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Seasonal variation and intra urban heterogeneity of the entomological risk of transmission of dengue and yellow fever in Abidjan, Côte d'Ivoire

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Abstract

Dengue and yellow fever are prevalent in Côte d'Ivoire and *Aedes* (*Stegomyia*) *aegypti* (Linnaeus), (Diptera: Culicidae), is known as the main vector. We aimed to assess seasonal variation and spatial heterogeneity in the transmission of both arbovirus diseases in Abidjan. Entomological surveys targeting larvae of *A. aegypti*, were carried out between November 2015 and August 2016 covering the four climatic seasons including a cohort of 100 houses randomly selected in three neighbourhoods. *A. aegypti* was the predominant species (96.6%) of mosquitoes resulting from the rearing of harvested larvae, and the only vector of dengue and yellow fever recorded during the study period. The highest proportion of water storage containers (45.5%) which represented the major breeding sites infested by the larvae of *A. aegypti*, was observed in Anoumabo. The house indices >5% and/or Breteau indices >20 recorded in each neighbourhood, during the different climatic seasons, indicated that there was, a high and permanent, heterogeneity in the transmission risk of dengue and yellow fever between the three neighbourhoods. In terms of transmission risk, Anoumabo was the neighbourhood with the highest risk compared to the two others, then, particular attention should be paid to this site in terms of surveillance by vector control programme in Abidjan.

KEYWORDS
Abidjan, *Aedes aegypti*, arboviruses, entomological risk, Stegomyan indices

INTRODUCTION

Since 2000, human health has been threatened by the resurgence of dengue fever, which continues to rage in several countries in West Africa (Ninove et al., 2009). Indeed, epidemics have been reported in Benin (Ujiie et al., 2012), Burkina Faso (Fournet et al., 2016; Tarnagda et al., 2014), Cape Verde and Senegal (Franco et al., 2010), Mali (Phoutrides et al., 2011) and Nigeria (Oyero & Ayukekbong, 2014). In Côte d'Ivoire, after the first case of dengue virus serotype 3 in 2008 (World Health Organization [WHO], 2009), several other studies have reported the presence of this arbovirus in the country (Akoua-Koffi et al., 2011; Aoussi et al., 2014; L'Azou et al., 2015; Moi et al., 2010; WHO, 2017). The country has also known since 2008, a resurgence of yellow fever (Attoh-Touré et al., 2010; Konan et al., 2009) and Zika was also reported (Akoua-Koffi et al., 2001).

These arboviruses are transmitted by *Aedes* mosquitoes, among which *Aedes aegypti* represents one of the main vectors (Bruce, 2005; Christopher et al., 2017; Gubler, 2002). This species has been repeatedly listed during entomological investigations in the district of Abidjan (Guindo-Coulibaly et al., 2010, 2019; Konan et al., 2009; Zahouli et al., 2016). Although it mainly colonizes domestic water storage containers (Konan et al., 2009; Koné et al., 2013), it was also found in what can be qualified as a waste of civilization such as used tires, discarded cans, car wrecks, etc. (Degallier et al., 1988; Konan et al., 2013; Weeraratne et al., 2013). It also colonizes certain natural sites such as tree hollows and the leaves of sheathed plants, found around human dwellings. Moreover, the presence of domestic water tanks has been recognized as the most identified risk factor for the emergence of dengue, Zika and chikungunya (Weeraratne et al., 2013). In addition to *A. aegypti*, another vector, namely *Aedes albopictus*, first reported in Africa in 1989, in South Africa and present in other Central African cities (Kamgang et al., 2017), has also been recorded in Côte d'Ivoire (Konan et al., 2013; Zahouli et al., 2017).

