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Aedes albopictus MOSQUITO INFESTATION IN A MUNICIPALITY IN THE WESTERN REGION OF THE STATE OF SANTA CATARINA

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ABSTRACT: *Aedes albopictus* mosquito is widely distributed in tropical regions, as well as in temperate countries, and has been identified by the scientific literature as important to public health. There is a lack of studies on infestation, dispersion and the species association with the level of urbanization, breeding sites, types of property and seasonality. This study aimed to analyze the evolution of *A. albopictus* infestation along an urbanization gradient. The geographical reference of this study was the municipality of Chapecó, State of Santa Catariana. To assess dispersion and population fluctuation an urbanization gradient was created. Linear regression analysis was applied to evaluate the trend of infestation in each region in the study period. Mosquito infestation was higher in peri-urban and rural regions, and lower in more urbanized regions. The results are relevant for planning and implementing prevention actions for transmitted arbovirus diseases.

KEY WORDS: Arboviruses; Public health; Urbanization; Urban environments.

INFESTAÇÃO PELO MOSQUITO *Aedes albopictus* EM UM MUNICÍPIO DA REGIÃO OESTE DE SANTA CATARINA

RESUMO: O mosquito *Aedes albopictus* possui ampla distribuição em regiões tropicais, bem como nos países de clima temperado e tem sido apontado pela literatura científica como importante para a saúde pública. Observa-se a carência de estudos acerca da infestação, dispersão e a associação da espécie com o grau de urbanização, criadouros, tipos de imóveis e sazonalidade. Este estudo teve como objetivos, dentre outros, analisar a evolução da infestação por *A. albopictus* ao longo de um gradiente de urbanização. O estudo teve como referência geográfica o município de Chapecó (SC). Para avaliar a dispersão e a flutuação populacional foi criado um gradiente de urbanização. Para avaliar a tendência da infestação em cada região no período, foram utilizadas análises de regressão linear. A infestação pelo mosquito foi maior nas regiões periurbanas e rurais e menor nas regiões mais urbanizadas. Os resultados encontrados são relevantes no planejamento e na implantação de ações de prevenção das arboviroses transmitidas.

PALAVRAS-CHAVE: Ambientes urbanos; Arboviroses; Saúde pública; Urbanização.

INTRODUCTION

Aedes albopictus mosquito (Skuse 1894) Culicidae is probably from Southeast Asia and has spread to Europe, Africa and the Americas. It is widely distributed in tropical regions, as well as in temperate countries[1]. *A. albopictus* is popularly known as the Asian tiger mosquito and has been identified by scientific literature as important to public health[2]. Infestation by the mosquito and, consequently, its potential for transmitting associated pathologies, especially dengue, caused concern to health authorities throughout the 20th century, worsening, in Brazil, from 2014 onwards by the introduction of chikungunya fever and Zika virus[3, 4].

In Brazil, *A. albopictus* was registered for the first time in 1986, and in the south of the country, the first record took place in the State of Paraná in 1996. In 2003, the distribution of the mosquito species did not occur in only seven of its 27 Federation states: Acre, Amapá, Ceará, Piauí, Roraima, Sergipe and Tocantins5. Currently, the mosquito is spread throughout the national territory, with the exception of records in the State of Acre[6].

In the Americas, the mosquito *A. albopictus* is not considered as a carrier of arboviruses, although it has been demonstrated, under laboratory conditions, that Brazilian populations of this species have shown vector competence to become infected and to transmit virus diseases such as dengue and chikungunya, in addition to transmitting them successfully. Thus, health services remain alert to the infestation of this mosquito species in Brazil[7, 8].

A. albopictus is morphologically characterized as a medium-sized mosquito, dark in color, with white or silvery-white scales, distributed over the body and on the legs[9]. Like the others, mosquitoes of the genus *Aedes* have holometabolous development, composed of the egg, larva, pupa and adult stages[10]. Females lay their eggs individually on the inner walls of containers, just above the surface of the water. Eggs are resistant to desiccation, just as embryos can remain dormant in the environment for months. Diapause and/or quiescence allows populations to become well adapted in both temperate and tropical areas, remaining viable for a long period of time, even in the absence of water[11]. The feeding of the female of *A. albopictus* is predominantly zoophilic, which is responsible for the transmission of viruses. Females are infected during hematophagy, and can have several blood meals in the same gonadotrophic cycle, a fundamental process for the development and maturation of oocytes and subsequent egg production[12].

