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Population dynamics of *Aedes aegypti* (Diptera: Culicidae) in the last six years in Villa Clara, Cuba

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Abstract

Throughout history, humanity has suffered from the scourge of potentially fatal viral and parasitic diseases. The objective of the research was to analyze the population dynamics of the *Aedes aegypti* mosquito species over the last six years in the province of Villa Clara, Cuba. The research was carried out in Villa Clara province, and covered the 13 municipalities. An observational, descriptive, ecological, retrospective, and statistical study was conducted using data stored in an Excel database. The study covered the period from 2020 to 2025, encompassing all 13 municipalities. The total number of *Ae. aegypti* mosquito breeding sites (larval stage) reported by these municipalities during the six years analyzed was entered into this database. The primary data come from official records aggregated monthly, organized into two main dimensions: Temporal dimension: monthly time series (January–December) for each year of the study period. Spatial dimension: disaggregated by the province's 13 municipalities. The integrity of the database was verified, and no imputation of missing data was required for the selected subset. Regarding the municipalities with the highest incidence, Santa Clara stands out as the most prevalent, followed by Placetas, Sagua la Grande, Manicaragua, and Caibarién. As for the monthly incidence, June stands out, followed by November, July, October, September, and August. The overall annual trend for *Ae. aegypti* infestations in Villa Clara province during the six years covered by the study was downward. It is concluded that arboviral infectious diseases are closely related to climatic seasonality, which confirms the seasonal cyclical behavior of mosquitoes.

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Keywords: *Ae. aegypti*, population dynamics, last six years, Villa Clara

1. Introduction

Throughout history, humanity has suffered from the scourge of potentially fatal viral and parasitic diseases [1-3], including: Yellow Fever, Dengue, Zika, Chikungunya, Malaria, Chagas, Leishmaniosis, Onchocercosis, Angiostrongylosis, Fasciolosis, among many others, and in most of them, a vector organism is often a common factor [4-6]. These diseases are widespread in the tropics, with local variations in terms of the risk of transmission and dispersal, and are therefore highly dependent on rainfall, temperature and rapid unplanned urbanization, among other factors [7-9].

Since the dawn of civilization, infectious diseases have affected humanity [10-12]. The early history of infectious diseases was characterized by sudden and unpredictable outbreaks, often of epidemic proportions [3,13,14].

A significant group of diseases transmitted by this zoological group (mosquitoes) are capable of infecting and replicating in arthropods as well as in vertebrate hosts [15-17]. Therefore, arboviruses are defined as diseases caused by a virus and transmitted by arthropods [18,19]. These diseases are considered a real problem in several countries, as they limit economic and social development, since mosquitoes play an important role in the transmission of viruses belonging to the families Togaviridae, Flaviviridae, and Bunyaviridae [17,20,21].

Millions of people suffer from arthropod-borne vector-borne infections; Among these, culicids are undoubtedly the most important in terms of hygiene and health [2,22,23], because they are one of the priority health problems in almost all tropical and subtropical regions [24-26] and are responsible for the maintenance and transmission of the pathogens that cause dengue, yellow fever, West Nile fever, Chikungunya, Zika, Malaria and lymphatic filariasis, among other deadly and debilitating infections [25,27-30].

Aedes aegypti Linnaeus, 1762, known as the yellow fever mosquito, is of African origin and the main vector for the transmission of dengue and Zika in our region, although it is also implicated in Chikungunya fever, yellow fever, and several types of encephalitis [17,19,31]. It is a very domestic species that takes advantage of water stored in and around homes, and has therefore adapted to living alongside humans [2,22,32].

Dengue has spread in recent decades and remains the leading arbovirus [10,33,34], while Chikungunya and Zika have emerged in recent years [3,35,36]. Malaria remains the world's leading parasitic health problem [37,38]. An estimated 429,000 deaths were recorded in 2015. Approximately 90% of malaria-related deaths globally occur in Africa, 70% of which are among children under five years of age [22].

The emergence and resurgence of arboviral infections has been a growing phenomenon in the last decade [36,39,40]. The changing epidemiology and the factors responsible for this dramatic resurgence of these diseases are diverse and complex [41-43]. A large proportion of human diseases are zoonotic. Furthermore, demographic, social, and environmental changes, both global and local, have facilitated the transmission and spread of infection to humans [44-46].

In Cuba, the incidence of these entities, both parasitic and viral, undoubtedly constitutes a health problem [47], with a tendency to increase the number of cases, as well as the populations of vector organisms [48-50].

The objective of the research was to analyze the population dynamics of the *Aedes aegypti* mosquito species over the last six years in the province of Villa Clara, Cuba.

