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ORIGINAL ARTICLE

OVITRAP-BASED MONITORING AND INFESTATION ANALYSIS OF *Aedes aegypti* IN BRAZIL

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ABSTRACT

Aedes aegypti has been the primary vector of dengue transmission since the 17th century. This study aimed to analyze the infestation index of *Ae. aegypti* in the municipality of Itaquiraí, Mato Grosso do Sul, Brazil, using ovitrap-based monitoring. Weekly ovitrap collections were conducted in five urban neighborhoods from March 2015 to December 2018. Two key entomological indicators were analyzed: the Egg Density Index (EDI) and the Ovitrap Positivity Index (OPI). A total of 62,198 *Ae. aegypti* eggs were collected, with 29.7% of traps testing positive. The overall EDI was 35.2%, peaking in April (48.8%). The highest annual EDI was recorded in 2015 (55.3%). Annual OPI values were 75.9% in 2015, 24.4% in 2016, 15.4% in 2017, and 16.2% in 2018. Monthly OPI peaks occurred in April (2015), February (2016), and January (2017 and 2018). The Poisson distribution ($\lambda = 4.50$) suggested a mean of 4.5 eggs per trap per sampling period. The Negative Binomial distribution ($r = 0.36$, $p = 0.07$) indicated an aggregated dispersion pattern. The Log-Normal distribution parameters (shape = 1.32, location = 18.00, scale = 0.00) revealed that a small proportion of traps accounted for high egg densities. The study concludes that oviposition varied substantially across the monitoring period and was spatially clustered. The period of highest transmission risk occurred from January to April. Environmental and climatic factors, alongside consistent control and monitoring actions, are critical for reducing vector populations. Entomological surveillance using ovitraps, combined with community awareness campaigns, constitutes an essential strategy for guiding preventive and vector control measures.

KEY WORDS: Surveillance; insect traps; mosquitoes; arboviruses, dengue.

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INTRODUCTION

Aedes aegypti (Diptera: Culicidae) belongs to the family Culicidae, genus *Aedes*, and subgenus *Stegomyia*. It is a cosmopolitan mosquito species, established in 167 countries (Wilkerson et al., 2021). It has remained the primary vector of dengue fever from the 17th century to today (Menezes et al., 2021).

Dengue transmission occurs predominantly through vector-mediated mechanisms, whereby female *Ae. aegypti* mosquitoes acquire the virus during a blood meal from an infected host and subsequently transmit it to other individuals. Additionally, vertical or transovarial transmission can occur, whereby infected females pass the virus to part of their offspring, perpetuating viral circulation across generations (Brazil, 2024). Dengue virus, a member of the family Flaviviridae, genus *Flavivirus*, comprises four distinct serotypes: DENV-1, DENV-2, DENV-3, and DENV-4 (Lopes et al., 2014).

Brazil has experienced a substantial disease burden from dengue, with approximately 6,103 confirmed deaths and an additional 761 under investigation as of 2024 (Brazil, 2024). In the State of Mato Grosso do Sul, 32 deaths have been confirmed among 16,207 reported cases, yielding an incidence rate of 706.4 per 100,000 inhabitants. The municipality of Itaquiraí ranked seventh statewide, with a particularly alarming outbreak in 2015, reporting 32,875 cases and 15 associated deaths (Brazil, 2024).

Effective control of arboviral diseases, including dengue, chikungunya, Zika virus, and urban yellow fever, depends critically on the surveillance of *Ae. aegypti* populations. Entomological monitoring enables the timely implementation of vector control strategies and supports the development of predictive models for outbreak risk assessment (Gonçalves e Sá et al., 2019). Such models are pivotal within public health surveillance frameworks, as they facilitate the early detection of increases in vector density and guide targeted responses to avert or mitigate outbreaks (Oliveira e Cruz et al., 2024).

One of the most effective tools for monitoring mosquito populations is the ovitrap, a low-cost, high-sensitivity device designed to simulate natural oviposition sites for gravid females. These traps typically contain a wooden or paper substrate on which mosquitoes deposit their eggs, allowing for the quantification of oviposition activity and inference of local adult population density (Marques et al., 1993; Luz et al., 2003; Silva, 2019).

Systematic deployment of ovitraps has proven effective not only for detecting seasonal fluctuations in *Ae. aegypti* populations but also for assessing the effectiveness of vector control interventions in endemic areas. Spatial and temporal analyses of ovitrap data can inform robust predictive models capable of estimating arbovirus transmission risks based on entomological indices and environmental variables (Barcellos & Lowe, 2014).

