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Diversity of Forensic Insects in Three West Coast Locations of The Gambia

تنوع الحشرات الجنائية في ثلاثة مواقع على الساحل الغربي لغامبيا

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Abstract

This study examined forensic insect diversity across three Gambian communities representing urbanization gradients: Brikama (urban), Gunjur (semi-urban), and Faraba (rural). Using RESCUE POP Fly Traps baited with rotten beef, dipterans were collected over 24-hour periods and identified morphologically. Seven species were documented, with Chrysomya albiceps dominating all sites. Brikama showed highest diversity (6 species; Simpson's D=0.622, Shannon H=1.162), Gunjur the lowest (D=0.213, H=0.369), and Faraba intermediate values (D=0.476, H=0.669). Similarity indices (Sørensen, Bray-Curtis) indicated moderate overlap between Brikama-Gunjur but lower Brikama-Faraba similarity. Calliphoridae was the predominant family. Results demonstrate that urbanization and habitat type significantly influence forensic insect communities, highlighting the necessity of location-specific data for accurate post-mortem interval estimation. This work provides foundational entomological data for The Gambia's forensic investigations, though broader geographical sampling is recommended to fully characterize the country's forensic insect biodiversity.

Keywords: forensic sciences, entomology, insect diversity, species richness, urbanization

المستخلص

فحصت هذه الدراسة تنوع الحشرات الجنائية عبر ثلاثة مجتمعات غامبية تمثل تدرجات التحضر: بريكاما (حضرية)، غونجور (شبه حضرية)، وفارابا (ريفية). باستخدام مصائد الذباب من نوع RESCUE POP المطعمة بلحم البقر الفاسد، تم جمع ذوات الجناحين (Dipterans) على مدى فترات 24 ساعة وتم تحديدها مورفولوجياً (شكلياً).

تم توثيق سبعة أنواع، حيث سيطرت ذبابة Chrysomya albiceps على جميع المواقع. أظهرت بريكاما أعلى تنوع (6 أنواع؛ معامل سيمبسون D = 0.622، معامل شانون H = 1.162)، بينما أظهرت غونجور أدنى تنوع (D = 0.213، H = 0.369)، وكانت فارابا ذات قيم متوسطة (D = 0.476، H = 0.669). أشارت مؤشرات التشابه (سورينسن، براي-كيرتيس) إلى تداخل متوسط بين بريكاما وغونجور، ولكن تشابهاً أقل بين بريكاما وفارابا. كانت فصيلة الذباب الأزرق (Calliphoridae) هي الفصيلة السائدة.

توضح النتائج أن التحضر ونوع الموطن يؤثران بشكل كبير على مجتمعات الحشرات الجنائية، مما يسلط الضوء على ضرورة وجود بيانات خاصة بالموقع من أجل التقدير الدقيق للفترة الزمنية بعد الوفاة. يوفر هذا العمل بيانات تأسيسية في مجال علم الحشرات للتحقيقات الجنائية في غامبيا، على الرغم من التوصية بأخذ عينات جغرافية أوسع لتوصيف التنوع البيولوجي للحشرات الجنائية في البلاد بشكل كامل.

الكلمات المفتاحية: علوم الأدلة الجنائية، علم الحشرات، تنوع الحشرات، ثراء الأنواع، التحضر

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1. Introduction

Forensically important insects offer scientifically rigorous evidence that can either corroborate or refute investigative hypotheses, playing a crucial role in legal proceedings. Among these, dipterans (true flies) represent the most extensively documented group in forensic casework globally. Current taxonomic records indicate approximately 150,000 described dipteran species across 158 families [1], making them particularly significant for forensic applications.

Forensic entomologists increasingly rely on insect evidence. Blow flies (Calliphoridae), flesh flies (Sarcophagidae), and house flies (Muscidae) typically arrive first at death scenes. These early colonizers provide crucial time-of-death estimates through their predictable development cycles [2] that served as biological clock with remarkable precision [3]. Furthermore, their geographic distribution patterns can indicate whether a body has been moved after death [4].

Later-arriving beetles - including hide beetles (Dermestidae), checkered beetles (Cleridae) and carrion beetles (Silphidae) are more relevant during advanced decomposition, providing clues about longer post-mortem intervals that the early-arriving flies cannot reveal [5].

While forensic entomology is well known for estimating time of death [6], it also plays a crucial role in toxicology. When insect larvae feed on decomposing remains, they actually absorb and concentrate any drugs or toxins present - essentially preserving a chemical record of what substances were in the body. This approach has proven valuable when traditional toxicological analyses fail due to advanced tissue decomposition.

