oral sclerite (AOS) occurs between the mouth hooks. The dorsal cornu resembles a bird wing and bears three to four moderately sclerotized dorsal projections. An oval white unsclerotized area is present near the ventral cornu, which is darkly pigmented with a pointed brown apex. Thoracic segments possess complete bands of spines (Figure 4.11: B), while the anterior spiracles are yellow and composed of 10–13 papillae. The anterior margins of abdominal segments three to seven bear four to five rows of spines. Posterior spiracles are circular and brown, surrounded by an open peritremal ring. The spiracular button is absent, and the middle spiracular slit is slightly longer than the lateral slits, consistent with the findings of Sukontason *et al.* (2018).



A

B

Figure (4.11): A. general view of the third larval instar of *Chrysomya megacephala*; B, spine bands

4.12.12 Diagnostic keys of Muscidae — Third larval instar

1-

1a Posterior spiracles distinctly raised on a darkened stalk; spiracular slits peripheral and bow-shaped, never straight *Atherigona orientalis*

1b Posterior spiracles not raised on a darkened stalk 2

2-

2a Spiracular slits straight, never serpentine; peritreme typically pale and poorly pigmented 3

2b Spiracular slits serpentine to tortuous; peritreme often darkly pigmented 4

3-

3a Abdominal segments 1–7 covered by complete anterior and posterior bands of dark spines; anal division truncated abruptly *Morellia* sp. (not recorded in this study)

3b Abdominal segments without complete posterior spine bands Muscina/Synthesiomyia — see Grzywacz *et al.* 2017 for further separation

4-

4a Posterior spiracles kidney-shaped; mouthhooks asymmetric; extra-anal and postanal papillae absent *Musca* spp. —

4b Posterior spiracles rounded; mouthhooks symmetric; extra-anal and postanal papillae well developed Hydrotaea/Ophyra — see Grzywacz *et al.* 2017 for further separation

4' (within *Musca*)

a Anal plate small, barely visible in lateral view; dorsal surface of the anal division bare of spines *Musca domestica* (Figure 4.12)

b Anal plate large and clearly visible in lateral view; dorsal surface of the anal division covered with spines *Musca autumnalis* (not recorded in this study)



Figure (4.12): General view of the third larval instar of *Musca domestica*

Diagnostic Characteristics of *Dermestes maculatus* De Geer, 1774:

Larvae of *Dermestes maculatus* are densely covered with long and thick setae (Figure 4.13). The ventral region is yellowish-brown, whereas the dorsal surface is dark brown. A distinct yellow median stripe extends longitudinally along the dorsal surface. Larval length ranges from 13–23 mm. The ninth abdominal segment bears a pair of posterior spine-like processes known as urogomphi (Uro), which curve posteriorly. The tarsus lacks supplementary setae (Sups) on the ventral side. Small posteriorly directed tubercles (Rt) occur along the external margin of the antecostal suture of the sixth abdominal segment, numbering approximately 24 tubercles. The abdominal region is pale yellow in coloration (Díaz-Aranda *et al.*, 2018).



Figure (4.13): General view of Larvae of *Dermestes maculatus*

Diagnostic Characteristics of *Dermestes frischii* Kugelann, 1792:

Larvae of *Dermestes frischii* are densely covered with long and thick setae (Figure 4.14). The ventral surface is yellowish-brown, whereas the dorsal surface is dark brown. A yellow median stripe extends along the body axis. Larval length ranges from 18–25 mm. The first thoracic segment possesses a distinct median dark spot (Dsp). The ninth abdominal segment bears a pair of posteriorly curved urogomphi (Uro). The tarsus contains one or two rows of supplementary setae (Sups) on the ventral surface. Small retrorse tubercles (Rt) occur on the outer margin of the antecostal suture of the sixth abdominal segment, numbering approximately 12 tubercles. These characters agree with the descriptions of Rees (1943) and Díaz-Aranda *et al.* (2018).



Figure (4.14): General view of Larvae of *Dermestes frischii*

4.12.13 Adult Identification Keys

4.12.14 Key A — Orders of Forensically Significant Insects in This Study (adults)

1-

1a Wings absent in the caste examined; mesosoma and gaster separated by a narrow, node- or scale-bearing waist of one or two segments; antennae sharply elbowed (geniculate) Hymenoptera: Formicidae (worker/queen ants) ... see Formicidae, at the end of this document

1b Wings present, or if apparently absent the body is fly- or beetle-like, never ant-waisted; antennae not elbowed 2

2-

2a Forewings hardened into elytra that meet edge-to-edge in a straight mid-dorsal line, concealing the membranous, folded hindwings Coleoptera, later in this document

2b A single pair of membranous forewings; hindwings reduced to small club-shaped halteres Diptera, immediately below

4.12.15 Diptera**4.12.16 Key C — Families of Diptera Represented in This Study (adults)****4.12.17 Key C — Adults****1-**

1a Ptilinal suture and frontal lunule absent; antennal arista bare or short-plumose only at the base; wing with a false (spurious) longitudinal vein crossing the r-m and dm-cu cells Syrphidae ... *Eristalis tenax*

1b Ptilinal suture and frontal lunule present; arista variably plumose; no spurious vein 2

2-

2a Meron bears a vertical row of stout setae above the hind coxa; body metallic blue, green, or bronze throughout, or grey with a black tessellated (checkerboard) abdominal pattern 3

2b Meron without such a row of setae; body grey to black, or brownish, never uniformly metallic Muscidae, below

3-

3a Thorax and abdomen uniformly metallic blue, green, or bronze Calliphoridae, below

3b Thorax grey with three longitudinal black stripes, non-metallic; abdomen grey with a black tessellated pattern Sarcophagidae

4.12.18 Family Calliphoridae**4.12.19 Key C1 — Genera and Species of Calliphoridae (adults)****1-**

1a Stem vein of the wing setose on its dorsal surface; ampulla (the sclerite before the base of the wing) entirely dark subfamily Chrysomyinae ... 3

1b Stem vein bare dorsally; ampulla pale, oval subfamily Calliphorinae
... 2 (Figure 4.15: A, B).

2-

2a Under-surface of the calypter with dense fine hairs; thorax non-metallic, dark-striped; abdomen shining metallic blue; scutellum base and anterior spiracle pale yellowish *Calliphora vicina* (Figure 4.16).

2b Under-surface of the calypter bare; thorax and abdomen uniformly shining green, blue, or bronze; mesonotum with 6–8 acrostichal bristles
Lucilia sericata

3-

3a Anterior (thoracic) spiracle black; upper facets of the compound eye visibly larger than the lower facets *Chrysomya megacephala*

3b Anterior spiracle pale (white to cream); ommatidia uniform in size 4

4-

4a Proepisternum (the sclerite immediately above and in front of the fore coxa, below the anterior spiracle) bears a single differentiated bristle
Chrysomya putoria

4b Proepisternum without such a bristle *Chrysomya albiceps*



A

B

Figure (4.15): A. presence of setae on the stem vein (R); B. absence of setae on the stem vein (R)

4.12.20 *Calliphora vicina* Robineau-Desvoidy, 1830 (European blue bottle fly)

Taxonomic position: Order Diptera; Family Calliphoridae; Subfamily Calliphorinae; Genus *Calliphora*; Species *C. vicina* Robineau-Desvoidy, 1830.

Synonyms: *Musca erythrocephala* Meigen, 1826; *Calliphora monspeliaca* Robineau-Desvoidy, 1830; *C. scutellata* Macquart, 1834; *C. insidiosa* Robineau-Desvoidy, 1863.

Adult diagnosis: Body length 7–12 mm. Head black above, cheeks orange-brown below (Figure 4.16) lower face black. Thorax black with four faint dark longitudinal stripes and shining grey pruinescence; acrostichal bristles present; anterior spiracle pale; hind coxal region bears fine hypopleural bristles. Wings hyaline to lightly infusate basally, veins brown; calypters and halteres pale. Abdomen metallic blue with a tessellated (checkered) pattern of pale pruinescence and pale setae.

Differentiated from close relatives by: from *Lucilia sericata* (adult) by the feathered under-surface of the calypter and the non-metallic, dark-striped thorax; (larva) by the presence of the accessory oral sclerite and complete peritreme.

Forensic importance: A classic primary colonizer of fresh carrion in temperate climates, frequently among the first insects to arrive and oviposit; larval development rate under known temperature is routinely used to estimate a minimum post-mortem interval (Smith, 1986; Amendt *et al.*, 2010, eds.).



Figure (4.16): General lateral view of the adult *Calliphora vicina*

4.12.21 *Chrysomya megacephala* (Fabricius, 1794) (oriental latrine fly)

Taxonomic position: Order Diptera; Family Calliphoridae; Subfamily Chrysomyinae; Genus *Chrysomya*; Species *Ch. megacephala* (Fabricius, 1794).

Synonyms: *Musca megacephala* Fabricius, 1794.

Adult diagnosis: Body length approximately 6–12 mm, head large and conical. Eyes red-brown. Antennae black, slender. Thorax dark blue, anterior pronotal margin with three short pale stripes. Calypters white, setose ventrally. Halteres black. Abdomen shining metallic green. Anterior thoracic spiracle black; upper ommatidia of the compound eye visibly larger than the lower (Figure 4.17: A, B, C).

Differentiated from close relatives by: from the other two *Chrysomya* species here (adult) by the black anterior spiracle and enlarged upper ommatidia;

(larva) by lacking both the fleshy dorsolateral processes of *Ch. albiceps* and the true dorsal-cornu window of *Ch. putoria*.

Forensic importance: A dominant primary colonizer of fresh carrion in warm and tropical/subtropical climates, often displacing native Calliphoridae; widely used for PMI estimation and, because larvae can also infest living tissue, a recognized agent of myiasis (Smith, 1986; Amendt *et al.*, 2010, eds.).

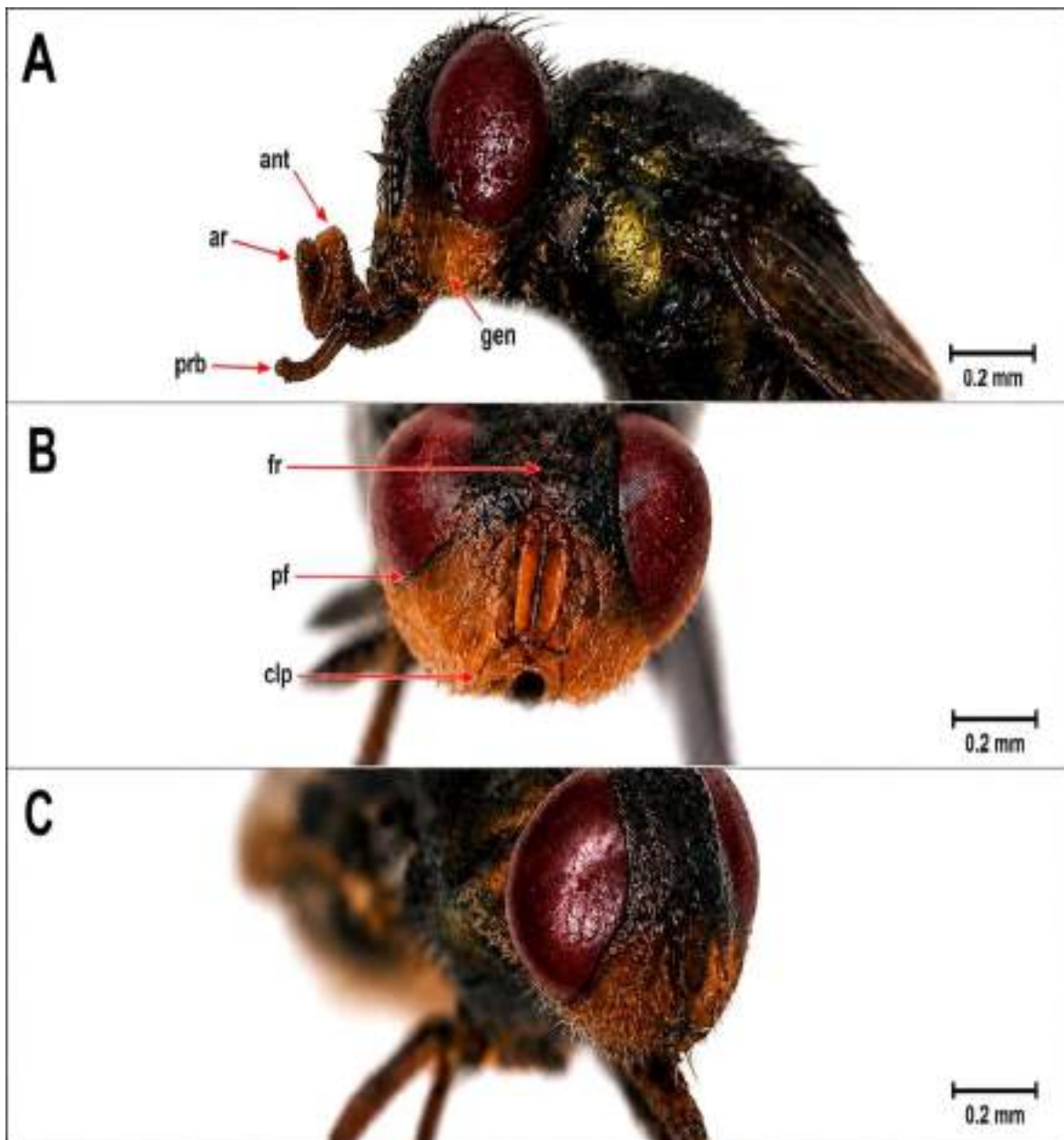


Figure (4.17): Head morphology of the adult *Chrysomya megacephala* (Fabricius, 1794). (A) Lateral view showing the antenna (ant), arista (ar), gena (gen), and proboscis (prb). (B) Frontal view showing the frons (fr), parafacial (pf), and clypeus (clp). (C) Oblique anterolateral view of the head.

