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SCIENTIFIC NOTE

Mosquito species (*Diptera*: *culicidae*) collected after tropical storm cristobal in Merida, Yucatan, South-east Mexico

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Abstract
After the tropical storm Cristobal, we performed special adult entomological collections in the peri-domicile of 35 houses from 25 neighborhoods of Mérida, Yucatan, Mexico in response to complaints from the community about an increased nuisance due to an abundance of mosquitoes. A total of 1,275 specimens from four genera and 13 species were collected: *Aedes taeniorhynchus* (92%), *Culex quinquefasciatus* (72%), *Aedes aegypti* (72%), *Psorophora mexicana* (36%), *Psorophora cyanescens* (32%), *Aedes scapularis* (24%), *Culex nigripalpus* (24%), *Aedes albopictus* (8%), *Psorophora ferox* (4%), *Haemagogus equinus* (4%), *Aedes trivittatus* (4%), *Culex coronator* (4%), *Culex iolambdis* (4%). From these collections, the increased mosquito nuisance was mainly the result of invasive species such as *Aedes taeniorhynchus* and *Psorophora*. City wide, vehicle mounted ULV spraying was performed by the MoH and the municipality of Merida to control adult mosquito populations. We report *Culex iolambdis* for the first time in Merida and *Psorophora mexicana* for the state of Yucatan.

Keywords Mosquitoes · Surveillance · Tropical storm · Mexico

From the 1st to 6th June of 2020, the tropical storm Cristobal moved across the Yucatan Peninsula in South-East Mexico. Characterized by its large size, winds and associated heavy rainfall, (with a record 623.3 mm) it caused widespread damage mainly due to flooding in the Mexican state of Yucatan, including the capital city of Merida (CONAGUA 2020). Following its course there were many reports from the residents of Merida which contained complaints about an increased nuisance due to an abundance of "giant black mosquitoes", that were perceivably different from the common species (*v.g. Aedes* or *Culex* spp.), which had invaded neighborhoods and housing units in the East and West of the city with an associated concern for the potential spread of arboviruses (TYT 2020a, b).

Because of the COVID-19 contingency, non-intrusive rapid activities of surveillance and control of invasive nuisance species were implemented as part of response by the local Ministry of Health (MoH) to the reports of the community. Mosquito surveillance in urban areas is an integral part of the entomological surveillance protocol of the MoH of Yucatan and in many tropical cities of Mexico (DOF 2015). Ovitrapping for *Aedes* species, mainly *Aedes aegypti* is a systematic method (CENAPRECE 2015a) now set as a network with 5,183 ovitraps (dark containers with water and a rough surface covered with oviposition pieces of paper) distributed throughout the city (Gonzalez-Olvera et al. 2021); however, this method only detects container breeding mosquito species. Adult collections with portable electric aspirators are also performed across the city for adult mosquito

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surveillance, but only in 2–3 cross sectional surveys every year since 2013 (CENAPRECE 2015b).

Merida city capital of Yucatan state has a warm subhumid climate (Aw0 (x ') (i') g), with an average annual temperature of 28 °C; the minimum and maximum is 16 °C and 36 °C in January and May, respectively. The rainfall average is 1342.9 mm per year, with the rainy season occurring from May to November (García 2004). Special adult entomological collections were carried out from the 9th to 30th of June 2020 (three days after the storm finished) in the peri-domicile of 35 houses from 25 neighborhoods of Mérida city (Fig. 1). Staff of the Collaborative Unit for Entomological Bioassays of the Autonomous University of Yucatán (UCBE-UADY) and the local MoH, carried out 10-min collections per house of adult mosquitoes attracted to humans between 8:00 and 14:00 h with Prokopack aspirators (Vazquez-Prokopec et al. 2009). Collected specimens were preserved in containers and transferred to UCBE-UADY for sacrifice by freezing (-20 °C) and were later identified using specialized keys (Darsie and Ward 2005; Harrison et al. 2008). Sample of the specimens were sent to the National Entomology Laboratory of Instituto de Diagnóstico y Referencia Epidemiológicos (InDRE) of the Mexican Ministry of Health for species confirmation and were deposited in the InDRE Collection of Arthropods with Medical Importance (CAIM).