Forensic entomology has become even more powerful thanks to new scientific breakthroughs [7]. We can now extract human DNA from insect larvae found at crime scenes - a game-changing technique that's helping identify suspects in violent cases like homicides and sexual assaults. These techniques are especially crucial in cases where other biological evidence has degraded beyond recognition.

This study investigates the species richness and abundance of forensic insects within the West Coast Region of Gambia to provide preliminary entomological data that can be used by forensic entomology investigators in forensic casework. The objectives were:

1. To determine species of forensic insects in the communities.
2. To compare the diversity of the species using various indices.
3. To identify the species with significant potential for forensic entomology investigations.
4. To initiate the establishment of a database of insects of forensic importance for Gambia.

2. Materials and Methods

2.1 Study area

The study was conducted in the West Coast Region of the Gambia (Figure.1). The Gambia is the smallest country (~11,300 km2) in Africa. It lies between latitude 13° 04' N to 13° 49' N and longitude 13° 48' W to 16° 49' W. It consists of a narrow band of land, which is about 400 km long and about 30 km wide on each side of the River Gambia. The river Gambia flows through the centre of the country, dividing the country into the north and south banks, and empties into the Atlantic Ocean [8]. The country shares borders to the north, east and south by the Republic of Senegal, and to the west by the Atlantic Ocean. The climate is Sahelian, characterized by extended dry season from November to May, and a short-wet season from June to October. Rainfall varieties from 850 mm to 1200 mm, a mean temperature of about 25 °C with temperature range

