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Hotspots of *Aedes aegypti* (Diptera: Culicidae) larvae in Abidjan, Southern Côte d'Ivoire

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Abstract
During the last 10 years, Abidjan District has been a focus of dengue and yellow fever epidemics. To better control the vectors, identification of urban areas having the highest density of *Aedes* mosquitoes is essential.
Geographical coordinates of larval habitats sampled within the ten municipalities of Abidjan allowed geostatistical analysis to build an ordinary kriging. Larva were classified at genus levels, counted, and reared until adult emergence for species identification.
A total of 37,158 mosquito larvae from the ten municipalities were collected and identified to genus. *Aedes aegypti* was the most widely distributed species, being found in 60 to 80% of habitats such as rubbish dumps, banana plants and unused tires. A high larval density (more than 100 *Ae. aegypti* larvae/liter) was predicted in Abidjan except the South-West of Abobo and Adjamé. Moreover, high larval densities of 234-350 *Ae. aegypti* larvae/liter were predicted in Cocody.
A very strong spatial heterogeneity was observed for *Ae. aegypti* in Abidjan City. The ease of international travel in high-standing municipalities and the presence of vulnerable communities in poor municipalities could increase the risk of epidemic emergence.

Keywords: hotspots, *Aedes aegypti*, dengue fever, geostatistical prediction, Abidjan

1. Introduction

Environmental disturbance characterized by climate change, uncontrolled urbanization and human activities contributes to create ecological changes with having substantial impact on vectors biology causing emergence of several vector-borne diseases such as yellow fever, malaria and dengue [1, 2]. Dengue is an arbovirus transmitted mainly by Aedes female mosquitoes. These vectors are also responsible for the transmission of chikungunya, yellow fever and Zika viruses [3, 4]. People at risk to dengue infection has been estimated to 3.9 billion living in 129 countries [5]. Symptoms from dengue fever has non-specific (fever, joint pain) which in many cases leads to misdiagnosis since the application of the biological diagnosis is limited to healthcare point [6]. No treatment exist so far and the management of symptoms are the best option for patient with good immune system to fight the virus [4]. In Côte d'Ivoire, confirmed cases of dengue fever were notified for the first time in April 2017. Two fatal cases out of 623 suspected cases have been identified. Most infections were due to serotype 2 (66%). In Abidjan, the capital of the country, 78% of cases confirmed were identified in Cocody-Bingerville health districts [5]. The main risk factors identified is the high density of mosquito breeding sites, especially during the rainy season [7]. Moreover, infected migrants are involved in local transmission [8] when susceptible vectors are present. In Africa, Dengue fever is mainly transmitted by *Aedes Aegypti* [9] which was found in Côte d'Ivoire [10,11]. For a better control of the vectors, it is crucial to concentrate implementation of interventions in high-risk areas demonstrated to be areas of high population density of the vector, named as hotspots of dengue vector. Thus, the aim of this study is to map hotspots areas of dengue vector in Abidjan where vector control interventions will be implemented in order to prevent outbreaks of dengue fever in Abidjan the epicenter of most dengue outbreaks.

2. Materials and Methods

2.1. Study area

The study was carried out in the city of Abidjan southern Côte d'Ivoire. The area covers 57,735 ha and located between 5°20’11” latitude North and 4°01’36” longitude West. Abidjan area is around 750 km² with 4,395,243 inhabitants representing 42% of the total urban population in Côte d'Ivoire [12]. Composed on 10 municipalities, Abidjan is divided into two parts such as Abidjan North (Abobo, Attécoubé Yopougon, Adjamé, Plateau, Cocody) and Abidjan south (Koumassi, Marcory, Treichville, Port-Bouet) (Figure 1).

