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Mapping Risk Prone Zones of Malaria Vector Species in Cross River State, Nigeria

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In Nigeria, malaria is an endemic vector-borne disease causing deaths and affecting a greater proportion of her population more than any other vector-transmitted disease. This has implication on economic development and national security. The specific objectives of the study were to examine the ecological factors favourable for the breeding of malaria vector species, identify major malaria vector species in the area and their endemic zones as well as compare malaria occurrence between two areas within and outside the breeding ground. Data were obtained using thematic maps of environmental variables in accordance with World Health Organization thresholds for environmental variables favourable to the species' survival. In addition, data on clinically certified data of malaria cases were obtained from Roll Back Malaria Office in Calabar. Data obtained were analysed using buffering, query/Boolean analysis, overlay operations and independent samples test. The spot survey analysis showed that *An. melas*, *An. gambiea* and *An. arabiensis* species occurred across the north-eastern, central and southern parts of the state particularly parts of Oban low lands in Obanliku, Odukpani and Calabar while *An. melas* was predominant in Yakurr, Boki, Etung and Ikom. The major conclusion is that about 99% of Cross River State is favourable to malaria vector species survival as a result of the state's high precipitation and temperature and that the more closely the communities to mosquito breeding site, the greater the risk of malaria infection.

Key words: Malaria vector-species, Boolean analysis, GIS, *Anopheles* mosquito, cross river state

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INTRODUCTION

Studies have shown that vector-borne diseases require an intermediate living agent for their transmission. Vector-borne diseases such as malaria constitute a threat and burden on the human populations and its effect could have serious impediment to economic development and productivity of a nation (Akpama, 2010). Their epidemiology is environment related (Brooker *et al*., 2004; Sankoh and Ye, 2011) other factors such as expanse breeding site and number of persons per room amongst others (Gamage-Mendis *et al*., 1991; Clarke *et al*., 2002). In Africa and Nigeria in particular, malaria is a serious vector-borne disease causing deaths and affecting a greater proportion of her population more than any other vector-transmitted disease. This has implication on economic development and national security mostly when a greater percentage of her active population is affected by the disease. According to Alaba and Alaba (2003), over 200 million cases of malaria occur every year and the number is increasing. More perturbing, is the fact that, malaria cases are reported even in areas where it had been controlled, thereby making it one of the greatest health problems facing man mostly in the tropics.

Indeed, malaria remains one of the greatest killers of young children in the developing world and it imposes a considerable economic burden resulting from high morbidity levels within the active population. The World Health Organization estimates show that over 80% of clinical cases of malaria occur in Africa south of the Sahara. Malaria is transmitted by anopheles mosquitoes which breed in surface water pools where environmental conditions are suitable their development (WHO, 2005, 2006). Cross River State over time has experienced a growing rise in the scourge of vector-borne diseases resulting in millions and thousands of illnesses and deaths, respectively; a situation so worrisome such that planners seek to evolve basic tools for planning intervention measures. These risk factors are proximity to water body, vegetation cover, temperature, rainfall and altitude (Gunawardena *et al*., 1994; Henri *et al*., 2010). In Nigeria, malaria infection and distribution by mosquito vectors vary across the different ecological zones of the country, yet not much study has been carried out to ascertain factors favourable to their survivals (Akpama, 2010).

It is therefore necessary for a study such as this to be carried out in Cross River State to avoid the inherent problems of its prevalence as well as suggest intervention measures that will emphasize species-specific and cost effective approach rather than waste resource for its control. Indeed, attempts have been made in the past to study the spatial distribution of malaria vector using aerial photography (Olorunfemi, 1983), but relatively few studies have been carried out using environmental variables to map risk prone zones of malaria vector-species in Cross River State, the flagship of tourism in Nigeria. In addition, few of the available studies considered one or two of the environmental variables (Sutherst *et al*., 1995; Lindsay *et al*., 1998; Henri *et al*., 2010) while neglecting others. Indeed, the dynamics of malaria vector species distribution considering the ecological parameters requires a more powerful and sophisticated system such as GIS and Remote Sensing data which provides a general extensive synoptic coverage of large areas than aerial photography. Remote Sensing (RS) and Geographic Information System (GIS) therefore provide new tools for advanced ecosystem management (Wilkie and Finn, 1996; Rincon-Romero and Londono, 2009) and threat detection. The aim of this study was to map risk prone zones of malaria vector species in Cross River State. The specific objectives were to: examine the ecological factors favourable for the breeding of malaria vector, examine the major malaria vector in the area and their endemic zones as well as compare malaria occurrence between two areas within and outside the breeding ground.