Diagnostic Characteristics of *Chrysomya albiceps* (Wiedemann, 1819)

Taxonomic position: Order Diptera; Family Calliphoridae; Subfamily Chrysomyinae; Genus *Chrysomya*; Species *Ch. albiceps* (Wiedemann, 1819).

Synonyms: *Musca albiceps* Wiedemann, 1819; *Musca bibula* Wiedemann, 1830.

Adult diagnosis: Adults measure approximately 7–12 mm in length. The antennae are dark brown with a plumose arista. The anterior thorax is metallic bluish-green, and the anterior spiracle is white. The scutum possesses dark transverse markings together with two narrow longitudinal stripes extending anteriorly. Wings are hyaline to slightly infuscated, being darker near the base. The subcostal region is dark brown, and the calypters are white with fine hairs on their lower surfaces. Legs are black, whereas the abdomen is metallic bluish-green with purplish reflections. The first abdominal tergite is black in males and green in females, while tergites II–IV commonly bear black posterior marginal bands (Figure 4.18). These characteristics correspond well with the descriptions reported by Carvalho and Mello-Patiu (2008) and Akbarzadeh *et al.* (2015).

Forensic importance: A primary colonizer whose third-instar larvae are also facultatively predatory on the larvae of other necrophagous flies, a behavior that can distort PMI estimates if not accounted for; medically and forensically significant as a myiasis agent (Smith, 1986; Amendt *et al.*, 2010, eds.).



Figure (4.18): Lateral view of *Chrysomya albiceps* (adult)

4.12.22 Diagnostic Characteristics of *Chrysomya putoria* (Wiedemann, 1830) (African latrine fly)

Taxonomic position: Order Diptera; Family Calliphoridae; Subfamily Chrysomyinae; Genus *Chrysomya*; Species *Ch. putoria* (Wiedemann, 1830).

Synonyms: *Musca putoria* Wiedemann, 1830; *Ch. puloria* Seguy, 1928.

Adult diagnosis: Body length approximately 8–10 mm, dark metallic green to blue, wings sometimes appearing shiny black. Face with a black mark; frons black in both sexes, eyes near-contiguous in the male. Abdomen banded black along tergal posterior margins. Proepisternum bears a single differentiated bristle (Figure 4.19). These observations agree with the descriptions of Carvalho and Mello-Patiu (2008) and Akbarzadeh *et al.* (2015).

Differentiated from close relatives by: (adult) from *Ch. albiceps* by the differentiated proepisternal bristle; (larva) from both congeners by the dorsal-

cornu window, absent in *Ch. albiceps* and reduced to a small pale spot in *Ch. megacephala*.

Forensic importance: Strongly associated with latrines and fecal matter as well as carrion, a primary colonizer in its native African range and useful as both a sanitation and forensic indicator species (Smith, 1986; Amendt *et al.*, 2010, eds.).



Figure (4.19): Lateral view of *Chrysomya putoria* (adult)

4.12.23 Diagnostic Characteristics of *Lucilia sericata* (Meigen, 1826)

4.12.24 *Lucilia sericata* (Meigen, 1826) (common green bottle fly)

Taxonomic position: Order Diptera; Family Calliphoridae; Subfamily Calliphorinae; Genus *Lucilia*; Species *L. sericata* (Meigen, 1826).

Synonyms: *Musca sericata* Meigen, 1826; *Phaenicia sericata* Hall, 1948.

Adult diagnosis: Body length approximately 6.5–12.5 mm. Antennae black. Thorax with strong bristles and three transverse sutures; mesonotum with 6–8 acrostichal bristles. Wings hyaline, veins brown, shining. Calypter bare on its under-surface. Mid tibia with 2–3 anterior setae and 2–4 posterodorsal setae. Abdomen oval, shining green to blue-green or metallic blue; posterior margin of the fused tergite 1+2 bare of setae (Figure 4.20). These characters agree with those reported by Akbarzadeh *et al.* (2015).

Differentiated from close relatives by: from *Calliphora vicina* by the absence of an accessory oral sclerite; (adult) by the bare calypter under-surface and the uniformly metallic thorax.

Forensic importance: One of the most important forensic indicator species worldwide: a primary colonizer used extensively for PMI estimation, and — because it is also the principal blow fly used in maggot debridement therapy — a species with direct medical as well as forensic significance (Smith, 1986; Amendt *et al.*, 2010, eds.).



Figure (4.20): Lateral view of *Lucilia sericata* (adult)

4.12.25 Family Sarcophagidae**4.12.26 Key C2 — Species of Sarcophagidae (adults)****1-****1a** Vein R1 bare of setulae along its dorsal surface 2**1b** Vein R1 bearing a complete row of setulae along its dorsal surface*Sarcophaga haemorrhoea* (Figure 4.21)**2-****2a** Hind tibia with a row of long, erect setae along its posteroventral surface 3**2b** Hind tibia without such a row of long setae 4**3-****3a** Fused syntergite of abdominal tergites 7+8, and tergite 5, both black 5**3b** Fused syntergite of tergites 7+8, and tergite 5, both red *Sarcophaga albiceps***4-****4a** Face grey; antenna brown to blackish *Sarcophaga vagans* (Figure 4.22)**4b** Face yellow; antenna reddish, darkening apically *Sarcophaga (Liopygia) ruficornis***5-****5a** Tergite 4 bearing a pair of stout, erect marginal setae *Sarcophaga carnaria*

5b Tergite 4 without such a pair of setae *Sarcophaga (Helicophagella) altitudinis*

4.12.27 *Sarcophaga haemorrhoea* Meigen, 1826

Taxonomic position: Order Diptera; Family Sarcophagidae; Genus *Sarcophaga*; Species *S. haemorrhoea* Meigen, 1826.

Synonyms: *Erichsonia ambulatrix* Robineau-Desvoidy, 1863.

Adult diagnosis: Body length 6–8 mm. Compound eyes reddish dark-brown; antennae brown to blackish. Thorax black-grey. Wings hyaline; vein R1 bears a complete row of 6–8 setulae dorsally, and the third vein bears 7–9 setae dorsally and 2–4 ventrally. Fused syntergite of tergites 7+8 black; tergite 5 red (Figure 4.21).

Differentiated from close relatives by: the setose vein R1 is unique to this species in the key; every other species treated here has a bare R1.

Forensic importance: Sarcophagidae are, like Calliphoridae, primary or near-primary colonizers of fresh carrion in many regions; many species are larviparous (depositing first-instar larvae directly rather than eggs), which can shift the effective starting point used for PMI calculations relative to egg-laying Calliphoridae (Smith, 1986; Amendt *et al.*, 2010, eds.).



Figure (4.21): Dorsal view of *Sarcophaga haemorrhhoa* (adult)

4.12.28 *Sarcophaga vagans* Meigen, 1826

Taxonomic position: Order Diptera; Family Sarcophagidae; Genus *Sarcophaga*; Species *S. vagans* Meigen, 1826.

Synonyms: *Sarcophaga frenata* Pandellé, 1896.

Adult diagnosis: Body length 5–6 mm. Eyes reddish-brown; antennae brown-black; thorax grey and black; legs black. Hind tibia lacking a well-developed row of long ventral setae. Fused syntergite of tergites 7+8 black, bearing 4–6 setae; tergite 5 red, with medium-length, fine, dense setae (Figure 4.22).

Differentiated from close relatives by: from *S. (Liopygia) ruficornis* by the grey (versus yellow) face and brown-to-blackish (versus reddish, apically darkened) antenna.

Forensic importance: Treated in the dissertation among the carrion-associated *Sarcophaga* fauna of forensic interest in Iraq, in the same general primary/early-colonizer role as its congeners (Smith, 1986).

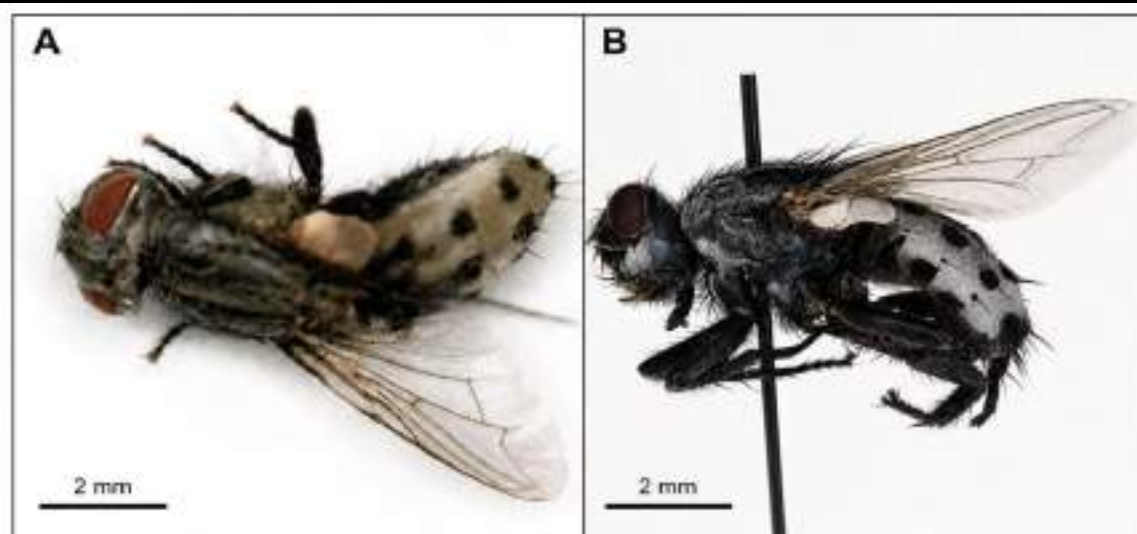


Figure (4.22) Adult *Sarcophaga vagans*: (A) dorsal view, (B) lateral view.

