House-Level Risk Factors for *Aedes aegypti* Infestation in the Urban Center of Castilla la Nueva, Meta State, Colombia

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*Aedes aegypti* is the main vector of the dengue virus in Colombia. Some factors have been associated with its presence; however, in the local context, it has not been sufficiently evaluated. The present study seeks to identify the socioeconomic, environmental, and behavioral factors associated with the presence and abundance of *A. aegypti* in urban dwellings in the municipality of Castilla la Nueva. A cross-sectional cohort study was conducted in houses in the urban area of the municipality of Castilla la Nueva, where 307 houses were sampled by systematic random sampling during May 2018. A multifactorial survey was used to measure the socioeconomic, environmental, and behavioral factors as explanatory variables. The infestation and relative abundance were established by the presence of larval stages and ovitraps. The associated factors for the presence and abundance of *A. aegypti* were identified using negative binomial and logistic regression models. A positive housing infestation of 33.2% was identified by direct inspection and 78.5% with ovitraps. The main factors positively associated with the presence and abundance of *A. aegypti* were one-story homes (PR = 2.26; 95% CI: 1.31–3.87), the storage of water for domestic use (PR = 1.91; 95% CI: 1.18–3.09), and local conditions such as disorganized backyard (PR = 79.95; 95% CI: 10.96–583.24) and the proportion of shade greater than 50% of the backyard (PR = 62.32; 95% CI: 6.47–600.32). And, it is negatively associated with residential gas service (PR = 0.3; 95% CI: 0.16–0.58) and self-administered internal fumigation (PR = 0.37; 95% CI: 0.2–0.69). The presence and abundance of *A. aegypti* were explained by interrelated socioeconomic, environmental, and behavioral factors where local conditions and habits such as the organization of the patio, knowledge about vector biology, and cleaning containers are identified as main topics for future prevention strategies for the transmission of dengue in the local and national context.

1. Introduction

*Aedes aegypti* is the primary vector of the dengue fever virus (DFV) in Colombia. Its adaptation to the local anthropic conditions and capabilities of transmission of other viruses such as Zika and chikungunya makes the presence and abundance of this vector a significant threat to public health [1–4]. In 2019, there were 117,339 cases of dengue fever (116,065 classic presentation cases and 1,274 severe presentation cases); the case-fatality proportion of severe dengue was 13.8% (176 deaths) [5]. Additionally, the economic and social impact of the disease has been estimated as 1,198.73 DALYs loss per million, US$225,896,097 costs of medical services and premature deaths, and an estimate of US$104,267,878 in expenses related to epidemiological control and surveillance [6].

So far, prevention strategies for the transmission of DFV have been based on socioeconomic, environmental, and cultural determinants [4, 7, 8]. Several research works have identified social marginality, lack of utilities (drinkable
water, residual disposal, and sewage) [9–11], access to health care, land use, and migratory status as the main socioeconomic factors associated with the abundance of the vector [12, 13].

Similarly, other factors such as traditional cultural dynamics, health education, and behavior have been identified as critical [14, 15]. Also, temperature, rainfall, relative humidity, and some specific conditions of the residences are environmental factors that have been associated with the vector presence. In this same dimension, maintenance, state of the patios, and proportion of shadow in the patios have been related to the distribution, abundance, breeding, and mosquito survival [16–19].

The control of vectors in Colombia is conducted following protocols designed for generalized conditions without considering the local particularities. This has hindered the effective execution of programs of vector control and dengue prevention [20–24]. Additionally, the use of the Stegomyia larval index in the regular entomological surveillance programs in Colombia is not adequate to estimate the presence of the vector or the risk of transmission of the vector-borne viral diseases [20, 22]. To overcome these problems, the use of ovitraps and their derived indices have shown higher sensitivity to determine the presence of A. aegypti [22, 25, 26]. According to these, there is a research gap on the factors that favor breeding sites and the abundance of the vectors at regional scales.

In Colombia, the lack of utilities such as water supply, sewage, residual disposal, and nonregulated urbanization have been essential factors related to the vector’s presence and dengue outbreaks [4]. However, outbreaks of dengue have occurred even in places that do not have such problems, which indicates that other factors are affecting the presence of the vector and the risk of dengue. For example, the municipality of Castilla la Nueva in the Department of Meta has a well-developed urban area with access to basic utilities and has implemented programs to prevent the disease [27]. However, the average incidence of dengue in the last ten years is 2,630 cases per 100,000 person-years (estimated with midyear population), including a peak of 7,436 cases per 100,000 person-years in 2019 [28]. That is why this study aims to identify other socioeconomic, environmental, and behavioral factors associated with the presence and abundance of A. aegypti in the municipality of Castilla la Nueva. Our findings allow the identification of parameters that can be used to improve the education, control, and surveillance programs of dengue in local communities.

2. Materials and Methods

2.1. Study Area. The study was conducted in the urban center of the municipality of Castilla la Nueva, in the Department of Meta, Colombia (3°49‘–3°50’N, 73°40‘–73°42’W). It has an estimated population of 8,787 (2018 projection), distributed as 4,337 (49.4%) in urban areas and 4,450 (50.6%) in rural areas. The urban area has 1008 residential properties in 13 neighborhoods, with approximately 60 blocks (Figure 1). The town of Castilla la Nueva has three types of housing construction: one-story house in regular neighborhoods, an apartment complex (one neighborhood), and a one-floor building with an irregular organization with some precarious housing (nonregulated constructions on public land), which are primarily located closer to the Guamal river. Some of these houses do not have access roads, and they lack at least one utility (domestic gas supply) (information available in the geportal of Instituto Colombiano Agustin Codazzi) [29]. In general, the population of Castilla la Nueva has an excellent social condition, broad coverage in utilities (aqueduct, sewerage, and electricity), as well as in education and health services for its entire population [27].

2.2. Study Design and Sampling Strategy. An observational cross-sectional study was designed and conducted. The study was developed during May 2018 in the urban area, taking households as sampling units. The month of May was selected mainly because of the beginning of the rainy season, which is theoretically related to the increase in the abundance of mosquitoes and the beginning of the peaks of dengue cases. The entomological sampling and the delivery of the multifactorial survey were designed systematically in the urban area of Castilla la Nueva. The systematic sampling was carried out according to what was established for the Stegomyia larval index in Colombia [7, 30]; the sample size was calculated using the formula for proportions in a finite set [31]. A 244-house sample was estimated. The sample size was expanded by 30% more, considering the possible losses, empty houses, or the refusal to participate voluntarily in the study, obtaining a total sample size n of 317 houses. At the first building in each block, the sampling was conducted, moving clockwise and maintaining a sampling interval every three houses (N/n), following the national guideline [7]. All the sampled houses were georeferenced. The inclusion criteria for participation were being inhabited, the person responding to the survey should be an adult (18+) and obtain the permission of the owner or tenant. A letter of consent was always presented.

