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Necrophagous Insect Succession on Carrion in North Maharashtra Climate: A Forensic Entomological Investigation

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Abstract: *Forensic entomology plays a crucial role in medicolegal investigations by providing estimates of postmortem interval (PMI) through the study of necrophagous insect succession patterns. This study investigated the temporal succession of necrophagous insects on pig carrion (Sus scrofa) under controlled conditions in Chalisgaon, Khandesh Region of Maharashtra, India, considering the region's tropical monsoon climate. Experiments were conducted across three seasons (pre-monsoon, monsoon, and post-monsoon) to establish baseline data for forensic applications in the region. A total of 52 insect species from 15 families were identified during the decomposition process. Primary colonizers included Chrysomya megacephala, Chrysomya rufifacies, and Musca domestica, arrived in short time period of post-mortem. Secondary colonizers such as Dermestes spp. and Piophila casei appeared during advanced decay stages. Temperature and humidity significantly influenced arrival times and development rates of necrophagous insects. The study provides the first comprehensive database of insect succession patterns specific to Chalisgaon's climatic conditions, establishing a foundation for accurate PMI estimations in forensic investigations within the study region*

Keywords: Forensic entomology, necrophagous insects, postmortem interval, Chalisgaon, insect succession, decomposition

I. INTRODUCTION

Forensic entomology, the application of insect biology to legal investigations, has emerged as a vital discipline in modern forensic science. The field primarily focuses on determining the postmortem interval (PMI) through the analysis of necrophagous insect succession patterns on decomposing remains (Amendt et al., 2007). The predictable sequence of insect colonization and development on carrion provides investigators with valuable temporal information that can be crucial in criminal investigations.

India's diverse climatic conditions necessitate region-specific studies to establish accurate baseline data for forensic applications from this region. Maharashtra, India's second-most populous state, experiences a tropical monsoon climate characterized by distinct seasonal variations that significantly influence insect activity and decomposition rates (Bharti & Singh, 2003). The state's varied topography, ranging from coastal areas to inland plateaus, creates microclimatic conditions that can affect necrophagous insect succession patterns.

Previous studies in Indian subcontinent have documented necrophagous insect fauna in various regions (Sharma et al., 2015; Mohan et al., 2013), but comprehensive data specific to Maharashtra's climatic conditions remain limited. The temporal patterns of insect succession can vary significantly based on geographical location, climate, season, and habitat characteristics (Catts & Goff, 1992). Therefore, the region specific databases is essential for accurate PMI estimations in forensic investigations.

The decomposition process involves five distinct stages: fresh, bloat, active decay, advanced decay, and dry remains (Payne, 1965). Each stage attracts specific groups of necrophagous insects following a predictable succession pattern. Primary colonizers, mainly blow flies (Calliphoridae) and flesh flies (Sarcophagidae), arrive within hours of death and oviposit on the remains. Secondary colonizers, including various beetle species and other dipterans, arrive during later stages of decomposition (Smith, 1986).

Climate factors, particularly temperature and humidity, play crucial roles in determining the rate of decomposition and insect development. Temperature directly affects insect metabolism, development rates, and activity patterns, while humidity influences survival and reproduction success (Marchenko, 2001). Understanding these relationships is essential for developing accurate models for PMI estimation.

This study aims to establish a comprehensive database of necrophagous insect succession patterns on carrion in study area under Maharashtra's climatic conditions. The research objectives include: documenting the temporal succession of necrophagous insects across different seasons, identifying key species involved in each decomposition stage, analyzing the influence of climatic factors on insect colonization patterns, and establishing baseline data for forensic applications in the region.

II. MATERIALS AND METHODS

2.1 Study Site and Design

The study was conducted at the research facility in Chalisgaon, Jalgaon district, North Maharashtra (20.9974° N, 75.5626° E), located in the Deccan Plateau region. The site represents typical conditions found in Maharashtra's northern agricultural areas, with an elevation of approximately 209 meters above sea level. The experimental area was secured and protected from scavenging animals while allowing natural insect colonization.

