International Journal of Entomology Research
ISSN: 2455-4758; Impact Factor: RJIF 5.24
Received: 14-11-2018; Accepted: 17-12-2018
www.entomologyjournals.com
Volume 4; Issue 1; January 2019; Page No. 26-31

Diversity and abundance of mosquitoes in the city of Ouagadougou, Burkina Faso

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Abstract

Countries in West Africa are subject to emerging mosquito-borne diseases like dengue fever, West Nile virus infection. This could be the result of sanitation issues due to the rapid growth of population in some cities. Since four years, the capital city of Burkina Faso is experiencing dengue epidemic without reliable data. For a better understanding of mosquitoes population dynamic in the city, this study was undertaken in order to provide subsequent information on mosquitoes diversity and density. Three districts were surveyed for mosquitoes sampling according to the level of urbanization to take into consideration the city heterogeneity. In each district, adult mosquitoes and larva were collected in rainy and dry seasons in different habitats to monitor mosquitoes population. Collected mosquitoes were identified and sorted by genus and species. Four (04) genera of mosquitoes identified as *Culex* (71.9%), *Aedes* (22.2%), *Anopheles* (5.7%) and *Mansonia* (0.2%) were recorded in this study. Out of these four genera, eight (08) mosquitoes species were recorded: *Culex quinquefasciatus, Culex decens, Culex cinereus, Aedes aegypti, Anopheles gambiae s.l, Anopheles funestus, Mansonia africana and Mansonia uniformis.* The diversity was found to be seasonal dependant with some species being observed at specific time point. Mosquitoes spatial relative abundance show that *Culex quinquefasciatus* is the most abundant mosquitoes species independently to location. Some species like *Anopheles gambiae s.l.* and *Aedes aegypti* were predominant at Yamtenga and Zongo respectively. These data suggest a potential map of the risk of mosquito-borne disease emergence in the city for a better control strategies.

Keywords: mosquito-borne diseases, diversity, urban, Burkina Faso

1. Introduction

Mosquitoes are known as the most important disease vectors in the world because of their ability to carry various pathogenic agents such as viruses, protozoa and helminthes. The breeding ecology of the species vary considerably in different localities, thus significantly influencing mosquito-borne disease transmission in such areas [1, 2]. There are several other characteristics of mosquito species that contribute to their success in new habitats. For example; rapid growth, short lifespan, high fecundity, the ability to utilize a broad range of habitats, association with human activity and fewer natural enemies are several factors that will determine their likelihood of establishment [3].

Today, human activities are the main causes of ecosystem disturbance driving species towards adaptation, or extinction [4]. Man-made environmental modifications have been suspected to be at the origin of the diversification and radiation of the major human malaria vector, the mosquito *Anopheles gambiae* through the creation of new ecological niches in marginal habitats [1, 5]. The spread of new agricultural practices combined with deforestation and creation of water reserves has been hypothesized to be the original environmental change prompting ecological niche specialization within *Anopheles gambiae* through divergent selection in these new habitats [6]. It was also shown that the land use changes such as deforestation, agricultural development, water control systems, urbanization are likely to vary vectors dispersal abilities, From the point of view of agricultural practices, we also know that some users crops with insecticides can encourage the emergence of resistance to insecticides [7, 8] that can promote the survival of vectors and increasing their densities.

Once saved by land degradation phenomenon because of the abundance of arable land, the regions of Burkina Faso are now subject to an environmental crisis. Internal migration of populations of degraded areas to those in favor of agro-pastoral activities contribute to accelerating the degradation of these areas [9]. This change can lead to emerging and re-emerging diseases, especially zoonotic pathogens [10]). Because of the lack of reliable cure, vaccine or therapy, emerging diseases pathogens must be monitored to avoid public health disasters [11]. In Africa, particularly in Burkina Faso, though several studies have elucidated mosquito species composition and distribution in larval breeding habitats [12, 13]. However, the main part of these studies was done in rural area. Since, 2013, dengue epidemic occur frequently [14-17] and cause with malaria in the country a high morbidity. So, understanding vector species' distribution and dynamics in relation to their fluctuating environment is of paramount importance to better understand the epidemiology of the diseases these mosquitoes transmit and then better direct vector control strategies Here, we describe how the le level of urbanization modulate mosquitoes diversity and abundance in urban setting.

