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Received: 13 June, 2019

Accepted: 16 July, 2019

Published: 17 July, 2019

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Research Article

Longitudinal spatial distribution of *aedes aegypti* (Diptera: Culicidae) during the yellow fever epidemic in Angola, 2016

Abstract

Background and aims: Angola is one of the countries included in the endemic areas of yellow fever transmission in Africa. The objective of this study was to obtain information about the longitudinal spatial distribution and the mainly breeding sites of *Ae. aegypti* in Angola during the yellow fever epidemic in Angola during 2016.

Methods: Angola is located in the western region of Southern Africa. The country limited by the Atlantic Ocean in the west, in the north with the Republic of Congo and the Democratic Republic of Congo, in the eastern with the Republic of Zambia, and in the south with the Republic of Namibia. It is divided in 18 provinces. The sampling was carried out in 51 municipalities distributed in all provinces, in villages and neighborhoods with suspicious and confirmed cases of yellow fever during February- October 2016. The number of houses inspected was 20 only one time during the months for to determine presence or absence of *Aedes aegypti*.

Results: *Ae. aegypti* presence was observed in 16/18 (88.8%) of the province 42/51 (82.3%) of the municipalities and 241/277 (87%) of the villages or neighborhoods sampled. Fifteen news municipalities that represent new records for *Ae. aegypti* presence in Angola were notified. *Ae. aegypti* larvae were collected in 22 types of containers, mainly in water storage containers followed by plants in water and potted, artificial miscellaneous containers and used car tires in Luanda.

Conclusions: This work expanded the knowledge on distribution and breeding sites of *Ae. aegypti* in Angola.

Introduction

Aedes aegypti is native from Africa and spread to other tropical countries in the 17th and 18th centuries [1-3]. Other species of mosquitoes of the genus *Aedes* including *Aedes albopictus*, *Aedes africanus*, *Aedes simpsoni* and *Aedes luteocephalus* are registered in the African continent and are considered potential vectors of dengue, yellow fever, chikungunya, zika and other arbovirus [4-6]. *Ae. aegypti* was registered in Angola in 1903 [7].

Angola is one of the countries included in the endemic areas of yellow fever transmission in Africa and where there have been outbreaks of this disease in 1971 and in 1988 in its capital Luanda, as well as, sporadic cases identified through the surveillance system. Prior to these outbreaks, serological samples were taken for antibodies to arboviruses where it was shown that the virus was active in some areas of the south and

southeast of the country where the ecological conditions are favorable, but note that if there were cases, these ones were not notified due to the absence of facilities for diagnosis previous and during the decade of the 60's of the last 20th century [8-12].

Yellow fever virus is an RNA virus that belongs to the genus Flavivirus. It is related to West Nile, St. Louis encephalitis, and Japanese encephalitis viruses. This virus is transmitted to humans by mosquitoes. Among the vector species in Angola are *Aedes africanus* responsible for the maintenance of sylvatic transmission; *Aedes simpsoni* in rural habitats in the northeast of the country; *Aedes metallicus* and *Aedes vittatus* responsible in the southwest and in the central west *Aedes luteocephalus* [13]. In urban area such as Luanda *Aedes aegypti* is present with a strong association with humans and is the responsible for the urban transmission [14, 15]. In another hands dengue activity has been reported sporadically in the country too [16].

In general, to literature on mosquito fauna in Angola and, in particular, to the presence of genus *Aedes* are reflected in several researchers by various authors [17-20], During the second half of the XX century 48 mosquito's species were registered. *Ae. aegypti* presence was summarized in several localities of the country during these studies [13]. There is only scanty data available about *Ae. aegypti* during this century in Angola [14,21]. For this reason the objective of this study was to obtain information about the spatial distribution and the mainly breeding sites of *Ae. aegypti* in Angola during the yellow fever epidemic registered in Angola during 2016.

