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Insect Utilization in Criminal Investigations: The Imperative of Forensic Entomology and its Future Future Prospects

Madona Mathew [a++*]

[a] *Department of Forensic Science, Usha Martin University, Jharkhand, India.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

Forensic entomology is the practice of collecting, examining, and presenting insect-related evidence to support forensic investigations. The findings from such investigations play a vital role in civil and criminal cases, including law enforcement, conflict resolution, and national security matters. These findings are recognized and accepted by various legal systems worldwide. This paper specifically delves into the criminal aspect of forensic investigations, focusing on the role of forensic entomology within the field of criminology.

In criminal cases, particularly those involving murder, forensic investigations aim to address key questions concerning the 'when,' 'where,' and 'how' of the crime. However, when a considerable amount of time has passed since the victim's death and most other biological evidence has deteriorated or become unrecoverable, the analysis of insect evidence found on the deceased

[++] *Assistant Professor;*
**Corresponding author: Email: madona2908mj@gmail.com;*

becomes a crucial method for uncovering details about the victim's demise. This is where forensic entomology takes center stage, and it serves as the primary emphasis of this paper.
The following review encompasses a comprehensive exploration of the history, methodology, and scientific principles of forensic entomology. It discusses the utility of forensic entomology in criminal investigations, highlights landmark cases where entomological evidence played a pivotal role in solving crimes, and considers the potential for further development and expansion within this field."

Keywords: Forensic entomology; insects; postmortem interval; corpse.

1. INTRODUCTION

“Forensic entomology, also referred to as "medico-legal" entomology, is the scientific examination of arthropods, particularly insects, maggots, and other pests, in connection with criminal activities. This field within forensic science primarily involves identifying insects and other arthropods associated with human remains, which are then used to determine the location and time of death” [1]. Arthropod evidence can provide insights into whether the body was relocated after the victim's demise or if it was disturbed at various locations, either by animals or by the perpetrator returning to the crime scene. However, the central goal of forensic entomology is to ascertain the post-mortem interval or the amount of time that has passed since death [2,3]. The findings from these investigations are subsequently presented as evidence in criminal court cases. The role of insects in criminal investigations has been a topic of growing interest in the field of forensic science. Forensic entomology, the scientific study of insects and their behavior as it relates to legal investigations, has emerged as a crucial tool in solving crimes, particularly those involving postmortem events [4-6]. In this comprehensive exploration of the subject, we delve into the myriad ways insects have become an indispensable asset in crime solving and the critical role of forensic entomology.

Criminal investigations have come a long way from the traditional methods of detective work and evidence analysis. In today's world, forensic science plays a pivotal role in assisting law enforcement agencies and the criminal justice system. It encompasses various sub-disciplines, each contributing to a deeper understanding of crime scenes and providing essential clues to decipher complex cases [7-9].

One such sub-discipline, forensic entomology, has made significant strides in aiding criminal investigations. Unlike more conventional forms of forensic science like fingerprint analysis or DNA profiling, forensic entomology is an unusual yet indispensable branch that capitalizes on the ecological interactions between insects and deceased bodies. This field has evolved into an essential tool for solving crimes, particularly those where the timeline of events is in question or bodies are discovered in advanced stages of decomposition [10-13].

The utilization of insects in criminal investigations hinges on one fundamental principle: the predictable succession of insects in and around a corpse. Insects are nature's cleanup crew, and when a body becomes available as a food source, various species of insects arrive at the scene in a fairly predictable sequence [9,14-16].

The timeline of insect colonization and their life cycles can provide forensic entomologists with invaluable information about the postmortem interval (PMI), which is the time that has elapsed since death. Understanding the PMI is often a critical aspect of criminal investigations, especially when the deceased's last known whereabouts are uncertain. The study of necrophagous insects, those that feed on decaying flesh, allows entomologists to establish an approximate time of death and investigate the circumstances leading to it.

Fly larvae, commonly known as maggots, are often the first insects to arrive at a decomposing body. They lay their eggs on or near the corpse, and these eggs hatch into maggots that feed on the decaying flesh. By examining the developmental stage of these maggots and the environmental conditions at the crime scene, forensic entomologists can estimate the time since death with remarkable accuracy. This information is invaluable for investigators trying to establish alibis, timelines, or the sequence of events leading up to a death.

Seasonal and geographical variations in insect populations and behaviors add a layer of complexity to the field, as different insects become involved in the decomposition process

depending on factors like climate and location. This complexity highlights the importance of forensic entomologists' expertise in understanding regional entomofauna and its interaction with decomposing bodies.

Forensic entomologists do not just provide answers about time of death; they can also contribute.

Traditionally, factors such as ambient temperature and weather conditions during the days following the crime scene are used to estimate the time of death. This estimation can be refined by correlating these factors with the developmental rates of key arthropod species found on or within the corpse. Maggots, commonly known as fly larvae, are typically the primary and secondary decomposers of animal remains and cadavers. By understanding the developmental rates and pertinent information regarding these decomposer species at varying temperatures, it is often possible to accurately determine the time of death.