2. Materials and Methods

2.1. Study area descriptions

The research was carried out in Villa Clara province, Cuba, whose provincial capital is Santa Clara municipality and covered the 13 municipalities that make up the province. In Villa Clara, specialists from the Provincial Unit for Surveillance and Antivectorial Fight (UPVLA) have recorded 316 370 homes and buildings in the general universe, out of which 236 391 belong to the urban universe (74.7%). They have also registered in such homes or buildings distributed over the 13 municipalities, approximately 1 587 745 water containers with conditions for the breeding, proliferation, and dissemination of the afore-mentioned Culicidae (Figure 1).

Source: Provincial Meteorological Center of Villa Clara

Fig 1: Administrative map of Villa Clara province

2.2. Type of study
An observational, descriptive, ecological, retrospective, and statistical study was conducted using data stored in an Excel database. The study covered the period from 2020 to 2025, encompassing all 13 municipalities of Villa Clara province, Cuba. The total number of *Ae. aegypti* mosquito breeding sites (larval stage) reported by these municipalities during the six years analyzed was entered into this database.

2.3. Methods and techniques for the collection of data
A review of the existing statistical records and archives was made at the Provincial Unit for Surveillance and Antivectorial Struggle (UPVLA) and at the Provincial Department of Health Statistics in Villa Clara, where all the entomological history of the work cycles conceived in the 13 municipalities of the province is compiled. Such information is periodically reported in statistical tables established for such purposes by the National Directorate for Surveillance and Antivectorial Struggle (DNVLA) and the Department of Health Statistics at the Ministry of Public Health (MINSAP).
The information that will be collected is based on the work cycles established for vector surveillance and control, aimed at the focal work with the universe of houses and buildings in the urban and rural areas of the 13 municipalities of the province. Our research, however, will be focused on the urban universe (related to the ecology of the vector under study). The periodicity of the cycles is monthly, in the case of this universe.

2.4. Data analysis and processing
This study analyzes the spatial and temporal dynamics of crime hotspots in Villa Clara province, Cuba, during the period 2020–2025. The primary data come from official records aggregated monthly, organized into two main dimensions:

- **Temporal dimension:** monthly time series (January–December) for each year of the study period.
- **Spatial dimension:** disaggregated by the province's 13 municipalities: Corralillo, Quemado, Sagua la Grande, Encrucijada, Camajuaní, Caibarién, Remedios, Placetas, Santa Clara, Cifuentes, Santo Domingo, Ranchuelo, and Manicaragua.

The integrity of the database was verified, and no imputation of missing data was required for the selected subset.
The graphs presented in this study are derived from direct descriptive statistical operations on the raw data *C*. The mathematical definitions for each visualization are detailed below:

Monthly temporal evolution
This graph represents the monthly fluctuation of the focus to identify seasonal patterns and epidemiological/social peaks.
Variable: $C_{y,m}$ represents the number of cases reported in year *y*, and month *m*.
Dominio:

$$y \in [2020,2025],\ m \in [1,12].$$

Graphic representation: X= {Jan, Feb,…,Dec} $Y_y = C_{y,m}$ $\forall m$ each annual series is plotted as a distinct continuous line to facilitate year-on-year comparison.

Inter-municipal comparison
It allows for the evaluation of the relative burden of each municipality within the province for a given period.
Calculation of municipal totals: for a specific municipality *i* and year *y*, the annual total $T_{i,y}$ is calculated as the cumulative sum of the monthly reports:

$$T_{i,y} = \sum_{m=1}^{12} C_{y,m,i}$$

Visualization: clustered bar chart where the X-axis represents the municipalities ($i = 1 \dots 13$) and the height of the bar corresponds to $T_{i,y}$(o $C_{y,m,i}$ if the view is monthly).

Heat map
Used for the rapid visual detection of "hot spots" where the incidence exceeds critical thresholds.
Data matrix: a matrix *H* of dimensions 6×12 (Years × Months) is constructed.
Color function: the chromatic intensity *I* at the coordinate (y, m) it is a direct function of the magnitude of the case, normalized with respect to the maximum value of the data set (C_{max}): $I(y,m) = \frac{C_{y,m}}{C_{max}} \times 100\%$. The YlOrRd (Yellow-Orange-Red) color spectrum is used, where higher values (intense red) indicate greater focus.