Materials and Methods

Brief description of the study area

The Republic of Angola is located in the western region of Southern Africa, with a surface area of 1 246 700 km². The western of the country is limited by the Atlantic Ocean, in the north limited with borders, with the Republic of Congo and the Democratic Republic of Congo, in the eastern with the Republic of Zambia, and in the south with the Republic of Namibia figure 1. Angola is divided in 18 Provinces: Bengo, Benguela, Bie, Cabinda, Cunene, Huila, Huambo, Cuando Cubango, Cuanza Norte, Cuanza Sul, Lunda Norte, Lunda Sul, Luanda (capital of the country), Malange, Moxico, Namibe, Uige and Zaire. The country is rich, especially in minerals diamonds, iron, manganese, among others, oil and agriculture stands out



Figure 1: Map of Angola divided by provinces and the borders represented.

as a producer of coffee and corn. The climate has two seasons raining between September to middle of the May and dry season to June to August [22]. Angola population was estimated at 25 789 024 inhabitants (given by the last National Census conducted on May 15-31, 2014 National Institute of Statistics).

Entomological sampling, execution time and identification of samples

The sampling was carried out in 51 municipalities distributed in 18 provinces, in villages and neighborhoods with suspicious and confirmed cases of yellow fever in the period of February- October 2016. Sample collections of immature stages of mosquitoes were carried out in the dwellings with the presence of cases and in the surroundings of the same, not moving more than 100 meters in all directions from the house subject to the investigation, the number of houses and patios reviewed was 20 in each visited locality only one time. All deposits with water were checked for the presence of the vector. The larvae were collected using a dropper, placed in flasks with 70% alcohol labeled with the data of the place of collection, date and type of deposit. For the taxonomic classification of the mosquito samples, larvae III and IV stage were selected only. We reviewed works related to the taxonomy and systematics of these insects [13,23-25], but chose to use the morphological keys for presenting relevant information about the *Aedes* genus in Angola. It is convenient to clarify that taxonomic works carried out in the last years make a relocation of the *Aedes* Meigen species, 1818 in other genera [26], however, we decided in this work not to use the classification proposed by these authors.

Results

The total of provinces municipalities and neighborhoods sampled are shown in table 1, resulting with *Ae. aegypti* presence in 16/18 (88.8%) of the province 42/51 (82.3%) of the municipalities and 241/277 (87%) of the villages or neighborhoods. *Ae. aegypti* was recorded during this study in the 7 municipalities that make up Luanda province in 2016 (Belas, Cacucaco, Viana, Icolo de Bengo, Quissama, Cazenga and Luanda (municipality with the same name as the province and composed of the districts of Ingombota, Rangel, Samba, Sambizanga, Maianga and Kilamba Kiayi) and 174/182 (95.6%) of the neighborhoods sampled.

A total of 15 news municipalities that represent new records for *Ae. aegypti* presence in Angola during 2016 are showed in table 2. Luanda was not included in this table because it presented several modifications in its administrative division in the two periods that are compared and Bie for not being sampled in 1973 while Bengo for not existing as a province in 1973. A total of 512 *Ae. aegypti* larvae were collected in a total of 65 breeding sites divided into 12 types, where water storage containers (buckets, tanks, cisterns, drums, basins and washing container) contributed to the major *Ae. aegypti* presence 44/65 (67%) followed by miscellaneous containers 8/65 (12.3%); used car tires 7/65(10.7%) and cement blocks 6/65 (10%) table 3.

Table 1: Provinces, Municipalities and villages or neighborhoods with *Aedes aegypti* presence during yellow fever epidemic in Angola, February-October, 2016.