The absence of effective prophylactic and therapeutic tools against these arboviral infections is often mentioned to explain their rapid spread. Also, studies in Côte d'Ivoire have shown that urbanization is associated with a high abundance of *Aedes* larvae and a predominance of artificial containers as breeding sites, mainly colonized by *A. aegypti*, the main vector of these arboviral infections, in the city of Abidjan (Zahouli et al., 2017). Of note, this vector has a clear preference for anthropogenic sites over sylvatic sites (Guindo-Coulibaly et al., 2019). Due to the increased risk of epidemic related to arboviruses, it appears necessary to define appropriate indicators to monitor and detect any outbreak of these viral infections. To this end, the WHO has defined entomological indices namely, the house index (HI) and the Breteau index (BI) (Sanchez et al., 2006), the most commonly used to define the zones requiring vector control campaigns (Focks, 2003; WHO, 2011a). The main objective of this study was therefore to assess the level of epidemic risk of yellow fever and dengue through the evaluation of entomological indices in an anthropogenic environment such as Abidjan, the economic capital of Côte d'Ivoire.

MATERIALS AND METHODS

Ethics statement

Ethical clearance for this study was obtained from the National Committee for Ethics and Research of Côte d'Ivoire (04 August 2015; No. 040/MSLS/CNER-dkn). This study also received approval from the Direction Générale de la Santé in Côte d'Ivoire and health authorities' of the involved districts. At each study site, permission to work was granted by the chief of the municipality. Community members were informed about the objectives, procedures and potential risks and benefits of the study. Participation in mosquito larvae collection was strictly voluntary.

Study sites

The study was carried out in the municipalities of Adjamé, Marcory and Port-Bouët in Abidjan economic capital of Côte d'Ivoire (Figure 1). Abidjan is located in the south-east of the country with about 5,000,000 inhabitants (Recensement General de la Population et de l'Habitat, 2014). It is crossed by the Ebrié lagoon and has an equatorial climate with two rainy seasons (March–July and October–November) and two dry seasons (December–February and August–September). Abidjan experienced epidemics of dengue fever in 2008, 2017 and 2019, and cases continue to be reported.

A sampling site was chosen in each municipality. The three neighbourhoods chosen are populous areas with no real subdivision and where there are some houses made of abandoned construction equipment. Two neighbourhoods (i.e., Anoumambo and Petit-Bassam in Marcory and Port-Bouët municipalities, respectively) were surrounded by a lagoon but not the neighbourhood of Bromakoté in Adjamé municipality. Previous data from the Pasteur Institute of Côte d'Ivoire indicated the presence of a patient who contracted dengue only in Petit-Bassam. No cases of dengue were reported in Anoumambo and Bromakoté. In addition, criteria that provided ideal conditions for the transport of new vector species and virus strains were also used to select these three neighbourhoods (WHO, 2016a). The first criterion was the presence and abundance of artificial breeding sites (i.e., discarded tires and containers) commonly widespread in the urban area of Abidjan (Koné et al., 2013; Zahouli et al., 2016, 2017). In addition to this first criterion, Anoumambo was chosen due to its precarious characteristics. In this neighbourhood, there is practically no drinking water supply network, leading the population to store water permanently for their daily needs. The water storage containers have been recognized as breeding sites for *Aedes* mosquitoes (Koné et al., 2013). In addition, in Anoumabo there is virtually no drainage system for rainwater meaning that remaining water in the environment can also be a breeding site for mosquitoes. In Bromakoté, the first criterion was combined with the presence of a railway station and several bus stations favourable to the transport of new species and virus strains. In Petit-Bassam, the criterion of the abundance of artificial breeding sites was combined with the presence of a port (favourable to the transport of new species and virus strains) and the container terminal of the autonomous port of Abidjan in

