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Mosquito fauna and the first record of *Aedes vittatus* (Diptera: Culicidae) in Kassala State, eastern Sudan

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Abstract

Globally mosquito-borne diseases (MBDs) represent a real public health problem especially those transmitted via *Aedes* mosquitoes. Among these *Aedes vittatus* Bigot plays an important role in the transmission of some arboviruses viz yellow fever, dengue fever, Zika, and chikungunya viruses. Several regions in Sudan suffered from *Aedes*-borne diseases, especially dengue fever, and yellow fever. Entomological surveys were conducted in Kassala State, eastern Sudan to determine the mosquito fauna. A total of 4,682 adult mosquitoes were collected and identified. These included *Anopheles arabiensis*, *Culex quinquefasciatus*, *Cx. pipiens*, *Ae. aegypti*, and *Ae. Vittatus*. This is the first detection of *Ae. vittatus* in Kassala State, Sudan. The detection of *Ae. Vittatus* might indicate a risk for transmission of some arboviruses in the area. Therefore, more studies are needed to determine the spread and the possible public health risks due to this invasive mosquito species in Kassala State and other neighboring states.

Keywords: *Aedes vittatus*, invasive mosquito, first record, Kassala State, Sudan

1. Introduction

Aedes mosquitoes are responsible for the transmission of several mosquito-borne diseases (MBDs) such as dengue (DF), yellow fever (YF), chikungunya (CHIKV), and Zika ^[1, 2]. Currently, these MBDs have become widely distributed due to the spread of invasive mosquito species (IMS) in new geographical regions around the world ^[3, 4]. The dispersal of these IMS to new regions is mainly via passive transportation activities as for the cases of *Ae. Aegypti* and *Ae. albopictus* ^[4, 5]. Moreover, some *Aedes* mosquitoes, such as *Ae. Vittatus* has been reported to invade new countries around the world ^[6, 7]. Hence, the geographical expansion of the IMS, particularly *Aedes* mosquitoes has complicated the epidemiological situation of arboviral infections and outbreaks in some regions ^[8, 9].

Aedes (Fredwardsius) vittatus (Bigot, 1861) as an IMS spreads throughout Africa, Asia, Latin America, and Europe ^[2, 6, 10]. *Aedes vittatus* is an anthropophilic voracious biter of humans mosquito that breeds in habitats close to human dwellings (i.e. peridomestic mosquito) as well as in forest habitats (i.e. sylvatic mosquito) ^[11]. This species plays an important role in the maintenance and transmission of several arboviruses in several countries around the world ^[2, 12]. It has been incriminated as an important vector of YF in Africa as evidenced by virus isolations and its highly anthropophilic behavior ^[13, 14]. Besides, *Ae. Vittatus* has been incriminated in the transmission of other arboviruses of public health importance in Africa viz., DF, CHIKV, and *Zika virus* in Africa and Europe ^[2, 15].

Aedes vittatus was recorded in different administrative states in Sudan, including the Nuba Mountain area in Southern Kordofan ^[16], Sennar State ^[17], El Geneina in Southern Darfur State ^[18], Khartoum State ^[19], and River Nile State ^[20]. In these studies *Ae. Vittatus* was found in peridomestic rural and urban habitats ^[18-20]. In addition, *Ae. Vittatus* was found to breed either in artificial water containers (i.e. clay pots, barrels, plastic water tanks, etc.) ^[18] or outdoor aquatic habitats (i.e. cement cisterns, water pools, irrigation canals, etc.) ^[19, 20].

Although this species was recorded in some areas that had outbreaks of public health important arboviruses *viz* DF and YF such as South Darfur State [18], the role of *Ae. vittatus* in disease transmission has not been studied. However, in 1940 *Ae. vittatus* was only incriminated in the epidemic of YF that occurred in Nuba mountain in Sudan [16].

