Mosquito Surveillance in Mexico: The Use of Ovitraps for Aedes aegypti, Ae. albopictus, and Non-Target Species

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Mosquito surveillance in Mexico: the use of ovitraps for *Aedes aegypti*, *Ae. albopictus*, and non-target species

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Abstract

Vector-borne diseases are of great public health concern in Mexico. Timely surveillance and control measures require methods to quickly detect mosquito population fluctuations. Surveillance is important also to detect the establishment of uncommon mosquito species. Ovitraps have been a convenient way to detect the presence of female mosquitoes. For these reasons, the Mexican Ministry of Health adopted a mosquito surveillance program using ovitraps in the country. In this study, we present the checklist of 12 target and non-target species that have been collected nationwide in ovitraps since 2013. We include distributional and ecological notes as well as the medical importance of each species. Our results showed that ovitraps can be used to estimate mosquito diversity in urban and semi-urban areas.

Key Words: mosquito control; diversity; collecting method; mosquito-borne diseases

Resumen

Las enfermedades transmitidas por vectores son una gran preocupación para la salud pública en México. Las medidas oportunas de vigilancia y control requieren métodos para detectar rápidamente las fluctuaciones de la población de mosquitos. La vigilancia también es importante para detectar el establecimiento de especies de mosquitos poco comunes. Las ovitrampas han sido una forma conveniente de detectar la presencia de mosquitos hembras. Por estas razones, el Ministerio de Salud de México adoptó un programa de vigilancia de mosquitos usando ovitrampas en el país. En este estudio presentamos la lista de verificación de doce especies blanco y no blanco que se han recolectado a nivel nacional en ovitrampas desde el 2013. Incluimos notas de distribución y ecológicas, así como la importancia médica de cada especie. Nuestros resultados mostraron que las ovitrampas se pueden usar para estimar la diversidad de mosquitos en áreas urbanas y semiurbanas.

Palabras Clave: control de mosquitos; diversidad; método de recolección; enfermedades transmitidas por mosquitos

Vector-borne diseases, such as dengue, chikungunya, and Zika are of great public health concern in Mexico. During 2014 to 2017, the Mexican Ministry of Health reported 91,836 confirmed cases of dengue; 13,564 cases of chikungunya; and 11,865 cases of Zika (DGE 2017). The consistently high number of vector-borne disease cases has made mosquito vector control a primary priority in the country. Control programs include governmental planned strategies and community participation such as "National days of elimination of breeding," "Clean backyard," and "Stored water management" campaigns.

In Mexico, *Aedes aegypti* (L.) and *Aedes albopictus* Skuse (both Diptera: Culicidae) are the main vectors of vector-borne diseases. Previous studies have reported *Ae. aegypti* present in 28 states of Mexico (Ibáñez-Bernal & Martínez-Campos 1994a; Mora-Covarrubias et al. 2010; Ávila-Rodríguez et al. 2012; Espinoza-Gómez et al. 2013; Kuri-Morales et al. 2017). In addition, *Ae. albopictus* has been reported in 12 states of the country (Francy et al. 1990; Ibáñez-Bernal & Martínez-Campos 1994b; Pesina et al. 2001; Flisser et al. 2002; Martínez & Estrada 2003; Villegas-Trejo et al. 2010; Salomón-Grajales et al. 2012; Torres-Avendaño et al. 2015; Ortega-Morales et al. 2016; Ortega-Morales & Siller-Rodríguez 2016).

For both vectors, timely surveillance and control measures in endemic or high-risk locations for disease transmission requires sensitive methods to quickly detect changes in mosquito abundance. Surveillance is important also to detect the establishment of uncommon or invasive species in regions where they have not been reported (Hernandez-Avila et al. 2013; Chaverri et al. 2018). Urban and semi-urban larval habitats of *Ae. aegypti* and *Ae. albopictus* usually are comprised of a variety of containers. Natural containers include water-filled tree holes, bamboo internodes, and bromeliad axils (Ceretti-Junior et al. 2014; Docile et al. 2017). *Aedes aegypti* prefer artificial containers such as small cisterns, discarded tires, flower vases, buckets, and cans (Cheong 1967; Yee et al. 2010; Estallo et al. 2011).