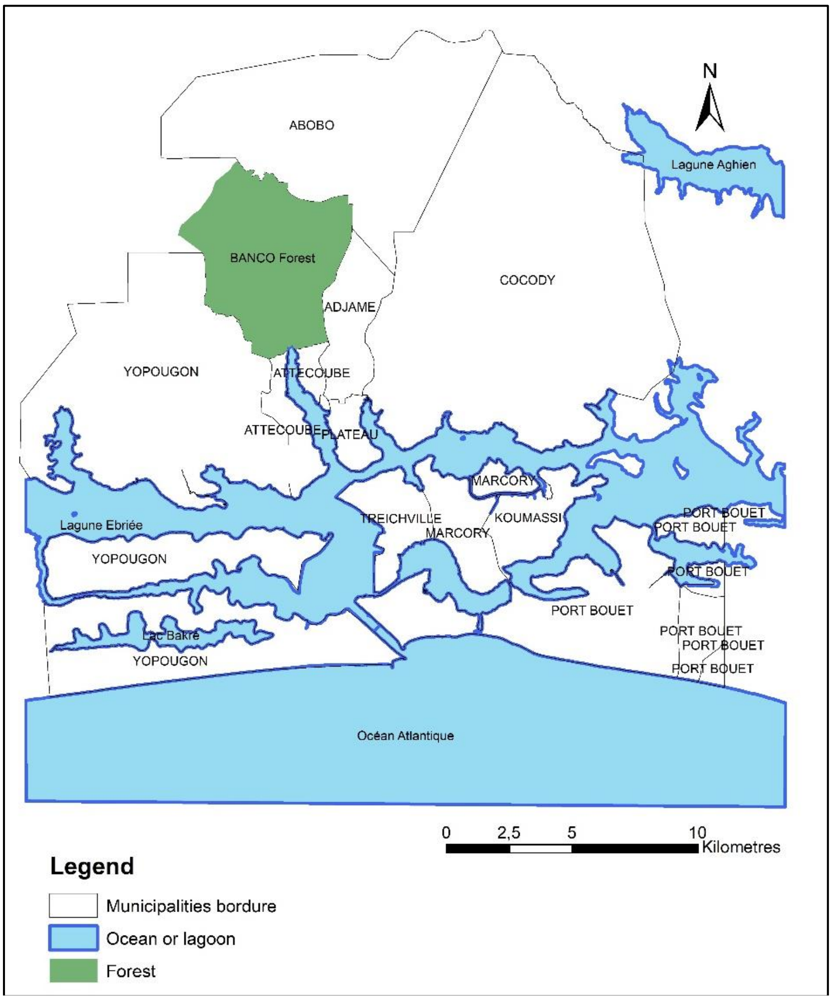


Fig 1: Study Area showing the 10 municipalities in Abidjan

The climate is subequatorial, hot and humid, which includes a long rainy season (May-June-July), a short rainy season (September-November) and two dry seasons (long dry season December-March), with a very variable duration the recent years. Rainfall is relatively abundant with an average of 1,500 mm per year. A mean temperature is around 27 °C and the average annual humidity is more than 80%. The choice of Abidjan is due to the fact that this city have experienced several outbreaks of dengue since years [13, 14].

2.2. Breeding sites prospection and identification of Aedes larvae

From one municipality to another, larvae were gradually and continuously collected using dipping method every month over 4 months (from May to August 2017). All sites and places around dwellings, likely to contain water, were inspected for larvae collection. Indeed, using 500 ml aluminum ladles, the larvae and pupae are drawn from the water and put in the containers. The larvae that had been collected were sieved using different sieves in other plastic containers to separate the waste from the larvae. Once the sieving phase was completed, the larvae and pupae were transferred to plastic drums and brought to the entomology laboratory of our university in Abidjan. When the breeding sites water was insufficient to contain a dipper, a pipette was used to collect larvae. Larvae were counted, and the amount of water measured based on the dipper volume. This allowed calculate the larval density. Moreover, geographical coordinates of each breeding sites have been recorded in Universal Transverse Mercator (UTM) unit using a GPS device. Larvae have been sorted and classified into genus based on the positions onto water surface. Larvae were kept alive until the adult emergence then adult were morphologically identified as *Aedes aegypti* or other Aedes species using binocular magnifier.

2.3. Mapping of hotspot and kriging by geostatistical analysis

The spatial distribution of *Ae. aegypti* larvae was performed using the Geostatistical Analyst extension of Arcmap 10.2.1 software and UTM coordinate. Geographical coordinates sampling from various locations in the study sites (municipalities) allowed geostatistical analysis to build an ordinary kriging. Ordinary kriging is one of the classic kriging techniques used. The prediction of the value $Z^*(x_0)$ corresponding to the linear sum of the known measured values (i.e. the observed values) makes it possible to make a spatial prediction of the unmeasured point x_0, based on the following equation:

$Z^*(x_0) = \sum_{i=1}^{n} \lambda_i Z(x_i)$ [15, 16]

where $Z^*(x_0)$ is the predicted value at the unmeasured position x_0, $Z(x_i)$ is the value measured at position x_i, λ_i is the weighting coefficient of the position measured at x_0 and n is the number of positions in the neighborhood search. The distribution of the input data allows a model to be fitted to describe the spatial continuity of the data and show the spatial relationship between pairs of points.

