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HEALTH SCIENCES

Identification and Spatial Distribution of *Aedes aegypti* and *Aedes albopictus* populations in the State of Santa Catarina, Brazil between 2013 and 2023

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Abstract: Diseases caused by mosquito-borne pathogens have spread globally, posing a growing threat to public health. This study aimed to evaluate the distribution of breeding sites and properties that were positive for the presence of *Aedes aegypti* and *Aedes albopictus* in the health macro-regions of Santa Catarina, between 2013 and 2023, seeking to identify seasonal and geographic occurrence patterns to support vector control strategies. This is an ecological study with secondary data provided by the *Diretoria de Vigilância Epidemiológica do Estado de Santa Catarina* (DIVE, State of Santa Catarina Epidemiological Surveillance Directorate), tabulated by year and macro-region, including mosquito samples grouped by property and breeding site category. Kruskal-Wallis tests were performed, followed by Dwass-Steel-Critchlow-Fligner multiple comparisons - DSCF. The analysis revealed that 5.78% of the populations were of *Aedes albopictus* and 94.22% of *Aedes aegypti*. The macro-region with the most *Aedes aegypti* populations was the Grande Oeste, and the most critical year was 2023. The Planalto Norte and Nordeste had the highest concentration of *Aedes albopictus*, peaking in 2022. Commercial and residential properties were the most affected. The disparities observed between macro-regions, years, and species suggest that regional and temporal factors play an important role in the distribution of mosquitoes.

Key words: *Aedes*, Communicable diseases, Mosquito control, Mosquito vectors.

INTRODUCTION

Diseases caused by mosquito-borne pathogens have spread globally, posing a growing threat to public health. Species of the genus *Aedes*, such as *Aedes (Stegomyia) aegypti* and *Aedes (Stegomyia) albopictus*, are prominent vectors of several arboviruses, including those that cause dengue, Zika, chikungunya, and yellow fever (Kraemer et al. 2015). The emergence and re-emergence of these infectious diseases is facilitated by the continued and rapid spread of mosquitoes, representing a significant challenge to global health (Lwande et al. 2020).

Ae. aegypti is considered the main vector of arboviruses dengue (DENV), Zika (ZIKV) and chikungunya (CHIKV) in Brazil (Lima-Camara 2016), in addition to having played an important role in the urban cycle of the yellow fever virus (YFV) in the country at the beginning of the 20th century (Benchimol 1994). This culicidae is present in tropical and subtropical regions of the world, including most of the Americas, Africa, Southeast Asia and all of India (Kraemer et al. 2015, Martelli et al. 2015), where it often presents synanthropic and anthropophilic behavior, being closely associated with humans (Natal 2002). On the other hand, *Ae albopictus* is native to Southeast Asia, where it presents more frequently wild habits (Hawley 1988). This is a species of mosquito considered one of the most invasive in the world, demonstrating vector competence for more than 20 arboviruses (Gratz 2004, Tatem et al. 2006). In some countries of the world, *Ae. albopictus* is considered the main vector of DENV (Rezza 2012), Zika (Grard et al. 2014) and CHIKV (Bonilauri et al. 2008, Grandadam et al. 2011). However, in Brazil, this species is considered a potential vector of these arboviruses (Ferreira-de-Lima et al. 2020); it may be present both in areas with relative vegetation coverage (De Lima-Camara et al. 2006) and in more urbanized areas (Leta et al. 2018, Kamal et al. 2018, Ayllón et al. 2018).

Although considered sympatric species, *Ae. aegypti* and *Ae. albopictus* females usually lay their eggs in different breeding sites. While immature forms of *Ae. aegypti* are more commonly found in containers that accumulate water, such as discarded non-reusable items, barrels, water tanks and tires (Lopes et al. 1993), larvae and pupae of *Ae. albopictus* are more common in natural breeding sites, such as tree holes (Ferreira-de-Lima et al. 2020). However, immature forms of *Ae. aegypti* have also already been found in natural breeding sites located in urban areas, such as bromeliads (Varejão et al. 2005, Ceretti-Junior et al. 2016) and tree holes (Bermudi et al. 2017, Dalpadado et al. 2022), just like those of *Ae. albopictus* can be found in artificial containers (Ferreira-de-Lima et al. 2020).

In Brazil, monitoring of *Ae. aegypti* and *Ae. albopictus* is conducted by the Municipal Health Departments, under the guidance and coordination of the States and the Ministry of Health (Ministério da Saúde et al. 2009). Vector monitoring and control is carried out by agents in charge of combating endemic diseases; they visit dwellings, identifying and eliminating potential mosquito breeding sites. They also provide guidance to the population on preventive and treatment measures regarding containers that cannot be eliminated. The activities carried out by these agents (ACEs) include: *Delimitação de Focus* (DF, Focus Delimitation), *Levantamento de Índice com Tratamento* (LI+T, Index Survey with Treatment), *Tratamento* (T, Treatment), *Pesquisa Vetorial Especial* (PVE, Special Vector Investigation), *Bloqueio de Transmissão* (BT, Transmission Blocking), *Revisão de Área* (RA, Area Review), *Investigação de Denúncia* (ID, Complaint Investigation), *Levantamento Rápido de Índice* (LIRAa, Rapid Index Survey) and *Levantamento de Índice Amostral* (LIA, Sample Index Survey), as described in the Technical Guidelines Manual for Field Personnel (Governo do Estado de Santa Catarina et al. 2019). Entomological surveillance of these vector mosquitoes aims to mitigate mainly the impact of epidemics caused by DENV, ZIKV and CHIK.