Moreover, integrating ovitrap data with meteorological information, such as temperature and humidity, enhances the predictive power of these models, given that such factors directly influence mosquito development, survival, and reproductive behavior (Barreto et al., 2020). In this context, ovitraps serve as strategic tools for the formulation of public policies aimed at arbovirus prevention and control, optimizing resource allocation and improving collective health outcomes (Brazil, 2025a).

Therefore, the present study aimed to analyze *Ae. aegypti* infestation indices in the municipality of Itaquiraí, Mato Grosso do Sul, from 2015 to 2018, using ovitraps as a monitoring tool. Our findings provide critical insights to support entomological monitoring and guide control strategies in areas affected by urban arboviral transmission.

MATERIAL AND METHODS

The study focused on the urban zone of the municipality, where ovitraps were installed across five neighborhoods: Centro I, Centro II, Centro III, Primavera I, and Primavera II. In 2015, no ovitraps were installed in Centro III due to logistical constraints (Figure 1).

Study Area

This study was conducted in the municipality of Itaquiraí, located in the southern region of the State of Mato Grosso do Sul, Brazil (latitude: -23.4755; longitude: -54.1892; elevation: 340 m). The local climate is classified as humid subtropical (Cfa), with average temperatures ranging from 14 °C in the coldest months to highs exceeding 30 °C in summer. Annual precipitation typically ranges from 1,400 to 1,700 mm (Itaquirai, 2024). The municipality has an estimated population of 19,423 inhabitants and encompasses a territorial area of 2,063.717 km² (IBGE, 2024).

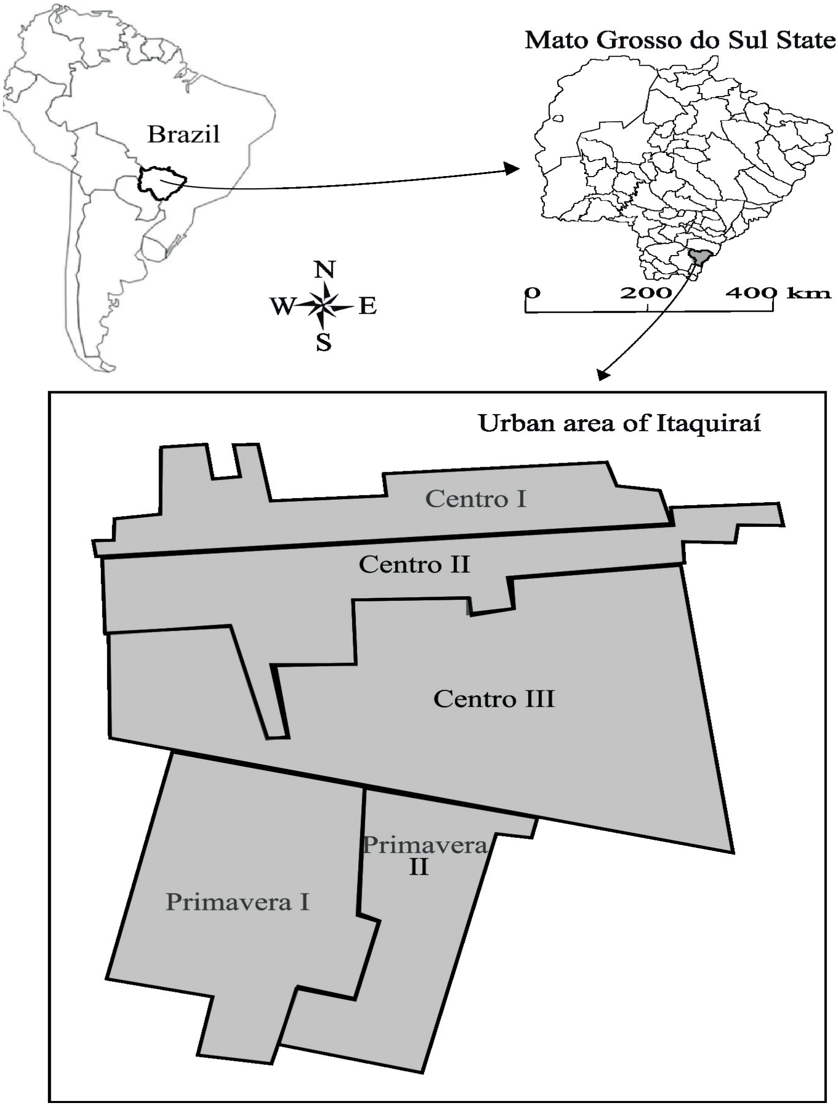


Figure 1. Urban neighborhoods of Itaquiraí, Mato Grosso do Sul, Brazil, where ovitraps were installed to collect *Aedes aegypti* eggs from March 2015 to December 2018.