MATERIALS AND METHODS

Study area: The study was carried out in Cross River State. Cross River State is one of the 36 States that make up the Federal Republic of Nigeria. It comprises eighteen (18) Local Government Areas namely Calabar Municipality, Odukpani, Akamkpa, Obubra, Ikom, Ogoja, Obudu, Akpabuyo, Yakurr, Boki, Bekwarra, Abi, Biase, Etung, Yala, Bakassi, Calabar South and Obanliku. The national population census figure of 2006 shows that Cross River State has a population of 2.89 million persons and a population density of 125 persons km^{-2} (NPC, 2006). Cross River State is located at the south southern margin of Nigeria. It lies between latitudes 5°32' and 4°27' north of the equator and longitudes 7°50' and 9°28' east of the Greenwich Meridian. It has an area of 23, 074 km^{-2}. The land mass of the state is equally divided into basement and sedimentary basins. Cross River State falls within the tropical-humid with wet and dry seasons, with average temperatures ranging between 15-30°C and the annual rainfall between 1300-3000 mm. The high plateau of Obudu experiences climatic conditions which are markedly different from the generalised dry and wet period in the rest of Cross River State. Temperatures are 4-10°C lower due to high altitude than in the surrounding areas.

Cross River State can be broadly divided into the following sub-climatic regions: the moderated sub-temperate within the high plateaus of Obudu and the hot, wet tropical extending from the southern lowlands to the central and northern hinterland parts. The state is home to one of the last remaining contiguous forest stands in West Africa and is still a unique habitat for several primate species. The forest ecosystem stabilizes local weather patterns and provides water in this region of Nigeria. The favourable climate of tropical, humid, dry and wet seasons gives rise to rich agricultural lands, thus encouraging both perennial and annual crop cultivation. Cross River State falls in tropical zone, except the Obudu Plateau in Obanliku Local Government Area which has a sub-temperate climate. The vegetation zones of this area show that the State falls within the mangrove swamp forest in the south, stretching through the deciduous and Savannah regions in the north. Hence, due to its north-south stretch, there are at least four distinct ecological zones in the State ranging from mangrove and swamp forests towards the coast, tropical rain forests further inland and savannah woodlands in the northern parts of the state. The highlands of the Obudu Plateau offer mountain type vegetation (Ita, 2011).

Sampling technique and data collection procedure: The stratified sampling technique was employed to identify malaria vector species prone areas/zones by Local Government Areas. The unit of the research observation is based on Local Government Administrative Blocks of Cross River State. These blocks served as sample sites for this study.

Data types and sources: The study made use of data on rainfall, altitude, soils, temperature, population and vegetation of the study area as well as data on clinical data (GPS survey). The sets of data were obtained from varying sources. Population data was obtained from the National Population Office, Cross River State (CRS); rainfall data (Scale: 1:11 000,000) was obtained from Ministry of Environment Metro. Department CRS; Administrative map of LGA (Scale: 1:25 000) was obtained from Ministry of Lands and Survey, CRS; temperature and altitude data (Scale: 1:11 000, 000) were obtained from DAMS Owode, Ogun State; soil data (Scale: 1:11 000, 000) was obtained from Ministry of Agriculture CRS; streams data (Scale: 1:25 000) was obtained from the Department of Geo/Reg. Plan. University of Calabar while clinically reported data (Malaria GPS Survey) from 2008-2009 was obtained Roll Back Malaria Unit CRS. The various thematic maps were brought to Universal Transverse Mercator projection zone 33.