In total, 1,275 specimens of mosquito from 4 genera and 13 species were collected: *Aedes taeniorhynchus* (92%), *Culex quinquefasciatus* (72%), *Aedes aegypti* (72%), *Psorophora mexicana* (36%), *Psorophora cyanescens* (32%), *Aedes scapularis* (24%), *Culex nigripalpus* (24%), *Aedes albopictus* (8%), *Psorophora ferox* (4%), *Haemagogus equinus* (4%), *Aedes trivittatus* (4%), *Culex coronator* (4%), *Culex iolambdis* (4%) (Table 1). The collection with Prokopack aspirators while being attracted to the collectors suggests that they are anthropophilic to a greater or lesser

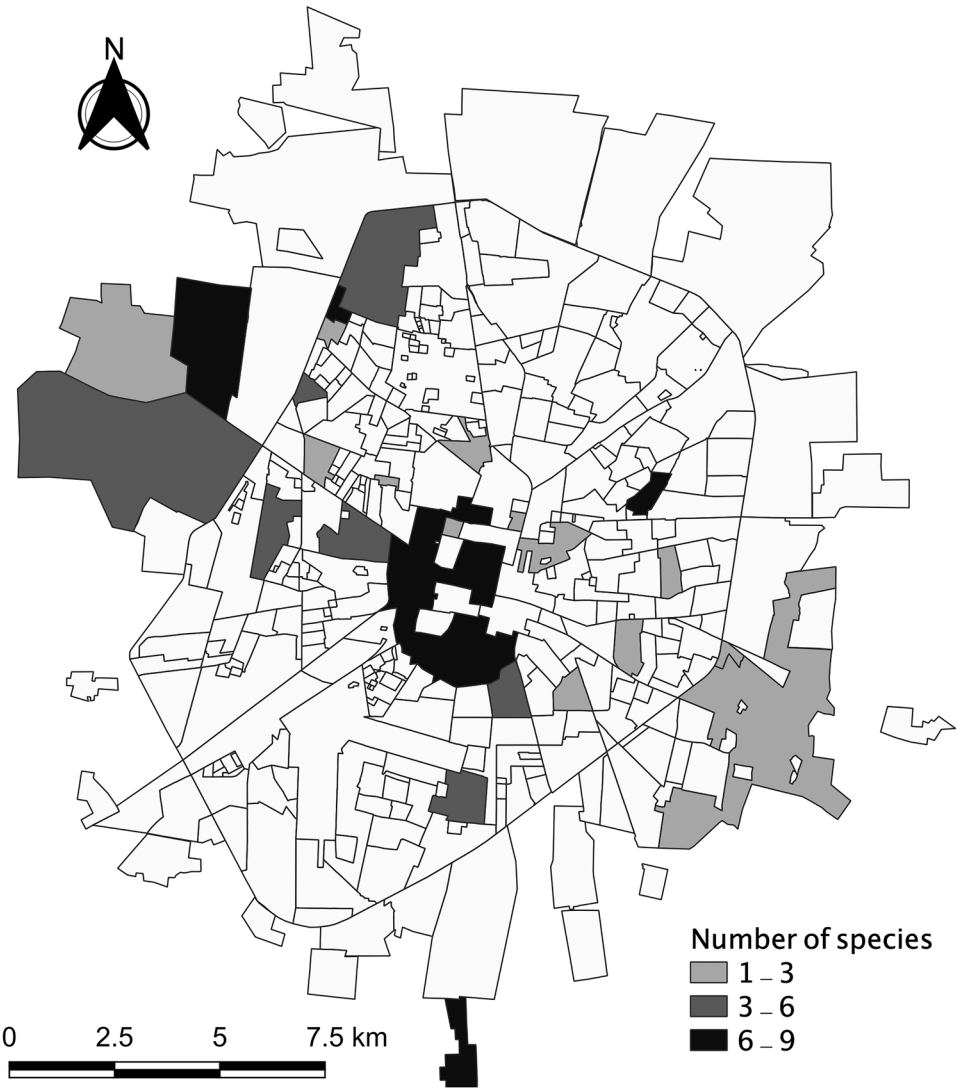

Fig. 1 Species of mosquitoes collected after the tropical storm Cristobal (June 2020) with Prokopack aspirators in the peridomicile of houses (dots) and various neighborhoods (shaded areas) of the city of Merida, Yucatan, Mexico

Table 1 Mosquito species collected from different neighborhoods after tropical storm Cristobal in Merida, Yucatan, and their collection parameters

