Forensic Entomology in Rural India: Using Insect Life Cycle Analysis to Estimate Post-Mortem Intervals in Unidentified Bodies

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ABSTRACT: This research paper investigates how the application of forensic entomology is used to estimate post-mortem intervals (PMI) in rural India, an area with significant geographic and climatic diversity that influences decompositional processes. The study's primary objective was to determine how environmental factors affect the colonization patterns and developmental stages of carrion-associated insects and thereby refine the accuracy of PMI estimations in forensic contexts. Employing Geographic Information System (GIS) tools, this study systematically collected and analyzed data on insect species distribution, their development stages, and the corresponding environmental conditions of various rural locales across India. Key findings indicate that temperature and humidity significantly affect insect activity, which in turn impacts PMI estimates. Additionally, the study found that larvae stages were predominant across cadavers, providing a reliable indicator for estimating early PMI stages. The implications of these findings are profound, suggesting that integrating GIS with traditional forensic entomology offers a more robust approach to PMI estimation, enhancing both the scientific rigour and reliability of forensic investigations in rural settings. This research contributes to the forensic sciences by providing a methodological framework that can be adapted to diverse environmental conditions, potentially improving legal outcomes in criminal cases.

KEYWORDS: Forensic Entomology, Post-Mortem Interval, Geographic Information Systems, Rural India, Insect Development Stages, Environmental Impact on Decomposition.

INTRODUCTION

Basically forensic entomology, a branch of forensic science, utilizes the study of insects and their arthropodal brethren on decomposing remains to estimate the post-mortem interval (PMI), a critical element in legal and criminal investigations. The accuracy of determining PMI can significantly impact the direction of criminal investigations and judicial outcomes, particularly in cases involving unidentified

bodies. This scientific discipline finds its relevance not only in urban settings but has proven increasingly vital in rural areas where forensic resources are limited and environmental factors can complicate death investigations. The roots of forensic entomology stretch back to the 13th century, but its modern application in criminal cases began to flourish in the late 20th century. The growth and development rates of insects and their successive waves on a cadaver can reveal the elapsed time since death with remarkable accuracy, providing invaluable information in cases where human witnesses may be absent or unreliable. The application of this field in rural India presents unique challenges and opportunities due to the diverse climatic conditions and varied insect fauna, which significantly influence decomposition rates Sukumar *et al.*, (2017).

The utilization of forensic entomology in rural India is essential due to several factors. Firstly, the vast and varied geographic expanse of the country provides a multitude of environments from arid deserts to tropical forests, each hosting unique entomo-fauna that can affect decomposition differently. Secondly, the socio-economic conditions in rural regions means that there are many deaths which may go unreported or unnoticed for extended periods, making traditional methods of PMI estimation less reliable. In these contexts, insects become crucial forensic indicators Aggarwal *et al.*, (2003).

In recent studies, researchers have emphasized the importance of specific insect species as indicators of PMI. For instance, *Calliphoridae* (blow flies) are among the first to colonize a body and their lifecycle stages can be used to pinpoint the time since death with a narrow margin of error. However, factors such as local climate, accessibility of the body, presence of toxins or drugs, and even the cause of death can alter the typical insect colonization and development patterns. This variability underscores the need for localized research to better understand and calibrate forensic entomology applications in rural Indian settings Sarthak *et al.*, (2016).

Moreover, the presence of pesticides or other chemicals in the rural agricultural landscapes of India can significantly affect the decomposition process and, consequently, insect development. Recent reviews have highlighted how the ingestion of toxins by insects can provide clues not only about the PMI but also about the

presence of substances that may be related to the cause of death, adding another layer of complexity and utility to forensic entomology Widyana, (2023).

Despite its potential, forensic entomology in India faces challenges such as lack of awareness, insufficient training among forensic professionals, and the absence of standardized protocols tailored to the Indian context. These challenges hinder the full utilization of this forensic tool in rural areas. To overcome these barriers, continued education and the development of region-specific insect databases are recommended. Such efforts could improve the accuracy of PMI estimations across diverse Indian rural settings and increase the credibility of forensic entomology within the legal system (Matuszewski, 2021).

In conclusion, forensic entomology plays a critical tool for the investigation of deaths in rural India, where traditional forensic methods may fall short. By developing localized knowledge bases and training forensic professionals in entomological techniques, the accuracy and reliability of PMI estimates can be significantly enhanced, thereby strengthening the forensic and legal resolution of death cases in these underserved areas.

MATERIALS AND METHOD

The methodology employed in this study aimed to systematically gather and analyze entomological data to estimate post-mortem intervals (PMIs) in rural India. This section outlines the research design, including data collection source, specific data collection parameters, and the analysis tool used.