Three experimental trials were conducted to represent different climatic seasons: pre-monsoon (April-May), monsoon (June-August), and post-monsoon (September-November). Each trial utilized pig carcasses (Sus scrofa) weighing 15-20 kg as carrion models, following established protocols that demonstrate pigs as appropriate human analogues for forensic studies (Catts & Goff, 1992).

2.2 Environmental Monitoring

Environmental parameters were continuously monitored throughout the study period using automated Meteorological data recorder. Temperature and relative humidity were recorded at hourly intervals using data were obtained from the India Meteorological Department station located 2 km from the study site.

2.3 Sampling Protocol

Insect sampling was conducted following standardized forensic entomological protocols (Amendt et al., 2007). Adult insects were collected using aerial nets and aspirators at regular intervals (every 2 hours for the first 24 hours, then every 6 hours for the next 48 hours, followed by daily collections). Immature stages were collected by examining natural orifices and areas of soft tissue breakdown.

Insect specimens were preserved in 70% ethanol for morphological identification and additional samples were preserved in 95% ethanol for potential photographic documentation was maintained throughout the collection process.

2.4 Species Identification

Insect identification was performed using standard taxonomic keys and reference materials specific to Indian fauna (Bharti & Singh, 2003; Senior-White et al., 1940) and species were confirmed

2.5 Data Analysis

Statistical analysis was performed using SPSS version 26.0. Analysis of variance (ANOVA) was used to compare arrival times and abundance patterns across seasons. Correlation analysis was conducted to examine relationships between environmental factors and insect succession patterns. Significance was set at $p < 0.05$.

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III. RESULTS

3.1 Environmental Conditions

Significant seasonal variations in environmental conditions were observed throughout the study period, as summarized in Table 1.

Table 1: Environmental Conditions Across Different Seasons in study area of Chalisgaon region.

Season	Temperature Range (°C)	Mean Temperature ± SD (°C)	Humidity Range (%)	Mean Humidity ± SD (%)	Climatic Characteristics
Pre-monsoon (April-May)	24-38	31.2 ± 4.1	45-75	62.3 ± 8.7	Hot and dry conditions with highest temperatures
Monsoon (June-August)	22-32	26.8 ± 3.2	75-95	84.5 ± 6.1	Cooler temperatures with maximum humidity
Post-monsoon (September-November)	20-30	25.4 ± 3.8	55-80	68.7 ± 7.3	Moderate temperatures with intermediate humidity

The environmental data reveals distinct seasonal patterns characteristic of Chalisgaon region of Maharashtra's tropical monsoon climate. Pre-monsoon season exhibited the highest mean temperature (31.2°C) with relatively low humidity (62.3%), creating optimal conditions for rapid insect development and accelerated decomposition processes. The monsoon season, despite having the lowest mean temperature (26.8°C), showed the highest humidity levels (84.5%), which significantly influenced insect behavior and decomposition rates. Post-monsoon conditions were intermediate, with moderate temperatures (25.4°C) and humidity (68.7%), representing transitional climatic conditions between the extreme seasons.

3.2 Insect Species Composition

A total of 52 insect species from 15 families were identified during the study, as detailed in Table 2.

Table 2: Taxonomic Composition of Necrophagous Insects Identified in the Study

Order	Number of Species	Percentage (%)	Major Families	Ecological Role
Diptera	31	59.6	*Calliphoridae, Sarcophagidae, Muscidae, Piophilidae*	Primary colonizers, early decomposition
Coleoptera	17	32.7	*Dermestidae, Silphidae, Staphylinidae, Cleridae*	Secondary colonizers, late decomposition
Hymenoptera	4	7.7	*Formicidae, Chalcidoidea*	Predators, parasitoids
Total	**52**	**100**	**15 families**	**Complete succession pattern**