Located in the South of Brazil, Santa Catarina is a state that has geographic and environmental characteristics that favor the occurrence of arboviruses, including a climate conducive to the proliferation of vectors, great diversity of ecosystems, and intense urbanization, tourism and agricultural activities (Monteiro 2001, Minuzzi 2010, Silveira & Rodrigues 2015). As a result, the Santa Catarina state has faced annual dengue epidemics since 2014, with a growing death rate (Dalla Vecchia et al. 2018). In 2022, Santa Catarina registered 138,231 notifications of dengue cases, of which 60.42% (83,523) were confirmed. In 2023, it presented 248,231 notifications with 48.15% (119,525) of confirmations, almost double the previous year (Governo do Estado de Santa Catarina et al. 2022, 2023).

In this connection, investigating the frequency of *Ae. aegypti* and *Ae. albopictus* different types of breeding sites occurrence can help identify the main areas of infestation of these culicids. Such information will allow identifying the areas with the highest risk of transmission of urban arboviruses, helping to support the implementation of preventive measures in these locations (Leta et al. 2018). Thus, this study aims to evaluate the spatial distribution of breeding sites and, consequently, of the vector mosquitoes *Ae. aegypti* and *Ae. albopictus*, in the State of Santa Catarina, Brazil. The hypothesis was that there has been an increase in the number of breeding sites for both species over time, with distinct spatial patterns across the health macroregions of Santa Catarina. Furthermore, it is assumed that, although *Ae. aegypti* and *Ae. albopictus* females typically prefer artificial and natural breeding sites, respectively, both species are progressively adapting to anthropized environments, reflecting ecological plasticity and the influence of urban expansion on their distribution.

MATERIALS AND METHODS

Area and type of study

This is an ecological study conducted using secondary data from the State of Santa Catarina, Brazil, collected between 2013 and 2023. Santa Catarina is one of the three states in the Southern Region of Brazil whose territory is divided into six geosystems: Planície Quaternária, Serras do Leste Catarinense, Planalto Sedimentar, Escarpa da Serra Geral, Planalto dos Campos Gerais, and Planalto dos rios Iguaçu e Uruguai. Politically, the state municipalities are distributed among 20 microregions (IBGE 2022), which are grouped into seven health macro-regions (Diretoria de Vigilância Epidemiológica de Santa Catarina & Gerências Regionais de Saúde 2024) (Figure 1).

The variability of temperature in the state presents striking differences among the plains, plateaus, and mountains. The temperature declines on average 0.65°C for every 100 meters of altitude (Governo do Estado de Santa Catarina et al. 2016). Santa Catarina is considered one of the states with the best distribution of rainfall throughout the year due to its relief in different regions of the state (Monteiro 2001).

The climate is predominantly subtropical and according to the Köppen classification (Köppen 1936), there is a predominance of the Cfa climate type (temperate climate, without a dry season and hot summer), on the Atlantic slope and in the far west, and Cfb (temperate climate, without a dry season and cool summer) in the highest portions of the plateaus. In some specific regions, there is also a small zone characterized by the Af climate (a hot climate without a dry season), which extends from the northern coastal plain of Santa Catarina into the State of Paraná (Uhlmann et al. 2012, Dubreuil et al. 2018).

Data Collection and Analysis

The data collected between 2013 and 2023 by the disease control agents in the municipalities of Santa Catarina were used. Secondary data were made available by the Epidemiological Surveillance Directorate - DIVE upon official request. Prior to the analyses, data quality control procedures were applied, including the identification of duplicate records, inconsistencies, and incomplete information. Records presenting missing or undefined values for the variables of interest were excluded from the corresponding analyses. Therefore, the results reflect only complete and valid records available for each analyzed variable.