Research Design

The study utilized a qualitative research design focusing on a systematic collection of entomological evidence from human cadavers discovered in rural areas. The primary data source was insects collected from these cadavers, with particular attention to their species, developmental stages, and the environmental conditions at the time of collection.

Data Collection

The data were collected according to the following parameters detailed in the table below:

Parameter	Description
Source of Data	sects collected from human cadavers found in rural areas of India
Collection Site	Various undisclosed rural locations in India
Insect Types	Predominantly Diptera and Coleoptera families
Data Collection Period	From January 2020 to December 2021
Environmental Data	mperature, humidity, and precipitation levels recorded at the time of insect collection
Collection Technique	Use of entomological nets, manual collection, and traps
Specimen Preservation	Specimens preserved in 70% ethanol immediately after collection

Data Analysis

The analysis of the collected data was conducted using Geographic Information System (GIS) software. GIS was employed to analyze the spatial distribution of the insect populations and correlate these distributions with environmental variables such as temperature and humidity. The software facilitated the modelling of potential PMI estimates based on the geographical and environmental factors affecting insect development stages.

The GIS analysis helped in visualizing the distribution patterns and provided insights into how different environmental conditions influence the decomposition process and insect activity, crucial for accurate PMI estimation in forensic cases.

This methodology ensures a comprehensive analysis of the entomological evidence, which is essential for providing accurate PMI estimates that are crucial in forensic investigations, particularly in the challenging and variable environments of rural India.

RESULTS AND DISCUSSION

The results of the study are presented through a series of tables, which detail the findings from the GIS analysis of insect distribution and environmental factors. Each table is followed by a comprehensive interpretation and discussion of the data.

Interpretation:

Calliphoridae was the most frequently encountered insect family, found on 30% of the cadavers. This prevalence is indicative of their rapid colonization capabilities and their utility in early PMI estimation. Sarcophagidae and Muscidae were also significantly present, suggesting varied colonization depending on the environmental conditions and state of decomposition.

Interpretation:

Most cadavers were examined under moderate to high temperature and humidity conditions, which are ideal for rapid insect colonization and growth. This suggests that PMI estimations in these conditions could be more accurate due to the increased predictability of insect life cycles.

Interpretation:

Larvae were the most commonly found development stage, indicating that most bodies were discovered within a time frame that supports active larval development. This stage provides valuable data for estimating a minimum PMI.

Interpretation:

Insect density and species vary significantly with location type, affecting PMI estimates. Forested areas showed the highest density, suggesting that such environments might support faster insect colonization due to higher moisture and protection from direct sunlight.

Interpretation:

There is a clear inverse relationship between higher temperatures coupled with higher humidity and the development time of insects. As temperatures and humidity increase, the development time decreases, suggesting faster life cycle progression and potentially shorter PMIs.

Interpretation:

This table highlights the crucial impact of environmental variables on PMI estimation. Increased temperatures generally decrease the time needed for insect development, improving PMI estimation accuracy. However, humidity and seasonal variations can introduce variability in insect activity and species presence, necessitating adjustments in PMI estimations.

The analysis using GIS tools provided a detailed understanding of how environmental factors influence insect colonization and development on cadavers. The variability in insect species, development stages, and environmental conditions across different locations in rural India requires careful consideration when estimating PMI, as these factors significantly impact the accuracy of forensic entomological assessments.

RESULT AND DISCUSSION

The analysis of entomological evidence across various rural locations in India has provided a comprehensive set of data that enriches our understanding of post-mortem interval (PMI) estimation. The results, presented in the preceding section, corroborate and extend findings from the existing literature, addressing some of the noted gaps, particularly in the context of integrating geographical and environmental data with forensic entomology.

Integration of Environmental Data

The results from Table 2 and Table 5 demonstrate a significant correlation between environmental conditions (temperature and humidity) and insect activity levels, as well as developmental stages. This finding is consistent with prior research such as that by Villet et al. (2009), which highlighted the influence of climatic conditions on the development rates of carrion-feeding insects. Our study advances this understanding by mapping these conditions using GIS, providing a spatial analysis that has been largely absent in previous studies. The integration of GIS allows for a more nuanced understanding of how specific local conditions can affect insect life cycles, thereby impacting PMI estimates.

Species Variation and Distribution

Our findings in Table 4, which detail insect density and species variation by location type, align with those of Sarthak et al. (2016), who noted the prevalence of different insect species across various environments in India. The detailed GIS analysis provides a visual representation of these variations, offering insights into species-specific colonization patterns. This contributes to filling the literature gap concerning the lack of

detailed mapping of insect species distribution in relation to forensic applications in rural settings.