4.12.29 Family Muscidae

4.12.30 Key C3 — Genera and Species of Muscidae (adults)

1-

1a Head sub-triangular in lateral profile; antenna reaching the upper margin of the epistome and inserted near mid-eye height; presutural dorsocentral setae enlarged; body generally strongly setose *Atherigona orientalis*

1b Head not sub-triangular; antenna not reaching the epistome margin, inserted below mid-eye height 2

2-

2a Body shining metallic black-green 3

2b Body grey to black, dull, non-metallic 4

3-

3a Maxillary palps orange-yellow; ocellar triangle blunt-tipped; ventral surface of the hind femur with a comb-like row of long setae
Hydrotaea aenescens

3b Maxillary palps black to dark brown; ocellar triangle pointed; ventral surface of the hind femur without a comb-like row of setae *Hydrotaea albuquerquei*

4-

4a Anepimeron and/or meron with setae immediately above the anterior katepisternal margin 5

4b Anepimeron without such setae 6

5-

5a Terminal section of wing vein M straight or only gently curved forward; antenna and abdominal apex dusky grey; scutellar tip pale *Muscina stabulans*

5b Terminal section of vein M sharply bent forward; antenna and abdominal apex orange; scutellum black *Synthesiomyia nudiseta*

6-

6a Mesonotum grey with four dark longitudinal stripes; proepisternum dark, setose *Musca domestica* (Figure 4.23)

6b Mesonotum grey with two dark stripes, each forking into a Y-shape in the female; proepisternum dark, bare *Musca sorbens*

4.12.31 Diagnostic Characteristics of *Musca domestica* Linnaeus, 1758 ***Musca domestica* Linnaeus, 1758 (House fly)**

Taxonomic position: Order Diptera; Family Muscidae; Genus *Musca*; Species *M. domestica* Linnaeus, 1758.

Synonyms: *Sphora australis* Robineau-Desvoidy, 1830; *Musca consanguinea* Rondani, 1848; *M. flavinervis* Thomson, 1869; *M. biseta* Hough, 1898; *M. divaricata* Awati, 1916; *Degeeria obscura* Pont, 1968.

Adult diagnosis: Adults are 6–9 mm in length and gray in color (25). The M vein is distinctly curved. The humeral callus resembles a mouse ear and bears 2–3 bristles. The abdomen is yellowish in males with a dark median longitudinal stripe and irregular gray to black lateral patches. Females generally possess darker abdominal markings. The compound eyes are reddish (Figure 4.23). These observations correspond to the descriptions of Sawaby *et al.* (2018) and Al-Saffar (2003). immunity (Smith, 1986; Amendt *et al.*, 2010, eds.)

Forensic importance: A synanthropic, largely non-necrophagous filth fly whose larvae typically develop in feces and decaying organic waste rather than fresh carrion; when present on remains it is more often a secondary or incidental visitor than a primary PMI indicator, though it remains a well-documented member of the carrion insect co



Figure (4.23): Dorsal view of *Musca domestica* (adult)

4.12.32 Family Syrphidae

4.12.33 *Eristalis tenax* (Linnaeus, 1758) (drone fly)

Taxonomic position: Order Diptera; Family Syrphidae; Genus *Eristalis*; Species *E. tenax* (Linnaeus, 1758).

Adult diagnosis:

The species *Eristalis tenax* was identified according to the taxonomic keys of Zumpt (1965). Adults are medium to large-sized flies that closely resemble honeybees due to protective mimicry (Figure 4.24). The head is large with well-developed compound eyes, and the antennae are short, consisting of three segments with a dorsal arista. The thorax is dark-colored and covered with dense setae, while the abdomen is broad and marked with distinctive yellow to orange bands or patches. The wings are transparent and exhibit the characteristic venation pattern of the family Syrphidae, including the presence of a well-developed spurious vein located between the longitudinal veins, which is an important diagnostic feature of the family. The legs are slender and adapted for rapid movement and hovering flight. These morphological characteristics collectively distinguish *Eristalis tenax* from other members of the family Syrphidae (Zumpt, 1965).

It is a secondary insect that can bind to carcasses during various stages of decomposition, as adults are attracted to environments rich in decomposing organic matter and high humidity. The presence of this species on carcasses has been recorded in numerous forensic studies, indicating its potential role in the succession of insects associated with the decomposition process. The larvae of this species also live in moist environments rich in decomposing organic matter, which explains why adults are attracted to decomposition sites and carcasses. Peck (1988) pointed to the registration of members of the Syrphidae family on human and animal carcasses during various stages of decomposition, while Byrd and Castner (2010) explained that some serphidae species are secondary insects associated with carcasses and their presence can be used to explain insect succession and estimate the time periods associated with decomposition.

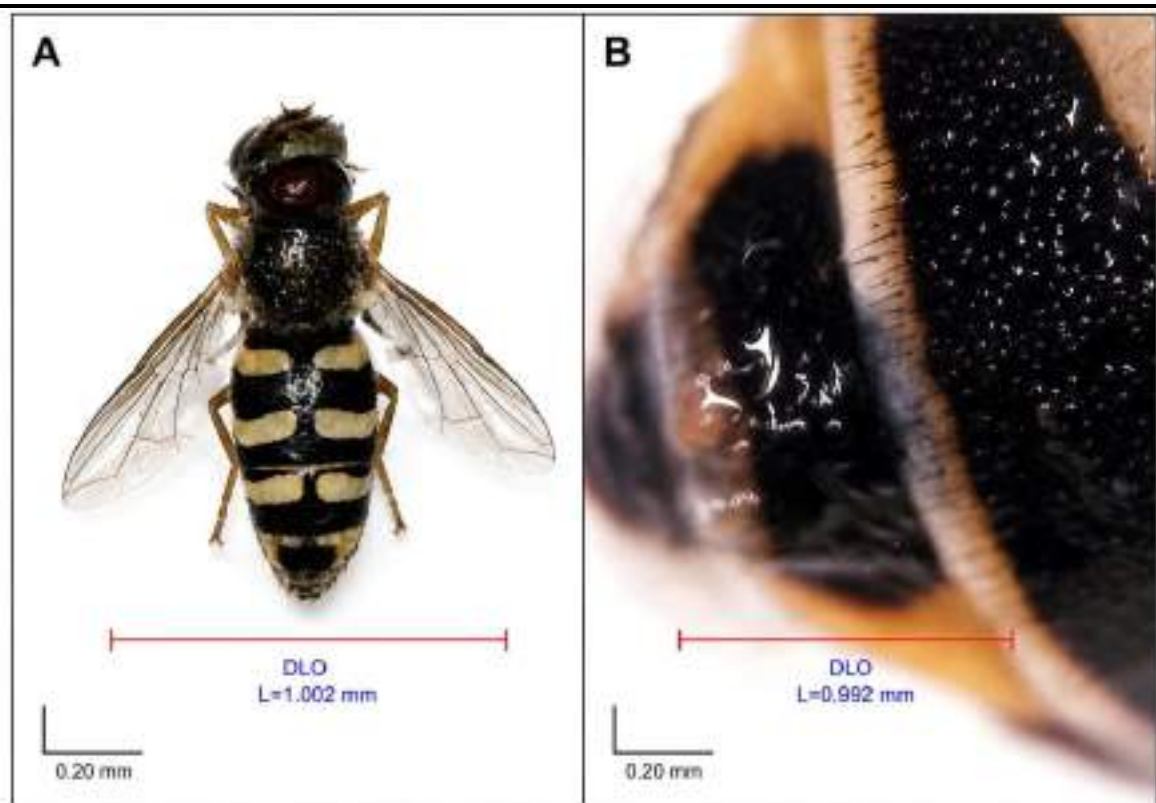


Figure (4.24): Adult *Eristalis tenax* (A) Lateral view; (B) Posterior end of the abdomen

4.12.34 Coleoptera

4.12.35 Key B — Families of Coleoptera Represented in This Study

1-

1a Body densely clothed in fine recumbent setae or broad scales, often forming a mottled or banded pattern on the elytra; antennae short, terminating in a loose or compact club 2

1b Body glabrous, sparsely setose, or with long erect setae only (never scale-clothed); elytra unicolorous or with sharply demarcated maculae rather than mottling 3

2-

2a Body ovoid to elongate-oval, strongly convex; abdomen with the last tergite (pygidium) concealed beneath the elytra; antennal club 3-segmented
Dermestidae, below

3-

3a Body compact, broadly ovoid to short-oval, strongly convex and shining; head retractable under the pronotum; antennae geniculate with a compact, laterally compressed club; fore tibiae flattened and armed with a row of spines along the outer margin; elytra truncate, leaving 1–2 abdominal tergites exposed Histeridae, below

3b Body not as above 4

4-

4a Body elongate, parallel-sided or gently tapering, densely clothed in erect setae over its whole surface; antennae clubbed; tarsal formula 5-5-5 Cleridae, below

4b Body not densely setose overall; elytra without erect vestiture 5

5-

5a Body elongate-parallel, only weakly convex; elytra short, leaving five or more abdominal tergites exposed dorsally; antennae filiform to weakly clubbed, of 9–11 segments Staphylinidae, below

5b Body ovoid, strongly convex, entirely black and shining, without erect setae; legs fossorial, tibiae dilated and dentate; tarsal formula reported in the source as 5-4-4 Tenebrionidae, below

4.12.36 Family Dermestidae

4.12.37 Key B1 — Species of *Dermestes*

1-

1a Elytral apex with a fine reticulate (mesh-like) microsculpture *Dermestes maculatus* (Figure 4.25)

1b Elytral apex smooth, without reticulate microsculpture 2

2-

2a Lateral margins of the abdominal ventrites each with a discrete black spot
..... 3

2b Lateral margins of the abdominal ventrites without a black spot 4

3-

3a Setae at the apex of the abdominal ventrites and pygidium white; head and legs likewise white-setose *D. frischii* (Figure 4.26)

3b Setae at the apex of the abdominal ventrites and pygidium tawny/brown; head and legs likewise brown-setose *D. ater* (Figure 4.27)

4-

4a Basal tarsomere of the meso- and metathoracic legs longer than the second tarsomere *D. leechi*

4b Basal tarsomere of the meso- and metathoracic legs shorter than the second tarsomere *D. peruvianus* (Figure 4.28)

4.12.38 *Dermestes maculatus* De Geer, 1774 (Hide beetle)

Taxonomic position: Order Coleoptera; Family Dermestidae; Genus *Dermestes*; Species *D. maculatus* De Geer, 1774.

Synonyms: *Dermestes vulpinus* Fabricius, 1781; *D. elongatus* Hope, 1834; *D. senex* Germar, 1842.

Diagnosis: Body length 5.5–10 mm, elongate-oval. Legs and antennal scape pale yellowish on the underside. Head and pronotum clothed in golden-tipped setae, the sides of the pronotum bearing a dense, wide golden pubescent band. Elytra with grey and yellow setae in a mottled pattern; the elytral apex bears a fine reticulate (mesh-like) microsculpture not seen in the other four species in

this collection. Venter clothed in white setae, with scattered black spots along the sides of the abdomen Figure (4.25: A, B, C).

Forensic importance: Along with other *Dermestes* species, a characteristic late-arriving colonizer of dry, advanced-decomposition and skeletal-stage remains, where it feeds on desiccated tissue, skin, and ligament; its presence is a standard indicator of the later post-mortem interval and it is also a well-known pest of dried animal products (hides, dried fish, stored skins) (general forensic entomology knowledge; Smith, 1986; Amendt *et al.*, 2010, eds.).

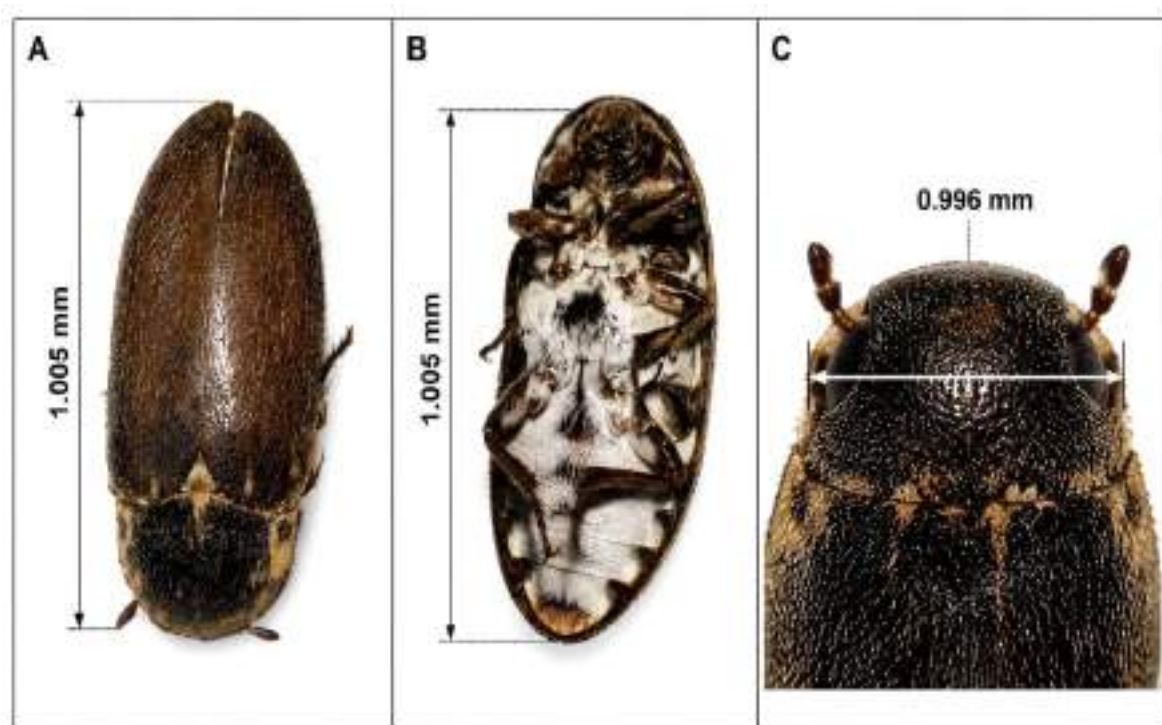


Figure (4.25): Adult of *Dermestes maculatus* (De Geer, 1774). A: Dorsal view, B: Ventral view

4.12.39 *Dermestes frischii* Kugelann, 1792

Taxonomic position: Order Coleoptera; Family Dermestidae; Genus *Dermestes*; Species *D. frischii* Kugelann, 1792.