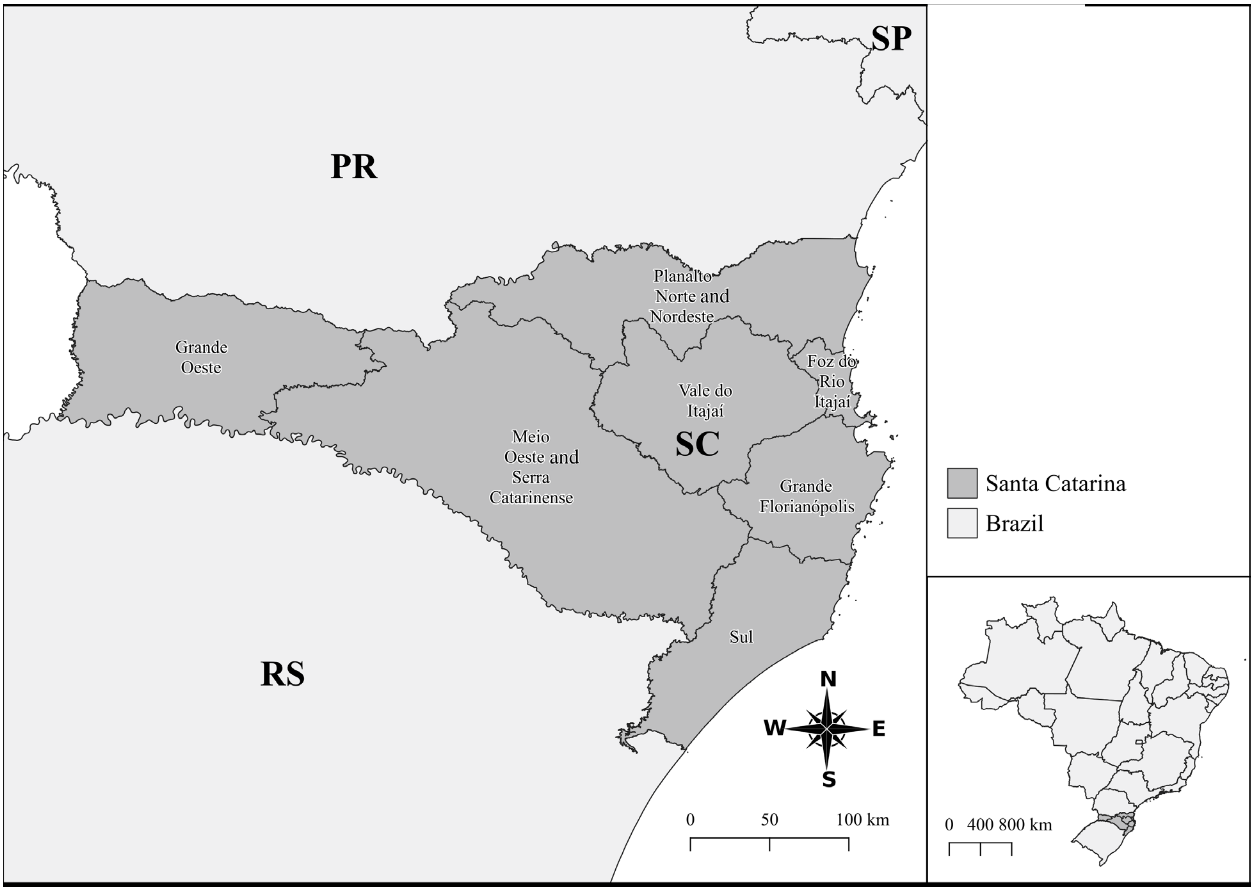

Figure 1. Study area highlighting the Health Macro-regions of Santa Catarina (SC). Bottom right corner: map of Brazil, with the State of Santa Catarina highlighted.

The variables used in the analyses were the same as those entered in the bulletins used by the disease control agents in their field collections: species (*Ae. albopictus*; *Ae. aegypti* and others), type of property (residential; commercial; vacant lot; strategic point; others) and type of breeding site (water tank/elevated; other water storage tanks/low level; small mobile tanks; fixed tanks; tires and other rolling stock; garbage/scrap/debris; natural deposits; "traps"). It is worth noting that the surveillance methodology adopted by DIVE in Santa Catarina differs from the practices used in states with a longer period of infestation by vectors and outbreaks of arboviruses. In Santa Catarina, larvae traps are still used to monitor mosquitoes, which is why, in this study, the category 'trap' was considered a type of breeding site. The data entered in the bulletins and reviewed in this study were collected according to the methodology described by the Ministry of Health in the technical guidelines manual for field personnel (Governo do Estado de Santa Catarina et al. 2019).

In order to assess the difference between the *Ae. aegypti* and *Ae. albopictus* vectors' population frequencies, the data were grouped by Health Macro-region according to the year and species. To assess the frequency of vector populations by type of property and by type of breeding site, the samples were grouped by category of the aforementioned variables, without taking the species into account. Data normality was assessed using the Shapiro–Wilk test. As the data did not meet normality assumptions, non-parametric Kruskal–Wallis tests with effect size estimates were applied, followed by Dwass–Steel–Critchlow–Fligner (DSCF) post hoc comparisons when significant differences were detected. Additionally, to explore temporal trends in the occurrence of immature *Aedes* forms in Santa Catarina, a linear regression model was performed using *year* as the independent variable and the *positive records* as the dependent variable. This analysis was conducted as an exploratory approach to assess overall temporal patterns over the study period. All statistical analyses were performed using Jamovi (The Jamovi Project 2022), and graphical representations were produced using Microsoft Excel.

This study was reviewed and approved by the Research Ethics Committee of the *Universidade do Sul de Santa Catarina* (CEP - UNISUL) under Consolidated Opinion No. 6,873,745, which is a prerequisite for the release of data by DIVE. The research protocol was prepared in accordance with the guidelines of Resolution No. 466/12 of the National Health Council, ensuring that all stages of the study met the ethical standards required for research involving humans.

