Unplanned Urbanization Promotes the Proliferation of Disease Vector Mosquitoes (*Diptera: Culicidae*)

T.B.C. Alavo*[,1], A.Z. Abagli[1], M. Accodji[1] and R. Djouaka[2]

[1]*Département de Zoologie et Génétique, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, 01 BP 526 Cotonou, Bénin*

[2]*International Institute of Tropical Agriculture (IITA), Benin*

Abstract: Malaria is a vector-borne disease transmitted by female *Anopheles* mosquitoes. These mosquitoes reproduce themselves in collections of natural or artificial water. To control them, chemical insecticides are intensively sprayed. This intensive use of chemicals has led to the development of resistance of mosquitoes to insecticides. As result, the control of mosquito is increasingly difficult. It is therefore important to look for other control methods against the malaria vector for the elaboration of an integrated mosquito management programme.

The aim of the present work is to assess the impact of urbanization on the proliferation of mosquitoes in Benin, West Africa. The entomological data are correlated with the three levels of urbanization that characterize the areas covered by the present study. The density of mosquitoes' larva according to the 3 levels of urbanization is determined and the mosquitoes' fauna and density in regard to the environment compared.

High amount of mosquitoe larval breeding sites are encountered in the non-urbanized districts (unplanned urbanization) whereas the urbanized districts contain no mosquito larval breeding sites at all. The majority of adult mosquitoes collected came from the districts where urbanization is anarchical or not well planned. These results have permitted to conclude that unplanned urbanization is a factor that favours the proliferation of mosquitoes. It is therefore suggested to consider well planned urbanization and cleaning up of unhealthy locations as an important part of mosquitoes control programmes.

Keywords: Unhealthy environment, Mosquitoes proliferation, Urbanization, Mosquito control.

1. INTRODUCTION

Malaria is one of the worse affections that make most of victims around the World. It affects approximately 500 million people in the world with 1.5 to 3 million deaths per year of which over 90% of deaths occur in Africa mainly to the most vulnerable people such as children [1, 2].

Malaria is a vector-borne disease transmitted by female mosquitoes named *Anopheles* mosquitoes. These mosquitoes reproduce themselves in collections of natural or artificial water. To control them, chemical insecticides such as organochlorines, organophosphates and synthetic pyrethroids are intensively used. This intensive use of chemical insecticides has led to the phenomenon of development of insecticide resistance in these mosquitoes. This resistance to insecticides concerns even the organochlorine DDT, however, known for its knock-out effect and its extreme persistence [3]. This makes mosquitoes' control increasingly difficult. Apart from the problem of resistance to insecticides, intensive use of chemicals has harmful effects on human health and environment. While the immediate effect of the toxicity of the products is generally low, the use of these chemicals may, in the long term, seriously affect public health, particularly with regard to women fertility (ability to achieve pregnancy) and cancer [4]. It is therefore essential to look actively for other alternative methods that permit the reduction of the use of chemicals.

According to Akogbéto [5], the dynamic of malaria transmission in Cotonou (Benin, West Africa) by anophelines varies from one ecological zone to another. Since the existence of larval breeding sites is linked to human activity in the environment, the intensity of transmission of vector-borne diseases is probably related to the environment.

The present work is aimed at assessing the impact of urbanization on the proliferation of malaria vector mosquitoes in Benin, West Africa. The entomological data are correlated with the three levels of urbanization that characterize the areas covered by the present study. The density of larval mosquito is determined according to 3 levels of urbanization and mosquito fauna and density in regard to the environment was compared.

2. MATERIALS AND METHODS

2.1. Study Areas

Six districts of the city of Cotonou, Benin (West Africa) were chosen. These districts have been classified into three categories according to their respective level of urbanization: the non-urbanized (unplanned urbanization) areas (Ladji and Towéta2), semi-urbanized areas (Jericho and Sènadé1) and the urbanized areas (Houéyiho1 and Cocotiers).

*Address correspondence to this author at the Département de Zoologie et Génétique, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, 01 BP 526 Cotonou, Bénin; Tel: +229-97875438;
E-mail: thieryalavo@hotmail.com

1874-4079/10

2.1.1. Ladji and Towéta2

These districts have not been divided into demarcated plots. They are lagoonal and rural districts without modern infrastructure. There are in these districts many wetlands and floodable locations. There is no plan of modern urbanization and houses are built anarchically using three types of materials: brick wall + roof with sheet metal, bamboo wall + roof with sheet metal, bamboo wall + straw roof. These districts are unhealthy and unfit for human accommodation. The majority of the people live in poor health and social conditions and are exposed to serious health dangers.