“Sometimes, the location of a crime differs from where the victim's body is discovered. This information can be established based on the presence of distinctive arthropods with known distributions not typically found in the area where the body was located. Likewise, a meticulous analysis of collected insect evidence can assist in resolving other criminal cases, such as tracing the origins of vehicles and accessories used in crimes or identifying the source of drug shipments. Such insights can be gleaned from the characteristic geographic distributions revealed by arthropod evidence” [1].

2. A BRIEF HISTORICAL OVERVIEW OF FORENSIC ENTOMOLOGY

While traces of a scientific field resembling forensic entomology can be traced back to as early as the 13th century in historical texts, the notion of forensic entomology as a tool for crime-solving is relatively recent. The first documented instance of forensic entomology can be attributed to Sung Tz’u, a Chinese lawyer and investigator, who chronicled a unique event in his career in his book titled 'Hsi Yuan Lu,' translated as 'Washing Away of Wrongs' or 'Instructions To Coroners.' In this account, Mr. Tz’u used flies to apprehend a murderer. After a man was found dead near a rice field, having been stabbed, Mr. Tz’u gathered the suspects and asked them to provide their farming tools for examination. Although no direct evidence was found, flies began to swarm around one of the tools, the same flies found on the victim's body. This led the investigator to the murderer, who later confessed.

While this case laid the foundation for future developments in forensic entomology, there was a scarcity of subsequent documentation on the subject. Forensic entomology gained more significant recognition in the late 19th century and played a crucial role in major cases in the late 20th century. The first modern case related to forensic entomology was recorded in 1855 when a French physician named Louis François Étienne Bergeret, often referred to as the 'father of forensic entomology,' used insects found on the bodies of child victims to accurately determine their time of death, ultimately leading to the murderer's identification. However, except for a few well-known cases, the application of forensic entomology in criminal investigations did not become commonplace until the late 20th century, experiencing a surge in popularity over the last 30-40 years.

3. STAGES OF DECOMPOSITION

The field of forensic entomology comes into play once the process of decomposition has run its course, typically divided into five stages:

(i) Fresh Stage: This initial stage, lasting for the first two days post-mortem, begins at the time of death and continues until bloating sets in. Insects are attracted to the body approximately 10-15 minutes after death, but egg-laying usually occurs later. Notable morphological changes are limited during this stage, but chemicals released by the body are vital in attracting insects.

(ii) Bloated Stage: Following the 'Fresh Stage,' the bloating stage continues until the 7th day after death. Putrefaction commences, leading to an excess production of gases and body bloating due to the activities of anaerobic bacteria. This phase attracts Diptera larvae, which can typically be collected by the second day.

(iii) Decay Stage: Extending from the 7th to the 13th day after death, this stage sees the abdominal wall penetrate, causing deflation and marking the end of bloating. The temperature rises to about 10-14 degrees before gradually decreasing by the stage's end. Carcass biomass transforms into dipteran larval biomass, which later escape the carcass to pupate.

(iv) Post-decay Stage: Beginning around the 10th day and lasting until the 23rd day after death, this stage begins once dipteran larvae leave the carcass, leaving behind 'byproducts of decay' (BOD).

(v) Dry Stage: The final stage, spanning from the 20th to the 90th day post-mortem, during which the BOD is expected to have dried up, leaving only dry bones. The transition from the Post-decay stage to the Dry stage is the slowest of all stages.

4. TYPES OF INSECTS USED IN FORENSIC ENTOMOLOGY

Upon death, the victim's body initiates autolysis, a process in which cells break down from the inside out. This self-destruction of soft tissue in the gastrointestinal tract releases molecules such as 'apeneumones,' which attract arthropods. Different stages of body decomposition produce these molecules, which can influence insect behavior. For instance, sulfur-based compounds attract flies to decomposing corpses, while ammonia-rich compounds prompt egg-laying, affecting the oviposition of insects.

Insects found on decomposing bodies can generally be categorized into four groups:

(I) Necrophages: Insects that feed on carcasses.
(II) Parasites or Predators: Species that prey on necrophagous insects.
(III) Omnivores: Insects that consume both carcasses and other insects like wasps and ants.
(IV) Incidentals: Other species, including arachnids and springtails, that may occasionally inhabit carrion."

The first two categories of insects hold paramount significance in forensic entomology, with beetles (Coleoptera) and flies (Diptera) being the most noteworthy. Among flies, the prevalent species are house flies (Muscidae), blow flies (Calliphoridae), and flesh flies (Sarcophagidae). Blow flies and flesh flies are typically the initial insects to appear when decomposition commences, while house flies arrive later, during the bloated stage. These flies lay eggs in natural openings or wounds on the body, which hatch into larvae known as maggots. Once the feeding process is complete, these maggots relocate to drier areas to begin pupation.

5. CONCLUSION

Forensic entomology is an emerging discipline within the broader scope of forensic technology and sciences. It has gained substantial recognition and become an indispensable tool in criminal investigations. In today's world, forensic experts' roles extend beyond hard tissue examination, with an increasing involvement in criminal investigations as part of forensic teams. This necessitates greater awareness of emerging sciences like forensic entomology and their applications in forensics. However, for many within the forensic science community, insects hold an exotic status, potentially contributing to the limited recognition that forensic entomology deserves.