The stable model predicted the presence or density of larvae in unsampled areas without the addition of anisotropy. This procedure allowed estimating the values of unsampled areas, based on data values observed in areas sampled [17–21]. Data on the number of *Aedes aegypti* larvae collected (confirmed after adult emergence) and the measurement of the volumes of water from breeding sites made possible to model and estimate the larval densities by neighborhoods. A map representing the densities of *Aedes aegypti* larvae in the urban area of Abidjan has been produced as well as the standard error map associated. Six classes have been defined with geometric interval.

3. Results

3.1. An overview on breeding sites and larvae collected

Overall, 1,524 water collection points identified as breeding sites were prospected in the city of Abidjan. A total of 242 out of 1,524 sites harbored larvae or pupae. *Aedes aegypti* deposits was the most widely distributed with an average of 60 to 80% of prospected deposits. The more concentrated breeding sites were found in the municipalities of Yopougon, Koumassi, Treichville and Port-Bouet (Figure 2).

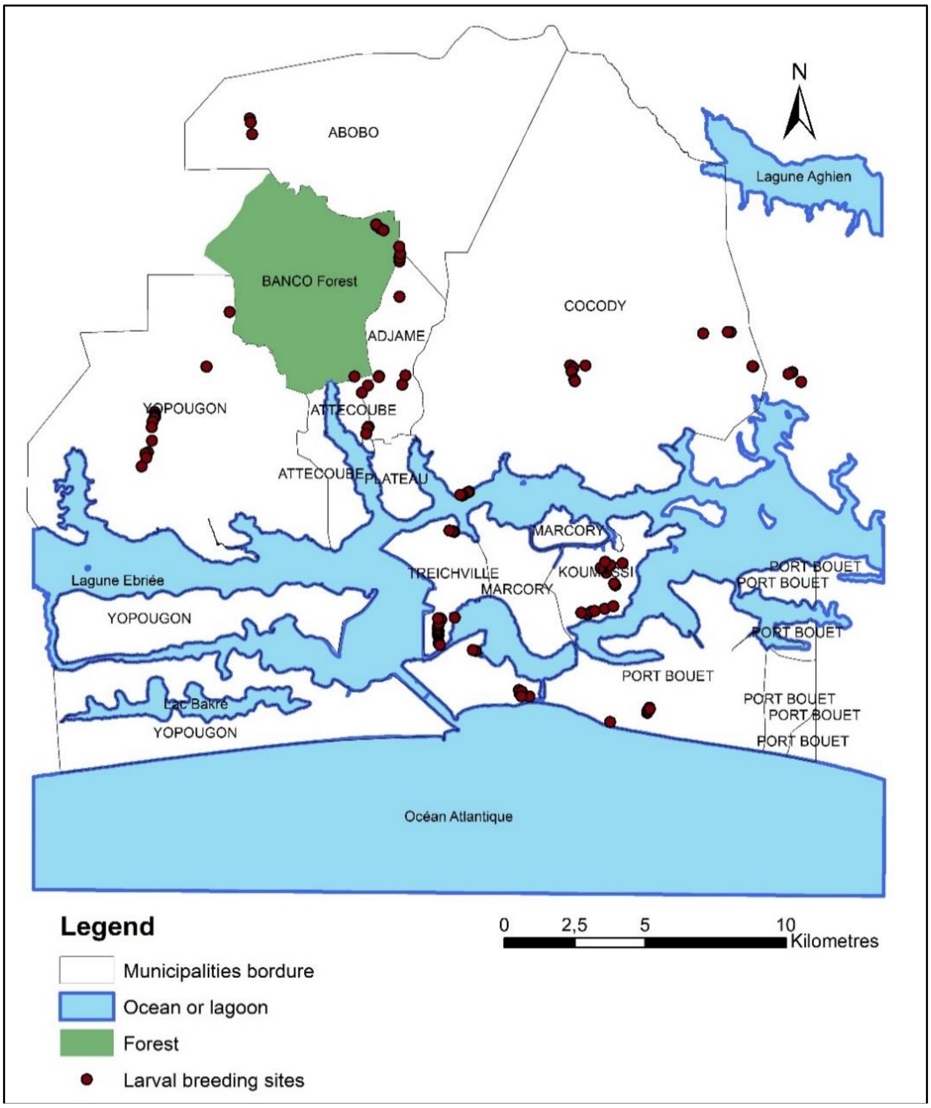


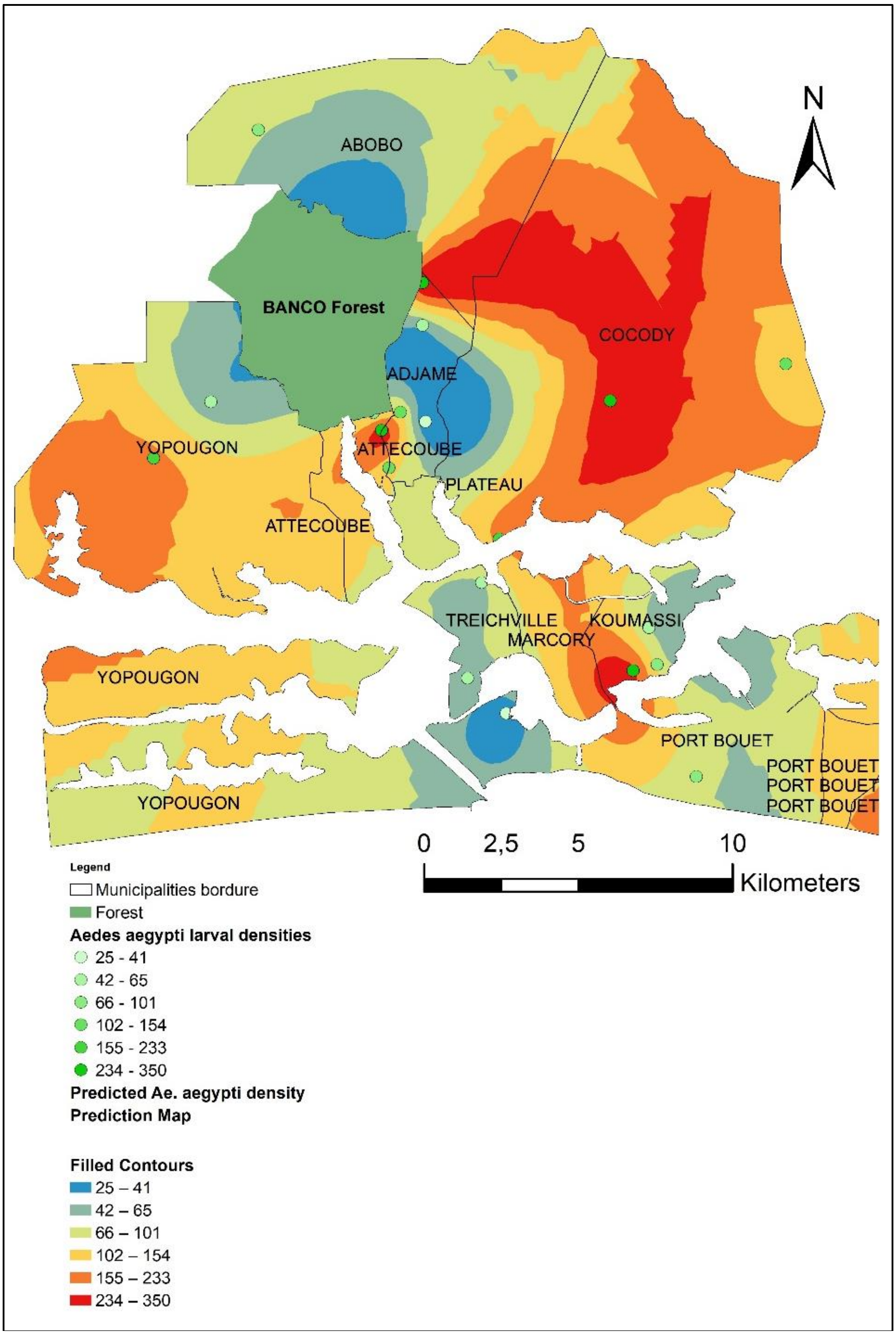
Fig 2: Spatial distribution of mosquito breeding sites in Abidjan

The genus Aedes was collected in plastic covers (n = 1, 0.4%), disposable cup (n = 1, 0.4%), container (n = 2, 0.8%), electric pole (n = 4, 1.6%), tire (n = 243, 96.8%). In these breeding sites, 90% (n = 35,062) of *Aedes aegypti* larvae were collected against 7% (n = 2,858) of Anopheles larvae and 3% (n = 1,004) of *Culex* larvae. The percentage of breeding sites between municipalities ranged from 7 to 15%.