Cumulative ranking (Top 5)
Identify the jurisdictions with the greatest absolute historical burden during the six years of study.
• **Five-Year Cumulative Sum:** for each municipality i, the total sum is calculated

$$S_i: S_i = \sum_{y=2020}^{2025} \sum_{m=1}^{12} C_{y,m,i}$$

- **Selection:** the set is ordered $\{S_i\}$ in descending order and the first 5 elements are extracted: Top 5 = $\{i \mid S_i \in \text{highest 5 values of } \{S_1, \dots, S_{13}\}\}$

Total Annual Trend
Allows for evaluation of the provincial total in each of the study years.
- **Calculation of provincial total:** for a specific municipality i and one year y, the annual total $T_{i,y}$ it is calculated using the formula mentioned above:

$$T_{i,y} = \sum_{m=1}^{12} C_{y,m,i}$$

- **Visualization:** in the graph, the X-axis represents the years ($i = 2020 \dots 2025$) and the Y-axis corresponds to $T_{i,y}$.

Technical References
Statistical processing and graphic generation were performed using Python scripts, prioritizing reproducibility and efficient resource usage:

Matplotlib: rendering of high-resolution scientific graphs.
Tkinter: graphical interface.
Native structures: use of dictionaries and lists for lightweight matrix manipulation.

2.5. Ethical aspects

For the conduct of the research, informed consent was taken into account, as well as the ethical standards that made it possible to promote and ensure respect for all participants in the study, so that their criteria/opinions and individual rights were respected, in order to generate new knowledge without violating the ethical principles of privacy and confidentiality of personal information [51].

3. Results and Discussion

Regarding the municipalities with the highest concentration, Santa Clara stands out as the most prevalent (Figure 2), a result that agrees with previous studies on the matter [9,52,53]. It is followed in order by the municipalities of Placetas, Sagua la Grande, Manicaragua, and Caibarién, which largely coincides with the results obtained in research carried out in this province in previous years [9,41,50], with only slight changes in the position/location of the municipalities of Manicaragua, Ranchuelo, and Caibarién, where the latter now stands out among the five municipalities with the highest concentration, which was not the case in the historical chronology of this province for *Ae. aegypti*.

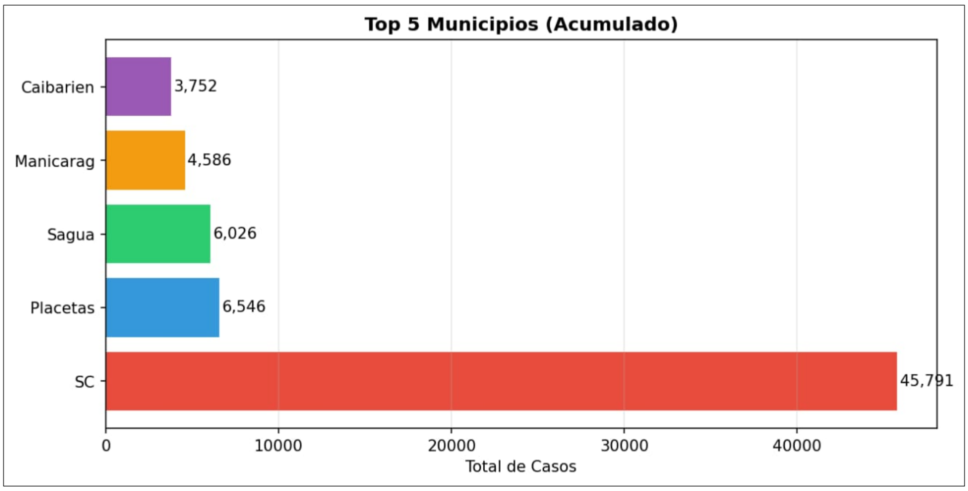


Fig 2: Results of the municipalities with the greatest focus during the study period in the province of Villa Clara

A clearer view of the above is shown in figure 2, which reveals that the municipality of Santa Clara had the highest concentration of cases during the six years of the study, with 2022 being the year with the highest concentration, followed by 2023, and then 2020 and 2021, respectively (Figure 3). These results are consistent with those obtained in previous years in the same province [9,41,54]. It is important to note that this higher concentration in the municipality of Santa Clara is related to its status as an urban area with a higher population density and a deficient supply of potable water. This necessitates the use of numerous and varied water storage containers in homes. Therefore, it is reasonable to consider that urbanization positively impacts the number of reported cases, a finding consistent with results obtained by other authors, both in Cuba and in other countries of the Americas [3,23,41,55].