Species	***Ae. (Stegomyia) aegypti***	***Ae. (Ochlerotatus) scapularis***	***Ae. (Ochlerotatus) taeniorhynchus***	***Ae. (Stegomyia) albopictus***	***Ae. (Ochlerotatus) trivittatus***	***Cx. (Culex) coronator***
Neighborhood						
Amapolita	X		X			
Bojórquez			X			
Cámara de la Construcción	X	X	X			
Caucel Pueblo			X			
Centro	X		X	X		
Ciudad Caucel	X		X			
Fco. de Montejo	X		X			
Gran Santa Fe Norte	X	X	X			
Industrial	X		X			
Jacinto Canek			X			
Kanasín	X					
Las Brisas	X	X	X			X
Magnolias	X		X			
Morelos Oriente	X		X			
Mulsay		X	X			
Pacabtún			X			
Pedregales de Oriente			X			
Petronila	X					
Roma II	X		X			
San José Tecoh	X	X	X			
San José Vergel	X		X			
Santa Cecilia	X		X			
Santa Rosa	X		X		X	
Xmatkuil	X	X	X	X		
Yucatán			X			
Collection parameters						
Total specimens collected	153	32	712	17	3	3
Average number of individuals collected (per positive house)	4.4±7.0	0.9±3.2	20.3±48.4	0.5±2.1	0.1±0.5	0.1±0.5
Relative abundance (%)	12.0	2.51	55.84	1.33	0.24	0.24
Percentage of houses positive for collection (%)	65.7	20	86.6	8.6	2.9	2.9
Percentage of neighborhoods sampled and where the species was found (%)	72.0	24.0	92.0	8.0	4-0	4.0

Table 1 (continued)

Cx. (Melanoconion) iolambdis	*Cx. (Culex) nigripalpus*	*Cx. (Culex) quinquefasciatus*	*Hg. (Haemagogus) equinus*	*Ps. (Janthinosoma) cyanescens*	*Ps. (Janthinosoma) ferox*	*Ps. (Janthinosoma) mexicana*
Neighborhood						
	X	X				
		X		X		X
	X	X		X		X
Caucel Pueblo						
	X	X		X		
		X		X		X
		X		X		X
		X		X		X
		X				
						X
		X				
X	X	X				
	X					
		X				
		X				X
Pacabtún						
		X				
Petronila						
Roma II						
		X				X
		X				
		X				
	X	X				
		X	X	X	X	X
				X		
Collection parameters						
2	12	178	8	99	13	43
0.1±0.1	0.3±0.9	5.1±10.6	0.2±1.4	2.8±9.1	0.4±1.9	1.2±3.5
0.16	0.94	13.96	0.63	7.76	1.02	3.37
2.9	17.1	60	2.9	25.7	5.7	28.6
4.0	24.0	72.0	4.0	32.0	4.0	36.0

X = Presence of the species in the neighborhoods

± = Standard error

degree. Most of the species have been previously reported in Merida, from larvae growing in containers predominantly in the peri-domicile (backyard). Reports come largely from larval surveys made by the MoH and research projects (Najera-Vazquez et al. 2004; Zapata-Peniche et al. 2007; Manrique-Saide and Zapata-Peniche 2010; Manrique-Saide et al. 2010; Baak-Baak et al. 2016). In this context, one of the most important factors which contribute with mosquito diversity in Merida is the wide availability and productivity of artificial and natural breeding sites (Manrique-Saide and Zapata-Peniche 2010), which include bottles, bath, cooking and washing utensils, pet animal drinking dishes, swimming pool, flowerpots, small plastic rubbish, large tanks, tires, natural holes (rocks, trees), cans, laundry tubes, discarded appliances, stormwater drains/catch basins and miscellaneous objects (Zapata-Peniche et al. 2007; Manrique-Saide et al. 2008).

The most abundant species collected was *Aedes (Ochlerotatus) taeniorhynchus*, which represented 56% of the collected specimens, with a wide distribution in the houses (86.6%) and neighborhoods (92%) sampled (Table 1). This species, known as the black salt marsh mosquito, has been reported as a predominant species after storms (Morrow et al. 2008). In Yucatan, it is very common in the coastal areas (Manrique-Saide et al. 2010) and frequently invades Merida (which is 30 km from the coast) in large numbers after storm winds, heavy rains, and flooding events (Manrique-Saide and Zapata-Peniche 2010). The other most common and widely distributed species collected were *Culex quinquefasciatus* and *Aedes (Stegomyia) aegypti* (Table 1), which were collected in lower numbers than *Ae. taeniorhynchus* but were found in 60–70% of the houses and neighborhoods sampled. Both species, well adapted to the human environment and breed in peridomiciliary man-made breeding sites (Zapata-Peniche et al. 2007; Manrique-Saide et al. 2008), are common in Merida and other human settlements of Yucatan (Najera-Vazquez et al. 2004; Baak-Baak et al. 2016).