3.2. Spatial distribution predicted of larval density

Larval density was lowest in Adjamé with 54.5 larvae/liter, especially around the Gare-Nord (112 larvae/liter). Port-Bouët and Treichville have 57 and 58 larvae/liter, respectively. Abobo had a density of 94 larvae/liter while Attécoubé, Cocody, Koumassi and Yopougon had more than 100 larvae/liter (Figure 3).

A high larval density of *Aedes aegypti* of more than 100 larvae/liter has been predicted everywhere in the city of Abidjan except the South-West of Abobo and Adjamé near Banco National park. The high larval densities of *Aedes aegypti* (234-350 larvae/liter) were predicted in Cocody in a concave-shaped corridor going from South to West. In addition, a high concentration of larvae has been predicted in South-East of Abobo, in the corner border of Cocody and Adjamé municipalities. The southern lagoon portion of Koumassi has a predicted larval density similar to the one of the Center of Cocody. However, a larval density between 102 and 233 larvae/liter was predicted over a large area of Cocody except the western border where the densities were between 25 and 100 larvae/liter (Figure 3).



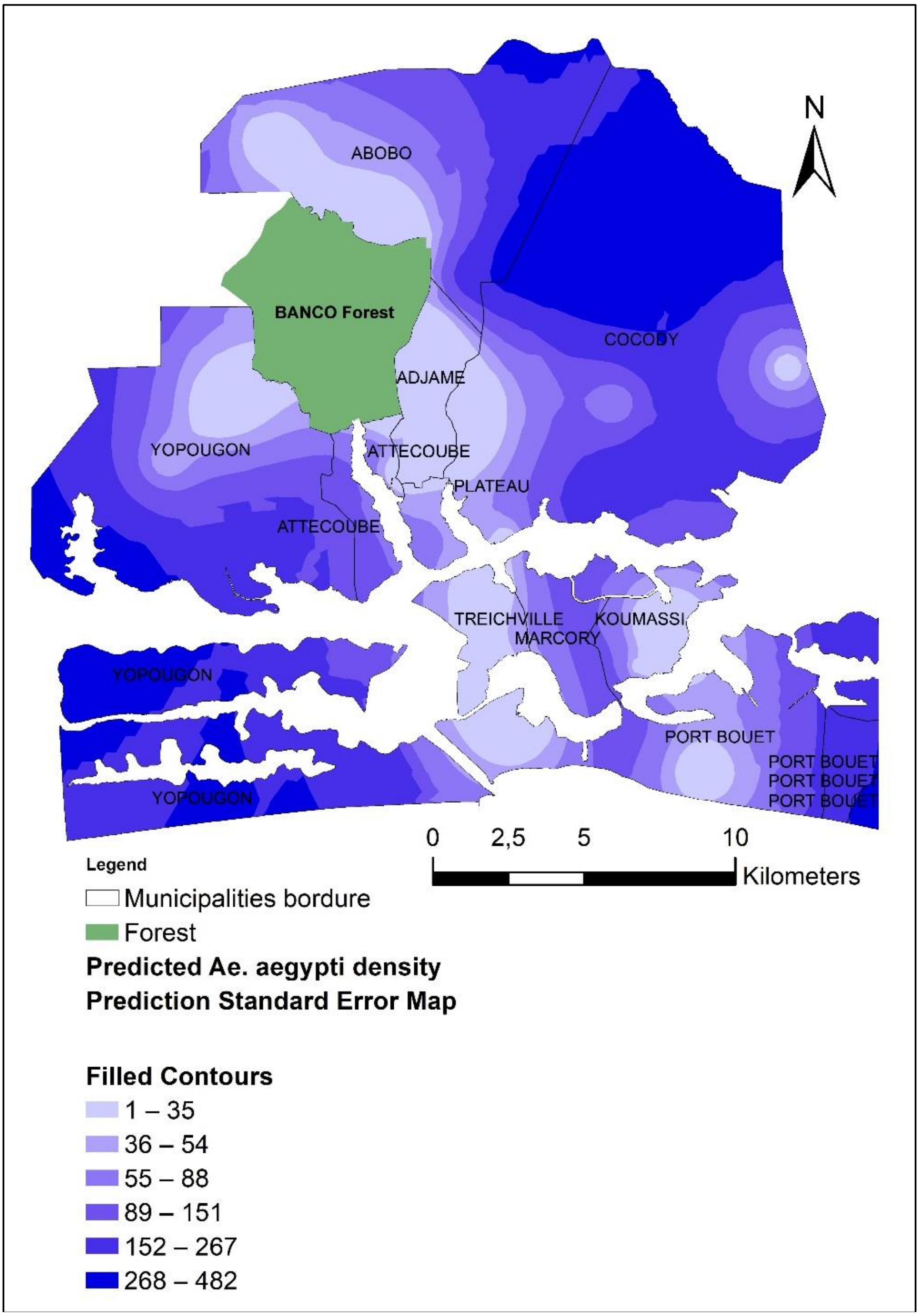


Fig 3: Hotspot of *Aedes aegypti* larval densities in Abidjan district. a. Density prediction map, b. Standard error associated to density prediction

4. Discussion

This study highlighted a potential hotspot of larval densities of *Aedes Aegypti* in 10 municipalities of the city of Abidjan in order to focus vector control interventions in areas more at risk of dengue fever. It appears that the highest *Aedes* larval densities have been found in areas with 80% of productive breeding sites. These results could be explained by the presence of many adult mosquitoes and the availability of cottages in these neighborhoods. Indeed, in Abobo, several unsanitary places with blocked wastewater delivery points were identified. This favors the establishment of small/large water collections due to the difficulty in draining rainwater and bad sanitations. In Cocody, inhabitants unconsciously create small collection of water in flowerpots of gardens which becomes breeding sites favorable to the development of mosquitoes. In general, temporary water points are widespread in municipalities where drinking water delivery is difficult and scare. Indeed, people collect water in barrels poorly covered all the time which then facilitate access to mosquitoes. In addition, larvae from *Aedes* genus were abundant in prospecting areas teeming