Provinces Sampled	Ae. aegypti Presence	Municipalities Sampled and Coordinates	Ae. aegypti Presence	Villages or neighborhoods	Ae. aegypti Presence
Benguela	x	Catumbela 12°25'S 13°32'E	x	Bairro 27	x
		Cubal 13°2'S 14°14'E	x	Kalomanga	x
		Lobito 12°21'35"S 13°31'51"E	X	Cassai	x
				Caponte	x
		Baia Farta 12°36'25"S 13°13'15"E	NP	Casansh	NP
				Benguela 12°33'S 13°25'E	x
Bengo	x	Dande 7°34'S 15°29'E	x	Center	x
		Quibaxe 8°40'S 14°53'E	x	Center	x
		Pango Alukem 8°43'S 14°28'E	x	Center	x
		Bula Atumba 8°32'15"S 14°51'58"E	x	Center	x
Bie	x	Kuito 12°31'S 17°34'E	x	Bairro Azul	x
				Fatima	NP
				Kunge-Kagondo	x
				Bairro Piloto	x
				Bairro Cantinflas	x
Cabinda	x	Cabinda 5°33'S 12°12'E	x	Center	x
				Tcipindi	x
				A luta continua	x
				Amilcar Cabral	x
		Cacongo 5°14'S 12°08'E	x	Chicamba Massabi	x
Cuando Cubango	-	Menongue 14°39'20"S 17°41'03"E	NP	Menongue center	NP
Cuanza Norte	x	Cazengo (Ndatando) 9°8'S 14°55'E	x	Ndatando	x
				Bairro Sassa	x
				Catome de Encima	x
				Sabizanga	x
		Golungo Alto 9°8'S 14°46'E	x	Center	x
		Cambambe 9°45'31"S 14°30'44"E	x	Center	X
Cuanza Sul	x	Cela 11°21'30"S 15°7'10"E	NP	Wakokungo	NP
		Libolo 10°2'S 14°38'E	NP	Calulo	NP
				Capopa	NP
				Guelele Velho	NP
		Amboim 10°51'S 14°22'E	x	Gia	NP
				Cerâmica	x
		Quijumburu	x		

		Porto Amboim 10°43'S 13°45'E	x	Lila	x		
				Tando	x		
				Torre do Tombo	x		
				Medungue	x		
		Sumbe 11°12'19"S 13°50'30"E	x	Center	x		
				São Joao	x		
				Salinas	x		
				Americo Boa Vida	x		
				Chingo	x		
Cunene	x	Cuanhama 17°04'S 15°44'E	x	Naipala I	x		
				Naipala II	x		
				Castilhos	x		
				Kafito	x		
				Ehafo	NP		
				Namacunde 17°18'S 15°51'E	x	Santa Clara	x
				Cahama 16°17'S 14°19'E	x	Tehaimbo	NP
						Yangoda	x
Huambo	x	Londumbali 12°10'S 15°20'E	x	Hoji-ya-Henda	x		
				Alto Hama	x		
		Huambo 12°46'S 15°44'E	x	Benfica Alto	x		
				Cacilhas Norte	x		
				Chiva Inmaculada	x		
				Mungo 11°40'S 16°10'E	-	Candimba	NP
		Caala 12°51'S 15°33'E	x	Catalenga Velha	x		
				Cangola	x		
Huila	x	Longonjo 12°38'46"S 16°14'50"E	x	Bongo	x		
		Lubango 14°55'S 13°29'E	x	Nossa Senhora do Norte	x		
				Da lange	x		
				Comandante Cow Boy	x		
		Caconda 13°46'S 15°05'E	x	Cruzeiro	NP		
				Lombingo	x		
		Quipungo 14°49'S 14°33'E	-	Kawe Noholongo	NP		
Luanda*	x	Luanda 8°50'S 13°14'E (7 municipalities)	x	Center	x		
						182	174
Lunda Norte	-	Capenda Camulemba 9°25'46"S 16°14'50"E	NP	Muxinda	NP		
				Xamiquelembe	NP		
				Cuango 9°08'40"S 18°2'47"E	NP	Cafunfo	NP
				Bala Bala	NP		
		Chitato 7°20'42"S 20°49'11"E	NP	Caxinde	NP		
Lunda Sul	x	Saurimo 9°39'32"S 20°23'36"E	x	Candembe	x		

Province	Sampled	Coordinates	Sampled	Municipalities	Presence
Malange	x	Malange 9°32'S 16°21'E	x	Carrera Tiro Z-1	x
Moxico	x	Luena 11°46'59"S 19°54'41"E	x	Quimbanda	NP
				Kapango I	x
				Kapango II	x
				Luuu	x
				Synai	NP
Namibe	x	Namibe 15°11'43"S 12°9'3"E	x	5 de abril	x
Uige	x	Uige 7°37'S 15°3'E	x	Papelão Ana Paula Z-3	x
				B Dunga Z-1	NP
				B Candom be Velho	x
				Quixicongo	NP
		Negage 7°46'S 15°16'E	x	Capopa	NP
				Kabala	NP
				Quisseke	x
Zaire	x	Soyo	x	Nkungua Yenquele	x
		6°08'S 12°22'E		1 ^o Maio	x
				Kitona	NP
				Kifuma	NP
		Nzeto 7°13'44"S 12°51'54"E	x	Salinas	x
Totales_18	16	51	42	277	241

*Luanda was sampled in all municipalities because the major numbers of yellow fever cases were reported in Luanda. NP: Not *Aedes aegypti* larvae presence.