The synanthropic process of the species is not as intense as that of *A. aegypti*. *A. albopictus* is better adapted to natural environments, forest fragments and rural areas. It has diurnal habits and hematophagic activity peaks occur during morning and evening twilight[13-14]. Both natural and artificial containers are habitats for the development of its immature forms. Eggs can be laid in all possible objects that can store water, temporarily or permanently. In natural environments, it uses bamboo stumps, hollow trees, bromeliads and others[15].

The diversity of breeding sites directly contributes to the production of adult mosquitoes, allowing an increase in the proliferation of the species. Therefore, the identification of these containers and the types of properties where the species is found is of utmost importance for directing monitoring and control actions[12]. Knowing abiotic conditions such as temperature, humidity, rainfall, seasonality and occupation of geographical space by the human population that influence the proliferation of mosquitoes can also contribute to the effectiveness of population control[16].

A. aegypti and *A. albopictus* coexist and compete for resources, especially breeding sites. Coexistence is characterized by the segregation of different habitats, avoiding direct competition. While A. aegypti predominates in urban areas, *A. albopictus* predominates in rural environments, however, the two species coexist in peri-urban areas[17]. In the municipality of Chapecó, State of Santa Catarina, both species have been occurring for 20 years[18].

There is a lack of studies in the southern region of Brazil on infestation, dispersion and the association of *A. albopictus* with breeding sites, types of properties and seasonality of the records. In this context, this study aimed to a) compare the annual infestation of *A. albopictus* to *A. aegypti* in the municipality of Chapecó; b) verify the seasonality of the infestation by *A. albopictus* in the municipality; c) analyze the evolution of *A. albopictus*

infestation along an urbanization gradient and; d) identify the pattern of association between *A. albopictus* with the types of breeding sites and types of properties.

METHODOLOGY

The geographical reference of this study was the municipality of Chapecó, in the Western region of the State of Santa Catarina (27º05'47" S; 52º37'06" W), altitude of 674 meters. The municipality has 626.06 km² area, an estimated population of 216,654 inhabitants and 113.2 km² urban area, approximately19. It has a mesothermal climate, an average temperature ranging from 15 to 25 °C, an average relative humidity of approximately 73%20. Until 2012, the municipality had 30 neighborhoods and seven rural districts, which were used as a territorial reference for the present study.

SAMPLE BY URBANIZATION GRADIENT AND DATA COLLECTION

Data regarding the record of breeding sites of *Aedes albopictus* and *A. aegypti* Linnaeus 1762 (positive breeding sites for the presence of larvae, pupae or adult mosquitoes) from January 2009 to June 2019 were obtained in the form of electronic spreadsheets generated from the database of the Environmental Health Surveillance Service of the municipality of Chapecó. Data on the monthly and annual frequency of *A. albopictus* breeding sites were used, according to the occurrence by neighborhood, type of property and type of breeding sites. The categorization of these data followed the nomenclature used by the National Dengue Plan Control (PNCD), in which the types of properties are residential, commercial, vacant lands (TB) and strategic points (PE) which, as described in the PNCD, are establishments that have several potential breeding sites for the mosquito. The classification of breeding site types was A1 - elevated breeding sites: water tanks and gutters; A2: breeding sites at ground level: cisterns, barrels and the like; B: furniture: flower dishes, animal drinkers, defrost trays of refrigerator and the like; C: fixed: swimming pools, tanks under construction, gutters, drains; D1: tires; D2: liable to be removed: disposable materials, bottles, cans and the like; E: natural: foliage, bromeliads and the like.

As a method for monitoring infestation, the Chapecó PMCD used, in the period, larvaltraps at a density of 1 for every 100 properties between 2009 and 2013 and eggtraps at a density of 1 for every 300 properties in 2014 and 2015. Throughout the period, the PMCD used the Aedes Infestation Index Rapid Survey (LIRAa) method with two annual events, November and April. Likewise, throughout the period there was a record of approximately 350 PE, which were systematically inspected, every two weeks, and if larvae or pupae were found, samples were collected and identified[21].