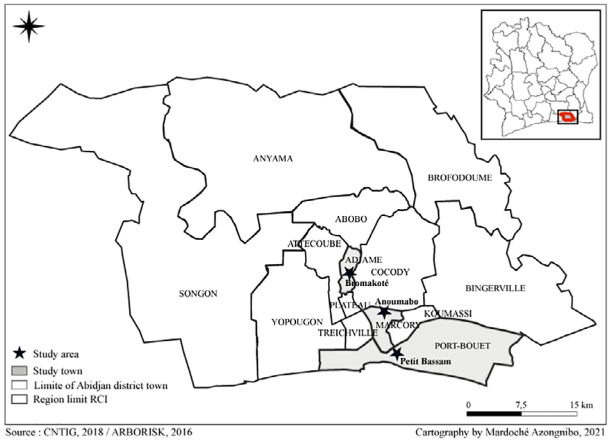

FIGURE 1 Location of the three study sites within the communities of Abidjan

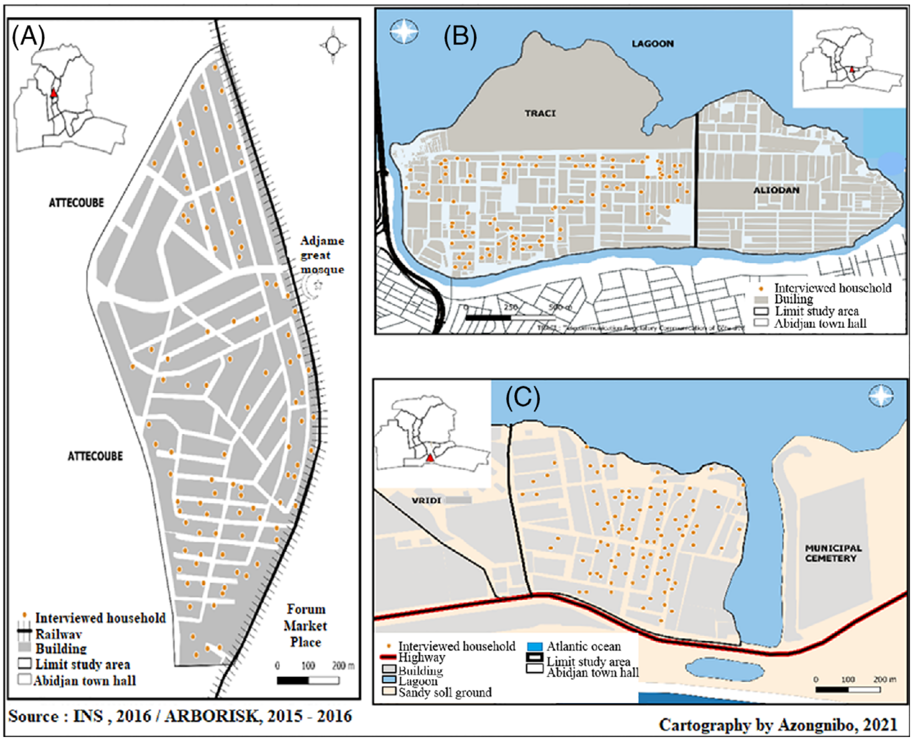

FIGURE 2 Location of the 100 surveyed houses in the neighbourhoods of Bromakoté (a), Anoumabo (b) and petit-Bassam (c)

which *A. albopictus*, the second vector of dengue fever, was recorded (Konan et al., 2013).

Study design

In each neighbourhood, four house-to-house entomological surveys were carried out according to the four climatic seasons encountered in Abidjan. Thus, the surveys in each neighbourhood were implemented, respectively, in November 2015 (short rainy season [SRS]), the second one in February 2016 (principal dry season [PDS]), the third one in May 2016 (principal rainy season [PRS]) and the fourth one in August 2016 (short dry season [SDS]). The surveys were undertaken in 100 houses at each study site. The houses were selected randomly using mapping software. The sample size of the 100 houses was determined using Yamane's (1967) simplified sample size calculation formula. The following parameters were inputted within Yamane's formula; 5% precision, 95% confidence level, estimated plots per neighbourhood (Anoumabo, $N = 1113$; Bromakote, $N = 1008$; Petit-Bassam, $N = 986$) and a response rate of 10%. Before house selection, the plots of each study site were digitized within the OpenStreetMap platform. For each study site, the data generated were retrieved in shapefiles (shp) format to generate 100 random points using QGIS software version 2.14.4. The generated waypoints were entered into a Global Position System version Garmin eTrex 20x. Larvae were collected from the houses indicated by the waypoints in each survey site (Figure 2). In case of refusal of the inhabitants of a given house to participate, the neighbouring house (left or right) was investigated. During these surveys, mosquito larvae were collected in order to identify the breeding sites of *Aedes* larvae and to estimate the entomological indices for epidemic risk, namely the HI, the container index (CI) and the BI.