Method of data preparation and software/tool employed: In this study, GIS (Geographic Information System) tools were used to generate data used to map risk prone zones of malaria vector species. Data were prepared for inference using buffering, query/Boolean analysis and overlay operations Digital thematic maps of altitude, forest, soils, temperature, streams and rainfall were prepared using ARCGIS 9.3. Resultant maps were produced that meet the criteria for favourable zones. In addition, the scales of the collected data were harmonized to a common scale of 1:11 000,000 as well as coordinate system to enhance effective spatial analysis and presentation. However, the following software/tools were used viz., ARCGIS 9.3, ARCVIEW 3, Microsoft, Microsoft Excel and GPS.

Methods of data analysis: Data obtained were analysed using buffering, query/Boolean analysis, overlay operations and independent samples test.

Statistical data analysis: The independent samples test statistics was used to compare the relationship between clinical cases of malaria incidence in communities within 1500 m buffer away from streams and communities located away the buffer zones. To achieve this, clinically certified data of 2007-2009 with GPS attached coordinates were linked into the ARCGIS 9.3 with communities point feature mapped through spatial joins. Through this, an overlay operation was carried out. The resultant map shows communities malaria incidence within buffer zone and that outside the buffer zones. Finally SPSS version 17.0 software for windows was then used to ascertain if there was any significant relationship between point A and B in terms of malaria incidence case scenario over time (t) period.

RESULTS

Modelling risk to malaria: Result of the query operation shows that vegetation cover, altitude, soils, rainfall and temperature are the most influencing environmental parameters influencing the distribution of malaria vector species. Hence, for GIS-predicted distribution, digital thematic maps of these five ecological variables were prepared. Threshold for identification of favourable range of ecological parameters and integration of thematic maps for malaria vector species distribution is shown in Table 1. From each reported area, lower and upper limits (forest cover (k = 1), altitude (k = 2), rainfall (k = 3) temperature (k = 4), soils (k = 5) were identified and denoted as k. Sets of minimum and maximum limits denoted as {Mnk} and {Mxk} were identified for each variable. The favourable areas for distribution of the

Table 1: Thresholds for favourable environmental factors

ID	K	Max limit	Min limit
1	Vegetation	Evergreen tropical wet forest	Moist deciduous forests
2	Altitude	Elevation below 4500 m	Elevation above 1 m
3	Rainfall	Rainfall below 3500 mL	Rainfall above 1500 mL
4	Temperature	Temperature <28°C	Temperature >20°C
5	Streams	Buffer distance of 1500 m	
6	(Soils)	Hydromorphic soils (coastal soils)	Reddish Gravelly soils on sandstones

WHO/UNICEF (2003)

species were extracted using Boolean operation of one and zero. This simple model denotes all geographic locations having favourable values of the habitat variables, forest, temperature, rainfall and altitude and soils, respectively.

Boolean model analysis was used to identify ranges environmental factors favouring the survival of malaria vector species. For soil, the Boolean model classified the soil of Cross River State into six distinct groups of marine and coastal soils which falls into hydromorphic soil classification type; soils on crystalline rocks which belong to soil classification types of highly ferruginous tropical soils; reddish gravelly soils on shale, this is of ferrallitic soils; reddish-yellow gravelly soils on crystalline acid rocks also of ferrallitic soils; reddish-yellow gravelly soils on sand stones of ferrallitic soils and weakly developed soils of eutrophic brown Soils. Among these groups, the marine and coastal (hydromorphic) soils are favourable for malaria species survival going by the Boolean model analysis.

Generally, for most of the species, the number of breeding sites is proportional to amount of rainfall and its seasonal pattern. Extreme conditions restrict mosquito proliferation. Low rainfall creates less number of breeding habitats while high rainfall flushes mosquito eggs (Beck *et al*., 1994). In this study, 8 categories of rainfall ranging from <1600 to >3000 mm were considered. Boolean analysis shows that the entire study area is favourable for the survival of malaria vector; as a result of its high rainfall giving rise to evergreen tropical wet and moist deciduous forests. This climatic variation influences the breeding status of mosquito population (Henri *et al*., 2010). Henri *et al*. (2010) and Sankoh and Ye (2011) noted that temperature, rainfall, vegetation cover and humidity are important determinant factors for the *Anopheles* distribution mostly in Africa.