2.1.2. Sènadé1 and Jéricho

Houses in these two districts are built using brick wall + concrete roof, brick wall + roof with sheet metal, bamboo wall + roof with sheet metal. The districts have been divided and houses are built on well demarcated plots and the streets well laid-out although not well constructed. The rate of insalubrity in the two districts is less than that of Ladji and Towéta.

2.1.3. Houéyiho1 and Cocotiers

These two districts are located in downtown of the city of Cotonou. They have been divided up and houses are built on well demarcated plots. The streets are well laid out, constructed and clean. Houses are built here with two types of materials: Brick wall + concrete roof, brick wall + roof with sheet metal or tile. There is a total absence of insalubrity in these districts.

2.2. Data Collection

2.2.1. Identification of larval mosquitoes breeding sites and Determination of larval density

2.2.1.1. Identification of Larval Breeding Sites

In the semi-urbanized (Jericho and Sènadé1) and urbanized districts (Houéyiho1 and Cocotiers) we drove by car at a speed of 20 km per hour and wandered through the streets of the study areas in order to identify and record all breeding sites (permanent, semi permanent and temporary) encountered in the districts. In the non-urbanized districts (Ladji and Towéta2) where the streets are not suitable for car driving, 5 areas with a surface of 100m x 100m were selected in each of the two non-urbanized districts. The larvae of the mosquitoes species collected were thereafter identified.

2.2.1.2. Determination of Larval Densities in Mosquitoes Breeding Sites

The measuring of larval density took place following two different procedures. These procedures are described as follows:

Procedure 1

In case where the larval breeding site is very deep and wide, the measuring of larval density has been carried out as follows:

- The site was divided into 4 parts
- 10 samples were taken with ladle from each part
- The number of larva of each mosquito species present in these samples was counted
- The calculation of larva density was performed as follows:
- Total number of larvae of the species / N x volume of the ladle. N is the number of samples.

Procedure 2

This method is used for small water collections such as: flower pots, abandoned shoes, etc. In this case, the measuring of the density was carried out as follows:

- The entire water of the breeding site was poured into a first container and its volume determined
- After water settled down, samples of a known volume were taken with a ladle and poured into another container
- The number of larva of each mosquito species was counted by using a pipet and the density of mosquito larvae was calculated in the same way as above.

The volume of the ladle used in both procedures is 200 ml.

2.2.2. Determination of the Number and Species of Mosquitoes Per Housing

In order to establish a relationship between the environment and the mosquitoes, an information sheet was elaborated. The aim of this sheet is to collect the following information: type of environment around the house, type of room where mosquitoes were captured, the number of people who spent night in the room, protection measures used against mosquitoes biting in the sprayed room and the number and species of mosquitoes collected.

The method of mosquitoes' collection consisted in displaying first of all a white woollen cloth on the floor inside the bedrooms of surveyed households. Doors and windows are first closed and the bedrooms were then sprayed with the household insecticide manufactured by Total company (France). This product contains 0.117% D-Tetramethrin, 0.315% Prallethrin, 0.006% Deltamethrin and 0.046 D-D-transcyphenothrin. To apply the chemical, short bursts were sprayed into the air while moving about the room during about 10 seconds. The bedrooms were kept closed for 10 minutes so that mosquitoes came into contact with the insecticide and fell down onto the woollen cloth. Mosquitoes were then removed from the woollen cloth into microtubes and brought to laboratory for identification. Using a stereomicroscope, collected mosquitoes were observed one by one, based on their morphology in order to determine the number of individuals of each collected species. Ten bedrooms of similar dimensions were randomly sprayed throughout each district.

2.2.3. Data Analysis

Correlation coefficients (Pearson) between the three levels of urbanization and the number of larval breeding sites, larva density as well as the number of collected imago were respectively calculated using SPSS statistics package.