Sudan is endemic to several arboviruses causing diseases, *viz* DF, YF, and CHIKV. Therefore, studies to determine the involvement of possible mosquito vectors in the transmission of these viruses will help our understanding of the epidemiology of the MBDs as well as to design better control strategies. This study was carried out from April 2019 to September 2020 to determine the mosquito fauna in DF endemic area in eastern Sudan. Here we report the first detection of *Ae. vittatus* in Kassala State, eastern Sudan.

2. Materials and methods

2.1. Study area

The entomological survey was carried out in Kassala State

one of the eastern Sudan States (34° 12' - 36° 57' E, and 15° 12' - 17° 12' N) (Fig. 1). Kassala State is with an area of 55,374 km² and with a total population of about 1,789,806. The state encompasses 12 administrative Localities with its capital Kassala Town. The state is bordered by Eritrea and Ethiopia from the east, the Red Sea, and, the River Nile states from the north, Khartoum and Gadarif States from the west, and the Gedarif State from the south. Kassala State consists of flat plains in most of its parts, with rocky outcrops and hilly terrain comprising the rest of the area. The largest of the state's aquifers is the Gash Basin, which has an estimated storage capacity of 600 million m³ and runs North, from the Eritrean highlands and through Kassala State. The state experience, a semi-desert climate in the northern part, and a savanna with a low rainfall climate. The state with large horticultural gardens (i.e. Sawagi), particularly inside Kassala Locality. The annual average rainfall is 350 to 400 mm /annum and the temperature is 33 °C to 47 °C.

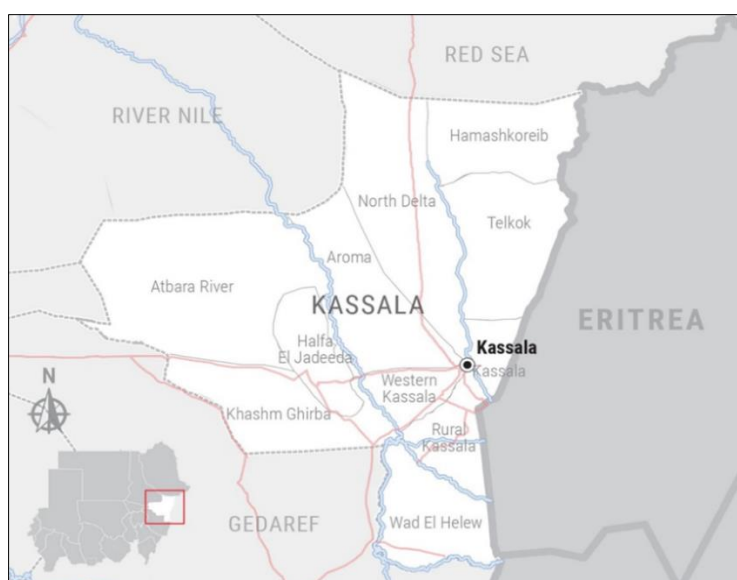


Fig 1: A map showing the study area () in Kassala State, eastern Sudan (Source: <https://reports.unocha.org/en/country/sudan/card/7ji3ScqWjh/>)

2.2. Study sites

In this study, 9 sites were selected to conduct the entomological surveys in Kassala State (Table 1). The selected sites represent different environmental settings such as residential areas (i.e. Al Barno, Al Khatmyia, Al Shaheed Tag Al Ser, Awaad, Fatto Al Sukria, Mokram, Wad Sherifai, and Garb Al Gash) and agricultural areas (i.e. Al Sawagi Aljanubia) (Table 1).

Table 1: Locations of the study sites selected in Kassala State, eastern Sudan.

Study sites	Coordinates	
	N	E
Al Barno	15 28 525	036 23 317
Al Khatmyia	15 25 740	036 25 242
Al Sawagi Aljanubia	15° 25 088	036° 23 061
Al Shied Tag Al Ser	15 26 427	036 24 045
Awaad	15 24 452	036 34 236
Garb Al Gash	15 27 161	036 22 786
Fatto Al Sukria	15 22 326	036 22 760
Mokram	15 27 898	036 26 036
Wad Sherifai	15 22 246	036 26 670

2.3. Entomological surveys

In this study, 12 sites were surveyed for mosquito larvae and adults from April 2019 to September 2020. In each site, mosquitoes were collected for three consecutive days every month throughout the study period. The mosquito-surveyed sites were georeferenced using a Geographical Positioning System (GPS 12 XL; German, U.S.A) with an accuracy of 1-5 meters).