In order to assess dispersion and population fluctuation in the municipality, an urbanization gradient was created. From the city center, four regions were established based on the intensity of urbanization: center, neighborhoods, peri-urban and rural districts, as described below:

Center Region: comprised the five neighborhoods of the Center region being Centro, Jardim Itália, Maria Goretti, Presidente Médice and São Cristóvão. This region is the oldest part of the city. It is the region that houses the population with the highest purchasing power, and its structure is, primarily, of buildings and vertical condominiums. It is a more urbanized region where public administrative services, shops and some small industries are found. In this region, buildings occupy the largest area of land and vacant land is rare.

Neighborhood Region: included 11 neighborhoods adjacent to the Center region. These neighborhoods have adequate urban infrastructure and basic sanitation services. These are residential neighborhoods, with mostly horizontal constructions (houses) where gardens often occupy half or more of the occupied land. There is an average frequency of vacant lands of one per block. Small businesses and industries of the most varied segments are frequent.

Peri-urban Region: this is the peripheral region of the city formed by the belt of 14 neighborhoods (year 2012). This region has a poorer sanitation and building infrastructure and a more recent history of urbanization. Sanitation services are still in the study or implementation phase, although water supply and waste collection occur

regularly. This is the region with the population with the lowest purchasing power, workers from the large agro-industries installed in the municipality. The presence of many vacant lands is found (on average approximately 02 per block) and the buildings are horizontal, in most cases with less than 100 m^2.

Rural District Region: formed by seven rural communities, at least 10 km from the city. They house villages with 100 - 900 residences. As they are far from the urban area, they lack basic sanitation services. The communities have small businesses and a strong interaction with the rural environment.

DATA ANALYSIS

To assess infestation (number of mosquito breeding sites) over the years, a comparison was made with infestation by the *A. aegypti* mosquito, also monitored by the PMCD. The annual absolute values were transformed into a logarithm to minimize the effect of the amplitude. To assess seasonality, mean values of monthly frequency of breeding sites and standard error were used as a measure of dispersion. The monthly frequencies were tested by Shapiro-Wilk Normality test and the Kruskal-Wallis test was applied to compare them. Tukey's post-test was used to compare the months, pairwise.

Linear regression analysis was used to assess the trend of infestation in each region in the period. This analysis provides a trend line in the period, an association value (R^2) as well as an equation that defines cause and effect, in this case, percent breeding sites recorded over the period evaluated. In a complementary way, the mean percentages of breeding sites in each region were compared. For this, an ANOVA analysis was used followed by Tukey post-test.

To check the association of the annual frequency of breeding sites, according to the type of property and the type of breeding site, a Principal Component Analysis (PCA) was run in the software PAST[22]. The data matrix was previously log transformed [Log(x+1)] to reduce the effect of amplitude on the analysis.

ETHICAL ASPECTS

Despite the secondary nature of the data, the study relied on the awareness and agreement of the manager of the environmental health surveillance sector in the municipality of Chapecó, State of Santa Catarina, involved in the study.

RESULTS

A total of 373 breeding sites of *A. albopictus* and 8,871 breeding sites of *A. aegypti* were recorded in the period. The year 2009 showed the smallest difference in the number of breeding sites between the two species (17). For A. albopictus, there were 73, and for *A. aegypti*, 90 breeding sites. Between 2009 and 2014, there was a reduction in infestation by A. albopictus, stabilization between 2015 and 2017, and a small growth in 2018 and 2019 (Figure 1)

There was a higher mean number of *A. albopictus* breeding sites in the hottest months of the year, January to April, peaking in March (Figure 2). This difference was significant ($Hc = 61.8$; $p < 0.0001$) compared to the other months

In the regions Neighborhoods (Figure 3A) and Center (Figure 3B), there was a reduction in *A. albopictus* infestation in the study period. In the Rural District region (Figure 3C), the frequency of breeding sites fluctuated, with a slight upward trend over the period. In the peri-urban region (Figure 3D), there was a strong tendency to increase the frequency of breeding sites. The difference in the frequency of breeding sites between regions was significant ($Hc = 19.48$; $p = 0.0002$).