RESULTS

Data collected between 2013 and 2023 provide an overview of the presence of *Ae. aegypti* and *Ae. albopictus* mosquitoes in the state of Santa Catarina. During the period mentioned 3,282,684 immature larvae or pupae of *Ae. aegypti* and 201,452 *Ae. albopictus* were identified in the state. The health macro-region with the highest *Ae. aegypti's* immature forms record was the Grande Oeste, with 28.5% (n=935,871) of the overall total, followed by the Planalto Norte and Nordeste, with 26.2% (n=860,200), Foz do Rio Itajaí, with 18.9% (n=619,783), Grande Florianópolis, with 14.5% (n=475,182), Vale do Itajaí, with 6.3% (n=208,080), Meio Oeste and Serra, with 3.2% (n=104,923), and the Sul, with 2.4% (n=78,645). On the other hand, records of the presence of immature forms of the mosquito *Ae. albopictus* are concentrated in the Planalto Norte and Nordeste Health Macro-region, with 36% (n=72,490) of the general total, followed by Vale do Itajaí with 18.2% (n=36,652), Foz do Rio Itajaí with 15.7% (n=31,598), Grande Florianópolis, with 13.1% (n=26,453), Grande Oeste with 9.7% (n=19,622), Meio Oeste and Serra with 3.9% (n=7,785) and South with 3.4% (6,852) (Table I, Figure 2 and Table SII - Supplementary Material).

Table I. Number and percentage of immature forms of the *Aedes aegypti* and *Aedes albopictus* mosquitoes recorded from 2013 to 2023 in the State of Santa Catarina, Brazil.

Health Macro-regions	***Aedes aegypti* (%)**	***Aedes albopictus* (%)**
Planalto Norte and Nordeste	860.200 (26,2%)	72.490 (36,0%)
Vale do Itajaí	208.080 (6,3%)	36.652 (18,2%)
Foz do Rio Itajaí	619.783 (18,9%)	31.598 (15,7%)
Grande Florianópolis	475.182 (14,5%)	26.453 (13,1%)
Sul	78.645 (2,4%)	6.852 (3,4%)
Meio Oeste and Serra Catarinense	104.923 (3,2%)	7.785 (3,9%)
Grande Oeste	935.871 (28,5%)	19.622 (9,7%)
Total	**3.282.684 (100%)**	**201.452 (100%)**

Considering the number of immature individuals of each species, per year, we can observe that the highest presence rate of *Ae. aegypti* is concentrated in the year 2023 with 22.9% of the total (n=753,170). Next are the years 2022 with 20.4% (n=669,044), 2021 with 18.1% (n=595,757), 2020 with 12.1% (n=396,763), 2019 with 9.9% (n=326,134), 2018 with 5.1% (n=167,014), 2017 with 3.6% (n=117,883), 2014 with 3.1% (n=101,508), 2015 with 2.2% (n=71,693), 2016 with 2% (n=66,317) and 2013 with 0.5% (n=17,401). For *Ae. albopictus*, the highest record of immature presence was observed in 2022, with 19.8% of the general total (n=39,860). Similar frequencies were recorded in 2023, with 19.3% (n=38,865), and 2021 with 17.5% (n=35,300). Next came 2019 with 12.2% (n=24,584), 2020 with 10.6% (n=21,408), 2018 with 7.1% (n=14,239), 2015 with 4.5% (n=9,137), 2017 with 4.5% (n=9,023), 2016 with 4.4% (n=8,814), and 2014 with 0.1% (n=222). In 2013, the presence of *Ae.*

