Census and distribution of *Aedes albopictus*[1] (Skuse, 1894) in Acapulco, Guerrero, Mexico.

Censo y distribución de *Aedes albopictus*[1] (Skuse, 1894) in Acapulco, Guerrero, Mexico.

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Abstract. *Aedes albopictus* is considered a secondary vector of dengue, chikungunya, and Zika in Mexico. This species has exponentially increased its distribution throughout Mexico. Following the passage of hurricane Otis in October 2023 in Acapulco, an emergency plan for vector control of *Aedes aegypti* was activated as part of the entomological surveillance activities, including the collection of adults. The results of the collection allowed detecting the presence of *Ae. albopictus* in the urban area of Acapulco, Guerrero. For this reason, entomological monitoring actions were intensified, and collection actions were conducted in seven cemeteries with the objective of documenting the presence of this vector. The results of the study document the establishment of *Ae. albopictus* in the urban area of

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Acapulco and its coexistence with *Ae. aegypti*. The results reinforce the idea of monitoring the introduction of exotic vectors in strategic sentinel sites such as cemeteries, as well as intensifying control activities after a natural disaster that inevitably contributed to an increase in vector populations due to the presence of rainfall.

Key Words: Vectors, mosquitoes, huracan Otis, *Ae. albopictus*

Resumen. *Aedes albopictus* es considerado un vector secundario del dengue, chikungunya y Zika en México. Esta especie ha aumentado exponencialmente su distribución en todo México. Tras el paso del huracán Otis en octubre de 2023 en Acapulco, se activó un plan de emergencia para el control de vectores de *Aedes aegypti* como parte de las actividades de vigilancia entomológica, incluida la colecta de adultos. Los resultados de la colecta permitieron detectar la presencia de *Ae. albopictus* en el casco urbano de Acapulco, Guerrero. Por ello, se intensificaron las acciones de seguimiento entomológico y se realizaron acciones de recolección en siete cementerios con el objetivo de documentar la presencia de este vector. Los resultados del estudio documentan el establecimiento de *Ae. albopictus* en el casco urbano de Acapulco y su coexistencia con *Ae. aegypti*. Los resultados refuerzan la idea de monitorear la introducción de vectores exóticos en sitios centinela estratégicos como los cementerios, así como intensificar las actividades de control luego de un desastre natural que inevitablemente contribuyó al aumento de las poblaciones de vectores debido a la presencia de lluvias.

Palabras clave: Vectores, mosquitos, Huracán Otis, *Ae. albopictus*

Introduction

Arboviruses such as dengue, chikungunya and zika are a public health problem in Mexico and the rest of the world, mainly in tropical and subtropical regions (WHO 2023). In Mexico, chikungunya and zika viruses have generated epidemic outbreaks in 2015 and 2016, respectively (Garay-Moran et al. 2017, Hernández-Ávila et al. 2018). The first documented case of dengue in Mexico occurred in 1971 (Clarke et

al. 2024), and since then the country has experienced epidemic outbreaks of dengue throughout its history every 3 to 5 years (Johansson et al. 2016), mainly by serotypes 1 and 2 (Vasquez-Pichardo et al. 2011, Gutiérrez et al. 2023). The Pan American Health Organization issued an Epidemiological Alert in early December 2023 for the sustained circulation of dengue 3 in the Central American Isthmus and Mexico (PAHO-WHO 2023). In the same year, dengue serotype 3 circulated in all endemic states of Mexico (except Mexico City, Tlaxcala, and Zacatecas), the states with the highest disease burden were Yucatan, Veracruz, Quintana Roo, Morelos, Puebla, Chiapas, Guerrero, Tabasco, Campeche, and Oaxaca, and the urban areas identified with the highest transmission included the localities of Merida, Cancun, Veracruz, Campeche, Cordoba, Tizimín, Cuernavaca, and Acapulco (SSA 2023). Specifically, on October 24, 2023, in the coastal area of Acapulco, Hurricane Otis made landfall as a category 5 hurricane on the Saffir-Simpson scale with maximum winds of 270 kilometers per hour (https://rapidmapping.emergency.copernicus.eu/EMSR703). The estimated economic damage was 16 billion dollars (USD), 51 deaths were recorded, and a total of 350 deaths were estimated. This meteorological phenomenon caused dengue transmission in Acapulco to double its growth rate and effective reproductive number (Rt). In response to the natural disaster, health authorities from the National Center for Disease Prevention and Control (CENAPRECE) and the Guerrero State Government implemented an emergency vector control plan, which included vehicle-mounted ground fogging throughout the town, larval control and intradomiciliary thermal fogging in priority areas identified with active transmission. As part of the evaluation of the impact of operational activities, CENAPRECE conducted entomological surveillance activities through the collection of resting adults inside homes, identifying the presence of *Ae. albopictus*. The objective of this study was conducting entomological sampling in cemeteries within the urban area of the city of Acapulco in order to confirm the presence of this species, document the establishment and coexistence of *Ae. aegypti and Ae. albopictus*.

