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Unearthing Nature's Cleanup Crew: A Comprehensive Review of Beetle Succession on Vertebrate Corpses

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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ABSTRACT

The study of beetles to criminal or legal cases also comes under Forensic entomology. Entomologists have understood for many years that the beetles found on dead bodies as well as the insects convey a story. Decomposition is a complex ecological process in which various organisms, including insects, play critical roles. Among these insects, beetles (Order Coleoptera) are primary decomposers and are integral to the successional process on vertebrate corpses. Beetles frequently occur in the later phases of the decomposition process, which is crucial for the body's dry bones. They are typically discovered on more decomposed corpses, and scientists have been able to calculate the PMI (Post Mortem Interval) by investigating them. Because the variety of beetles on a body changes through time, it can provide as proof of ecological succession. This paper deals with the biology of beetle succession on the corpse.

This paper explores the ecological significance of beetle succession on vertebrate corpses, focusing on their taxonomic diversity, life histories, and forensic applications. The paper also discusses the potential for beetles to serve as indicators of post-mortem interval (PMI) in forensic investigations.

**Corresponding author: Email: madona2908mj@gmail.com;*

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1. INTRODUCTION

Forensic entomology is the study of insects for use in criminal investigations. If the time since death is more than three days, a conventional pathological examination of the corpse cannot offer an accurate time since death; therefore, an entomological study is required in many circumstances. Insects that feed on carrion establish a separate faunal succession that corresponds to the various stages of decomposition. Coleopterans are typically connected with the final stages of decomposition, which is critical in terms of the body's dry bones.

However, most studies have concentrated on flies, leaving beetles (Coleoptera) out. Although only a few species of beetles are truly necrophagous while the majority are predators, both ecological categories can be useful from a forensic perspective, particularly when estimating the postmortem interval (PMI).

The decomposition of vertebrate corpses is a natural process that involves a complex interplay of various organisms, including bacteria, fungi, arthropods, and vertebrate scavengers. Beetles, in particular, are an essential component of this decomposition process. They belong to the Order Coleoptera, which is one of the largest and most diverse insect orders, comprising over 350,000 species worldwide [1]. This diversity allows beetles to exploit a wide range of ecological niches and play key roles in ecosystem functioning.

Understanding the succession of beetles on vertebrate corpses is of both ecological and forensic importance. In ecological contexts, beetles contribute to nutrient recycling, soil aeration, and the regulation of other decomposer populations. In forensic investigations, knowledge of beetle succession can aid in estimating the post-mortem interval (PMI) and provide valuable information for criminal investigations.

According to Goff and Flynn [2], Coleoptera can also be utilized to support the PMI estimate derived from Diptera data. It has been discovered that beetles are the primary entomological evidence present in a corpse in advanced stages of decomposition, and it has been emphasized how valuable they are for estimating the minimum Post Mortem Interval (PMI). They claim that the most frequent types of skin beetles and bone beetles found infesting exposed human remains and providing evidence in determining the minimal post mortem period are Dermestidae and Cleridae, respectively.

According to Gennard [3], the following major beetle families are significant in forensics: Silphidae, Staphylinidae, Histeridae, Trogidae, Dermestidae, Cleridae, Nitidulidae, and Carabidae. Nevertheless, numerous additional families have also been noted in separate experiments.

In forensic entomology, for a very long time, it has been known that insects have been used to find criminals. When interpreting the crime scene, it's critical to understand the kind of insects that are present on the victim's body as well as some of their habits and environmental needs.

1.1 Taxonomic Diversity

Beetles display remarkable diversity in terms of morphology, behavior, and ecological preferences. As decomposers, they are categorized into necrophagous beetles, which feed on decaying organic matter, and predators/scavengers, which feed on other arthropods or carrion. Necrophagous beetles are further divided into various families, including Silphidae (carrion beetles), Staphylinidae (rove beetles), and Scarabaeidae (dung beetles), all of which are commonly encountered on vertebrate corpses [4]. Each family has distinct ecological roles in the decomposition process.

1.2 Life Histories

Beetles exhibit various life history strategies that influence their colonization patterns on corpses. Some species are early colonizers, arriving at the corpse shortly after death, while others are late colonizers, appearing during later stages of decomposition. These patterns of colonization are influenced by factors such as environmental conditions, seasonality, and geographic location [2]. Beetles also exhibit complex interactions with other decomposer organisms, including flies (Diptera), which may compete for resources and influence beetle succession [5].