Information bias was controlled with training and standardization of the interviewers, conducting a pilot test, quality control of the survey, and confidentiality of the information, and confounding biases, with binary logistic regression statistical analysis.

A multidimensional survey collected the information; the instrument was prepared in digital format for mobile phones or tablets using the Epi Info application (https://www.cdc.gov/epiinfo/mobile.html). Technicians of the Secretary of Health delivered the survey. The survey was divided into three parts: socioeconomic, environmental, and behavioral.

The following variables were measured in the socioeconomic dimension: age, gender, level of education, income, occupation, type of health insurance, rental or owned, socioeconomic status, number of bedrooms, number of inhabitants of the house, water supply, and garbage collection frequency (Table 1). The variables measured in the environmental dimension were type of residence, concrete washbasins (water tanks), water containers, and building
material for walls, floor, and roof. Additionally, maintenance of the house, organization of the patio, and the proportion of shade in the patio were recorded. These conditions are necessary to establish the local conditions index, following the methodology based on Tun-Lin et al. [17] and Manrique-Saide et al. [18] (Table 2). Finally, factors related to knowledge, attitudes, and practices regarding the vector and dengue included the reasoning and motivations for water storage and travel outside the municipality (Table 3).

2.3. Entomological Variables. The information regarding the presence of immature stages of *A. aegypti* was generated by direct inspection in potential breeding sites following the methodology established by the Pan American Health Organization and the guidelines for Colombia [7, 30]. Three entomological indicators were used: (1) positive house by the presence/absence of immature stages of *A. aegypti*, (2) positive ovitraps by the presence/absence of positive ovitraps, and (3) the number of eggs per ovitrap. A single sampling was carried out with ovitraps for a month, and eggs collected in the ovitraps were counted using a stereomicroscope at 20 times magnification.

The ovitraps were located inside the houses, mainly in the courtyard, in a shady and cool place, on the floor, or at 1.5 meters high in houses where small children or pets lived. The ovitrap was assembled with a 2-liter plastic bottle cut in half and painted black, and then a strip of white cloth was attached inside. The piece bottle is then filled up with 0.95 liters of water, and 1 gram of *Bacillus thuringiensis* var. *israelensis* (Bti) granulated was added, according to Alarcón et al. [25].

2.4. Data Analysis. Exploratory data analysis was conducted to describe the distribution and frequencies of the variables. After this, the association between independent variables and the outcomes was estimated using bivariate cross-tabulation tests (chi-squared test or Fisher’s exact test). The prevalence ratio (PR) was calculated for each variable. The

![Figure 1: Map of Castilla la Nueva. The map specifies the 13 neighborhoods and each of the survey units and sampling units with ovitraps.](image-url)
Table 1: Frequencies (n, %) of socioeconomic factors associated with identifying positive houses for immature stages of *A. aegypti* (PR, 95% CI; $\chi^2$) and factors associated with the presence of positive ovitraps (PR, 95% CI; $\chi^2$).

| Variables                  | n (%) | Positive houses | Positive ovitraps |
|----------------------------|-------|-----------------|-------------------|
|                            |       | PR (95% CI)     | $\chi^2$          |
|                            |       | $\chi^2$        | No PR (95% CI)    | $\chi^2$ |
| Sex                        |       |                 |                   |
| Female                     | 227 (73.9) | 1.03 (0.72, 1.48) | 0.0005 |
| Male                       | 80 (26.1)  | 1.00            | 64 16 1.00        |
| Age                        |       |                 |                   |
| From 18 to 39              | 144 (46.9) | 1.00            | 32 112 1.00       |
| From 40 to 60              | 130 (42.3) | 1.00            | 29 101 0.99 (0.56, 1.77) 0.88 |
| >60                        | 33 (10.7)  | 0.85 (0.63, 1.15) | 5 28 1.6 (0.57, 4.48) |
| Education level            |       |                 |                   |
| None                       | 4 (1.3)   | 12 (0.51, 280.09) | 3 1 0.95 (0.54, 1.69) |
| Primary                    | 97 (31.6) | 1.88 (0.2, 17.52) | 77 20 1.02 (0.90, 1.15) |
| High school                | 139 (45.3)| 1.85 (0.2, 17.06) | 111 28 1.03 (0.92, 1.16) |
| Technician or technologist | 52 (16.9) | 1.78 (0.18, 17.19) | 42 10 1.03 (0.89, 1.20) |
| Professional               | 10 (3.3)  | 9.33 (0.71, 122.57) | 5 5 0.63 (0.34, 1.17) |
| Postgraduate               | 5 (1.6)   | 1.00            | 3 2 1.00          |
| Occupation                 |       |                 |                   |
| Housewife                  | 136 (44.3) | 1.00            | 103 33 1.00       |
| Unemployed                 | 32 (10.4) | 1.35 (0.59, 3.07) | 27 5 1.08 (0.92, 1.27) |
| Employee                   | 69 (22.5) | 1.56 (0.84, 2.88) | 55 14 1.02 (0.89, 1.17) |
| Student                    | 15 (4.9)  | 1.29 (0.41, 4.02) | 8.19 11 4 0.93 (0.68, 1.27) |
| Independent worker         | 51 (16.6) | 1.66 (0.85, 3.27) | 42 9 1.06 (0.92, 1.22) |
| None                       | 2 (0.7)   | 1.27 (0.07, Inf) | 1 1 0.64 (0.16, 2.54) |
| Pensioner                  | 2 (0.7)   | 0.58 (0.36, 0.98) | 2 0 2.89 (0.29, Inf) |
| Family income              |       |                 |                   |
| ≤1 MW                      | 147 (47.9) | 1.09 (0.79, 1.49) | 120 27 1.08 (0.96, 1.21) |
| 1-2 MW                     | 145 (45.7) | 0.81 (0.59, 1.12) | 108 37 0.91 (0.81, 1.02) |
| 3-4 MW                     | 9 (2.9)   | 1.71 (0.93, 3.13) | 3.76 9 0 8.6 (0.46, 2.23) |
| >4 MW                      | 6 (2.1)   | 1.00            | 4 2 1.00          |
| Number of people           |       |                 |                   |
| From 1 to 5                | 261 (85)  | 1.00            | 55 206 1.00       |
| From 6 to 9                | 43 (14)   | 0.98 (0.49, 1.95) | 1.53 9 34 1.01 (0.46, 2.23) |
| >10                        | 3 (1)     | 4.07 (0.36, 45.51) | 2 1 0.13 (0.01, 1.5) |
| Number of rooms            |       |                 |                   |
| From 1 to 3                | 262 (85.3) | 1.00            | 58 204 1.00       |
| From 4 to 6                | 40 (13)   | 2.51 (1.28, 4.93) | 7.95* 7 33 1.34 (0.56, 3.19) |
| >7                         | 5 (1.6)   | 0.57 (0.06, 5.17) | 1 4 1.14 (0.12, 10.37) |
| Overcrowding               |       |                 |                   |
| From 0.2 to 1.8            | 217 (70.7) | 1.00            | 42 175 1.00       |
| From 2 to 2.7              | 69 (22.5) | 0.69 (0.38, 1.26) | 1.71 20 49 1.5 (0.96, 2.36) |
| >2.9                      | 21 (6.8)  | 0.73 (0.27, 1.95) | 4 17 0.88 (0.35, 2.18) |
| Property condition         |       |                 |                   |
| Own                        | 184 (59.9) | 1.26 (1.06, 1.51) | 5.36* 147 37 1.05 (0.93, 1.18) |
| Rent                       | 123 (40.1) | 1.00            | 94 29 1.00        |
| Water supply service       |       |                 |                   |
| Yes                        | 307 (100) | NA              | 241 66 NA         |
| Water supply frequency     |       |                 |                   |
| Every day                  | 307 (100) | NA              | 241 66 NA         |
| Garbage collection service |       |                 |                   |
| Yes                        | 307 (100) | NA              | 241 66 NA         |
| Garbage collection frequency|       |                 |                   |
| From 2 to 3 days           | 307 (100) | NA              | 241 66 NA         |
| Electric service           |       |                 |                   |
| Yes                        | 307 (100) | NA              | 241 66 NA         |
| Cable television service   |       |                 |                   |
| Yes                        | 250 (81.4) | 0.78 (0.54, 1.13) | 1.23 192 58 0.89 (0.79, 1.01) 1.80 |
| No                         | 57 (18.6)  | 1.00            | 49 8 1.00         |
Table 1: Continued.