Given the biological specificity for aquatic habitats, the collection of eggs and larvae using ovitraps has been a convenient way for detecting the presence of adult female mosquitoes. Ovitraps do not require electrical power sources, additional carbon dioxide (Snetselaar et al. 2014), or daily monitoring. These traps are safe, reusable, and inex-

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pensive (CDC 2017). For these reasons, ovitraps are one of the most practical tools for surveillance of container-inhabiting *Aedes* (Wu et al. 2013; Codeço et al. 2015; Chaverri et al. 2018).

Material and Methods

In 2013, the Mexican Ministry of Health implemented a mosquito surveillance program using ovitraps. The ovitraps used by the national surveillance program are 1 L black colored plastic cups, filled with tap water, and lined with a strip of filter paper along the water margin where female *Aedes* species lay their eggs. Every year, 250,000 ovitraps are placed in 712 semi-urban and urban locations (with or without active presence of dengue, Zika, or chikungunya cases) covering all 32 states of the country (including Mexico City). Ovitraps are placed outdoors either at randomly selected houses (after obtaining informed consent) or nonresidential areas (CENAPRECE 2017). Ovitraps are monitored weekly, when the water is changed, and the paper strip from each positive ovitrap is collected by public health technicians and transported to the laboratory. Eggs are hatched and reared to the fourth instar, and identified using the morphological identification keys of Schick (1970), and Clark-Gil & Darsie (1983). In this study, we present a checklist of mosquito species that have been collected nationwide in ovitraps since 2013. We include distributional and ecological notes, as well as the medical importance of each species.

Results and Discussion

Aedes (*Georgecraigius*) *epactius* Dyar & Knab (Diptera: Culicidae): *Aedes epactius* was the most commonly collected species in ovitraps from Mexico City, and less frequently in the states of Morelos and Puebla. This is a common mosquito species in arid and semi-arid regions of Mexico, including urban and suburban areas. In the Mexico Valley area (including the states surrounding Mexico City: Estado de Mexico, Hidalgo, Morelos, Puebla, Queretaro, and Tlaxcala), *Ae. epactius* generally appears in spring and early summer. Populations usually decrease when the rainy season starts. *Aedes epactius* also is known as the rock-hole mosquito where its natural developmental habitats are water filled rock cavities (Zavortink 1972). In Mexico, immature stages of this species have been found in a wide variety of artificial containers such as buckets, discarded tires, flower vases, and watering canals for cattle. Commonly, this mosquito prefers clean water with limited leaf material. Adults are crepuscular and are most active at dusk. Females are highly anthropophagous and usually rest indoors in dark, warm places. Although *Ae. epactius* is highly anthropophagic, its role as a possible vector of human disease is currently unknown.

Aedes (*Protomacleaya*) *gabriel* Schick (Diptera: Culicidae): This species was collected only from ovitraps in the subtropical forest of Sierra Madre del Sur in southern Morelos. Although *Ae. gabriel* is historically considered endemic to Mexico, it has only been reported in the states of Jalisco, Morelos, and Zacatecas (Schick 1970; Henimeann & Belkin 1977). This species has been poorly studied, so the true abundance of *Ae. gabriel* is unknown in the regions where it occurs. This is especially true during the rainy season when rainwater filled tree holes and rock holes become larval habitats. Adults are diurnal and females have been collected when they attempt to feed on humans. The medical importance of *Ae. gabriel* is unknown.