3. RESULTS

3.1. Larval Breeding Sites and Density

3.1.1. Number and Types of Larval Breeding Site

The exploration of surveyed districts revealed 3 types of larval breeding sites: breeding sites of *Anopheles* larva,

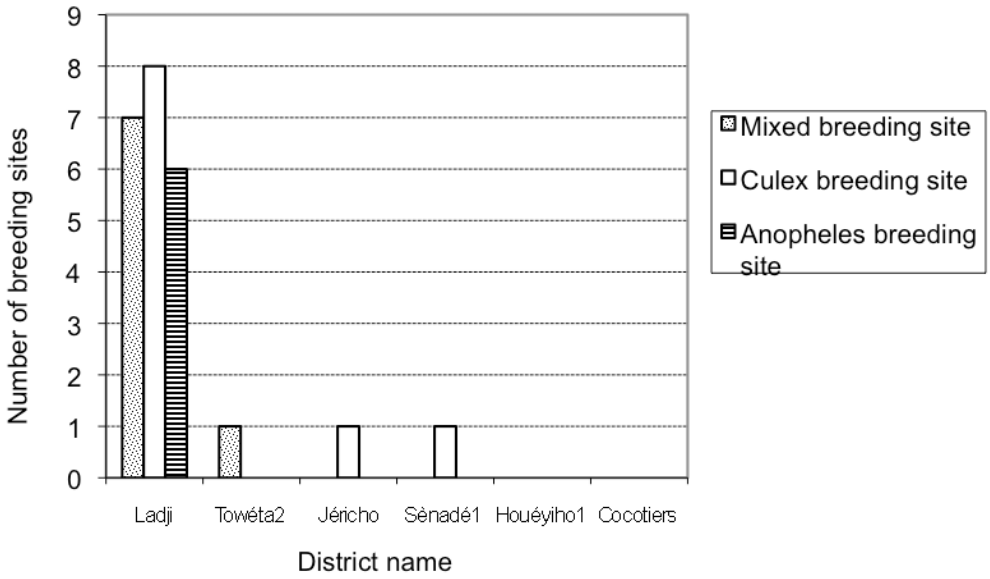

Fig. (1). Number and types of identified larval breeding sites.

breeding sites of *Culex* larva and breeding sites of both mosquitoes genera.

The analysis of Fig. (**1**) shows that:

- *Anopheles* breeding sites are found only in the non-urbanized district (Ladji). These larval breeding sites are essentially either marshes, wells or abandoned canoes and jars.
- *The Culex* larval breeding sites are found in both non-urbanized and semi-urbanized districts (Ladji, Sènadé1 and Jericho). The non-urbanized district (Ladji) contained the highest number of this larval breeding type (8).
- The mixed larval breeding sites (those that produce both *Culex* and *Anopheles* larva) were found in the two non-urbanized districts (Ladji and Toweta2) with Ladji district containing, however, the highest number of this larval breeding type (7).

These results indicate that the non-urbanized Ladji district is the area that contains high amount of the three types of identified larval breeding sites and that the 2 urbanized districts (Houéyiho1 and Cocotiers) contain no mosquito larval breeding sites at all. Statistical analysis revealed that there is a strong negative correlation (r= -0.9) between levels of urbanization and the number of identified larval mosquitoes' breeding sites.

3.2. Average Densities of Larva

The average density of *Anopheles* larva was 78 larva / liter and 12 larva / liter in the non-urbanized Ladji and Towéta 2 districts respectively (Fig. **2**). As for the *Culex* larva, these densities were respectively 145, 89, 15 and 3 larva / liter in Ladji, Jericho, Towéta2 and Senadé 1 (Fig. **3**).

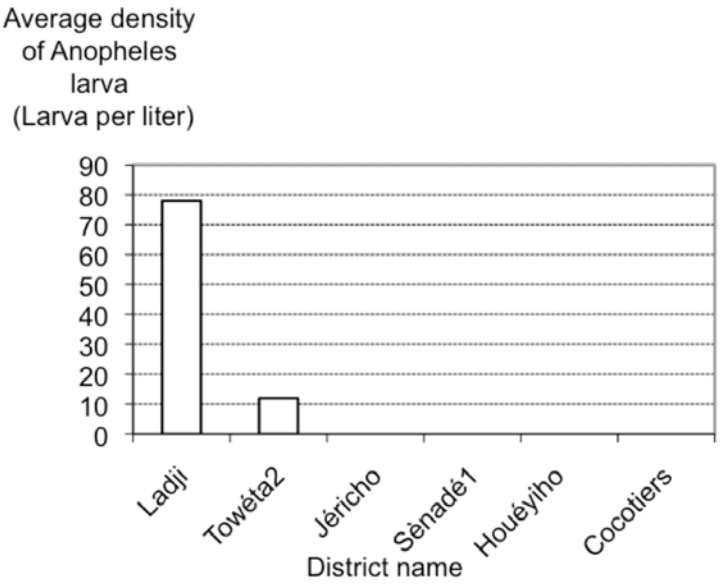

Fig. (2). Average densities of *Anopheles* larva.