Synonyms: *D. poliinctus* Hope, 1834; *D. sibericus* Erichson, 1846; *D. uniformis* Rey, 1889.

Diagnosis: Body length 6–10 mm. Head white-pubescent with a tuft of yellow setae; pronotal disc with golden-and-white down along the anterior margin and both sides. Elytra with grey setae irregularly mixed with brown and white, and a small patch of golden setae basally (Figure 4.26: A, B, C). Venter white-setose except at the sides; apex of the fifth ventrite grey-setose.

Forensic importance: A dry-stage carrion colonizer within the same forensic role as *D. maculatus* (see above); also, a recognized stored-product pest of animal-derived materials (general forensic entomology knowledge; Smith, 1986).

Distribution: Previously recorded in Iraq by Augul & Al-Saffar (2019) and again by Faraj (2018) from northern Iraq.

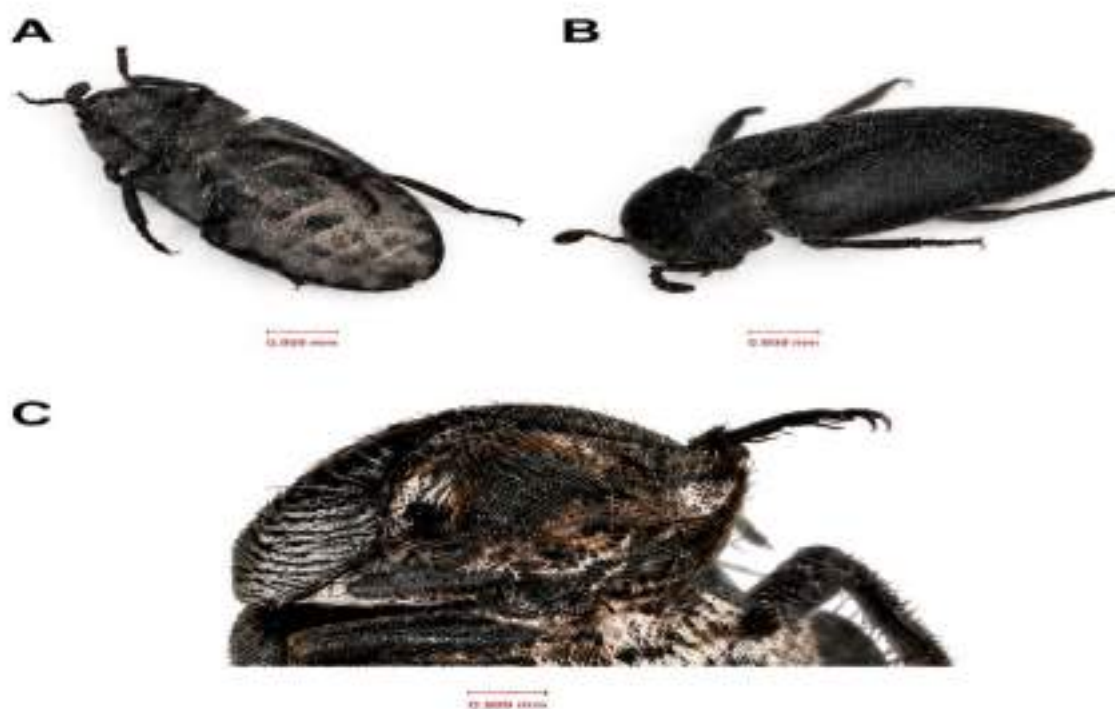


Figure (4.26): Diagnostic morphological features of the adult *Dermestes frischii* Kugelann, 1792. (A) Ventral view of the adult showing the abdominal sternites. (B) Dorsal view of the adult. (C) Lateral view of the head showing the compound eye, antenna, and mouthparts.

4.12.40 *Dermestes ater* De Geer, 1774 (black larder beetle)

Taxonomic position: Order Coleoptera; Family Dermestidae; Genus *Dermestes*; Species *D. ater* De Geer, 1774.

Synonyms: *D. cadaverinus* Fabricius, 1775; *D. domesticus* Germar, 1824.

Diagnosis: Body length 9–13 mm. Body entirely clothed in dense, sand-yellow pubescence; pronotal disc with clusters of yellow setae. Abdomen golden-setose throughout, overlaid with black spots of variable size on the sides and midline. Elytra variegated light and dark, golden-yellow setose Figure (4.27: A, B, C, D).

Forensic importance: Late-stage carrion colonizer and a well-known stored-product pest, in the same forensic role as its congeners above (general forensic entomology knowledge; Smith, 1986).

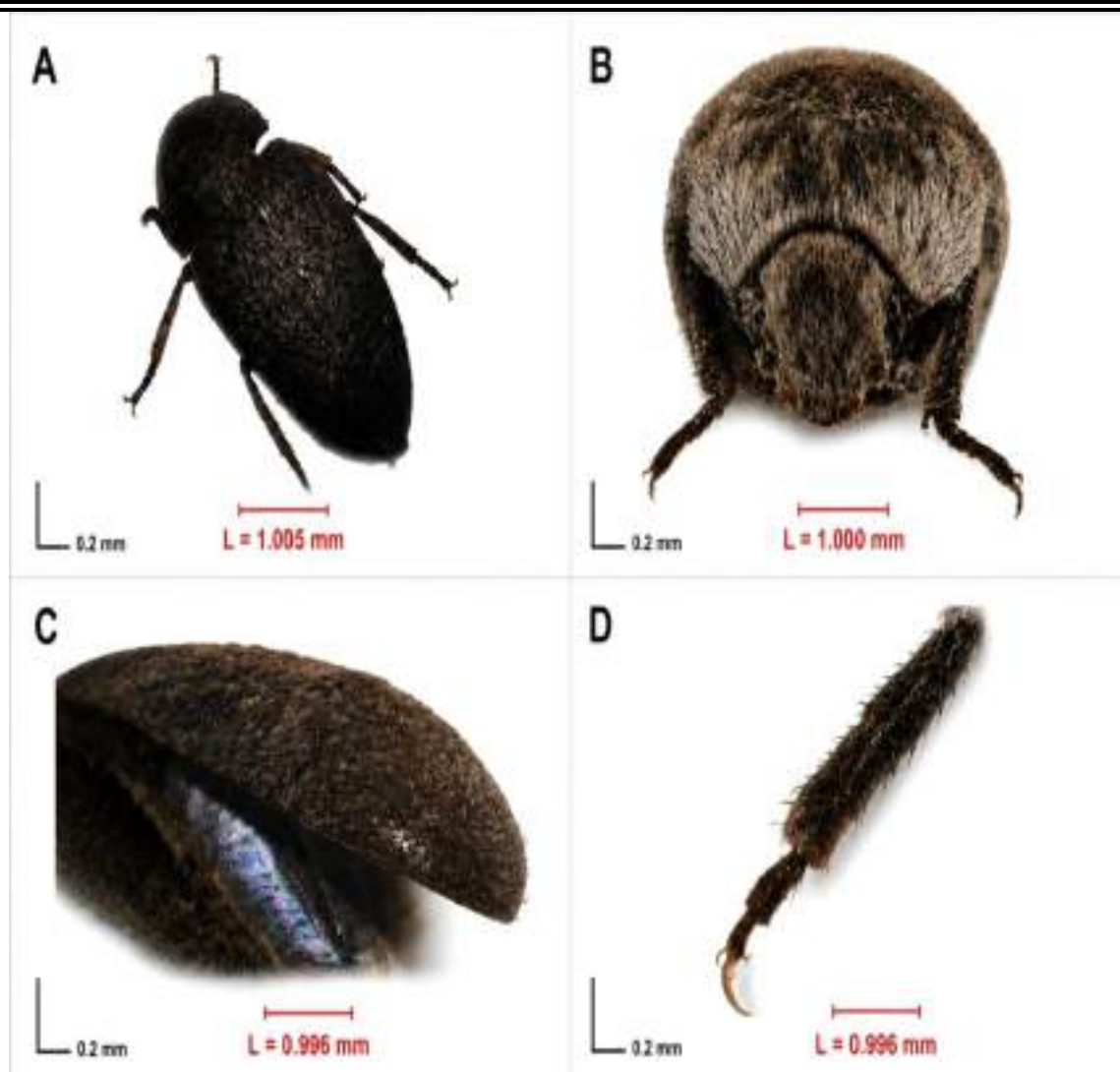


Figure (4.27): Adult *Dermestes ater* De Geer, 1774 A: Dorsal view. B: Anterior view of the head and pronotum. C: Elytral apex (lateral view). D: Foreleg showing the tarsal claw

4.12.41 *Dermestes peruvianus* Laporte, 1840

Taxonomic position: Order Coleoptera; Family Dermestidae; Genus *Dermestes*; Species *D. peruvianus* Laporte, 1840.

Diagnosis: Body length 8–11 mm, dark grey overall. Legs and antennal scape pale yellowish beneath. Head and thoracic setae golden-tipped; sides of the thorax bare (no lateral setal band, unlike *D. maculatus*); elytra brownish. Abdomen with fine brownish setae (Figure 4.28: A, B, C). The basal tarsomere of the meso- and metathoracic legs is shorter than the second tarsomere.

Forensic importance: Dry-stage carrion colonizer and stored-product pest, in the same general forensic role as its congeners (general forensic entomology knowledge; Smith, 1986).

Distribution: Broadly cosmopolitan, with concentration in Asia (Háva & Kalík, 2005); North America and Britain (Robinson, 2005); Italy (Nardi & Háva, 2013); gypt (Yones *et al.*, 2010); Turkey (Holloway & Kadej, 2019).