Field collection of adult mosquitoes was done using V-Mart Super photo-catalyst Black Hole mosquito tipe Bio Trap (Perangkap Nyamuk) (original KOREA (BHTs), and Prethrum Spray Catches (PSCs). The BHTs were set at 06:00h and collected 12hr later. In each site, 4 traps were used to collect adult mosquitoes from indoor and outdoor habitats (2 traps in each habitat). The BHTs were connected to a power source before sunset and collected the next morning just after sunrise. The daily captured adult mosquitoes were sucked up using electric aspirators and transferred into well-labeled paper cups covered at the top with a mosquito mesh fixed with plastic rubber. Moreover, in each site, 8 rooms were selected to collect adult mosquitoes resting indoors using PSCs. Mosquitoes were knocked down between 06:00-

8:00 am. The knocked-down mosquitoes in each room were placed into a petri-dish with wet cotton and filter paper. Field-collected mosquitoes by BHTs and PSCs were then transported to the Entomology laboratory, Kassala State Ministry of Health. The field-collected mosquitoes were then identified morphologically to species following proper mosquito identification keys [21-23].

2.4. Statistical analysis

The data obtained from the entomological surveys were analyzed using descriptive methods.

3. Results

3.1. Mosquito fauna

A total of 4682 adult mosquitoes were collected from

surveyed sites in the Kassala area. The mosquito fauna of the area comprised five mosquito species. These species were *Anopheles arabiensis*, *Culex (Cx.) quinquefasciatus*, *Cx. (Cx.) pipiens*, *Aedes aegypti*, and *Ae. vittatus*.

3.2. Relative abundance of mosquito species

A total of 4,682 adult mosquitoes were captured in the Kassala area. *Culex* spp. formed more than 70% of the mosquito collection in the area (Figure 2). In addition, *Cx. pipiens* (1781; 38.0%) and *Cx. quinquefasciatus* were the most abundant mosquito species recorded in the area (Figure 3). As shown in table 2, mosquito species were recorded in varied numbers in the surveyed sites in the area with the highest number in the Al Sawagi Aljanubia site (700;) and the lowest in Awaad (351) (Figure 4).

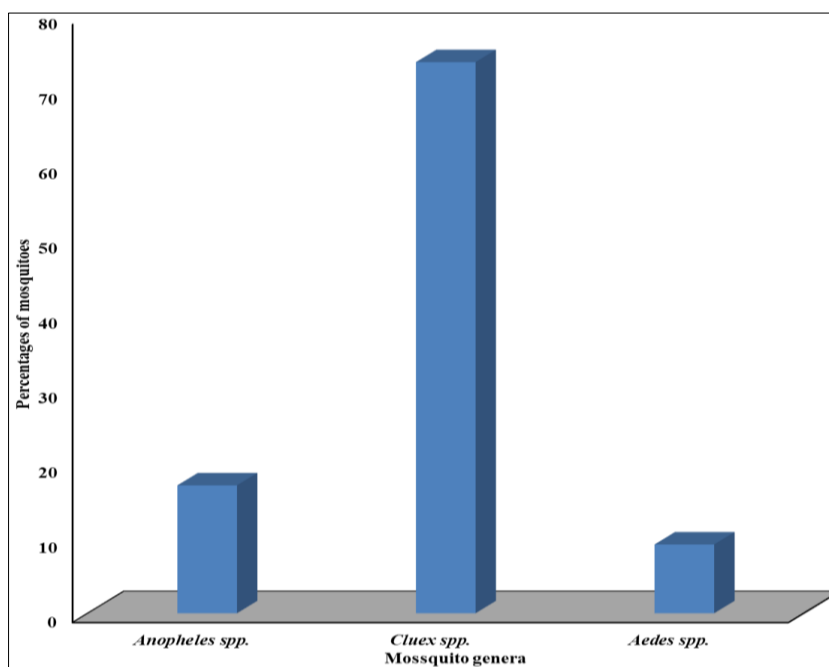


Fig 2: Percentages of mosquitoes of different genera recorded in Kassala State, eastern Sudan from 2019 to 2020

