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Dynamics of the focality of *Aedes aegypti* (Diptera: Culicidae) in the short-term using the objective regressive regression methodology in Villa Clara, Cuba

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Abstract

The early history of infectious diseases was characterized by sudden and unpredictable outbreaks, often of epidemic proportions. The objective of this research was to determine the short-term dynamics of *Aedes aegypti* breeding sites using mathematical modeling, during the period 2010–2025 in Villa Clara province, Cuba. An observational, descriptive, ecological, retrospective, and statistical study was conducted using simple random probability sampling, covering all 13 municipalities of Villa Clara province during the period 2010–2025. The sample consisted of the number of *Ae. aegypti* breeding sites reported by these municipalities during the 16 years analyzed, which were modeled using objective regression analysis. The months of March, June, July, October and November turned out to be those with the greatest focus, with a marked incidence in the months of July and November. Regarding the municipalities with the highest concentration for *Ae. aegypti*, they turned out to be Santa Clara, followed by the municipalities of Placetas, Manicaragua and Sagua la Grande. It is concluded that the presence of the *Aedes aegypti* mosquito species in Villa Clara province shows a short-term trend towards an increase, with almost total consistency across municipalities and throughout the year. Therefore, the entomoepidemiological risk to the entities that transmit this vector organism is also high.

Keywords: *Aedes aegypti;* Short term; Focus dynamics; Objective Regressive Regression; Villa Clara

1. Introduction

Since the beginning of civilization, infectious diseases have affected humans [1-3]. The early history of infectious diseases was characterized by sudden and unpredictable outbreaks, often of epidemic proportions [4-6].

Throughout history, humanity has suffered from the scourge of potentially fatal viral and parasitic diseases, including Yellow Fever, Dengue, Zika, Chikungunya, Malaria, Chagas disease, Leishmaniosis, Onchocercosis, Angiostrongylosis, and Fasciolosis, among many others. In most of these diseases, a vector organism is often a common factor [7-9]. These diseases are widespread in the tropics, with local variations in risk, and are therefore highly dependent on factors such as rainfall, temperature, and rapid, unplanned urbanization [10-12].

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Millions of people suffer from infections transmitted by arthropod vectors; among these, culicids are undoubtedly the most important in terms of hygiene and health, because they are one of the prioritized health problems in almost all tropical and subtropical regions [13-15] and are responsible for the maintenance and transmission of the pathogens that cause Dengue, Yellow fever, West Nile fever, Chikungunya, Zika, Malaria, and Lymphatic filariosis, among other deadly and debilitating infections [16-18].

Dengue fever has spread in recent decades and continues to be the main arbovirus [19-21] and Chikungunya and Zika have emerged in recent years [6,22,23]. Malaria remains the world's leading parasitic health problem [24,25]. An estimated 430 000 deaths were registered in 2024. About 90% of malaria-related deaths globally, occur in Africa, 70% of which happen in children under five years old [8,12,26].

The emergence and re-emergence of arboviral infections are a growing phenomenon in the last decade. The changing epidemiology and the factors responsible for this dramatic resurgence of such diseases are complex [27-29]. A large proportion of human diseases are zoonotic. In addition, global and/or local demographic, social, and environmental changes have led to the spread of infection to humans [15,30,31].

In Cuba, the incidence of these entities, both parasitic and viral, is undoubtedly a health problem [32], with a tendency to increase the number of cases, as well as the populations of vector organisms [3,25,33].

The objective of the research was to determine the dynamics of the focality for *Aedes aegypti* in the short term through mathematical modeling, during the period 2010-2025 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

Figure 1 Administrative map of Villa Clara province

2.2. Type of study

An observational, descriptive, ecological, retrospective, and statistical study was conducted using simple random probability sampling during the period from 2010 to 2025, covering the 13 municipalities of the Villa Clara province. The sample consisted of the number of *Ae. aegypti* infestations reported by these municipalities during the 16 years analyzed.

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. Regarding the Objective Regression Methodology (ROR)

To work with the Objective Regression Method (ROR) [34], a database is required. This database is organized by arranging the data in ascending chronological order. Then, in the first step, dichotomous variables DS, DI, and NoC are created, where:

NoC: Number of cases in the database,

DS = 1 if NoC is odd; DI = 0 if NoC is even. When DI=1, DS=0, and vice versa.