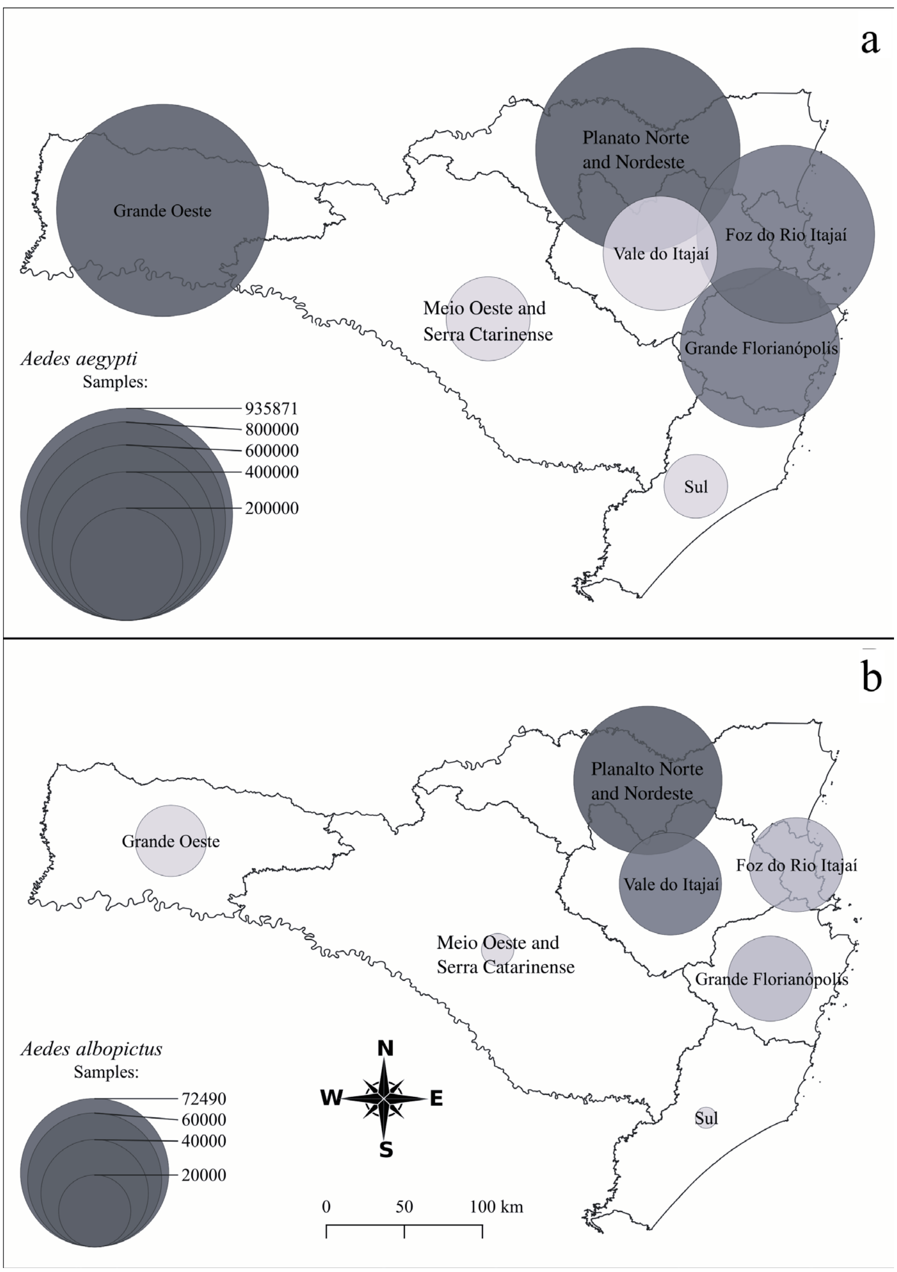

Figure 2. Spatial distribution of immature *Aedes aegypti* (a) and *Aedes albopictus* (b) found in the Santa Catarina Health Macro-regions between 2013 and 2023.

albopictus was not recorded in Santa Catarina (Figure 3 and Table SIII). The linear regression analyses, performed to assess temporal trends in the frequency of positive records of immature *Aedes* forms in Santa Catarina over the study period showed that for *Ae. aegypti*, the model indicated a significant increasing trend over time (β=10,897; $p<0.001$), with the year variable explaining 36.1% of the variability in the annual frequency of positive records (R^2=0.361). Similarly, for *Ae. albopictus*, a significant positive temporal trend was observed (β=613; $p<0.001$), with the model explaining 28.3% of the observed variability (R^2=0.283). These results indicate a temporal increase in the occurrence of immature forms of both species during the study period.

Considering the properties that were considered positive for the vector, that is, those where immature individuals of the *Aedes* genus were found, regardless of the species, the highest number was observed in the categories Commerce (n=124,099) and Residence (n=106,992), followed by the categories: Others (n=54,985), Strategic Point (n=30,852) and Vacant Land (n=3,696) (Table II, Table SIV). Regarding the number of positive breeding sites, that is, those where immature *Aedes* were detected, the largest number was observed in traps installed by the ACEs for vector monitoring (n=231,058), followed by small mobile breeding sites (n=32,129), garbage and scrap locations (n=23,182), tires and other rolling stock (n=11,792), fixed breeding sites (n=8,983), containers at ground level for domestic storage (n=8,410), natural deposits (n=4,157) and elevated water tanks (n=913) (Table III, Table SV).

The Kruskal–Wallis test indicated statistically significant differences in the frequency of positive populations when comparing mosquito species, health macro-regions, and years ($p<0.001$). Effect size estimates indicated a large magnitude of differences for species (ε^2=0.263), year (ε^2=0.393), and health macro-regions (ε^2=0.167), suggesting that the observed differences are not only statistically significant but also of substantial practical relevance.

