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ARTICLE

Aedes albopictus (Skuse, 1894) (Diptera: Culicidae) a mosquito species to be kept under surveillance in Cuba

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Abstract:
Millions of people suffer from infections transmitted by arthropod vectors; among them, culicidae are undoubtedly the most important hygienic-sanitary ones, because they constitute one of the priority health problems in almost all tropical and subtropical regions. The objective of the research consisted in analyzing the development dynamics of mosquito populations of the *Aedes albopictus* species in Villa Clara province, Cuba during the period 2016-2020. The research covered the 13 municipalities of Villa Clara. An observational, descriptive, ecological, retrospective and analytical statistical (by decision tree/exploratory data analysis) study was conducted. The study was based on the collection of positive samples/number of outbreaks reported in the 13 municipalities of the province, in the different months of the period analyzed, for the mosquito species *Ae. albopictus*, where each sample point corresponded to the number of specimens collected in one of the years covered, with one of the months of the year in question (12 months), the 13 municipalities, and one type of reservoir (9 types of reservoirs). This resulted in 7 020 observations, which constitutes the sample size. The low presence of the species under analysis was observed, with very low population densities; on the other hand, the variables with the greatest impact on population dynamics were municipality and type of reservoir, with emphasis on the surveillance system and the low tank, as the preferred oviposition and breeding sites for this species. It is concluded that *Ae. Albopictus* has a high adaptive capacity and high ecological plasticity, with a marked correspondence between the ecology and habitat of the species under analysis.
Key words: *Aedes albopictus*, decision tree, Cuba, population dynamics, surveillance.

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1 | INTRODUCTION

Millions of people suffer from infections transmitted by arthropod vectors; among them, culicines are undoubtedly the most important hygienic-sanitary ones, because they constitute one of the priority health problems in almost all tropical and subtropical regions (1), (2), (3) and are responsible for the maintenance and transmission of pathogens that cause Dengue, Yellow Fever, West Nile Fever, Chikungunya, Zika, Malaria, Lymphatic Filariosis, among other deadly and debilitating infections (4), (5), (6).

Dengue has spread in recent decades and continues to be the leading arbovirosis (7), (8), (9) and have emerged, Chikungunya and Zika in recent years (10), (11), (12), with a marked irruption of Zika virus in the European continent, transmitted by the mosquito species *Ae. Albopictus* (13), (14), (15), (16), (17).

The emergence and re-emergence of arboviral infections are an increasing phenomenon in this last decade (3), (14), (18). The changing epidemiology and factors responsible for this dramatic resurgence of such diseases are complex (19), (20), (21). A large proportion of diseases of humans are zoonotic. In addition, global and/or focal demographic, social and environmental changes have led to the spread of infection to humans (20), (22), (23). In Cuba, the incidence of these entities, both parasitic and viral, is undoubtedly a health problem (24), with a tendency to increase the number of cases, as well as the populations of vector organisms (20), (25), (26), (27), (28), (29). The objective of the research was aimed at analyzing the development dynamics of *Ae. Albopictus* mosquito populations in Villa Clara province, Cuba during the period 2016-2020.

2 | METHODS

2.1. Study area

The research was carried out in the province of Villa Clara, Cuba, whose provincial capital is the municipality of Santa Clara and covered the 13 municipalities that make up the province, which is located in the central region of the island of Cuba (Latitude: 22º 29'40" N, Longitude: 79º28'30" W). In Villa Clara province, specialists of the Provincial Unit of Surveillance and Antivectorial Control (UPVLA) have registered about 316 370 dwellings and/or premises in the general universe, of which 236 391 belong to the urban universe (74.7%) and an average of approximately 1 581 850 tanks used for water storage in these dwellings and/or premises, with conditions for the breeding, proliferation and dissemination of culicidae of this species distributed in the 13 municipalities.

2.2 Type of study

Observational, descriptive, ecological, retrospective and analytical-statistical study (based on multivariate analysis, by means of decision tree/exploratory data analysis), in the period from 2016 to 2020.

2.3 Population

The population of mosquitoes of the species *Ae. Albopictus* (adult phase) of the 13 municipalities that make up the province Villa Clara, Cuba (2016 to 2020).

2.4 Sample

The results of the collection of positive samples/number of outbreaks reported in the 13 municipalities of Villa Clara province, in the different months of the period analyzed (2016-2020), of the Ae. Albopictus mosquito species in the adult phase are presented.

Each sample point (observation) corresponds to the number of specimens collected in one of the years comprised, between 2016 and 2020 (5 years), with one of the months of the year in question (12 months), one municipality of Villa Clara province (13 municipalities) and one type of reservoir (9 types of reservoirs). This resulted in 7 020 observations, which constitutes the sample size. (The sample size was calculated by the generalized multiplication theorem; that is, by multiplying the number of years by the number of months, by the number of municipalities and by the number of types of deposits ($5^x12^x13^x9=7\ 020$).

2.5 Type of sampling used

Census sampling, which attempts to include the entire population of adult mosquitoes living in the urban universe, although only those detected by vector control workers are included.

2.6 Methods and techniques for the collection of information

The documentary review of the records and statistical files existing in the Provincial Unit of Surveillance and Vector Control (UPVLA) and in the Provincial Department of Health Statistics of Villa Clara, where the entire entomological history of the work cycles conceived in the 13 municipalities of the province is compiled, which is periodically reported in statistical tables established for such purposes by the National Directorate of Surveillance and Vector Control (DNVLA) and the Department of Health Statistics of the Ministry of Public Health (MINSAP).

The information collected is based on the work cycles established for surveillance and vector control, aimed at focal work in the universe of dwellings and premises in urban and rural areas of the 13 municipalities of the province, but in the case of our research it was 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.

2.7 Information processing

The data were organized by means of the Windows Excel application, by years and months; that is, 11 columns were placed: the first one with the municipalities and the provincial accumulated, the remaining ones with the years and their respective focus.

The second had a total of 14 columns; the first with the years and the average focal point, while the following 12 columns represent the months with their respective focal point and the last one, the total by years, in each of the municipalities of the province. After organizing the data, we proceeded to obtain the time series and trend for each of the variables mentioned, which was reflected in the figures prepared for all the municipalities, according to the variables under analysis.

The following were considered as independent variables: Year, Month, Municipality and Type of deposit, while the dependent or predictor variable was the number of adult Ae. Albopictus specimens/specimens. The statistical technique used was the decision tree, from which a classification model of the observations was created by considering the influence of the independent variables included in the study.

The method used to grow the tree was the exhaustive CHAID (Chi-square automatic interaction detector), which is an algorithm that allows the automatic detection of interactions by means of Chi-square. At each step, CHAID chooses the independent variable (predictor) that has the strongest interaction with the dependent variable. The categories of each predictor are merged if they are not significantly different with respect to the dependent variable. The comprehensive analysis indicates that all possible splits for each predictor variable are examined, and treats all variables equally, regardless of the type and number of categories.

The depth of the tree was chosen in advance with a value of three (three levels). As restrictions, the minimum number of cases in a parent node was taken as 100 and in a branch node as 50.

3 | RESULTS

The results of the collection of positive samples of adult mosquitoes of the species *Ae. Albopictus* during the period from 2016 to 2020 in the province of Villa Clara are presented. Each sampling point (observation) corresponds to the number of adult individuals collected in one of the years between 2016 and 2020 (5 years), one of the months of the year in question (12 months), one municipality of Villa Clara province (13 municipalities) and one type of reservoir (9 types of reservoirs). This results in 7020 observations, which constitutes the sample size. (The sample size is calculated by the generalized multiplication theorem, i.e. multiplying the number of years by the number of months, by the number of municipalities by the number of deposit types 5·12·13·9=7 020.

The number of adult individuals collected in each observation was considered as the dependent variable. Four independent or predictor variables were considered: year, month, municipality and type of deposit where the adult individuals were collected.

The statistical technique used was the decision tree, from which a classification model of the observations was created by considering the influence of the independent variables included in the study.