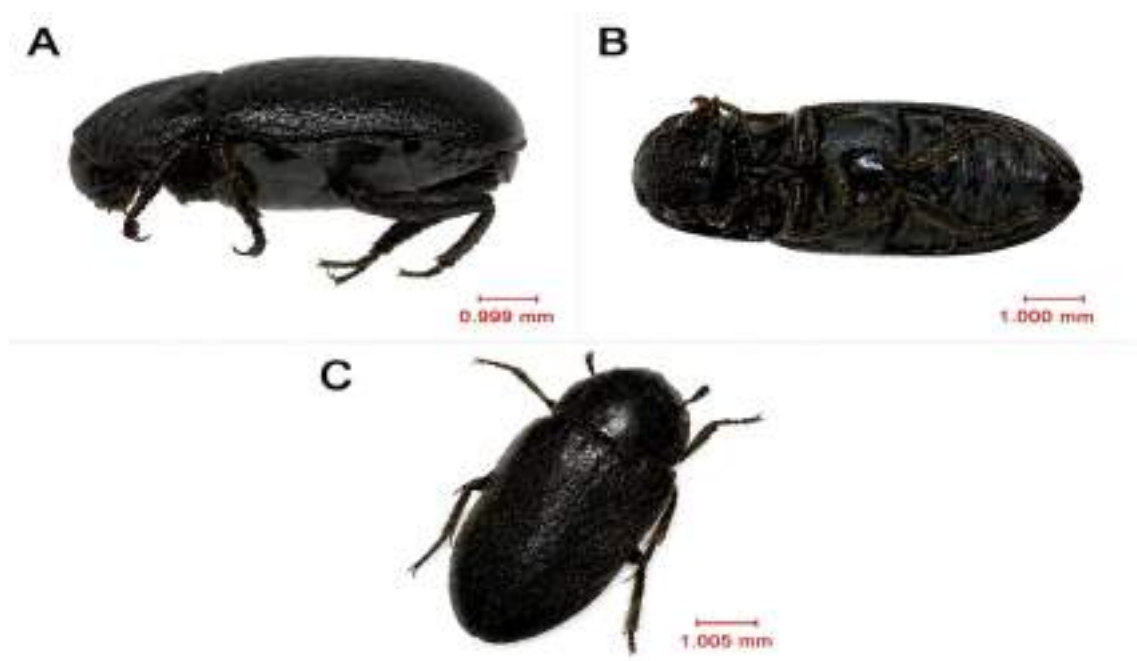


Figure (4.28): Adult *Dermestes peruvianus* Laporte, 1840: (A) lateral view, (B) ventral view, and (C) dorsal view

Family Histeridae

4.12.42 Key B2 — Species of Histeridae

1-

1a Prosternal process bears a distinct lateral fovea (pit); elytra black with pale (white to golden) maculae *Euspilotus richteri* (Figure 4.29)

1b Prosternal process without a lateral fovea; elytra unicolorous black, without pale maculae *Saprinus subnitescens* (Figure 4.30)

4.12.43 *Euspilotus richteri* Lewis, 1907

Taxonomic position: Order Coleoptera; Family Histeridae; Subfamily Saprininae; Genus *Euspilotus*; Species *E. richteri* Lewis, 1907.

Diagnosis: Body length 2.3–3.8 mm, shining black; elytra black bearing white or golden maculae (Figure 4.29: A, B). Pronotal disc with fine, smooth punctures, scattered laterally and denser toward the elytral base, with a row of small setae basally. Antennal club densely punctate on its basal third, smooth and scattered on the anterior third, with sensory groups arranged in clusters of two, three and four. Elytra with 1–4 complete discal striae, the outer stria curving near the base, the fourth stria closing in a curved arc. Anterior tibiae bear 10–11 marginal denticles. Prosternal process bears a distinct lateral fovea.

Forensic importance: Histerid beetles are predominantly predatory at carrion, feeding on the eggs and larvae of necrophagous flies rather than on carrion tissue directly; their presence and relative abundance are used as indirect indicators of the necrophagous insect community and of decomposition stage (general forensic entomology knowledge; Smith, 1986; Amendt *et al.*, 2010, eds.).

Distribution: Argentina and other Neotropical localities, per the wider genus range (Mazur, 2011); also reported from Iran (Tüzün *et al.*, 2010) and, more broadly, across many countries of the Old World (Mazur, 1997; Lackner, 2010).



Figure (4.29): Adult of *Euspilotus richteri* Lewis, 1907. A, dorsal view showing the characteristic elytral pattern; B, ventral view

4.12.44 *Saprinus subnitescens* Bickhardt, 1909

Taxonomic position: Order Coleoptera; Family Histeridae; Subfamily Saprininae; Genus *Saprinus*; Species *S. subnitescens* Bickhardt, 1909.

Synonyms: *S. fagniezi* Auzat, 1912; *S. lecontei* Casey, 1916; *S. meridionalis* Ihssen, 1949; *S. simulans* J. Sahlberg, 1913.

Diagnosis: Body length 2.5–4.0 mm, shining black, elytra unicolorous (no pale maculae). Hypomeron bare of setae. Frons flat to shallowly and sparsely micropunctate, lateral punctures confined to the sides. Elytral striae clear basally; the disc is impunctate out to the second dorsal stria, the punctures

narrowing toward the elytral apex and nearly disappearing along the sutural stria anteriorly. Anterior tibiae bear 9–10 marginal denticles. Prosternal process lacks a lateral fovea (Figure 4.30: A, B, C, D).

Forensic importance: Predatory at carrion on fly eggs and larvae, in the same general forensic role as *Euspilotus* above; Shayya *et al.* (2018) record this species as the most abundant histerid collected on carrion in Lebanon during both active and advanced decomposition, supporting its use as a decomposition-stage indicator.

Distribution: Central and southern Europe, North Africa, Spain (incl. Canary Is.), Portugal (incl. Madeira), Turkey, and Central Asia; introduced to North America (Mazur, 2011); also recorded from Lebanon (Shayya *et al.*, 2018).

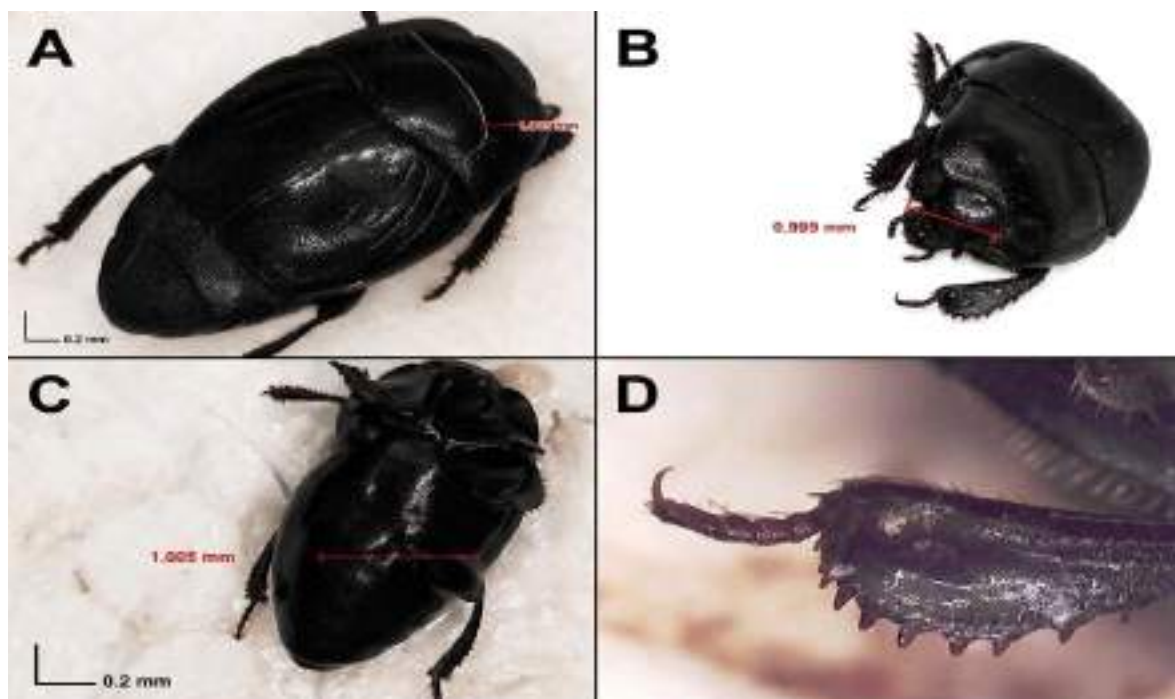


Figure (4.30): Diagnostic morphological characters of the adult *Saprinus subnitescens* Bickhardt, 1909. (A) Dorsal view showing the oval, strongly convex body and elytral striae. (B) Frontal view of the head and pronotum. (C) Ventral view showing the prosternum, mesosternum, metasternum, and abdominal sternites. (D) Enlarged view of the fore tibia showing the characteristic stout teeth used as a diagnostic feature.

4.12.45 Family Cleridae

A single species of forensic interest is represented in this study; no couplet is needed.

4.12.46 *Necrobia rufipes* (De Geer, 1775) (red-legged ham beetle)

Taxonomic position: Order Coleoptera; Family Cleridae; Genus *Necrobia*; Species *N. rufipes* (De Geer, 1775).

Synonyms: *Clerus rufipes* De Geer, 1775; *Corynetes flavipes* Klug, 1842; *Corynetes glabra* Jurin, 1814; *Corynetes reticulata* Klug, 1842.

Diagnosis: Body length ranges 3.5–7.0 mm across sources consulted (dissertation: 4–6 mm; Zayoor Omar *et al.*, 2020, Kurdistan Region–Iraq: 4.2–6.8 mm), elongate-oval, slightly convex, sides sub-parallel, widest near the apical fourth. Head, pronotum and elytra shining metallic green to greenish-blue, densely setose-punctate. Legs and antennae red, the antennal club darker (dark brown to black). Eyes coarsely granulate, sparsely short-setose. Tarsal formula 5-5-5. (Figure 4.31: A, B, C, D).

Forensic importance: A characteristic dry-stage/skeletal-stage carrion colonizer and one of the most economically significant stored-product pests among Cleridae, attacking dried fish, cured ham, cheese rind, and hides — both roles are reflected in its common name (UF/IFAS EDIS fact sheet, Williams & Scharf, 2024, citing Hasan *et al.*, 2020a).

Distribution: Cosmopolitan (UF/IFAS EDIS fact sheet, citing Hasan *et al.*, 2020a); recorded from carrion and carcasses in contact with soil at multiple Kurdistan Region localities — Garmian, Sulaymaniyah and Erbil — in January and March 2018 (Zayoor Omar *et al.*, 2020).

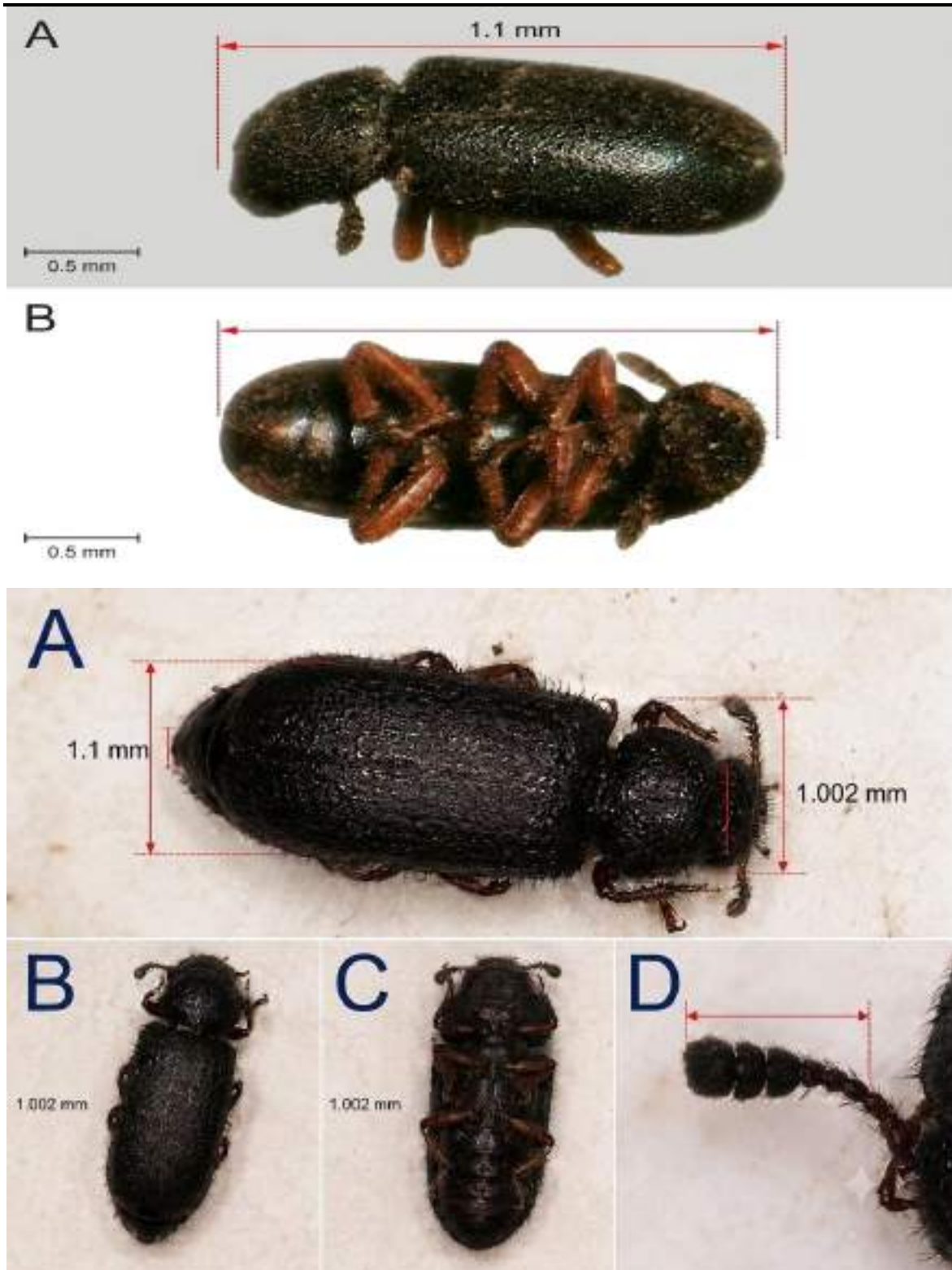


Figure (4.31): Diagnostic morphological characters of the adult *Necrobia rufipes* (De Geer, 1775). (A) Dorsal view of the adult showing the elongated body and elytra. (B) Frontal view of the head and pronotum. (C) Ventral view showing the thoracic and abdominal sternites. (D) Antenna showing the characteristic antennal segments.