In addition, the analysis broadly categorized the vegetation of Cross River State into seven distinct categories of forest types. Out of all climatic conditions, rainfall plays a vital role in forested areas and hence forest classification mainly rests on rainfall. Areas where rainfall is > 2500 mm along with average daily temperature of 25°C are categorized as tropical wet evergreen forests. Moist evergreen and semi evergreen forest areas have rainfall>1500-5000 mm. However, from series of researches *An. melas* is reported to be found in evergreen forested areas (Thomas and Lindsay, 2000). In line with this, the model used in this study identified evergreen tropical wet and moist deciduous forests as favourable areas for the distribution of Malaria vector species in Cross River State. Furthermore, mosquito species have different temperature threshold levels. Besides mosquito survival and longevity, duration of sporogony in mosquito is temperature dependent. At temperature lower than 20°C, duration of sporogony in mosquito is prolonged beyond 30 days, i.e., more than the average mosquito's lifespan and hence active malaria transmission does not take place. At extreme temperatures, longevity of mosquitoes is drastically reduced. A temperature map consisting of 5 categories from <20->28°C was used. From these categories, temperature thresholds of 25-28°C were brought out as favourable range for the species while temperature below 20°C was not favourable for Malaria species survival. Malaria Vector species prefer to establish their population at various heights where optimum ecological requirement for their survival is satisfied. Survey of Nigeria map showing 5 categories of altitude from sea level to 1817 m was used. It is observed as well as verified from the literature that the entire study area is favourable for the establishment of the population of malaria vector species. Devi and Jauhari (2004) have it that the species favourable range from sea level is within 4000 m altitude.

Malaria vector species predicted zones: This study examined the altitudinal range of malaria predicted zones taking into account the classification threshold in Table 1. GIS- predicted areas favourable for malaria vector species is represented in yellow while unfavourable area is shown in blue (Fig. 1). The total land area in square kilometers of favourable zone is estimated as 21, 281 km^2 while that of unfavourable zone is estimated as 200 km^2, a ratio of 1:106 total land area of unfavourable zone to favourable. Humid tropical climate (1300-3000 mm rainfall; 30°C mean annual temperature) prevails in Cross River State, except on the Obudu Plateau, where the climate is sub-temperate with temperatures of 15 and 23°C. Therefore Obudu Plateau in Obanliku Local Government Area (LGA) happens to fall within the unfavourable area for malaria vector prevalence.

Effect of distance to streams in modelling malaria risk: The presence of water bodies is a very important factor for mosquitoes breeding. This assertion holds ground considering a number of works done. Le Sueur and Sharp (1996) studied the incidence of malaria and discovered in