From a scientific perspective, as elaborated in this paper, the study of necrophagous insects can unlock uncharted territory and open doors to various fields. Nonetheless, there are still gaps in research that may lead to new questions and studies without conclusive answers. It's a double-edged sword for a forensic discipline, as it relies on reliability and adherence to specific criteria. Although established guidelines and standards can enhance the quality of entomological expertise, excessive regulations may impede the field's development. Judges need to acknowledge that each case possesses unique characteristics and may not yield a single definitive answer.

While forensic entomology faces challenges on its path to mainstream acceptance, it is steadily progressing in that direction. In the future, collaboration between classical forensic scientists and natural history academics, such as forensic entomological experts, may offer solutions to these challenges. It has the potential to facilitate the right questions and provide answers grounded in both forensic and scientific expertise, bridging the gap between basic research and applied science and providing realistic answers while managing expectations appropriately."

6. LIMITATIONS

(i) Estimating the time of death is heavily reliant on accurate temperature data. However, local weather patterns can vary depending on the distance of the measuring station from the crime scene, potentially affecting the accuracy of temperature readings.

(ii) Forensic entomology is contingent on the presence of insects at the crime scene. Some locations, especially hot and arid areas, may lack suitable insect populations. Additionally, insect availability during winter is typically limited.
(iii) The process of decomposition is time-consuming, making forensic entomology a time-sensitive investigative tool.
(iv) Measures such as freezing, burying, or wrapping the body in plastic or similar materials can impede insect access to the corpse.

7. FUTURE PROSPECTS

Forensic entomology represents a valuable resource in the realm of forensic studies and research. Experts in this field can determine the age of insects found at crime scenes, aiding in understanding their behaviors and activities. This, in turn, helps narrow down the time frame of insect colonization and yields crucial information about an individual's time, place, and manner of death, as discussed at length above. An enhanced comprehension of the variables and error rates in these studies can enable forensic experts to offer more precise assistance to law enforcement and medical personnel tasked with crime scene investigations, ultimately refining the investigative procedures. This field has come a long way since its inception, and its future prospects are promising and multifaceted. As technology and scientific advancements continue to evolve, forensic entomology is poised to make even greater contributions to the field of forensic science and criminal investigations.

One of the key areas where forensic entomology is likely to see significant progress is in the development of analytical techniques. With the continuous improvement of DNA analysis methods, entomologists can extract and analyze genetic material from insects found at crime scenes with greater precision and speed. This allows for more accurate species identification and the establishment of insect timelines with higher confidence.

In addition to DNA analysis, other technologies, such as high-resolution imaging and spectroscopy, are becoming more accessible and advanced. These tools enable entomologists to capture detailed images and spectral data from insects, their life stages, and their habitats, which can offer critical insights into the circumstances surrounding a crime. The future of forensic entomology lies in its ability to collaborate with other forensic disciplines. Integrating entomological evidence with traditional forensic techniques like fingerprint analysis, ballistics, or toxicology can provide a more comprehensive picture of a crime scene. This interdisciplinary approach is likely to be increasingly adopted, leading to more accurate and holistic crime scene reconstructions.

Climate change is altering insect behavior and distribution patterns. Forensic entomologists will need to adapt to these changes, as different insect species may colonize cadavers in new regions or at different times. Understanding these shifts is crucial for accurate post-mortem interval estimations. Moreover, it may be necessary to develop new databases and models that account for the effects of climate change on insect behavior.

The future of forensic entomology also hinges on the training and education of forensic entomologists. This includes the development of comprehensive curricula and training programs, as well as the establishment of certification standards. Well-trained forensic entomologists will be better equipped to provide expert testimony in court and to contribute effectively to criminal investigations.

As forensic entomology continues to play a crucial role in the criminal justice system, ethical and legal considerations will become more pronounced. Questions regarding privacy, the use of insect evidence, and the admissibility of entomological findings in court will need to be addressed. Developing clear guidelines and regulations in this regard will be vital for the future of the field.

Ongoing research in the field of forensic entomology is essential to advance its capabilities. Researchers are continuously exploring new ways to improve the accuracy of post-mortem interval estimation, refine species identification methods, and uncover novel applications of entomological evidence in forensic investigations. The integration of cutting-edge technologies, such as artificial intelligence and machine learning, into entomological research may open up new avenues for analysis and interpretation.

In conclusion, the future prospects of forensic entomology are bright and promising. With the continuous evolution of analytical techniques,

interdisciplinary collaboration, adaptation to climate change, improved training and education, ethical and legal considerations, and ongoing research and development, forensic entomology is set to make even greater contributions to the field of forensic science. This fascinating discipline will continue to aid in solving crimes, providing valuable evidence, and ensuring justice is served. As the science of forensic entomology continues to evolve, its potential to revolutionize the field of forensic science is indeed a compelling prospect.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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