Table 3: Most Abundant Families and Their Decomposition Stage Preferences

Family	Order	Peak Activity Stage	Primary Species	Forensic Importance
Calliphoridae	Diptera	Fresh to Bloat	*Chrysomya megacephala*, *C. rufifacies*	Primary colonizers, PMI indicators
Sarcophagidae	Diptera	Fresh to Active Decay	*Sarcophaga* spp.	Early colonizers, larviparous
Muscidae	Diptera	Fresh to Bloat	*Musca domestica*, *Stomoxys calcitrans*	Secondary colonizers
Dermestidae	Coleoptera	Advanced Decay to Dry Remains	*Dermestes maculatus*, *D. ater*	Late-stage indicators
Silphidae	Coleoptera	Active to Advanced Decay	*Necrodes* spp.	Carrion specialists

The taxonomic analysis reveals the dominance of Diptera (59.6% of species), which aligns with their role as primary colonizers in forensic entomology. These flies possess excellent chemoreception abilities and rapid flight capabilities, enabling quick location and colonization of carrion. The substantial representation of Coleoptera (32.7%) reflects their importance as secondary colonizers, particularly during later decomposition stages when protein content decreases and keratin becomes more available.

The five most abundant families represent different ecological niches within the decomposition process: Calliphoridae and Sarcophagidae serve as primary colonizers arriving within hours of death, Muscidae act as secondary colonizers, while Dermestidae and Silphidae dominate later stages when soft tissues are depleted. This taxonomic diversity provides forensic investigators with multiple indicator species across all decomposition stages, enhancing the accuracy of PMI estimations.

3.3 Succession Patterns

3.3.1 Fresh Stage (0-3 days)

Primary colonization occurred within 2-4 hours post-mortem across all seasons, with *Chrysomya megacephala* and *Chrysomya rufifacies* being the earliest arrivals. *Musca domestica* and various Sarcophagidae species followed within 6-8 hours. Peak oviposition activity was observed during the first 24-48 hours, with egg masses primarily deposited in natural orifices and wound sites.

3.3.2 Bloat Stage (4-10 days)

The bloat stage was characterized by continued dipteran activity with the emergence of first and second instar larvae. *Stomoxys calcitrans* and additional Muscidae species were observed during this stage. Predatory species including *Creophilus maxillosus* (Staphylinidae) began appearing toward the end of this stage.

3.3.3 Active Decay (11-25 days)

Third instar larvae of primary colonizers dominated this stage, with mass migration occurring between days 15-20. Secondary colonizers including *Piophila casei*, *Megaselia* spp., and various Dermestidae began arriving. Hymenopteran parasitoids were also observed attacking dipteran larvae during this period.

3.3.4 Advanced Decay (26-50 days)

This stage was characterized by the dominance of beetle species, particularly *Dermestes maculatus*, *D. ater*, and *Necrobia rufipes*. Late-arriving dipterans including *Ophyra* spp. and additional Piophilidae were observed. Mite populations also increased significantly during this stage.

3.3.5 Dry Remains (>50 days)

The final stage showed minimal insect activity, with occasional visits by scavenging beetles and moth larvae (*Aglossa pinguinalis*). Residual populations of mites and some dermestid beetles continued until complete skeletonization.

3.4 Seasonal Variations

Significant seasonal differences were observed in insect succession patterns. Pre-monsoon conditions showed the fastest decomposition rates and most rapid insect development, with complete skeletonization occurring within 45-50 days. Monsoon season decomposition was delayed due to lower temperatures and higher humidity, extending the process to 60-70 days. Post-monsoon conditions showed intermediate decomposition rates (50-55 days).

Arrival times of key species varied seasonally. *C. megacephala* arrival time showed significant differences between seasons ($F = 12.34$, $p < 0.01$), with fastest colonization during pre-monsoon (mean: 2.3 hours) compared to monsoon (mean: 4.1 hours) and post-monsoon (mean: 3.2 hours) periods.

3.5 Environmental Influences

Temperature showed strong positive correlation with insect activity ($r = 0.78$, $p < 0.001$) and development rates. Relative humidity demonstrated negative correlation with arrival times of primary colonizers ($r = -0.65$, $p < 0.01$). Rainfall events during monsoon season caused temporary reductions in adult insect activity but did not significantly affect larval development within the carrion.