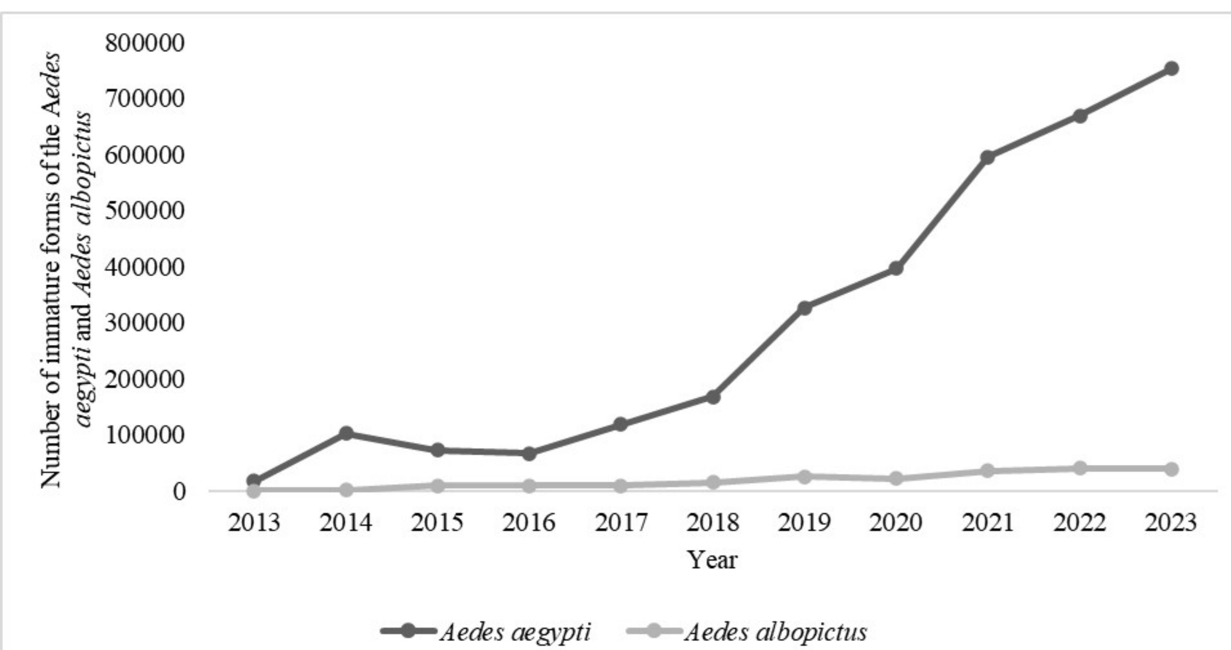

Figure 3. Number of immature forms of the *Aedes aegypti* and *Aedes albopictus* mosquitoes recorded by year from 2013 to 2023 in the state of Santa Catarina, Brazil.

The DSCF multiple comparison test revealed a significant difference between the presence of vectors in the Foz do Rio Itajaí macro-region compared to the Meio Oeste and Serra Catarinense and Sul macro-regions (p=0.024 and p=0.019, respectively). The Grande Oeste macro-region also showed a significant difference when compared to the Meio Oeste and Serra Catarinense and Sul macro-regions (p=0.034 and p=0.049, respectively). The Meio Oeste and Serra Catarinense macro-region showed a trend toward statistical significance compared with the Planalto Norte and Nordeste (p=0.059) (Table SI).

The results obtained from the DSCF test to compare the presence of vectors by year revealed a significant difference between 2013, when there was a considerably lower number of records (17,401), compared to the years 2018 (p=0,014), 2019 (p=0,01), 2020 (p=0,01), 2021 (p=0,003), 2022 (p=0,002) and 2023 (p=0,002), while 2014 presented a significant difference (also with a smaller n = 101,730) when compared to the years 2019 (p=0,024), 2020 (p=0,05), 2021 (p=0,018), 2022 (p=0,021) and 2023 (p=0,011) (Table SI).

The second test stage was carried out taking into account the number of properties and breeding sites that tested positive (showing the presence of immature mosquitoes) for the genus *Aedes* in each related category, regardless of the species. The Kruskal-Wallis tests performed to check the difference between each category of property and location revealed statistically significant differences ($p<0.001$). Large effect sizes were observed for both property categories ($\varepsilon^2=0.258$) and breeding site types ($\varepsilon^2=0.331$), indicating marked heterogeneity in the distribution of *Aedes* populations across these categories. The DSCF comparisons showed that the number of positive properties in the commercial category (124,099) demonstrates a significant difference when compared to the categories strategic point, with 30,852 positive breeding sites (p=0.001), vacant land, with 3,696 positive breeding sites ($p<0.001$) and others, with 54,985 positive breeding sites (p=0.01). The others category, in addition to presenting a significant difference when compared to the business category, shows a difference between the categories residence, with 106,992 positive properties (p=0.018) and vacant land ($p<0.001$). The strategic point category, in addition to presenting significant differences when compared to the businesses, also differs from the categories residence (p=0.002) and vacant land ($p<0.001$). Finally, the residence category also presents a significant difference when compared to the number of populations in the vacant land category ($p<0.001$) (Table SII).

Table II. Number of properties positive for *Aedes aegypti* and/or *Aedes albopictus* in the respective categories, by Health Macro-regions in the period 2013 to 2023 in the State of Santa Catarina, Brazil.

Health Macro-regions	Commerce	Strategic Point	Residence	Waste land	Others
Planalto Norte and Nordeste	39159	3177	22801	418	8744
Vale do Itajaí	13110	3115	6905	208	2539
Foz do Rio Itajaí	23908	5431	21280	576	10098
Grande Florianópolis	23383	6741	20004	1067	12087
Sul	2345	470	2328	72	537
Meio Oeste and Serra Catarinense	3366	437	8317	161	1440
Grande Oeste	18828	11481	25357	1194	19540
Total	**124099**	**30852**	**106992**	**3696**	**54985**

The multiple comparisons carried out to check the differences between the categories in relation to the number of deposits revealed that the categories TRAP, with 231,058 positive breeding sites, and A1 (elevated water tank), with 913 positive breeding sites, both have a significant difference when compared to the other seven categories (p=<0.001) (Table SII).