Ovitrap Deployment and Egg Collection

Egg collection was performed weekly from March 2015 through December 2018. In 2015, eight ovitraps were deployed per neighborhood; in subsequent years, this number was standardized to seven traps per neighborhood. The number of ovitraps installed in December was lower than in other months due to a lack of human resources to conduct collections.

The ovitrap used is a standard, low-cost surveillance tool for monitoring populations of *Ae. aegypti* and *Ae. albopictus* in urban environments. These devices are highly sensitive and easy to handle, enabling early detection of mosquito presence, even in areas previously considered non-infested, and facilitating the evaluation of vector control interventions. Each ovitrap consisted of a black plastic container (one liter capacity) filled with 300 mL of tap water and 1 mL of brewer's yeast, used as an oviposition attractant. A rough-surfaced wooden paddle (Eucatex®) was placed inside the container as the egg-laying substrate (Figure 2). Traps were spatially distributed at intervals of 200 meters, following national guidelines and population density recommendations (Brazil, 2022).

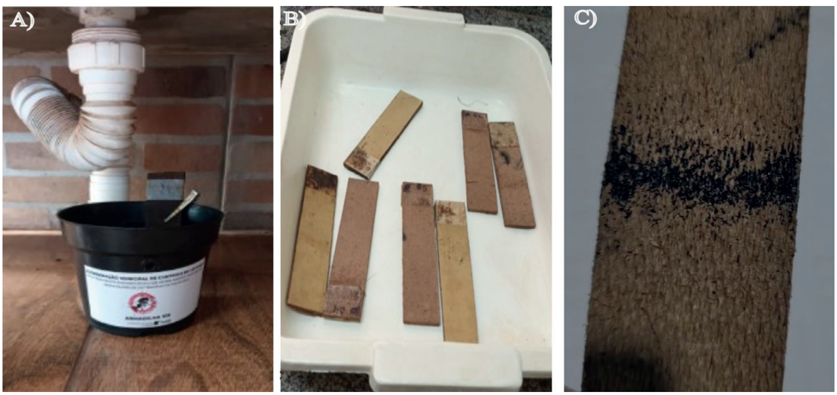


Figure 2. A) Ovitrap, B) Rough-surfaced wooden paddles (Eucatex®) used in ovitraps, C) Wooden paddle with *Aedes* eggs, used for egg collection in Itaquiraí, Mato Grosso do Sul, Brazil.

Weekly, paddles were collected and transported to the Entomology Laboratory of the Itaquiraí Municipal Health Department. In the laboratory, the paddles were left to air dry for two to three days at room temperature, without overlapping, and subsequently examined under a stereomicroscope to count the eggs. For species confirmation, the egg-laden paddles were submerged in trays containing water to allow larval hatching. The larvae were fed with cat food until reaching the third instar. At that point, they were preserved in 70% ethanol, and a portion (20%) was identified using a compound light microscope based on morphological keys (Brazil, 2022).

Data Analysis

Field data were recorded per trap and neighborhood and compiled into Excel spreadsheets. Monthly and yearly egg counts were used to calculate two primary entomological indices: 1) Ovitrap Positivity Index (OPI) = (Number of positive traps/ Total number of traps inspected) × 100; 2) Egg Density Index (EDI) = Total number of eggs/ Number of positive traps.

To evaluate the spatial distribution of *Ae. aegypti* oviposition, the egg count data were fitted to four theoretical frequency distributions considered most appropriate for ecological count data: Poisson, Negative Binomial, Binomial, and Log-Normal distributions. These models allowed inference of dispersion patterns and population aggregation across the monitored areas.

RESULTS

Egg Abundance and Annual Trends

Over the four-year monitoring period, a total of 62,198 *Aedes* eggs were collected. Only *Ae. aegypti* was identified. The highest number of eggs was recorded in 2015, with 48,382 specimens, accounting for 77.8% of the total. In subsequent years, the egg counts were markedly lower: 6,210 in 2016, 3,449 in 2017, and 4,157 in 2018 (Table 1). The media weekly egg count per year was 1,344 in 2015, 138 in 2016, 94 in 2017, and 72 in 2018. The mean number of eggs per positive paddle was 35.2.