Material and methods

Study area

The city and port of Acapulco is located on the Mexican Pacific coast in the geographic rectangle (bounding box) formed by the following geographic coordinates (EPSG code:4326) -100.00476 (minimum longitude), 16.71173 (minimum latitude), -99.69626 (maximum longitude), and 16.93538 (maximum latitude) (Figure 1). The total area includes 14274 hectares where approximately 779566 people live in 223924 dwellings (INEGI 2023) with an average number of inhabitants per dwelling of 3.7 (INEGI 2023).

Selection of cemeteries

The National Institute of Geography and Statistics has registered a total of 17 cemeteries in the urban area of Acapulco. The heat islands represent the contrast of the average annual temperature per urban pixel (100 x 100 m) versus the average annual temperature of the rural pixels in the same geographic area of the city (Fig. 1) (INEGI 2020). Six cemeteries were selected based on the following characteristics: public and private, as well as their location in the periphery or interior of the city. Additionally, a cemetery on the free highway from Acapulco to CDMX (not shown on the map) was included.

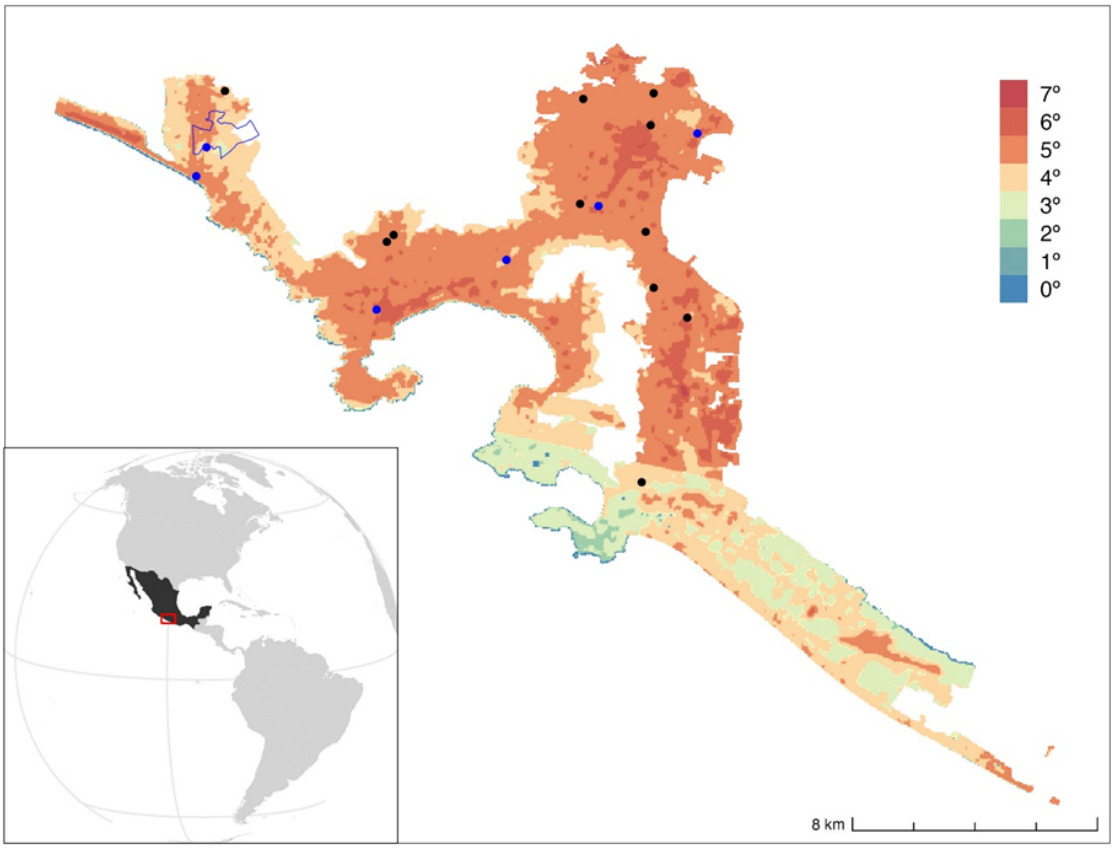


Fig. 1. Geographic distribution of cemeteries in the urban area of Acapulco and Heat Islands. The points on the map correspond to the cemeteries (the points in blue represent the cemeteries sampled) and the polygon in blue corresponds to the San Isidro neighborhood.

Fig. 1. Distribución geográfica de los cementerios en el área urbana de Acapulco e Islas del Calor. Los puntos del mapa corresponden a los cementerios (los puntos en azul representan los cementerios muestreados) y el polígono en azul corresponde al barrio de San Isidro.

Entomological Surveys

Entomological collections of resting adults were conducted from November 29 to December 1, 2023. The resting mosquitoes were collected in moist, shaded, leaf littered locations around graves, under trees, and inside niches. Two or three previously trained entomologists walked longitudinally through the cemeteries for 15