Two other species, *Aedes (Ochlerotatus) scapularis* (Rondani) and *Culex (Culex) nigripalpus* (Theobald), were collected in low numbers but found in around 30% of the neighborhoods. These species have been also previously reported from Merida, with low numbers and breeding in outdoor containers (Zapata-Peniche et al. 2007; Baak-Baak et al. 2016). The remaining species of the genera *Culex* and *Aedes*, including *Ae. (Stegomyia) albopictus*, have been previously reported breeding in low numbers in Merida and suburban areas (Najera-Vazquez et al. 2004; Zapata-Peniche et al. 2007; Manrique-Saide and Zapata-Peniche 2010; Contreras-Perera et al. 2019; Gonzalez-Olvera et al. 2021). This is consistent with previous surveys in Merida, where most of the mosquito species reported were found in a variety of artificial and natural breeding sites. Especially, *Ae. aegypti*, *Cx. thriambus*, *Cx. quinquefasciatus*, and *Cx. coronator* were observed in all categories of breeding sites described above (Manrique-Saide et al. 2008; Manrique-Saide and Zapata-Peniche 2010; Baak-Baak et al. 2016).

Some of the reports in the media and on social media described large mosquitos similar to *Psorophora* species (TYT 2020a, b). Indeed, three *Psorophora* species: *Ps. (Janthinosoma) cyanescens* (Coquillett), *Ps. (Janthinosoma) ferox* (von Humboldt) and *Ps. (Janthinosoma) mexicana*, were collected from houses at Merida. *Ps. cyanescens* were collected in larger numbers than the others, but both *Ps. cyanescens* and *Ps. mexicana* were collected in around 30% of the neighborhoods sampled. These species are not commonly found, much less with such abundance and distribution, in the residential urban area of Merida. In fact, we report the species *Ps. mexicana* for the first time for the state of Yucatan, previously this species was reported in the locality of Lerma and the south of Campeche State in the Yucatan Peninsula (Heinemann and Belkin 1977). *Cx. iolambdis* represent new record for the city of Merida, this species is common in the coast and flooded areas of Yucatan. And was reported in the municipalities of Dzemul and Progreso in Yucatan State (Baak-Baak et al. 2016; Navarrete-Carballo et al. 2021). We argue that local invasion of these species was because of the storm. Now sum 30 reported species for Merida (Najera-Vázquez et al. 2004; Zapata-Peniche et al. 2007; Manrique-Saide and Zapata-Peniche 2010; Baak-Baak et al. 2016). *Ps. mexicana* can be distinguished from other related species by its hind tarsomere 4 entirely dark scaled, rarely with pale scales at base and its 5 tarsomere entirely or rarely partially pale scaled. The larva and males of *Ps. mexicana* are unknown (Darsie and Ward 2005; Harrison et al. 2008).

Similar events occurred in St. John's County, FL (comparable climate conditions as Yucatan) from Hurricane Matthew and Irma (2016 and 2017 respectively). The flooding triggered mosquito population outbreaks after 10 and 9 days (2nd peak event after a month), respectively (with similar species composition as reported in this study). In response of the outbreaks, the control services used intensively and extensively both ground (ULV, larvicides) and aerial applications for control (Weaver et al. 2020).

From these results, it is reported that the increase in mosquitoes was due to invasive species such as *Ae. taeniorhynchus* and *Psorophora* species (TYT 2020a, b). City wide, vehicle mounted ULV spraying was performed by the MoH and the municipality of Merida to control adult mosquito populations. An intensive campaign to eliminate mosquito breeding sites with "*Descacharrización*" (Barrera et al. 2015) complemented by the distribution of larvicide was also performed as part of the protocol to control *Ae. aegypti* in emergency situations to prevent the risk of dengue, chikungunya and Zika transmissions.

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Declarations

Competing interests We declare no conflict of interest.

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