DS represents a sawtooth function, and DI represents the same function but inverted, such that the variable to be modeled is trapped between these parameters, thus explaining a large amount of variance.

Next, the curves are modeled, and finally, the regressed variables with the greatest impact are added. Subsequently, the Regression analysis module of the SPSS statistical package version 19.0 (IBM Company) will be executed, specifically the ENTER method where the predicted variable and the ERROR are obtained.

Next, the autocorrelograms of the ERROR variable were obtained, paying attention to the peaks of the significant partial autocorrelations (PACF). The new variables were then calculated considering the significant lag of the PACF. Finally, these regressed variables were included in the new regression in a process of successive approximations until white noise was obtained in the regression errors.

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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 [35].

3. Results and Discussion

Table 1 shows the descriptive statistics for the number of light bulbs per month, where we can see the maximum value per column in red and the minimum in green. Therefore, the maximum of the mean value corresponds to October and the minimum to December. The month with the greatest variability was October and the month with the least was May; results that coincide with those of other authors in previous years [3,9,12].

Table 1 Descriptive statistics for the number of hotspots per month in the province of Villa Clara, Cuba. 2010-2025

	N	Minimum	Maximum	Media	Standard deviation
Year	238	2010	2026	2018.00	4.909
January	225	.0	1522.0	127.431	293.3698
February	225	.0	1360.0	115.484	264.4775
March	225	.0	1541.0	109.262	258.3486
April	225	.0	1909.0	106.578	279.8831
May	225	.0	1420.0	111.360	258.0832
June	225	.0	2081.0	153.262	341.6121
July	225	.0	1936.0	119.662	273.4179
August	225	.0	2547.0	131.040	329.3270
September	225	.0	1643.0	138.631	312.8787
October	225	.0	1900.0	161.751	353.8550
November	224	.0	2012.0	141.366	315.7494
December	225	.0	1413.0	97.138	226.5387
Total	224	.0	17429.0	1519.089	3256.8633
Valid N (by list)	223				

It can be seen that the correlations between all months and the total (Tables 2-4) were highly significant (99%) for all months. Therefore, in our strategy, we performed ROR modeling of the totals and used simple regressions to calculate the models for the months in question. The year variable had a significant correlation, at 95%, with the months of March and May [26,29,36].

Table 2 Correlation between the months of January-April with the total

		Year	January	February	March	April	Total
Year	Pearson correlation	1	0.089	0.100	0.134*	0.021	0.087
	Sig. (bilateral)		0.182	0.133	0.045	0.757	0.194
	N	238	225	225	225	225	224
Jan	Correlation of Pearson	0.089	1	0.971**	0.917**	0.761**	0.934**
	Sig. (bilateral)	0.182		0.000	0.000	0.000	0.000
	N	225	225	225	225	225	224
Feb	Correlation of Pearson	0.100	0.971**	1	0.956**	0.791**	0.965**
	Sig. (bilateral)	0.133	0.000		0.000	0.000	0.000
	N	225	225	225	225	225	224
March	Correlation of Pearson	0.134*	0.917**	0.956**	1	0.810**	0.960**
	Sig. (bilateral)	0.045	0.000	0.000		0.000	0.000
	N	225	225	225	225	225	224

April	Correlation of Pearson	0.021	0.761**	0.791**	0.810**	1	0.853**
	Sig. (bilateral)	0.757	0.000	0.000	0.000		0.000
	N	225	225	225	225	225	224
Total	Correlation of Pearson	0.087	0.934**	0.965**	0.960**	0.853**	1
	Sig. (bilateral)	0.194	0.000	0.000	0.000	0.000	
	N	224	224	224	224	224	224
* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).							

Table 3 Correlation between the months of May-July and the total

		Year	**May**	**June**	**July**	**Total**
Year	Correlation of Pearson	1	0.132*	0.113	0.127	0.087
	Sig. (bilateral)		0.047	0.091	0.057	0.194
	N	238	225	225	225	224
May	Correlation of Pearson	0.132*	1	0.933**	0.952**	0.958**
	Sig. (bilateral)	0.047		0.000	0.000	0.000
	N	225	225	225	225	224
June	Correlation of Pearson	0.113	0.933**	1	0.927**	0.956**
	Sig. (bilateral)	0.091	0.000		0.000	0.000
	N	225	225	225	225	224
July	Correlation of Pearson	0.127	0.952**	0.927**	1	0.947**
	Sig. (bilateral)	0.057	0.000	0.000		0.000
	N	225	225	225	225	224
Total	Correlation of Pearson	0.087	0.958**	0.956**	0.947**	1
	Sig. (bilateral)	0.194	0.000	0.000	0.000	
	N	224	224	224	224	224
* The correlation is significant at the 0.05 level (2 tails).						
** Correlation is significant at the 0.01 level (2-tailed).						

