Distribution and abundance of Aedes aegypti and Aedes albopictus (Diptera: Culicidae) in Benin, West Africa

Germain Gil Padonou (pagergil@yahoo.fr)  
Centre de Recherche Entomologique de Cotonou (CREC)

Alphonse Keller Konkon  
University of Abomey-Calavi

Albert Sourou Salako  
Centre de Recherche Entomologique de Cotonou (CREC)

David Mahouton Zoungbédji  
University of Abomey-Calavi

Razaki Ossé  
Université Nationale d'Agriculture de Porto-Novo

Arthur Sovi  
University of Parakou

Roseric Azondekon  
Centre de Recherche Entomologique de Cotonou (CREC)

Aboubakar Sidick  
Centre de Recherche Entomologique de Cotonou (CREC)

Juvénal Minassou Ahouandjinou  
Centre de Recherche Entomologique de Cotonou (CREC)

Constantin Jesukédè Adoha  
Centre de Recherche Entomologique de Cotonou (CREC)

André Aimé Sominahouin  
Centre de Recherche Entomologique de Cotonou (CREC)

Filemon Tokponnon  
Centre de Recherche Entomologique de Cotonou (CREC)

Bruno Akinro  
Centre de Recherche Entomologique de Cotonou (CREC)

Haziz Sina  
University of Abomey-Calavi

Lamine Baba-Moussa  
University of Abomey-Calavi

Martin Akogbeto  
Centre de Recherche Entomologique de Cotonou (CREC)

Research Article

Keywords: Aedes aegypti, Aedes albopictus, distribution, abundance, biting behaviors, Benin

Posted Date: March 15th, 2023
Abstract

Background

Updated information on the distribution and abundance of *Aedes aegypti* and *Aedes albopictus* is crucial to prepare African countries like Benin for possible arbovirus outbreaks. This study aims to evaluate the geographical distribution, the abundance, and the biting behaviors of these two vectors in Benin.

Methods

Three sampling techniques (Human Landing Catch (HLC), Larval sampling, and Ovitrapping) were used to collect both immature and adult stages of *Aedes spp* in 23 communes located along the North-South and East-West transect of Benin. Adult *Aedes* mosquitoes were collected indoors and outdoors using HLC. Mosquito eggs, larvae, and pupae were collected from containers and ovitraps and morphologically identified, then confirmed by Polymerase Chain Reaction (PCR).

Results

Overall, 12,428 adult specimens of *Aedes spp*, out of which 76.53% (n = 9508) and 19.32% (n = 2400) were morphologically identified as *Ae. aegypti*, and *Ae. albopictus* respectively. Geographically, *Ae. aegypti* was encountered across the North South transect unlike *Ae. albopictus* which was only encountered in the southern part of the country, with a strong preponderance in Avrankou and Ifangni. Furthermore, exophagic behaviors were observed in both vectors.

Conclusion

This updated distribution of *Aedes* mosquitoes in Benin will help to accurately identify areas at risk of arboviruses, to better plan future vector control interventions.

Background

The *Aedes* (Stegomyia) *albopictus* (Skuse, 1894) tiger mosquito is currently one of the most invasive species that has successfully colonized most tropical and temperate regions globally [1]. Native to Southeast Asia, the species spread to several other parts of the world except Antarctica [1, 2]. Genetic evidence suggests that this global invasion of *Ae. albopictus* is strongly associated with anthropogenic actions such as the trade of used tires (passive dispersal), transport (sea and land) and travel [3–5]. Kamgang et al. [6] suggest that the ecological plasticity of the *Aedes* species allows them to proliferate in a wide range of climates and habitats. Given the ability of *Aedes albopictus* to tolerate low temperatures [7], it is now present in temperate regions where it lives in sympatry with *Ae. aegypti*. Both species share the same types of larval habitats located in urban and peri-urban environments [8]. Such larval habitats can be domestic (water reservoirs and flowerpots), peri-domestic (discarded reservoirs and used tires) or natural (tree holes and plant axils) [9, 6]. The ease of expansion of *Ae. aegypti* and *Ae. albopictus* has created conducive conditions to the emergence of human arboviruses such as Chikungunya, Zika, dengue fever, and yellow fever in new geographical areas [10]. Over the past 30 years, the distribution and epidemiological impact of these arboviruses on public health have increased considerably [11]. In Africa, *Ae. albopictus* was first identified in South Africa in 1989, and was quickly brought under control [12]. Two years later (1991), in West Africa, this vector was reported in Delta State in Nigeria where it has since spread [4, 13]. In Central Africa, *Ae. albopictus* was reported in Cameroon in 2000 [14], and has since expanded across the region. Curiously, this expansion of *Ae. albopictus* in Central Africa coincided with the emergence of dengue (DENV), Zika (ZIKV) and chikungunya (CHIKV) viruses in urban settings [15]. Paupy et al. [16] suspected that this mosquito would play a leading role in the occurrence of
these diseases in the region. In West Africa, although the first detection of *Ae. albopictus* was reported three decades ago in Nigeria, it was not detected in neighbouring Benin until 2021, a country that shares 773 kilometres of border with Nigeria [17]. Between July and August 2010, two cases of dengue were diagnosed in France in travellers from Cotonou, Benin [18, 19]. Between April and July 2019, height confirmed cases of dengue including two deaths were recorded in the departments of Atlantique, Littoral and Ouémé in southern Benin [20]. According to Padonou *et al.* [21], the diagnosis of confirmed dengue cases in a given area is an indication of the area's strong infestation by mosquitoes of the *Aedes* genus. Recently, cases of dengue virus infections have been recorded in Rosso area in Senegal [22, 23]. In 2022, dengue epidemics affected the economic capital of Côte d'Ivoire with 380 cases of dengue detected [23]. In addition, several studies have shown a strong association between the distribution of vectors and the risk of occurrence of a disease [21, 24]. In the case of arboviruses, the results obtained have enabled the development of risk maps [25–27]. These maps are useful for decision-making, as they allow control interventions to target with precision the most affected areas. In Benin, the distribution area of *Ae. albopictus* is still poorly known. Moreover, even if *Ae. aegypti* is very often found in routine entomological collections, an update of its distribution area in the country is required. This study establishes the distribution map of *Ae. aegypti* and *Ae. albopictus* in Benin. This proposed tool is a prerequisite that will be used to prepare the country's response to potential arbovirus epidemics.