The method used to grow the tree was the exhaustive CHAID (Chi-square automatic interaction detector), which is an algorithm that allows the automatic detection of interactions by means of Chi-square. At each step, CHAID chooses the independent variable (predictor) that has the strongest interaction with the dependent variable. The categories of each predictor are merged if they are not significantly different with respect to the dependent variable. The adjective exhaustive indicates that all possible splits for each predictor variable are examined and treats all variables equally, regardless of the type and number of categories.

The depth of the tree was chosen in advance with a value of three (three levels). As restrictions, the minimum number of cases in a parent node was taken as 100 and in a branch node as 50. In the result, the following were obtained as variables of influence: year, type of deposit, municipality and month. In other words, all the variables considered influenced the model. The variable: year was forced to be the first predictor variable, so it gives rise to the first level of the tree. This was done to begin with an analysis of the temporal evolution of the distribution of adult individuals of *Ae. Albopictus* in the period analyzed.

Although all variables acted as predictors, little regularity is observed in their location in the classification tree. From the second level of the tree onwards, there is no single predictor variable per level, unlike how it was obtained in the decision tree for the population dynamics of *Ae. aegypti* (3). As a result, a total of 54 nodes were obtained, of which 36 are terminal. From here on in the text, nodes will be referred to with a capital N followed by the node number (Figure 1).

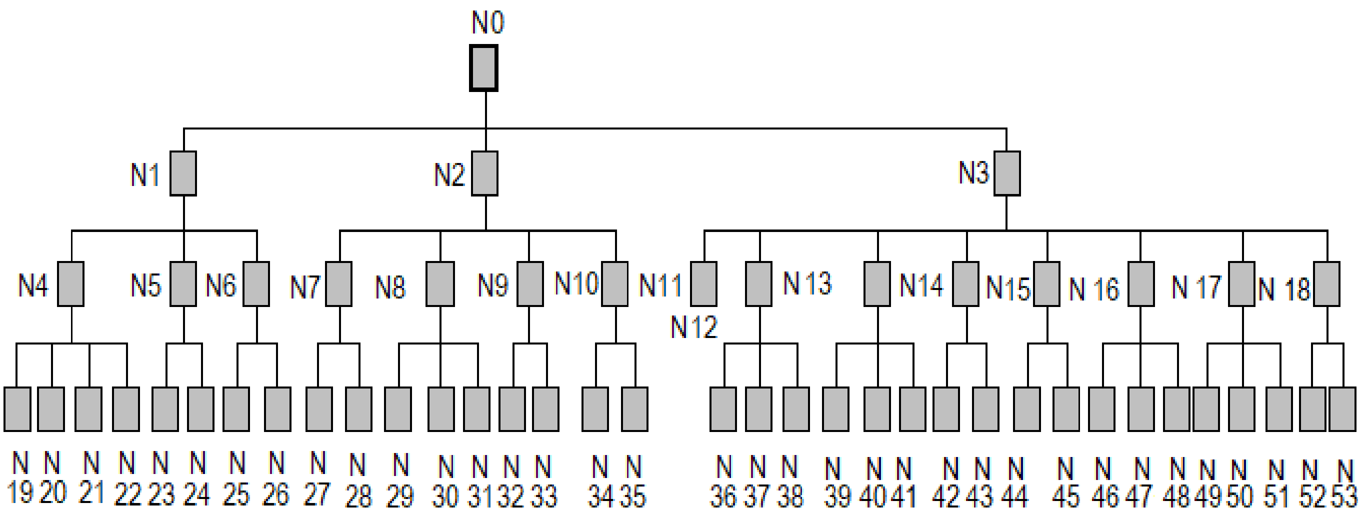

Fig. 1: *Decision tree map*

Analysis of level zero

N0 includes the total number of observations n=7020. The mean was 2,402 individuals per observation and the standard deviation was approximately 8,756. This indicates that there is a large variability in the samples collected (the number of individuals collected varies greatly from one observation to another). However, a comparison with the results achieved for *Ae. aegypti* under these same conditions shows that both the mean and variance are much lower for Ae. Albopictus.

For N0: the mean was 2.402, however, the median is zero. The range of 178, indicating the existence of several extreme points far away from the center of the data.

Analysis of the first level of the tree

From N0, starting from the first predictor variable "year", three nodes are derived: N1, N2 and N3.

N1: This node corresponds to the year 2016, it includes 1 404 observations, which represents 20% of the total observations made in the five years. The mean is 4.509 individuals per observations and the standard deviation is 14.548; indicating high variability (Figure 2).

N2: corresponds to the year 2017 also includes 1.404 observations representing 20% of the total. The mean is 2.330 individuals per observations and the standard deviation is 7.601.

N3: Corresponds to the years of 2018, 2019 and 2020. It includes 4.212 observations. The mean was 1.723 individuals per observation, the standard deviation is 6.006.

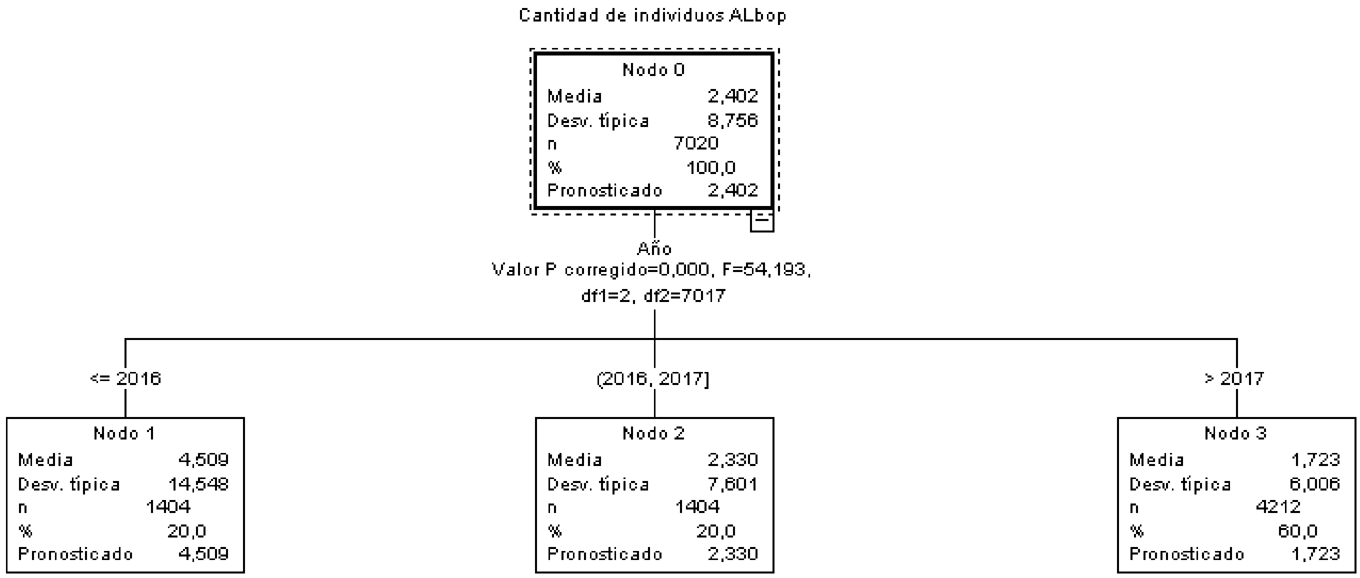

Fig. 2: *First level of the decision tree*

On the other hand, variability, although high, has also been decreasing over time. This variability indicates that there is high diversification in terms of the action of the independent variables by groups of observations.

Analysis of the second level of the decision tree

The second level does not have a single predictor variable, but rather the predictor variable is different for the different parent nodes (Figure 2).

Year 2016 "N1"

N1 gives rise to two nodes: N4, N5 and N6. The predictor variable was the type of tank.

N4: groups low tank, other, destroyed artificial and non-destroyed artificial. The mean is 3.503 and the standard deviation is 6.673.