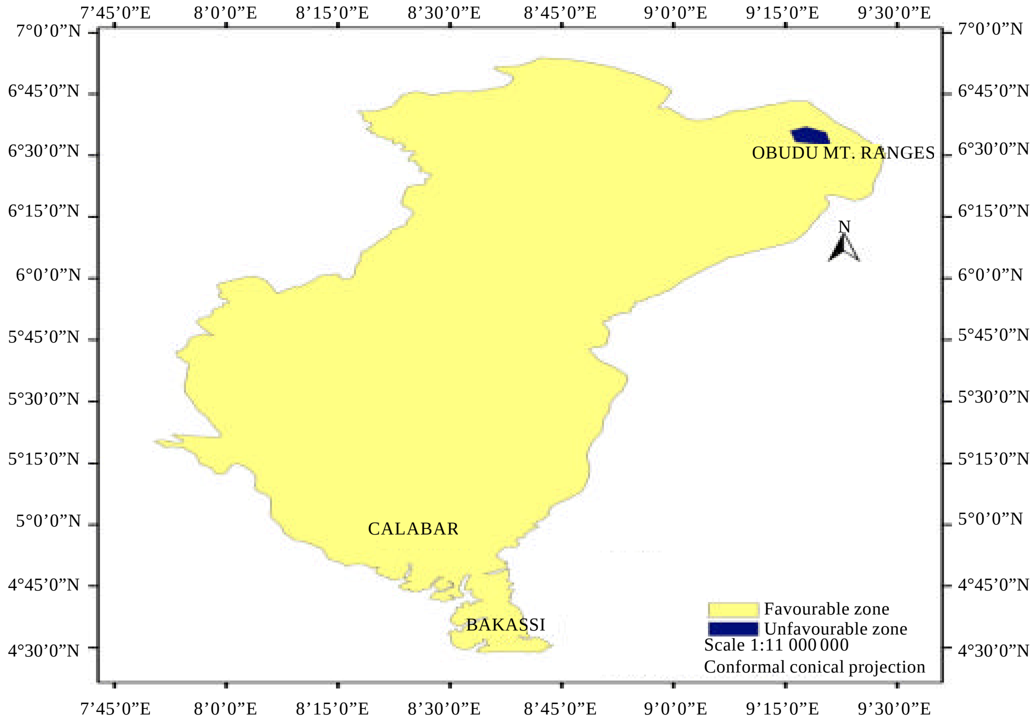

Fig. 1: Malaria predictive map of cross river state

the Mamfene area that a prevalence of cases was recurring at a specific geographic location. It was expected that a breeding focus probably existed at that location as well. Although, little could be determined from first attempts to plot the findings at a 1:250, 000 scale, when these coordinates were plotted on a 1:50, 000 topographic maps, they coincided with a water body in the area (Fig. 2).

Streams buffer-modelling to malaria risk: The normal flight range of mosquitoes as suspected is estimated to be within the range of 1500 m. Hence, a buffer of 1500 m is created around the rivers as well as streams in the study area. Further analysis is targeted towards looking at the number of communities located within these breeding sites as well as communities located outside these sites. Therefore Fig. 3 shows a 1500 m buffer away from streams.

Communities' buffer-modelling of malaria risk: Distances between population centres and breeding sites were estimated through buffer operation in Fig. 4 and maps associating epidemiologic and entomologic data were generated. Risk of malaria transmission was assessed with consideration of vectorial capacity and flight range of each *Anopheles* species. However, independent samples test statistics was employed to compare the relationship between location A and B.

Where:

A = Location within the Buffer zone

B = Location outside the Buffer Zone

Result: t-calculated = 2.20; table-t = 1.86; df = 8 and alpha level = 5%. Therefore, result of independent samples test indicates that there is a significant difference between malaria prevalence clinical cases in area within the buffer zone than area outside the buffer zone. According to World Health Organization estimates of about 110 million clinical cases of malaria worldwide per year over 80% of these occur in Africa south of the Sahara. Malaria is transmitted by *Anopheles* mosquitoes which breed in surface water pools where environmental conditions are suitable for both vector and parasite development (WHO, 2006).

GPS spot survey data to modelling occurrence of malaria vector species: The resultant maps are obtained by integrating the five thematic maps using the Boolean model. The favourable areas for malaria vector specie are shown in yellow while the deep blue colour area represents unfavourable area. However, the spot distribution of three major malaria vector species *An. melas*, *An. gambiae* and *An. arabiensis* obtained with the use of GPS is represented in Fig. 5. A greater part