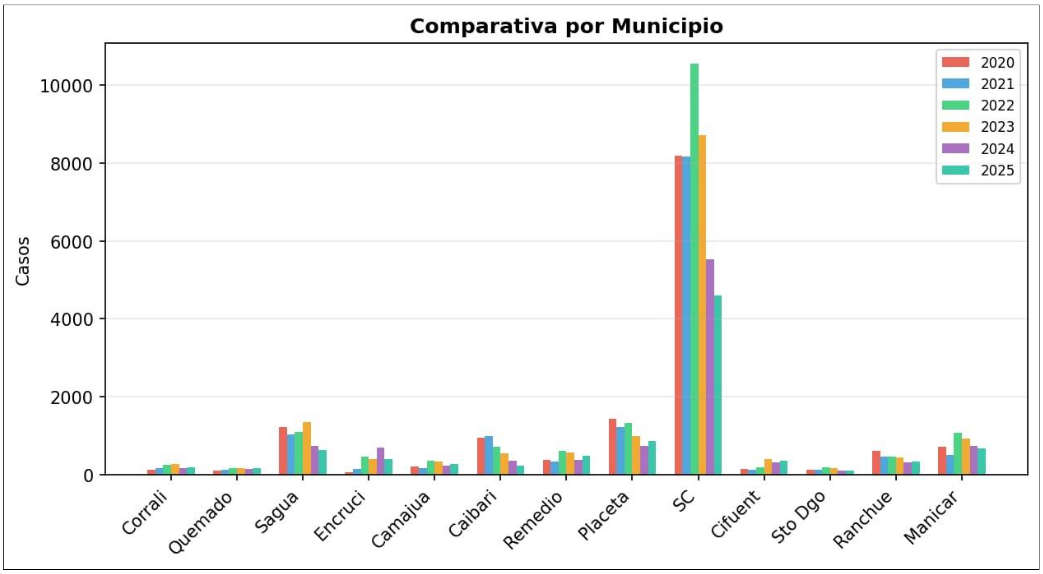


Fig 3: Distribution of *Ae. aegypti* focus by municipalities during the six years of study

In relation with the evolution of monthly focality (Figure 4), the months of June stand out in the following order, followed by November, July, October, September and August; it is worth noting that four of the months with reports of greater focality are located within the rainy period for Cuba, which corresponds to some extent with results obtained in previous years, both for this province, as well as in other localities of the country [9,41,53,55,56], with 2022 being the year with the highest sustained focality for months during the six years that the study covered.

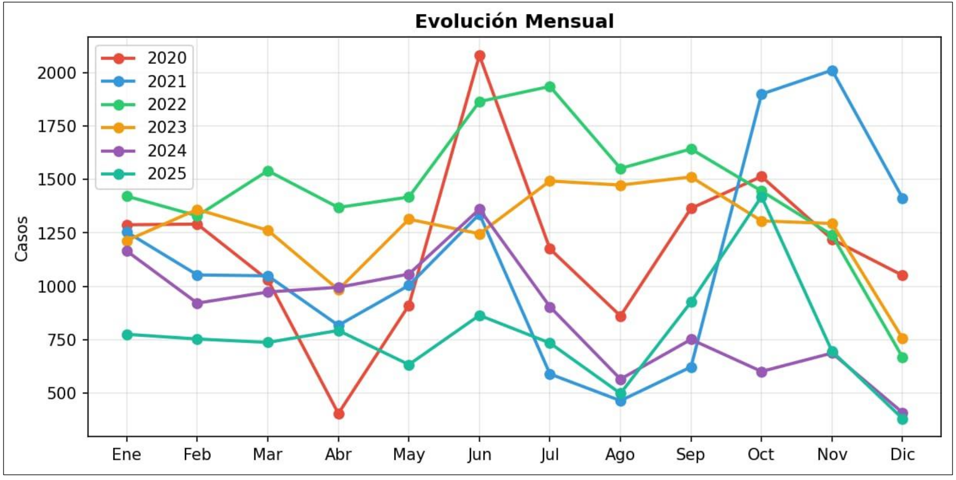
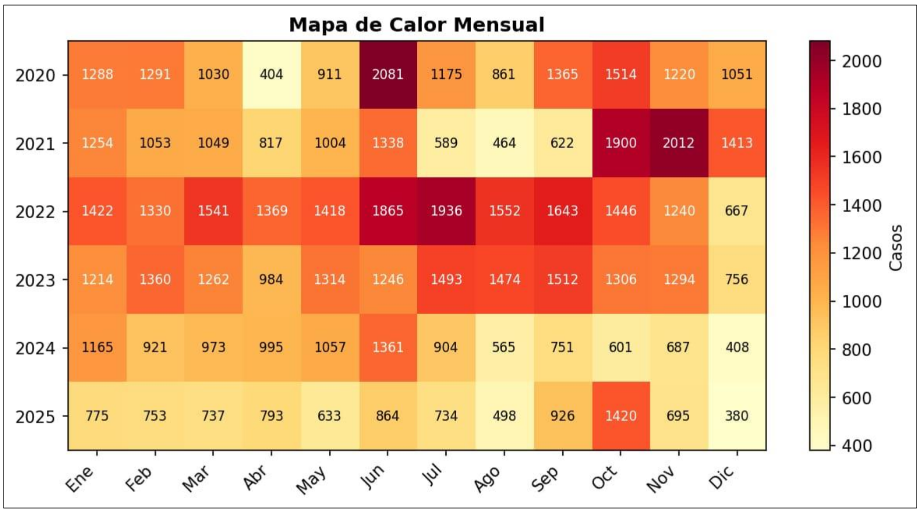