2. Material and Methods

2.1 Study area

The study was done in Ouagadougou (12° 21′ 58″ N and 1° 31′ 05″ W) the capital city of Burkina Faso. Located in the center of the country, the city harbored approximately 2 637 303 inhabitants in 2016 [18]. The city population have increased rapidly from 709,000 inhabitants in 1996 to 2,637,303 inhabitants in 2016 [18] concomitantly with spectacular spatial growth. In 2016, Ouagadougou extended over more than 219 km2, compared with an estimated 33 km2 after the independence in 1960. The sprawling of Ouagadougou has created patches of urbanization which are different from each other in many of their characteristics. The age of buildings, their density, parceling and planning, the building style, the building materials, vegetation, access of the inhabitants to sanitation infrastructure and services, socio-economic condition of the inhabitants and land-use are all socio-ecological parameters which vary between different areas of the city [19]. Indeed Ouagadougou city is characterized by. structured areas were areas allotted by the township authority with public services, such as tap water and sanitation and where parcels of land were allocated to specific inhabitants. Unstructured areas referred to areas that developed without cadastral organization and without public services.

The city is subject to a tropical savannah climate, including two mains seasons: the dry season and the rainy season. The annual rainfall is 750 to 900 mm. The rainy season is between June and October, and the dry season consists in two parts: a cold and dry season is between November and January, and the hot and dry season is between February and May.

The study was conducted in three districts: Dapoya, Yamtenga, Zongo. These districts were selected using a geographical approach that took into account the city heterogeneity [20]. This approach was based on the analysis on the level of urbanization [19, 20]. Indeed, Dapoya is an old urbanized and densely populated district, characterized by close-together houses with numerous households. Yamtenga and Zongo are peripheral connecting to the town eastern and western part respectively. Yamtenga is characterized by condensed precarious houses built with local materials. However in Zongo houses are disperse

2.2 Sampling design

On each site, 10 concessions were randomly selected and monitored for the collection of adult mosquitoes and larvae. Each selected concession was visited three times according to the seasons; representing a visit to hot dry season, a visit during the rainy season and another in cold dry season. During these visits, two consecutive days of adult mosquitoes collection were done indoor and outdoor. Breeding sites composed of different types of water bodies found near the concessions were prospect for larvae sampling.

2.3 Mosquitoes sampling and laboratory processing

For adult mosquitoes collection, both traditional and modern houses were sampled for mosquito collection in each study site. CDC light traps and aspirator catch were used to catch adult's mosquitoes in each study. Indoor resting females were also caught by an aspirator in daytime while CDC light trap was used to sample mosquitoes by night. Outdoor resting mosquitoes sampling, some microhabitants outside and near the sampled houses were visited and mosquitoes caught aspirator. All mosquitoes were transported in laboratory, knocked-down in freezer and conserved at -20°C for identification

For larvae, different microhabitats consisted in pundles, jars, used tires and other containers were visited. Approximately 500ml of water containing larvae were taken by breeding sites prospected and brought back to the laboratory for screening and breeding of mosquito larvae. For dams the dipper method were used for sampling. Different habitat types were surveyed to enroll a various mosquito. On the sampling site, predators were eliminated prior to conditioning and transportation of larvae to the laboratory. Larvae were reared in forage water in insectary until adult and killed in freezer for identification.

Collected adult mosquitoes including both CDC, aspirator catches and also insectary-emerged adults were identified using standard morphological identification keys.

2.4 Data analysis

For data analysis, Rstudio version 2.12.2, and SPSS version 21 software were used to generate the graphs and perform the statistical tests. The chi-square test and the Kruskal-Walis test were used to compare mosquitoes relative abundance and density according to location and season with a threshold of significance α = 5%. In addition, the diversity of mosquito populations collected was evaluated using the Shannon index of diversity and Pielou index of equitability.