to 30 minutes or before reaching the end of the cemetery. Mosquitoes collected with the CDC Backpack aspirator were transferred with a castro tube to properly labeled observation cups and then transferred to a room with controlled conditions of temperature and relative humidity for preservation and subsequent taxonomic identification. Adult samples were identified following the key of Rueda (2004) and were sent to the Instituto de Diagnóstico y Referencia Epidemiológica (INDRE) of the Secretaría de Salud de México for species confirmation and entomovirological diagnosis.

Results

It was determined that all cemeteries were positive for *Ae. aegypti* and *Ae. albopictus*. A total of 179 *Ae. aegypti* (48 females and 131 males) and 177 *Ae. albopictus* (85 females and 92 males) were collected in the seven Acapulco cemeteries (Fig. 1 and Fig. 2). Los análisis con los modelos lineales generalizados mixtos (Generalized Linear Mixed Models) usando la distribución binomial negativa sugieren que no existen diferencias entre las el número de adultos ($\beta_x = -0.011\,, \mathrm{IC95\%} = -0.681 \text{ a } 0.659$), machos ($\beta_x = -0.434\,, \mathrm{IC95\%} = -1.156 \text{ a } 0.287$) y hembras ($\beta_x = 0.655\,, \mathrm{IC95\%} = -0.030 \text{ a } 1.340$) entre ambas especies. The climatological conditions of temperature and average precipitation of the sampled sites are reflected in Figure 3, where the maximum (40 Celsius) and minimum (20 Celsius) temperatures can be seen for a whole year (January 2023 - January 2024). Similarly, for the effective reproductive number (Rt), monitoring was carried out for one year, in the results obtained we can mention that the highest Rt value (15) is shown in July and August 2023 (Fig. 4) and later in January 2024 the value is repeated, so it is of utmost importance to carry out entomological surveillance in those months due to the high values in the Rt. Finally, Figure 4 shows the map of the Mexican Republic showing the states with previous records of the presence of *Ae. albopictus* (light gray) and the states where the presence of the mosquito has not been recorded (dark gray). This shows the presence of the mosquito in almost all of southern Mexico, leaving the north of the country as an

area without records of the mosquito; however, this does not indicate that *Ae. albopictus* is absent in these states.