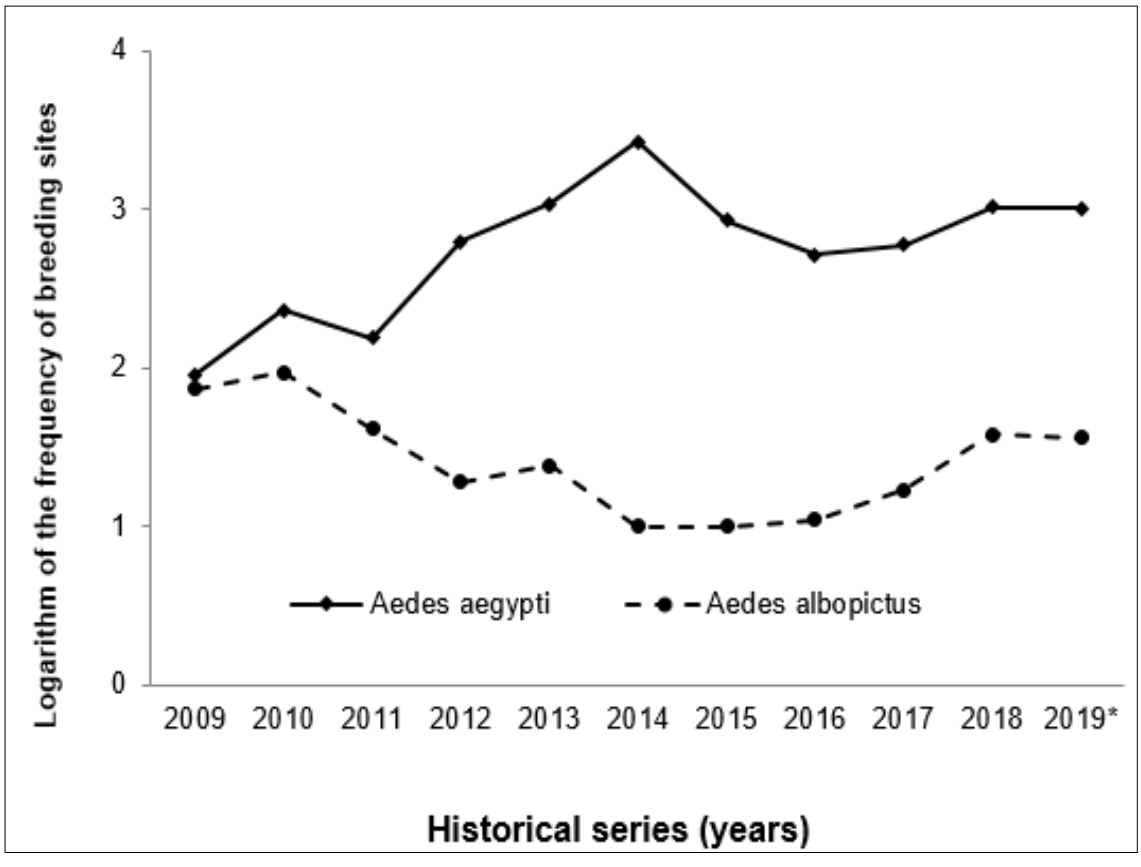

Figure 1. Comparison by logarithm the annual evolution of the number of breeding sites of *Aedes albopictus* and *A. aegypti,* in the municipality of Chapecó, State of Santa Catarina, 2009 to July 2019.