**Methods**

**Study area**

This study was carried out in Benin, more specifically in 23 of the 77 communes in the country (Fig. 1). Ten of the investigated communes were selected due to their closeness to Nigeria, where *Ae. albopictus* was first detected three decades ago.

The 23 communes were selected according to their representativeness of the 03 major eco-climatic zones in the country:

**Area of degraded forests with a subequatorial climate**

This area is characterized by two rainy seasons (Mid-March to Mid-July, and September to November), and two dry seasons (December to Mid-March, and Mid-July to August). Its annual rainfall varies from 1300 to 1500 mm/year [28]. The communes surveyed in this area, as part of this study include: Abomey-Calavi, Porto-Novo, Adjara, Avrankou, Ifangni, Sakété, Pobé, Kétou, Lokossa, Klouékamè, Zagnanado, Bohicon and Grand Popo (Fig. 1). Abomey-Calavi and Porto-Novo are the most urbanized while the others are peri-urban or rural.

**Area of savannas with a Sudano-Guinean climate**

This area has two seasons: a rainy season (April to October) and a dry one (November to March). Its annual rainfall varies between 1200 and 1300mm [28]. Investigated communes in this area include Savè, Dassa, Bantè, Parakou, Nikki, Djougou and Corpago which are predominantly peri-urban or rural (Fig. 1).

**Area of savannahs with a Sudanian climate**

A dry season from November to May, and a rainy season from June to October characterize this area. Its climate is of the Sudanian type. The communes of Gogounou and Ségbana were investigated here [28] (Fig. 1).

Overall, in each of all these communes, the surveys were carried out in two villages selected at random. The geographical coordinates of the surveyed villages were recorded using smartphones in order to map the distribution and density of *Ae. albopictus* and *Ae. aegypti*.

**Mosquito collection techniques**
To determine the different mosquito species of the Aedes genus, even those present at low frequency in all the study communes, three sampling techniques were used between July 2021 and October 2022. These are:

**Ovitrapping**

The ovitraps used, were made with a painted black polyethylene bottle, which contained 50 cl of water. A rectangular hardboard plate (5 cm x 20 cm) was introduced in the black polyethylene bottle to serve as a support for mosquito egg laying. Twelve ovitraps were placed per site, with 4 sites surveyed per commune. These traps were approximately 100 metres apart from each other. They were fixed to a tree or a wall, about 1.5 cm from the ground, using a nail and a metal string, for about 5 to 7 days in the domestic (yard) and peri-domestic environments. The ovitraps were regularly inspected to avoid egg hatching as much as possible. However, when larvae were observed in the traps, they were collected and brought back to the insectary of the “Centre de Recherche Entomologique de Cotonou” (CREC) for rearing until adulthood. The adults were then identified, counted and released into cages. Between the 5th and the 7th day, the ovitraps were withdrawn, and the hardboard plate brought back to the insectary of CREC. The eggs laid were counted and put in water at the insectary to enable hatching and development until adulthood. Adults that emerged were then identified and counted. They were grouped into a pool of 10 individuals, taking into account their geographical origin, their sex, the date of collection, then stored at -80°C.