Table 4 Correlation between the months of August-December with the total

		Year	August	Sept.	October	Nov.	December	Total
Year	Correlation of Pearson	1	-0.005	0.050	0.093	0.063	0.003	0.087
	Sig. (bilateral)		0.938	0.455	0.166	0.351	0.960	0.194
	N	238	225	225	225	224	225	0.224
August	Correlation of Pearson	-0.005	1	0.925**	0.781**	0.705**	0.620**	0.854**
	Sig. (bilateral)	0.938		0.000	0.000	0.000	0.000	0.000
	N	225	225	225	225	224	225	224

Sept	Correlation of Pearson	0.050	0.925**	1	0.866**	0.830**	0.771**	0.944**
	Sig. (bilateral)	0.455	0.000		0.000	0.000	0.000	0.000
	N	225	225	225	225	224	225	224
Oct	Correlation of Pearson	0.093	0.781**	0.866**	1	0.951**	0.875**	0.943**
	Sig. (bilateral)	0.166	0.000	0.000		0.00	0.000	0.000
	N	225	225	225	225	224	225	224
Nov	Correlation of Pearson	0.063	0.705**	0.830**	0.951**	1	0.947**	0.930**
	Sig. (bilateral)	0.351	0.000	0.000	0.000		0.000	0.000
	N	224	224	224	224	224	224	223
Dec	Correlation of Pearson	0.003	0.620**	0.771**	0.875**	0.947**	1	0.880**
	Sig. (bilateral)	0.960	0.000	0.000	0.000	0.000		0.000
	N	225	225	225	225	224	225	224
Total	Correlation of Pearson	0.087	0.854**	0.944**	0.943**	0.930**	0.880**	1
	Sig. (bilateral)	0.194	0.000	0.000	0.000	0.000	0.000	
	N	224	224	224	224	223	224	224

* The correlation is significant at the 0.01 level (2 tails).
Abbreviators: Sept. (September), Oct. (October), Nov. (November), Dec. (December).

The main statistics of the model showed that the explained variance R was 99.4%, with errors of 401.7 foci, which are relatively small compared to the variability of the standard deviation of the foci. The ANOVA test yielded a highly significant Fisher's F-statistic (99%), with a value of 881.74.

In the case of the model coefficients, the trend (NoC) was found to be negative but not significant (Table 5). The model depends on the regressed foci in 14 cases, 9 cases, and 5 cases, so the non-significant parameters were left in the model, as they contribute to the explained variance.

Figure 1 shows the histogram of the short-term model residuals, where it can be seen that they do not differ from the normal distribution.

Table 5 Results of the short-term model coefficients

Coefficients[a, b]						
Model		**Non-standardized coefficients**		**Standardized coefficients**	**t**	**Sig.**
		B	**Standard error**	**Beta**		
1	DS	114.360	70.738	0.022	1.617	0.108
	DI	29.755	70.460	0.006	0.422	0.673
	NoC	-0.547	0.479	-0.020	-1.142	0.255
	Step182	4036.401	438.826	0.077	9.198	0.000
	Step196	-2080.031	458.228	-0.040	-4.539	0.000
	Step56	-6272.841	426.778	-0.120	-14.698	0.000
	Step51	-5478.225	421.641	-0.105	-12.993	0.000
	Step210	-4697.393	446.413	-0.090	-10.523	0.000
	Step70	3135.044	409.868	0.060	7.649	0.000