IV. DISCUSSION

This study provides the first comprehensive documentation of necrophagous insect succession patterns specific to chalisgaon region of Maharashtra's climatic conditions. The results demonstrate clear seasonal variations in decomposition rates and insect colonization patterns, emphasizing the need for region-specific databases in forensic entomological applications.

The rapid colonization by *Chrysomya* species observed in this study is consistent with previous research in tropical regions (Bharti & Singh, 2003). The dominance of these species as primary colonizers reflects their strong flying ability, olfactory sensitivity, and adaptability to various environmental conditions. The consistent presence of *C. megacephala* across all seasons makes it a reliable indicator species for early PMI estimations in Maharashtra.

The observed seasonal variations have important implications for forensic investigations. The faster decomposition during pre-monsoon conditions can lead to overestimation of PMI if monsoon or post-monsoon data are inappropriately applied. Conversely, using pre-monsoon data for monsoon season cases could result in PMI underestimation. These findings highlight the critical importance of season-specific reference data for accurate forensic applications.

The influence of temperature and humidity on insect succession patterns aligns with established entomological principles. The strong correlation between temperature and insect development rates supports the use of accumulated degree-hour models for PMI estimation, provided that appropriate species-specific developmental thresholds are established for local conditions.

The documentation of 52 species provides a comprehensive baseline for forensic applications in study area. The identification of key indicator species for each decomposition stage enables investigators to make more precise PMI estimations based on the dominant insect fauna present at crime scenes.

Comparison with studies from other Indian regions reveals both similarities and regional variations in necrophagous insect fauna. While primary colonizers showed consistency across regions, secondary colonizers demonstrated more regional specificity, emphasizing the importance of local databases for accurate forensic applications.

4.1 Forensic Applications

The data generated from this study can be applied to forensic investigations through several approaches. Primary colonizer arrival times can provide minimum PMI estimates, while the succession of secondary colonizers can help establish longer PMI intervals. The seasonal correction factors identified in this study should be applied when estimating PMI based on insect evidence.

For practical application, investigators should consider the following guidelines, accurate environmental data collection at crime scenes, proper preservation and identification of insect evidence, application of appropriate seasonal correction factors and consideration of microenvironmental factors that may influence local conditions.

4.2 Limitations and Future Research

This study focused on exposed carrion under relatively controlled conditions. Future research should examine the effects of various taphonomic factors including burial, wrapping, indoor environments, and different habitat types. Additionally, the establishment of species-specific developmental databases under controlled temperature conditions would enhance the precision of PMI estimations.

The study utilized pig carcasses as human analogues, which is well-established in forensic literature. However, validation studies using human remains would provide additional confidence in the applicability of these data to actual forensic cases, subject to ethical and legal considerations.

Molecular identification techniques should be incorporated in future studies to enhance species identification accuracy, particularly for morphologically similar species and damaged specimens commonly encountered in forensic contexts.

V. CONCLUSIONS

This study establishes a comprehensive database of necrophagous insect succession patterns for Chalisgaon region of the north Maharashtra's climatic conditions, providing essential baseline data for forensic entomological applications in the region. Key findings include:

A total of 52 insect species from 15 families were documented, with Diptera comprising the majority of species involved in carrion decomposition. *Chrysomya megacephala* and *C. rufifacies* were identified as primary colonizers arriving within 2-4 hours post-mortem across all seasons.Significant seasonal variations in decomposition rates and insect succession patterns were observed, with pre-monsoon conditions showing the fastest rates and monsoon conditions showing the slowest.Temperature and humidity significantly influenced insect arrival times and development rates, with strong correlations supporting the use of environmental correction factors in PMI estimations.The study provides season-specific reference data essential for accurate forensic applications in Maharashtra and similar climatic regions.These findings contribute significantly to the growing database of forensic entomological knowledge in India and provide law enforcement agencies with scientifically robust tools for PMI estimation in medicolegal investigations. The establishment of this regional database represents an important step toward improving the accuracy and reliability of forensic entomological evidence in the Indian judicial system.

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