Larval collection

A hundred houses selected randomly in each study site were visited in order to find inside or in their close environment any filled container with water and therefore likely to harbour at least one mosquito pre-imaginal stage. All containers with water, found inside and outside human dwellings were inspected for the presence of mosquito larvae. The containers were numbered and data were noted: the presence or absence of larvae, the name of the sampling site and the house number. The containers have been classified according to WHO guidelines used in dengue-endemic regions (WHO, 2011b). In brief, containers were therefore grouped into water storage tanks or cisterns (>15 L); small water containers used for daily cooking and cleaning activities (<15 L); discarded containers (including waste of civilization and abandoned domestic containers); natural containers (including natural tree, leaves of sheathed plants and bamboo holes); other containers (including wells, artificial containers used by households and which cannot be destroyed, e.g., animal drinking pots, flower pots) and used tires.

Mosquito larvae were collected using a ladle or a pipette depending on the size of the container, from all positive containers. These larvae were brought back in plastic cups to the insectarium of

TABLE 1 Proportion of adults of Culicidae emerged from larvae collected from breeding sites in three neighbourhood of Abidjan

		Anoumabo		Bromakoté		Petit-Bassam		Total	
Genera	Species	*n*	%	*n*	%	*n*	%	*n*	%
Aedes	*Aedes aegypti*	1178	96.0	760	96.4	614	97.9	2552	96.6
Culex	*Culex quinquefasciatus*	49	4.0	26	3.3	12	1.9	87	3.3
	Culex tigripes	0	0	0	0	1	0.2	1	0.0
Anopheles	*Anopheles gambiae*	0	0	2	0.3	0	0	2	0.1

Abbreviation: *n*, number of mosquitoes; %, percentage.

FIGURE 3 Potential breeding sites of *Aedes* mosquitoes in the three study sites of Abidjan

the Centre d'Entomologie Médicale et Vétérinaire to be reared to the adult stage. Adult mosquitoes resulting from this rearing were identified at the genus and species level under a binocular microscope, referring to Edwards (1941) and Huang (2004) keys.

Data analysis

Data were entered into a spreadsheet, cross-checked and transferred into R version 3.5.1 (2018-07-02). The Pearson's Chi-squared test (χ^2) was used to compare the proportion of positive breeding sites of *A. aegypti* populations within the three neighbourhoods and also to compare the proportion of the different types of breeding sites.

The abundance of *Aedes* larvae was assessed using the WHO larval indices, namely the HI (representing the percentage of positive houses in *Aedes* larvae), the CI (percentage of positive containers in *Aedes* larvae) and the BI (number of positive containers in *Aedes* larvae per 100 houses).The chi-squared test was used to compare the HI and CI between seasons and between study sites. All differences were considered significant at $p < 0.05$.

The evaluation of the risk of transmission of arboviruses by *A. aegypti* in each study site was estimated on the basis of the WHO criteria which stipulate that:

- An area is considered to be at high risk of promoting the transmission of dengue and chikungunya viruses by *A. aegypti* if HI or BI or CI, respectively, exceeds 5%, 20% and 3% (Khatun et al., 2015; WHO, 2003).
- An area is considered to be at high risk of favouring the transmission of Zika and yellow fever viruses by *A. aegypti* if HI or BI or CI exceeds 5, 4 and 3%, respectively (WHO, 1971, 2016b).