N5: groups together: elevated tank, cistern, natural tanks and liquid waste, with a mean of 0.196 and standard deviation of 0.726.

N6: only located: surveillance. The mean is 25.788 and the standard deviation is 34.642.

The most alarming results are obtained for the surveillance tank type (N6), with a mean much higher than the other two nodes in which the mean is below 4. This suggests that the detection of the vector in the rest of the reservoir types is not adequate; perhaps there is a lack of experience for its detection.

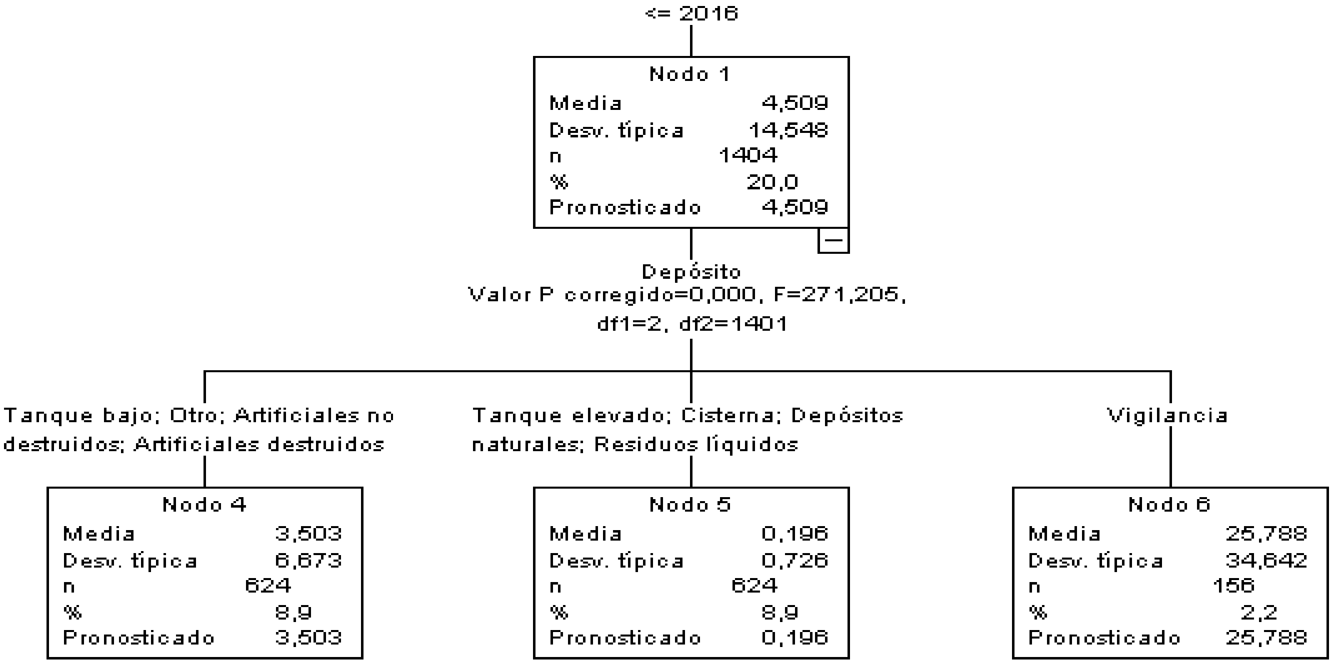

***Fig 3:** Second level of the decision tree for the year 2016*

Year 2017

N2 gives rise to three nodes: N7, N8, N9 and N10. The predominant predictor variable for node differentiation was deposit type (Figure 4).

The mean values for N7, N8 and N9 are below 4, observing a mean value of 8.827 for the surveillance deposit, which is located in N10. As in 2016, the surveillance deposit offers the highest mean values for the number of individuals collected.

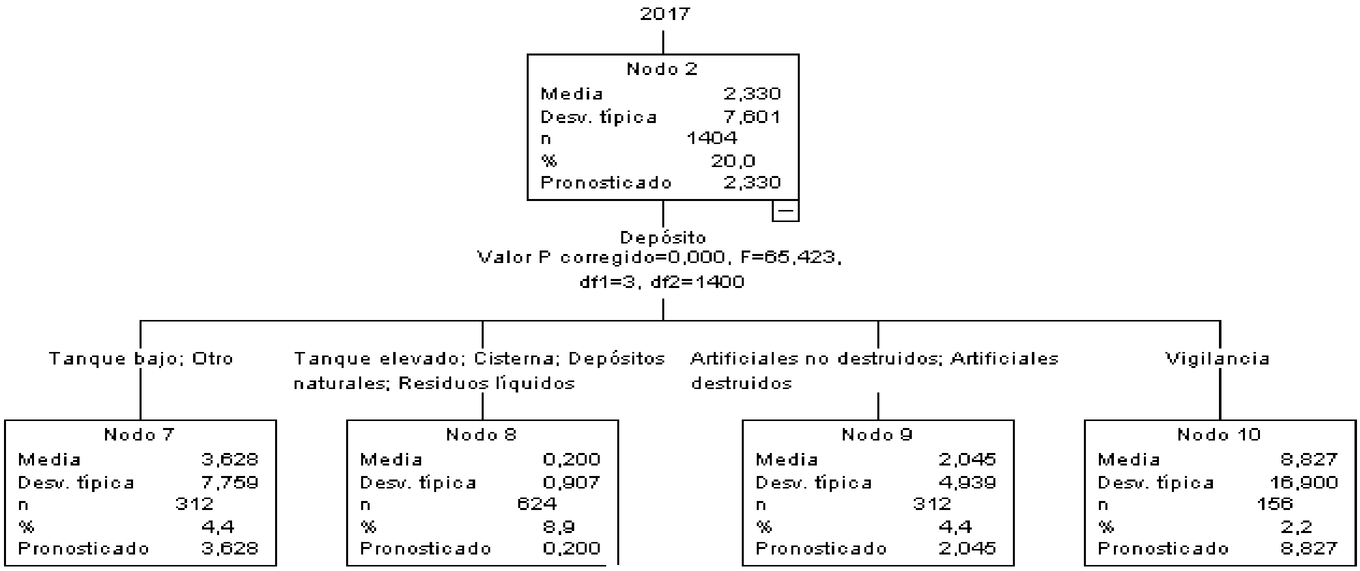

***Fig 4:** Second level of the decision tree for 2017*

Years 2018, 2019 and 2020

N3 gives rise to three nodes from N11 to N18. The predictor variable was municipality (Figure 5).

Of these nodes, four present means below zero, indicating very little presence of the vector these is for the nodes:

- N11 with mean 0.009 (Corralillo).

- N12 with a mean of 0.772 for the municipalities of Quemado and Santa Clara.
- N16 (Caibarién and Manicaragua) with mean 0.461.
- N18 (Santo Domingo) with mean 0.142.

For the municipalities included in these nodes, the mean values indicate that practically no vector samples were collected.

This is followed by nodes N13 and N15 with means of 1.195 and 1.744 respectively, also with very few individuals collected.

The municipalities with the highest number of individuals collected were Encrucijada (N14) with a mean of 5.596 and Cifuentes, the most affected with a mean of 7.657.