Table 2: *Aedes aegypti* larval presence in provinces, municipalities and areas sampled in 1973 and in 2016 except Luanda province during the yellow fever epidemic, Angola, February-October 2016. (NP: Not *Ae. aegypti* presence).

Sampled Provinces in 1973	Areas or municipalities with <i>Ae. aegypti</i> presence in 1973.	Municipalities with <i>Ae. aegypti</i> presence in 2016	Municipalities with <i>Ae. aegypti</i> presence in 1973 and 2016.
Benguela	Benguela, Lobito, Cui	Cubal, Catumbela*	Benguela, Lobito
Cabinda	Cabinda	Cacongo	Cabinda
Cuando Cubango	Menongue	NP	NP
Cuanza Norte	NP	Cazengo	
Cuanza Sul	Sumbe, Mussende, Gungo, Río Gango	Amboim, Porto Amboim	Sumbe
Cunene	Ondjiva	Namacunde Cahama	Ondjiva (Cuanhama)
Huambo	(Huambo Sede), Bailundo	Lomduimbali, Caala Longonjo	(Huambo Sede), Bailundo
Huila	Lubango, Matala, Jamba	Caconda	Lubango
Lunda Norte	Dundo	NP	
Lunda Sul	Saurimo	NP	Saurimo
Malange	Malange	NP	NP
Moxico	Dilolo	NP	NP
Namibe	Namibe	NP	Namibe sede
Uige	(Uige sede) Damba	Negage	(Uige sede),
Zaire	Mbanza Congo, Noqui	Soyo, Nzeto	Mbanza Congo
Totals 15	24	15	12

Table 3: Areas with new records of *Aedes aegypti*, number of samples analyzed, and their main breeding sites except in Luanda province in Angola, February -October, 2016.

Municipalities with new register of <i>Ae. aegypti</i> presence	Total of larvae collected	Types and total of breeding sites with <i>Ae. aegypti</i>
Cubal	28	2 buckets 2 water storage tank
Catumbela	63	2 water storage tank, 1tin , 1 used car tires
Cacongo	10	1 tin
Amboim	29	2 used car tires, 1 tin
Porto Amboim	34	4 cisterns, 4 water storage tanks
Namacunde (Santa Clara)	28	2 water storage tanks
Cahama	20	2 water storage tanks, 1 bucket
Lomduimbali	53	1 used car tires, 2 drums ,1 basin, 2 water storage tanks
Caala	22	2 Concrete block, 1 tin, 1 drum
Longonjo	45	1 used car tires, 4 Concrete block, 2 water storage tanks
Caconda	41	2 water storage tanks, 2 laundries, 1 Cemented ditch
Negage	26	1 bucket, 2 Bottles, 1 water storage tanks
Cazengo	68	2 water storage tanks, 4 buckets, 2 basins, 2 used car tires
Soyo	27	2 buckets
Nzeto	18	1 casserole, 1 bucket
Totales	512	65

A total of 32 760 households were surveyed in all Luanda municipalities during February to October of which 9 711 (29.6%) were positive to *Ae. aegypti* mosquito larvae. During the study period House index oscillated between 4.9 in February to 4.3 in October. The total of container inspected was 156 789 of these 4 478 (2.8%) were positive to larvae. Container index oscillated between 6.3 in February to 2.1 in October. Breteau index oscillated between 62.2 in February to 5.8 in October figure 2. The average household container with water was 4.7. *Ae. aegypti* was collected in 22 types of containers, where water storage containers 3 501/4478(78.1%) contributed to the major *Ae. aegypti* presence in Luanda followed by plants in water and potted 346/4478 (7.7%); artificial miscellaneous containers (tins, jars, bottles., etc 335/4478 (7.4%) and used car tires 296/4478 (6.8%).

Aedes aegypti was found associated with larvae of *Culex sp* and *Anopheles sp.* at the breeding sites in several municipalities belonging Luanda, Cuanza Sul, Benguela and Bengo provinces.

