Aedes aegypti, the dengue fever mosquito in Mexico City. Early invasion and its potential risks

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Abstract

Introduction: Mexico City has no endemic presence of *Aedes aegypti*, and it is therefore free of vector-borne diseases, such as dengue fever, Zika and chikungunya. However, evidence has shown the presence of *Aedes aegypti* eggs in the city since 2015. **Objective:** To report the constant and increasing presence of *Aedes aegypti* eggs in Mexico City from 2015 to 2018. **Methods:** Surveillance was carried out using ovitraps. Eggs were counted and hatched in order to determine the species. **Results:** From 2015 to 2018, 378 organisms were identified as *Ae. aegypti*. In total, 76 *Aedes aegypti*-positive ovitraps were collected at 50 different places in 11 boroughs of the city. Northeastern Mexico City was the area with the highest number of positive traps. **Conclusions:** The results may be indicating a period of early colonization and the probable existence of cryptic colonies of the mosquito; Mexico City could be at risk of experiencing vector-borne epidemics.

KEY WORDS: *Aedes aegypti*. Mexico City. Vector-borne diseases. Mosquitoes Entomological surveillance.

El mosquito del dengue en la Ciudad de México. Invasión incipiente de Aedes aegypti y sus potenciales riesgos

Resumen

Introducción: La Ciudad de México no tiene presencia endémica de *Aedes aegypti*, por lo que está libre de enfermedades transmitidas por vector como dengue, Zika y chikunguña. Sin embargo, existe evidencia de la presencia de huevecillos en la urbe desde 2015. **Objetivo:** Reportar la presencia constante y en aumento de huevecillos de *Aedes aegypti* en la Ciudad de México de 2015 a 2018. **Método:** Se realizó vigilancia a través de ovitrampas; se contabilizaron y eclosionaron huevecillos para determinar la especie. **Resultados:** De 2015 a 2018 fueron identificados 378 organismos como *Aedes aegypti*. En total fueron colectadas 76 ovitrampas positivas a *Aedes aegypti* en 50 sitios distintos de 11 alcaldías. El noreste de la Ciudad de México fue el área con mayor positividad. **Conclusiones:** Los resultados pueden estar indicando un periodo de colonización incipiente y la probable la existencia de colonias crípticas del mosquito, por lo que la Ciudad de México podría estar en riesgo de presentar epidemias de enfermedades transmitidas por vector.

PALABRAS CLAVE: *Aedes aegypti*. Ciudad de México. Enfermedades transmitidas por vector. Mosquitos. Vigilancia entomológica.

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Introduction

The *Aedes aegypti* mosquito (order: Diptera; family: Culicidae; subgenus *Stegomyia*), originally described as *Culex aegypti* by Carl Linnaeus in 1792, is the main vector for the transmission of arboviruses (contraction of “arthropod-borne viruses”) such as those that cause yellow fever, dengue, Zika and chikungunya. The diseases caused by these arboviruses are called vector-borne diseases (VBD). Currently, 30 states of Mexico report cases of endemic VBDs, with Tlaxcala and Mexico City (CDMX – *Ciudad de México*) being the only VBD-free states.

CDMX is 2,240 m above sea level, and its annual average temperature ranges from -2 °C to 28 °C. It has temperate-sub-humid, semi-cold-sub-humid-humid, semi-dry temperate climates, as well as seasonal rains in the summer, with an average annual rainfall of 720 mm.^{1,2} Owing to these geographical and climatic characteristics, it constituted an area with little probability for the establishment of *Aedes aegypti*, a species adapted to tropical and subtropical climates. However, recent evidence shows an intermittent presence of the mosquito in the city.^{3,4}

There are causative factors for *Aedes aegypti* introduction and colonization. Continuous urbanization (legal and illegal), housing poor conditions and overcrowding, insufficient access to water and sewerage and deficient waste management; climate change and water and air temperature increase in urban areas,^{5,6} as well as mobility of individuals from places with permanent mosquito presence, can induce dispersal of the vector and the virus.^{7,8} The interaction of these factors puts CDMX at risk of becoming an area where mosquitoes (and the arboviruses they transmit) can become established.