RESULTS

Taxonomic composition of adult mosquitoes emerged from collected larvae

A total of 1200 houses (i.e., 100 houses/study site/season), were visited during this study. From those houses, 4089 water containers were recorded and among them, 676 were found to be positive, that is, containing at least one larva of the genus *Aedes*. The collected larvae supplied a total of 2642 adult mosquitoes that divide into three genera, 96.6% of *Aedes*, 3.3% of *Culex* and 0.1% of *Anopheles* (Table 1). Mosquitoes of the *Aedes* genus were predominant in all three study sites, followed by those of the *Culex* genus. The *Anopheles* genus, very poorly represented, was collected only in the Bromakoté neighbourhood. *A. aegypti*, one of the main vectors of dengue and yellow fever, accounted for more than 96% of the mosquitoes collected in each of the three study sites.

Breeding site types of *A. aegypti* in the three neighbourhoods of Abidjan

A total of 4089 potential breeding sites for *Aedes* mosquitos were identified during the larval surveys carried out inside and outside the 1200 houses visited, during the four climatic seasons, in the three neighbourhoods of Abidjan. These potential breeding sites (Figure 3) were divided into water storage tanks ($n = 2414$; 59.0%), used tires ($n = 584$; 14.3%), other containers ($n = 492$; 12.0%), discarded containers ($n = 432$; 10.6%), small water containers ($n = 163$; 4.0%) and natural containers ($n = 4$; 0.1%). Six hundred and seventy-six (16.5%) of the identified potential breeding sites were found infested with *A. aegypti* mosquito larvae. The proportions of these positive breeding sites were, respectively, 22.5%, 10.2% and 16.7% in Anoumabo, Bromakoté and Petit-Bassam. We observed a statistical difference in the proportion of positive breeding sites between the three neighbourhoods ($\chi^2_2 = 84.166$; $p < 0.001$) with Anoumabo showing the highest proportion of positive breeding sites. These positive breeding sites consisted of water storage tanks (45.6%), used tires (20.7%), discarded containers (16.9%), other containers (13.3%), and small water containers (3.5%). Significant differences were observed between the types of breeding sites found positive for *A. aegypti* larvae ($\chi^2_4 = 80.18$; $p < 0.001$). The water storage tanks were the most frequently positive breeding sites in all the three neighbourhoods during the entire study period, except for the short rainy season with used tires as the most positive breeding sites in the three neighbourhoods. Although with low proportions compared to water storage containers and used tires, the discarded containers, other containers and small water containers were also found throughout the study period but with lower proportions of *Aedes* larvae positivity during the long dry season (Figure 4).

Seasonal variation of WHO larval indices

Across all the three study sites, house indices of 37.3%, 18%, 45% and 27.3% were found in the short rainy season, principal dry season,