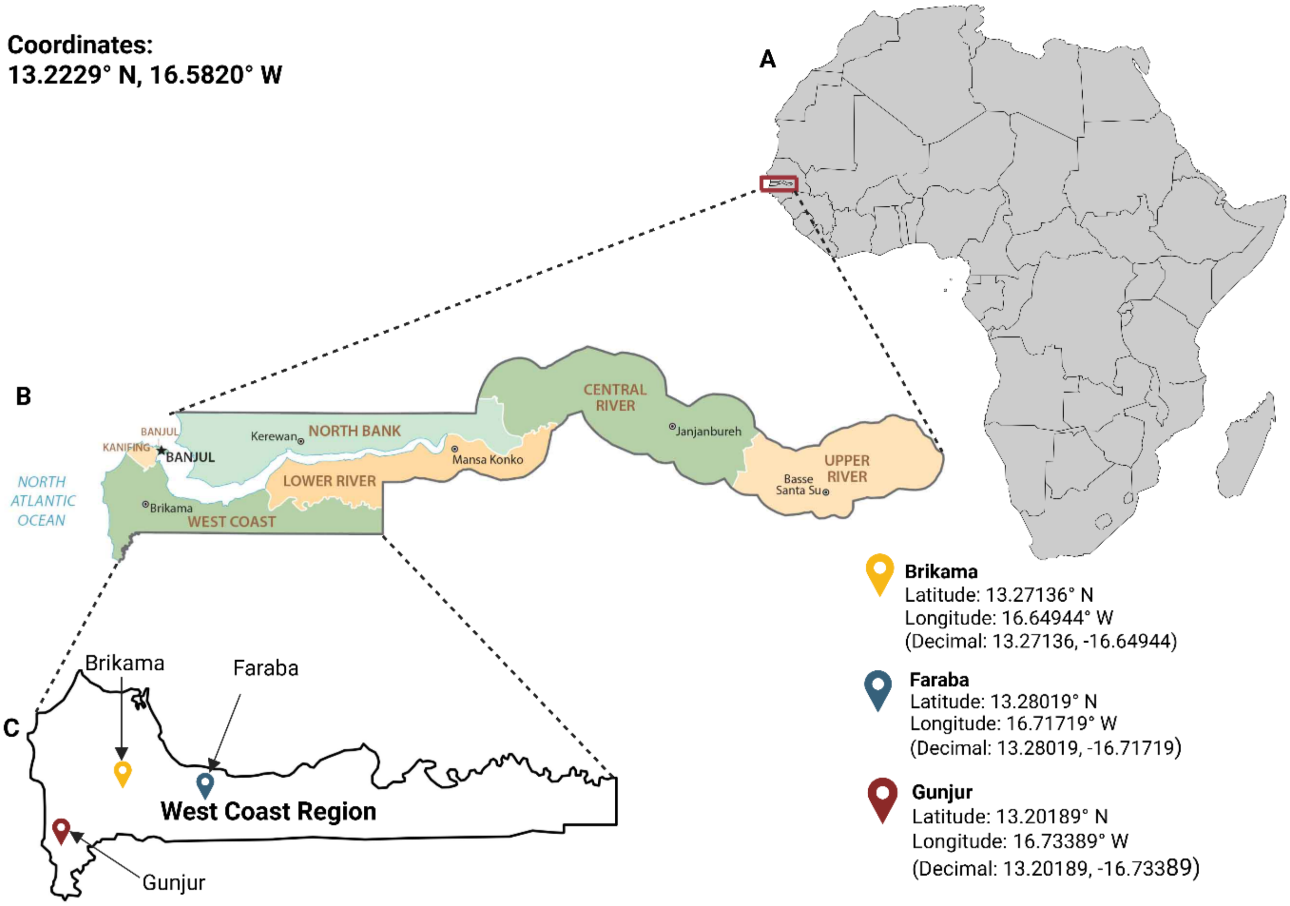

Figure 1: *Geographic location of the study area: (A) Africa with Gambia highlighted, (B) Gambia showing the West Coast Region, and (C) West Coast Region with study sites in Gambia.*

of 18 °C to 33 °C. The relative humidity in the country averaged 68% along the coastal belt, but lower (41%) during the dry season in the inland. Generally, the relative humidity of over 70% is recorded across the country during the wet season.

2.2 Study Locations

The study was carried out in three locations, namely Brikama (urban), Gunjur (semi urban) and Faraba (rural setting) (Figure.1).

2.2.1 Brikama

Brikama is located within longitude -16° 38' W: latitude 13° 16' N in Kombo central District, West Coast Region (WCR). It is the regional capital of Western Region and the headquarters of Brikama Area Council (BAC). It is approximately 35km south west of Banjul with an estimated population of 699,704 people [9] (Figure.1).

2.2.2 Gunjur

Gunjur, a key coastal community in southwestern Gambia, functions as a critical fish landing site. With geographic coordinates of 13° 20'N, -16° 73'W, it supports a population of approximately 21,000 people [9] (Figure.1).

2.2.3 Faraba

Faraba is a small village on longitude -16° 71'W and latitude 13° 28'N, approximately 10 kilometres from the main town of Brikama along the south bank road of the Gambia.

Table 1. *Species abundance of insects of forensic interest collected from three different geographical locations of Gambia*

Species	Brikama	Gunjur	Faraba
Chrysomya albiceps	71	225	53
Chrysomya regalis	0	0	34
Chrysomya chlorophyga	103	0	0
Sarcophaga exuberans	6	0	0
Helicobia spp	2	0	0
Lathyrophthalmus vicarians	3	0	0
Musca domestica	22	31	0

2.3 Trapping of adult flies and morphological identification

Two sites were identified within each location for fly sampling. On each site, two RESCUE POP Fly Trap (Sterling International, Spokeane, WA, USA) baited with rotten beef were deployed to attract and capture the adult dipterans.

Each trap was deployed for 24 hours before retrieval. The flies entrapped were taken to the laboratory, enumerated and killed using ethyl acetate before preservation in 85% ethanol. Thereafter, the flies were sorted into morpho species and sent to an insect taxonomist for identification to species level at the Insect Museum, Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria, Nigeria. All flies were identified to species level because of the need to establish a baseline record of the species in the country.

2.4 Data analysis

Data were analyzed using diversity indices and similarity indices.

2.4.1 Diversity Indices

The Alpha diversity of the insect species of the three communities were determined and compared using Simpson diversity index (1-D) [10] and Shannon index [11]. The Beta diversity that measured the differences and similarities between the three communities used Sorensen's similarity index [12] and Bray-Curtis dissimilarity index [13].

2.4.1.1 Simpson's diversity index (1-D)

$$\text{Diversity measure} = 1 - \sum ni\,(ni - 1)/N\,(N - 1) \quad (1)$$

Where:

ni is the total number of each species and N is the total number of all the species.

2.4.1.2 Shannon and Weiner index (H′) was computed from the formula:

$$H' = -3.3219 \sum ni/ N \log (ni/N) \quad (2)$$

Where:

ni is the total number of each species and N is the total number of all the species.