3. Results

3.1 Study area characterization

Climatic data from the study sites have shown that the relative humidity is lower in Yamtenga than in the other two zones while the temperature is higher in this zone than compared to Zongo and Dapoya (Figure 1). However, precipitation were quite same in the three area. When looking at houses structure, we noticed that peri-urban districts (Zongo and Yamtenga) harbored mainly traditional/mixed houses (75.9% and 81.6% respectively). At Dapoya, a central area, houses were mainly modern (59.2).

In term of mosquitoes breeding sites, artificial containers were found to be for productive with majority being mud pots, 31 (35.23%) followed by puddles, 19 (21.59%) plastic drums, 17 (19.32%), metal dish/Box, 12 (13.64) and tires, 9 (10.23%). While in Dapoya, we did not found larvae in puddles, this kind of breeding site was the most productive in Yamtenga.

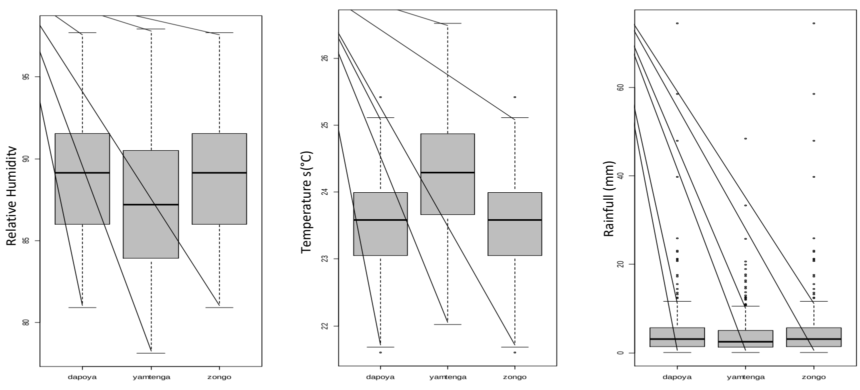


Fig 1: Characterization of the sampling sites

3.2 Seasonal variation of mosquito populations diversity and abundance

Four (04) genera of mosquitoes identified as Culex (71.9%), Aedes (22.2%), Anopheles (5.7%) and Mansonia (0.2%) were recorded in this study. This large proportion of Culex mosquitoes mainly come from adult collection. The specific composition of mosquitoes population vary according to the stage of development. While in adult mosquitoes Culex were the most prevalent, Aedes were the main part of larvae population. Out of these four genera, eight (08) mosquitoes species were recorded: Culex quinquefasciatus, Culex decens Culex cinereus Aedes aegypti, Anopheles gambiae s.l, Anopheles funestus, Mansonia africana and Mansonia uniformis. The diversity was found to be seasonal dependant with some species being observed at specific time point (Figure 2). For example, three of the encountered mosquitoes species, namely Anopheles funestus, Mansonia africana and Mansonia uniformis, were exclusively found in the rainy season, while Culex. cinereus was only encountered during the hot dry season. Anopheles gambiae s.l., Aedes aegypti, Culex quinquefasciatus and Culex decens are found in all seasons.

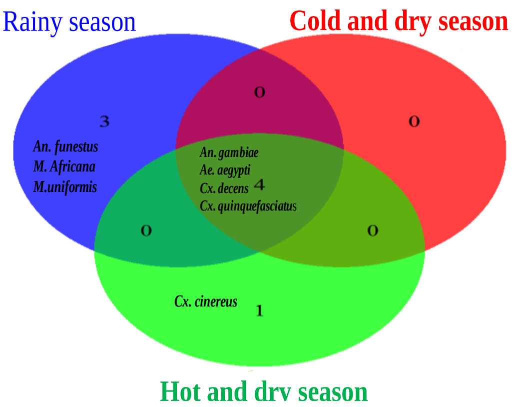


Fig 2: Mosquitoes diversity according to season An: Anopheles, Ae: Aedes, Cx: Culex, M: Mansonia

So, the species richness was high during the rainy season with seven species while in the cold dry season it passes to four species. This high diversity in rainy season was confirmed by diversity index. As state, the Shannon diversity index (H) was 0.9543 in the rainy season while in the cold dry season it was 0.047. As for the Pielou equitability index, it was high in the rainy season (J = 0.4904); while in the cold dry season (it was, J = 0,0339).