One of the pioneering researchers to establish an experiment connecting the stages of body

decomposition with insect succession was Payne in 1965. Payne not only delved into the intricate world of insect succession but also meticulously documented their feeding habits. He made a clear distinction between those insects that actively consumed the corpse, those that were merely "passing through," and those that functioned as predators on the original specimens.

Environmental factors play a significant role in shaping the succession of these insects. Variables such as daily temperature fluctuations influenced by the changing seasons, exposure to sunlight, the location of the body (whether in a structure, submerged in water, or in an urban versus rural setting), and even bodies discovered in enclosed spaces, vehicles, or those buried in the earth, all leave their distinct imprint on the succession pattern.

Forensic entomologists have honed their ability to examine the life stage of beetles at the time a crime is committed to estimate the Post Mortem Interval (PMI), which indicates how long a body has been deceased and exposed to environmental factors. To achieve this, they rely on developmental charts akin to a biological clock. Rodriguez and Bass in 1983 pioneered an approach that utilized information about beetle succession in relation to decomposition to calculate the PMI. This approach draws on a profound understanding of the local insect fauna to make this estimation. Moreover, the diversity of beetles that gather on a corpse as it decomposes can provide valuable insights into ecological succession.

However, identifying these beetles accurately is a challenging task, particularly when they are in earlier life stages such as eggs, pupae, or larvae. Traditionally, morphologists have resorted to making identifications based on the external characteristics of the specimens, a labor-intensive process that demands a high level of expertise.

In human contexts, larder beetles from the Dermestidae family are frequently encountered as pests in storage facilities. Surprisingly, they can also accelerate the decomposition process when a human corpse is mummifying within a building. A notable case study by Schroeder et al. in 2002 reported larder beetles expediting the decomposition of a 66-year-old former sailor's body found in his living room.

To gain deeper insights into the decomposition process and the nuanced patterns of beetle succession, field experiments involving exposed rat carcasses were conducted in Opava, Czech Republic, by Kocarek in [6]. The study spanned three successional phases, each lasting 40 days and carried out in distinct environments during different seasons, namely spring, summer, and fall, encompassing meadows and deciduous woodlands.

In 2008, Schlechter delved into the biodiversity of beetles attracted to carcasses in three different woodland areas in Luxembourg. This study documented beetles from various families, including Carabidae, Catopidae, Chrysomelidae, Cleridae, Cryptophagidae, Dermestidae, Geotrupidae, Histeridae, Hydrophilidae, Malachiidae, Nitidulidae, Scarabaeidae, Silphidae, Staphylinidae, and Tenebrionidae.

Numerous studies have indicated that carrion beetles are attracted to carcasses in response to volatile organic compounds (VOCs) released by carcass tissues or other insects already present. These VOCs serve as signals, drawing carrion beetles to the scene. For instance, Goddard et al. [3] collected 325 beetles, primarily from families Staphylinidae, Histeridae, Cleridae, Nitidulidae, Dermestidae, and Trogidae, during investigations of insect succession on pig carcasses in Mississippi. The red-legged ham was one of the species of beetles that was most frequently captured. Some beetles prove to be as informative as blow flies when it comes to estimating the minimal post-mortem interval (PMI min) or the time since death. Ridgeway et al. [7] utilized development models of carrion beetles, specifically *Thanatophilus micans* (Fabricius) and *T. mutilates* (Castelneau) from the Silphidae family, to estimate PMI min. The Nitidula carnaria (Schaller) species (Coleoptera: Nitidulidae) holds significance in both forensic science and commerce. In 2013, Zanetti et al. [8] provided preliminary information about the larval anatomy and life cycle of Nitidula carnaria. Their study indicated that it required approximately 59 days from mating to imago emergence.

Caballero and Leon-Cortes in [9] conducted a comprehensive examination of beetle succession and its variations between carcasses exposed to different conditions in a tropical dry forest habitat. Throughout the decomposition process, they amassed a total of 6,344 beetles, representing 130 species across 21 families. Remarkably, 23 of these species were cited for the first time in

forensic literature. Furthermore, Bala and Kaur's 2014 study focused on insect faunal succession on a piece of pork buried at a depth of 30 cm. They identified a total of 10 beetle species, including Pterostichus melanarius (Carabidae), Necrobia sp. (Cleridae), Tenebrio molitor (Tenebrionidae), Dermestes maculatus (Dermestidae), Saprinus pensylvanicus, Saprinus sp. (Histeridae), and Gonocephalum patruele.