**Collection of mosquito immature stage**

Larvae and pupae were sampled in different types of larval habitats such as tin cans, coconut shells, water containers, tires of abandoned vehicles, jars, tree holes. These larvae and pupae were then transported to the CREC insectarium where they were reared until adulthood.

**Human Landing Catch (HLC)**

This method that collects adult mosquitoes was used in two sites (one central and one peripheral) selected in each commune. On each site, collections on human bait were carried out from 7 a.m. to 6 p.m. in two houses, with one collector seated inside and a second outside in each house, which makes a total of four collectors/site/day and 16 collectors/commune/day. Two teams of eight collectors each were therefore formed per commune. The first team collected from 7 a.m. to 1 p.m., and was replaced by the second one from 1 p.m to 6 p.m. Collectors used haemolysis tubes to capture mosquitoes that tended to bite their bare feet and legs.

**Morphological and molecular identification**

Adult mosquitoes from the three sampling methods (ovitrapping, collection of immature, and HLC) were morphologically identified using a binocular and the keys of Edwards [29], and Yiau-Min [30]. Specimens of Aedes spp were referenced, preserved on RNA Later, and grouped according to species, locality, date and location (indoor/outdoor).

The legs of specimens of Aedes albopictus were used for the extraction of their DNA using the protocol of Linton et al. [31]. Due to a high degree of interspecific variation [32, 33], the ITS2 nuclear ribosomal spacer gene was amplified by PCR using primers 5.8S and 28S [34, 35]. The PCR product of Ae. albopictus was 509 bp and 518 bp according to sequences published on GenBank M95127 [35] and L22060 [36], respectively. PCR was performed in a volume of 50 μl containing 1× PCR buffer, 2 mM MgCl2, 0.2 μM of each dNTP, 100 pM of each primer, 2 U of Taq DNA polymerase and 2 μl of DNA to be amplified. The amplification was carried out using a thermocycler according to the following programme: initial denaturation at 94°C for 10 min; 40 cycles of denaturation at 94°C for 1 min; initial hybridization at 50°C for 1 min and hybridization at 72°C for 1 min. Final hybridization was performed at 72°C for 10 min. The products were migrated on 1.5% agarose gels containing 0.5 μg/ml ethidium bromide. Gels were photographed with a polaroid camera under UV illumination with standard procedures [37].
**Ethical considerations**

The protocol of this study was reviewed and approved by the “Comité Institutionnel d’Ethique pour la Recherche en Santé du Centre de Recherche Entomologique de Cotonou” (CIERS-CREC) (Ethical approval N°06-22/CREC/CIERS-CREC /SG). The collectors used were selected from the different study sites and trained to collect mosquitoes before they bite. They were all vaccinated against yellow fever and subjected to regular check-ups at the nearest health facility. In the occurrence of fever, they were immediately taken care of.

**Data analysis**

Data were analyzed using R statistical software, version 4.1.2 [38]. The Chi-square test of comparison of proportions was used to compare the distribution of each species according to the different eco-climatic areas. Species richness (S), which corresponds to the number of collected species, and their relative abundance (Pi) were computed (Pi = ni/N, where ni = number of species i; N = total number of species encountered; i = 1:S) per study site.

The Shannon-Weaver index (H), which shows the diversity of species, was determined in all 23 sites according to the formula:

\[ H = - \sum_{i=1}^{S} P_i \times \log_2(P_i) \]  

The equity index was also calculated:

\[ E = \frac{H}{\log_2 S} \]  

All these parameters were determined with the combined number of *Aedes* species obtained with the three sampling techniques to assess the proportion of the main dengue vectors and estimate the level of risk.

The human biting rate (HBR) for *Ae. aegypti* and *Ae. albopictus* was calculated as the number of mosquito species collected divided by the number of collectors day. The Poisson method [41] was used to estimate the confidence intervals of HBRs and compare them between study sites and locations (indoors and outdoors).