DISCUSSION

This study evaluated the frequency of *Ae. aegypti* and *Ae. albopictus* in Santa Catarina, Brazil, between 2013 and 2023, and revealed a significant predominance of *Ae. aegypti* - comprising 94.2% of the recorded populations during the study period. Previous studies indicate that *Ae. aegypti* is a predominant species in urban and peri-urban environments in Brazil, due to its strong association with anthropized environments, adaptation to human blood, and oviposition in artificial breeding sites (Rodrigues et al. 2015, de Oliveira & Neto 2017, Heinisch et al. 2019). In this study, it was observed that the Grande Oeste region of the state was the one that recorded the greatest presence of *Ae. aegypti*, which can be explained by the combination of socioeconomic, climatic, and population density factors (Governo do Estado de Santa Catarina et al. 2016). Studies such as that of Salvi et al. (2021) demonstrated that environmental conditions, such as temperature and humidity, combined with urban occupation density, significantly influence the proliferation of *Ae. aegypti*. Furthermore, the Grande Oeste macro-region is characterized by a large circulation of vehicles and people due to the large business companies settled in this area (Mamigonian 2023). Thus, *Ae. aegypti* was passively transported and settled first in the western region of the state, which was the first region of Santa Catarina to be infested by the vector (Busato et al. 2014). In light of these findings and based on the ecological insights of Milagre et al. (2025), the temporal increase and spatial heterogeneity of *Aedes* breeding sites may reflect ecological plasticity driven by anthropogenic disturbance. Just as long-term cattle grazing modified riparian forests without fully compromising soil functionality, progressive urbanization and environmental transformation in Santa Catarina likely impose selective pressures that enhance

Table III. Number of positive breeding sites for *Ae. aegypti* and/or *Ae. albopictus* in the related categories, by Health Macro-regions from 2013 to 2023 in the state of Santa Catarina, Brazil. TRAP = trap; A1 = elevated water tank connected to the public network and/or private supply system; A2 = Ground-level containers for domestic storage; B = small mobile breeding sites. C = fixed breeding sites; D1 = tires and other rolling stock; D2 = garbage, scrap and debris; E = natural deposits.

Health Macro-regions	A1	A2	TRAP	B	C	D1	D2	E
Planalto Norte and Nordeste	133	900	64756	3184	1105	1289	2554	378
Vale do Itajaí	27	669	18387	2680	845	732	2164	373
Foz do Rio Itajaí	158	1105	46854	5827	1810	1904	2907	728
Grande Florianópolis	211	1080	36390	12670	3564	3058	4582	1727
Sul	9	67	3834	610	123	479	499	131
Meio Oeste and Serra Catarinense	44	609	10534	1048	156	656	564	110
Grande Oeste	331	3980	50303	6110	1380	3674	9912	710
Total	**913**	**8410**	**231058**	**32129**	**8983**	**11792**	**23182**	**4157**

mosquito adaptability. Both *Ae. aegypti* and *Ae. albopictus* shows ecological flexibility that allows it to exploit new habitats and persist in human-modified environments. Thus, the distinct spatial patterns and growing number of breeding sites across Santa Catarina's macroregions likely result from interactions between urban expansion, environmental degradation, and vector adaptation.

Although present in all macro-regions evaluated, especially the Planalto Norte and Nordeste, the prevalence of *Ae. albopictus* infestation was lower in the state compared to *Ae. aegypti's*. The Planalto Norte and Nordeste health macro-region is characterized by a large presence of rural areas (Moreira et al. 2016), which explains the biggest presence of *Ae. albopictus* (de Souza et al. 2022). Although there is evidence that competition may occur between the two species, especially when they share the same habitat (Passos et al. 2003, Serpa et al. 2008), studies suggest that *Ae. albopictus* has adaptive advantages in environments close to forested and rural areas, while *Ae. aegypti* adapts better to urbanized areas (Zequi et al. 2019). This competitive dynamic can influence the local distribution of each species, although coexistence in certain areas indicates that competition may not be intense enough to eliminate one of the species (De Lima-Camara et al. 2006, Honório et al. 2009). However, this competitive balance can shift according to habitat availability and climatic conditions, allowing both species to persist in sympatry in transitional landscapes (Lwande et al. 2020). These dynamics emphasize the importance of continuous entomological surveillance, especially in areas undergoing urban expansion, where changes in habitat structure may favor one vector over the other (Heinisch et al. 2025). It is worth noting that *Ae. albopictus*, considered a potential vector of arboviruses in Brazil (Ferreira-de-Lima et al. 2020), is frequently underreported. However, studies describing the presence and density of *Ae. albopictus* in Brazil point out the importance of its entomological monitoring (Pancetti et al. 2015, Ayllón et al. 2018, Variza et al. 2022).

The frequency of vectors in different categories of properties and breeding sites, with a high incidence in commercial premises and in dwellings, demonstrates the high adaptation of these mosquitoes, especially the *Ae. aegypti* (Harrington et al. 2001, Natal 2002) to anthropized environments. Previous studies indicate that areas with a high concentration of people are more likely to have breeding sites, due to inadequate water storage and incorrect disposal of containers (which may be a consequence of insufficient infrastructure), contributing to potential dengue outbreaks (Tauil 2001, Leão et al. 2016).

In addition, the high rate of immature forms captured in traps (installed by the professionals in charge of surveillance) indicates not only the adaptability of mosquitoes but also the effectiveness of this strategy for monitoring these vectors. The larvae traps reflect the continuous presence of vectors in the area, suggesting the need to enhance control strategies in these locations (de Resende et al. 2010). Our results reveal the continuous presence of immature forms of mosquitoes in mobile breeding sites and garbage, which is especially worrying in urban areas, since inadequate management of solid waste favors the proliferation of mosquitoes (de Paiva et al. 2012, Sobral & Sobral 2019). Furthermore, the mobility of small containers increases the dispersion of mosquitoes, expanding the area at risk of disease transmission (Lutinski 2013, de Oliveira & Moraes 2022). Our findings highlight the importance of integrated control strategies that include education on proper waste disposal and inspection programs in regions with greater waste accumulation.