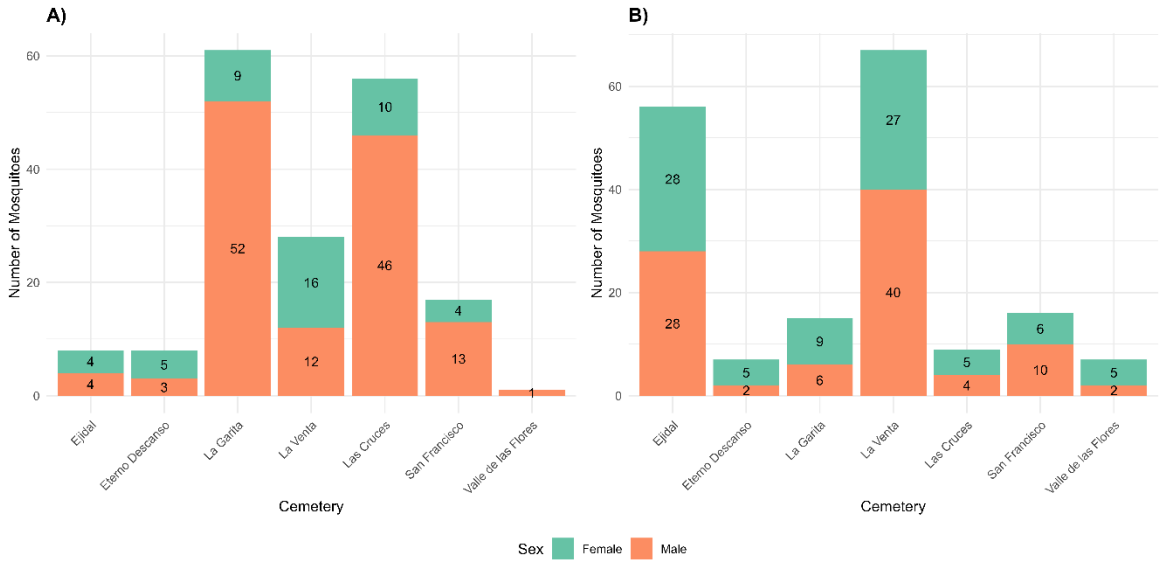
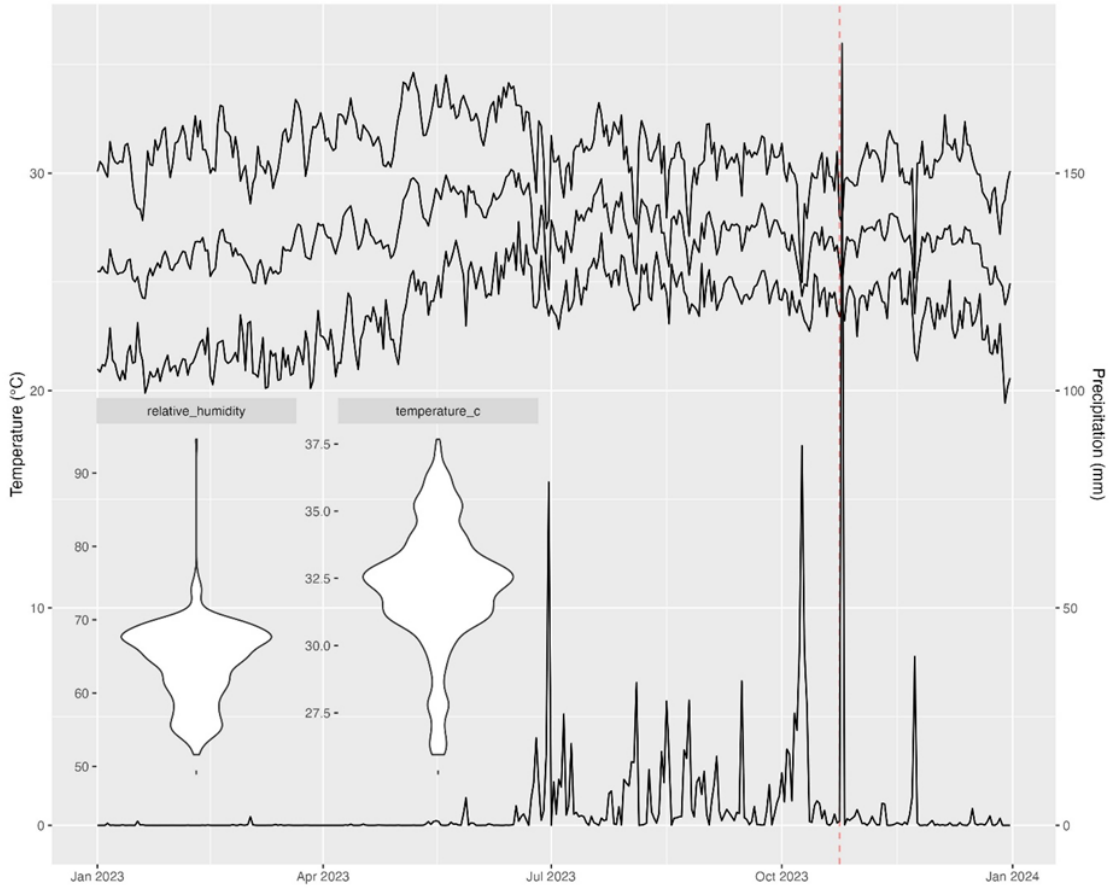