**Results**

**Diversity of the *Aedes* mosquito populations in Benin**

A total of 12,428 specimens of *Aedes spp* were collected over a two-year period, using the three sampling methods. Overall, the predominant species were *Ae. aegypti* (76.53% [75.77-77.27], n=9508), and *Ae. albopictus* (19.32% [18.63-20.02], n=2400). The other *Aedes* species included *Ae. luteocephalus* (3.50% [3.18-3.84]; n=435), *Ae. palpalis* (0.45% [0.34-0.58]; n=56), *Ae. vittatus* (0.13% [0.07-0.21]; n=16) and *Ae. africanus* (0.07% [0.03-0.14]; n=9) (Table 1). The lowest numbers of *Aedes* were observed in Savè (n=114) and the highest in Ifangni (n=4106). The species richness observed was 6, 4 and 3 respectively for the subequatorial, Sudano-Guinean and Sudanian areas (Table 2). According to the equitability index E, *Aedes* genus species was low (0.07 [0.03 - 0.012]) in the Sudanian area, as well as in the Sudano-Guinean area (0.08 [0.05 - 0.10]). The same applied to the Shannon-Weaver indices, which revealed low diversity in the northern (H=0.08 [0.03 - 0.13]) and central (H= 0.11 [0.08 - 0.14]) regions of Benin. Meanwhile, the equitability and Shannon-Weaver indices were relatively close to 1 in southern Benin and were respectively E= 0.42 [0.41 - 0.43] and H= 0.76 [0.74 - 0.77].

**Distribution and abundance of *Aedes* mosquitoes**

Twenty-three study communes distributed across the three eco-climatic areas were included in this study (Fig. 2). *Ae. albopictus* was identified in 12 communes including 11 (Avrankou, Adjara, Porto-Novo, Abomey-Calavi, Ifangni, Sakété, Pobè, Kétou, Adj-ouèrè, Bohicon and Zangnanado) located in the south of the country where the climate is subequatorial,
and one (Dassa) located in the centre of the country with a Sudano-guinean climate. No specimen of *Ae. albopictus* was observed in the remaining 11 communes.

Specifically, in southern Benin (subequatorial climate), out of a total of 9,985 specimens of *Aedes spp.* collected using the three sampling methods, 23.71% (n=2367) of *Ae. albopictus* were identified, against 71.27% (n=7116) of *Ae. aegypti*, 4.34% (n=433) of *Ae. luteocephalus*, and 0.69% (n=69) of others *Aedes* species (P<0.0001; χ²=16827; df=3) (Table 3). In this climatic zone, *Ae. albopictus* was absent from three communes (Lokossa, Klouekanmè and Grand-Popo). The highest frequencies of *Ae. albopictus* were recorded in Avrankou (51.72%; n=196) and Ifangni (42.16%; n=1731), and the lowest in Porto-Novo (7.41%; n=133) and Zangnanado (3.08; n=6).

Among the nine communes surveyed in the Sudano-Guinean and Sudanian areas (9 sites), only Dassa revealed 33 specimens of *Ae. Albopictus* with a frequency of 1.35% (33/2439) (Tables 1 & 3; Fig. 2). As observed in southern Benin (subequatorial climate), *Ae. aegypti* was also the predominant *Aedes* species in the northern part of the country where the climate is of the Sudano-Guinean or Sudanian type.

**Molecular identification of *Aedes albopictus***

A sample of 315 mosquitoes morphologically identified as *Ae. albopictus* were processed by PCR. All individuals analyzed showed a 509 bp fragment, confirming them as *Ae. albopictus* (Table 4).

**Human Biting Rate (HBR) in *Aedes aegypti* and *Aedes albopictus***

The biting rates of *Ae. aegypti* and *Ae. albopictus* varied significantly from commune to commune, and according to the location (indoor or outdoor). Overall, the mean biting rate for the whole study area was 4.31 bites/person/day (b/p/d) [4.02 - 4.61] for *Ae. aegypti* against 0.95 b/p/d [0.81 - 1.09] for *Ae. albopictus* (Table 5 & 6). It was four times higher in *Ae. aegypti* than in *Ae. albopictus* (Rate Ratio (RR) = 4.54; p<0.001).

The highest biting rate of *Ae. aegypti* was recorded in July 2021 (rainy season) in Porto-Novo (9.38 b/p/d [7.93 - 11.00]) and the lowest in Avrankou in August 2022 (0.19 b/p/d [0.038 - 0.55]) (Table 5). In *Ae. albopictus*, the highest biting rate was observed in August 2022 in Avrankou (2.75 b/p/d [2.00 - 3.69]) and the lowest in Porto-Novo (0.38 b/p/d [0.14 - 0.82]) in July 2021 (Table 6).

The data also revealed that the outdoor mean HBR was higher in both species (7.02 b/p/d for *Ae. aegypti* and 1.51 b/p/d for *Ae. Albopictus*), than the indoor mean HBR (1.59 b/p/d for *Ae. aegypti* and 0.39 b/p/d for *Ae. albopictus*). On average, the outdoor HBR was respectively 4.4 times (RR & 95% CI: 4.4 [3.69 - 5.28]) and 3.9 times (RR & 95%CI: 3.91 [2.71 - 5.78] higher in both *Ae. aegypti* and *Ae. Albopictus* compared to the indoor HBRs (Table 5 & 6).

