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Physical and human bases of the spatial distribution of *Culexquinquefasciatus* vector of lymphatic filariasis in the health district Ouidah-Kpomasè-Tori Bossito

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Abstract

The environment is a major determinant of the biodiversity of Lymphatic filariasis because of the bioecological preferences of its vector (*Culexquinquefasciatus)*. In this context, control of the disease can benefit greatly from knowledge of the spatial distribution of vectors. It is in this cedar that is part of the present study which aims to describe spatial distribution of *Culexquinquefasciatus* vector of lymphatic filariasis in the health area Ouidah-Kpomasè-Tori Bossito. The scientific approach is based on the collection, evaluation and processing of climatological data (temperature, precipitation, number of rainy days, relative humidity, wind, visibility and vapor pressure), data geographical (hydrography, relief, localities), biotic data (human presence and vegetation) and entomological data (nocturnal catches of mosquitoes on human bait and larval surveys). The results of this study show that the distribution of *Cx. quinquefasciatus* is characterized by concentration in the northwestern and southwestern area of Ouidah-Kpomassè-Tori Bossito health district and is non-random. Environmental factors explain this distribution and are mainly related to the frequency of alcohol production and the distance from localities to freshwater streams. But they contribute in a differential way.

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Introduction

Worldwide, there are more than 3,400 species of mosquitoes in tropical area, temperate up to the level of the Arctic Circle. Apart from their diversity, which is the subject of studies by biologists and entomologists, the major interest in mosquitoes concerns their involvement in the transmission of human pathogens (Manguin, 2013). Africa has a wide variety of human pathogens including 3 major genera of mosquitoes, Anopheles, Aedes and Culex.

Culexquinquefasciatus, an anthropophilic mosquito whose females preferentially feed at night and indoors is responsible for lymphatic filariasis. It is estimated that about 120 million people in 72 countries are currently infected and that 1 billion people live in areas where filariasis is endemic and where mass drug administration (MA) is needed (Aubry and Gaüzère, 2019).

Moreover, the transmission of this disease is not homogeneous due to spatial variations in eco-climatic factors. Thus the objective of this article is to contribute to a better control of the disease by characterizing the spatial distribution of *Culexquinquefasciatus* vector of lymphatic filariasis in the health districtOuidah-Kpomassè-Tori Bossito in Benin.

Ouidah-Kpomassè-Tori Bossito health district is located in the southwest of Benin, between 1°56'30'' and 2°16'20'' east longitude and between 6°18'30 '' and 6°38' 20'' north latitude (Fig. 1.).

It is bounded on the north by the commune of Allada, on the east by the commune of Zè and the commune of Abomey-Calavi, on the west by the communes of Bopa, Comé and Grand-Popo and finally to the south by the Atlantic Ocean. Its area is 783,763 km². The relief is flat, almost monotonous. The highest locality of the area, rises to more than 78 meters.

The average altitude is 39.62 m. More than 75% of the area is between 12 and 101 meters (Bio-Bangana, 2019). Soils are very diverse. The mineralogical composition of the soil can promote mosquito breeding, especially when combined with high moisture (Assoko, 2005).Keeping theeffects of lymphatic filariasis disease in mind, this study aims to apply GIS, agronomic, sociological and entomological study to identify the physical and human bases of the spatial distribution of *Culex quinquefasciatus* vector of filariasis in the Ouidah-Kpomasse-Tori Bossito health district in the Republic of Benin.

Materials and methods

Data used

The methodology implemented is essentially based on the collection and processing of entomological and environmental data. Entomological data can be used to report on population exposure to lymphatic filariasistransmission.

These data were collected through nocturnal captures of mosquitoes on human bait (Djènontin, 2010) and larval surveys using the Bruce-Chwatt method in 1985 (Bruce-Chwatt, 1985).

The collection of this data covers the period from October 2007 to December 2009. Every six weeks, a mosquito capture mission was organized. In total, 17 entomological missions were carried out.

Environmental data are varied and cover several areas: climatological data, geographic data and biotic data. Climatic variables include temperature, precipitation, and number of rainy days, relative humidity, wind, visibility and vapor pressure.

The geographical variables combine the hydrography, the relief, the localities come from the hydrographic database of the General Direction of water, the Numerical Model of Terrain of the CRU, the Database of the INSAE (2002) and hamlet census data carried out by the REFS project in 2007. The biotic variables consist of the human presence and vegetation (NDVI) that are respectively taken from the population census in 2007 by the project REFS / CREC and the SPOT Vegetation image covering the period from 1 July 2005 to 31 October 2005 were selected.