Discussion

The greater distribution of *Ae. aegypti* was observed in the provinces located in the central west, mainly in the coastal areas, which corresponds to the distribution of suspicious cases of yellow fever reported in the country (until June 27 there were a total of 3 496 suspicious cases of these 2 449 belonged to the coastal provinces for 70%, 903 to the provinces of Huila,

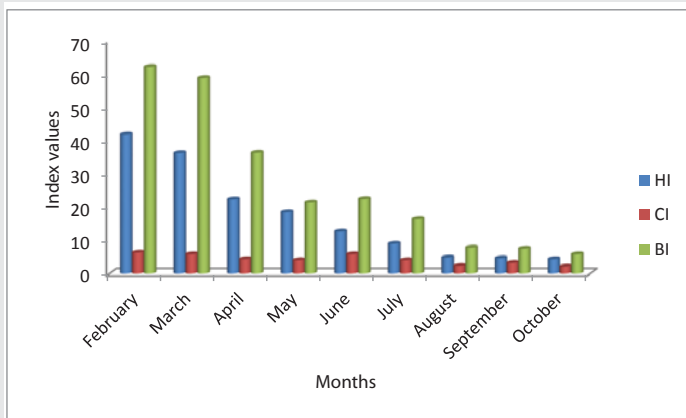


Figure 2: House index (HI), container index (CI) and Breteau index (BI) for *Aedes aegypti* values during the yellow fever epidemic in Luanda, Angola, February–October, 2016.

Huambo, Uige, K. North, Cunene and Malange for 25.8%, adding up in total for the west center area 95.8% of the total of suspected cases) [28]. The coastal strip in the western region where is located Luanda province is characterized by having the highest average temperatures and the lowest altitude with respect to sea level, fundamental factors for the distribution of the vector.

During the sampling carried out in the province of Luanda, *Ae. aegypti* in the 7 municipalities that compose it even at the end of May and the month of June belonging to the dry season (May–September) in which the samplings were carried out due to deficiencies with the supply and distribution of water in most of its municipalities which leads to the storage of this liquid in various deposits used for this function, resulting in the most positive presence of the vector, coinciding with previous results obtained in Luanda and other countries of the world [28–32].

It should be noted that part of the sites with the presence of *Ae. aegypti* found in the provinces sampled were in the exteriors and roofs of houses (used car tires, cement blocks, plants in water and potted) in the last months of the rainy season (February–April) and early the dry season (end of May) showing a reduction of the positivity in the samplings of the month of June in these types of breeding sites. These results suggest directing social mobilization to the cover of the deposits, mainly in areas where the water supply is due to laminar and unstable water and to the sanitation of yards and roofs of the houses before and during the rainy season.

Aedes aegypti was not found during the survey in the localities sampled in the provinces of Lunda Norte and Cuando Cubango which does not imply that it is not present, since in reports made before 1973 it was reported in Dundo, Lunda Norte and in Menongue, Cuando Cubango. This absence could be due to the reduce number of houses that were inspected in search of the vector and that these provinces were visited already at the end of June where many possible deposits of the vector's breeding sites were dry.

Conclusions

This work expanded the knowledge on distribution and breeding sites of *Ae. aegypti* in Angola with 15 new municipalities. On the other hand, the authors recommended first to extend the samplings of search of presence of the vector in the province of Bie and to repeat samplings in the provinces of Malange, Namibe and Lunda Norte in the rainy season. And second to reinforce the monitoring and surveillance of *Ae. aegypti* in the country because in the last years the arbovirus diseases have emerged and reemerged dramatically in the world including African continent.

Acknowledgments

The authors wish thanks to Ministry of Health and all Heads of Health at the provinces, municipalities and villages or neighborhoods levels in Angola; Angolan brigades vector control staff; Cuban specialists belonging to Control Program Anti-Larval Against Malaria (LABIOFAM) and the population in general for his contribution to the realization of this work.

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Citation: Marquetti Fernández MDC, Arletty T, Cani P, Flores YH (2018) Longitudinal spatial distribution of aedes aegypti (Diptera: Culicidae) during the yellow fever epidemic in Angola, 2016. Glob J Zool 4(1): 001-006. DOI: <http://dx.doi.org/10.17352/gjz.000011>