**Discussion**

*Aedes albopictus*, a mosquito vector of arboviruses, has expanded its coverage area globally, due to its ability to adapt to climate change and new environments [42, 43]. The alarming increase in dengue fever cases in some West African countries in recent years has received relatively less attention in Benin. This situation is justified by the lack of investigations on the distribution of the vector of this arbovirus. To date and to our best knowledge, only one study confirmed the presence of this vector in Benin [17]. Our study provides an overview of the distribution and abundance of *Ae. albopictus* found in sympatry with *Ae. aegypti* in Benin. It further identifies six different species of the *Aedes* genus.

Previous studies conducted in much smaller areas revealed the presence of four *Aedes* species in Cotonou [44], and three in Abomey-Calavi [21]. In the present study, *Aedes aegypti* was morphologically identified in all the surveyed communes with a relatively high frequency. This high abundance of *Ae. aegypti* could be justified by the native character of this species. Numerous studies had already mentioned this cohabitation between the two species in Brazil [45], Malaysia [46],
and neighboring Nigeria [47]. Given that Benin is located in the same eco-geographical region and shares approximately 773 km of border with Nigeria, it is therefore not surprising that the same trend is observed in certain communes of Benin which border Nigeria. This trend is further sustained by the fact that the two species share the same ecological niches/larval habitats. Similarly, in Mayotte, *Ae. albopictus* coexist with *Ae. aegypti* in 40% of breeding sites [48]. However, by Paupy et al. [49] reported that this coexistence of the two species in the breeding sites could be transitory, followed later by a reduction [50] or displacement of the native species [51, 52]. Competition between larvae of different species for nutrient resources is the most likely reason for the displacement of native mosquito species. The observed abundance of *Ae. albopictus* compared to *Ae. aegypti* in Avrankou and Ifangni, is therefore not surprising as the species had been described as one of the most invasive ones [43]. In neighboring Nigeria, for example, *Ae. albopictus* was detected in 1991 [13] and since then, published data have shown that the species has become well established and already exhibits dominance over *Ae. aegypti* in some parts of the country [53]. Moreover, the both rural and peri-urban characters of Avrankou and Ifangni could have favored the co-existence of *Ae. albopictus* and *Ae. Aegypti* in these two communes. According to Forattini [54], Brady et al. [55] and Brown et al. [56], the urban environment would favor the proliferation of *Ae. aegypti*, while rural and suburban areas would be much more favorable to the development of *Ae. albopictus*. This hypothesis is supported by the work of Kamgang et al. [57] in Cameroon and the Central African Republic who showed that *Ae. albopictus* preferentially colonizes containers containing plant debris or surrounded by vegetation, types of larval habitats often found in rural areas.

Our study reports a distribution of *Ae. albopictus* according to geographical areas. We observed a wide distribution of *Ae. albopictus* in the South East of Benin where a sub-equatorial climate reigns. On the contrary, no specimen of this species has been found in the North of the country where the climate is of the Sudanian type. This wide distribution of *Ae. albopictus* in southern Benin confirms the work of Adeleke et al. [53] who also reported that the mosquito rapidly spread in the southern part of neighboring Nigeria after its first detection in 1991. However, it has been reported that the invasion of this mosquito in some countries started in coastal areas [58] and subsequently progressed inland [43]. The low altitude of the coastal region of Benin justifies the high abundance of *Ae. Albopictus* in the coastal communes compared to the communes of the center and the north of the country where it is not detected. According to Farjana et al. [59], the presence and the population density of these arthropod vectors are highly dependent on climatic factors such as temperature, precipitation and relative humidity. The center and north of Benin being more arid or semi-arid with relatively higher temperatures, the presence of *Ae. aegypti* and the absence of *Ae. albopictus* is associated to a better tolerance to desiccation by *Ae. aegypti* unlike *Ae. albopictus* [60]. However, it should be noted that other studies have reported the presence of *Ae. albopictus* in semi-arid and arid areas, such as Pakistan and Saudi Arabia, where dengue fever outbreaks have previously been reported [61, 62]. In this context, the systematic sampling of mosquito conducted during longitudinal surveys covering both dry and rainy seasons, with good spatial coverage, are essential for determining the distribution area of *Ae. albopictus* particularly in the arid north of Benin.

Molecular data confirmed the presence of *Ae. albopictus* in the twelve municipalities where it was morphologically identified. This result is similar to that obtained by Yadouleton et al. [17] who confirmed the presence of this species in Benin by molecular evidence.

The evaluation of the biting behavior of *Ae. Aegypti* and *Ae. albopictus* performed in this study shows that these two vectors are exophagic. A similar trend was observed in Ghana [63], and Reunion Island. This exophagic behaviors of the two vectors could limit the effectiveness of vector control interventions often deployed inside homes such as Long Lasting Insecticidal Nets and Indoor Residual Spraying. However, some studies conducted in Asia, Latin America [49, 64], Côte d'Ivoire and Niger [65, 66] revealed that, *Ae. aegypti* was endophagic.