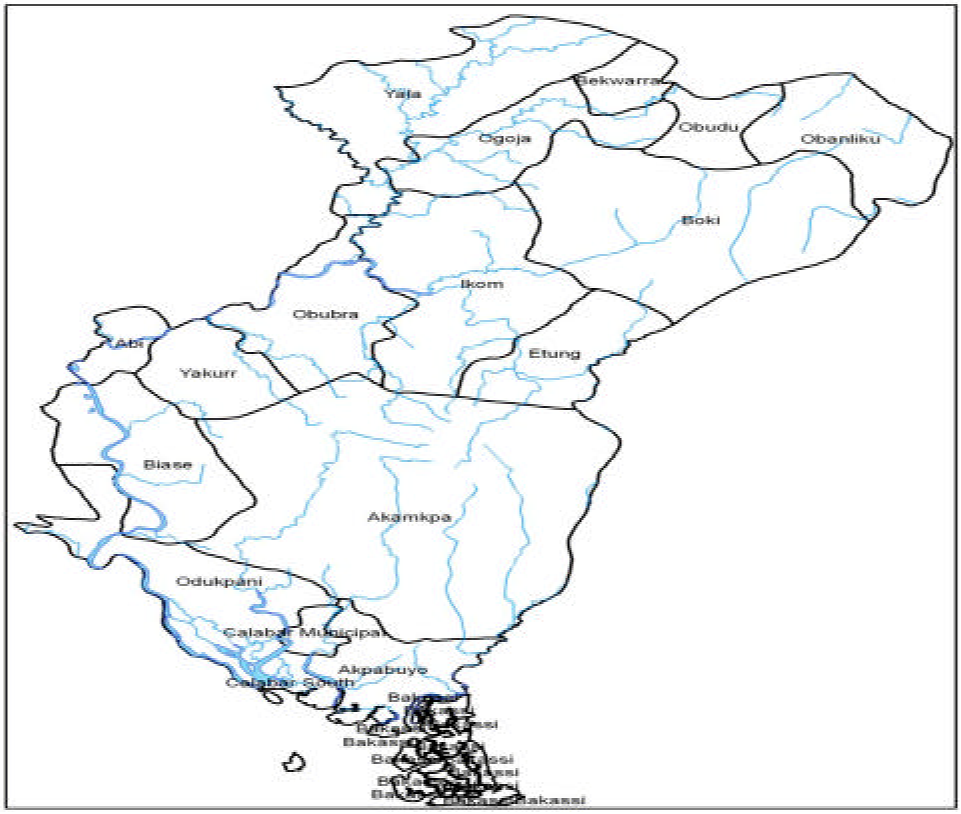

Fig. 2: Cross river state map showing rivers

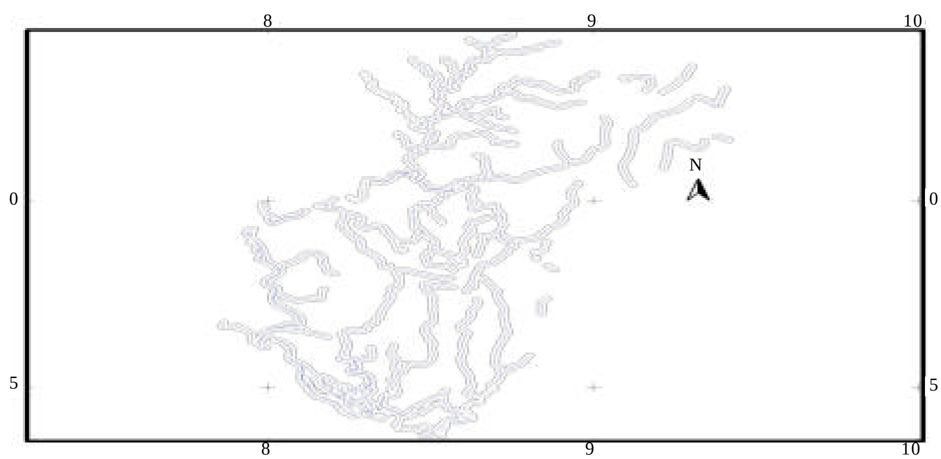

Fig. 3: Buffer of 1500 m

of the central region and eastern fringes of the region is dominated by *An. melas*. *An. gambiae* is observed from the southern favourable zone of Cross River and parts of the northern mountain ranges while pockets of *An. arabiensis* where recorded also in the southern region of the state. This therefore implies that *An. melas* and *An. gambiae* are the dominant malaria vector species (Fig. 5).