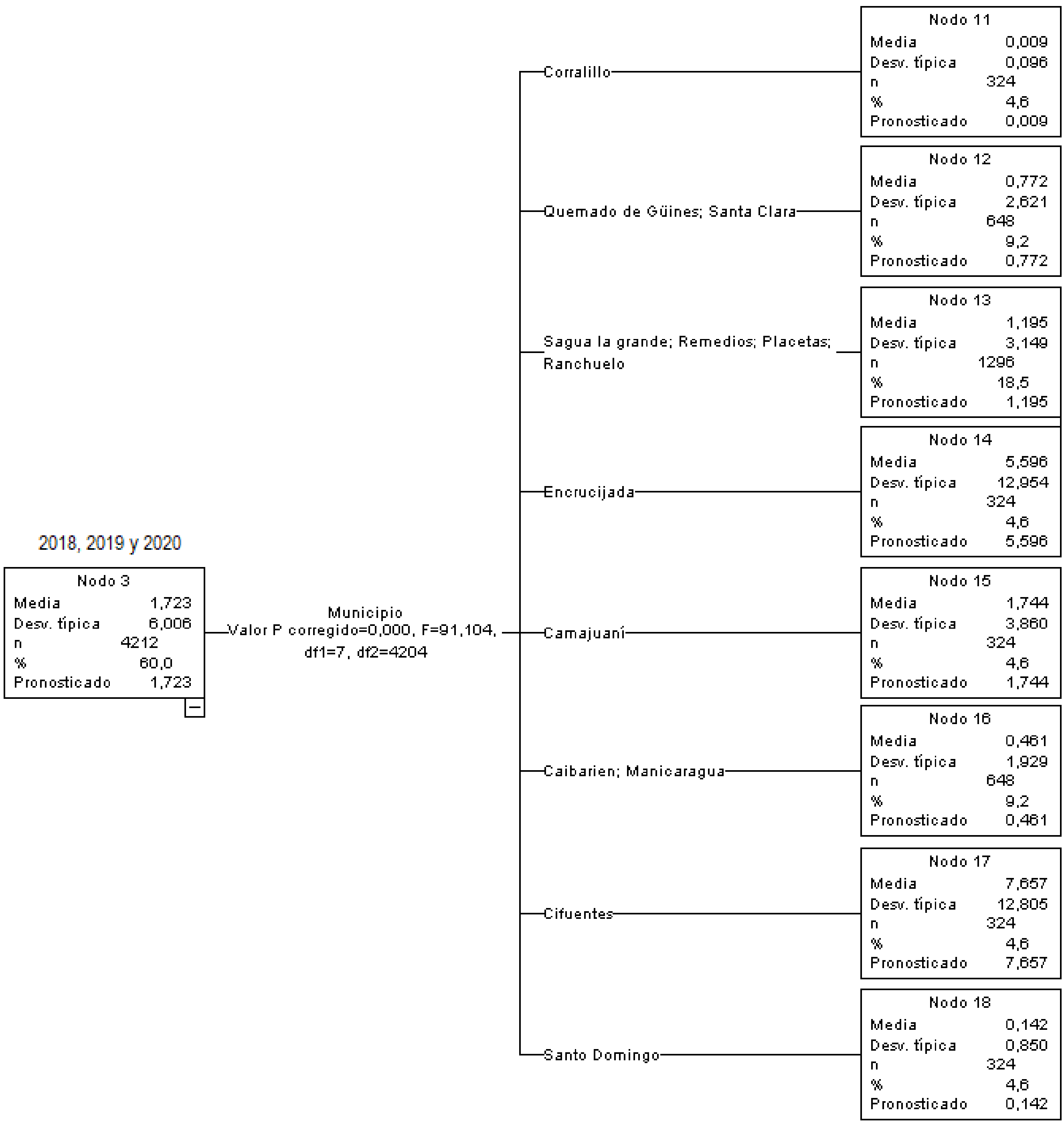

Fig. 5: *Second level of the decision tree for the period of years 2018, 2019 and 2020*

Analysis of the third level of the decision tree

Regarding the third level of the decision tree, little regularity is observed (Figure 6). From N4 four nodes are derived from N19 to N22, the predictor variable was municipality.

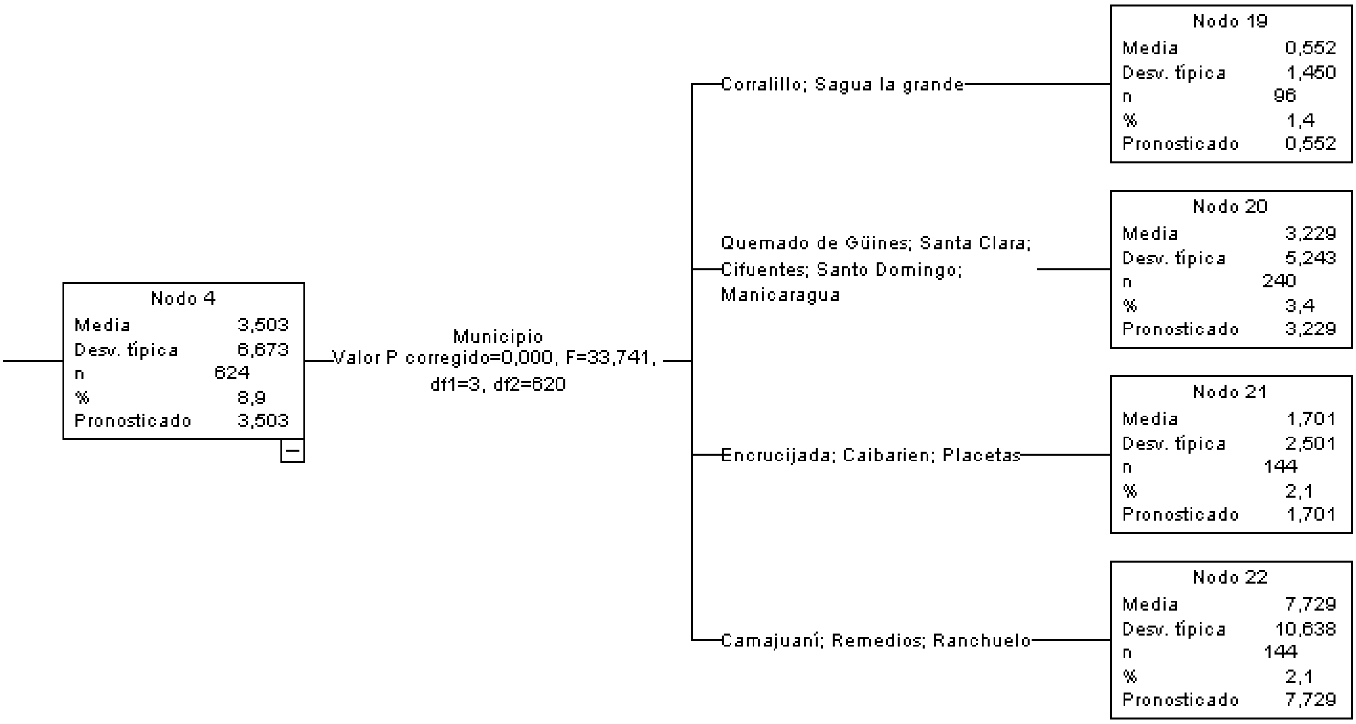

***Fig 6**: Third level of the decision tree child nodes derived from N4*

Two nodes N23 and N24 are derived from N5, see Figure 7. The predictor variable was deposit type and the highest mean results were obtained for N23, but in both cases they are very low as they are below zero, less than one individual collected (Figure 7).

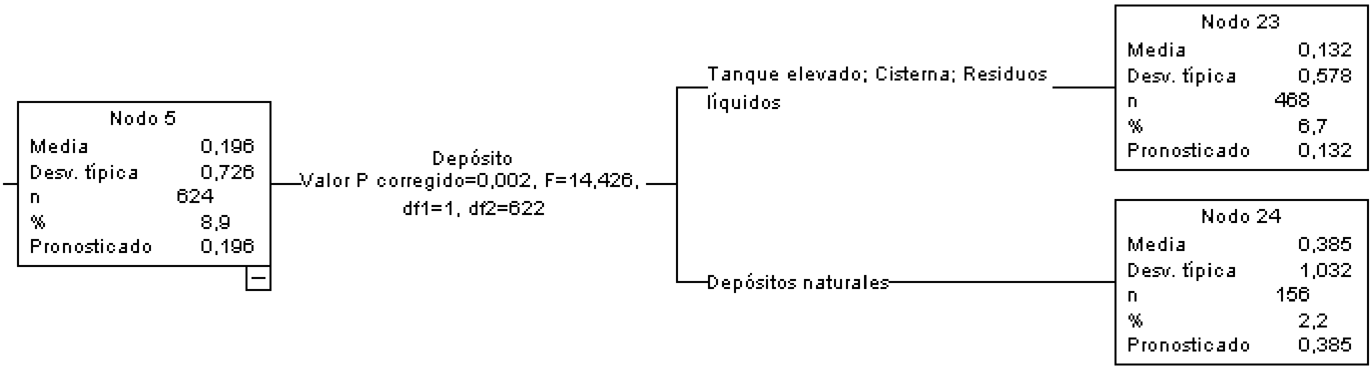

***Fig. 7:** Third level of the decision tree child nodes derived from N5*

From N6, two nodes N25 and N26 are derived, while in N25 the mean is very low (2.792), while in N26, the mean is quite high 45.500, which means that in the municipalities included in N26 there was a lack of vector control (Figure 8).

