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GIS-based Modeling of Mosquitoes Population Dynamics in relation to Vegetation Distribution within University of Uyo Town Campus, Uyo, Akwa Ibom State, Nigeria.

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Abstract: The role of remote sensing and geographic information system (GIS) techniques is fast gaining prominence in the monitoring of vectors and infectious disease spread. Mosquitoes are important vectors of several diseases of humans across the world. In order to better understand some ecological aspects linking vegetation dynamics and vector population, we examined the spatial and temporal distribution of flora and malaria vector within university of Uyo town campus using GIS based techniques. The results showed that the flora and vector population varied significantly ($P<0.05$) between the studied locations per time within the campus. During the first week, the least mean (5.25) abundance of the vector was recorded at point 1 while the highest (28.5) was recorded at point 3. During the second week, the least mean (11.25) abundance of the vector was recorded at point 1 while the highest (29.25) was recorded at point 3. For the third week, the least mean (28.0) abundance of the vector was recorded at point 4 while the highest (58.25) was still recorded at point 3. During the fourth week, the least mean (14.25) abundance of the vector was recorded at point 4 while the highest (43.0) was recorded at point 3. On the other hand, the vegetation comprised of 16 plants species (mostly herbs and grasses) from 11 families. *Eleusine indica* was the most frequently (75%) encountered species. Conclusively, patterns of variation in mosquito population were sensitive to vegetation dynamics in studied sites within the campus. These observations have application in ecology and public health.
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1. Introduction

Mosquitoes have great medical significance because they constitute major public health problems across the world. Approximately up to one million people die due to mosquito-borne diseases and over 247 million people become ill in tropical and subtropical areas of the world as reported by the World Health Organization (Guruprasad *et. al*., 2014). These scores are related to such diseases as malaria, lymphatic filariasis, yellow fever, encephalitis and rift valley fever (Anosike *et al*., 2007). Hence, the diversity of mosquito species belonging to genera *Culex, Aedes* and *Anopheles* serves as significant vectors of several serious diseases (Weaver and Reisen, 2010; Kilpatrick, 2011). Furthermore, mosquito bites can cause a considerable annoyance and pain to humans. This nuisance also has negative economic consequences (Connelly and Carlson, 2009). Mosquitoes are among the most sensitive insects to environmental changes; their survival, density and distribution are dramatically influenced by small changes in environmental conditions (vegetation and landscape features, abiotic factors, latitudes, elevation, temperature, humidity and the availability of suitable larval habitats) (Grillet, (2000); Wamae *et al*., 2000; Berger *et al*., 2012).

It has been estimated that approximately one million people died from the direct consequences of *P. falciparum* malaria infection in 1997 (Snow *et al*., 1999) and that 75% of these deaths occurred among pre-school children. The malaria parasite is one of the most significant infectious agents' African children encounter as they pass through childhood. Malaria does not only pose a risk to human survival but the repeated clinical consequences of infection during early life place a burden on households, health services and ultimately the economic development of endemic nation (Bloom and Sachs, 1998, Mbong *et. al.* 2020). This justifies the scientific argument that malaria endemism in the tropics, especially in Africa, is contributory to its perpetual state of depressed economic growth. These macro-estimates of its economic burden and the strong correlation observed provides clear support for a renewed effort which was aimed at halving malaria mortality as at the year 2010. This was referred to as the Roll Back Malaria (RBM) initiative (Nabarro and Taylor, 1998). This optimistic goal had been conceived at a time when existing and affordable therapeutics were rapidly failing and health service provision dwindled with vaccines seen as a distant dream. This menace till now is further aggravated by poverty, conflict and corruption within the affected African states (Desowitz, 1999). Nevertheless, in line with escaping this desperation, there is a renewed hope offered by new and old approaches aimed at disease management and the prevention of infection.