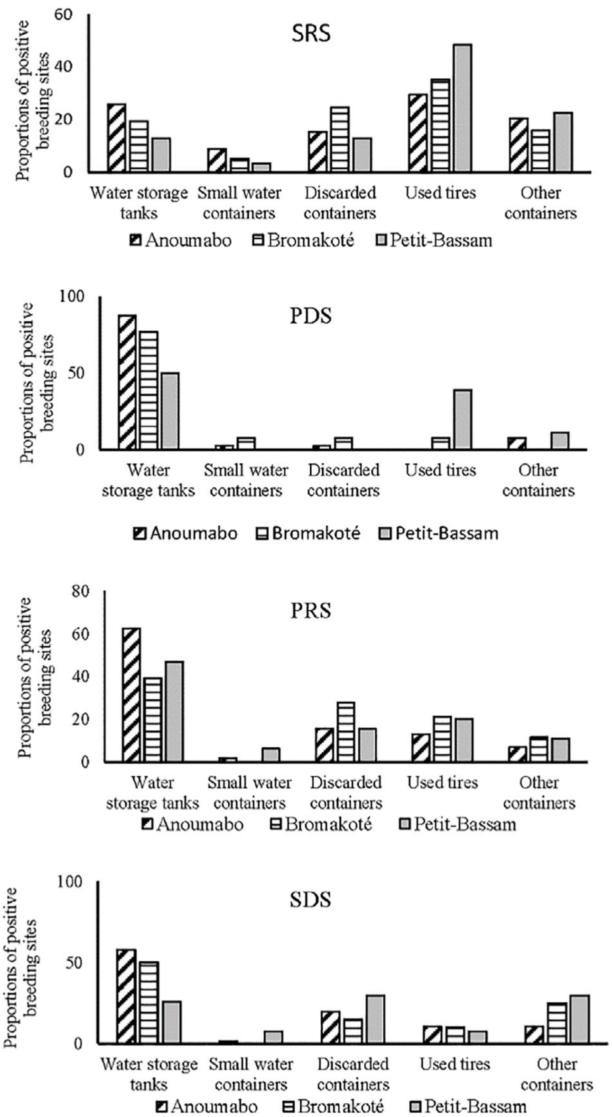

FIGURE 4 Proportions of positive breeding sites types according climatic seasons in three neighbourhoods of Abidjan. PDS, principal dry season; PRS, principal rainy season; SDS, short dry season; SRS, short rainy season

TABLE 2 Seasonal variation of the World Health Organization larval indices in three neighbourhoods of Abidjan

Seasons	Number of houses	Positive houses	Total containers	Positive containers	House index (95% CI)	Container index (95% CI)	Breteau index
SRS	300	112	1083	197	37.3 (31.8–43.1)	18.2 (15.9–20.6)	65.7
PDS	300	54	728	71	18 (13.8–22.8)	9.8 (7.7–12.1)	23.7
PRS	300	135	1327	285	45 (39.3–50.8)	21.5 (19.3–23.8)	95
SDS	300	82	951	123	27.3 (22.4–32.8)	12.9 (10.9–15.2)	41

Abbreviations: CI, confidence interval; PDS, principal dry season; PRS, principal rainy season; SDS, short dry season; SRS, short rainy season.

TABLE 3 Heterogeneity of *Aedes aegypti* larval indices in three neighbourhoods of Abidjan

Study sites	Total houses	Positive houses	Total containers	Positive containers	House index (95% CI)	Container index (95% CI)	Breteau index
Anoumabo	400	183	1575	354	45.8 (40.8–50.8)	22.5 (20.4–24.6)	88.5
Bromakote	400	101	1487	151	25.3 (21.1–29.8)	10.2 (08.7–11.8)	37.8
Petit-Bassam	400	99	1027	171	24.8 (20.6–29.3)	16.7 (14.4–19.1)	42.8

Abbreviation: CI, confidence interval.

principal rainy season and short dry season, respectively (Table 2), with a significant difference between seasons ($\chi^2_3 = 57.321$; $p < 0.001$). Thus, the highest HI was obtained during the principal and the short rainy seasons. Container indices of 18.2, 9.8, 21.5 and 12.9 were recorded in the short rainy season, the principal dry season, the principal rainy season and the short dry season, respectively, and they also showed a significant difference between seasons ($\chi^2_3 = 58.843$; $p < 0.001$). The highest CI was observed during the principal and short rainy seasons with no significant difference ($p = 0.3032$). Breteau indices were estimated at 65.7, 23.7, 95 and 41, respectively, during the same study seasons. This index was relatively low in principal and short dry seasons, intermediate in the short rainy season and high in the principal rainy season.

Intra urban heterogeneity of WHO larval indices

Table 3 show WHO' larval indices variation between the study sites (Table 3). House indices of 45.8%, 25.3% and 24.8% were recorded in Anoumabo, Bromakoté and Petit-Bassam, respectively. These indices showed a significant difference between these three study sites ($\chi^2_2 = 52.861$; $p < 0.001$). The HI recorded in Anoumabo was almost double that recorded in the other two sites. The container indices were 22.5%, 10.2% and 16.7% in Anoumabo, Bromakoté and Petit-Bassam, respectively, with significant difference between sites ($\chi^2_2 = 84.166$; $p < 0.001$). Breteau indices were 88.5, 37.8 and 42.8 in Anoumabo, Bromakoté and Petit-Bassam, respectively. These Breteau indices recorded in the three neighbourhood were very high (>20) based on the WHO classification meaning our study sites were all at high risk for yellow fever and dengue transmission. The district of Anoumabo showed the highest BI compared to the two other districts.