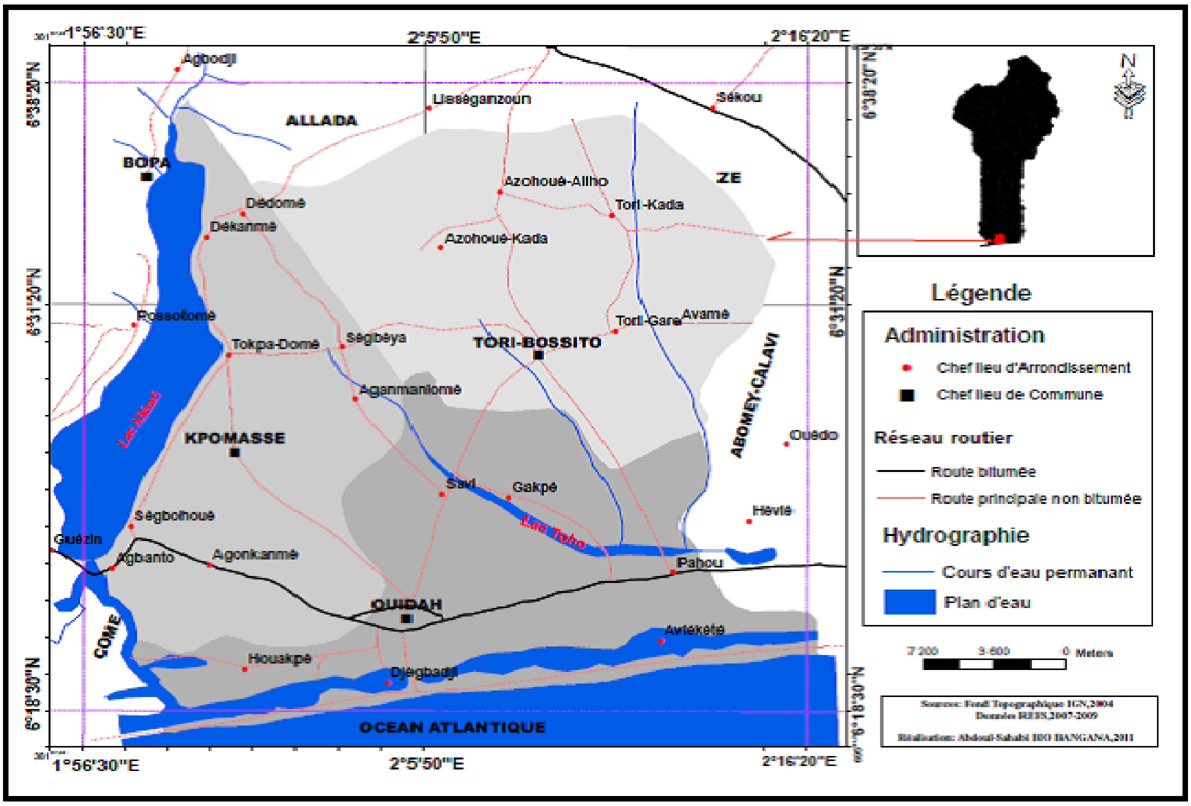

Fig. 1. Ouidah-Kpomassè-Tori Bossito health district Administrative map.

Data processing

The descriptive spatial analysis from the ArcGis software was used and consisted in the analysis of the spatial structure through the use of indices (Moran, Getis-Ord General G, Anselin Local Moran and Getis-OrdGi *).