Given that CDMX is surrounded by states with *Aedes aegypti* permanent presence and endemic VBDs (State of Mexico and Morelos), and since it has high human and foreign transportation mobility, as well as atmospheric temperature increase (Fig. 1), since 2009 was the use of ovitraps established for mosquito monitoring. Ovitrap are dark containers that are lined inside with an oviposition substrate and that are filled with water;⁹ they simulate the places where the mosquito lays its eggs and constitute a tool for the monitoring of *Aedes aegypti* and other mosquitoes.¹⁰⁻¹² The first registration of *Aedes aegypti* eggs in CDMX was carried out in 2015;³ ever since, a constant increase in the number of ovitraps with mosquito eggs has

been detected. In this article, the presence of the mosquito detected using ovitraps from 2015 to 2018 is reported, and the potential establishment of *Aedes aegypti* in CDMX, as well as the possible risk it represents for public health, are discussed.

Method

Collections were carried out according to the National Center for Preventive Programs and Disease Control Methodological Guidelines.⁹ The ovitraps consisted of 1-L black plastic containers. As oviposition substrates, 12 cm wide by 35 cm long nonwoven (Pellon) fabric (F-1600) sheets were used. The inner surface of the ovitrap was lined with the substrate and filled with water, without reaching the upper edge in order to leave 2-3 cm of the sheets exposed (which is the area where the females lay their eggs), and placed on shady places at less than 1.5-m height. The ovitraps were checked every seven days and the sheets with eggs were removed, onto which the eggs found in the water or at the bottom of the ovitraps were deposited, which were washed, lined with new sheets, replenished with clean water and placed back at the same place.

The nonwoven sheets were submitted to the Pan-chimalco Regional Center for Vector Control Entomological Research and Bioassay Unit, in Morelos, where the count and hatching of the eggs, as well taxonomic determination of the organisms, were carried out. For hatching, the nonwoven sheets were submerged in water in plastic trays containing 1 L. The hatched larvae were fed rat kibble. The emerged adults were placed in plastic mesh cages and fed ad libitum with a sugar solution. Rearing temperature was 29 ± 2 °C, with 60-70 % relative humidity and natural light-dark periods. The larvae were taxonomically characterized during the third and fourth stages of development. For larvae and adult specimens stratification, Ibáñez-Bernal and Martínez-Campo¹³ and Darsie and Ward¹⁴ taxonomic keys were used.

The ovitraps were placed at non-residential public areas such as gardens, public squares and parks, nature reserves within the urban area, avenues and traffic islands. External areas with free access to health centers, schools, churches, markets, sports or recreation units, community centers, foreign bus stations and piers (at Xochimilco) were also included. Annually, 2,240 ovitraps were placed, except in 2015, when 1,440 were used, with all 16 CDMX districts being covered.

Figure 1. A) Mexico City average annual maximum temperature and **B)** annual historical precipitation (mm). Source: <https://smn.cna.gob.mx/es/climatologia/temperaturas-y-lluvias/resumenes-mensuales-de-temperaturas-y-lluvias>

Figure 2. Location of the sites with *Aedes aegypti*-positive ovitraps collected in Mexico City (urban and satellite map view).

Results

From the collections carried out between 2015 and 2018, 1,531 ovitraps with eggs were detected, collected at 358 different places. Total number of eggs was 48,477, out of which 16,171 were hatched; 378 were *Aedes aegypti*, which represented 0.77 % of hatching success. In total, 76 *Aedes aegypti*-positive ovitraps were collected at 50 different places in 11 districts (Fig 2. and Table 1). The highest number of larvae was collected in September (rainy season); however, positivity was detected from May to November (Table 1).

Sixteen sites were positive on more than one occasion, and most records occurred in north, northeast and center CDMX (Table 1 and Fig. 3A). Several places were areas with a high attendance of both local and foreign people, as well as tourist areas (e.g., San Juan de Aragón Park and Zoo, Tepeyac Reserve, TAPO bus station and Xochimilco Zacapa Pier). In some cases, positivity was repeated between years, and in others, positivity was detected at different collections within the same year (Table 1).