	Step93	-2818.454	414.460	-0.054	-6.800	0.000
	Step205	-3684.882	429.285	-0.070	-8.584	0.000
	Step42	2918.407	420.477	0.056	6.941	0.000
	Step140	2882.325	425.802	0.055	6.769	0.000
	Step191	-2421.659	437.930	-0.046	-5.530	0.000
	Step65	2230.636	407.033	0.043	5.480	0.000
	Step112	2535.747	414.498	0.048	6.118	0.000
	Lag14Total	0.998	0.013	1.005	74.615	0.000
	Lag5Total	-0.003	0.010	-0.003	-0.332	0.741
	Lag9Total	0.034	0.011	0.034	3.091	0.002

a. Dependent variable: Total

b. Linear regression through the origin

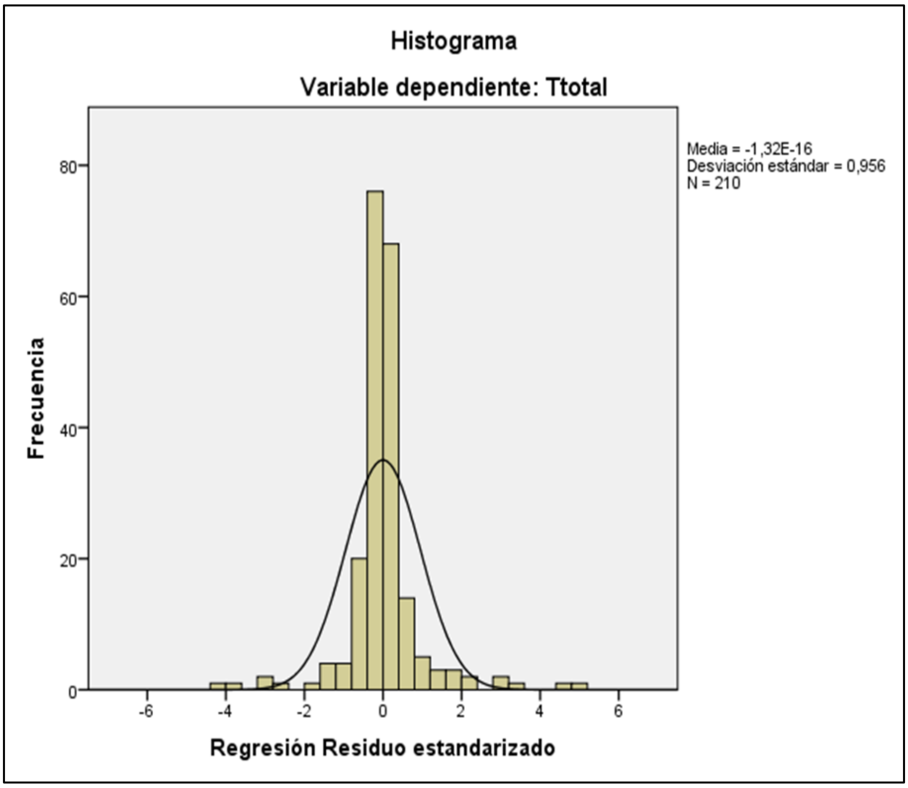

Figure 2 Histogram of waste from all sources in the short term. Villa Clara 2010-2025

Figure 2 shows how the model works with its respective real data and the short-term forecasts, results that agree with those obtained by other authors on the matter, as well as in other infectious entities [9,23,37,38].