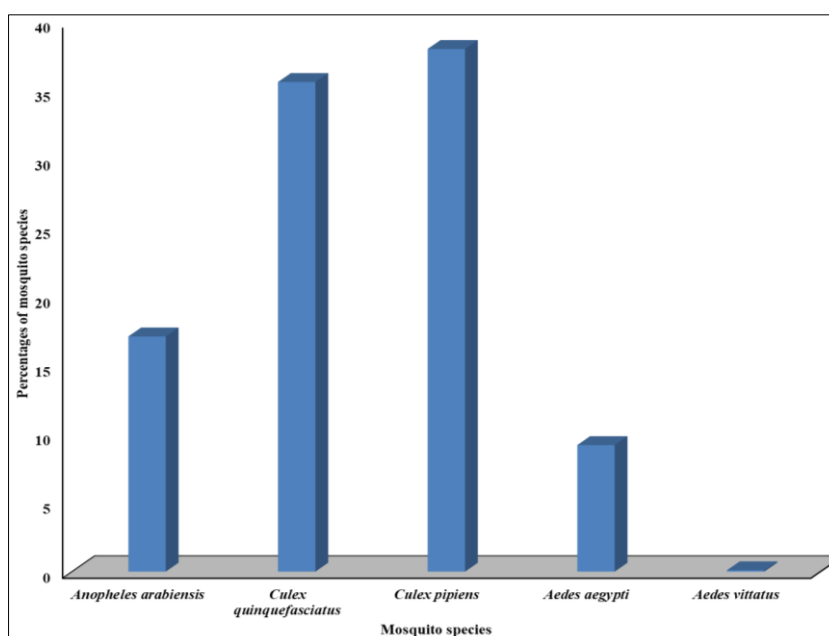


Fig 3: Percentages of different species of mosquitoes recorded in Kassala State, eastern Sudan from 2019 to 2020

Table 2: Numbers of mosquito species collected in the surveyed sites in Kassala State, eastern Sudan from 2019 to 2020

Study sites	Coordinates		Numbers (%) of mosquito species					Total
			<i>Anopheles arabiensis</i>	<i>Culex quinquefasciatus</i>	<i>Culex pipiens</i>	<i>Aedes aegypti</i>	<i>Aedes vittatus</i>	
	N	E						
Al Barno	15° 28" 525	36° 23" 317	97	229	228	100	0	654
Al Khatmyia	15° 25" 740	36° 25" 242	72	213	250	50	0	585
Al Sawagi Aljanubia	15° 25" 088	36° 23 061	216	205	207	70	2	700
Al Shaheed Tag Al Ser	15° 26" 427	36° 24" 045	12	308	190	24	0	534
Awaad	15° 24" 452	36° 34" 236	90	99	147	15	0	351
Garb Al Gash	15° 27" 161	36° 22" 786	60	186	205	62	0	513
Fatto Al Sukria	15° 22" 326	36° 22" 760	87	179	162	37	0	465
Mokram	15° 27" 898	36° 26" 036	37	121	278	51	0	487
Wad Sherifai	15° 22" 246	36° 26" 670	130	128	114	20	1	393
Total			801	1668	1781	429	3	