From the foregoing, it is apparent that first-hand knowledge of key underlying factors in the environment affecting the endemism and distribution of these vectors is critically necessary. Since this knowledge may better contribute towards identifying and managing the vector spread. Hence, the integration of geographical information systems (GIS) techniques as rapid and accurate tools for the determination and prediction of vector numeric spread within study locations and relating it to vegetation physiognomy is a step forward in the right direction. In line with this, the present study aimed at assessing the abundance and distribution of mosquito populations in some selected locations in relation to vegetation distribution within the university campus using Geographic Information System.

2. Material and Methods

2.1 Study Area

This study was carried out within the vicinity of University of Uyo Town campus which situates in the Urban District of Uyo Local Government Area. Uyo city lies between longitudes 7° 55' 21" E and latitudes 4° 52' 35" N and is the capital of Akwa Ibom State which falls within the Niger-delta region of Nigeria. The town witness a marked dry season which spans mid-November to March whereas the wet season begins around April to October. The rain bearing onshore South-West wind and the North-East trade winds blowing across the Sahara which is associated with harmattan are the prevailing winds. The mean annual rainfall ranges from 300 mm to 3500 mm while mean annual temperature lies between 21^0C to 29^0C. The climate of the area supports a firm luxuriant tropical rain forest (Mbong, *et. al.* 2021).

2.2 Mosquito Abundance evaluation

Data on the abundance of female *Anopheles* mosquitoes were obtained from weekly collections at 4 sampling stations within the study area. Sampling stations were spread evenly (200-m distant) along three 2.4-km transects which intersected at a central station. Non-attractive methods were used (resting shelters) in order to avoid disrupting the natural distribution by attracting mosquitoes from outside of the immediate vicinities of sampling stations. Mosquitoes were aspirated from resting shelters (trash cans) using a hand-held vacuum between 0700 and 0900 hours throughout the study duration (June –July, 2019) of peak adult activity (Burkett-Cadena *et al.* 2008). Samples were returned to the laboratory for species-level identification using morphological characters of adult females (Darsie and Ward, 2005).

The analysis was focused on unfed females because this group (composed mostly of host seeking females) is the section of the population that is most important from the disease perspective, as potentially infectious vectors. In addition, since unfed females are physiologically geared towards finding a host, it is most plausible that this cohort in particular is influenced by host distribution. Blood-engorged and egg-laden (gravid) females are more concerned with locating sites for resting and / or oviposition than encountering a suitable host, respond differently to environmental cues than do un-fed females and were therefore excluded from the analysis.

For each week, the mosquito's abundance values were rescaled to reflect the season's overall abundance using the equation:

$$Abundance = \frac{Abundance_0 - Abundance_{min}}{Abundance_{max} - Abundance_{min}}$$

Where:
Abundance = the rescaled abundance for a particular month
$Abundance_0$ = the observed abundance for the month
$Abundance_{min}$ = the minimum abundance for the month,
$Abundance_{max}$ = the maximum abundance for all months within the study period.

2.3 Phyto-diversity sampling

Vegetation and soil were systematically sampled with a 1m x 1m quadrat. In each quadrat, plants were identified to species level and their frequency and density were obtained by enumeration. Unknown plant species were collected and identified with the aid of voucher specimens in Botany and Ecological studies Departmental Herbarium, University of Uyo, Nigeria according to the methods of Ogbemudia and Mbong (2013).

Species diversity indices was estimated following Shanon-Weinner's diversity equations:

$$H = -sum[(pi) \times \ln (pi)]$$

$$pi = \frac{\text{number of individual species}}{\text{total number of samples}}$$

$$D = 1 - \frac{\Sigma n(n-1)}{N(N-1)}$$

Where: n = number of individuals of species
N = total number of individuals of all species

Shannon-Weinner index were computed using site specific plant abundance data with the aid of Statistical software Past 7 (Hammer *et. al.* 2001).