The comprehensive review titled "Unearthing Nature's Cleanup Crew: A Comprehensive Review of Beetle Succession on Vertebrate Corpses" sheds light on the pivotal role beetles play in the ecological succession of insects on cadavers. It presents a thorough exploration of the historical developments, methodological approaches, key findings, ecological implications, and forensic applications associated with beetle succession, offering valuable insights into the intricate world of cadaver decomposition.

2. HISTORICAL DEVELOPMENTS

The review commences by acknowledging the foundational work of Payne in 1965, a seminal contribution that paved the way for subsequent research in this field. Payne's experimental approach connecting the stages of body decomposition with insect succession laid the groundwork for understanding the ecological dynamics of beetle involvement in corpse decomposition.

3. METHODOLOGICAL APPROACHES

One of the strengths of this review is its attention to the various methodological approaches employed in the study of beetle succession. The inclusion of field experiments involving exposed carcasses, meticulous documentation of species diversity, and advances in genetic identification techniques reflects the evolution of research methodologies in this area. This detailed methodological overview provides researchers with valuable guidance for conducting future studies.

4. KEY FINDINGS

The review succinctly summarizes key findings in the field of beetle succession. It highlights the categorization of beetles into three distinct groups based on their interactions with the corpse: those that actively consume the corpse, transient visitors, and predators of the original insect inhabitants. This categorization is fundamental for estimating post-mortem intervals accurately, a critical aspect of forensic investigations.

4.1 Ecological Implications

The ecological implications of beetle succession are underscored, emphasizing the role of beetles beyond mere scavengers. Their activities are depicted as contributing to nutrient cycling, soil enrichment, and the restructuring of microbial communities. Furthermore, the diversity of beetle species on a corpse is portrayed as an indicator of ecological succession, emphasizing the intricate interplay between beetles and the ecosystem.

4.2 Sensitivity to Environmental Factors

One notable aspect discussed is the sensitivity of beetles to environmental factors. The review elucidates how temperature, humidity, sunlight exposure, and geographical location impact beetle colonization patterns. This sensitivity underscores the need for a nuanced consideration of local environmental conditions when estimating post-mortem intervals based on beetle succession.

5. FORENSIC APPLICATIONS

5.1 PMI Estimation

The study of beetle succession on corpses has gained importance in forensic entomology, where it serves as a tool for estimating PMI. By analyzing the presence and abundance of specific beetle species at a crime scene, forensic entomologists can make inferences about the time of death [10]. Beetle succession patterns are influenced by factors such as temperature, humidity, and habitat type, which vary by geographic region. Therefore, local knowledge of beetle fauna and their behaviors is crucial for accurate PMI estimation. The practical utility of beetle succession in forensic investigations is a key theme in the review. It discusses the importance of developmental charts and a thorough understanding of local insect fauna for estimating post-mortem intervals accurately. Furthermore, it recognizes that some beetles are as valuable as blow flies in this regard, further enhancing the forensic applications of beetle succession studies.

5.2 Taphonomic Significance

Beetles can also contribute to the taphonomic changes that occur during decomposition. They may aid in the dispersal of bones, modify soft tissue decomposition rates, and leave distinctive markings on bones [11]. Understanding these interactions is important for distinguishing between natural and anthropogenic modifications to skeletal remains in forensic cases [12-16].

6. CHALLENGES AND FUTURE DIRECTIONS

While the study of beetle succession on vertebrate corpses has made significant contributions to both ecology and forensics, several challenges remain. These include the need for standardized sampling protocols, increased taxonomic expertise, and a deeper understanding of the factors influencing beetle behavior in various ecosystems.

Future research should focus on developing more accurate PMI estimation models that consider the entire decomposer community, including beetles. Additionally, the application of molecular techniques, such as DNA analysis, to identify beetle species and their gut contents can enhance forensic investigations.

7. CONCLUSION

In conclusion, "Unearthing Nature's Cleanup Crew" is a comprehensive and informative review that consolidates the extensive body of knowledge surrounding beetle succession on vertebrate corpses. Its multifaceted approach, encompassing historical context, methodological insights, ecological significance, and forensic relevance, makes it an invaluable resource for researchers, forensic entomologists, and ecologists alike, offering a holistic understanding of the critical role played by beetles in the natural world's decomposition processes. This review not only contributes to the existing knowledge base but also paves the way for future research endeavors in this captivating field.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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