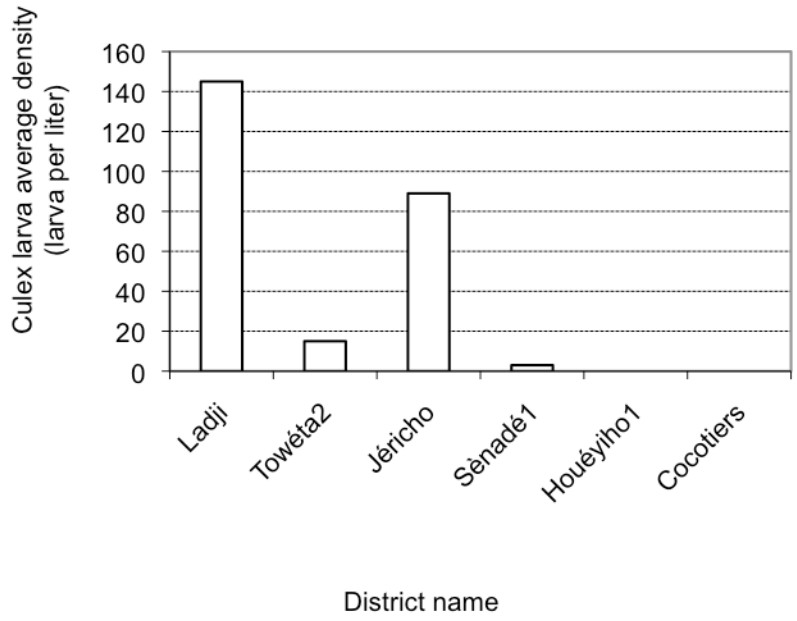

Fig. (3). Average densities of *Culex* larva.

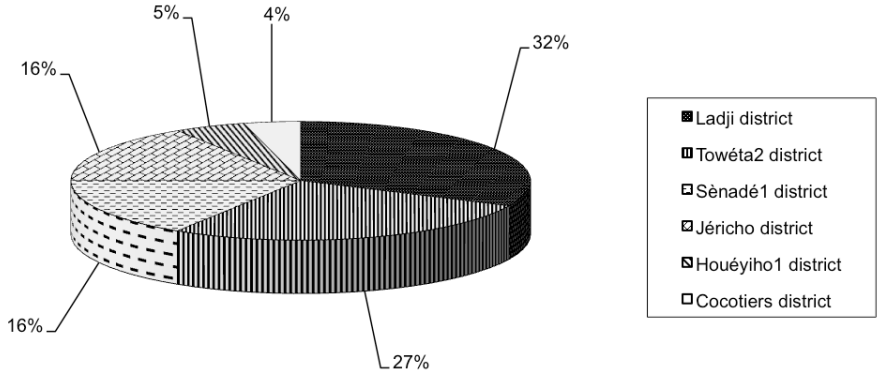

Fig. (4). Overall distribution of adult mosquitoes.

Statistical analysis revealed that there is a strong negative correlation (r = -0.92) between levels of urbanization and the average larval densities.

3.3. Distribution of Adult Mosquitoes

Thirty two (32%), 27%, 16%, 16%, 5% and 4% of adult mosquitoes collected came from Ladji, Towéta2, Sènadé1, Jericho, Houéyiho1 and Cocotiers, respectively. In other words, the majority (59%) of adult mosquitoes collected came from the 2 non-urbanized districts (Ladji and Towéta2) against 9% from the two urbanized districts (Houéyiho1 and Cocotiers) (Fig. **4**).

The examination of collected adult mosquitoes permitted to identify three mosquitoes genera: *Anopheles spp*., *Culex spp*. and *Aedes spp*.

Statistical analysis revealed that there is a strong negative correlation (r= - 0.99) between levels of urbanization and the number of collected adult mosquitoes.