2.4 GIS Modeling Techniques

Global positioning System (GPS) was used to track the coordinates of the different sampling points within the study area in which data were predetermined (weekly vector abundance and Shannon-Weinner index). These points were interpolated on a geo-referenced base map of Uyo using Arc GIS version 10.3. The weekly vector abundance and the Shannon-Weinner index of vegetation diversity were matched against the coordinates of the sampled points. Moreover, the Inverse distance Weighted (IDW) interpolation determined cell values using a linearly weighted combination of a set of sample points. In this the weight becomes a function of inverse distance. The different layers of the vector- vegetation parameters produced by the algorithm were employed to produce these maps.

3. Results

The results show the spatial and temporal variability in the abundance and distribution of female mosquitoes on a weekly basis across the sampling points within the campus. It records that during the first week, the least mean (5.25) abundance of the vector was recorded at point 1 while the highest (28.5) was recorded at point 3. During the second week, the least mean (11.25) abundance of the vector was recorded at point 1 while the highest (29.25) was recorded at point 3. For the third week, the least mean (28.0) abundance of the vector was recorded at point 4 while the highest (58.25) was still recorded at point 3. During the fourth week, the least mean (14.25) abundance of the vector was recorded at point 4 while the highest (43.0) was recorded at point 3 (Table 1). This reflected in GIS maps (FIG. 1 -4).

Table 2 reveals the floral composition of the study points within the University Campus. It reveals a total of 16 plants species (mostly herbs and grasses) from 11 families. *Eleusine indica* was the most frequently encountered species being present in three (3) points out of the four.

Table 3. Comparison of diversity indices (Sp, species number; Sr, speceis richness; Bd, beta-diversity; H', diversity; Cd, concentration of dominance; E, evenness/equitability).

Table 1: Phytodiversity and Mean Mosquitoes abundance (± SE) within the Study Area

Mean Abundance	Point 1	Point 2	Point 3	Point 4
Northing:	**5^0 2' 40.85" N**	**5^0 2' 18.57" N**	**5^0 2' 18.36" N**	**5^0 2' 10.68" N**
Easting:	**7^0 55' 27.26" E**	**7^0 55' 32.15" E**	**7^0 55' 25.97" E**	**7^0 55' 27.40" E**
Shannon-Weinner	0.993	0.6616	1.797	1.32
Week 1	5.25±0.21	13.25±2.19	28.5±1.21	11.25±1.06
Week 2	11.25±2.6	14.5±1.87	29.25±2.20	15.25±1.72
Week 3	44.75±4.31	41.5±5.22	58.25±2.11	28.0±3.02
Week 4	19±1.68	20.25±3.12	43±4.21	14.25±3.11

Table 2: Floral Composition within University of Uyo Town Campus

Point 1 (Long 5^0 2' 40.85" N; Lat.7^0 55' 27.26" E)	**Family**	**Growth habit**
Altenanthera sessils (L.) R.Br. ex DC.	Amaranthaceae	Herb
Eleusine indica (Linn.) Gaertn	Poaceae	Grass
Laportea aestuans (Linn.)	Urticaceae	Herb
Point 2 (Long 5^0 2' 18.57" N; Lat.7^0 55' 32.15" E)		
Acacia auriculiformis A. Cunn. Ex Benth	Fabaceae	Tree
Eleusine indica (Linn.) Gaertn	Poaeceae	Grass
Setaria verticilata (L.) P. Beauv.	Poaceae	Herb
Point 3 (Long 5^0 2' 18.36" N; Lat. 7^0 55' 25.97" E)		
Caladium bicolor Vent.	Araceae	Herb
Chromolaena odorata (L.) R. M. King & H. Rob.	Asteraceae	Shrub
Commelina benghalensis L.	Commelinaceae	Herb
Eleusine indica (Linn.) Gaertn.	Poaceae	Grass
Lagenaria breviflora (Benth.)	Cucurbitaceae	Herb
Solenostemon monostachyus (P. Beauv.) Briq.	Labiatae	Herb
Point 4 (Long 5^0 2' 10.68" N; Lat. 7^0 55' 27.40" E)		
Ageratum conyzoides Linn.	Asteraceae	Herb
Caladium bicolor Vent.	Araceae	Herb
Emilia sonchifolia (L.) DC. ex DC.	Asteraceae	Herb
Khyllinga erecta Schumach.	Cyperaceae	Sedge
Ludwigia erecta (L.) H. Hara	Onagraceae	Herb
Solenostemon monostachyus (P. Beauv.) Briq.	Labiatae	Herb
Tridax procumbens Linn.	Asteraceae	Herb
Xanthosoma sagittifolium (L). Schott	Araceae	Shrub