2.4.1.3 Sorensen's similarity index

$$SI = 2 \times |X \cap Y| / |X| + |Y| \quad (3)$$

Where:

$|X \cap Y|$ = the number of common species in communities X and Y.

X = the total species in community X

Y = the total species in community Y.

2.4.1.4 Bray-Curtis dissimilarity index

Quantify the dissimilarity in species compositions across the communities using counts for both species presence and abundance.

$$BC = 1 - 2\,C_{xy} / S_x + S_y \quad (4)$$

Where:

C_{xy} = Number of common species in both communities x and y

S_x = Total number of species in community X

S_y = Total number of species in community Y

3. Results

550 individual forensic insects, comprising 7 distinct species from 4 families (Calliphoridae,

Table 2. *Species composition of insects of forensic interest in three different locations of Gambia*

Species	Family	Subfamily	Brikama	Gunjur	Faraba
C. albiceps	Calliphorida	Chrysomyinae	+	+	+
C. regalis	Calliphorida	Chrysomyinae	-	-	+
C. chlorophyga	Calliphorida	Chrysomyinae	+	-	-
S. exuberans	Sarcophagidae	Sarcophaginae	+	-	-
Helicobia spp	Sarcophagidae	Sarcophaginae	+	-	-
L. vicarians	Syrphidae	Eristalinae	+	-	-
M. domestica	Muscidae	Muscinae	+	+	-

+ = present, - = absent

Sarcophagidae, Syrphidae, and Muscidae), were collected across three communities in the West Coast Region of Gambia: Brikama, Gunjur, and Faraba (Table1 & 2).

Species richness varied significantly among the communities. Brikama exhibited the highest species richness with 6 species. Gunjur and Faraba had considerably lower species richness, with 2 species each (Table1 & 3).

In terms of abundance, Gunjur had the highest total number of individuals collected (256), followed by Brikama (207), and then Faraba (87) (Table 3). The dominant species in terms of abundance differed across the communities. In Gunjur, *Chrysomya albiceps* was overwhelmingly dominant, accounting for 225 out of 256 individuals. In Brikama, *Chrysomya chlorophyga* was the most abundant species (103 individuals), closely followed by *C. albiceps* (71 individuals). In Faraba, *C. albiceps* was the most abundant (53 individuals), with *Chrysomya regalis* also present in significant numbers (34 individuals) (Table 1).

Table 3 compares the diversity of forensic insects across the three communities. Several key metrics were evaluated, including the total number of individuals (N), the number of species recorded, the Simpson Diversity Index (D), and the Shannon Diversity Index (H). Diversity indices illustrated differences in community structure. Brikama had the highest species richness, with 6 species and the large insect population size (207). It also had the highest Simpson (D = 0.622) and Shannon-Weiner (H= 1.162) indices, indicating a relatively balanced distribution of species. Gunjur and Faraba present a sharp contrast, despite sharing the same number of species: Gunjur, with a highest insect population (N = 256), shows the lowest diversity (D = 0.213, H = 0.369) compared to Faraba with intermediate diversity values (N = 87, D = 0.476, H = 0.669). This suggests that while both communities contain just two species, Gunjur had a much more uneven distribution of individuals among the species than in Faraba.

Species composition also varied among the sites (Table 2). *Chrysomya albiceps* was the only species found in all three communities. *Musca domestica* was present in both Brikama and Gunjur but absent in Faraba. C. regalis was exclusively found in Faraba. The remaining species (*Chrysomya chlorophyga, Sarcophaga exuberans, Helicobia* spp, and *Lathyrophthalmus vicarians*) were unique to Brikama. Similarity and dissimilarity indices revealed the degree of overlap in species composition and abundance between community pairs. Based on Sorensen's similarity index, Brikama and Gunjur shared 50% of their species (0.50), as did Gunjur

Table 3. *Diversity indices of insects of forensic interest in Gambia*

Community	N	No species	Simpson *(D)*	Shannon-Weiner *(H)*
Brikama	207	6	0.622	1.162
Gunjur	256	2	0.213	0.369
Faraba	87	2	0.476	0.669

Common species	$C_{BG} = 2$	$C_{GF} = 1$	$C_{BF} = 1$
Sorensen's similarity	$2C_{BG}/S_B + S_G$ 2 x 2/6 + 2 0.50	$2C_{GF}/S_G + S_F$ 2 x 1/2 + 2 (0.5)	$2C_{BF}/S_B + S_F$ 2 x 1/6 + 2 (0.25)
Dominant family	Calliphoridae	Calliphoridae	Calliphoridae
Bray-Curtis Dissimilarity	$1 - 2C_{BG}/S_B + S_G$ 0.598	$1 - 2C_{GF}/S_G + S_F$ (0.691)	$1 - 2C_{BF}/S_B + S_F$ (0.640)