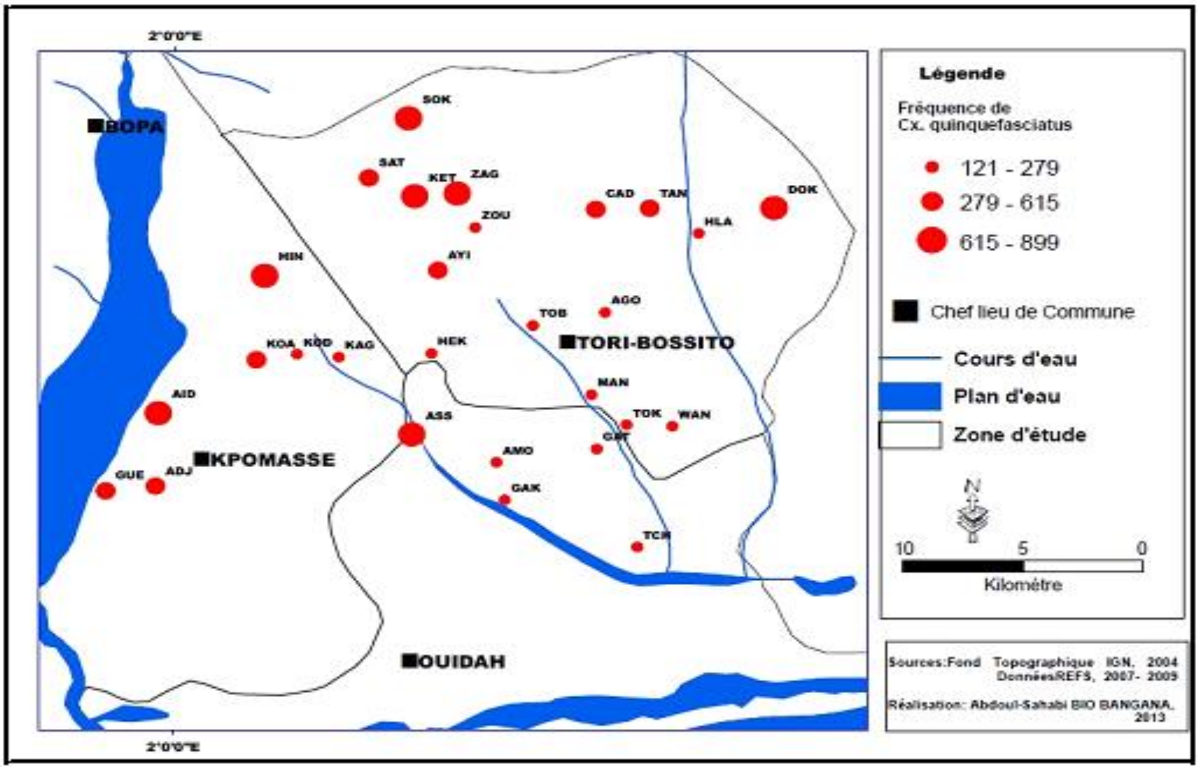

Fig. 2. Spatial distribution of *Cx. quinquefasciatus*.

The operation "ACP", analysis in Principal Components, was used for the analysis of the structure of statistical data through the correlations between the variables and the identification of the factorial axes. This follows the multiple linear regression to analyze the contribution of environmental parameters in the spatial distribution of *Culexquinquefasciatus*. The regression function was then inverted at the spatial level to produce a distribution map. These model is evaluated from the residue normality test and the BREUSH-PAGAN variance homogeneity test.