Fig. 2. Distribution of *Ae. aegypti* and *Ae. albopictus* in cementeries. Number of mosquitoes collected by species and sex (female or male) in seven cemeteries. Bars represent the total number of individuals collected per cemetery, with males and females shown as stacked segments.

Fig. 2. Distribución de *Ae. aegypti* y *Ae. albopictus* en cementerios. Número de mosquitos recolectados por especie y sexo (hembra o macho) en siete cementerios. Las barras representan el número total de individuos recolectados por cementerio, y los machos y las hembras se muestran como segmentos apilados.



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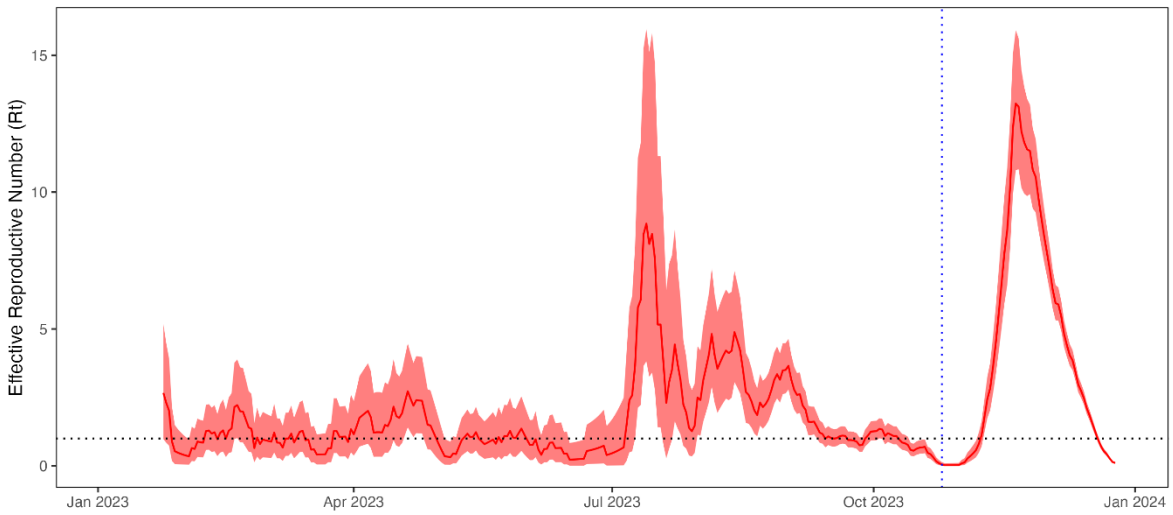
157 Fig. 3. Temperature, precipitation and microclimatic conditions in the Acapulco
158 locality. In the graph the curves represent the temperature (average, minimum and
159 maximum) and precipitation of the Acapulco locality, and the violin plots represent
160 the temperature and humidity recorded in the cemeteries with the Kestrell Drop AGs.

161 Fig. 3. Temperatura, precipitación y condiciones microclimáticas en la localidad de
162 Acapulco. En la gráfica las curvas representan la temperatura (promedio, mínima y
163 máxima) y precipitación de la localidad de Acapulco, y las gráficas de violín
164 representan la temperatura y humedad registradas en los cementerios con los
165 Kestrell Drop AG.