4.12.47 Family Tenebrionidae

A single species is represented in this study; no couplet is needed. This species is not treated in the dissertation (see gap note below).

4.12.48 *Mesostena puncticollis* Solier, 1835

Taxonomic position: Order Coleoptera; Family Tenebrionidae; Subfamily Pimeliinae; Tribe Tentyriini; Genus *Mesostena*; Species *M. puncticollis* Solier, 1835.

Diagnosis: Head globular, black, with scattered fine punctation; clypeus black, slightly concave. Mandibles triangular, tridentate. Labrum goblet-shaped. Terminal segment of the maxillary palp funnel-shaped, roughly three times the length of the preceding segment. Antenna clavate, 11-segmented. Pronotum cup-shaped, shining black. Elytra black, elongate-oval, with seven rows of fine punctures. Protibia tubular, armed with small spines. Tarsal formula given in the source as 5-4-4. Abdomen shining black, elongate-oval, of five visible segments Figure (4.32: A, B).

Forensic importance: Not established from the sources available for this project.

Distribution: Recorded from Kurdistan Region–Iraq (Nooraldeen Abdullah Agha, Hamad & Mawlood, 2026); also independently recorded from Turkey (as Pimeliinae: Tentyriini) and from Central Asia in other literature located during this project but not used as a source here, since it was not part of the supplied reference list.



Figure (4.32): Adult *Mesostena puncticollis*: (A) ventral view, (B) dorsal view.

4.12.49 Hymenoptera: Formicidae

Forensic importance (family level): Ants are considered forensically significant primarily because they accelerate the skeletonization of remains: as generalist scavengers and predators they remove soft tissue rapidly once they discover a carcass, and their bite/sting marks on skin and bone can be mistaken for peri-mortem trauma if not correctly recognized during an examination (order-level introduction to Hymenoptera of forensic importance).

4.12.50 Subfamily Formicinae

4.12.51 Key D1 — Species of Formicinae

1-

1a Ocelli absent; antenna inserted well away from the clypeal margin

Camponotus xerxes (Figure 4.33)

1b Ocelli present; antenna inserted close to the clypeal margin genus
Cataglyphis ... 2

2-

2a Petiole with an acute (pointed) apex *Cataglyphis livida* (Figure 4.34)

2b Petiole with a rounded apex 3

3-

3a Head and mesosoma dark brown, contrasting with the black gaster
Cataglyphis nodus

3b Body entirely black *Cataglyphis diehlii*

4.12.52 *Camponotus xerxes* Forel, 1904

Taxonomic position: Order Hymenoptera; Family Formicidae; Subfamily Formicinae; Genus *Camponotus*; Species *C. xerxes* Forel, 1904.

Diagnosis: Body length 13–16 mm, black and semi-glossy except for the antennal scapes and legs, which are reddish-brown. Ocelli absent. Antenna 12-segmented, its insertion set well back from the fronto-clypeal suture. Mesosoma dorsum distinctly curved in lateral profile; pronotum unmodified. Genae and posterior head surface bare of setae. Mesosoma dorsum entirely black. Gaster of five segments; tergites 1–3 glossy at their apical margins (Figure 4.33: A, B)

Forensic importance: As a large-bodied generalist scavenger/predator ant, contributes to the skeletonization role described for the family above; no species-specific forensic study was located in the sources consulted for this project.



Figure (4.33): *Camponotus xerxes*. (A) Lateral view of the worker showing the overall body morphology. (B) Lateral habitus illustrating the characteristic body profile and petiole.

4.12.53 *Cataglyphis livida* André, 1881

Taxonomic position: Order Hymenoptera; Family Formicidae; Subfamily Formicinae; Genus *Cataglyphis*; Species *C. livida* André, 1881.

Diagnosis: Body length 4–6 mm, yellow to orange, with fine yellow setae on the body and legs. Ocelli present but small. Gaster finely setose. Petiole node with a pointed (acute) apex (Figure 4.33: A, B).

Forensic importance: Fast-running, heat-tolerant desert ants of this genus are active diurnal scavengers at carrion in arid environments, consistent with the family-level skeletonization role described above; no species-specific forensic study was located in the sources consulted for this project.

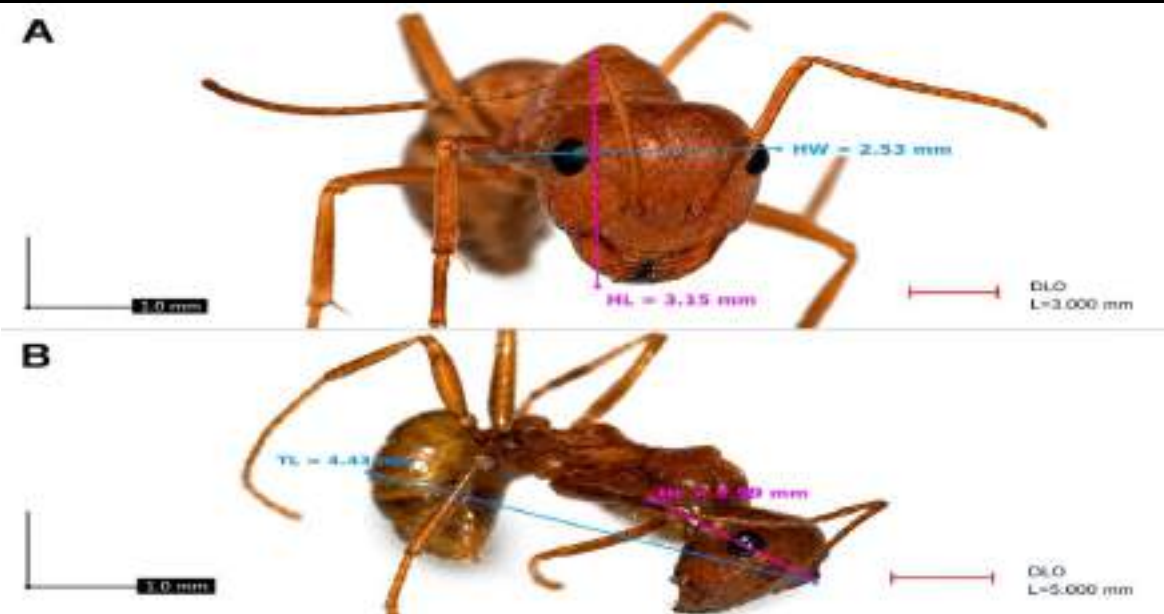


Figure (4.34): Diagnostic morphological features of *Cataglyphis livida*. (A) Frontal view of the head showing the large compound eyes and antennae. (B) Lateral view of the body showing the elongated mesosoma, petiole, and gaster.

4.12.54 Subfamily Myrmicinae

4.12.55 Key D2 — Species of Myrmicinae

1-

1a Postpetiole articulating with the mid-dorsal surface of the first gastral segment; gaster heart-shaped in dorsal view *Crematogaster auberti*

1b Postpetiole articulating with the mid-ventral surface of the first gastral segment; gaster pear-shaped in dorsal view 2

2-

2a Last four antennal segments elongate, weakly club-shaped (sub-clavate) *Messor syriacus* (Figure 4.35)

2b Last three antennal segments elongate, distinctly club-shaped (clavate) *Pheidole minuscula*

4.12.56 *Messor syriacus* Santschi, 1927

Taxonomic position: Order Hymenoptera; Family Formicidae; Subfamily Myrmicinae; Genus *Messor*; Species *M. syriacus* Santschi, 1927.

Diagnosis: Body length 4–7 mm. Mesosoma dark brown; head and gaster black. Antenna 12-segmented, the last four segments elongate. Fine setae cover the body except for the mesosoma. Propodeum triangular but with an unarmed (non-toothed) apex — treated in the source as diagnostic for the species. Gaster base brown, remainder black; ventral surface finely setose, dorsal surface bearing longer setae (Figure 4.35: A, B)

Forensic importance: *Messor* is primarily a granivorous (seed-harvesting) genus; its occurrence at carrion is more consistent with generalist scavenging/predation opportunities than with a dedicated necrophagous role, but it still contributes to the family-level skeletonization effect described above.



Figure (4.35): Morphological characteristics of the worker ant *Messor syriacus*. (A) Lateral view showing the robust body, distinct petiole and postpetiole, and large gaster. (B) Frontal view showing the broad head, strong mandibles, compound eyes, and geniculate antennae.

Conclusions

and

Recommendations

Conclusions

1. The decomposition process of dog and pig carcasses under the environmental conditions of southern Iraq followed a predictable succession pattern of decomposition stages accompanied by distinct changes in the associated insect community.
2. Insect succession proved to be a reliable biological indicator for estimating the postmortem interval under local environmental conditions, confirming its forensic importance in medico-legal investigations.
3. The third-instar larvae represented the most reliable developmental stage for estimating the postmortem interval because of their consistent occurrence, measurable growth characteristics, and suitability for thermal age calculations.
4. Postmortem interval estimation was successfully achieved using larval length measurements together with accumulated degree hour (ADH) calculations, providing complementary approaches that improved the reliability of PMI estimation.
5. Burial conditions significantly altered decomposition dynamics and insect succession, indicating that burial depth and burial environment should always be considered when estimating the postmortem interval.
6. Different carcass types and environmental habitats influenced the composition and succession of forensically important insect species, demonstrating the importance of developing region-specific forensic entomological databases.
7. A total of 19 forensically important insect species belonging to three orders were identified. The order Diptera was represented by eight species: *Calliphora vicina*, *Lucilia sericata*, *Chrysomya megacephala*, *Chrysomya albiceps*, *Chrysomya putoria*, *Musca domestica*, *Sarcophaga*

Conclusions and Recommendations

vagans, and *Sarcophaga haemorrhoea*. Species of the family Calliphoridae were the first insects to arrive at the carcasses and were the most dominant during the early stages of decomposition, whereas species of Muscidae and Sarcophagidae appeared successively as decomposition progressed. The order Coleoptera was represented by eight species: *Dermestes frischii*, *Dermestes maculatus*, *Dermestes ater*, *Dermestes peruvianus*, *Necrobia rufipes*, *Saprinus subnitescens*, *Euspilotus richteri*, and *Mesostena puncticollis*. These species were mainly associated with advanced decomposition and the skeletal stage, particularly members of Dermestidae and Cleridae, whose abundance increased as the carcasses became drier. The order Hymenoptera was represented by three species: *Cataglyphis livida*, *Camponotus xerxes*, and *Messor syriacus*, which occurred during different decomposition stages and were associated with the environmental conditions surrounding the carcasses.

8. Morphological examination provided accurate identification of the forensically important insect species collected during all stages of decomposition.
9. This study provides baseline forensic entomological data for southern Iraq and contributes valuable regional information that can support future forensic investigations and improve the accuracy of postmortem interval estimation under hot climatic conditions.