| Variables                        | n (%) | Positive houses | Positive ovitraps | \( \chi^2 \) | \( \chi^2 \) |
|----------------------------------|-------|----------------|-------------------|-------------|-------------|
| **Internet service**             |       | PR (95% CI)     |                   |             |             |
| Yes                              | 159 (51.8) | 0.86 (0.63, 1.18) | 0.65 | 116 | 0.86 (0.77, 0.97) | 5.35* |
| No                               | 148 (48.2) | 1.00 |                   |             |             |
| **Service domestic gas**         |       | PR (95% CI)     |                   |             |             |
| Yes                              | 251 (81.8) | 0.51 (0.38, 0.69) | 13.9* | 191 | 0.85 (0.76, 0.96) | 3.97* |
| No                               | 56 (18.2) | 1.00 |                   |             |             |
| **Socioeconomic levels**         |       | PR (95% CI)     |                   |             |             |
| Level 1                          | 113 (36.8) | 0.94 (0.5, 1.78) | 0.65 | 99 | 0.99 (0.88, 1.11) | 0.69 |
| Level 2                          | 127 (41.4) | 0.79 (0.42, 1.48) | 1.00 | 55 | 1.00 |             |
| Level 3                          | 67 (21.8) | 1.00 |                   |             |             |
| **Irregular urbanization area**  |       | PR (95% CI)     |                   |             |             |
| Si                               | 42 (86.3) | 1.82 (1.05, 3.18) | 4.54* | 36 | 1.64 (0.72, 3.73) | 1.49 |
| No                               | 265 (13.7) | 1.00 |                   |             |             |
| **Health regime**                |       | PR (95% CI)     |                   |             |             |
| Subsidized                       | 184 (59.9) | 1.01 (0.73, 1.39) | 1.03e – 30 | 147 | 0.96 (0.85, 1.08) | 0.34 |
| Contributory                     | 123 (40.1) | 1.00 |                   |             |             |

MW = minimum wage in Colombia. Bold number and asterisk represent statistical significance of \( p < 0.05 \).

Table 2: Frequencies (n, %) of environmental factors associated with identifying positive houses with immature stages of A. aegypti (PR, 95% CI; \( \chi^2 \)) and in the presence of positive ovitraps (PR, 95% CI; \( \chi^2 \)).

| Variables                        | n (%) | Positive houses | Positive ovitraps | \( \chi^2 \) | \( \chi^2 \) |
|----------------------------------|-------|----------------|-------------------|-------------|-------------|
| **Housing type**                 |       | PR (95% CI)     |                   |             |             |
| House                            | 236 (76.9) | 2.26 (1.31, 3.87) | 10.2* | 189 | 1.09 (0.94, 1.28) | 1.14 |
| Apartment                        | 71 (23.1) | 1.00 |                   |             |             |
| **Wall type**                    |       | PR (95% CI)     |                   |             |             |
| Cement                           | 289 (94.1) | 1.00 |                   |             |             |
| Plastic fiber                    | 1 (0.3) | 1.04 |                   |             |             |
| Wood                             | 14 (4.6) | 1.08 (0.52, 2.22) | 2.04 | 13 | 1.19 (1.02, 1.40) | 5.63 |
| Zinc sheet                       | 3 (1) | 1.00 |                   |             |             |
| **Floor type**                   |       | PR (95% CI)     |                   |             |             |
| Tile                             | 276 (89.9) | 1.05 (0.60, 1.82) | 2.54 | 24 | 1.18 (1.04, 1.34) | 7.39* |
| Cement                           | 26 (8.5) | 1.05 (0.60, 1.82) | 2.54 | 24 | 1.18 (1.04, 1.34) | 7.39* |
| Land                             | 5 (1.6) | 1.00 |                   |             |             |
| **Roof type**                    |       | PR (95% CI)     |                   |             |             |
| Eternit roof tile                | 289 (94.1) | 1.2 (0.56, 2.59) | 0.06 | 226 | 0.94 (0.76, 1.16) | 0.05 |
| Zinc tile                        | 18 (5.9) | 1.00 |                   |             |             |
| **Concrete washbasins (water tanks or low tank)** |       | PR (95% CI)     |                   |             |             |
| Yes                              | 269 (87.6) | 1.92 (0.96, 3.82) | 3.56 | 215 | 1.17 (0.93, 1.46) | 1.97 |
| No                               | 38 (12.4) | 1.00 |                   |             |             |
| **Other types of water container** |       | PR (95% CI)     |                   |             |             |
| Yes                              | 113 (36.8) | 0.82 (0.58, 1.16) | 1.03 | 85 | 0.94 (0.82, 1.06) | 0.85 |
| No                               | 194 (63.2) | 1.00 |                   |             |             |
| **More than one water container** |       | PR (95% CI)     |                   |             |             |
| Yes                              | 75 (24.4) | 1.06 (0.70, 1.61) | 0.09 | 59 | 1.01 (0.62, 1.63) | 0.001 |
| No                               | 232 (75.6) | 1.00 |                   |             |             |
| **House maintenance**            |       | PR (95% CI)     |                   |             |             |
| Well maintained                  | 264 (86) | 1.00 |                   |             |             |
| Moderately maintained            | 25 (8.1) | 1.50 (0.97, 2.34) | 2.70 | 24 | 1.25 (1.13, 1.38) | 8.43* |
| Poor maintained                  | 18 (5.9) | 1.00 (0.51, 1.97) | 1.7 | 17 | 1.22 (1.07, 1.39) | 8.43* |
| **Patio (backyard) condition**   |       | PR (95% CI)     |                   |             |             |
| Tidy                             | 123 (40.1) | 1.00 |                   |             |             |
| Moderately tidy                  | 109 (35.5) | 1.03 (0.74, 1.44) | 0.22 | 105 | 1.40 (1.27, 1.55) | 90.5* |
| Untidy                           | 75 (24.4) | 1.06 (0.74, 1.52) | 1.68 | 68 | 1.06 (0.94, 1.20) | 68.7* |
| **Shadow in the patio**          |       | PR (95% CI)     |                   |             |             |
| <25%                             | 20 (6.5) | 1.00 |                   |             |             |
| 25–50%                           | 83 (27) | 1.07 (0.76, 1.52) | 1.68 | 68 | 1.06 (0.94, 1.20) | 68.7* |
| >50%                             | 204 (66.4) | 0.85 (0.62, 1.18) | 1.72 | 32 | 1.26 (1.09, 1.46) | 4.01 |