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167 Fig. 4. Effective reproductive number (Rt). The solid red line represents the
168 estimated Rt over time, while the shaded area indicates the 95% confidence interval.
169 The horizontal dashed line at Rt = 1 marks the thereshold above wich diasease
170 transmission is sustained. The blue vertical dashed line highligths a specific
171 intervention or event that occurred during the study period.

172 Fig. 4. Número reproductivo efectivo (Rt). La línea roja sólida representa el Rt
173 estimado a lo largo del tiempo, mientras que el área sombreada indica el intervalo
174 de confianza del 95%. La línea discontinua horizontal en Rt = 1 marca el umbral por
175 encima del cual se mantiene la transmisión de la enfermedad. La línea discontinua
176 vertical azul resalta una intervención o evento específico que ocurrió durante el
177 período de estudio.

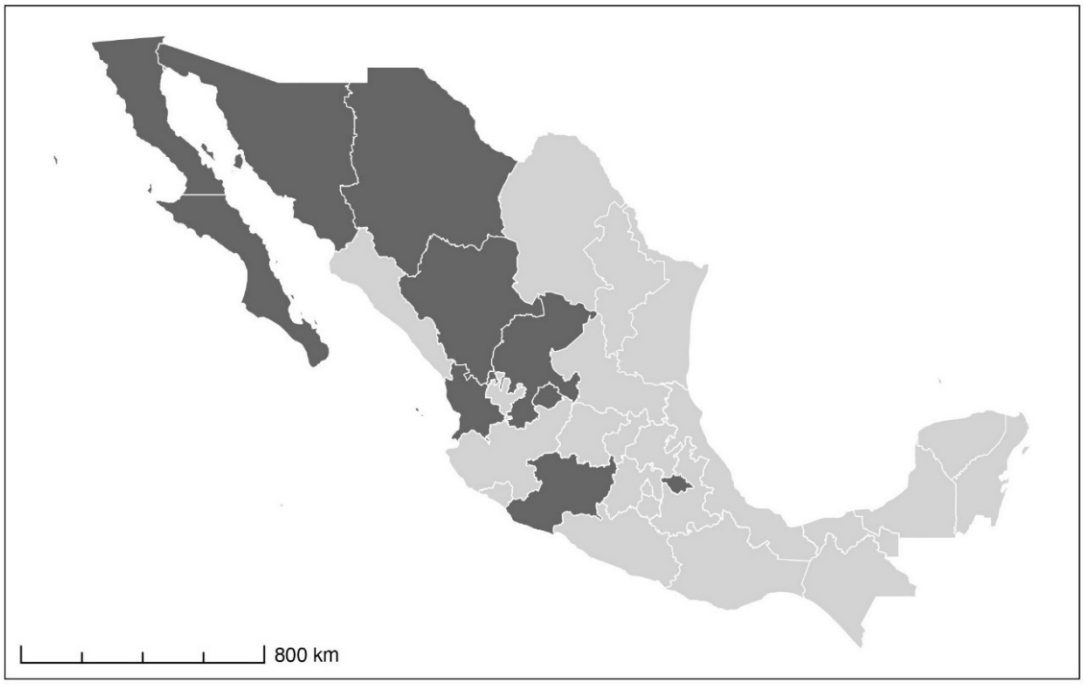

Fig. 5. Regions in Mexico without reports of *Ae. albopictus.* The map shows in dark gray the states where *Ae. albopictus* is absent.

Fig. 5. Regiones de México sin reportes de *Ae. albopictus*. El mapa muestra en gris oscuro los estados donde *Ae. albopictus* está ausente.