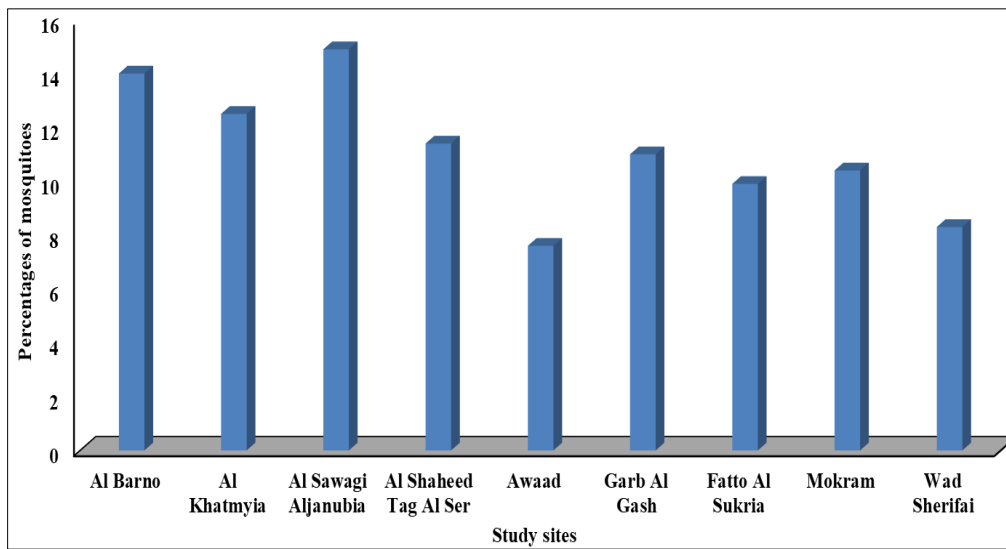


Fig 4: Percentages of mosquitoes collected from the surveyed sites in Kassala State, eastern Sudan from 2019 to 2020.

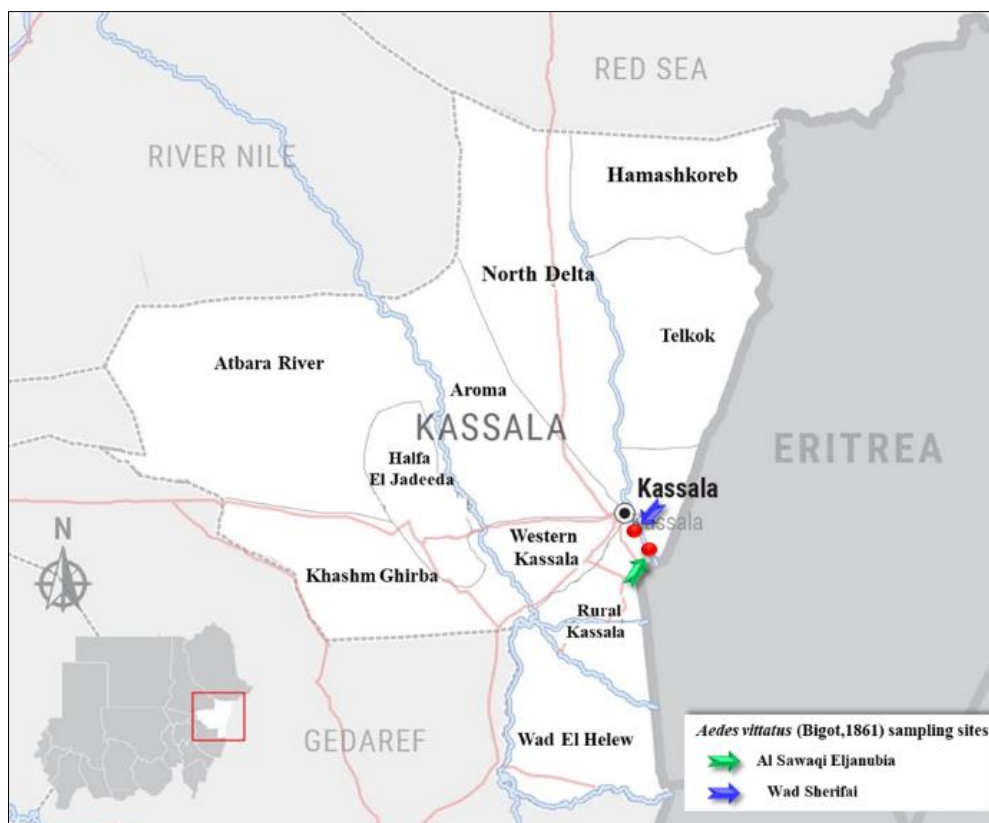


Fig 5: *Aedes vittatus* Bigot sampling sites in Kassala State, eastern Sudan during 2019-2020