Bold number and asterisk represent statistical significance of \( p < 0.05 \).
| Variables                                      | n (%)     | Positive houses | Positive ovitraps | \( \chi^2 \) | \( \chi^2 \) |
|-----------------------------------------------|-----------|----------------|------------------|--------------|--------------|
| **Mobility outside the municipality**         |           |                |                  |              |              |
| Yes                                           | 244 (79.5)| 72             | 172              | **0.62**     | **0.62**     |
| No                                            | 63 (20.5) | 30             | 33               | 1.00         | 1.00         |
| **Frequency of mobility outside the municipality** |           |                |                  |              |              |
| Does not travel                                | 61 (19.9) | 29             | 32               | 1.00         | 1.00         |
| Daily                                         | 8 (2.6)   | 3              | 5                | 0.79 (0.31, 2.00) | 4             | 4             | 0.63 (0.31, 1.26) | 6.61 | 6.61 |
| Weekly                                        | 35 (11.4) | 11             | 24               | 0.66 (0.38, 1.15) | 29             | 6             | 1.06 (0.90, 1.25) | 9.66 | 9.66 |
| Every 15 days                                  | 44 (14.3) | 17             | 27               | 0.81 (0.51, 1.28) | 37             | 7             | 1.08 (0.94, 1.25) | 5.31 | 5.31 |
| Monthly                                       | 159 (51.8)| 42             | 117              | **0.55** (0.36, 0.80) | 121            | 38             | 0.94 (0.84, 1.05) | 6.03 | 6.03 |
| **Concrete washbasins cleaning**              |           |                |                  |              |              |
| Yes                                           | 254 (82.7)| 84             | 170              | **0.97** (0.64, 1.47) | 205            | 49             | 1.19 (0.98, 1.44) | 3.52 | 3.52 |
| No                                            | 53 (17.3) | 18             | 35               | 1.00         | 1.00         |
| **Frequency of concrete washbasins cleaning** |           |                |                  |              |              |
| It has no tank                                 | 38 (12.4) | 7              | 31               | 1.00         | 1.00         |
| From 2 to 8 days                               | 249 (81.1)| 85             | 164              | 1.16 (0.75, 1.80) | 200            | 49             | 1.88 (0.89, 4)    | 6.68 | 6.68 |
| From 9 to 15 days                              | 15 (4.9)  | 7              | 8                | 1.43 (0.81, 2.53) | 10             | 5              | 0.92 (0.26, 3.3)  | 5.39 | 5.39 |
| From 20 to 30 days                             | 5 (1.6)   | 3              | 2                | 1.83 (0.88, 3.81) | 5              | 0              | 3.6e+04 (0, Inf)   | 1.62 | 1.62 |
| **Identify covered water containers**          |           |                |                  |              |              |
| Yes                                           | 38 (12.4) | 15             | 23               | 1.00         | 1.00         |
| No                                            | 269 (87.6)| 84             | 170              | 0.48         | 33             | 5             | 1.00         | 1.27 | 1.27 |
| **Reasons for water storage**                  |           |                |                  |              |              |
| Custom                                        | 29 (9.4)  | 7              | 22               | 0.71 (0.36, 1.37) | 23             | 6              | 1.01 (0.83, 1.23) | 2.83 | 2.83 |
| Does not store water                           | 47 (15.3) | 8              | 39               | 1.00         | 1.00         |
| Domestic use                                   | 231 (75.2)| 87             | 144              | **1.91** (1.18, 3.09) | 184            | 47             | 1.06 (0.92, 1.23) | 5.39 | 5.39 |
| **Knowledge of the biological behavior of the vector** |           |                |                  |              |              |
| Yes                                           | 185 (60.3)| 58             | 127              | 1.00         | 1.00         |
| No                                            | 122 (39.7)| 44             | 78               | 1.15 (0.74, 1.77) | 94             | 28             | 0.97 (0.86, 1.09) | 1.00 | 1.00 |
| **Knowledge of breeding sites**                |           |                |                  |              |              |
| Yes                                           | 267 (87)  | 87             | 180              | 1.00         | 1.00         |
| No                                            | 40 (13)   | 15             | 25               | 1.85 (1.2, 2.8) | 32             | 8              | 1.02 (0.86, 1.2)  | 2.6e – 03 | 2.6e – 03 |
| **Vector knowledge**                           |           |                |                  |              |              |
| Yes                                           | 290 (94.5)| 92             | 198              | **0.54** (0.35, 0.83) | 229            | 61             | 1.00         | 0.26 | 0.26 |
| No                                            | 17 (5.5)  | 10             | 7                | 1.00         | 1.00         |
| **Knowledge of arboviruses**                   |           |                |                  |              |              |
| Yes                                           | 283 (92.2)| 90             | 193              | 1.00         | 1.00         |
| No                                            | 24 (7.8)  | 12             | 12               | 1.57 (1.02, 2.43) | 19             | 5              | 1.00 (0.81, 1.25) | 5.3e – 03 | 5.3e – 03 |
| **Biting control strategy**                    |           |                |                  |              |              |
| Physical                                       | 229 (74.6)| 78             | 151              | 1.11 (0.76, 1.62) | 184            | 45             | 1.10 (0.95, 1.28) | 1.42 | 1.42 |
| Chemistry                                      | 78 (25.4) | 24             | 54               | 1            | 0.15         | 57             | 21             | 1             | 1.00         |
| **Breeding site control strategies**           |           |                |                  |              |              |
| Actions on the tank                            | 234 (76.2)| 81             | 153              | 1.20 (0.81, 1.80) | 182            | 52             | 0.96 (0.84, 1.10) | 0.15 | 0.15 |
| Use of insecticides and chlorine               | 73 (23.8) | 21             | 52               | 1            | 0.61         | 59             | 14             | 1             | 1.00         |
| **Spray the house with insecticides**         |           |                |                  |              |              |
| Yes                                           | 237 (77.2)| 69             | 168              | 1.00         | 1.00         |
| No                                            | 70 (22.8) | 33             | 37               | **1.61** (1.17, 2.22) | 52             | 18             | 0.93 (0.80, 1.00) | 0.66 | 0.66 |
| **Fumigation frequency**                       |           |                |                  |              |              |
| From 1 to 8 days                               | 261 (85)  | 169            | 92               | 1.00         | 1.00         |
| Every 15 days                                  | 11 (3.6)  | 7              | 4                | 0.95 (0.60, 1.49) | 3              | 8              | 0.92 (0.64, 1.33) | 4.61 | 4.61 |
| Monthly                                       | 35 (11.4) | 29             | 6                | 1.28 (1.07, 1.59) | 9              | 26             | 0.94 (0.77, 1.15) | 0.69 | 0.69 |
| **How do you spray insecticides?**            |           |                |                  |              |              |
| Self-application                               | 229 (74.6)| 67             | 162              | **0.65** (0.47, 0.90) | 183            | 46             | 1.07 (0.92, 1.25) | 1.07 | 1.07 |
| Contract fumigation                            | 8 (2.6)   | 2              | 6                | 0.75 (0.22, 2.51) | 7              | 2              | 1.00 (0.66, 1.54) | 1.00 | 1.00 |
| Do not spray                                   | 70 (22.8) | 33             | 37               | 1.00         | 1.00         |