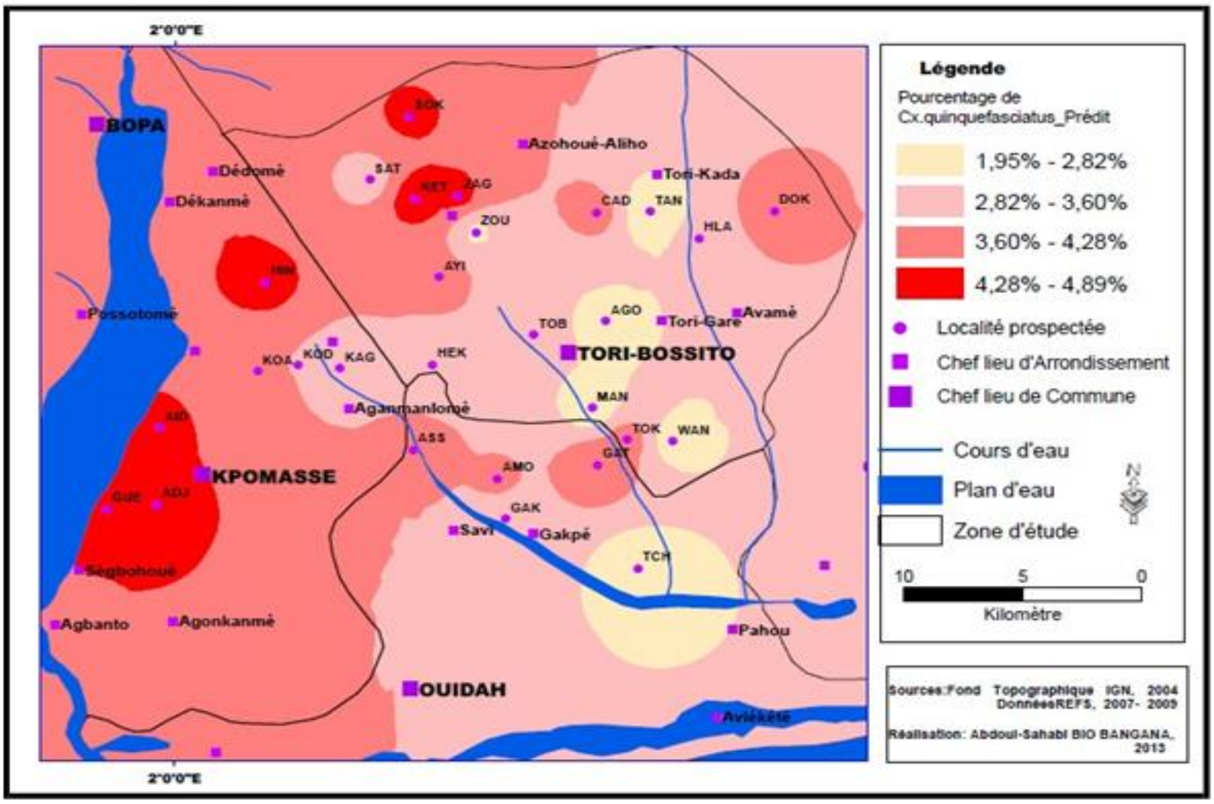

Fig. 3. Prediction of the spatial distribution of *Cx. quinquefasciatus* percentages.

Results

Spatial distribution of Culexquinquefasciatus

The spatial distribution of *Cx. quinquefasciatus* (Fig. 2) is characterized by a tendency for frequency concentration in the north and southwest portions of the site. The evaluation of the Moran autocorrelation index gives the following results: Moran index = 0.216246; Expected index = -0.037037; Variance = 0.022155; Z score = 1.701664. The autocorrelation index of Moran is close to 0, there is spatial independence for this realization of the regionalized random variable. According to these statistics, the frequencies of *Cx. quinquefasciatus*at a collection point are not influenced by the frequencies observed at the neighboring points. It is therefore not possible to predict the frequencies of *Cx. quinquefasciatus* in a hamlet, knowing the frequencies observed in another hamlet, relying on the distance that separates them.

The concentration index of the high and low values of Getis-Ord General G gives the following results: General G Observed = 0.000041; Expected General G = 0.000040; Variance of General G = 0.000000; Z score = 0.303864.

The Z score is different from 0 and low. There are probably spatial aggregates of weak values expressing the local existence of spatial autocorrelation.

The statistical reversal of the spatial independence of the regionalized random variable observed with the Moran index, requires us to push the analysis by checking the relationships between the frequencies observed and the environment.

Table 1. Correlation coefficients between the three axis and environmental parameters.

Environmental parameters	Axis1	Axis2	Axis3
VENT	0,97	-0,05	-0,16
VISIBILITE	-0,68	0,01	-0,35
PLUIE	0,94	0,09	0,27
HR	0,97	-0,07	-0,19
PRESSION	-0,97	0,06	-0,03
TEMPER	0,65	-0,22	-0,31
NJP	0,63	0,24	0,65
NDVI	-0,01	0,12	0,83
TOPO	-0,7	0,2	0,51
POP	-0,03	0,9	-0,22
NH	0,04	0,95	-0,18
DCED	-0,83	0,02	-0,02
DCES	0,58	0,29	0,62
NPA	0,42	0,06	-0,31
FPA	0,56	-0,2	-0,09
GDCP	0,32	0,31	-0,12
GDAE	-0,05	-0,09	0,06
GDR	0,45	0,06	-0,25
TH_TB	-0,1	0,9	-0,1
TH_MB	0,37	0,38	-0,29
TH_A	0,14	-0,09	0,2

Legend:DCED=Distance from localities to the Freshwater River; DCES=Distance from localities to brackish watercourses;GDCP=Domestic deposits, epigees linked to the behaviour of populations; GDAE=Domestic deposits, epigees linked to economic activities; GDR=Domestic deposits, epigees linked to the relief; TH_TB = number of dwellings with clay walls; TH_MB= Number of dwellings with brick (cement) walls; TH_A=Number of dwellings with brick (cement) and clay walls.