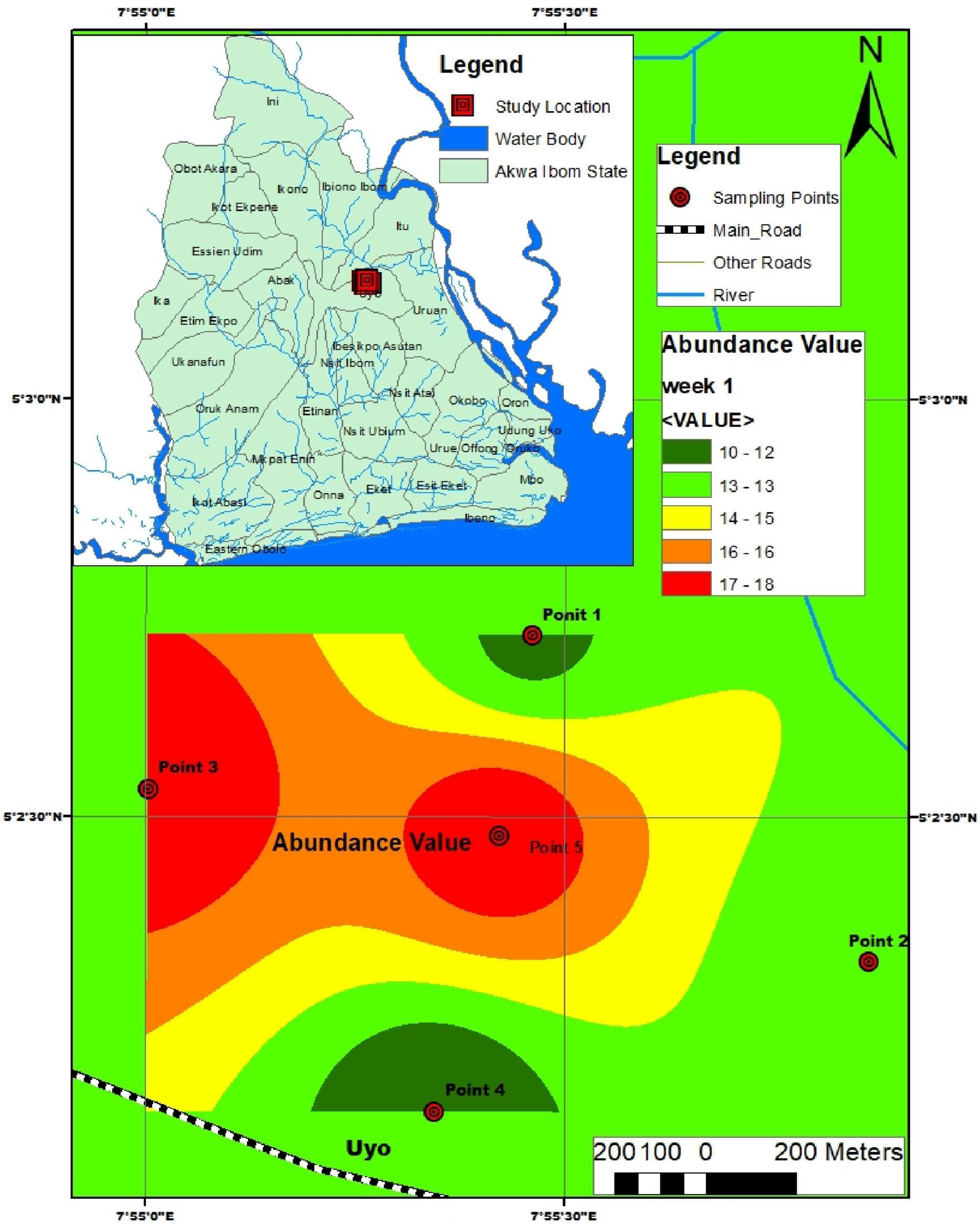

Figure 1: Abundance and Distribution of Female Mosquitoes for Week 1

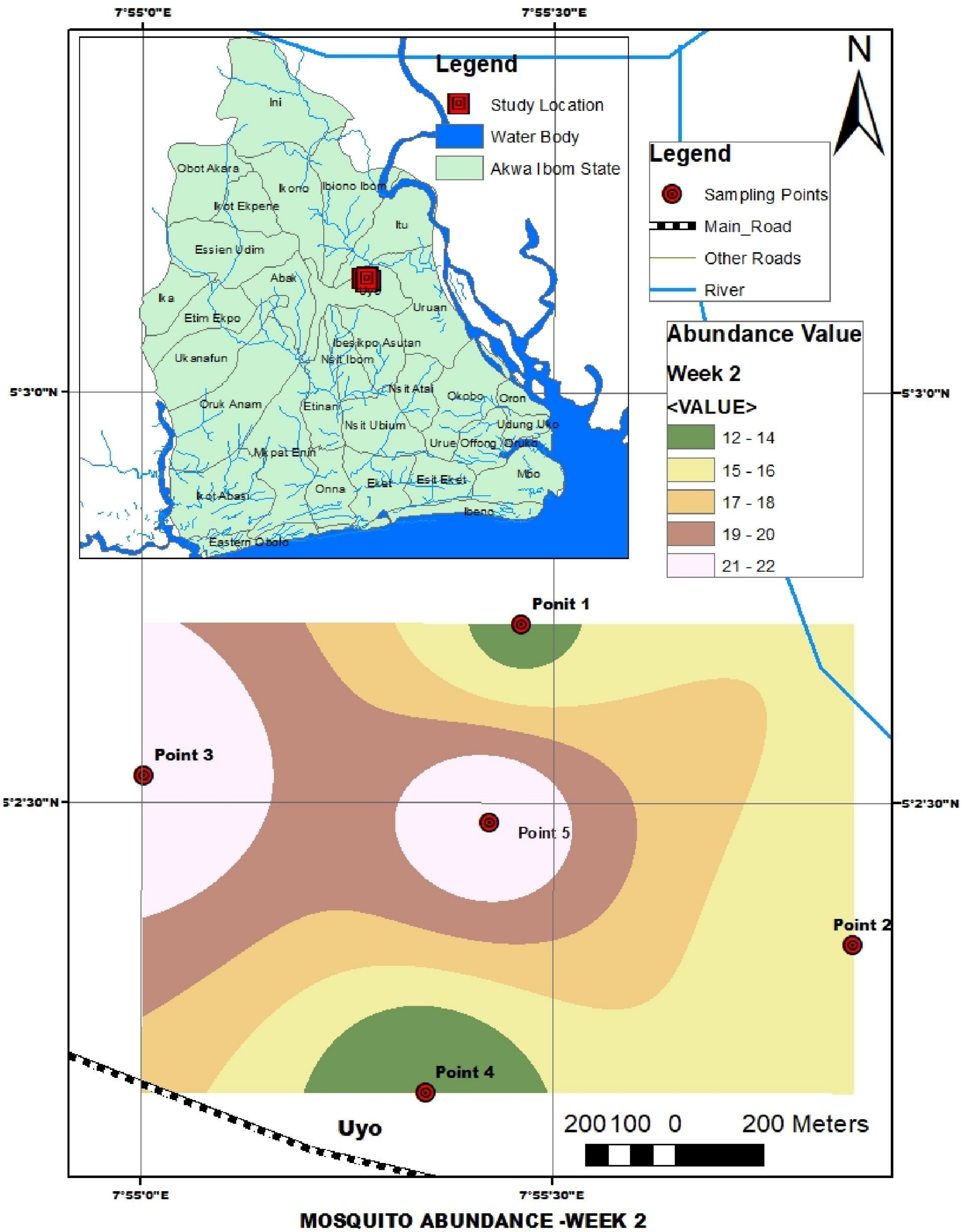

Figure 2: Abundance and Distribution of Female Mosquitoes for Week 2

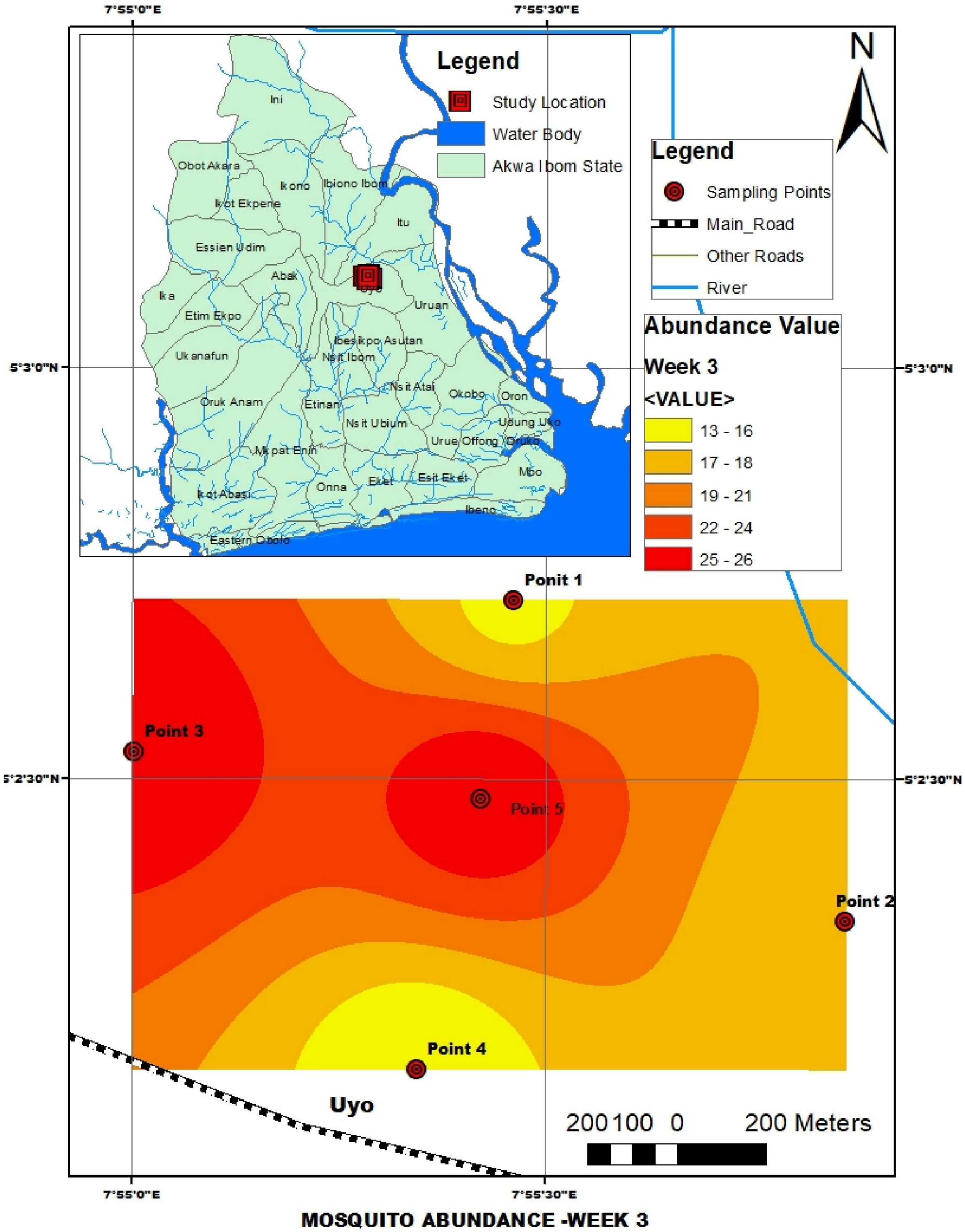

Figure 3: Abundance and Distribution of Female Mosquitoes for Week 3

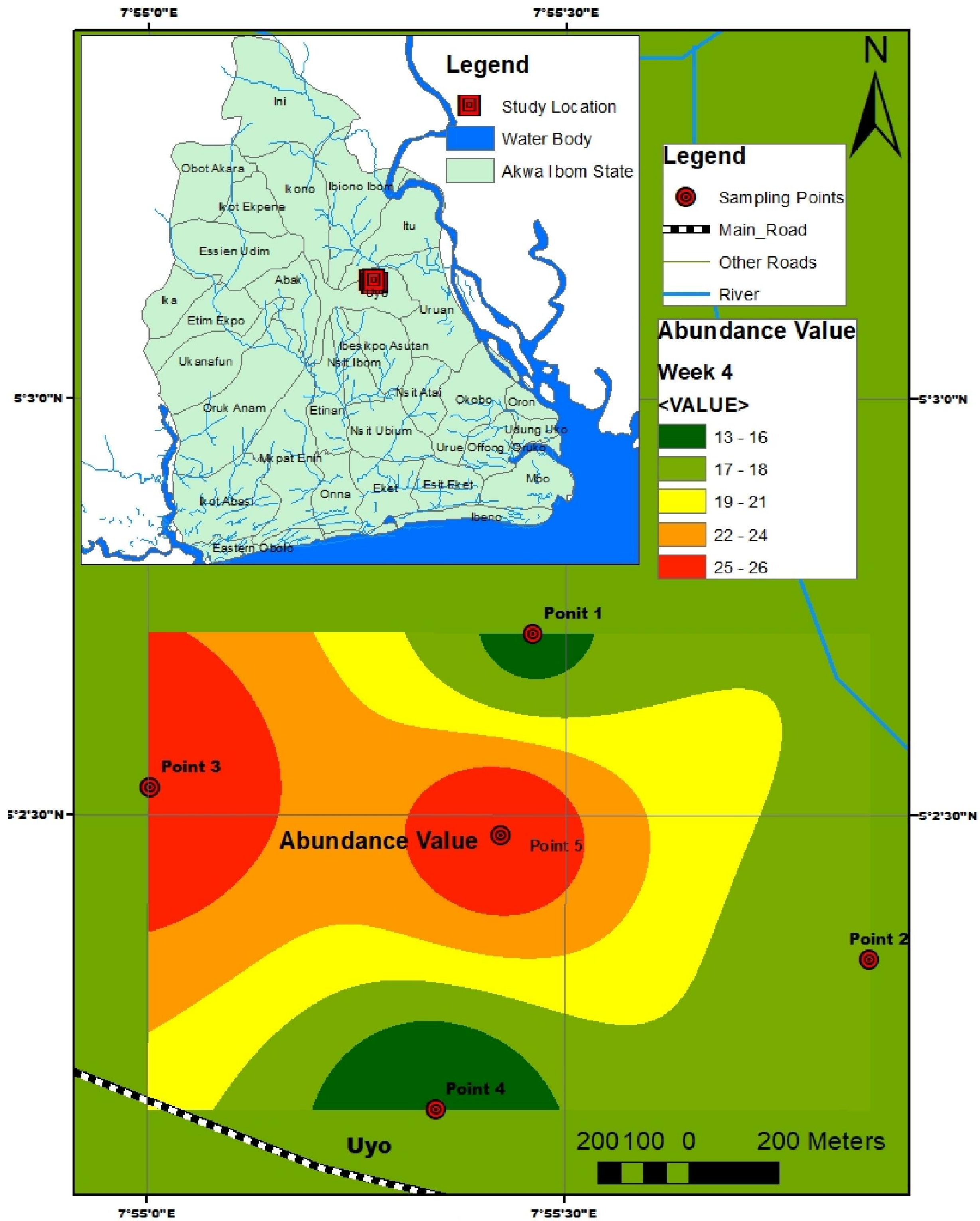

Figure 4: Abundance and Distribution of Female Mosquitoes for Week 4

4. Discussion

The result of the current study confirms the presence of Mosquitoes in the studied locations. Vector presence varied significantly ($P<0.05$) within locations throughout the period of study. This is consistent with the reports of (Keating *et. al*. 2004; Kenea *et. al*. 2011; Allison *et al*. 2013 and Burkett-Cadena *et. al.