Bold number and asterisk represent statistical significance of \( p < 0.05 \).
adjusted prevalence ratio was calculated using bivariate logistic regression. A multivariate model was built using the variables with significant associations found in the bivariate analysis (p value > 0.05). Similarly, negative binomial regression models were used to assess the association of variables with the egg counts per ovitraps. The stepwise forward selection was used to select the variables for the final model using the Akaike information criterion (AIC). R statistical software (V: 3.6.1) was used, including the following packages epiDisplay and nortest [32].

2.5. Ethical Considerations. Each participant was informed of the aims and implications of study participation. Participation in the study was voluntary, and participants signed a letter of informed consent. The study was authorized by the Institutional Ethical Committee (Comité de Ética Institucional, CES University, Act 116 of 2018) and the department and municipality health branches (Secretaría de Salud del Meta y Secretaría de Salud de Castilla la Nueva).

3. Results

3.1. Entomological Indices. Three hundred and seven residences (96.8%) from the estimated sample (317 houses) participated in the study (questionnaire and trap allocation). The entomological survey allowed determining a general housing infestation proportion of 33.2% in the urban area of the municipality. The presence of concrete washbasins and other forms of in-house water storage for laundry and other housekeeping tasks contributed the most to the infestation index with 22.48% followed by 200-liter metal barrels (6.84%), pet waterers (1.95%), bottles (0.98%), aquatic plants (0.65%), and flower pots (0.33%). A total of 241 (78.5%) positive residences were identified with the ovitraps in the sampling method—the number of eggs per ovitraps of A. aegypti was an average of 74.6; 75% of the traps had a capture of fewer than 238 eggs, and the maximum value of eggs was 1.512.

3.2. Results of Socioeconomic, Environmental, and Behavioral Dimensions. Most of the participants were women (73.9%). Many participants (76.9%) had at least a high school education, and 1.3% had not received any education. The main occupation identified was housekeeper (44.3%) followed by formal work (22.5%) and self-employed (16.6%). Most of the surveyed population (52.1%) had an income of 2 times the minimum wage in Colombia (approximately US$550). 59.9% of the population owned their house, and all the households in the municipality have access to essential utilities (water, garbage collection, electricity) (Table 1).

76.9% of the residences corresponded to one-story brick and mortar houses, cement roof tiles, tiled floors, and concrete washbasins. 86% of the homes presented good maintenance of painted walls, doors, and windows. However, 24.4% had a disorganized patio, and 35.5% had a partially disorganized patio. In addition, 66.4% of patios had a proportion greater than 50% of shade (Table 2).

As main behavioral factors, it was observed that most of the surveyed population traveled outside the municipality (79.5%), some of them monthly (51.8%). Regarding the habits, it was found that 82.7% of the respondents stated that they wash the reservoirs at least every week. 75.2% of the community stated that the main reason for storing water was domestic activities such as dishwashing, cooking, housekeeping, and laundry.

A significant proportion of the surveyed population demonstrated some knowledge of the vector (94.5%), the breeding sites of the vector (87%), and the role in the transmission of arboviruses (92.2%). However, 39.7% could not describe the behavior and the place of oviposition for A. aegypti, which shows that a significant proportion of the population is unaware of important aspects of the biology of the vector.

Regarding the practices to prevent reproduction and mosquito bites, it was found that, in a high percentage of households (77.2%), the people in their homes every eight days generally perform self-application of insecticides. Additionally, they used physical barriers (mosquito nets, window hooks, electric rackets) and controlled actions in the tank, which included washing the tank and some lids that could prevent the entry of mosquitoes (Table 3).

3.3. Factors Associated with the Presence of Positive Residences and Positive Ovitraps. The bivariate analysis showed that socioeconomic factors such as the number of bedrooms in residence (between 4 and 6 bedrooms), home ownership, and living in an irregular urban development zone were factors significantly associated with positive houses for the presence of immature A. aegypti. In contrast, the factor having domestic gas showed an opposite effect, with a 1.4 times lower probability of finding infested residences than households that do not have this service (PR = 0.51; 95% CI: 0.38–0.69). About the environmental factors, it was found that one-story homes are strongly associated with the presence of vector mosquitoes (PR = 2.26; 95% CI: 1.31–3.87).

The most relevant behavioral factors identified were the storage of water for domestic use (PR = 1.91; 95% CI: 1.18–3.09) and mobility outside the municipality (PR = 0.62; 95% CI: 0.45–0.86), in which the frequency of monthly mobility showed a lower probability of finding infested residences than households that do not have this service (PR = 0.51; 95% CI: 0.38–0.69). About the environmental factors, it was found that one-story homes are strongly associated with the presence of vector mosquitoes (PR = 2.26; 95% CI: 1.31–3.87).

An association between positive ovitraps and socioeconomic factors such as Internet service and domestic gas was observed since a home with Internet access and gas was less likely to have positive ovitraps. About the environmental factors, it was observed that rustic cement floors (PR = 1.20; 95% CI: 1.05–1.36), houses with moderate maintenance (PR = 1.25; 95% CI: 1.13–1.38), disorganized patios (PR = 1.34; 95% CI: 1.23–1.47), and a proportion of shade greater than 50% in the patio (PR = 1.26; 95% CI: 1.09–1.46) increased the probability of finding positive ovitraps (Tables 1 and 2).
3.4. Modeling of Explanatory Factors for the Presence and Abundance of A. aegypti. Positive associations with one-story house, undergraduate education level, and owning the home were significant variables associated with the probability of infested residences. On the other hand, having domiciliary gas service and in-house fumigation showed a negative association with the probability of infestation at 3.33 and 2.7 times for larval stages, respectively. Mobility outside the municipality and knowing the vector were also factors identified by the model that decreased the infestation probability; however, these factors were not significant.