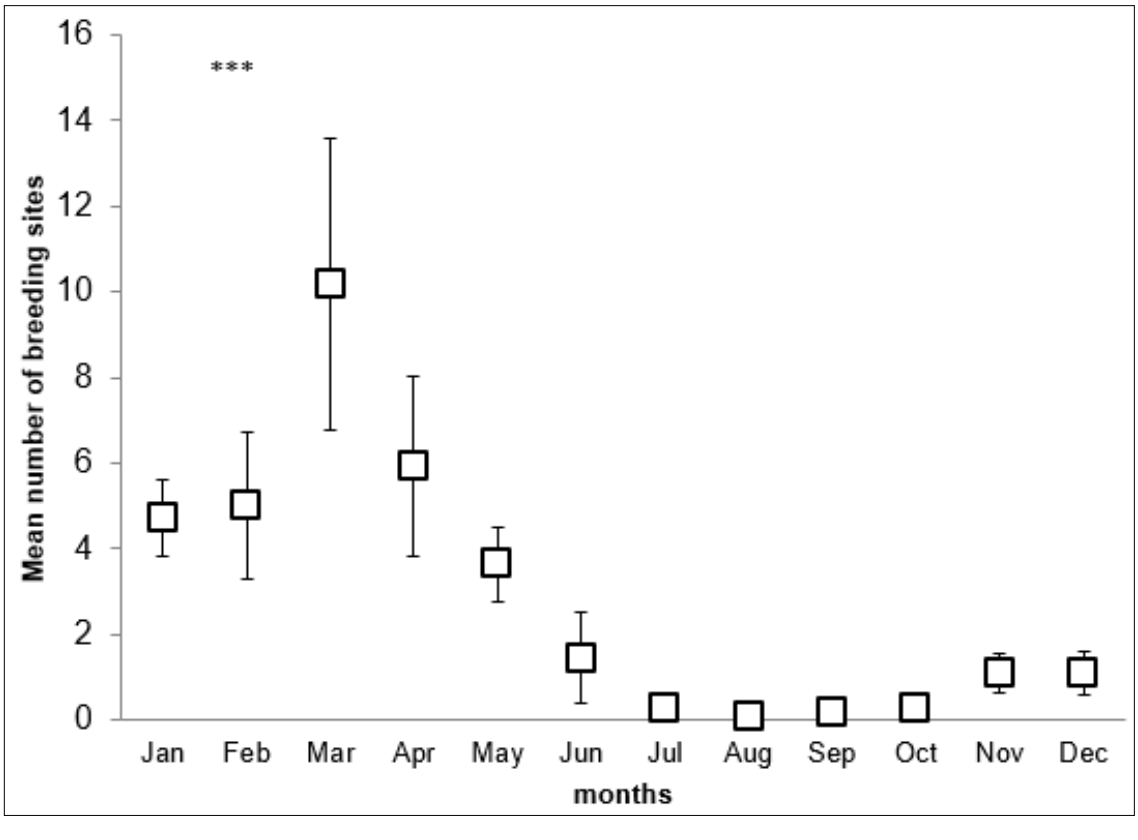

Figure 2. Monthly comparison of the number of breeding sites of *Aedes albopictus* in the municipality of Chapecó, State of Santa Catarina, 2009 to July 2019. *** (Hc = 61.8; p <0.0001) with the other months.