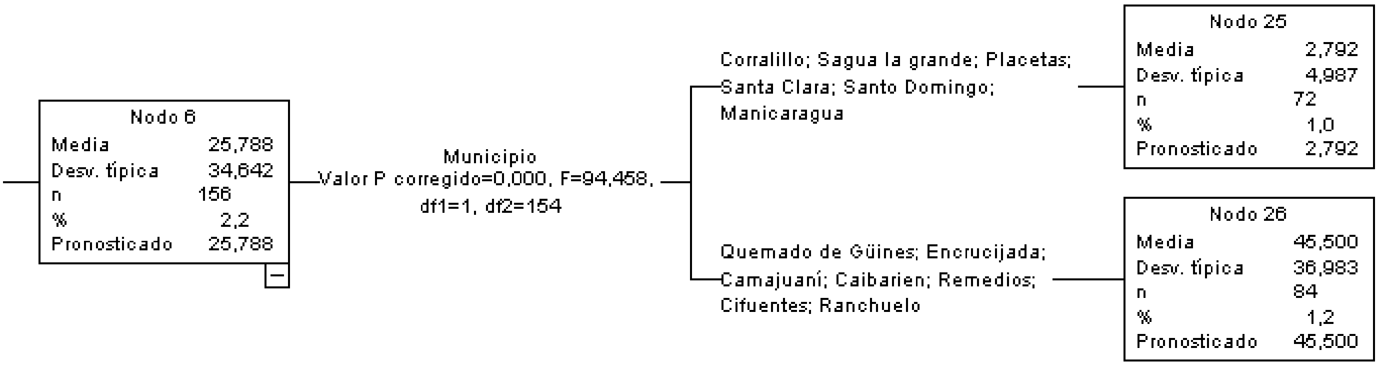

Fig. 8: *Third level of the decision tree child nodes derived from N6*

From N7 nodes N27 and N28 are derived, the predictor variable was municipality and the mean values 1.278 and 8.917 respectively, these are also low values (Figure 9).

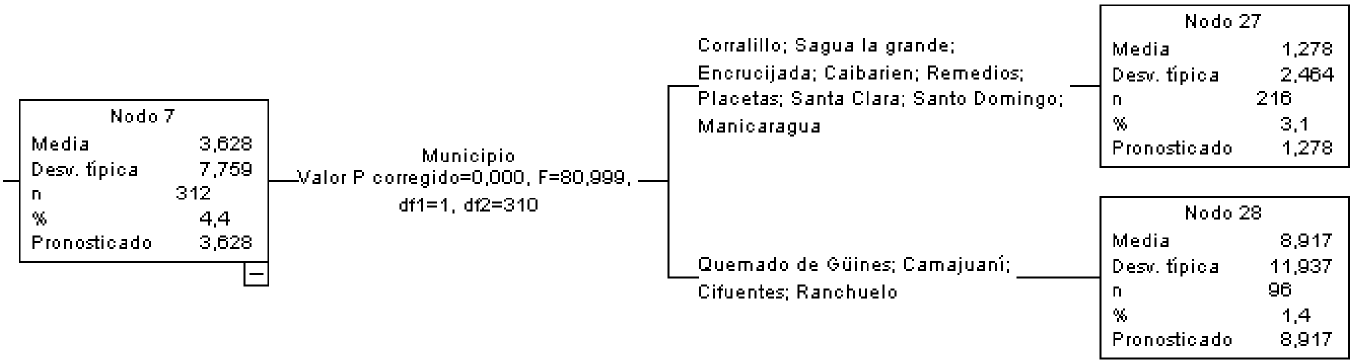

Fig. 9*: Third level of the decision tree decision tree child nodes derived from N7*

Three nodes N29, N30 and N31 were derived from N8. The predictor variable was municipality. All mean values are below zero (Figure 10).

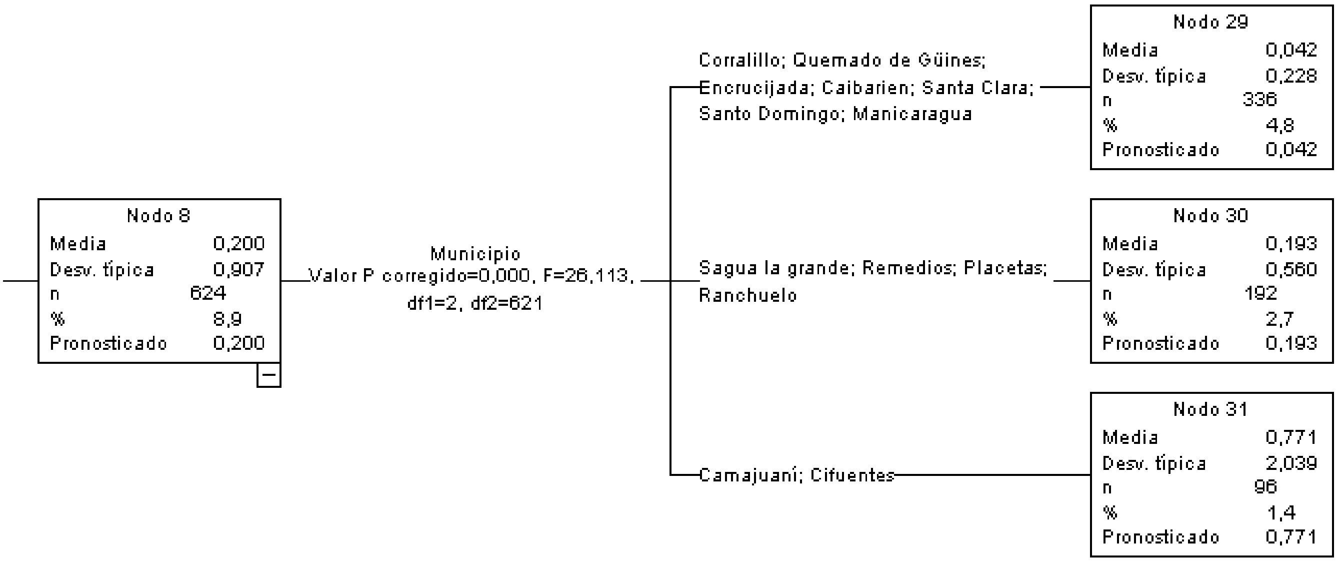

Fig. 10: *Third level of the decision tree decision tree child nodes derived from N8*

From N9 nodes N32 and N33 are derived, this is an atypical case because here the predictor variable was month, the most affected months being July, August and October with a mean of 5.269 (Figure 11).