Recommendations

1. Establish a national forensic entomology database for Iraq that documents the distribution, seasonal occurrence, and succession patterns of forensically important insect species.
2. Promote the routine application of forensic entomology in medico-legal investigations and integrate insect evidence into postmortem interval (PMI) estimation.
3. Establish specialized forensic entomology laboratories and provide training for crime scene investigators in the proper collection, preservation, and identification of insect evidence.
4. Conduct further studies to determine the developmental thresholds and accumulated degree hours (ADH) of locally important forensic insect species to improve the accuracy of PMI estimation.
5. Expand future research to evaluate the effects of different environmental conditions, burial depths, soil characteristics, and seasonal variations on decomposition and insect succession.
6. Encourage forensic entomotoxicology studies to investigate the influence of drugs, toxins, and other chemical substances on insect development and PMI estimation.
7. Conduct additional forensic entomological studies on special scenarios, including buried, burned, submerged, and concealed remains, to improve the applicability of forensic entomology under different conditions.
8. Encourage the use of pig carcasses as suitable experimental models for future forensic decomposition and insect succession studies.

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Appendices

Appendices

Supplementary Statistical Figures

The figures below present supplementary graphical summaries of results discussed in Sections 4.1 and 4.11 (temporal abundance of the nine forensically important taxa, and PMI comparisons by carcass type, burial level, and burial site/depth). They are placed here, rather than in the main text, because the corresponding numerical results are already presented in Tables 4.1-4.5, 4.6-4.14 and 4.17.

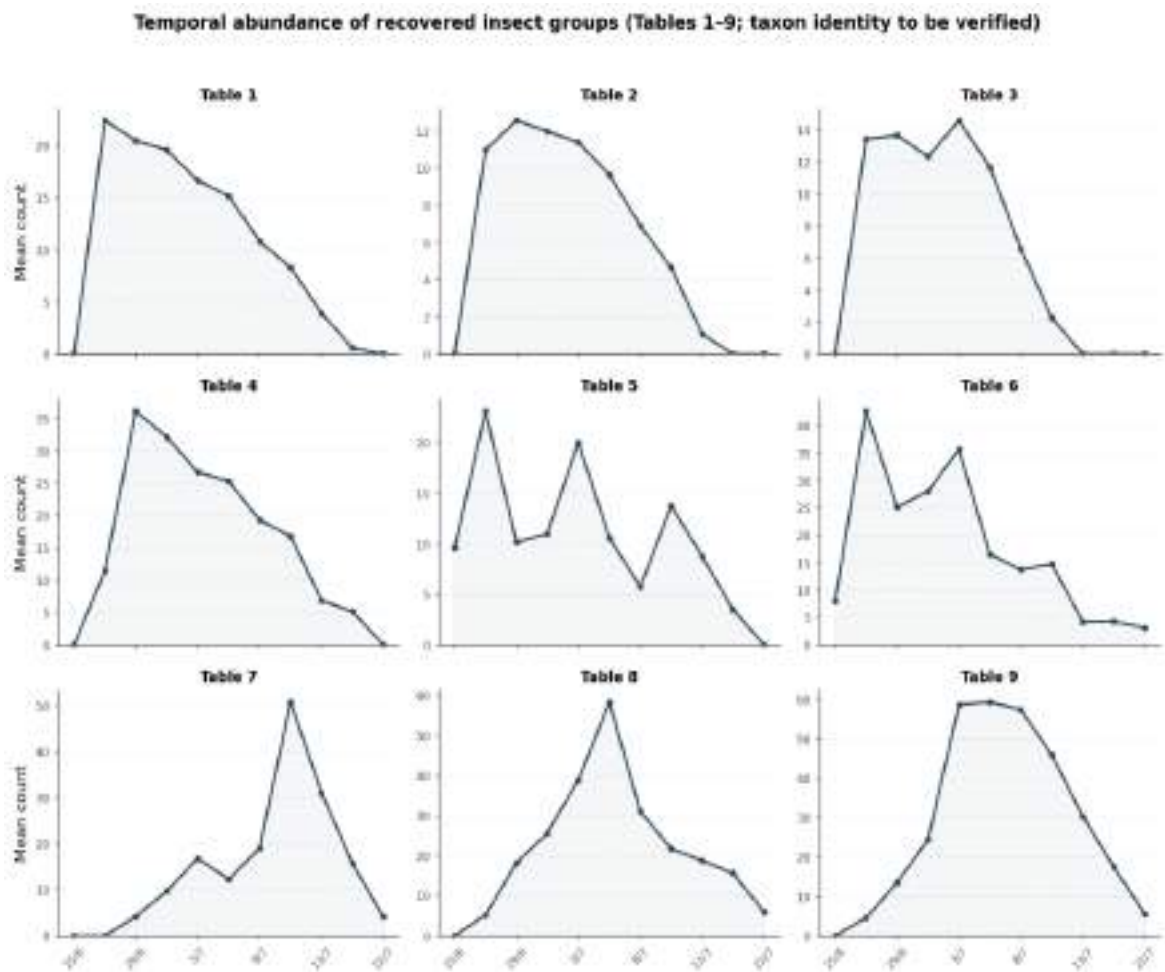


Figure (A.1): Temporal abundance (overall date means) of the nine taxa across the eleven sampling dates (25 June–22 July 2025): 1 *Calliphora vicina*, 2 *Lucilia sericata*, 3 *Musca domestica*, 4 *Chrysomya megacephala*, 5 *Chrysomya albiceps*, 6 *Sarcophaga vagans*, 7 *Dermestes frischii*, 8 *Dermestes maculatus*, 9 *Necrobia rufipes*.

Appendices

Official Task-Facilitation and Approval Letters

The following official letters authorized and facilitated the field research conducted for this study at the two study sites in Al-Daghara District, Al-Diwaniyah Governorate.



Figure D.1. Task-facilitation letter issued by the General Directorate of Al-Diwaniyah Municipalities, Ministry of Construction, Housing and Public Municipalities.

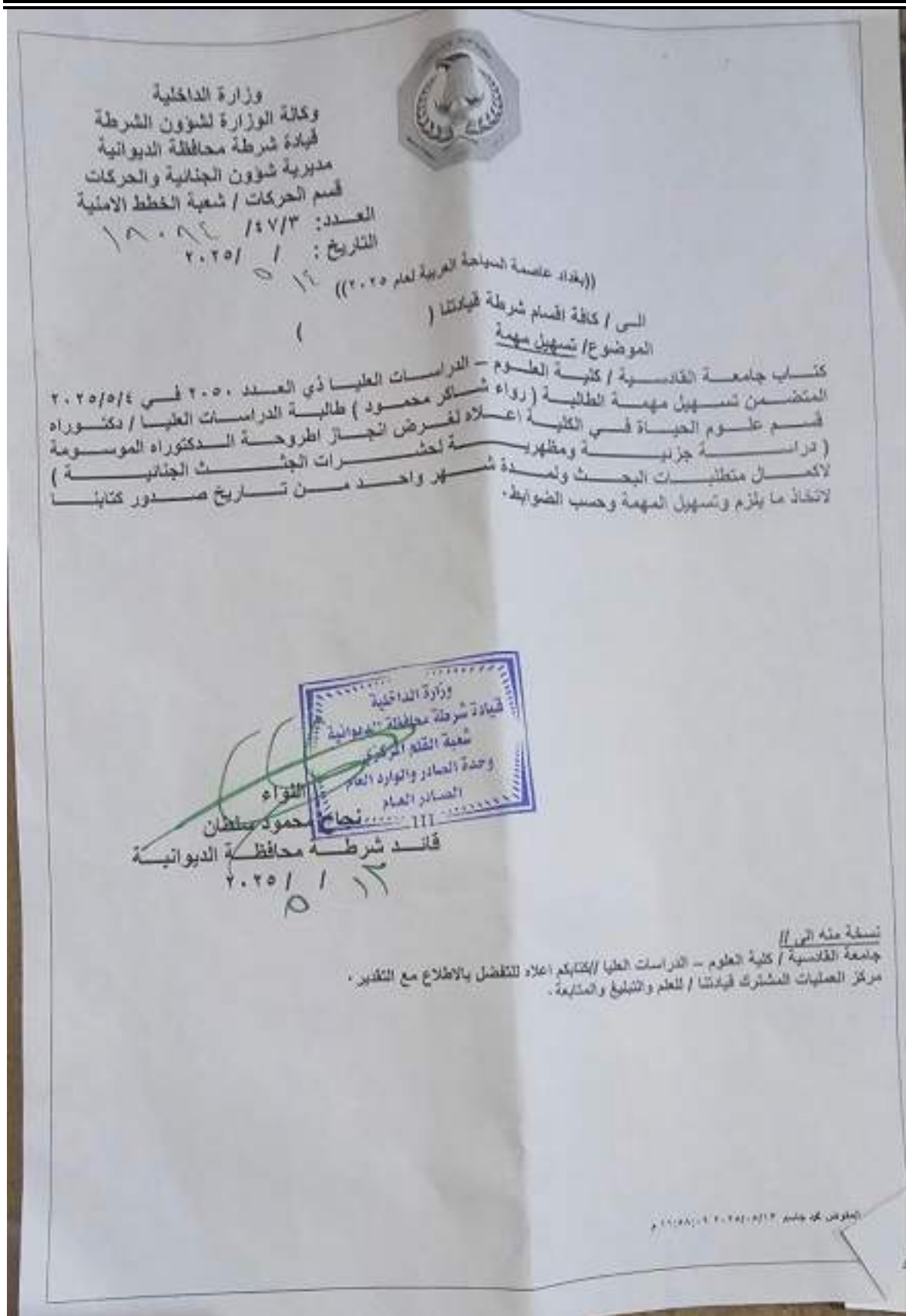


Figure D.2. Task-facilitation letter issued by the Al-Diwaniyah Police Directorate, Ministry of Interior.

Specimen Identification Correspondence and Reports

Iraq Natural History Research Center and Museum, University of Baghdad

The insect specimens collected during this study were submitted to the Iraq Natural History Research Center and Museum, University of Baghdad, for taxonomic identification. The official correspondence and the resulting identification reports are provided below.

Appendices


وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research
جامعة بغداد
University of Baghdad
مركز بحوث ومتحف التاريخ الطبيعي
Iraq Natural History Research Center and Museum

No :
 Date :

العدد : ٥٢١
 التاريخ : ٢٠٢٦/٥/١٠

الى /جامعة بغداد / قسم الشؤون العلمية
 م / تشخيص نماذج

تحية طيبة ...
 انارة الى ما جاء بكتاب جامعة القادسية / كلية العلوم
 المرفق ٣٢٨٢ في ٢٠٢٥/٧/٢٥ والحقا بكتابنا المرفق ٥١٢ في
 ٢٠٢٦/٥/٦
 يرجى التفصيل بالموافقة على مفتحتهم لغرض تزويدهم بنسخة من
 تقرير تشخيص المجموعة الثانية من النماذج المرسلة من قبل
 طالبة الدراسات العليا الدكتوراه (رواء شكري محمود) .

مع التقدير ...

المرفقات
 - تقرير التشخيص
 - نسخة من الكتاب أعلاه

م. د. سهيل ياسين جاسم
 مدير المركز/وكالة

نسخة منه الى :
 - قسم الحشرات واللافهريات - تقرير رقم المرفق (٣٢) في (٢٠٢٦/٥/١٠)
 - المسطرة والارشفة الالكترونية

العراق - بغداد - باب المعظم - مجمع الكليات ص.ب. 59037
 هاتف : المدير : 4168361 - بدلة : 416579
 E-mail : info@nhm.uobaghdad.edu.iq Web site : nhm.uobaghdad.edu.iq

Figure E.1. Official request for specimen identification submitted to the Iraq Natural History Research Center and Museum, University of Baghdad.