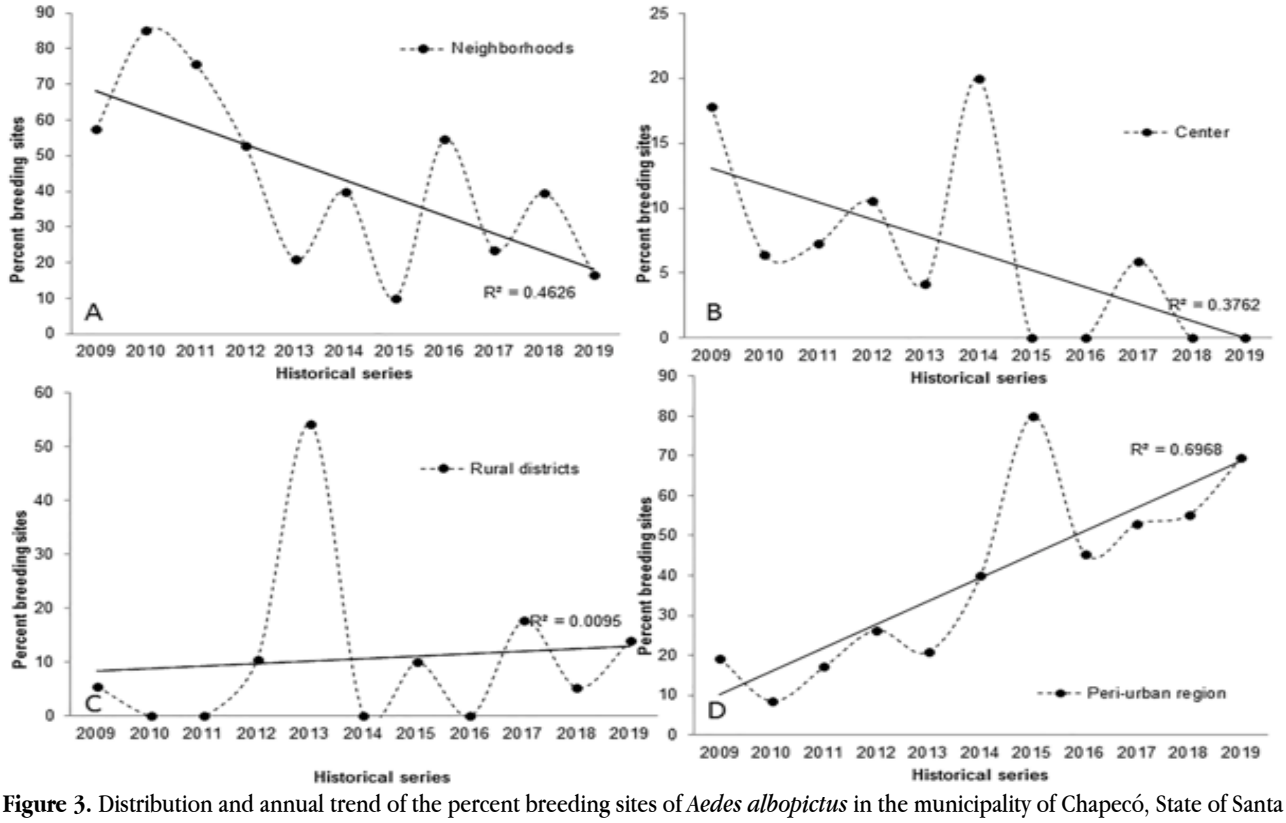

Figure 3. Distribution and annual trend of the percent breeding sites of *Aedes albopictus* in the municipality of Chapecó, State of Santa Catarina, according to the regions evaluated, 2009 to July 2019. R2: Linear regression.

Altogether, 86.3% variation in the occurrence of *A. albopictus* breeding sites, according to the types of properties, was explained by components 1 and 2 of PCA. Residences with 50.13% variation, and PE with 28.42% were the most important vectors in the analysis. There was an association of mosquito breeding sites with "O", "R" and "TB" properties in 2009, 2010 and 2011, with "C" in 2012 and 2013 and with "PE" in 2016, 2017, 2018 and 2019. The breeding sites of 2014 and 2015 occurred regardless of the type of property (Figure 4).

A total of 80.0% variation in the occurrence of the breeding sites of *A. albopictus*, according to the types of breeding sites, was explained by components 1 and 2 of PCA. An association of mosquito breeding sites with breeding sites type "B", "C" and "D2" was found in the years 2018 and 2019 and with "A2", "D1" and "E" in 2009, 2010 and 2011. The breeding sites of the other years occurred regardless of the type of property (Figure 5).

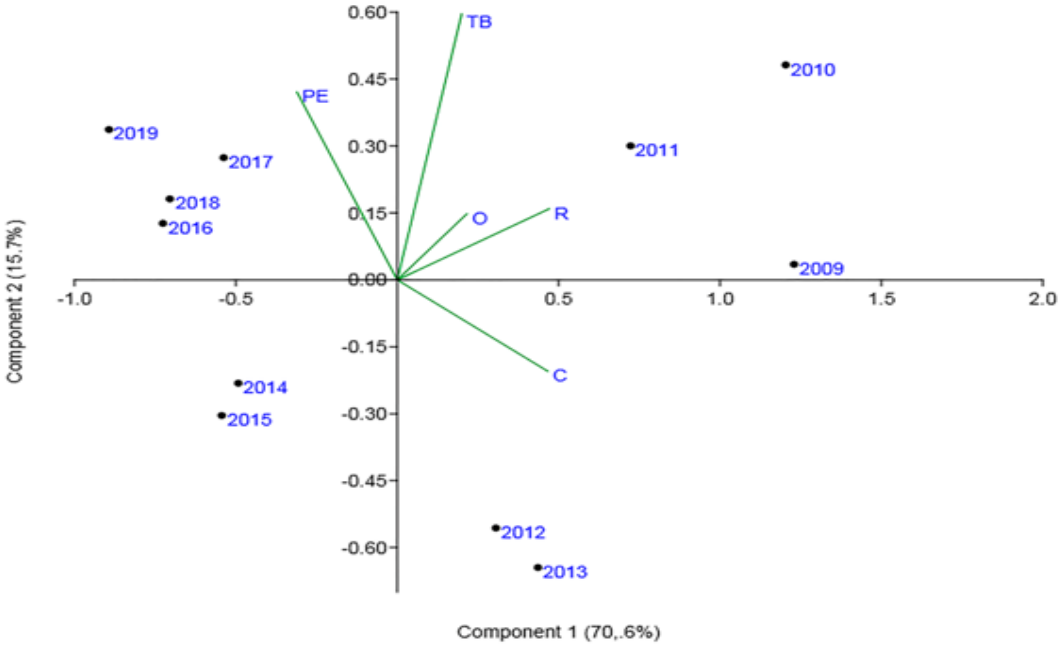

Figure 4. Scatterplot of the scores of the annual number of breeding sites of *Aedes albopictus* and the type of property, 2009 to July 2019. C: commercial real states; R: residences; PE: strategic points; TB: vacant lands; O: other property.