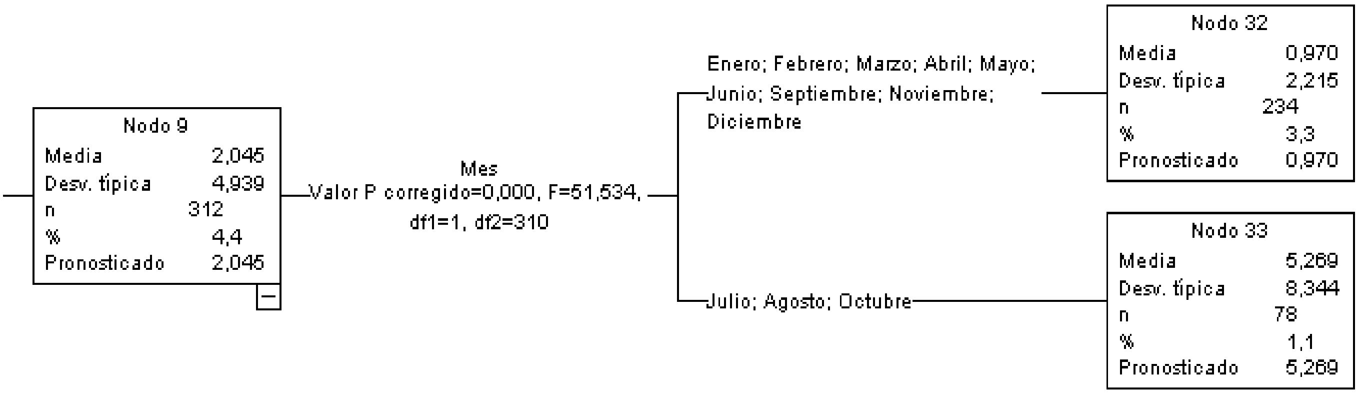

Fig. 11: *Third level of the decision tree decision tree child nodes derived from N9*

From N10, nodes N34 and N35 are derived, the predictor variable was municipality. The most affected municipalities were those located in N35 with a mean of 14. 271 (Figure 12).

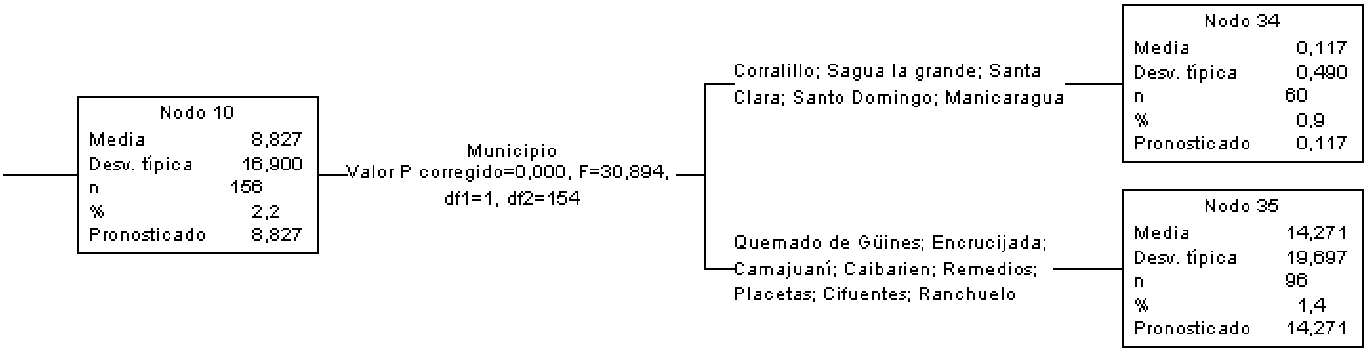

Fig. 12*: Third level of the decision tree decision tree child nodes derived from N10*

No child nodes were derived from N11 due to the low variability (standard deviation 0.096). In this node, the mean was very low indicating high vector control.

Three nodes N36, N37 and N38 with very low means were derived from N12. The predictor variable was type of deposit (Figure 13).

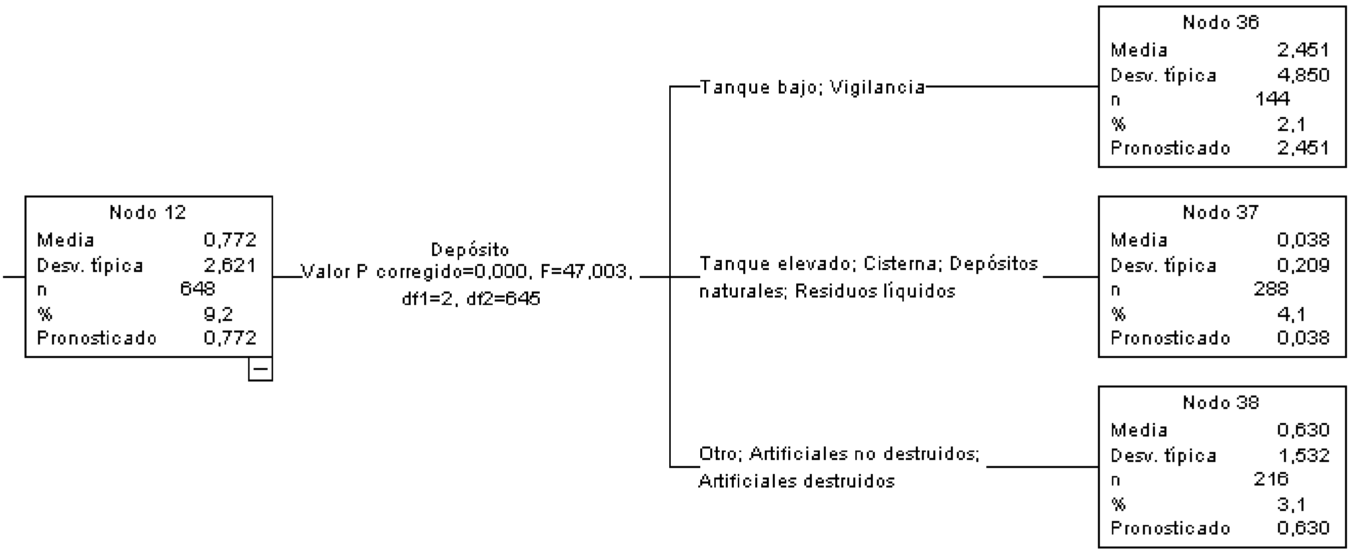

Fig. 13: *Third level of the decision tree decision tree child nodes derived from N12*

From N14, N39, N40 and N41 were derived with very low mean values. The predictor variable was deposit type (Figure 14).

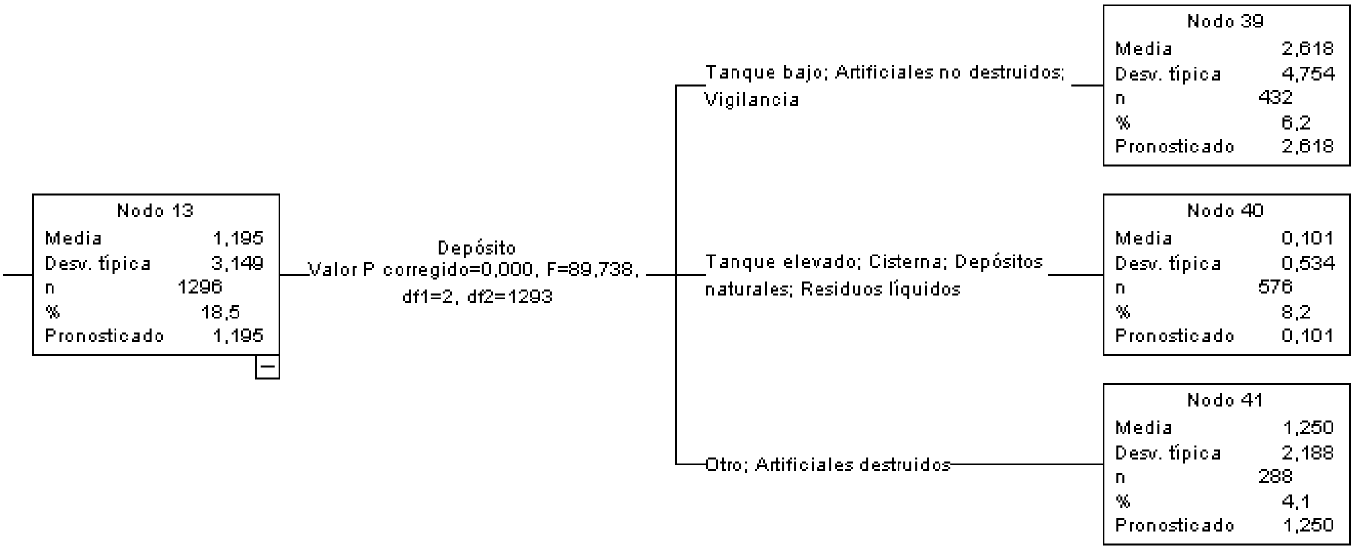

Fig. 14: *Third level of the decision tree decision tree child nodes derived from N13*

N42 and N43 nodes were derived from N14. The predictor variable was deposit type and it is observed that the deposits located in N42 show the highest number of individuals collected, with a mean of 9.911 (Figure 15).