C_{BG} = Common species between Brikama and Gunjur, C_{GF} = Common species between Gunjur and Faraba, C_{BF} = Common species between Brikama and Faraba

and Faraba (0.50). Brikama and Faraba were less similar, sharing only 25% of their species (0.25). The Bray-Curtis dissimilarity index, which considers abundance, showed that Gunjur and Faraba were the most dissimilar communities (0.691). Brikama and Faraba were also quite dissimilar (0.640). Brikama and Gunjur exhibited the lowest dissimilarity among the pairs (0.598), indicating a relatively greater similarity in species abundance patterns compared to the other pairings. All three communities were dominated by species belonging to the Calliphoridae family (Table 3).

4. Discussion

This study aimed to provide preliminary entomological data for forensic investigations in the West Coast Region of The Gambia by determining the species of forensic inse1cts present, comparing their diversity, identifying species with potential forensic importance and initiating the establishment of a relevant database.

The findings revealed a diverse assemblage of forensic insects across the sampled communities, with a total of 7 species identified from 4 families. The dominance of Calliphoridae across all sites aligns with numerous studies demonstrating the crucial role of blow flies as primary colonizers of carrion in various ecosystems globally [14].

Due to their early colonization of remains and consistent developmental cycles, these insects are particularly useful for estimating the minimum post-mortem interval (PMI_{min}) [15]. Interestingly, the observed species richness and diversity patterns deviate from conventional assumptions about urbanization's effects on biodiversity. Contrary to the general trend where urban areas typically show reduced diversity due to habitat destruction, fragmentation and pollution [16], Brikama, an urban zone, recorded the highest species richness and diversity (Simpson's D = 0.622; Shannon-Weiner H = 1.162).

However, urban environments can be complex mosaics of human-modified landscapes, including green spaces, gardens, and derelict areas, which can create diverse microhabitats supporting a range of species [17, 18]. The higher diversity in Brikama could be attributed to such habitat heterogeneity, providing more niches for different insect species compared to the potentially more uniform habitats sampled in the semi-urban (Gunjur) and rural (Faraba) sites in terms of attractiveness to these specific forensic insect species.

Gunjur (semi-urban) and Faraba (rural) both had significantly lower species richness (2 species each) compared to Brikama. While they shared the same number of species, their diversity indices differed, with Faraba (Simpson's D = 0.476, Shannon-Weiner H = 0.669) showing higher diversity than Gunjur (Simpson's D = 0.213, Shannon-Weiner H = 0.369). This difference is primarily explained by the concept of evenness, which is incorporated into diversity indices like Simpson's and Shannon-Weiner [19, 20]. In Gunjur, the community was heavily dominated by *C. albiceps,* with *M. domestica* present in much lower numbers. This uneven distribution of individuals among species resulted in a lower diversity index. In contrast, while *C. albiceps* was also the most abundant species in Faraba, *C. regalis* was present in a relatively higher proportion compared to *M. domestica* in Gunjur, leading to a more even distribution and thus higher diversity despite the same species richness. The high abundance of *C. albiceps* in Gunjur might indicate particularly favorable conditions for this species in that specific semi-urban environment, potentially related to resource availability or reduced competition from other species as previously reported [21-23].

The Sorensen's similarity index highlighted the shared species between communities. The fact that Brikama and Gunjur, and Gunjur and Faraba, shared 50% of their species composition suggests some overlap in the species that can colonize these different habitats. The lower similarity between Brikama and Faraba (0.25) is expected given Brikama's higher species richness and the presence of several species not found in Faraba. The Bray-Curtis dissimilarity index, which accounts for abundance, provided a more diverse view. The highest dissimilarity between Gunjur and Faraba (0.691) underscores the substantial differences in the relative abundance of species between these two sites, despite their similar species richness and Sorensen similarity. The lowest dissimilarity between Brikama and Gunjur (0.598), while still indicating significant differences, suggests a somewhat closer relationship in terms of species abundance patterns compared to the other pairs.