3.3. Detection of *Aedes vittatus* Collected in Kassala State, eastern Sudan

In total 3 adults of *Ae. vittatus* were collected in two sites in the Kassala area in October 2019 (Figure 5). One male *Ae. vittatus* was collected from a bedroom in a residential area at Wad Sherifai by the BHTs. The other collected *Ae. vittatus* were 2 females from the agricultural area of Al Sawagi Aljanubia by pyrethrum spray collections (PSCs).

The important diagnostic characteristics to confirm the occurrence of *Ae. vittatus* specimens from the sampling sites in Kassala are presented in figure 6. The mosquito specimens were identified as *Ae. vittatus* and differentiated from other found *Aedes* mosquitoes by the following morphological characteristics. The presence of narrow dark scales and three pairs of small round white spots distributed along the dorsocentral area of the scutum (Figure 6 (A)). The identified *Aedes* specimens with tibiae dark, each with a subbasal white spot and a white band at about basal 0.33 on fore- and mid- and at about 0.50 on hind-tibia (Figure 6 (B)). In addition, the mosquito specimens have a distinct white band on the proboscis (Figure 6 (C)).

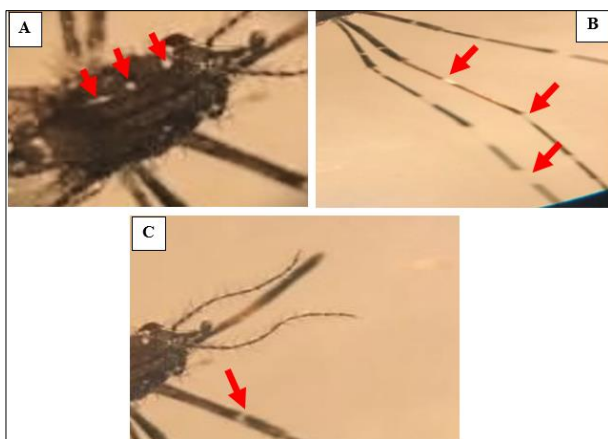


Fig 6: Specimens of *Aedes vittatus*; (A) Scutum showing narrow dark scales and three pairs of small round white spots distributed along the dorsocentral area. (B) Tibiae dark, each with a subbasal white spot and a white band at about basal 0.33 on the fore- and mid- and at about 0.50 on the hind-tibia. (C) Proboscis of *Aedes vittatus* with a distinct white band

4. Discussion

Studies on the mosquito species composition of mosquitoes are very important for our understanding of the epidemiology of mosquito-borne diseases (MBDs) and for designing proper control strategies against these diseases. This study was conducted as entomological surveys in selected sites in Kassala State, eastern Sudan from April 2019 to September 2020, to determine the occurrence, abundance, and distribution of the mosquito species. Five mosquito species were recorded; *Anopheles arabiensis*, *Culex quinquefasciatus*, *Cx. pipiens*, *Aedes aegypti* and *Ae. vittatus*. The mosquitoes recorded in this study were also previously reported in different regions in Sudan [20, 24, 25, 26, 27, 28, 29]. However, previous studies conducted in Kassala mainly focused on the dengue fever and malaria vectors, *Ae. aegypti* and *An. arabiensis*, respectively [30-34]. The studies showed that *Aedes aegypti* only the *Aedes* mosquitoes found in Kassala State [30-32]. Hence, this study documents the occurrence of *Ae. vittatus* in Kassala State, eastern Sudan for the first time.