Fig 4: Evolution of focality by month during the six years covered by the study

All of the above is closely related to climatic variables, especially temperature, precipitation, humidity, atmospheric pressure, and wind speed, as demonstrated in previous studies conducted in this province [9,41,50,56]. The marked influence of temperature on mosquito breeding sites, particularly for *Ae. aegypti* (Figure 5), is noteworthy, as it manifests in the shortening of the life cycle. Temperature acts as a catalyst for this cycle, with sustained temperatures above 30°C shortening it from 9-12 days to as little as five days [9,41,50].

Furthermore, there is a marked correlation between the epidemic outbreaks of Dengue and the seasonal periods established for Cuba, since it is precisely in the months of June, November, July, September and October, where the largest epidemic outbreaks of this infectious entity occur, with the occurrence of said outbreaks being more likely in the last four months of the year [50,53,55,56], something very similar occurred in Cuba for the emerging entity Chikungunya (CHIKV), which broke out last year as an epidemic outbreak and with an exponential growth throughout the year.



	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
2020	1288	1291	1030	404	911	2081	1175	861	1365	1514	1220	1051
2021	1254	1053	1049	817	1004	1338	589	464	622	1900	2012	1413
2022	1422	1330	1541	1369	1418	1865	1936	1552	1643	1446	1240	667
2023	1214	1360	1262	984	1314	1246	1493	1474	1512	1306	1294	756
2024	1165	921	973	995	1057	1361	904	565	751	601	687	408
2025	775	753	737	793	633	864	734	498	926	1420	695	380

Fig 5: Map with color contrasts for monthly heat and its relationship with the focus on *Ae. aegypti* during the six years of the study

Figure 6 shows the total annual trend in terms of the focality of *Ae. aegypti* in the province of Villa Clara during the six years covered by the study, showing a downward trend of this variable, which is not a true reflection of the reality in these last four years, after the COVID-19 pandemic, but we can assert that these results confirm the seasonal cyclical behavior of the culicids [9,41,56].

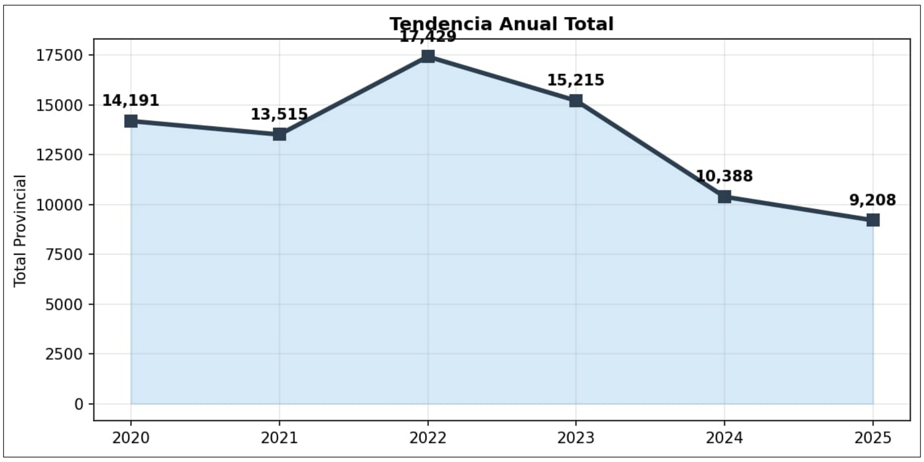


Fig 6: Total annual trend of *Ae. aegypti* focus in Villa Clara province during the six years of the study

4. Conclusion

The overall annual trend in terms of the focality of *Ae. aegypti* in the province of Villa Clara during the six years covered by the study was a decrease in this variable; where it is evident that the arboviral infectious entities have a close relationship with climatic seasonality, which confirms the seasonal cyclical behavior of the culicids.

4.1. Transparency

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study, and that any iscrepancies from the study as planned have been explained.

4.2. Competing Interests

All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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