Discussion and Conclusions

This study confirms the presence of *Ae. albopictus* in the urban area of Acapulco. This species was detected in November 2018 in two rural localities of the Costa Chica of Guerrero near the border with the state of Oaxaca (González-Acosta et al. 2019). These localities are between 120 km to 212 km away from the port of Acapulco and considering the speed of invasion (~60km/year) documented in the United States (Kraemer et al. 2019), it was expected that between two and four years this species could be introducing into the port Acapulco (between 2020 and 2022). At intercontinental scales, historically the most important pathways of introduction include voyages of conquest, and with trade in goods and materials (Cuthbert et al. 2023), at national or local scales species dispersal is along transport routes (Swan et al. 2022, Vavassori et al. 2022), so it is not uncommon to find *Ae. albopictus* in the Port of Acapulco, due to its high flow of tourists from all over the country (such as

Mexico City which has documented presence of this species (Dávalos-Becerril et al. 2019), from neighboring states with presence of *Ae. albopictus* such as Oaxaca, Puebla, Morelos, and Estado de México (Villegas-Trejo et al. 2010; Adeniran et al 2020; Ortega-Morales et al. 2022; Sánchez-Reyes et al. 2023) and from coastal localities of Guerrero that probably have the presence of this species.

The Specific Action Program 2020-2024 of the Prevention and Control of Vector-borne Diseases and Arthropod Venom Poisoning Program of CENAPRECE (SSA 2021), considers the city of Acapulco as a priority locality for prevention and control actions, as well as for epidemiological surveillance and entomological surveillance. The central objective of the entomological surveillance system in Mexico is to determine the spatial and temporal distribution of vector abundance and prevalence, and the information generated provides a tool for the evaluation of integrated vector management interventions, and egg samples are the raw material for biological testing of insecticides (SSA 2020). However, these parameters are not yet included for the *Ae. albopictus* mosquito, which could create a problem in the future, leaving aside the control of this mosquito.

The Mexican entomological surveillance system with ovitraps (Wright et al. 2023), has allowed timely detection of the introduction of *Ae. aegypti* and *Ae. albopictus* in Mexico City (Kuri-Morales et al. 2017, Dávalos-Becerril et al. 2019) and the State of Mexico (Ortega-Morales et al. 2022, Sánchez-Reyes et al. 2023), as well as documenting the establishment of *Ae. aegypti* in Mexico City (Mejia-Guevara et al. 2020). Biological material of *Ae. aegypti* from ovitraps has allowed us to determine susceptibility to insecticides (Kuri-Morales et al. 2018), evaluate commercial repellents (Kuri-Morales et al. 2018), commercial aerosol insecticides (Kuri-Morales et al. 2018), and determine the efficacy of aerial spraying (Dzul-Manzanilla et al. 2019). After mentioning the scope of the strategies designed for the control of *Ae. aegypti* in localities with introduction of *Ae. albopictus* as in the case of Acapulco and in localities where the mosquito has become established, prevention and control programs should perform the same strategies previously mentioned but focused on *Ae. albopictus*.

In Acapulco as in the rest of Mexico, the primary vector of dengue, chikungunya, and Zika viruses is *Ae. aegypti*. The mosquitoe *Ae. albopictus* has a wide distribution in Mexico (Yanes-Arenas et al. 2018; Ortega-Morales et al. 2022), and although it has been detected with dengue and zika viruses (Ibáñez-Bernal et al. 1997; Huerta et al. 2017; Correa-Morales et al. 2019), its role in the transmission of these arboviruses and in general its function as a secondary vector in localities with similar abundance between both species is unknown (López-Soliz et al. 2023). In Acapulco, dengue, chikungunya and zika viruses have been detected in *Ae. aegypti* (Martinez et al. 2014; Dzul-Manzanilla et al. 2015; Dzul-Manzanilla et al. 2016; Diaz-Quinoñez et al. 2016; Correa-Morales et al. 2019) and with the current introduction of *Ae. albopictus* in Acapulco, health authorities have the opportunity to clarify the primary or secondary role of both species in the transmission of arbovirosis with the entomovirological surveillance system (Correa-Morales et al. 2019).

Following Hurricane Otis, entomological collections of adults in resting sites inside the home detected the presence of *Ae. albopictus* inside one house in a sampling of more than 100 houses. Sampling in seven cemeteries in Acapulco documented the introduction of *Ae. albopictus* into the urban area of Acapulco. The cemeteries were originally built on the outskirts of the localities, but with the passage of time and the growth of the urban sprawl, the localities were integrated and formed metropolitan areas where the cemeteries became embedded within the urban centers. The cemeteries constitute isolated patches within the urban area with no apparent connection between them, but with a high abundance and diversity of breeding sites inside each cemetery, as well as in the surrounding urban area.