Developmental Stages and PMI Estimation

The prevalence of larvae, as noted in Table 3, supports the work of Sharma et al. (2015), who also observed a dominance of larval stages on cadavers in similar climatic conditions. The rapid progression from eggs to larvae under certain temperature and humidity conditions, detailed in Table 5, enhances our understanding of developmental timelines critical for accurate PMI estimation. This finding is crucial as it supports the development of more precise developmental models for forensic use, especially in varying environmental conditions as noted in rural India.

Implications of Increased Temperature and Humidity

The inverse relationship between increased temperature and the developmental time of forensic-relevant insects, as observed in Table 6, offers critical insights into the effects of global warming and climate variability on forensic investigations. These results are in line with the predictive models suggested by Matuszewski (2021), emphasizing the need for forensic models to adapt to changing environmental conditions. By understanding these dynamics, forensic entomologists can better predict the impact of climatic trends on decomposition rates and insect colonization patterns.

The significance of these findings extends beyond the academic realm into practical applications in forensic science, particularly in rural India where environmental conditions vary greatly and resources may be limited. The use of GIS tools, as demonstrated in our study, provides a valuable methodology for enhancing the accuracy of PMI estimates in real-world forensic contexts. This approach not only helps in filling the existing literature gap by integrating spatial analysis with entomological data but also offers a replicable model for other regions experiencing similar forensic challenges.

This discussion underscores the importance of integrating environmental data with entomological studies to improve the accuracy and reliability of PMI estimates. The enhanced understanding of insect development dynamics, influenced by local environmental conditions, represents a significant advancement in the field of forensic entomology. Future research should focus on expanding the geographic scope of similar

studies and exploring the impact of other environmental factors such as precipitation and wind patterns on insect activity and decomposition processes.

CONCLUSION

The study effectively demonstrated the critical role of forensic entomology in estimating post-mortem intervals (PMIs) in rural India, incorporating the use of Geographic Information System (GIS) tools to analyze and map insect distribution and environmental factors. The research confirmed that variations in temperature and humidity significantly influence insect activity and developmental stages, which are pivotal in accurately determining PMIs. Notably, the prevalence of larvae on cadavers provided a reliable indicator of the post-mortem period, particularly when correlated with local climatic conditions.

The integration of GIS into forensic entomology represents a significant methodological advancement, offering detailed spatial analysis that adds depth to traditional entomological approaches. This study filled important gaps in the literature by mapping species distribution and providing empirical data on how environmental factors affect insect life cycles, which are crucial for PMI estimates in forensic cases.

The broader implications of this research extend beyond forensic science, touching on aspects of environmental and climate science. The findings underscore the necessity for forensic methodologies to adapt to environmental changes, including global warming, which could alter decomposition rates and insect colonization patterns. This adaptation is crucial for maintaining the accuracy of forensic investigations in the face of climatic variability. Additionally, the methods developed in this study could serve as a model for other regions with similar geographic and environmental challenges, making it a valuable reference for global forensic and ecological research.

Overall, the integration of entomological data with advanced mapping and analysis techniques as demonstrated in this study provides a more comprehensive approach to forensic investigations, particularly in resource-limited settings like rural India. This approach not only enhances the accuracy of death time estimations but also contributes to the broader field of forensic science by introducing innovative tools and methodologies.

ACKNOWLEDGEMENT

The author thank the Head of Forensic Biology department Dr. Malojirao Sarjerao Bhosale .

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Table 1: Overview of Insect Species and Their Frequency on Cadavers

Insect Family	Number of Cadavers	Percentage (%)
Calliphoridae	45	30%
Sarcophagidae	30	20%
Muscidae	25	17%
Coleopteridae	20	13%
Other	30	20%

Table 2: Environmental Conditions at Collection Sites

Temperature Range (°C)	Humidity (%)	Cadavers Examined
15-25	45-55	40
26-35	56-65	50
36-45	66-75	30

Table 3: Insect Development Stages Found on Cadavers

Development Stage	Frequency
Eggs	20
Larvae	70
Pupae	30

Table 4: GIS Analysis of Insect Population Distribution

Location Type	Insect Density (insects/m²)	Common Species
Forested	50	Calliphora vicina
Urban Fringe	30	Lucilia sericata
Agricultural	40	Chrysomya megacephala

Table 5: Correlation Between Environmental Conditions and Insect Development

Temperature (°C)	Humidity (%)	Average Development Time (days)
15-25	45-55	14
26-35	56-65	10
36-45	66-75	7

Table 6: Impact of Environmental Variables on PMI Estimation Accuracy

Variable	Impact on PMI Estimation
Increased Temperature	Decreases estimation time
Increased Humidity	Increases insect activity
Seasonal Variation	Affects species availability