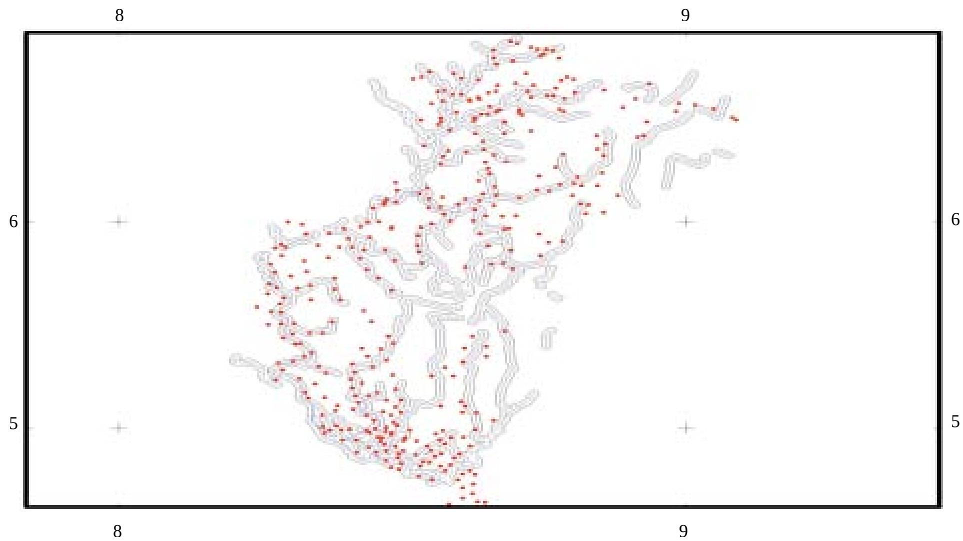

Fig. 4: Map of cross river state showing communities within and outside the buffer zone

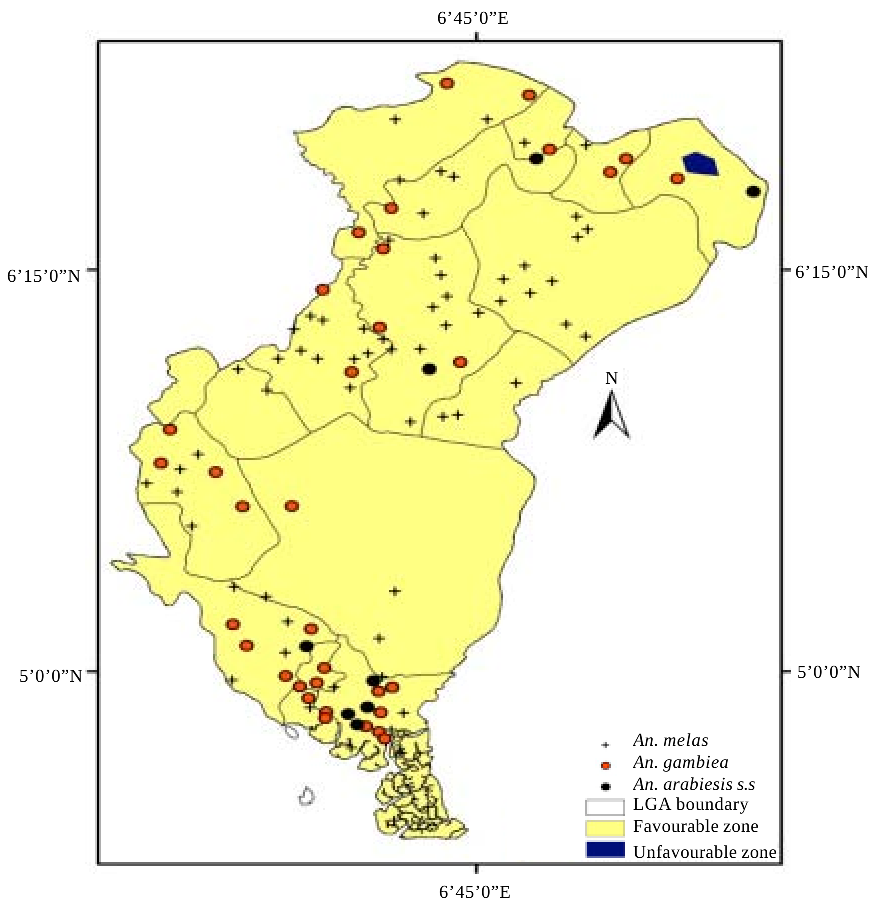

Fig. 5: GPS spot of occurrence of malaria vector species

DISCUSSION

The GIS-predicted new areas for distribution of malaria vector species offers insight into the prevailing environmental circumstances necessary for malaria prevalence in the study area. The spot survey analysis show that *An. melas*, *An. gambiae* and *An. arabiensis* species are observed across the north-eastern, central and south parts of the state particularly Calabar, Odukpani and part of Oban low lands while *An. melas* is predominant in Yakurr, Boki, Etung and Ikom. In a similar study, Henri *et al.* (2010) identified *Anopheles gambiae, Anopheles arabiensis* and *Anopheles funestus* as major *Anopheles* vector-species most responsible for malaria transmission in Africa. It is observed that GIS-based distribution overlaps the areas where the species has been reported earlier. Besides these areas, there are some new areas where surveys have not been conducted and the species (*An. melas*, *An. gambiae* and *An. arabiensis*) are likely to be found, example is the Akamkpa area. However, for validation, GIS-predicted areas were compared with reported distribution at micro level. The study shows that large area in Cross River, basically Akamkpa and Obanliku are favourable to *An. gambiea.* The species has also been reported in Ikom Local Government border, Etung near the Cameroun Border and Agbokum water fall area. The study through GIS also maps some areas favourable on the Akpabuyo border.