garages with plenty of abandoned tires and roadside lodges, because of the presence of their preferred oviposition lodges. The abundance of *Aedes* larvae compared to other genera could be explained by the larval coexistence under conditions of food shortage (0.95 mg / larva) favorable to a greater emergence of *Ae. aegypti* adult compared to *Culex quinquefasciatus* and was able to deprive *Cx. quinquefasciatus* of food needed to complete its metamorphosis [22]. For an intermediate dose of food (1.9 mg/larva), the dry weight of adults of *Cx. quinquefasciatus* decreases, and their larval development time increases when the ratio of *Cx. quinquefasciatus* / *Ae. aegypti* was low [22]. Furthermore, there are more and more breeding sites qualified as atypical because hosting several genera of mosquito [2]. Indeed, it has been found that some tyres are full of larvae of the genus *Aedes*, sometimes they are full of *Anopheles* or Culex genus. Despite this, the proportion of *Aedes* genus remains higher in these breeding sites (tyres) because of their natural adaptation, strong resilience and the resistance of eggs to desiccation [23, 24]. However, the density of *Anopheles* and *Culex* larvae remains high in some municipalities and could contribute to sustain the persistence of malaria or lymphatic filariasis in most of the poor neighborhoods characterized by poor management of water flow or obstruction of the gutters favoring an increase of *Culex* breeding sites (more sensitive to unsanitary places and polluted waters). Some studies found *Anopheles gambiae* to be adapted to polluted waters [25], though plenty rice shallows or vegetable farms favorable to *Anopheles* genus development [26] and not targeted in this study were identified in our study site.

5. Conclusion

The risk of the emergence of arbovirus diseases such as Dengue fever is increasing in many sub-Saharan Africa countries such as Cote d'Ivoire. As the health system of the country is fragile, it would be important to conduct regularly similar study in order to anticipate future outbreak and in case any focus the interventions in areas highly populated by Dengue vectors such as Aedes mosquito. In Côte d'Ivoire, Abidjan being the home of most of the outbreaks of dengue fever during the past 10 years, vector control interventions should prioritize hotspot areas characterized by a difficult access to water, poor sanitation and hygiene conditions where previous dengue outbreak started.

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