Determining the environmental distribution of Cx. quinquefasciatus

The principal components analysis carried out on the data related to the environmental parameters obtained in different hamlets shows that all the first three axes explain 62.25% of the initial information, which is sufficient to guarantee a precision of interpretation. Table 1 shows the correlation coefficients between each of the three axes and the environmental parameters. The quality of the representation of the different variables with respect to the factorial axis is expressed through the Pearson correlation coefficient values (Table 2). The analysis of this table indicates a negative and significant correlation at the 5% threshold between the axis 1 and the frequency of *Cx. quinquefasciatus*. Therefore taking into account the environmental parameters by this axis, when there is a high wind, a heavy rain, a relative humidity, a temperature, and a frequency of high alcohol production, the frequency of *Cx. quinquefasciatus* decreases as low visibility, low pressure, low topography, and a short distance from freshwater stream localities increase its frequency.

The analysis of the relations between the environment and the frequency distribution of *Cx. quinquefasciatus* suggests a possibility of mathematical formalization of its distribution. The regression performed is of linear type and gives an adjusted coefficient of determination of 0.637. This means that 63.7% of the variance is explained by the linear combination of the two variables mentioned above. The probability associated with Fisher's F test is 0.0001, that is, less than 0.01% chance of being mistaken considering that the amount of information provided by the frequency of alcohol production (FPA) and the distance from the localities Freshwater streams (DCED) as a whole are significant for the model. The resulting equation can therefore be written:Rac(FR_CQ) = 24, 22 – 1, 05 FPA + 0, 40DCED.

Obtaining this model offers the possibility of producing a theoretical map of the *Cx. quinquefasciatus*distribution in the Ouidah-Kpomassè-Tori Bossito health district.

Cartographic expression of equations

The mathematical formalization of the distribution of *Cx. quinquefasciatus* gives the possibility of producing a theoretical map of the distribution of the species in the Ouidah-Kpomassè-Tori Bossito health district (Fig. 3). We observe on this map very heterogeneous percentage areas of the *Cx. quinquefasciatus*species. In the whole health zone, the predicted percentages are arranged in bands, with a decrease from north-west to south-east. Since even temporary watercourses are rare in the north of the health area, the populations are forced to dig pools of rainwater catchment. Without major protection, these basins are obstructed by debris of all kinds. In contact with water, they decompose and make the organic medium. This situation is very favorable to the proliferation of *Culexquinquefasciatus* mosquito breeding sites. The north of the Ouidah-Kpomassè-Tori Bossito health zone presents the most favorable conditions for the ecology of the *Culexquinquefasciatus* species, since the model predicts high relative abundances in relation to the southern area.

Discussion

The spatial distribution of *Cx. quinquefasciatus* is characterized by concentration in the northwestern and southwestern zone of the Ouidah-Kpomassè-Tori Bossito health zone. Such distributions make it possible to suspect a spatial dependence in the frequency distribution of disease-carrying mosquitoes, hence the need to test spatial autocorrelation. The computation of the spatial autocorrelation indices carried out on the 28 hamlets of collection revealed that: the Moran index is close to 0. The realization of the regionalized random variable is thus independent. This means that the frequencies of *Cx. quinquefasciatus* in a collection hamlet are not influenced by the frequencies observed in neighboring hamlets. It is therefore not possible to predict the frequencies in a hamlet, knowing the frequencies observed in another hamlet based on the distance that separates them, hence the need to push the analysis by checking the Z scores. High and low value concentration index of Getis-Ord General G. In fact, this index gives low or even negative Z scores. Since a low negative Z and a low value p indicate a spatial aggregation of low values, we can say that according to these statistics, there are spatial aggregates of low values within which can be expressed a spatial autocorrelation. These results make it possible to say that the spatial distribution of *Cx. quinquefasciatus* is non-random. Management and aggregates have also been identified. The autocorrelation tests show the spatial independence and the fact that (absolute) space is insufficient to explain the observed distribution. Spatial structures highlighted cannot be explained in neighborhood relations. It is therefore important to use other factors that explain these observed distributions. The environment is positioned in this perspective as a factor likely to explain the observed distribution, hence the need to model this spatial distribution.