Furthermore, recorded species relative abundance was different across season (Table 1). *Culex quinquefasciatus* was abundant in each season, while *Aedes aegypti* and *Anopheles gambiae s.l.* mainly occurred in rainy season.

Table 1: Mosquitoes relative abundance variation across season

Species Name	Rainy season n=5942	Cold dry season n=3846	Hot dry season n=370	Overall year n=10158
Aedes aegypti	37.61%	0.10%	3.24%	22.16%
Culex quinquefasciatus	52.69%	99.32%	92.70%	71.81%
Culex descens	0.02%	0.18%	0.27%	0.09%
Culex cinereus	0.00%	0.00%	0.27%	0.01%
Anopheles gambiae s.l.	9.24%	0.39%	3.51%	5.68%
Anopheles funestus	0.08%	0.00%	0.00%	0.05%
Mansonia africana	0.34%	0.00%	0.00%	0.20%
Mansonia uniformis	0.02%	0.00%	0.00%	0.01%

n= total number of mosquitoes

3.3 Mosquitoes diversity and abundance across different settings

A total of 10,158 mosquitoes including 74% adults and 26% larvae were collected. Mosquitoes occurred mainly in Dapoya (47.1, n=4780) followed by Zongo (37, 5%, n=3807) and Yamtenga (15, 5%, n=1571). For larvae population, the occurrence was quite higher in Zongo (65.8%, n=1712) compared to the other sites (24,9%, n=647 and 9,4% n=244; respectively for Dapoya and Yamtenga). In adult mosquitoes, we noticed that the resting behavior of mosquitoes did not differ significantly (X-squared test, p-value = 0.55) with 81.6%, 73.3%, 74.1% being the indoor resting mosquitoes at Dapoya, Yamtenga and Zongo respectively.

For species diversity, some taxa were recorded in all three localities while some were specific to the district. Mainly, *Aopheles gambiae s.l., Aedes aegypti, Culex quinquefasciatus*, *Culex decens* and *Mansonia africana* were sampled in the three district (Figure 3). *Mansonia uniformis* and *Culex cinereus* were only found in Dapoya and Yamtenga respectively. Species like *Anopheles funestus* was present in Zongo and Yamtenga.

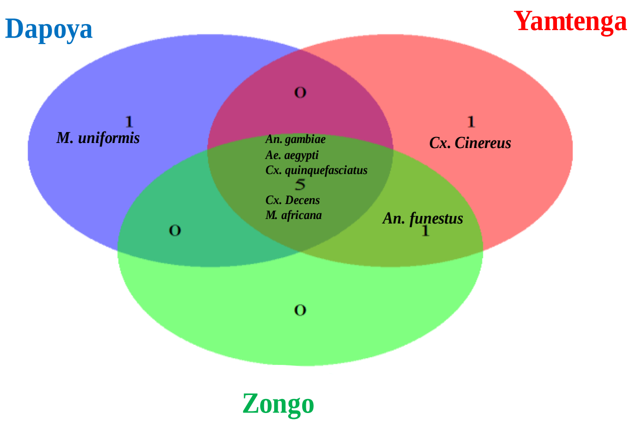


Fig 3: Mosquitoes diversity according to location An: Anopheles, Ae: Aedes, Cx: Culex, M: Mansonia

The greatest species richness was found in Yamtenga with seven species encountered; whereas, Dapoya and Zongo had six species. The Shannon diversity index was high in Zongo (0.7909) and Yamtenga (0.7274) but low in Dapoya (0.5263). The equitability index, was 0.4414 in Zongo, 0.3738 in Yamtenga and 0.2938 in Dapoya.