Fig. (**5**) shows that 46%, 20%, 16%, 11%, 5% and 2% of the total number of adults of anophelines collected came from Ladji, Towéta2, Sènadé1 Jericho, Houéyiho1 and Cocotiers. There are therefore much more adult anophelines encountered in non-urbanized districts (Ladji and Towéta2) in comparison to urbanized districts (Houéyiho1 and Cocotiers) where the number of adult anophelines collected is minimal.

The distribution of adult *Culex* mosquitoes is 26%, 21%, 19%, 16%, 9% and 9% for Ladji, Towéta2, Sènadé1, Jericho, Houéyiho1 and Cocotiers, respectively (Fig. **6**).

As for the *Aedes* genera, the percentages of adults collected are respectively 45%, 43%, 10%, 1%, 1% and 0% in Towéta 2, Ladji, Sènadé1, Jericho, Cocotiers and Houéyiho1 (Fig. **7**). The majority of adults of *Aedes* mosquitoes is thus found in the two non-urbanized districts.

A arithmetic average of the number of adult mosquitoes collected in various types of houses is represented in Fig. (**8**). This average is 42, 16, 13 and 2 adult mosquitoes in houses built with bamboo + straw, bamboo + sheet metal, brick + sheet metal and brick + concrete roof, respectively.

Analysis of Fig. (**8**) reveals that houses built with bamboo + straw (encountered in non-urbanized Ladji district) contained much more adult mosquitoes in comparison to

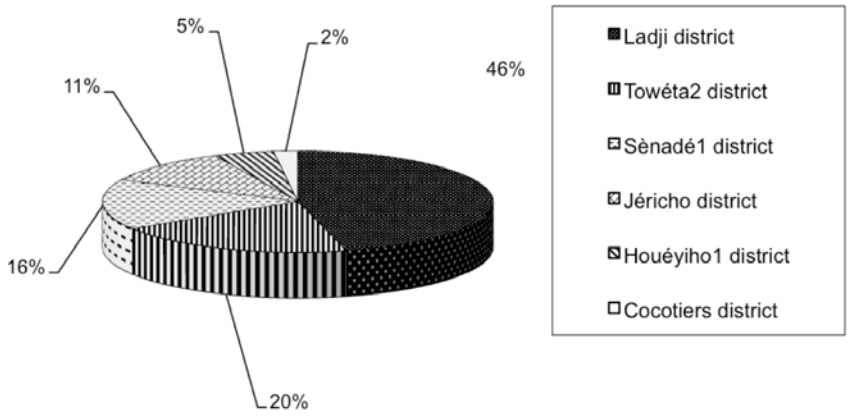

Fig. (5). Distribution of adult *Anopheles spp*.

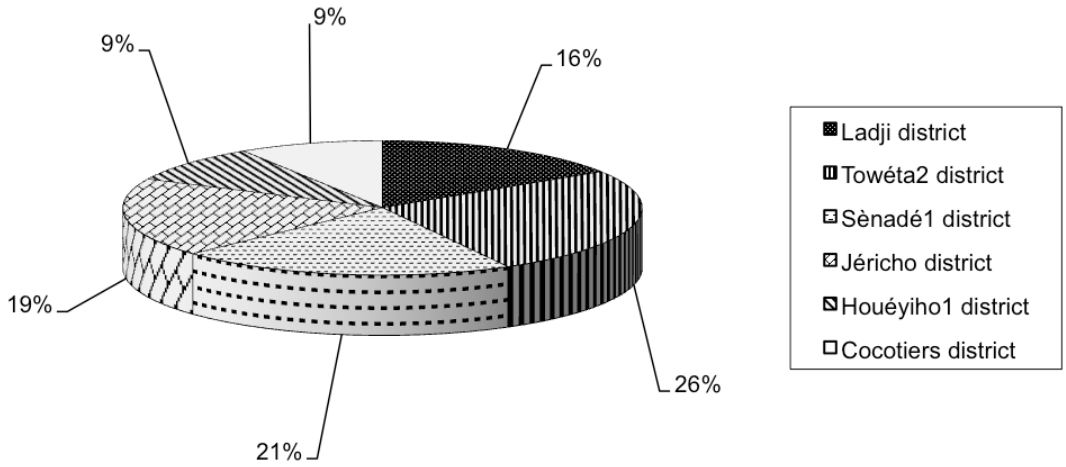

Fig. (6). Distribution of adult *Culex spp*.