Anopheles arabiensis was the only anopheline mosquito recorded in Kassala State in this study. This species was one of the most dominant mosquito species in the area. In

addition, it was recorded in all surveyed sites in the area. *Anopheles arabiensis* is the most common and the major malaria vector over a wide geographical range in Sudan [20, 24, 25, 26, 27, 35, 36]. It has been reported that *An. arabiensis* as the only anopheline mosquito vector in Kassala State [33-34]. In contrast, only two *Culex* spp. were recorded; *Cx. quinquefasciatus*, and *Cx. pipiens*. Similarly, the two species were recorded in all surveyed sites in Kassala State. These species are considered important vectors of Rift Valley fever and West Nile viruses as well as bancroftian filariasis [37-38]. The occurrence of these *An. arabiensis* and the *Culex* spp. (i.e. *Cx. quinquefasciatus*, and *Cx. pipiens*) represent a risk of transmission of MBDs viz malaria, lymphatic filariasis, rift valley fever, and WNV in the area.

Aedes mosquitoes recorded in this study included two species invasive species; *Ae. aegypti*, and *Ae. vittatus*. *Aedes aegypti* is the most common mosquito species in eastern Sudan, including Kassala State [30-32]. *Aedes aegypti* the yellow fever mosquito is considered one of the major vectors of arboviruses viz dengue fever (DF), yellow fever (YF), and chikungunya (CHIKV) virus, and *Zika virus* [39-40]. This species is found to be associated with the transmission and outbreak of dengue fever in most endemic areas in Sudan [18, 31, 41].

Previously, *Ae. vittatus* has not been recorded in Kassala State. Hence, this study documented *Ae. vittatus* in the Kassala State, Sudan for the first time. *Aedes vittatus* has a wide geographical range of distribution worldwide [2, 42]. This species has been found to inhabit sylvatic as well as peridomestic environments and readily feeds on humans [2, 42]. *Aedes vittatus* is a competent vector of arboviruses and it plays an important role in the transmission of several arboviruses viz Zika, CHIKV, and DF viruses throughout some European and African countries [2]. In addition, *Ae. vittatus* was found to play a role in outbreaks of YF in some African countries [2].

Similarly, *Ae. vittatus* was recorded in different regions in Sudan [16-20]. Although, this species was reported from endemic areas with dengue in Sudan [18], no evidence that *Ae. vittatus* plays a role in the transmission of MBDs in these regions. However, *Ae. vittatus* was incriminated to have a role in an outbreak of YF that struck the Nuba mountain in Sudan [16]. In this study, only 3 individuals of *Ae. vittatus* were collected in October 2019 in Wad Sheifai (one male) and Al Sawagi Aljanubia (2 females). The occurrence of *Ae. vittatus* in the State indicates that this species is probably peridomestic species. Hence, this species might have a role in the transmission of DF in the area, since Kassala State is one of the endemic areas with disease. However, the previous studies incriminated *Ae. aegypti* as the only vector of DF in the area because no other *Aedes* mosquitoes were recorded in the area [30-32]. Moreover, Kassala State has more recently experienced an outbreak of a deadly fever locally named “Kankasha” which was diagnosed as CHIKV [43]. Once again, the detection of *Ae. vittatus* in Kassala State in this study might provide evidence that this species most probably have a role in transmission arboviruses viz DF and/or CHIKV in the area. Therefore, studies more are needed to better understand the range and public health risks of this potential invasive mosquito species *Ae. vittatus* may pose in the Kassala State.

5. Conclusions

This study reports the first record of the *Ae. vittatus* in the

Kassala State, eastern Sudan. This mosquito vector might be introduced to the Kassala from neighboring countries. The occurrence of this competent vector is most probably a risk of transmission of arboviruses *viz* DF, yellow fever, West Nile vi, *Zika virus*, and chikungunya virus in the area. Therefore, more studies are needed to provide sufficient entomological data that can help in designing vector control strategies to prevent the spread of the *Ae. Vittatus* as well as the arbovirus infections can be transmitted by this mosquito vector in Kassala State.

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