Appendices



وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research
جامعة بغداد
University of Baghdad
مركز بحوث ومتحف التاريخ الطبيعي
Iraq Natural History Research Center and Museum
قسم الحشرات واللافقريات
Department of Entomology and Invertebrates

NO: _____
Date: _____

المسند: ٣٤
التاريخ: ٢٠٢٦/٥/١٠

قسم الحشرات واللافقريات
م / تشخيص نماذج

إن العينات المرسلة إلينا من قبل طالبة الدراسات العليا / الدكتورة (رواء شلكر محمود) . فقد تم التشخيص وكالاتي:

Dermestes maculatus DeGeer, 1774 (Coleoptera, Dermestidae) (No: 1)

Dermestes Peruvianus Laportede Castelnau, 1840 (Coleoptera , Dermestidae)

Dermestes maculatus DeGeer, 1774 (Coleoptera, Dermestidae) (No:2)

Saprinus Subnitescens Bickhardt, 1909 (Coleoptera, Histeridae)

Mesostena Puncticollis Solier, 1835 (Coleoptera , Tenbrionidae) (No:3)

Dermestes frischii kugelman, , 1792 (Coleoptera, Dermestidae) (N0:4)

Dermestes maculatus DeGeer, 1774 (Coleoptera, Dermestidae)

Dermestes ater DeGeer, 1774 (Coleoptera, Dermestidae)

Necrobia rufipes (Fabricius, 1781) (Coleoptera, Cleridae)

Euspilatus richteri Lewis, 1909) (Co leoptera, Histeridae)

Dermetes maculatus DeGeer, 1774 (Coleoptera, Dermestidae) (No:5)

(No: 6) ثلاثة

Chrysomya putoria (Wiedemann, 1830) (Diptera, Calliphoridae) (No:7)

Chrysomya albiceps (Wiedemann, 1819) (Diptera, Calliphoridae) (No:8)

Saprinus subnitescens Bickhardt, 1909 (Coleoptera, Histerida) (No:9)

تم المسح الضوئي بـ CamScanner

Chrysomya putoria (Wiedemann, 1830) (Diptera, Calliphoridae) (No:1)

Chrysomya megacephala (Fabricius, 1794) (Diptera, Calliphoridae) (No: ٢

Lucilia Sericata (Meigen, 1826) (Diptera, Calliphoridae) (N0:5)

٢ / ٣

Figure E.2. Specimen identification report issued by the Department of Entomology and Invertebrates listing the identified Coleoptera and Diptera specimens (first set).



Figure E.3. Official correspondence regarding the identification of the submitted specimens, Iraq Natural History Research Center and Museum.

Appendices

وزارة التعليم العالي والبحث العلمي
 Ministry of Higher Education and Scientific Research
 جامعة بغداد
 University of Baghdad
 مركز بحوث ومتحف التاريخ الطبيعي
 Iraq Natural History Research Center and Museum

رقم: ٥١٢
 التاريخ: ٢٠٢٦/٥/٦

إلى: / جامعة بغداد / قسم الشؤون العلمية
 م / تشخيص نماذج

تحية طيبة ...
 أشارة إلى ما جاء بكتاب جامعة القادسية/ كلية العلوم المرقم ٢٢٨٢ في ٢٥/٧/٢٥.
 يرجى التفصل بالموافقة على سفاحتهم لغرض تزويدهم بنسخة من تقرير تشخيص
 النماذج المرسلة طي كتابهم اعلاه.

... مع التقدير ...

الملاحظات
 - نسخة من الكتاب اعلاه
 - نسخة من تقرير التشخيص

ا.م. د. هناء هادي عبد الحسين الصفار
 مدير المركز

نسخة منه إلى:
 - قسم العشرات واللافريات - تقريركم المرقم (٢٢) في ٢٠٢٦/٥/٦
 - الصنارة والأرشفة الإلكترونية

العراق - بغداد - باب المظلم - مجمع الكليات ص.ب. ٤٩٥٣٧
 هاتف: ٤١٦٨٣٦١ - فاكس: ٤١٦٥٧٩
 E-mail: info@nhm.uobaghdad.edu.iq Web site: nhm.uobaghdad.edu.iq

Figure E.4. Official request for the specimen identification report, Iraq Natural History Research Center and Museum.



 وزارة التعليم العالي والبحث العلمي
 Ministry of Higher Education and Scientific Research
 جامعة بغداد
 University of Baghdad
 مركز بحوث و متحف التاريخ الطبيعي
 Iraq Natural History Research Center and Museum
 قسم الحشرات واللافقرات
 Department of Entomology and Invertebrates

NO: _____ العدد: ٣٢
 Date: _____ التاريخ: ٢٠٢٦/٥/٦

قسم الحشرات واللافقرات

م / تشخيص نماذج

إن العينات المرسلة اليها من قبل طالبة الدراسات العليا / الدكتوراه (رواء شاكر محمود) . فقد تم التشخيص
 وكالاتي:

الوجبة الاولى:

المجموعة الاولى:

Chrysomya megacephala (Fabricius, 1794) (Diptera, Calliphoridae)(No:1,3,7)
Lucilia sericata (Meigen,1826) (Diptera, Calliphoridae)(No:2)
Calliphora vicina Robineau-Desvoidy, 1830 (Diptera, Calliphoridae)(No:6)

المجموعة الثانية:

Chrysomya megacephala (Fabricius, 1794) (Diptera, Calliphoridae)(No:1,3,4,5,6,7)
Chrysomya putoria (Wiedemann, 1830) (Diptera, Calliphoridae)(No:2)

المجموعة الثالثة:

Chrysomya megacephala (Fabricius, 1794) (Diptera, Calliphoridae)(No:1)
Calliphora vicina Robineau-Desvoidy, 1830 (Diptera, Calliphoridae)(No:2)

المجموعة الرابعة:

Chrysomya megacephala (Fabricius, 1794) (Diptera, Calliphoridae)(No:1)
Musca domestica Linnaeus ,1758 (Diptera, Muscidae)(No:2)
Sarcophaga haemorrhhoa Meigen,1826 (Diptera, Sarcophagidae)(No:3)

المجموعة الخامسة:

Sarcophaga vagans Meigen, 1826 (Diptera , Sarcophagidae) (No:1,2)

Figure E.5. Specimen identification report listing the identified species by sample group (second set).

الخلاصة

هدفت هذه الدراسة إلى توثيق تعاقب الحشرات ذات الأهمية في الطب الشرعي، وتحديد أنواع الحشرات المرتبطة بجثث الحيوانات، وتقدير الفترة الزمنية بعد الوفاة في ظل ظروف بيئية مختلفة في محافظة الديوانية بالعراق. أُجريت تجارب ميدانية في موقعين متباينين، هما منطقة زراعية ومقبرة بشرية في قضاء الدغارة، باستخدام جثث كلاب يتراوح وزنها بين 30 و40 كيلو غراماً، وجثث خنازير برية يتراوح وزنها بين 60 و120 كيلو غراماً، وُضعت في ظروف دفن مختلفة (سطحية ودفن). نُفذت الدراسة في الفترة من 25 يونيو 2025 إلى 6 أبريل 2026. تم تحديد عينات الحشرات باستخدام الخصائص المورفولوجية والمفاتيح التصنيفية القياسية، بينما اقتصر التحليلات الإحصائية على الأنواع الأكثر وفرة وذات الأهمية في الطب الشرعي. يمكن تلخيص نتائج الدراسة على النحو التالي:

أولاً: تم تحديد ثمانية أنواع تنتمي إلى رتبة ذوات الجناحين: *Lucilia* و *Calliphora vicina* و *Chrysomya putoria* و *Chrysomya albiceps* و *Chrysomya megacephala* و *sericata* و *Musca domestica* و *Sarcophaga vagans* و *Sarcophaga haemorrhoea*، كانت حشرات عائلة Calliphoridae أول الحشرات التي استوطنت الجثث، وسادت خلال المراحل المبكرة من التحلل، بينما ظهرت حشرات عائلتي Muscidae و Sarcophagidae تدريجياً مع تقدم عملية التحلل.

ثانياً: تم تحديد ثمانية أنواع تنتمي إلى رتبة الخنافس: *Dermestes* و *Dermestes frischii* و *Necrobia rufipes* و *Dermestes peruvianus* و *Dermestes ater* و *maculatus* و *Saprinus subnitescens* و *Euspilotus richteri* و *Mesostena puncticollis*. ارتبطت هذه الخنافس بشكل أساسي بالمراحل المتقدمة والهيكلية من التحلل، حيث ازداد عدد أفراد عائلتي Dermestidae و Cleridae مع جفاف الجثث.

ثالثاً: تم تحديد ثلاثة أنواع تنتمي إلى رتبة غشائيات الأجنحة: *Cataglyphis livida* و *Camponotus xerxes* و *Messor syriacus*، لوحظت هذه الأنواع خلال مراحل مختلفة من التحلل، وارتبط وجودها بشكل رئيسي بالظروف البيئية المحيطة أكثر من ارتباطها بمرحلة محددة من التحلل.

رابعاً: مرّ تحلل الجثة بخمس مراحل متميزة: المرحلة الطازجة، ومرحلة الانتفاخ، ومرحلة التحلل النشط (الرطب)، ومرحلة التحلل المتقدم (الجاف)، والمرحلة الهيكلية. تراوحت مدة التحلل من 1.10 إلى 37.00 يوماً تقريباً. كان عمق الدفن هو العامل الرئيسي المؤثر على معدل التحلل، حيث استغرقت

الجثث المدفونة وقتاً أطول بكثير للتحلل مقارنة بالجثث الموجودة على السطح، بمتوسط 53.09 يوماً مقارنة بـ 20.92 يوماً على التوالي.

خامساً: لوحظت تأثيرات كبيرة لنوع الجثة، وبيئة الدراسة، وظروف الدفن على تعاقب الحشرات ووفرة أنواعها. وظهرت اختلافات واضحة في وقت وصول الحشرات وتكوين مجتمعاتها بين المعاملات المختلفة، حيث أدى الدفن إلى تأخير استيطان الحشرات وتقليل وفرتها مقارنةً بالجثث المكشوفة.

سادساً: اقتصر التحليلات الإحصائية على أكثر الأنواع وفرةً وأهميةً في الطب الشرعي، وهي: ذبابة *Calliphora vicina*، وذبابة *Lucilia sericata*، وذبابة *Musca domestica*، وذبابة *Chrysomya megacephala*، وذبابة *Chrysomya albiceps*، وذبابة *Sarcophaga vagans*، وذبابة *Dermestes frischii*، وذبابة *Dermestes maculatus*، وذبابة *Necrobia rufipes*، وأظهرت هذه الأنواع اختلافات كبيرة في وفرتها وأنماط تعاقبها تبعاً لنوع الجثة، وبيئة الدراسة، وظروف الدفن.

سابعاً: تم تقدير الفترة الزمنية بعد الوفاة باستخدام يرقات الطور الثالث (L3) من خلال تطبيق منهجين متكاملين: طريقة الساعات الحرارية المتراكمة (ADH) ونموذج إحصائي قائم على طول اليرقة. وقد اختلفت الفترة الزمنية المقدرة اختلافاً كبيراً تبعاً لنوع الجثة وبيئة الدراسة وظروف الدفن، مما يُبرز أهمية إدراج هذه المتغيرات في نماذج تقدير الفترة الزمنية بعد الوفاة في ظل الظروف البيئية الحارة.

ثامناً: تُعد هذه الدراسة إحدى تحقيقات علم الحشرات الجنائي التي أُجريت في درجات حرارة بيئية تتجاوز 40 درجة مئوية. وهي تُقدم أول مجموعة بيانات شاملة من محافظة الديوانية، جنوب العراق، حول تعاقب الحشرات وتقدير الفترة الزمنية بعد الوفاة لكل من الجثث المكشوفة على السطح والمدفونة. إضافةً إلى ذلك، تُقدم الدراسة مفاتيح تصنيفية لتحديد أنواع الحشرات المُسجلة، مما يُؤسس قاعدة بيانات مرجعية إقليمية قيّمة لعلم الحشرات الجنائي، ويدعم التحقيقات الطبية القانونية المستقبلية في البيئات الحارة الجافة.



جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة القادسية
كلية العلوم
قسم علوم الحياة

دراسة مظهرية وتشخيصية للحشرات ذات الالهية الجنائية المصاحبة للجثث ودورها في تقدير الفترة الزمنية بعد الوفاة

أطروحة

مقدمة إلى مجلس كلية العلوم/جامعة القادسية
وهي جزء من متطلبات نيل درجة الدكتوراه فلسفة/علوم الحياة

من قبل

رواء شاكر محمود الربيعي

بكالوريوس علوم حياة / 2009 / جامعة القادسية / كلية العلوم
ماجستير علوم الحياة / 2022 / جامعة القادسية / كلية العلوم

تحت إشراف

الأستاذ الدكتور حبيب وسيل كاظم شبر