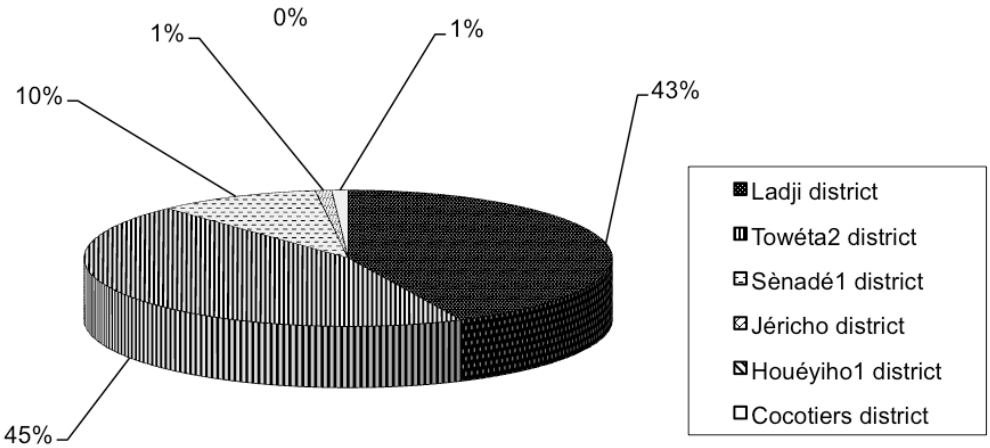

Fig. (7). Distribution of adults *Aedes spp*.

other types of houses especially those built with brick + concrete roof where the number of adult mosquitoes collected is minimal.

4. DISCUSSION

In recent years, several research scientists have been interested in the impact of urbanization on the proliferation of mosquitoes throughout the world [6-9].

According to Akogbéto [6], village houses that are built with bamboo wall and straw roof or sheet metal which facilitate entry and exit of mosquitoes by the chinks between bamboo and large openings between the top of the wall and the roof. After spraying houses in surveyed districts we have collected much more adult mosquitoes in houses built with bamboo wall and straw roof or sheet metal in comparison to other types of houses especially those built with brick wall

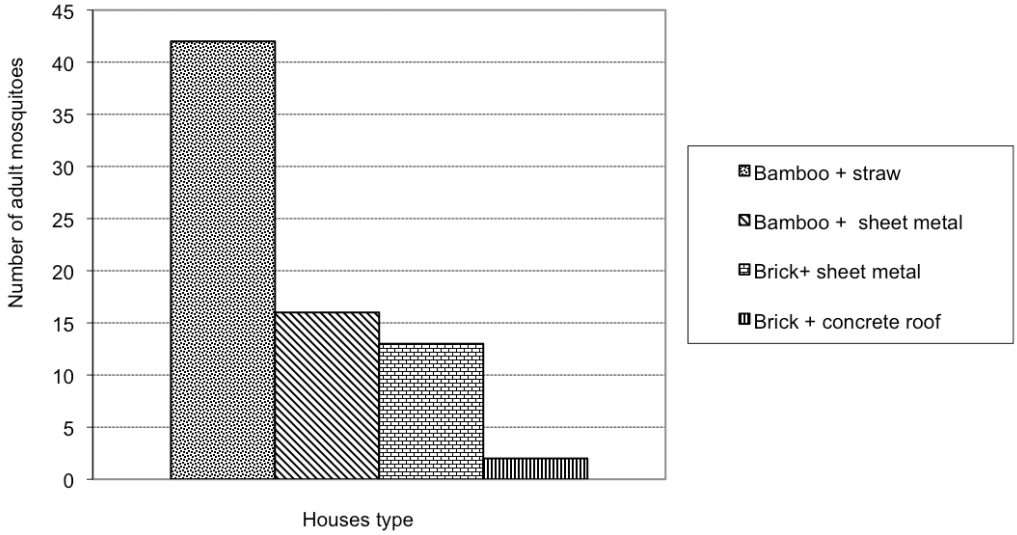

Fig. (8). Number of collected adult mosquitoes in different types of houses.

and concrete roof where the number of adult mosquitoes collected was very small.

Our results therefore corroborate with data published by Akogbéto [6]. According to this author, the highest rate of malaria transmission (47 infected mosquitoes bites per man per year) is observed in peri-urban lagoon area such as Ladji district. Our results also agree with the work of Roberts *et al*. [7] who showed that the entomological inoculation rate was 48.8 infected mosquitoes' bites per man per year in peri-urban areas and 167.7 infected mosquitoes' bites per man per year in rural areas.