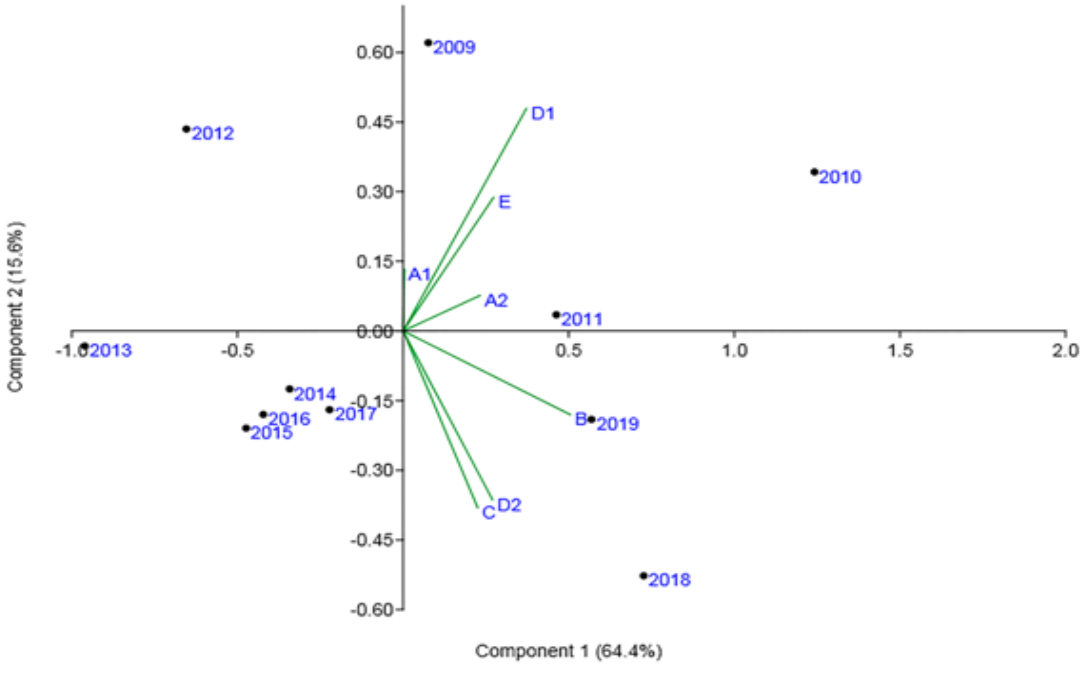

Figure 5. Scatterplot of the scores of the annual number of breeding sites of Aedes albopictus and the type of breeding site, 2009 to July 2019. A1: elevated breeding sites: water tanks and gutters; A2: breeding sites at ground level: cisterns, barrels and the like; B: furniture: flower dishes, animal drinkers, defrost trays of refrigerator and the like; C: fixed: swimming pools, tanks under construction, gutters, drains; D1: tires; D2: liable to be removed: disposable materials, bottles, cans and the like; E: natural: foliage, bromeliads and the like.

DISCUSSION

The rapid dispersal capacity of *A. albopictus*, combined with the facility to occupy different environments and cause damage to the health of several living beings, encouraged research on the potential of the mosquito to act as a vector of yellow fever and dengue in the Americas[23]. However, even though the target municipality has already had a dengue epidemic, this is the first study carried out in Chapecó (State of Santa Catarina) aiming at the distribution of the species.

The infestation by *A. albopictus* decreased in the municipality of Chapecó as the infestation by *A. aegypti* was increased over the 11 years evaluated. According to expectations, it was found that the infestation increases from January to April, the hottest period of the year. Infestation by A. albopictus was higher in peri-urban and rural regions and lower in more urbanized regions. There was an association of breeding sites with residences and with PE. In most years, breeding sites were registered independently of the types of breeding sites.