Positive ovitraps started being identified in the Northeast (2015, 2016 and first semester of 2017), which is an area that has a temperature that ranges

Table 1. Places in Mexico City where *Aedes aegypti* was collected using ovitraps between 2015 and 2018

Year	District	Site	Latitude	Longitude	Month	No. of larvae
2015	Azcapotzalco	Suburban train (Pantaco)	19.479908	-99.168761	September	14
	Gustavo A. Madero	Casa del Peregrino	19.483314	-99.109786	September	4
2016	Venustiano Carranza	Alameda Oriente	19.436358	-99.053873	September	1
	Venustiano Carranza	CONALEP Airport	19.424043	-99.057283	-	1
	Venustiano Carranza	TAPO	19.42989	-99.112319	-	1
2017	Álvaro Obregón	Mayan Baseball League	19.364826	-99.196399	September	14
	Álvaro Obregón	Valentín G. Farías Park	19.368711	-99.206424	September	1
	Azcapotzalco	Alameda Norte	19.500219	-99.178502	September	1
	Azcapotzalco	Renovación Nacional Sport Center	19.490113	-99.214643	September	2
	Azcapotzalco	Margarita Maza de Juárez Garden	19.490282	-99.199102	November	1
	Azcapotzalco	Chilapillas Park	19.479363	-99.208156	August	1
	Coyoacán	Santa Úrsula Sport Center	19.308975	-99.160651	October	8
	Coyoacán	Santa Úrsula Sport Center	19.308975	-99.160651	September	2
	Coyoacán	Las Montañas Park	19.347868	-99.123349	November	2
	Coyoacán	Las Montañas Park	19.347868	-99.123349	October	6
	Coyoacán	Santa Úrsula Park	19.303734	-99.159131	June	1
	Cuauhtémoc	Santiago Garden	19.449623	-99.135017	September	1
	Gustavo A. Madero	Basilica of Guadalupe	19.485171	-99.117862	October	1
	Gustavo A. Madero	San Juan de Aragón Park	19.462061	-99.073349	September	1
	Gustavo A. Madero	Carmen Serdán Sport Center	19.553124	-99.146329	July	1
	Gustavo A. Madero	Heberto Castillo Sport Center	19.497863	-99.089899	June	8
	Gustavo A. Madero	Luiggy Sport Center	19.484424	-99.095655	August	1
	Gustavo A. Madero	Luiggy Sport Center	19.484424	-99.095655	July	4
	Gustavo A. Madero	Luiggy Sport Center	19.484424	-99.095655	September	2
	Gustavo A. Madero	Miguel Alemán Sport Center	19.493173	-99.128598	September	8
	Gustavo A. Madero	North Corpus Christi Park	19.46648	-99.121144	August	2
	Gustavo A. Madero	North Corpus Christi Park	19.46648	-99.121144	July	1
	Gustavo A. Madero	Justicia Social Recreation Park	19.478533	-99.090386	August	4
	Gustavo A. Madero	Justicia Social Recreation Park	19.478533	-99.090386	August	1
	Gustavo A. Madero	Justicia Social Recreation Park	19.478533	-99.090386	November	5
	Gustavo A. Madero	Justicia Social Recreation Park	19.478533	-99.090386	September	2
	Gustavo A. Madero	Justicia Social Recreation Park	19.478533	-99.090386	September	1
	Gustavo A. Madero	Rancho Grande la Villa	19.501382	-99.118285	July	7
	Gustavo A. Madero	Tepeyac Reserve	19.504375	-99.107777	July	3
	Gustavo A. Madero	Tepeyac Reserve	19.504375	-99.107777	June	2
	Gustavo A. Madero	Tepeyac Reserve	19.504375	-99.107777	November	21

(Continues)

Table 1. Places in Mexico City where *Aedes aegypti* was collected using ovitraps between 2015 and 2018 (Continued)