Aedes (*Protomacleaya*) *podographicus* Dyar & Knab (Diptera: Culicidae): *Aedes podographicus* was collected in ovitraps from the states of Chiapas and Queretaro, constituting the first record in Queretaro. This is one of the most common mosquito species in the tropical regions of Mexico, and the most common species of the subgenus *Protomacleaya*. Larval habitats usually include natural water-holding habitats such as tree holes. However, *Ae. podographicus* also has been found in artificial containers such as discarded tires and flower vases, with murky water and abundant organic material at the bottom of the aquatic habitat site (Schick 1970). Adults are diurnal and females are active at ground level and in the tree canopy. They can feed on humans and are persistent biters even when the host is moving. Although *Ae. podographicus* has not been incriminated as a vector of human disease, its preferential feeding on humans and monkeys could have potential importance in the transmission of diseases such as yellow fever. For surveillance of presence of this disease in southeastern Mexico, we placed adult mosquito traps in the tree canopy using spider monkeys (*Ateles geoffroyi* Kuhl [Atelidae]) as bait. Large numbers of *Ae. podographicus* were collected together with *Sabethes chloropterus* (Humboldt) and *Haemagogus* spp. (both Diptera: Culicidae). However, no yellow fever virus infection was detected in any of the mosquitoes collected in those traps.

Aedes (*Stegomyia*) *aegypti* (L.): This species is the most medically important mosquito in Mexico, as it is the main vector of dengue, Zika, and chikungunya. The national mosquito surveillance program is focused mainly on this species. In the wild, immature stages of *Ae. aegypti* have been found in tree holes. In urban and semi-urban locations, it is commonly found in artificial containers such as discarded tires, buckets, flower vases, and any other domestic container able to collect rain water. Adults are diurnal and usually feed and rest in indoor environments.

Aedes (*Stegomyia*) *albopictus* (Skuse): In this study, *Ae. albopictus* was collected from ovitraps in the states of Chiapas, Hidalgo, Mexico City (A.I.O-M. unpublished data), Morelos, Nuevo León, San Luis Potosí, and Veracruz. Previously, this species has been collected commonly from ovitraps from the states of Chiapas, Coahuila, Hidalgo, Morelos, Nuevo León, Quintana Roo, San Luis Potosí, Sinaloa, Tamaulipas, and Veracruz (Ortega-Morales & Siller-Rodríguez 2016). In our current study, *Ae. albopictus* was collected in Mexico City, confirming its presence in Mexico's capital. Because this species has been incriminated as an arbovirus vector, *Ae. albopictus* is considered the second most medically important mosquito species in Mexico. Immature stages of *Ae. albopictus* are found commonly in a variety of artificial and natural containers with clean water, such as tree holes and bamboo internodes. This species is more common during the rainy season in tropical and subtropical regions of the states. Adults are diurnal and females can feed on a wide variety of hosts including humans. The recent record of *Ae. albopictus* in Mexico City is worrisome for public health officials because the Metropolitan Area of Mexico City is one of the world's most populated cities. In 2010, INEGI (Instituto Nacional de Estadística y Geografía) recorded 22 million people living in the Metropolitan Area of Mexico City. The presence of *Ae. aegypti* and *Ae. albopictus* make the Metropolitan Area of Mexico City an area at high risk of vector-borne disease outbreaks.

Haemagogus equinus Theobald (Diptera: Culicidae): In Mexico, 4 species of the genus *Haemagogus* has been reported, with *Hg. equinus* the most common. This mosquito was collected from ovitraps placed in the states of Chiapas, Hidalgo, and Morelos. This is the first record of *Hg. equinus* in Morelos State. This species occurs in the tropical forests in southern Mexico, and in the northeastern state of Tamaulipas, reaching their northernmost distribution in southeastern Texas, USA. In the wild, *Hg. equinus* develops mostly in tree holes but the species has been collected in artificial containers (discarded tires and buckets), always with murky water and organic material. The adults are active during the d, and females feed on humans along the shaded forest floor.