Culicidae species respond differently to the types of land occupation and cover[24]. Climatic and seasonal factors also influence population growth and dispersion of *A. albopictus*. Rainfall and temperature correlate positively with the species[25]. Besides the environmental, seasonal and climatic factors, the reduction of infestation by *A. albopictus*, in view of the increase in infestation by *A. aegypti* in the same period, suggests a better adaptation of the second to the resources offered (breeding sites) in relation to the first. Unlike the findings by Rey and Loubinos[17], who suggested the reduction of *A. aegypti* when in direct competition with A. albopictus, the results of the present study point to the opposite direction, showing the complexity of factors acting on both species.

The municipality of Chapecó had a population of 146,967 in the year 2000. This population, compared to the 2018 estimate, indicates a growth of approximately 47%19. During this period, the city grew vertically and horizontally. At the same time as the construction of many buildings in the center area was observed, the creation of many subdivisions on the periphery was identified, increasing the urbanized area and intensifying the urbanization process. Global and local climate changes (temperature and humidity) are perceived in the municipality due to the construction of the Foz do Chapecó Hydropower Plant on the Uruguay River, which flooded part of the territory. In the last ten years, a solid urban waste management system was implemented, which concentrated the waste on the outskirts of the city. Although these factors, together with the municipal vector control service, have not been independently assessed, they may have influenced the reduction in the number of *A. albopictus* breeding sites in Chapecó and their displacement to the peripheral regions of the city.

Still on seasonality, Egwu et al.[9] and Custódio et al.[26] reported that abiotic factors such as temperature, humidity and rainfall were responsible for the population fluctuation of the mosquito *A. albopictus*. The municipality of Chapecó is located in a subtropical region where humidity has changed over the years due to the damming of the Uruguay River for the construction of the Foz do Chapecó HPP, however, this factor does not fluctuate seasonally. Also, rainfall does not undergo major seasonal changes from one year to the next. In this context, temperature represents the most important climatic factor in the months of January, February, March and April, which may explain the greatest mosquito infestation in this period of the year.

Montagner, Silva and Jahnke[24] found that the relative frequency of A. albopictus is higher in more urbanized areas, while *A. aegypti* occurs regardless of the urbanization level. Medeiros-Sousa et al.[27] obsreved that A. albopictus was more frequent in some urban parks than in other areas of the city. Rey and Loubinos[17] suggested that the specific adaptation of *A. albopictus* may explain its occurrence in the peripheral region of the city. The findings presented by the abovementioned studies make it possible to understand the migration of the *A. albopictus* mosquito to the periphery of the city of Chapecó in the period, as well as the association of its breeding sites with residences and strategic points, predominant in this region.

Physical characteristics in the suburbs define the culicid communities, with greater diversity and abundance in the areas that offer the necessary conditions for their proliferation, as in the natural spaces, more frequent in the suburban areas[28]. Green areas and urban parks are

infrequent in the peri-urban area of Chapecó, however, the proximity to rural or conservation areas, associated with the lower percentage of buildings in relation to the land allows greater afforestation and the presence of environments favorable to the proliferation of *A. albopictus*.

The scientific literature has pointed out an association between the proliferation of *A. albopictus* and natural breeding sites, such as epiphytic plants such as bromeliads[29]. On the other hand, Martins et al.[30] stated that *A. albopictus*, due to its biological characteristics, can frequent the most varied types of breeding sites and exhibits an important adaptive potential regarding the occupation of urban spaces. These different findings on the adaptation of the species to urban environments suggest a diversity of factors acting on the mosquito that becomes adapted in a heterogeneous manner depending on the availability of breeding sites. This may have been the reality of the species in the municipality of Chapecó in the last decade, considering that natural environments such as bromeliads, bamboo and hollow trees are uncommon. In this context, the species has been using artificial breeding sites, but has not shown preference.

CONCLUSION

This study describes a reduction in the absolute number of breeding sites of the mosquito *A. albopictus* in the municipality of Chapecó at the same time that an increase in infestation by *A. aegypti* is observed. The species occurs seasonally and is more frequent in the summer months when the temperature is higher. From 2009 to 2019, it was noticed the migration of the relative infestation from the most urbanized areas to the peripheral region of the city. Residences (single-family houses) and strategic points, more frequent in the peripheral region of the city, are more associated with mosquito breeding sites, although the insect has not shown preference for any type of breeding site in the years evaluated.

The results add information about the seasonal and spatial occurrence of *A. albopictus* in the southern region of Brazil, where studies of this nature are scarce. With regard to the importance of this species to public health, the results found are relevant for planning and implementing prevention actions for transmitted arbovirus diseases.

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