Year	District	Site	Latitude	Longitude	Month	No. of larvae
	Gustavo A. Madero	Tepeyac Reserve	19.504375	-99.107777	November	5
	Gustavo A. Madero	Tepeyac Reserve	19.504375	-99.107777	October	7
	Gustavo A. Madero	San Juan de Aragón Zoo	19.461268	-99.081155	November	1
	Gustavo A. Madero	San Juan de Aragón Zoo	19.461268	-99.081155	September	10
	Iztacalco	Dr. Manuel Pesqueira TIII Health Center	19.394339	-99.070505	August	1
	Iztacalco	Metro Sport Center	19.387966	-99.094784	September	2
	Iztacalco	El Foro Park	19.3848	-99.111596	July	1
	Iztapalapa	Salvador Allende Swimming Pool	19.358232	-99.052353	August	1
	Iztapalapa	Antonio Gómez Rodríguez Library	19.348838	-99.061293	July	1
	Iztapalapa	Villa Estrella Social Center	19.351701	-99.092109	October	102
	Iztapalapa	Mexican Sport-Athletic Center	19.374861	-99.063031	September	1
	Iztapalapa	Santa Cruz Meyehualco Sport Center	19.345768	-99.048541	July	2
	Iztapalapa	Santa Cruz Meyehualco Sport Center	19.345768	-99.048541	September	1
	Iztapalapa	Francisco J. Mujica Garden	19.349013	-99.061294	September	10
	Miguel Hidalgo	CECYT 9	19.453899	-99.175013	October	1
	Miguel Hidalgo	CECYT 9	19.453899	-99.175013	September	1
	Miguel Hidalgo	Cañitas Garden	19.45346	-99.177568	July	4
	Tláhuac	Santa Catarina Health Center	19.307826	-98.968109	July	2
	Venustiano Carranza	Venustiano Carranza Conalep II	19.422892	-99.05879	September	1
	Venustiano Carranza	Lázaro Cárdenas Sport Center	19.414801	-99.119973	July	1
	Venustiano Carranza	Lázaro Cárdenas Sport Center	19.415124	-99.11997	November	22
	Venustiano Carranza	Lázaro Cárdenas Sport Center	19.414801	-99.119973	October	4
	Venustiano Carranza	Moctezuma Sport Center	19.434247	-99.097297	October	3
	Venustiano Carranza	Plutarco Elías Calles Sport Center	19.453841	-99.118303	July	26
	Venustiano Carranza	TAPO	19.42989	-99.112319	June	15
	Xochimilco	Tulyehualco Cultural Center	19.255422	-99.017332	August	1
	Xochimilco	Faculty of Arts and Design	19.251917	-99.11946	September	1
2018	Coyoacán	Huayamilpas Park	19.324223	-99.150507	September	2
	Gustavo A. Madero	San Juan de Aragón Park	19.462061	-99.073349	July	1
	Gustavo A. Madero	Lienzo Charro de Aragón	19.462163	-99.063339	July	1
	Gustavo A. Madero	Tepeyac Reserve	19.504375	-99.107777	July	1
	Gustavo A. Madero	San Juan de Aragón Zoo	19.461268	-99.081155	May	1
	Iztacalco	Pantitlán Park	19.4151	-99.058379	July	1
	Iztapalapa	Salvador Allende Swimming Pool	19.358232	-99.052353	August	1
	Iztapalapa	Salvador Allende Swimming Pool	19.358232	-99.052353	July	1
	Iztapalapa	Villa Estrella Social Center	19.351701	-99.092109	September	1

(Continues)

Table 1. Places in Mexico City where *Aedes aegypti* was collected using ovitraps between 2015 and 2018 (Continued)

Year	District	Site	Latitude	Longitude	Month	No. of larvae
	Iztapalapa	Santa Martha Sport Club	19.360389	-99.00439	September	1
	Xochimilco	Tulyehualco Cultural Center	19.255422	-99.017332	September	1
	Xochimilco	Acuexcomatl Environmental Education Center	19.260958	-99.028621	July	1
	Xochimilco	Zacapa Pier	19.248801	-99.092481	September	1
	Xochimilco	Zacapa Pier	19.248801	-99.092481	September	1