The logistic model designed for the positive ovitrap indicator revealed that the main factors associated were a disorganized patio (PR = 79.95; 95% CI: 10.96–583.24) and the proportion of shade greater than 50% of the patio (PR = 62.32; 95% CI: 6.47–600.32). The model also identified that cleaning the concrete washbasins was positively associated with gravid female mosquitoes in the residences (PR = 4.1; 95% CI: 1.64–10.22). The same environmental factors were also positively related to the abundance of A. aegypti by the negative binomial regression model for the number of eggs per ovitrap (Table 4).

4. Discussion

This study allowed the identification of socioeconomic, environmental, and behavioral factors associated with the presence and abundance of A. aegypti. The direct inspection of water containers and the captures of eggs of A. aegypti with ovitraps were adequate for the identification of the presence of the vectors as it has been reported by other studies [18, 23, 33–37]. Likewise, egg counts in ovitraps have shown to effectively determine the relative presence and abundance in a specific location since these counts have been correlated to the number of adults and the risk of viral transmission [24, 25, 38, 39].

The percentage of residences with the presence of the mosquito was 32.2%, which is similar to that reported by other studies [21, 40, 41]. However, this study shows that 200 L containers as the main breeding sites for A. aegypti (concrete washbasins, low tanks, laundry tanks, and barrel containers). These containers have been identified as the most prolific breeding sites (>60%) for mosquito production in Colombia [21, 40, 42, 43]. The ovitraps showed a better sensitivity to identify female mosquito intrusion than direct inspection of water containers finding a proportion of positivity twice the house index. This result is similar to that by Alarcon et al. [25] in the municipalities of Apartadó and Carepa, where the proportion of ovitraps was higher than 70% for both municipalities, while the proportion of positive residences varied between 1.92% and 58.2%. Other studies have also reported similar results in other municipalities and other countries such as Thailand and Mexico, suggesting that ovitraps are sensitive enough to determine the presence of the vector and can be useful as a tool for entomological surveillance [23, 26].

In the present study, the socioeconomic variables associated with the vector’s presence were the number of bedrooms in the house, property condition (rent/own), and some services such as gas and Internet. However, the latter two variables are not similar to those used in other studies [12, 34]. A study in Ecuador showed that many families in the same house with owners older than 35 years were identified as risk factors of vector presence [36]. These findings are comparable to our study where houses with many rooms, habitied by owners older than 39 years, were associated with mosquito vectors. To the extent of our knowledge, there are no reports of domestic gas and Internet service associated with the presence of the vector, so this would be the first report of this association. Association with other utilities such as drinkable water, sewage, and residual disposal has been reported previously [9, 10, 36, 37]. Internet access and access to basic utilities are related to access to knowledge and better living conditions related to positive preventive behavior [44].

Other research works in Colombia (Melgar, Girardot, and Villavicencio) have shown that houses in privileged neighborhoods have less density of the vector, thus less risk of exposure to dengue [12, 45]. However, in this study, the proportion of positive residences did not differ among the different socioeconomic levels as evidence that neither the type of construction nor the urban condition in the neighborhoods affects the presence of the vector. In this case, we believe that the presence of A. aegypti in the study areas is related to the environmental conditions rather than the socioeconomic level.

Regarding environmental factors, temperature has been identified as an important factor in the abundance, dispersion, and transmission of arboviruses by the mosquito [46–48]. However, in the tropics, the temperature does not have drastic variations during the year; other factors such as the living spaces and neighborhood characteristics become more important. In this study, we found that houses with concrete floors, poor maintenance, poor organization, and with a proportion of shade in the patio higher than 25% are houses with a higher probability of finding immature stages of mosquitoes. These results are similar to those reported in studies conducted in Bangladesh and Ecuador where the partial shading of the patio and inadequate maintenance of the house and patio increased the probability of finding the vector 13 times [35, 36].

Other factors related to the presence of the vector were behavioral factors. Habits and monthly frequency of travel out of the municipality showed a low probability of finding the mosquito in the study area. This suggests that people who travel with less frequency could permanently control breeding sites, minimizing the mosquito reproduction. These results are similar to those reported in studies of dengue transmission models by Stoddard et al. [49], where they determined that the basic reproductive number (R0) was 1.3 for exposure of the vector in house, compared with 3.75 when the exposure occurred elsewhere (e.g., schools or markets). Even though this model does not explain the vector-factor relationship, it shows a comparative framework of the potential importance of the mobility of people at risk and the relation of these with the vector and the capability of virus transmission.
The reasons and motivations for storing water in houses’ containers are behavioral factors to consider. In this municipality, all the population has access to tap water with constant supply; however, people decide to store water in the houses for, according to them, its use in “multiple house-keeping chores.” The presence of water containers was associated with a higher probability of the presence of the mosquito. This same association was found in a study in Dhaka, Bangladesh, where they found a threefold risk of the presence of the vector if water was stored compared with those residences where water was not stored [34]. Our results suggest the need to implement programs focused on modifying the practice of water storage without altering the activities in the houses.

We also evaluated the potential association of knowledge about the vector and dengue with the presence of the vector. Widespread global recommendations of control and prevention of mosquito populations and dengue transmission always include knowledge access and appropriation as essential [8]. A study in Ecuador evaluated vector knowledge before, during, and after the rainy season and found that during the rainy season, an education-based intervention had a preventive effect on the presence of the vector [36]. In the present study, a similar effect between knowledge and the presence of the vector was identified, which suggests expanding educational processes in different weather seasons as preventive strategies.

On the other hand, we found an association between spraying insecticide (by the inhabitants) and the presence of the vector. This effect was also reported in a systematic review by Samuel et al. [50], where insecticide sprays reduce the abundance of larval and adult forms of the mosquito and decrease in 4.3 times the risk of dengue fever. Indicating for our study that habits related to the self-application of insecticides and having an effect on mosquitoes is an acquired behavior, focusing on other physical or biological control methods with a lower risk of failure (resistance to insecticides).

The logistic model identified multiple explanatory factors associated with the presence of the vector in the participant households. The main associated factors were the house type, being an owner, and having professional inhabitants. These findings were surprising since they are characterized by the quality of life and possibly by a better understanding and attitudes toward preventive behaviors for controlling the vector. However, our results were similar to those reported in other studies in Cali [51], Java [52], and Thailand [53], where they demonstrated that people living in higher-income neighborhoods, have higher education levels, and have better jobs have higher risks of getting dengue fever. Regarding the type of residence, a traditional residence type older than 20 years of construction has been found to be associated with the presence of the mosquito [54].