Table 1. Number of *Aedes aegypti* eggs collected using ovitraps in five neighborhoods of Itaquiraí, Mato Grosso do Sul, Brazil, from March 2015 to December 2018.

Neighborhoods	Total eggs	Collection period (years)			
		2015	2016	2017	2018
	n (%)	n (%)	n (%)	n (%)	n (%)
Centro I	13,734 (22.1)	10,664 (17.1)	1,583 (2.6)	787 (1.3)	700 (1.1)
Centro II	14,550 (23.4)	11,329 (18.2)	1,522 (2.4)	785 (1.3)	914 (1.5)
Centro III	2,678 (4.3)	no collection	1,206 (1.9)	784 (1.3)	688 (1.1)
Primavera I	14,956 (24.0)	12,788 (20.6)	933 (1.5)	441 (0.7)	794 (1.3)
Primavera II	16,280 (26.2)	13,601 (21.9)	966 (1.5)	652 (1.0)	1,061 (1.7)
Total	62,198	48,382 (77.8)	6,210 (10.0)	3,449 (5.5)	4,157 (6.7)
Mean	12,439	9,676	1,242	689	831
Standard deviation	±5,534	±5,532	±303	±150	±157

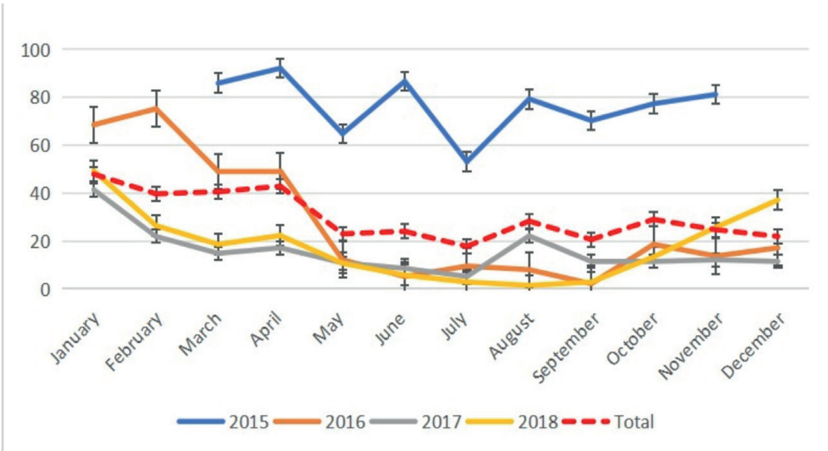
Variation in Oviposition Activity Across Neighborhoods

Egg distribution varied across neighborhoods. In Centro I, 13,734 eggs were collected (22.1% of the total), with most recorded in 2015. Centro II accounted for 14,550 eggs (23.4%), also predominantly in 2015. Primavera I yielded 14,956 eggs (24.0%), and Primavera II had the highest total, with 16,280 eggs (26.2%), again with a major concentration in 2015. Data from Centro III were available only from 2016 onward due to trap installation beginning that year.

Ovitrap Positivity Index (OPI) and Egg Density Index (EDI)

The annual Ovitrap Positivity Index (OPI) is shown in Figure 3. Of the 5,947 traps installed across all sampling points, 1,768 were positive, yielding a mean OPI of 29.7%. In 2015, the OPI was exceptionally high at 75.9%, with the highest monthly peak in April (92.2%). In 2016, the OPI dropped to 24.4%, with February showing the highest index (75.2%) and September the lowest (2.1%). A further decline occurred in 2017 (15.4% OPI), with January showing the highest positivity (41.4%) and July the lowest (5.1%). In 2018, the OPI remained low at 16.2%, peaking in January (49.3%) and reaching the lowest value in August (1.4%).

Figure 3. Ovitrap Positivity Index (OPI) (mean ± standard error) for *Aedes aegypti* in Itaquiraí, Mato Grosso do Sul, Brazil, from March 2015 to December 2018.



Weekly egg collection per month ranged from 88.33 to 718.18 eggs, indicating substantial seasonal variation in oviposition. Monthly Egg Density Index (EDI) values declined progressively over the study period: the highest annual EDI was recorded in 2015 (55.3%), followed by sharp decreases in 2016 (16.2%), 2017 (13.3%), and a slight rise in 2018 (16.6%). April exhibited the highest monthly EDI overall (48.8%), while December had the lowest (11.5%) (Table 2).