Figure 3. A) Districts with *Aedes aegypti*-positive ovitraps. The district where positive ovitraps were recurrently observed was Gustavo A. Madero (2015, 2017, 2018), followed by Azcapotzalco, Coyoacán, Iztacalco, Venustiano Carranza and Xochimilco, with two years of positive collections. The district with the highest positivity was Gustavo A. Madero, followed by Xochimilco, Venustiano Carranza and Iztapalapa. B) CDMX temperature ranges with positive ovitraps location during the 2015-2018 period.

between 5 and 28 °C, the highest in the city (Fig. 3B), and a temperate, sub-humid (lower humidity)/semi-dry temperate climate. However, for the second semester of 2017, the distribution range broadened and reached areas with a temperature ranging from 4 to 24 °C (temperate, sub-humid climate with intermediate humidity). For 2018, presence of the mosquito was recorded again in these areas (Fig. 3B and 4).

Discussion

Given that that in 2015 only two *Aedes aegypti*-positive ovitraps were recorded in places with high human mobility, it was considered to be an accidental introduction. However, the number of positive ovitraps did

increase in the ensuing 3 years, which leads to suppose that this finding was not solely due to accidental transport. The lack of larvae or adult specimens collection, coupled with the low proportion of eggs found and hatched, indicates that there are still no *Aedes aegypti* established populations, although CDMX is in a period of early colonization.

The recurrent presence of positive ovitraps at the same collection site might indicate the possibility of the existence of intermittent cryptic colonies of the mosquito. *Aedes aegypti* has domestic habits,^{15,16} females tend to oviposit in tanks, barrels and sinks that are kept with water for domestic use (usually due to an inadequate running water network).¹⁷ During the rainy season, tires, cans, buckets, flowerpots, or any

Figure 4. Chronology of the presence of *Aedes aegypti*-positive ovitraps in Mexico City's urban areas. 2017 was the year with the highest number of positive ovitraps.

container that can accumulate clean water, become ideal places for oviposition inside or outside the households.¹⁷ However, in the absence of places for oviposition in dry season, females can use alternate sites to deposit their eggs, such as water from water capture boxes, drainage sewers and PVC pipes in underground parking lots.¹⁸⁻²² These places tend to maintain a stable, warm temperature in shady areas with low evaporation,²² which makes them suitable for harboring mosquito colonies. In addition, these are spaces where observing the presence larvae or pupae is difficult, and thus become risk sites for CDMX.

An important factor to explain the increase in the distribution range of the mosquito is worldwide temperature increase.^{23,24} In Colombia and Bolivia, the mosquito has been found at 2,302 m and 2,550 m above sea level, respectively.^{25,26} In Mexico, the mosquito had previously been found at an altitude of 2,133 m.²⁷ Presence at these altitudes may be associated with a temperature increase. The same could be occurring in CDMX, the temperature of which has increased in recent decades. Temperature change makes for the weather to no longer be a barrier to the spread of the mosquito.

The results indicate higher positivity in the warmest areas of the city (northeast), which concentrate the highest population load, lack regular and adequate drinking water supply, and where there is a high risk of floods during the rainy season.²⁸ Furthermore, irregular human settlements (which lack public services) are also common in these areas.²⁹ In addition to this, people lack the habit of discarding things (i.e., collection and disposal of expendable containers) in patios, around houses or residential areas, thus contributing to the generation of temporary breeding sites.

CDMX is at risk of experiencing VBDs, which can be minimized by adequate surveillance implementation, social participation for creating awareness and diffusing the knowledge on VBDs, the mosquito and control methods; as well as health personnel training in order for them to know and handle the clinical practice guidelines for patient care.³⁰ By applying these strategies, CDMX will be able to monitor, limit and control *Aedes aegypti* populations and associated VBDs.

Ethical disclosures

Given that no experimentation with human or animal subjects was carried out for the conduction of this study, no specific authorizations were required by the authors' affiliation institutions. Collection locations are not on private property. The field studies did not involve endangered or protected species. The Panchimalco Regional Center for Vector Control Entomological Research and Bioassay Unit is certified by the National Center for Preventive Programs and Disease Control for the breeding and maintenance of mosquito colonies.

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Conflict of interests

The authors declare that they have no conflicts of interest.

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Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this investigation.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

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