A principal components analysis (PCA) performed on environmental factors generated three uncorrelated factorial axes. These three axes have been correlated with the frequencies of *Cx. quinquefasciatus*. Axis 1 is negatively correlated with the frequency of *Cx. quinquefasciatus*. As a result, when there is high wind, heavy rain, high relative humidity, high temperature, and high alcohol production frequency, the frequency of *Cx. quinquefasciatus* decreases as low visibility, low pressure, low topographic topography, and a short distance from freshwater stream localities increase its frequency. From this principal component analysis, we deduce, on the one hand, that there are relationships between environmental factors and the distribution of disease-carrying mosquitoes and, on the other hand, that there is a conflict between the ecological preferences of these mosquitoes. Indeed, not all environmental factors contribute in the same way to the determination of the observed spatial structure. Some environmental factors may become more easily an important constraint, a factor limiting the development and spread of the species. Based on the results of the analysis, we proceeded to reduce the number of explanatory variables by exclusion of the variables: number of alcohol producers (NPA), homestays and habitat types; identified the best model by comparing the AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) models (fish model, negative binomial model, linear regression model with transformation of the Box-Cox family of the dependent variable; a separate modeling of the four species of mosquito vectors of diseases and finally proceeded to the multiple linear regression.

Table 2. Correlation coefficients between mosquito disease vector species and major components.

Axis	Correlation coefficient and Probability	FrequencyofCx. *quinquefasciatus*
Axis1	R	-0,41
	Prob.	0,029
Axis2	R	0,02
	Prob.	0,918
Axis3	R	0,07
	Prob.	0,735

The model of *Cx. quiquefasciatus* involves two main determinants: the frequency of alcohol production and the distance of localities to freshwater streams. But it should be noted that the frequency of the species *Cx. quinquefasciatus* increases when the frequency of alcohol production decreases and that we move away from freshwater streams. The Culex grow in permanent or temporary basins of alcohol condensation in Ouidah-Kpomassè Tori Bossito area. Their eggs, grouped in "rafts" on the surface of the water, do not withstand high temperatures (Nasci and Miller, 1996). In fact the remoteness of the localities of the freshwater courses associated with the very deep water table in the north and the south-west of the health district Ouidah-Kpomassè and Tori Bossito, increase the periodicity of storage of water intended for the condensation alcohol. Since mosquito larvae only need 7 to 10 days for emergence, it is possible that this water provides several water cycles before a new alcohol production operation that will necessarily ensure the destruction of eggs. Also, in this area, the number of alcohol producers is higher than in the south-east area (Ouidah and south of Tori Bossito). But these producers are not professionals. So the frequency of alcohol production is low, that is to say of the order of 3 to 4 times a year. It is generally known that habitat is the preferred meeting point between vectors and humans. This is the place of the longest contacts, simply because the habitat is where the host spends the most time in immobility (sleep), at the time most appropriate for the nutritional activity of the mosquito , namely at night (Assoko, 2005). A study carried out in Burkina Faso in an irrigated area, has shown that the removal of habitat within a few hundred meters of an irrigated area or a river is the only realistic measure to limit the culicidal nuisance (Tia , 1992). These results are contrary to ours. Indeed, in the Ouidah-Kpomassè-Tori Bossito health district, the species *Cx. quinquefasciatus* proliferates more in remote locations of freshwater streams. In fact, the depth of the water table and the absence of watercourses force people to dig rainwater retention ponds, which are real mosquito deposits in Culex (Bio-Bangana, 2012).

On the basis of these trends, the distribution of the species has been formally described. During this formalization, we proceeded to the expression of the transformed frequencies according to the most determining factors. These distribution functions of the spatial distribution made it possible to produce spatial distribution maps of each of *Cx. quinquefasciatus*

Conclusion

The interest of this work is to write the spatial distribution of *Culexquinquefasciatus* vector of lymphatic filariasis in the health districtOuidah-Kpomasè-Tori Bossito. It has also produced a model of spatial distribution of the species. Indeed, a good vector control strategy must first take into account the environment that offers these vectors the ecological conditions favorable to their survival and reproduction. In the northwest and southwest, the driest regions, regions of artificial basins used for artisanal production of alcohol, the species *Cx. quinquefasciatus* is largely dominant.As a whole, two groups of environmental factors characterize the areas of concentration and significantly influence the spatial distribution of *Cx. quinquefasciatus*. The first group of factors is natural and consists of wind, visibility, relative humidity, temperature, precipitation, vegetation and topography. The second group evokes the anthropization of the environment and consists of the frequency of alcohol production and the distance from localities to freshwater and brackish watercourses. From these factors of the spatial organization of this species, a spatial distribution model has been realized. This model allowed the realization of a map of spatial distribution of frequencies of *Cx. quinquefasciatus* in the Ouidah-Kpomassè-Tori Bossito area.

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