DISCUSSION

Since the detection of the first case of DENV-3 in 2008 in Abidjan (WHO, 2009), the population has been regularly affected by this disease through reported epidemics (Aoussi et al., 2014; L'Azou et al., 2015; WHO, 2017). The main vector of this infection during these epidemics was the *A. aegypti* mosquito. *A. aegypti* has been reported in high proportions during recent entomological investigations carried out in Abidjan city (Guindo-Coulibaly et al., 2019; Zahouli et al., 2017). The mosquitoes are in permanent contact with humans who constantly create favourable conditions for their development (Koné et al., 2013). The current study, therefore, aimed to assess the seasonal variations in risk indices of arboviruses, particularly dengue fever and their heterogeneity between three districts in Abidjan.

The study showed a predominance of mosquitoes from the *Aedes* genus in all the three surveyed districts. Our findings are in line with previous studies carried out in Abidjan (Zahouli et al., 2017). The predominance of mosquitoes of the *Aedes* genus could be explained by the fact that the surveys largely targeted *Aedes* typical containers, and not those of *Culex* or *Anopheles*, located in the immediate environment of dwellings (Koné et al., 2013). *A. aegypti* was the species mainly found from the larvae collected. It was the only species recognized as a potential vector of dengue and yellow fever in this study. Our results corroborate those of Zahouli et al. (2016) and of Ouattara et al. (2019) in Abidjan and in Ouagadougou, who also reported the presence of this single species in urban areas. On the other hand, Konan et al. (2013) and Zahouli et al. (2017) reported the presence of *A. albopictus* in the urban environment of Abidjan, although in very small proportions compared to *A. aegypti*. The absence of this species from the mosquitoes fauna collected during our surveys could be due to the fact that *A. albopictus* has not yet adapted to local breeding sites. This species preferentially breeds in containers containing plant debris or surrounded by vegetation (Kamgang et al., 2010), but beyond that, this species has not been found in Abidjan in several other studies (Guindo-Coulibaly et al., 2019; Kpan et al., 2021; Zahouli et al., 2016). This may be explained by the absence of *A. albopictus* beyond its site of introduction at the coastal port. However, this is not the case in Yaounde, Cameroon (Kamgang et al., 2010) and in Bangui, the Central African Republic (Kamgang et al., 2013), where *A. albopictus* has become widely established. While the species is invading Central Africa *A. aegypti* remains the main vector of arboviruses in Abidjan. It was also the main vector of the Chikungunya epidemic in 2007 in Libreville (Pagès et al., 2009).

The study also showed that *A. aegypti* colonizes practically all kinds of containers in the immediate environment of humans, particularly water storage ones. These containers, which constitute the main breeding sites for this vector (Konan et al., 2011; Koné et al., 2013; Tezzo et al., 2021), are constantly used by the population of Abidjan to store water because of the inadequacy of the water supply network to serve a continuously growing population (Office National de l'Eau Potable, 2017). After water storage containers used tires represented the second most important category of breeding sites in terms of frequency. They represent also the breeding site frequently found positive for *A. aegypti* larvae in Treichville, another neighbourhood of Abidjan city (Koné et al., 2013). The dominance of water storage containers and the permanent presence of *A. aegypti* found in this study, combined with the fact that this mosquito can take several blood meals during the same gonotrophic cycle (Trips & Hausermann, 1986), contribute to a high risk of dengue or yellow fever outbreaks.