Explanatory models developed with positive ovitraps and the number of eggs per ovitrap found environmental factors associated with the presence of gravid females. The local conditions as poor maintenance, >50% patio shadow, and disorganized patio were associated with the presence and abundance of A. aegypti. These factors can also be related to the educational level, the quality of life, and other socioeconomic factors that promote the conditions for reproduction and the presence of the vector [55]. These factors have been reported previously in association with the presence of the vector and as for the risk of dengue transmission [18, 56].

The model also identified that washing the concrete washbasins is associated with the presence and abundance of the vector. However, the information of practices obtained may be influenced by participants’ answers since this practice is perceived as an accepted norm behavior. Also, we found that participants reporting washing the concrete washbasins weekly in participants’ residences reported a
higher infestation and abundance of the vector. These findings show that people know the importance of concrete washbasins’ cleanliness and frequency of cleaning, but this knowledge does not affect the behavior or the cleaning is not being performed adequately. The results are consistent with those reported in a study conducted in Bucaramanga, where an intervention of information, education, and communication was implemented. This intervention showed a modification of the knowledge about vector control practices, but this did not decrease the number of breeding sites or the incidence of dengue [57].

One limitation of this study is that we determined the presence and abundance of the immature stages of the vector (larvae, pupa, and eggs) without using the Stegomyia larval index or density or abundance of pupas or adults, important outcome indexes that might have shown an association with other factors. Second, the study’s cross-sectional nature only allowed collecting data at a specific time of the year (rain season). We consider that collecting information in the dry season could have led to different results since the vector’s abundance and presence could change in these two seasons.

5. Conclusion

The present study identified that the presence and abundance of A. aegypti in the study area are explained by socioeconomic, environmental, and behavioral factors such as home ownership status, housing type (traditional house older than 20 years of construction), service domestic gas, spray the house with insecticides, education level, profession, patio condition, shadow in the patio, and concrete washbasins cleaning, where the conditions of the residences and modes of living of its inhabitants played an important role. Additionally, the study concluded that the main mosquito breeding sites are large water containers larger than 200 liters in which entomological and community control actions should be focused. Likewise, the use of ovitraps as an entomological indicator of the presence of A. aegypti was shown to be more sensitive than direct inspection of water containers, suggesting that this tool could be used routinely for entomological surveillance in Colombia.

Finally, based on the identified factors, we recommend generating public policies focused on house maintenance, strategies that highlight the importance of patio organization, and adequate water container cleaning as topics in preventive education programs. In addition to these findings, efforts should be made to help the people to go from knowledge to practice. We believe that the implementation of these activities will help decrease the presence and abundance of the vector, thus reducing the risk of exposure to the dengue fever virus.

Abbreviations

Ae: Aedes
DFV: Dengue fever virus
Bti: Bacillus thuringiensis var. israelensis
PR: Prevalence ratio
AIC: Akaike information criterion.

Data Availability

All relevant study data are within the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors’ Contributions

A. Vásquez-Trujillo conceived and designed the study, performed analysis, and interpreted the manuscript. D. Cardona-Arango and A. M. Segura-Cardona performed analysis and interpreted the results. D. C. Portela-Cámara and N. Alves-Honório carried out analysis and interpretation. G. J. Parra-Henao designed the study, performed analysis, and interpreted and wrote the manuscript. All the authors approved the final version.

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References

[1] A. L. Costa-da-Silva, R. S. Ishinoh, H. R. C. d. Araújo et al., “Laboratory strains of Aedes aegypti are competent to Brazilian Zika virus,” PLoS One, vol. 12, no. 2, Article ID e0171951, 2017.
[2] S. Mbaika, J. Lutomiah, E. Chepkorir et al., “Vector competence of Aedes aegypti in transmitting Chikungunya virus: effects and implications of extrinsic incubation temperature on dissemination and infection rates,” Virology Journal, vol. 13, no. 1, pp. 114–119, 2016.
[3] M. Muñoz and J. C. Navarro, “Virus Mayaro: un arbovirus reemergente en Venezuela y Latinoamérica,” Biomédica, vol. 32, no. 2, pp. 286–302, 2012.
[4] J. C. Padilla, D. P. Rojas, and R. Sáenz, Dengue en Colombia: Epidemiología de la reemergencia a la hiperepidemia, Guías de impresión Ltda: Bogotá D.C., Bogotá, Colombia, 2012.
[5] INS Informe de Evento, Dengue. Grupo de Enfermedades Transmisibles. Dirección de Vigilancia y Análisis del Riesgo en Salud Publica, Instituto Nacional de Salud. Instituto Nacional de Salud. Bogotá D.C., Bogotá, Colombia, 2019.
[6] R. Castro Rodríguez, G. Carrasquilla, A. Porras, K. Galeraga-Gelvez, J. G. Lopez Yescas, and J. A. Rueda-Gallardo, “The burden of dengue and the financial cost to Colombia, 2010-2012,” The American Journal of Tropical Medicine and Hygiene, vol. 94, no. 5, pp. 1065–1072, 2016.
[7] Ministerio de Protección Social, INS, OPS, Gestión para la vigilancia entomológica y control de la transmisión de dengue, Ministerio de Protección Social, INS, OPS, Bogotá, Colombia, 2012.
[8] World Health Organization, UNICEF, FAO, Communication for Behavioural Impact (Combi). Communication For Behavioural Impact, World Health Organization, Geneva, Switzerland, 2012.
[9] A. B. Knudsen and R. Sloor, “Vector-borne disease problems in rapid urbanization: new approaches to vector control,” Bulletin of the World Health Organization, vol. 70, no. 1, pp. 1–6, 1992.

[10] R. Barrera, J. C. Navarro, J. D. Mora Rodriguez, D. Dominguez, and J. E. Gonzalez Garcia, “Deficiencia en servicios públicos y cría de Aedes aegypti en Venezuela,” Boletín de la Oficina Sanitaria Panamericana, vol. 118, no. 5, pp. 410–423, 1995.

[11] E. L. Estallo, G. Más, C. Vergara-Cid et al., “Spatial patterns of high Aedes aegypti oviposition activity in northwestern Argentina,” PLoS One, vol. 8, no. 1, 8 pages, Article ID e54167, 2013.

[12] J. Quintero, G. Carrasquilla, R. Suárez, C. González, and V. A. Olano, “An ecosystemic approach to evaluating ecological, socioeconomic and group dynamics affecting the prevalence of Aedes aegypti in two Colombian towns,” Cadernos de Saúde Pública, vol. 25, no. suppl 1, pp. s93–s103, 2009.

[13] M. Fuentes-Vallejo, D. R. Higuaí-Mendieta, T. García-Betancourt et al., “Territorial analysis of Aedes aegypti distribution in two Colombian cities: a chorematic and eco-system approach,” Cadernos de Saúde Pública, vol. 31, no. 3, pp. 517–530, 2015.