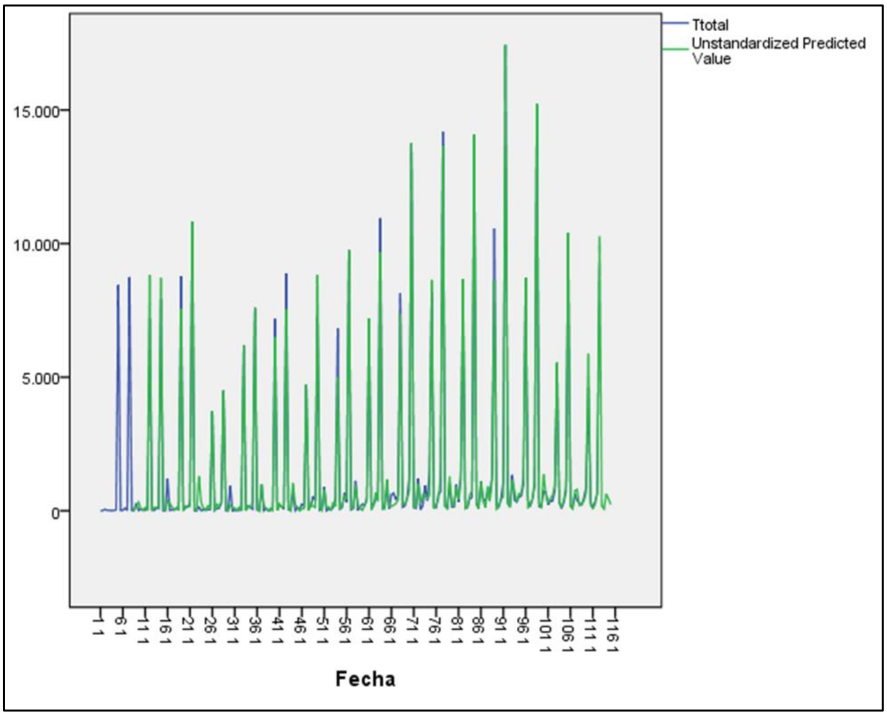

Figure 3 Actual Value vs. Forecast of Total Focus Areas in the short term

Table 6 shows the key statistics for the light bulbs by month, where the explained variances were high and the errors small. The Durbin-Watson statistic was close to 2 in all models, which is very beneficial for the model, as it indicates that a good model is obtained with the independent variables. For this reason, we used the value predicted by the model for the total light bulbs as the independent variable for the monthly models; in all cases, this variable was significant, something we already knew from the high correlation of the total light bulbs with each month.

The months of March, June, July, October and November turned out to be those with the greatest focus, results that coincide with those obtained for this same province in previous years [9,21,39], with a marked incidence in the months of July and November historically [21,23,39].

Table 6 Key statistics of the model by month. Villa Clara 2010-2025

Months	R (%) Variance Explained	Model error	Durbin Watson	F de Fisher	Signification
January	93.5	116.05	1.745	360.234	0.00
February	96.2	81.37	1.590	636.280	0.00
March	98.0	90.36	1.722	478.36	0.00
April	92.7	93.90	1.862	315.37	0.00
May	94.4	95.57	1.657	421.11	0.00
June	94.0	130.83	1.651	396.90	0.00
July	93.2	111.18	1.643	342.60	0.00
August	84.6	194.39	1.879	130.64	0.00
September	92.3	133.46	1.764	296.59	0.00
October	93.1	144.69	1.837	339.20	0.00
November	92.2	135.59	1.744	293.87	0.00
December	89.3	111.61	1.791	202.64	0.00
Total	99.4	401.72	1.939	881.74	0.00

Regarding the municipalities with the highest concentration (Table 7) for *Ae. aegypti*, they turned out to be: Santa Clara (provincial capital), followed by the municipalities of Placetas, Manicaragua and Sagua la Grande, results that also agree with those achieved in previous studies [9,21,39].

Table 7 Case summaries/focalities for *Ae. aegypti* in Villa Clara province

Case summaries[a]						
		Year	**Municipalities**	**Total**	**Unstandardized Predicted Value**	**Unstandardized Residual**
1		2026	Corralillo	.	185.33072	210.15594
2		2026	Quemado	.	71.75643	95.30608
3		2026	Sagua	.	638.08371	647.62201
4		2026	Encrucijada	.	446.49827	335.31975
5		2026	Camajuaní	.	237.30391	288.19044
6		2026	Caibarien	.	.	165.23997
7		2026	Remedios	.	.	498.83939
8		2026	Placetas	.	.	813.32193
9		2026	Santa Clara	.	.	4671.69987
10		2026	Cifuentes	.	.	288.84040
11		2026	Santo Dgo	.	.	110.07615
12		2026	Ranchuelo	.	.	281.78542
13		2026	Manicaragua	.	.	681.20231
14		2026	Totales	.	.	9261.34617
Total	N	14	14		5	14
a. Limited to the first 100 cases.						

Abbreviators: Dgo: Domingo.

4. Conclusion

The presence of the *Aedes aegypti* mosquito species in Villa Clara province shows a short-term trend towards an increase, with almost total consistency across municipalities and throughout the year. Therefore, the entomoepidemiological risk to the entities that transmit this vector organism is also high.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no area of conflict of interest.

Statement of ethical approval

Ethical standards were taken into account to promote and ensure respect for all participants in the study, in order to generate new knowledge without violating the ethical principles of privacy and confidentiality of personal information.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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