FERREIRA-GONCALVES and ALECRIM [8] have shown the influence of anthropogenic interventions on the modification of the urban ecosystem and demonstrated that this ecosystem makes the ideal environment for the proliferation of *Anopheles sp*, the malarial mosquitoes. The census of mosquitoes larval breeding sites carried out in the present study permitted to determine that the non-urbanized Ladji district contained the highest amount of all types of identified larval breeding sites. These larval breeding sites are essentially either marshes, wells or abandoned canoes and jars. Similarly, in the two semi-urbanized districts (Senade2 and Jericho), we identified larval breeding sites that are open gutters which have abundant number of larva of *Anopheles* sp. Although these results support published data by FERREIRA-GONCALVES and ALECRIM [8] they however seriously contradicts BIO-BANGANA works which do not consider open gutters as larval breeding sites [10]. Indeed, local people throw out a lot of garbage in open gutters, and this prevents water flow and provides an ideal environment for the development of *Anopheles* and other mosquitoes' larva in the gutters.

Results from ANTONIO-NKONDJIO *et al*. [9] obtained after spraying a village and a town in Cameroon showed that the number of adult *Anopheles* caught in the village is higher than the number of adult mosquitoes caught in the city. These authors also showed that as the level of urbanization progresses, the density of adult *Anopheles* decreases. That is what we observed in the present study. The number of adult *Anopheles* captured in the present study in the non-urbanized districts is higher than the number of adult *Anopheles* caught in urbanized ones. In addition, this work revealed that the density of adult mosquitoes is considerably reduced in houses located in districts where urban infrastructures are very well developed.

It should also be noted that the territory of the urbanized Houéyiho1 district is bordered to the west by a vast marshy area which is abundant in *Anopheles* and *Culex* larva. Because of the migration ability of adult mosquitoes, we should find a large population of mosquitoes on the territory of this urbanized district. This explains the fact that the number of adult mosquitoes collected in houses located in this district is a little bit higher that in houses located in the other urbanized district (Cocotiers) where there is no such marshy areas at all.

The present study permits to conclude that unplanned urbanization is a factor that favours the proliferation of mosquitoes. It is therefore suggested to consider well planned urbanization and cleaning up of unhealthy districts as important part of mosquitoes control programmes.

ACKNOWLEDGEMENT

This study is sponsored by the Rectorate of the University of Abomey-Calavi, Benin.

REFERENCES

[1] Danis M, Gentilini M. Le paludisme fléau mondial. Rev Prat 1998; 48: 254-7.

[2] Gachot B, Bruneel F, Behr C. Paludisme pernicieux. Rev Prat 2001; 51: 638-43.

[3] Balkew M, Elhassen I, Ibrahim M, Gebre-Michael T, Engers H. Very high DDT-resistant population of Anopheles pharoensis Theobald (Diptera: Culicidae) from Gorgora, northern Ethiopia. Parasite 2006; 13(4): 327-9.

[4] Carson R. Silent Spring. Mariner Books/Houghton Mifflin: USA, 1962, ISBN 0-618-24906-0.

[5] Akogbéto M. Etude des aspects entomologiques du paludisme cotier lagunaire. Thèse de Doctorat ès sciences, Université de Paris XI 1992; pp. 7- 21.

[6] Akogbéto M. Lagoonal and coastal malaria at Cotonou: entomological findings. Santé 2000; 10(4): 267-75.

[7] Robert V, Macintyre K, Keating J, *et al*. Malaria transmission in urban sub-Saharan Africa. Am J Trop Med Hyg 2003; 68(2): 169-76.

[8] Ferreira-Gonçalves MJ, Alecrim WD. Non-planed urbanization as a contributing factor for malaria incidence in Manaus-Amazonas, Brazil Rev Salud Publica (Bogota) 2004:156-166.

[9] Antonio-Nkondjio C, Simard F, Awono-Ambene P, *et al*. Malaria vectors and urbanization in the equatorial forest region of south Cameroon. Trans R Soc Trop Med Hyg 2005; 99(5): 347-54.

[10] Bio-Bangana AS. Cartographie des gîtes des vecteurs du paludisme et autres moustiques dans la ville de Cotonou. Mémoire de maîtrise en Environnement et Santé. Université d'Abomey-Calavi, Bénin 2004.

Received: May 22, 2009 Revised: August 10, 2009 Accepted: August 14, 2009