Although our study establishes the identification and distribution of *Ae. albopictus* in new localities in Benin, it does not focus on the diversity of subspecies of *Ae. aegypti*. This is a limitation that offers possibilities for future studies for a knowledge of *Ae. aegypti* subspecies in Benin. Another limitation worth noting is the sequencing of cytochrome oxidase 1.
gene (COX1) in *Ae. albopictus*, which would have made it possible to establish phylogenetic links between this species found in southeastern Benin and the original species from Asia [67].

**Conclusion**

This study provides the first data on the distribution, abundance and biting behavior of *Ae. albopictus* and *Ae. aegypti* in Benin. It reveals that, *Ae. albopictus* is well established in the southern part, but not in the northern part of Benin. Our findings suggest that the arid climate prevailing in the northern part of Benin may not be conducive to the invasive species *Ae. albopictus*. A predominance of *Ae. aegypti* over *Ae. albopictus* was observed in all the investigated communes, with the exception of Avrankou and Ifangni, two localities in southeastern Benin bordering Nigeria. The exophagic nature observed in the two vectors could limit the effectiveness of vector control interventions often implemented indoors (LLINs and IRS). The current study having provided a map showing the distribution of *Ae. albopictus* and *Ae. aegypti* will henceforth serve as a basis for the epidemiological surveillance of these vectors in Benin.

**Declarations**

**Acknowledgements**

We are grateful to the Ministry of Health of Benin who financially supported this study through the national budget. We also thank the technicians and researchers of the Centre de Recherche Entomologique de Cotonou (CREC) who provided technical support to the study both in the field and in the laboratory.

**Author contributions**

The study was designed and its protocol written by GGP, KAK, RO, ASS, and MCA. The data was collected by KAK, MDZ, ASS, AS, AAS, BA and HS. Molecular tests were performed by KAK, ASS, AS, JMA. GGP, KAK, ASS, AS and MCA wrote the manuscript. Statistical data analysis by BA, ASS and KAK. GGP, FT, LB, RA and MCA provided intellectual criticism of the manuscript content. All authors read and approved the final submitted manuscript.

**Funding**

Not applicable.

**Availability of data and materials**

The datasets that were analyzed in this study are available from the corresponding author and the lead author.

**Ethics for approval and consent to participate**

The protocol of the present study was reviewed and approved by the Comité Institutionnel d'Ethique pour la Recherche en Santé du Centre de Recherche Entomologique de Cotonou (CIERS-CREC) (Ethical approval N°06-22/CREC/CIERS-CREC /SG). The collectors used were selected from the different study sites and trained to collect mosquitoes before they bite. They all were vaccinated against yellow fever and were subjected to regular check-ups at the nearest health facility. In the occurrence of fever, they were immediately taken care of.