The presence, diversity, and abundance of breeding sites allows cemeteries to be connected to urban buffer areas reducing the effect of fragmented habitat and helping species to be introduced into a new habitat or city (Trewin et al. 2021a, Trewin et al. 2021b). Independent observation throughout the cemetery and in each cemetery suggests multiple introductions or demonstrates establishment several years ago that allowed dispersal throughout the cemeteries across corridors within the city. The Mexican official vector standard indicates surveillance for the

introduction of exotic vectors to new areas such as *Ae. albopictus* (DOF 2015) and cemeteries constitute ideal strategic anthropogenic environments to monitor the introduction of non-native mosquitoes such as *Ae. aegypti* and *Ae. albopictus* (Vezzani et al. 2007). The present study constitutes and reinforces the idea of targeted monitoring of the introduction of exotic vectors at strategic sentinel sites such as cemeteries, independent of surveillance at entry points.

Ae. albopictus is a cosmopolitan species distributed in all continents (Kraemer et al. 2015; Kraemer et al. 2019), and its physiological and ecological plasticity allows it to adapt in tropical, subtropical and temperate climates (Paupy et al. 2009). The nonlinear relationship between temperature and survival indicates an optimal temperature (max-min) of 32.6 °C (8.7-39.6) for *Ae. albopictus* and 32.7 °C (11.6-33.0) for *Ae. aegypti* (Mordecai et al. 2019, Souza and Weaver 2024). In our study we were able to determine that the optimal temperatures for both mosquitoes are in the range of temperatures monitored, so it is important to monitor the growth and development of both species.

Meteorological data (ERA5-Land Daily Aggregated - ECMWF Climate Reanalysis) indicate that the Acapulco locality has an average annual temperature of 27. 06 degrees Celsius (min = 23.54, 1Q = 26.23, median = 27.06, 3Q = 27.9, max = 30.17). The combination of the temperature of the microenvironments and the temperature exposed to the sun raises the average recorded during collection, independent of this fact, both species adjust to the environmental conditions, survive, and reproduce successfully in the cemeteries. Thus, the temperatures recorded during collection are completely congruent with those reported in the literature (Mordecai et al. 2019, Souza and Weaver 2024).

Hurricane Otis made landfall before November 2. During these dates, Mexicans honor their deceased relatives in cemeteries, increasing the number of people visiting cemeteries throughout the month of November, which is why cemeteries are potential arbovirosis transmission sites. In the context of prevention and control actions, the National STD Program indicates the implementation of larvae control and thermal fogging in public places of population concentration such as cemeteries,

due to the number of people who attend these celebration sites, making them a high-risk population. Likewise, CENAPRECE in collaboration with the Government of the State of Guerrero carried out vehicle-mounted ground fogging throughout the city, and larval control and intradomiciliary thermal fogging in priority areas identified with active transmission. Cemeteries are included in the transmission risk areas. On the other hand, and in response to natural disasters, these actions were intensified, contributing to control the population growth of vectors as a result of the presence of rain with the passage of this meteorological phenomenon.

The presence of a mosquito species of medical or veterinary importance in dengue endemic urban areas should be followed by a targeted surveillance program (suspicion of presence) or an extensive surveillance program in the urban area (in the state or country) to confirm the presence and/or determine the geographical spread of the species, respectively. Immediately and/or in parallel, the following points should be carried out; 1) virological diagnosis to incriminate the role of the alien species as primary or secondary vector, 2) diagnosis of susceptibility to insecticides and 3) control actions to eradicate or limit geographic expansion. Finally, in case of establishment and spread of a non-native mosquito species in urban localities endemic to dengue, chikungunya, zika and yellow fever, include them in prevention and control programs.

Complete and detailed information was generated on the presence of *Ae. albopictus* in places where it was presumed not to exist, in order to prepare future generations, training them to implement efficient control methods to avoid outbreaks of arboviruses as has been the case of dengue, sika, chik with the participation of the *Ae. aegypti* mosquito.

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