Water storage containers were the most frequently positive breeding sites in all three neighbourhoods during the entire study period, except for the short rainy season during which, used tires were the most positive breeding site. Water storage containers are always partially or filled with water. The fact that they are filled with water independently of rainfall means that they are a preferred larval habitat at all times of the year, especially during the principal dry season (Tezzo et al., 2021). The high positivity of tires for *Aedes* larvae during the short rainy season could be explained by the constant impounding of peridomestic breeding sites such as tires during this period. However, in the principal rainy season, the large quantities of rain over several days cause the washing of mosquito breeding sites. Thus, during the short rainy season, the temperature, humidity and reduced light inside tires create an environment favourable to *Aedes* breeding (Tezzo et al., 2021). However, when tires are stored for a long time without being cleaned, *Aedes* larvae can proliferate (Sripugdee et al., 2010). *Aedes* eggs are able to resist desiccation and can remain attached to tires for a long time, so tires may play a role in maintaining the *Aedes* mosquito population throughout the dry season (Rao & George, 2010). The disproportionate importance of the main *Aedes* breeding sites over the different climatic seasons indicates the main larval habitats and times to target in vector control strategies to reduce the risk of arbovirus transmission. Vector control based on the treatment or elimination of breeding sites would therefore be necessary to undertake during the principal dry season; this would reduce the proportions of positive breeding sites observed during the principal rainy season. These vector control activities would also be essential during the short dry season to prevent the proliferation of positive breeding sites in the short rainy season.

The larval indices (HI, CI and BI) calculated during our surveys showed a significant difference between seasons and study sites. The highest values of these indices have been obtained during the two rainy seasons. This fact could be explained by the presence of water storage containers and other types of containers such as discarded containers and used tires that we found during the surveys. Indeed, the water storage containers, are constantly filled with water, in addition to tires and discarded containers whose impoundment and productivity depend on the rainfall distribution (Konan et al., 2013), meaning that *A. aegypti* is permanently present.

The Anoumabo neighbourhood represented the site with the highest values of larval indices. This finding could be related to the environment of this site. Indeed, Anoumabo is a neighbourhood, which has a favourable environment for mosquito production. The failure of the rainwater drainage system in this neighbourhood could create mosquito breeding sites. Also, the populations of this neighbourhood store water permanently for their daily needs. The water storage containers have been recognized as breeding sites for *Aedes* mosquitoes (Koné et al., 2013). Indeed, these authors have shown the proliferation of the *A. aegypti* mosquito is associated with the behaviour of the human population of Abidjan, which is the practice to store water for domestic activities or washing.

The estimated larval indices in the current study were all above the thresholds indicated by the WHO to alert for a high risk for transmission of dengue and yellow fever viruses as well as other arboviruses such as Zika and chikungunya. Nevertheless, we note that the correlation between high stegomyia indices and the occurrence of an arbovirus outbreak is not always clear. Some studies did not find a significant association (Focks, 2003; Sulaiman et al., 1996), while others reported that these indices are predictive of the risk of dengue virus transmission (Sanchez et al., 2006; Thammapalo et al., 2008). Thus, in line with the latest authors, we can say that there is a permanent high risk of transmission of arboviruses at any time of the year in the city of Abidjan.

We conclude that sound prevention measures raising public awareness about vector breeding sites and their management as part of the overall control strategies are required.

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AUTHORS CONTRIBUTIONS

Conceptualization and Methodology, A.M. Adja, N. Guindo-Coulibaly and F. Fournet; Software and Cartography, N. Guindo-Coulibaly and K.R.M. Azongnibo; Validation, F. Fournet, A.M. Adja and N. Guindo-Coulibaly; Formal analysis, F. Fournet, A.M. Adja. and N. Guindo-Coulibaly; Investigation, N. Guindo-Coulibaly, M.D.S. Kpan, A.M.N. Kouadio, K.F. Assouho, D.D. Zoh and K.R.M. Azongnibo; Writing-Original Draft Preparation, N. Guindo-Coulibaly; Writing-Review and Editing, F. Fournet, A.M. Adja, R. Franck, N. Guindo-Coulibaly and M.D.S. Kpan; Supervision, A.M. Adja; Project Administration, A.M. Adja; Funding acquisition, A.M. Adja; All authors have read and agreed to the published version of the article.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data on the Culicidian fauna harvested are available. Data on the prospected breeding sites are available. Data on stegomyian indices are available.

ORCID

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