**Consent for publication**

Not applicable

**Competing interests**


The authors declare that they have no competing interests

References


### Tables

**Table 1.** *Aedes* mosquito’s composition and abundance in the study sites.
<table>
<thead>
<tr>
<th>Localities (Communes)</th>
<th>Aedes aegypti</th>
<th>Aedes albopictus</th>
<th>Aedes africanus</th>
<th>Aedes vitatus</th>
<th>Aedes palpalis</th>
<th>Aedes luteocephalus</th>
<th>Total</th>
<th>Taxa (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ifangni</td>
<td>1964 (47.83)</td>
<td>ni (Pi)</td>
<td>ni (Pi)</td>
<td>0</td>
<td>0</td>
<td>1 (0.02)</td>
<td>410</td>
<td>4</td>
</tr>
<tr>
<td>Kétou</td>
<td>139 (82.74)</td>
<td>22 (13.10)</td>
<td>1 (0.60)</td>
<td>0</td>
<td>3 (1.79)</td>
<td>3 (1.79)</td>
<td>168</td>
<td>5</td>
</tr>
<tr>
<td>Sakété</td>
<td>128 (55.41)</td>
<td>44 (19.05)</td>
<td>8 (3.46)</td>
<td>2 (0.87)</td>
<td>49 (21.21)</td>
<td>0</td>
<td>231</td>
<td>5</td>
</tr>
<tr>
<td>Pobè</td>
<td>771 (87.71)</td>
<td>92 (10.47)</td>
<td>0</td>
<td>0</td>
<td>16 (1.82)</td>
<td></td>
<td>879</td>
<td>3</td>
</tr>
<tr>
<td>Adja-Ouèrè</td>
<td>482 (87.96)</td>
<td>66 (12.04)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>548</td>
<td>2</td>
</tr>
<tr>
<td>Porto-Novo</td>
<td>1653 (92.14)</td>
<td>133 (7.41)</td>
<td>0</td>
<td>0</td>
<td>4 (0.22)</td>
<td></td>
<td>1794</td>
<td>3</td>
</tr>
<tr>
<td>Adjara</td>
<td>128 (85.33)</td>
<td>22 (14.67)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>150</td>
<td>2</td>
</tr>
<tr>
<td>Avrankou</td>
<td>178 (46.97)</td>
<td>196 (51.72)</td>
<td>0</td>
<td>2 (0.53)</td>
<td>3 (0.79)</td>
<td></td>
<td>379</td>
<td>4</td>
</tr>
<tr>
<td>Abomey –Calavi</td>
<td>181 (87.44)</td>
<td>26 (12.56)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>207</td>
<td>2</td>
</tr>
<tr>
<td>Bohicon</td>
<td>252 (89.68)</td>
<td>29 (10.32)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>281</td>
<td>2</td>
</tr>
<tr>
<td>Zangnanado</td>
<td>189 (96.92)</td>
<td>6 (3.08)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>195</td>
<td>2</td>
</tr>
<tr>
<td>Lokossa</td>
<td>200 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>Klouekanmè</td>
<td>251 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>251</td>
<td>1</td>
</tr>
<tr>
<td>Grand-Popo</td>
<td>600 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>600</td>
<td>1</td>
</tr>
<tr>
<td>Djougou</td>
<td>241 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>241</td>
<td>1</td>
</tr>
<tr>
<td>Copargo</td>
<td>301 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>301</td>
<td>1</td>
</tr>
<tr>
<td>Savè</td>
<td>114 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>114</td>
<td>1</td>
</tr>
<tr>
<td>Parakou</td>
<td>314 (98.74)</td>
<td>0</td>
<td>4 (1.25)</td>
<td>0</td>
<td>0</td>
<td></td>
<td>318</td>
<td>2</td>
</tr>
<tr>
<td>Nikki</td>
<td>152 (98.70)</td>
<td>0</td>
<td>1 (0.65)</td>
<td>0</td>
<td>1 (0.65)</td>
<td></td>
<td>154</td>
<td>3</td>
</tr>
<tr>
<td>Bantè</td>
<td>551 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>551</td>
<td>1</td>
</tr>
<tr>
<td>Dassa</td>
<td>206 (86.19)</td>
<td>33 (13.81)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>239</td>
<td>2</td>
</tr>
<tr>
<td>Eco-geographical zones</td>
<td>Total</td>
<td>Taxas (S)</td>
<td>Equitability (E) [95% CI]</td>
<td>Shannon (H) [95% CI]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>-------</td>
<td>-----------</td>
<td>---------------------------</td>
<td>----------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-equatorial climate (Oueme, Plateau, Atlantic, Mono, Couffo and Zou regions)</td>
<td>9989</td>
<td>6</td>
<td>0.42 [0.41-0.43]</td>
<td>0.76 [0.74-0.77]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudanese-Guinean climate (Collines, Donga and Borgou regions)</td>
<td>1918</td>
<td>4</td>
<td>0.08 [0.05-0.10]</td>
<td>0.11 [0.08-0.14]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudanese climate (Alibori region)</td>
<td>521</td>
<td>3</td>
<td>0.07 [0.03-0.012]</td>
<td>0.08 [0.03-0.13]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IC: confidence intervalle.

**Table 3.** Distribution and abundance of *Aedes* species by climate type.

<table>
<thead>
<tr>
<th>Eco-climatic zones</th>
<th><em>Aedes aegypti</em></th>
<th><em>Aedes albopictus</em></th>
<th><em>Aedes luteocephalus</em></th>
<th>Others Aedes</th>
<th>Total</th>
<th>Chi Square Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N(%)</td>
<td>N(%)</td>
<td>N(%)</td>
<td>N(%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-equatorial climate (Oueme, Plateau, Atlantic, Mono, Couffo and Zou regions)</td>
<td>7116 (71.27)</td>
<td>2367 (23.71)</td>
<td>433 (4.34)</td>
<td>69 (4.34)</td>
<td>9985</td>
<td>P&lt;2.2e-16; χ²=16827; df=3</td>
</tr>
<tr>
<td>Sudanese-Guinean climate (Collines, Donga and Borgou regions)</td>
<td>1879 (97.97)</td>
<td>33 (1.72)</td>
<td>1 (0.05)</td>
<td>5 (0.26)</td>
<td>1918</td>
<td>P&lt;2.2e-16; χ²=7263.3; df=3</td>
</tr>
<tr>
<td>Sudanese climate (Alibori region)</td>
<td>513 (98.46)</td>
<td>0</td>
<td>1 (0.19)</td>
<td>7 (1.34)</td>
<td>521</td>
<td>P&lt;2.2e-16; χ²=1999.8; df=3</td>
</tr>
</tbody>
</table>