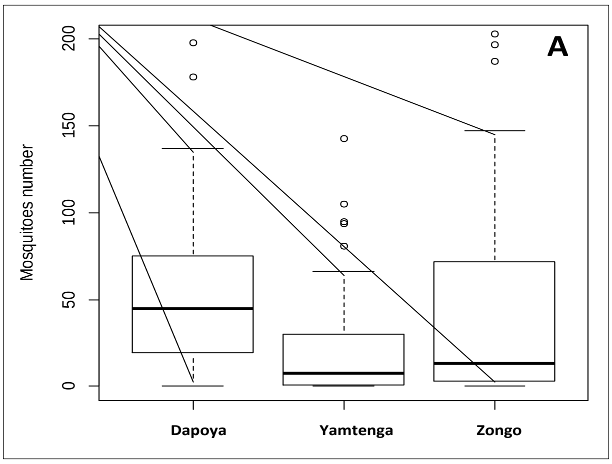
Mosquitoes spatial relative abundance given in Table 2 show that *Culex quinquefasciatus* is the most abundant mosquitoes species independently to location. Some species like *Anopheles gambiae s.l.* and *Aedes aegypti* were predominant at Yamtenga and Zongo respectively. The other species were found in small amount depending to the location.

Table 2: Spatial variation of mosquitos' relative abundance

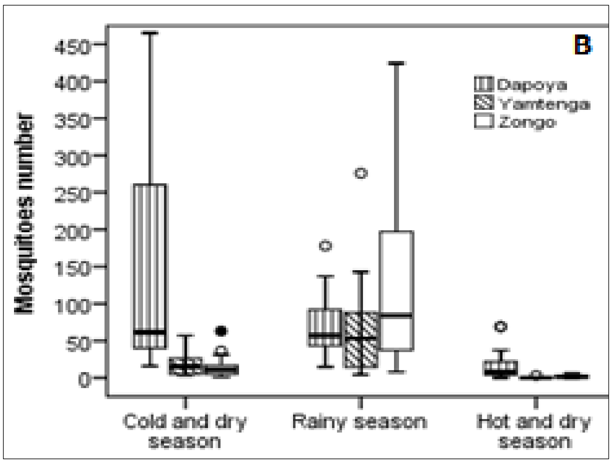
Species Names	Dapoya n=4780	Yamtenga n=1571	Zongo n=3807	All localities n=10158
Aedes aegypti	13.64%	3.18%	40.69%	22.16%
Culex quinquefasciatus	83.91%	71.87%	56.58%	71.81%
Culex descens	0.15%	0.06%	0.03%	0.09%
Culex cinereus	0.00%	0.06%	0.00%	0.01%
Anopheles gambiae	1.92%	24.44%	2.65%	5.67%
Anopheles funestus	0.00%	0.25%	0.03%	0.05%
Mansonia africana	0.36%	0.13%	0.03%	0.20%
Mansonia uniformis	0.02%	0.00%	0.00%	0.01%

When looking at mosquitoes densities (Figure 4A), Dapoya show the highest number of mosquitoes per sampling site with a median value of 45 mosquitoes/site, with an InterQuartile Range (IQR) = 21-75; Kruskal-Wallis chi-squared test, p-value = 0.00003). Yamtenga presented the lowest density (7.5, IQR: 0.75 -28). However, by taking into account mosquito's seasonal variation, different trends were observed for mosquitoes densities (Figure 4B). At the rainy season, the median value of mosquitoes per site was quite the same in the three districts with respectively 57.0 (IQR: 43.0-88.0); 53.0 (IQR: 14.5-87.5), 84.0 (IQR: 37.0-187.0) for Dapoya, Yamtenga, and Zongo (p-value = 0.22). Whereas in dry season, mosquitoes were abundant at Dapoya with the median value in cold-dry season being 61.5 (IQR: 43.0-229.5; p-value = 2.9e-6) in hot dry season 8.0 (IQR: 4.5- 22.0; p-value = 1.6e-7).

In addition, the study noticed that adult mosquitoes indoor density was significantly high in Dapoya 4.5 (range 1.0-690.0; p-value = 0.0087) compared to Zongo 2.0 (range 0.0-62.0) and Yamtenga 1.0 (range 0.0-38.0). For outdoor adult collection, any significant difference was observed (p-value = 0.2). Similarly, at larvae stage, Dapoya presented the highest density (16.0, IQR: 8.5-40.0, p-value = 0.01) followed by Zongo (13.0; IQR: 5.0-35.0), the lower value being found at Yamtenga (3.0, IQR: 1.0-17.0).



A: median number from the overall data;



B: seasonal trend of density variation per district

Fig 4: Mosquitoes densities variation per district.