Several species identified in this study have significant potential for forensic entomology investigations in The Gambia. *Chrysomya albiceps*, present in all three communities and often abundant, is a widely recognized forensically important species with well-established developmental data in various climates [24-26]. Its ubiquitous presence makes it a strong candidate for PMI estimations across different locations in the region. *C. regalis* and *C. chlorophyga*, although found in fewer locations, are also Calliphorids and likely to be forensically relevant, potentially providing additional data points for PMI estimations, especially in specific habitats. *Musca domestica*, the common house fly, is also known to colonize carrion, particularly in later decomposition stages or in urban environments, and its presence can provide valuable information [27]. The presence of Sarcophagidae (*Sarcophaga exuberans*, Helicobia spp) is also noteworthy, as flesh flies are often early colonizers and can supplement or replace blow fly data [28].

The Syrphidae species *Lathyrophthalmus vicarians* may not play a direct role in early decomposition but could become relevant under certain conditions or during later stages. This study therefore provides a foundational step in creating a comprehensive database of forensically significant insects in The Gambia. Accurately estimating the post-mortem interval (PMI) relies on identifying key species and analyzing their distribution and abundance across urban, semi-urban, and rural habitats. Since insect development varies with local environmental factors and regional fauna [29], establishing region-specific entomological data is vital. Future research should focus on:

- Gathering detailed developmental data for these species under different environmental conditions in The Gambia,
- Expanding sampling efforts to other regions and seasons, and
- Examining colonization patterns on various types of remains.

Such efforts will enhance the reliability of forensic entomology as a tool for law enforcement in the country.

4.1 Relevance of Species Distribution in Forensic Investigations

The observed differences in species distribution across the sampled communities have important implications for forensic entomology investigations in the West Coast Region of The Gambia.

4.1.1. Significance of a Widely Distributed Species:

The variations in species distribution observed among the sampled communities carry significant weight for forensic entomology applications in The Gambia's West Coast Region.

The discovery of *Chrysomya albiceps* across all study locations (Brikama, Gunjur, and Faraba) holds particular value for forensic investigations. As a species found in all the three regions, *C. albiceps* provides investigators with a dependable biological marker for estimating minimum post-mortem intervals (PMI_{min}). This widespread distribution means forensic teams can use this species' developmental stages to estimate time since death without requiring detailed knowledge of local insect populations at each specific crime scene.

When combined with region-specific developmental data, *C. albiceps* becomes a valuable reference species for PMI calculations [30]. Its presence across diverse locations suggests considerable ecological adaptability, indicating it will likely be present at death scenes throughout the region regardless of habitat differences. This reliability could streamline initial forensic assessments and provide a consistent benchmark when comparing with other insect evidence.

4.1.2. Significance of Species with Restricted Distribution:

Conversely, the presence of species with restricted distribution to specific communities, such as *Chrysomya regalis* in Faraba and *Chrysomya chlorophyga, Sarcophaga exuberans,* Helicobia spp, and *Lathyrophthalmus vicarians* exclusively in Brikama, is equally significant, albeit in a different way. Species with restricted distributions can serve as valuable geographic indicators. If a species known to be confined to a particular habitat type or location is found on remains, it can provide clues about where the death occurred or where the body was located during the period of insect colonization, especially if the body has been moved [31]. For example, finding *C. regalis* on remains in a location outside of Faraba might suggest that the body was at some point in or near Faraba.

Furthermore, these restricted species can provide additional data points for PMI estimation, particularly if their developmental data is known. While not as broadly applicable as a ubiquitous species, they can refine PMI estimates in the specific locations where they are found. The presence or absence of these species in relation to the expected fauna for a particular location, as observed in the present study, can also raise questions and guide the investigation.

A corpse discovered in Brikama missing typical local species—such as *Chrysomya chloropyga* or flesh flies (Sarcophagidae) could mean insects colonized the remains elsewhere before relocation. While broader application requires more data, these distribution patterns offer forensic value. They not only refine PMI estimates but may also reveal whether a body was moved postmortem, a detail that could prove crucial in homicide investigations.

5. Conclusion

As the first systematic study of forensic insects in The Gambia, this work addresses a critical research gap. Our findings challenge assumptions about uniform insect distribution, showing how microhabitats affect decomposition fauna. For practical use, future work should:

- Confirm species identities with more sensitive molecular methods
- Track seasonal variations in colonization
- Test these patterns in real case scenarios

This Gambia-specific data will let forensic teams adapt European/North American entomology models to West African conditions, where climate, urban sprawl, and insect diversity differ sharply.

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Conflicts of Interest

The authors declare no conflict of interest.

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