Chi Square Test: Test of comparison of the distribution of each species according to the different eco-climatic zones; N: number; %: percentage

**Table 4.** Molecular identification of *Aedes albopictus*. 
<table>
<thead>
<tr>
<th>Localities (Communes)</th>
<th>N-tested</th>
<th>N-confirmed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abomey-Calavi</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Adjarra</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Avrankou</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Ifangni</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Kétou</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Porto-Novo</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Bohicon</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Adja-ouèrè</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Dassa</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Pobè</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Zangnanado</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Sakété</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>315</td>
<td>315</td>
</tr>
</tbody>
</table>

N: number

**Table 5.** HBR in *Aedes aegypti.*
<table>
<thead>
<tr>
<th>Localities (Communes)</th>
<th>Periods</th>
<th>Nb Aedes aegypti collected</th>
<th>HBR/day</th>
<th>RR &amp; CI-95%</th>
<th>Total HBR/day</th>
<th>CI-95%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Indoors</td>
<td>Outdoors</td>
<td>Total</td>
<td>Indoors</td>
<td>Outdoors</td>
</tr>
<tr>
<td>Porto-Novo</td>
<td>May 2021</td>
<td>41</td>
<td>70</td>
<td>111</td>
<td>5.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.75&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>July 2021</td>
<td>5</td>
<td>145</td>
<td>150</td>
<td>0.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.13&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>October 2022</td>
<td>9</td>
<td>22</td>
<td>31</td>
<td>1.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.75&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>Rainy season (May-October 2022)</td>
<td>55</td>
<td>237</td>
<td>292</td>
<td>2.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.88&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ifangni</td>
<td>May 2021</td>
<td>7</td>
<td>49</td>
<td>56</td>
<td>0.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.13&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>July 2021</td>
<td>13</td>
<td>40</td>
<td>53</td>
<td>1.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>Rainy season (May-July 2021)</td>
<td>20</td>
<td>89</td>
<td>109</td>
<td>1.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.56&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Kétou</td>
<td>Dry season (August 2022)</td>
<td>2</td>
<td>20</td>
<td>22</td>
<td>0.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Avrankou</td>
<td>Dry season (August 2022)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.25&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Overall total</strong></td>
<td>Dry and rainy seasons (May 2021-August 2022)</td>
<td>153</td>
<td>674</td>
<td>827</td>
<td>1.59&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Nb, number; HBR, human biting rate; CI, confidence intervals; RR, rate ratio; HBR of *Aedes aegypti* with different superscript (a, b) are significantly different (p < 0.05).

**Table 6.** HBR in *Aedes albopictus.*
<table>
<thead>
<tr>
<th>Localities (Communes)</th>
<th>Periods</th>
<th>Nb <em>Aedes albopictus</em> collected</th>
<th>HBR/day</th>
<th>RR&amp;CI-95%</th>
<th>Total HBR/day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Indoors</td>
<td>Outdoors</td>
<td>Total</td>
<td>Indoors</td>
</tr>
<tr>
<td>Porto-Novo</td>
<td>May 2021</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>0.25&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>July 2021</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>0.13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>October 2022</td>
<td>2</td>
<td>13</td>
<td>15</td>
<td>0.25&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total</td>
<td>Rainy season</td>
<td>5</td>
<td>23</td>
<td>28</td>
<td>0.21&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(May 2021-October 22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ifangni</td>
<td>May 2021</td>
<td>6</td>
<td>15</td>
<td>21</td>
<td>0.75&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>July 2021</td>
<td>5</td>
<td>9</td>
<td>14</td>
<td>0.63&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total</td>
<td>Rainy season</td>
<td>11</td>
<td>24</td>
<td>35</td>
<td>0.69&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(May-July 2021)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ketou</td>
<td>Dry season</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>0.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(August 2022)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avrankou</td>
<td>Dry season</td>
<td>5</td>
<td>39</td>
<td>44</td>
<td>0.63&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(August 2022)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall total</td>
<td>Dry and rainy</td>
<td>37</td>
<td>145</td>
<td>182</td>
<td>0.39&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>seasons (May</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2021 -August 2022)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nb, number; HBR, human biting rate; CI, confidence intervals; RR, rate ratio; HBR of *Aedes albopictus* with different superscript (a, b) are significantly different (p < 0.05).

Figures
Figure 1

Map showing the study area.
Figure 2

Distribution and density of *Aedes albopictus* and *Aedes aegypti* a North-South Benin transect.

**Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- GraphicalabstractPadonouetalPV.pdf