Table 2. Average monthly distribution of *Aedes aegypti* eggs collected using ovitraps in Itaquiraí, Mato Grosso do Sul, Brazil, from March 2015 to December 2018.

Month	Eggs	Traps installed	Positive traps	Weekly egg mean	OPI (%)	EDI (%)
January	3,310	315	151	367.78	47.9	21.9
February	3,169	350	139	316.90	39.7	22.8
March	11,987	653	265	630.89	40.6	45.2
April	12,209	583	250	718.18	42.9	48.8
May	3,685	583	134	216.76	23.0	27.5
June	8,035	583	140	472.65	24.0	57.4
July	2,581	615	109	143.39	17.7	23.7
August	4,577	615	174	254.28	28.3	26.3
September	3,062	548	113	191.38	20.6	27.1
October	6,075	548	159	379.69	29.0	38.2
November	3,237	449	111	249.00	24.7	29.2
December	265	105	23	88.33	21.9	11.5
Total	62,192	5,947	1,768	359.49	29.7	35.2
Mean	27.24	494.58	147.33	335.77	30.0	31.6
Standard deviation	±74.95	±162.44	±63.94	±191.26	±10.1	±12.6

Legend: OPI = Ovitrap Positivity Index = (positive traps / total traps) × 100; EDI = Eggs Density Index = (number of eggs / number of positive traps).

Statistical Modeling of Spatial Distribution Patterns

Analysis of spatial distribution patterns revealed that aggregated distribution profiles best modeled egg counts. The Poisson distribution, with $\lambda = 4.50$, indicated an average of 4.5 eggs per trap per sampling event but failed to account for the observed heterogeneity. The Negative Binomial distribution, fitted with parameters $r = 0.36$ and $p = 0.07$, captured overdispersion in the data, suggesting a strongly aggregated pattern of oviposition.

The approximated Binomial distribution ($n = 60.75$; $p = 0.07$) was used for comparison but was less representative of the empirical data. Conversely, the Log-Normal distribution provided the best fit, reflecting high variability and positive skewness in egg counts, with the majority of traps containing few eggs and a minority exhibiting disproportionately high infestations.

The estimated parameters for the Log-Normal distribution were: shape = 1.32, location = 18.00, and scale = 0.00. The positive shape parameter supports a spatial aggregation pattern, where specific breeding *foci* serve as preferred oviposition sites. This modeling outcome is consistent with the behavioral ecology of *Ae. aegypti*, where environmental and microclimatic heterogeneity influences egg-laying behavior.

DISCUSSION

Despite widespread awareness of the health risks posed by dengue in Brazil, one of the countries with the highest global burden of this disease (Menezes et al., 2021), preventive measures are often neglected by the population. Anthropogenic environmental factors, such as the improper disposal of waste, accumulation of stagnant water in containers, drains, and gutters, contribute substantially to the proliferation of mosquito breeding sites (Brazil, 2025b). The high adaptability of *Ae. aegypti* allows its development in a wide range of water conditions, including polluted environments rich in organic matter or even domestic sewage, where fermentative processes attract females for oviposition (Azevedo, 2015).

Our study, conducted in an urban setting, suggests that such conditions were likely present in at least part of the sampling areas, influencing the high oviposition rates recorded, particularly during the first year. Urbanization, migration patterns, and inadequate infrastructure also contribute to the expansion of arboviral transmission (Silva et al., 2018).

The use of ovitraps proved to be a practical and sensitive method for monitoring *Ae. aegypti* populations across a range of densities. These traps mimic natural breeding sites and attract gravid females for oviposition, making them effective both as surveillance tools and as indirect population control mechanisms (Brazil, 2022). The elevated OPI and EDI observed during the first four months of each year, frequently exceeding 40%, signal a high transmission risk during this period (Gomes, 1998). This pattern may be partly explained by the behavior of *Ae. aegypti* females, which exhibit skip-oviposition, distribute their eggs across multiple breeding sites (Barreto et al., 2020).

A clear temporal decline in egg abundance was observed following the first year of monitoring, suggesting that vector control interventions may have had a measurable impact. These findings are consistent with those of Almeida et al. (2013), who reported similar oviposition patterns throughout the year in Costa Rica and Mato Grosso do Sul. However, this decline may also reflect changes in climatic factors, as vector dynamics are strongly influenced by temperature, humidity, and rainfall (Costa et al., 2010; Viana & Ignotti, 2013).