In Biase and Boki Local Government Areas, the deciduous moist forests on the eastern and western sides are favourable to *An. melas*. The entire area of Odukpani is also favourable to *An. arabiensis* species. The findings here are consistent with those of Kleinschmidt (2001) that *An. gambiae* and *An. arabiensis* are extensively distributed throughout most of sub-Saharan Africa; and that *An. arabiensis* is more dominant in drier areas while in humid areas *An. gambiae* predominates. It is also corroborates the findings of Lindsay *et al.* (1998) and Coetzee *et al.* (2000) that *A. arabiensis* and *A. gambiae* to be favourable in warmer and wetter environments, respectively. Statistically, this study has shown that the more closely the communities to mosquito breeding site, the greater the risk of malaria infection. The independent samples test shows a significant difference between the two samples of malaria clinical case scenarios. In other words, clinical cases of malaria in communities within the buffer zone are by far higher than communities outside the zone. It therefore conforms to the first Law of Geography that closer things/phenomena are more related than distant things (Tobler, 1970).

It may be proper to point out that GIS maps the distribution at micro level and these boundaries have no conformity with political boundaries. However, the only zone that is not suitable for the survival and distribution of these malaria species is the Obudu mountain ranges in Obanliku Local Government Area. This is because mosquito's survival and longevity and duration of sporogony are temperature dependent. In a similar study, Thomas *et al.* (2004) identified temperature, rainfall and humidity as factor influencing the relative distribution of *Anopheles*. Kleinschmidt (2001) and Thomas *et al.* (2004) noted that mosquito's development and frequency of blood feeding is temperature dependent, as its infection increases with rising temperature. At temperature lower than 20°C, duration of sporogony in mosquito is prolonged beyond 30 days, i.e., more than the average mosquito's lifespan and hence active malaria transmission does not take place. Furthermore, at extreme temperatures, longevity of mosquitoes is drastically reduced (Beck *et al.*, 1994).

Kleinschmidt (2001) opined that below 16°C, the development of anopheles ceases; and that 20 and 30°C are the optimal range of temperature for most vectors. This is because temperatures above the optimal range or tolerance level reduce the longevity of adult vectors and very few will survive the sporogony cycle of becoming infective. Asikihia *et al.* (2011) identified temperature range of 14-19°C as the minimum requirement needed for parasite development and 25-27°C as the optimum temperature for mosquitoes to live and breed. Asikihia *et al.* (2011) specified 40°C to be the highest temperature parasites and mosquitoes can survive. The present study therefore reveals that temperature, rainfall, vegetation cover and humidity are major determinant factors for the spatial distribution *Anopheles* in Cross River State. These factors have also been reported by earlier studies (Henri *et al.*, 2010; Sankoh and Ye, 2011; Asikihia *et al.*, 2011). The study reveals therefore that about 99% of Cross River State is found favourable to the malaria vector species.

CONCLUSION

A successful application of GIS in epidemiological studies is based on accurate and up-to-date spatial and aspatial database. This study shows that 99% of Cross River State is favourable to malaria vector species survival as a result of the state's high precipitation and temperature. Three major anopheles species of mosquitoes are identified and they vary spatially across the state. However, GIS capability can never be overemphasized in that; it is possible to map areas that cannot be easily accessible giving time and strength. Therefore, the evolving technology should be giving a pride of place in various academic disciplines and in the state government's drive to making the state free of malaria vector infection. In areas of drug failure, more emphasis needs to be given to vector control measures such as improved housing and better waste management techniques. GIS-based distribution can pinpoint areas of occurrence of *An. melas*, *An. gambiea* and *An. arabiensis* species at micro level, where species-specific environmental-friendly control measures can be strengthened. The technique is nevertheless especially useful in mapping vast and inaccessible areas.

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