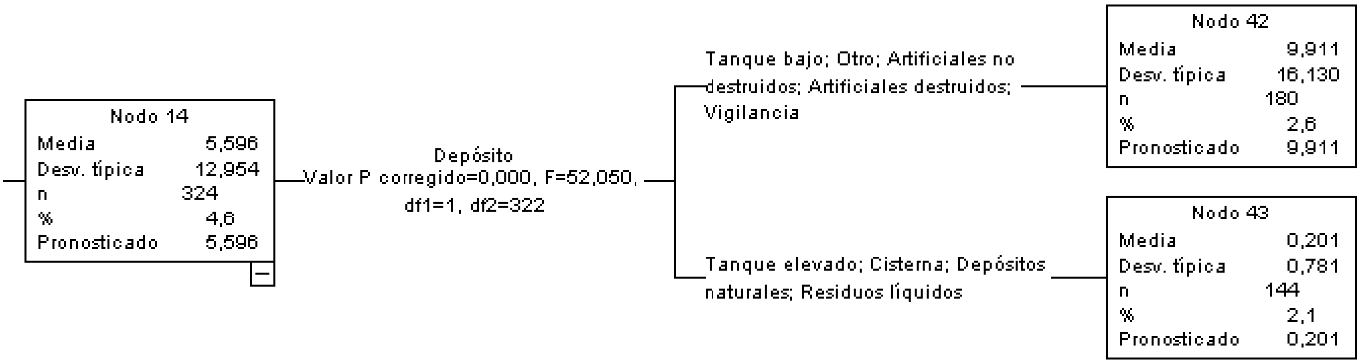

Fig. 15*: Third level of the decision tree child nodes derived from N14*

For N15, two child nodes N44 and N45 were obtained. The predictor variable was type of deposit. The mean values, although low, show a higher incidence in N44 with a value of 4.306 (Figure 16).

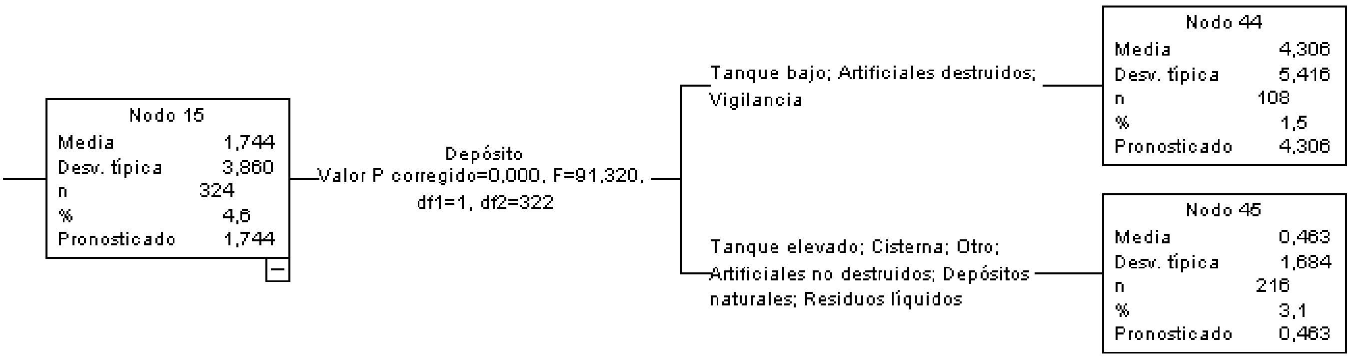

Fig. 16: *Third level of the decision tree child nodes derived from N15*

In N16 three nodes N46, N47 7 N48 are derived, the predictor variable was type of deposit. All mean values are very low (Figure 17).

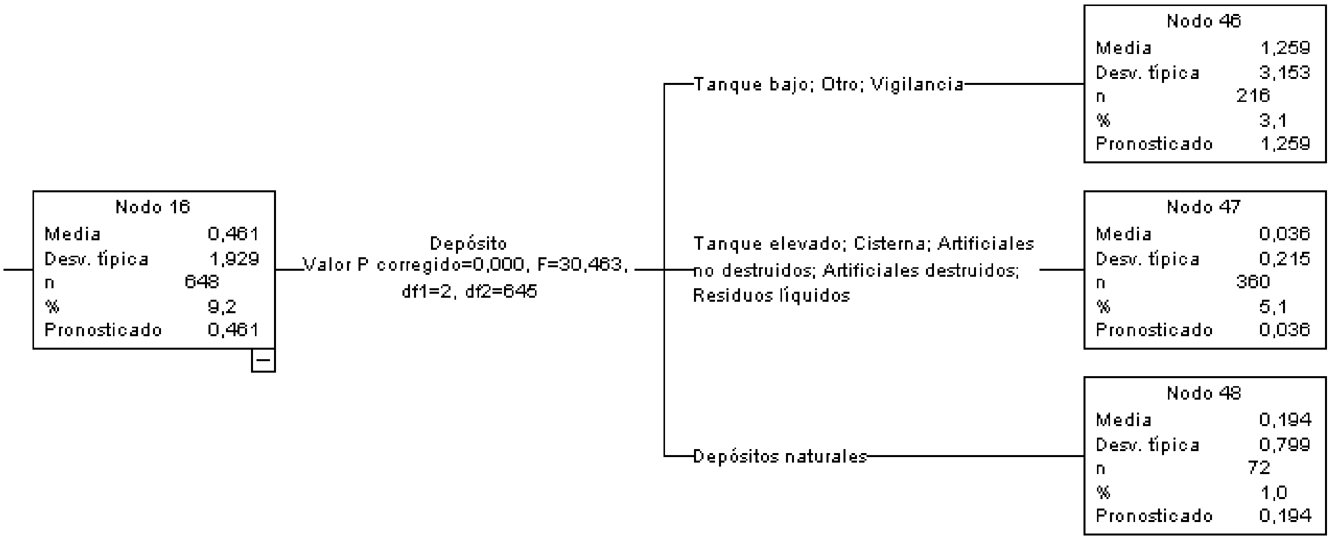

Fig. 17: Third level of the decision tree child nodes derived from N16

Three nodes N49, N50 and N51 are derived from N17, the predictor variable was type of deposit. A great difference between the means is observed, while in N50 the mean is very low (0.639) in N51 and N49, the means are very high with values of 9.204 and 19.375 respectively (Figure 18).