Temperature plays a critical role in the reproductive biology of *Ae. aegypti*. Optimal development occurs between 16 °C and 34 °C, with higher temperatures accelerating blood feeding frequency (hemophagy) but potentially reducing longevity and fecundity (Azevedo, 2015; López, 2022). In our study, oviposition peaks were concentrated in March and April, months typically characterized by milder temperatures and lower thermal amplitude. Conversely, the decline in egg counts observed toward the end of each year may be associated with extreme summer temperatures exceeding 32 °C, which are common in the region.

Humidity is another key factor influencing the mosquito's reproductive success. Relative humidity levels above 70% are conducive to oviposition and larval development, and may explain the consistently high egg counts during the first quarter of each year (Meira et al., 2021). Rainfall also contributes by increasing the availability of breeding sites. Although our data suggest that rainfall likely boosted oviposition early in the year, egg collection also occurred during dry months, emphasizing the need for year-round surveillance and proactive control strategies (Almeida et al., 2013; Zara et al., 2016).

The effectiveness of vector control strategies depends on a combination of mechanical, biological, legal, chemical, and integrated measures (Matos et al., 2022). The sharp decline in OPI and EDI following 2015 may reflect the implementation of intensified control actions by municipal health authorities. Nevertheless, sustained results depend not only on reactive responses during outbreaks but also on continuous monitoring and community engagement.

Our findings highlight a clear seasonal pattern in *Ae. aegypti* oviposition, with peak activity in late summer and early autumn (January to April). These results reinforce the importance of adjusting vector control timing to coincide with the period of greatest reproductive activity and, consequently, highest transmission potential (Araújo et al., 2019).

From a spatial perspective, our study demonstrates that *Ae. aegypti* exhibits aggregated distribution patterns in urban environments. The best fit of field data to the Negative Binomial and Log-Normal distributions suggests the presence of breeding hotspots, specific locations with disproportionately high infestation levels. The aggregation parameter $r = 0.36$ supports this conclusion, as also observed in previous ecological studies (Fantinatti et al., 2007; Barbosa et al., 2019).

The Poisson distribution, which assumes randomness and spatial independence, failed to capture the variability observed, further reinforcing the non-random and clustered nature of oviposition in the study area (Kraemer et al., 2015). These results have important implications for targeted vector control, which should prioritize high-risk areas rather than relying on homogeneous coverage.

Finally, the successful adjustment of oviposition data to a Log-Normal model reflects the presence of a few traps with very high egg counts, while most traps had low to moderate counts. This long-tailed distribution is consistent with the ecology of urban *Ae. aegypti* populations, and aligns with other entomological studies that have demonstrated heterogeneous spatial distributions shaped by both environmental conditions and mosquito behavior (Monteiro et al., 2014; Naves et al., 2015).

These insights are crucial for optimizing surveillance and intervention strategies. Identifying and prioritizing high-infestation zones can enhance the effectiveness and efficiency of public health efforts, ensuring that resources are allocated where the transmission risk is highest.

This study revealed significant spatiotemporal variation in *Ae. aegypti* oviposition activity across the urban area of Itaquiraí, Mato Grosso do Sul, between 2015 and 2018. The highest infestation indices were consistently observed between January and April, highlighting this period as the critical window for arboviral transmission risk. These findings underscore the need for intensified surveillance and vector control actions during the early months of the year.

Environmental and climatic factors, particularly temperature, humidity, and rainfall, played a central role in shaping mosquito dynamics. Moreover, the observed decrease in egg counts over the study period suggests a possible positive effect of sustained public health interventions, especially following the major outbreak recorded in 2015.

Entomological surveillance using ovitraps proved to be an effective and low-cost strategy for detecting and monitoring *Ae. aegypti* populations. When combined with community awareness campaigns, this approach can guide evidence-based control measures and support early warning systems for arboviral outbreaks.

The spatial analysis revealed a clustered distribution of breeding activity, with some urban regions acting as oviposition hotspots. This pattern emphasizes the importance of targeted control strategies, prioritizing high-risk areas to maximize the impact of resource allocation and reduce transmission potential.

Altogether, the integration of entomological data with environmental and spatial analyses provides a robust foundation for improving vector control programs. Tailored and proactive public health responses, informed by continuous monitoring, are essential for mitigating the burden of dengue and other arboviral diseases in endemic regions.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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