4. Discussion

Four genera of mosquitoes (*Anopheles*, *Aedes*, *Culex* and *Mansonia*) were encountered in this study. These genera were composed of eight species (*Anopheles gambiae s.l.*, *Anopheles funestus, Aedes aegypti, Culex quinquefasciatus, Culex cinereus, Culex decens, Mansonia africana* and *Mansonia uniformis*. These results highlight the potential risk of vector-borne diseases in the city of Ouagadougou. Indeed, each of these groups is involved in pathologies such as malaria, dengue, filariasis. Recent outbreaks of dengue fever in the city [14-16] are some examples of this potential risk. More, the study has highlighted, the specific colonization of some areas by mosquitoes and that depending on the season. The high presence and abundance of *Culex quinquefasciatus* in Dapoya could be explained by the urban status of this area, which offers favorable conditions for the development of this mosquito species. Indeed, the lack of rainwater drainage system and the poor quality waste management in household can lead to many breeding sites with polluted water. In fact, the larval sites encountered in this setting were mainly domestic containers, most often containing polluted water from households, and therefore very rich in organic matter suitable for the development of urban mosquitoes such as *Culex quinquefasciatus*. This mosquito was abundant the all year, being the main species collected in dry season. These results are also consistent with those of several authors [21, 22]. These authors have shown that *Culex quinquefasciatus* is more common in urban areas and this species is also considered to be the most dominant species in almost all cities in West Africa [23].

Aedes aegypti were mainly found in Zongo during the rainy season. The majority of breeding sites in this district were domestic containers such as mud, tires and plastic containers. The nature of the of larval breeding sites found in this locality can explained this occurrence. Indeed, *Aedes* are known to reproduce in small containers like old tires, plastic bag, dishes as reported by many authors [24-26]. These water sources are found mainly in rainy season when solid wastes are not adequately managed.

In contrast with the two other district, Yamtenga harbored puddles and temporary ponds in the rainy season. This picture of breeding sites lead to the abundance *Anopheles gambiae s.l.* in this locality. According to some authors, *Anopheles* larvae grow in relatively clean waters, unlike *Culex quinquefasciatus* larvae, which can develop in waters contaminated with organic matter. It has been reported that underground water could support puddles and created a permanent breeding sites[27]. This situation could contribute to sustainable malaria transmission in urban setting. In addition, previous studies have shown that the presence of fish ponds, water tanks for the irrigation of market gardeners and rice fields could be a source of proliferation of Anopheline, thus explaining the significant importance of malaria transmission. in peri-urban areas. However, the landscape modification changed the pattern of malaria transmission. Indeed, Anophelines were also found in Dapoya, a district that harbored more waste water and artificial breeding sites like dishes a type of habitat uncommon for *Anopheles* mosquitoes. This confirmed, the possible colonization of polluted water by Anophelines mosquitoes as reported by some authors[28, 29]. So, urban vector control strategic should look at how to limit artificial containers like metal and plastic dishes proliferation in urban setting. This result should be taken with caution when we look at increasing of the number of these artificial containers due to a defaulting management system of the solid wastes.

5. Conclusion

In total, four genera of mosquitoes, *Culex*, *Aedes*, *Anopheles*, *Mansonia* were collected during our study. These genera were composed of eight mosquitoes species with three species, *Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles gambiae s.l* being the most abundant. *Culex* was the most frequent and abundant mosquito genus reported in the city independently of season and location. Genus such as *Aedes* and *Anopheles* were predominant in Zongo and Yamtenga suggesting a possible map of the risk of these vectors borne diseases emergence. Finally, these results show that urban populations are exposed to the bites of various mosquito species and therefore to many vector-borne diseases. So there is a great need for a better mosquito control strategy in urban areas.

Competing interests

The authors declare that they have no competing interests.

6. Acknowledgment

The study was funded by The World Academy of Sciences (TWAS) Research Grants Programme in Basic Sciences (*Nº.:15-251 RG/BIO/AF/AC_I– FR3240287063*) to Dr Awa Gnémé. Authors are grateful to Pr Athanase Badolo and his lab for providing some materials for mosquitoes collection.

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