[14] C. Kendall, P. Hudelson, E. Leontsini, P. Winch, L. Lloyd, and F. Cruz, “Urbanization, dengue, and the health transition: anthropological contributions to international health,” Medical Anthropology Quarterly, vol. 5, no. 3, pp. 257–268, 1991.

[15] P. J. Winch, J. G. Rigau-Pérez, G. G. Clark, M. Ruiz-Pérez, E. Leontsini, and D. J. Gubler, “Community-based dengue prevention programs in Puerto Rico: impact on knowledge, behavior, and residential mosquito infestation,” The American Journal of Tropical Medicine and Hygiene, vol. 67, no. 4, pp. 363–370, 2002.

[16] E. L. Estallo, F. Sangermano, M. Grech et al., “Modelling the distribution of the vector Aedes aegypti in a central Argentine city,” Medical and Veterinary Entomology, vol. 32, no. 4, pp. 451–461, 2018.

[17] W. Tun-Lin, B. H. Kay, and A. Barnes, “The premise condition index: a tool for streamlining surveys of Aedes aegypti,” The American Journal of Tropical Medicine and Hygiene, vol. 53, no. 6, pp. 591–594, 1995.

[18] P. Manrique-Saide, C. R. Davies, P. G. Coleman et al., “The risk of Aedes aegypti breeding and premises condition in South Mexico,” Journal of the American Mosquito Control Association, vol. 29, no. 4, pp. 337–345, 2013.

[19] R. Maciel-De-Freitas, R. C. Peres, R. Souza-Santos, and R. Lourenço-de-Oliveira, “Occurrence, productivity and spatial distribution of key-premises in two dengue-endemic areas of Rio de Janeiro and their role in adults Aedes aegypti spatial infestation pattern,” Tropical Medicine and International Health, vol. 13, no. 12, pp. 1488–1494, 2008.

[20] D. A. Focks, “A review of entomological sampling methods and indicators for dengue vectors,” Dengue Bulletin, vol. 28, pp. 208–389, 2003.

[21] D. A. Focks, N. Alexander, E. Villegas, and W. H. Organization, Multicountry Study of Aedes aegypti Pupal Productivity Survey Methodology: Findings and Recommendations: No. TDR/IRM/DEN/06.1), WHO, Geneva, Switzerland, 2006.

[22] C. M. E. Romero-Vivas and A. K. I. Falconar, “Investigation of relationships between Aedes aegypti egg, larvae, pupae, and adult density indices where their main breeding sites were located indoors,” Journal of the American Mosquito Control Association, vol. 21, no. 1, pp. 15–21, 2005.

[23] P. Manrique-Saide, P. Coleman, P. J. McCall, A. Lenhart, G. Vázquez-prokopec, and C. R. Davies, “Multi-scale analysis of the associations among egg, larval and pupal surveys and the presence and abundance of adult female Aedes aegypti (Stegomyia aegypti) in the city of Merida, Mexico,” Medical and Veterinary Entomology, vol. 28, no. 3, pp. 264–272, 2014.

[24] M. R. Dibo, A. P. Chierotti, M. S. Ferrari, A. L. Mendonça, and F. ChiaraValletoto Neto, “Study of the relationship between Aedes (Stegomyia) aegypti egg and adult densities, dengue fever and climate in Mirassol, state of São Paulo, Brazil,” Memorias do Instituto Oswaldo Cruz, vol. 103, no. 6, pp. 554–560, 2008.

[25] E. P. Alarcón, Á. M. Segura, G. Rua-Uribe, and G. Parra-Henao, “Evaluación de ovitrampas para vigilancia y control de Aedes aegypti en dos centros urbanos del Urabá antioqueño,” Biomédica, vol. 34, no. 3, 2014.

[26] C. Ho, C. Feng, C. Yang, and M. Lin, “Surveillance for dengue fever vectors using ovitrap in Kaohsiung and Tainan in Taiwan,” Formosan Entomologist, vol. 25, pp. 159–174, 2005.

[27] Concejo Municipal de Castilla la Nueva, Acuerdo 015. Plan de Desarrollo ‘Capacidad y Visión para Servir a Mi Gente 2016-2019, Concejo Municipal de Castilla la Nueva, Nueva, Colombia, 2016.

[28] Instituto Nacional de Salud, SIVIGILA. Reporte de Vigilancia Rutinaria por municipio: Estadísticas de Vigilancia Rutinaria, Instituto Nacional de Salud, Bogotá, Colombia, 2020, http://portalsivigila.ins.gov.co/Paginas/Vigilancia-Rutinaria.aspx.

[29] IGAC. Instituto geográfico Agustín Codazzi, Sistema de proyección cartográfica para Colombia, IGAC. Instituto geográfico Agustín Codazzi, Colombia, 2020, https://origen.igac.gov.co/index.html.

[30] Ministerio de Salud de, Brasil, Levantamiento Rápido de Índices para Aedes aegypti u LIRAa para vigilancia entomológica del Aedes aegypti en Brasil: metodología para evaluación de los índices de Breteau y de Vivienda y tipo de recipientes, 2015, http://bvmssa.saudes.gov.br/bvspublicacoes/levantamento_rapido_indices_aedes_aegypti_liraa.pdf.

[31] L. C. Silva, “Diseño razonado de muestras y captación de datos para la investigación sanitaria,” Revista Panamericana de Salud Pública, vol. 10, no. 2, 2000.

[32] R Studio Team, 2015, http://www.rstudio.com/.

[33] K. K. Paul, P. Dhar-Chowdhury, C. E. Haque, R. Lindsay, and S. Hossain, “Socioeconomic and ecological factors influencing aedes aegypti prevalence, abundance, and distribution in Dhaka, Bangladesh,” The American Journal of Tropical Medicine and Hygiene, vol. 94, no. 6, pp. 1223–1233, 2016.

[34] P. Dhar-Chowdhury, C. E. Haque, R. Lindsay, and S. Hossain, “Socioeconomic and ecological factors influencing aedes aegypti prevalence, abundance, and distribution in Dhaka, Bangladesh,” The American Journal of Tropical Medicine and Hygiene, vol. 94, no. 6, pp. 1223–1233, 2016.

[35] A. Hiscox, I. Banks, P. T. Brey et al., “Risk factors for the presence of dengue vector mosquitoes, and determinants of their prevalence and larval site selection in Dhaka, Bangladesh,” PLoS One, vol. 13, no. 6, Article ID e0199457, 2018.

[36] A. M. Stewart Ibarra, S. J. Ryan, E. Beltrán, R. Mejía, M. Silva, and Á. Muñoz, “Dengue vector dynamics (Aedes aegypti) influenced by climate and social factors in Ecuador: implications for targeted control,” PLoS One, vol. 8, no. 11, Article ID e78263, 2013.