Culex (*Anoedioporpa*) *restrictor* Dyar & Knab (Diptera: Culicidae): *Culex restrictor* was collected in ovitraps placed in the state of Tabasco. Previously, this species has been reported from southeastern Mexico to the northeastern state of Tamaulipas (Ortega-Morales et al. 2015). *Cx. restrictor* commonly develops in tree holes and bamboo internodes but it also has been collected from artificial containers (such as discarded tires). Nothing is known about the biology of the adult stages or medical importance. In southeastern Mexico, adults have been collected using CDC light traps baited with octenol (A.I.O-M. unpublished data).

Culex coronator sensu lato Dyar & Knab (Diptera: Culicidae): In Mexico, the *Culex coronator* complex includes the species *Cx. coronator* Dyar & Knab, *Cx. ousqua* Dyar, and *Cx. usquatus* Dyar. We were unable to accurately distinguish which species from the complex was collected because identification relies on morphometric analysis of male genitalia and we only reared progeny to the larval stage. *Culex coronator s.l.* was collected from ovitraps in the state of Chiapas, where *Cx. coronator s.s.* and *Cx. ousqua* have been previously recorded (Casas-Martinez et al. 2012). Immature stages of *Cx. coronator s.l.* inhabit a variety of aquatic sites. In Mexico, members of this group have been collected in natural aquatic sites such as ponds and swamps, always with abundant emerging vegetation, and in the partially shaded margins of streams. They also have been collected in artificial containers, such as buckets and cattle drinking canals filled with clean water. Adults are most active at dusk and nighttime; females feed on birds and a variety of mammals (Molaei et al. 2006). Although many viruses have been isolated from *Cx. coronator s.s.*, the species is not considered a vector of human diseases.

Culex mollis Dyar & Knab (Diptera: Culicidae): *Culex mollis* was collected from ovitraps placed in the state of Tabasco. This species also is considered an uncommon mosquito. In historical records for Mexico, *Cx. mollis* has been recorded in only a few instances, and then from the tropical regions of southeastern Mexico (Díaz-Nájera & Vargas 1973). The immature stages of *Cx. mollis* are found commonly in tree holes with murky water and abundant organic material. The biology of the adult stage, feeding preference, and medical importance is unknown.

Culex quinquefasciatus Say (Diptera: Culicidae): This species was collected from ovitraps placed in the state of Tabasco. This is probably one of the most common mosquito species in Mexico. *Culex quinquefasciatus* has been recorded in all states of the country and its populations are stable throughout the year. This species uses a wide variety of natural and artificial habitats with abundant organic material. Larvae can be found in open ponds, ditches, and less frequently in axils of plants, discarded tires, flower vases, buckets, cattle drinking canals, and abandoned swimming pools. Adults are nocturnal and active from dusk to sunrise. Females are opportunistic and feed on a variety of hosts including birds, mammals, and humans. *Culex quinquefasciatus* has been incriminated as an important vector of St. Louis Encephalitis and West Nile Virus.

Limatus durhamii Theobald (Diptera: Culicidae): This species was collected in ovitraps placed in forests of the states of Campeche (Casas-Martinez et al. 2012), Chiapas, and Tabasco (A.I. O-M. personal observation). Generally, the immature stages of this mosquito have been found in sites such as bamboo internodes, fruit casings, axils of plants, and crab shells. However, in Mexico this species is most frequently found in artificial containers (buckets, discarded tires, and flower vases), always with clean water and low organic material. Adults are diurnal and females are persistent biters that commonly feed on humans. Although a number of viruses, including the yellow fever virus, have been detected in *Li. durhamii*, it is not considered an important vector of human disease.

Wyeomyia guatemala Dyar & Knab (Diptera: Culicidae): This species was collected from ovitraps placed in the state of Chiapas. Typically, *Wy. guatemala* lays eggs in bromeliad axils. Historical records of *Wyeomyia* have reported the presence of larvae in bromeliad axils in tropical regions in southeastern Mexico (Ortega-Morales et al. 2010). The adults are diurnal and live in the shade of tropical rain forests. Females fly near ground level and feed on humans. The medical importance of *Wy. guatemala* is unknown.

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