Traps play a fundamental role as surveillance instruments and should be inspected regularly to detect and monitor the presence of *Ae. aegypti* and *Ae. albopictus*, especially in non-infested areas (Governo do Estado de Santa Catarina et al. 2019). These traps are considered breeding sites by the state epidemiological surveillance agency and are essential for identifying foci and monitoring infestation levels in municipalities. However, one challenge faced is the limited access of ACEs to the previously installed traps, which prevents visits to more than 50% of homes, and ends up being characterized as one of the limitations of the study. The success in controlling the populations of *Ae. aegypti* and *Ae. albopictus* depends largely on the participation of the population, which needs to monitor the breeding sites inside and around their homes, no longer considering this responsibility as exclusive to the agents (Valle & Aguiar 2023, Lima-Camara 2024).

The data collected between 2013 and 2023 provide an overview of the presence of *Ae. aegypti* and *Ae. albopictus* in the state of Santa Catarina. The analyses carried out each year revealed an increase in the number of populations of both mosquito species over the years, with 2023 being the year with the highest number of *Ae. aegypti* and 2022 of *Ae. albopictus*. The increase in the presence of these species over the years, especially *Ae. aegypti*, may be an indication that the surveillance and control campaigns carried out in Santa Catarina are impacting the detection and recording of vector populations, with more locations being inspected, consequently bringing a more realistic scenario of mosquito infestation, a factor that may also be associated with the absence of detection of *Ae. albopictus* populations in 2013, considering that surveillance focused on this species may have been more intensive in subsequent years. Climatic variability also plays a crucial role in the spatial and temporal distribution of *Aedes* species (Soek et al. 2023). Santa Catarina experiences pronounced thermal and precipitation contrasts across its relief zones (Governo do Estado de Santa Catarina et al. 2016), which may influence larval development and adult survival (Prasad et al. 2024). Temperature variations and abnormally long periods of temperatures outside the usual range play a crucial role in the expansion of these species, especially in high-altitude regions, previously considered barriers (Barcellos et al. 2024). Recent studies have also shown that extreme weather events, such as those associated with El Niño, have intensified the proliferation and range expansion of *Aedes* species in different regions (Pirani et al. 2024, Barrera et al. 2023). These factors may partly explain the recent peaks in vector presence observed in the state, highlighting the sensitivity of both species to climatic fluctuations.

As for the health macroregions, the distribution of vectors varies significantly, with the Grande Oeste region presenting the highest incidence of *Ae. aegypti* and the Planalto Norte and Nordeste presenting the highest concentration of *Ae. albopictus*. In this time interval, there was a significant increase in positive samples, especially in 2023, for *Ae. aegypti*, and in 2022, for *Ae. albopictus*, possibly due to surveillance and control campaigns. The observed disparities between macro-regions, years and species are significant and suggest that regional and temporal factors play an important role in the distribution of these mosquitoes. In addition, the entomological assessment of properties and sites highlights the importance of targeted interventions in specific sites categories, such as businesses and residences, for effective control of vector populations.

With the increase in the number of populations recorded for both vectors, together with their ability to adapt to new sites, there is an urgent need for continuous inspection of their potential breeding sites, especially in the most affected regions of Santa Catarina, as well as its border regions. When examining the entomological data alongside epidemiological reports from the same period, an increase in *Aedes* populations appears to coincide with a marked rise in dengue notifications in Santa Catarina, particularly after 2019 (Governo do Estado de Santa Catarina et al. 2022, 2023). However, it is important to emphasize that causal inference cannot be drawn from this ecological analysis. In the first three months of 2022, there were 63 new municipalities with dengue transmission, half of them located in the South region of Brazil, where the rate of new municipalities with dengue increased from 1-2 per year to 10 in 2022 in the states of Santa Catarina and Rio Grande do Sul (Codeco et al. 2022). Environmental degradation and inadequate land-use management may further modulate these dynamics. Beys-da-Silva et al. (2025) describe how anthropogenic pressures, such as unregulated urban expansion, pollution, and ecosystem mismanagement, have altered coastal and freshwater systems in Rio Grande do Sul, potentially favoring conditions suitable for *Aedes* breeding in urban and peri-urban environments. Together, these findings from the literature are consistent with the hypothesis that both *Ae. aegypti* and *Ae. albopictus* are progressively adapting to anthropized environments, demonstrating ecological plasticity influenced by environmental mismanagement and urban growth across southern Brazil. Although direct correlation analysis was beyond the scope of this study, this temporal convergence reinforces the importance of entomological surveillance as an early indicator of arbovirus transmission risk. The expansion of *Ae. aegypti* in urban areas, coupled with the established presence of *Ae. albopictus* in peri-urban zones creates a favorable ecological scenario for the maintenance and intensification of dengue transmission in the state. In this context, strengthening vector control and surveillance strategies remains essential for public health planning in Santa Catarina.

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Data availability

The data supporting the findings of this study are available in the supplementary material associated with this article. Additional data and related materials are available from the corresponding author upon reasonable request.