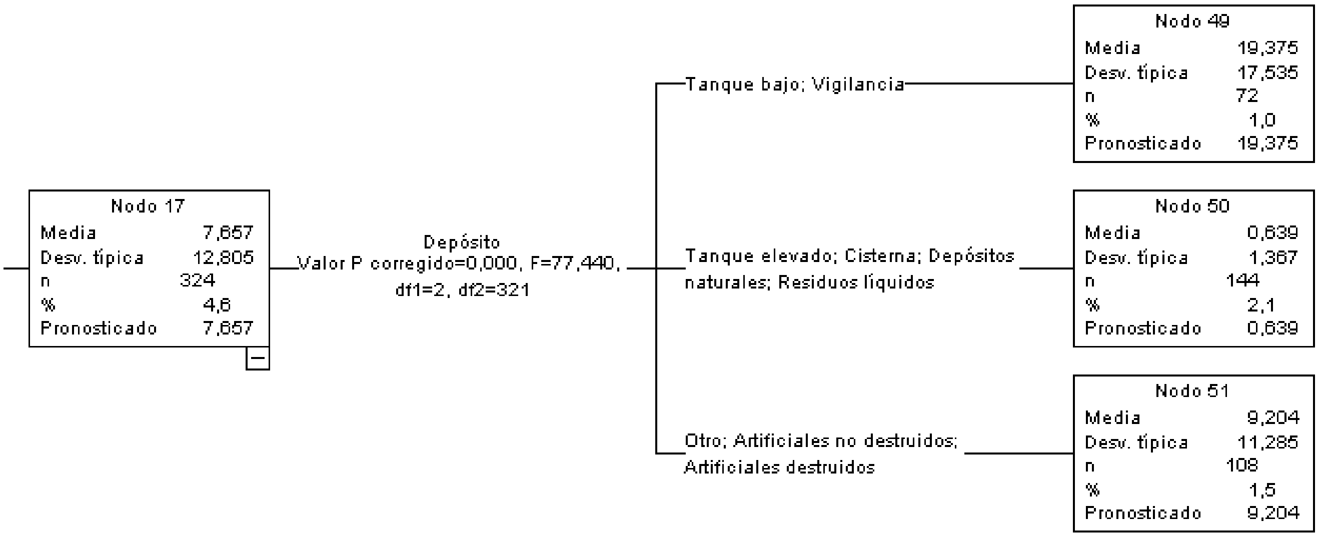

Fig. 18: Third level of the decision tree child nodes derived from N17

In N18, nodes N52 and N53 are derived. With very low means (below 1), here the predictor variable is year, N52 corresponds to the years 2018 and 2019, while N53 corresponds to 2020. A slight increase in the mean is observed for the year 2020 (Figure 19).

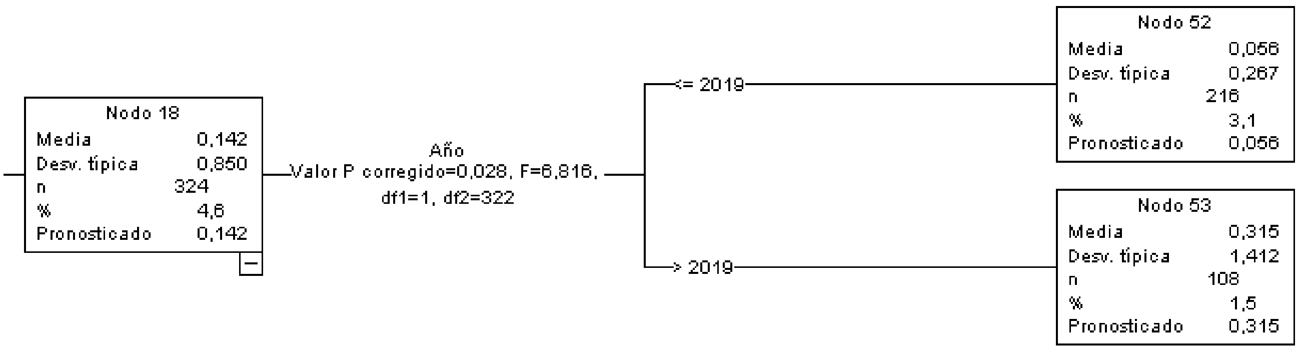

Fig. 19: Third level of the decision tree child nodes derived from N18

In general, a high level of control of this vector species was observed compared to the same period for Ae. Aegypti.

The highest mean values (above 10) are shown in table 1.

Table 1: *Highest mean values for the number of individuals collected, according to predictor variables*.

Years	Municipalities	Deposits	Half
2018, 2019 y 2020	Cifuentes	Low tank and surveillance	19.375
2017	Quemado, Encrucijada, Camajuaní, Caibarien, Remedios, Placetas, Cifuentes, Ranchuelo	Surveillance	14.271
2016	Quemado, Encrucijada, Camajuaní, Caibarien, Remedios, Cifuentes, Ranchuelo	Surveillance	45.500

From this table, a greater control of the vector is observed over the years, where the most affected municipalities were Quemado, Encrucijada, Camajuaní, Caibarien, Remedios, Cifuentes, Ranchuelo and Placetas, although Placetas only showed no control in 2017. Most of these municipalities managed to reduce the averages below 10, except Cifuentes, which even in 2020 shows a value of the average of 19.375, which is considered high for this vector if compared to the values exhibited by the rest of the municipalities.

The type of deposit with the highest number of samples collected was surveillance, which is a regularity evidenced in the model.

4 | DISCUSSION

The variables that had the greatest influence in the study were year, type of deposit, municipality and month (all the variables considered influenced the model). Although all the variables acted as predictors, little regularity was observed in their location in the classification tree; there is no single predictor variable per level from the second level of the tree onwards, unlike what was obtained in the decision tree for the population dynamics of *Ae. Aegypti* (3).

When comparing these nodes, it is observed that the mean decreases as the years go by, which indicates that the number of individuals per observation decreases over the years, so that the control of the vector species under analysis increased as the years went by, since the number of individuals per observation decreased, but not for *Ae. Aegypti*, where the opposite occurred (3). In relation to the number of specimens, the greatest number was collected in the monitoring system (Larvitraps), installed for the species in question and while in the study conducted in 2022 for *Ae. aegypti*, the predictor variable was the type of tank, differentiating the types of tanks into three groups, where the highest value of the mean corresponded to the low tank, but something very similar occurred in the rest of the years (2017-2020), as the low tank maintained predominance, corroborated by the values of the mean, a result that coincides with those obtained by other authors in this regard, and even in other provinces of Cuba (30), (31), (32).

As for the largest number of individuals collected by municipality, they turned out to be Cifuentes, Encrucijada, Quemado de Güines and Camajuaní, all of which is consistent with the ecology and biology of that species (31), (32), (33), not being so for *Ae. aegypti*, in the same study period, where, both the highest mean value and the standard deviation were higher in Santa Clara and lower, in the municipality Encrucijada, while for the case of the lengths of the series (11 years of annual data), the maximum value reached corresponded for the municipality Santa Clara, and the minimum, of zero, for the municipalities: Corralillo, Quemado, Encrucijada and Caibarién, results that agree with those obtained by other authors in this regard (34), (35), (36) and even for other mosquito genera. The great variability of the data obtained by municipality could be due to the incidence of the particular physical and geographic characteristics of each one of them, also associated with aspects inherent to the quality, capacity and preparation of the technical force dedicated to surveillance and vector control activities, as well as the stability of this qualified force, which does not behave in the same way in all territories.

When analyzing nodes N32 and N33, it turned out to be an atypical case, because here the predictor variable was month, being the most affected months: July, August and October with an average of 5.269, something very similar to what happened for the species *Ae. Aegypti* in Villa Clara province (2), (19), (20), (37). It is important to mention, as previously mentioned, that these months coincide with the period of increased rainfall, high temperatures and other variations in the status of the climate in our country, which also shows the interrelationship between these processes, results that agree with those obtained by other authors in this regard (2), (19), (20), (37).

It is notorious and relevant the fact that *Ae. Aegypti* and *Ae. albopictus* have gained ground and space in Villa Clara province, species of high entomoepidemiological risk, due to their involvement in several infectious entities (38), (39), (40), (41), among which stand out: Dengue, Yellow Fever, West Nile virus, Chikungunya and Zika virus; but reality has shown us, that at present, these two species are practically present throughout the length and breadth of the national geography, expanding increasingly, colonizing an important number of breeding sites generated by human activity together with environmental variables (42), thus showing their high ecological plasticity and high capacity to adapt to the most dissimilar ecological niches (20), (43).

5 | CONCLUSION

Ae. Albopictus showed a high adaptive capacity and high ecological plasticity, with a marked correspondence between the ecology and habitat of the species under analysis, and a tendency to increase its ecological dispersion and population densities over time, as well as a tendency to control the species over the years.

Conflict of interest

The authors express that there is no conflict of interest.

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