* 2013). The variation in numeric values of vector across the location and weeks are indications of preference or non-preference of different prevailing scenarios. This observation is well deserved since different studies have shown that mosquitoes are able to withstand different combinations of biotic and abiotic conditions. This variation most often than not is anchored within their immediate environments owing to the influence of natural and anthropogenic effects including vegetation density, host availability, presence of open pools and ponds, air temperature, shading effects, precipitation etc (Keating *et*. *al*. 2004, Burkett-Cadena *et. al.* (2013) and Mbong, *et. al.* 2021).

The evidences in this study confirm the applicability of GIS as an ecological modeling tool employed for monitoring and evaluation of vector population. This presentation further bear similarities with the reports of Kalluri *et al*., (2007) in their surveillance of arthropod vector–borne infectious diseases using remote sensing techniques; Tran *et al*., (2013) in presenting geographical information system-based multi criteria evaluation to map areas at risk for Rift Valley vector-borne transmission in Italy and El-Zeiny and Sowilem (2016b),who revealed the area under risk of mosquito transmitted diseases, using remote sensing and field surveys.

Though several conventional methods have been employed for vector borne disease control, most of these conventional methods have been based on the empirical knowledge and are more laborious, expensive, erroneous, and time consuming. The role of GIS modeling as highlighted in this result represents a viable and effective option. From this result, the integration of GIS technology may serve as a replacement for highly expensive or less effective conventional methods used in monitoring vector distribution and spread.

In this study, beyond mapping of the studied locations, the GIS technique offered and advantage of predicting vector abundance and species diversity at arbitrary locations within the grid neighborhood. This advantage made it possible for the establishment of a fifth random site (centrally proximal to the main four sites) within the grid with its corresponding vector abundance range. This may further emphasize the suitability of the technique in predicting spatial and temporal trends in this and other vector-borne disease transmission risk with reasonable accuracy.

Vegetation has been shown to alter the physico-chemical environment of mosquitoe larva in naturally occurring and artificial container habitats, such as tree holes and used tyres (Walker, *et. al.* 1991). Noticeable is the site-specific dissimilarities associated with the flora among breeding sites. This is believed to have contributed to the vicissitudes in vector spread within locations per time (Kenea *et al.* 2011). From the foregoing, it is clear that the presence of vegetation forms part of the constellation of ecological determinants influencing mosquito population within the campus.

The nature and density of vegetation components within different study sites have been shown to create micro-environments which influence site-specific vector distribution in previous reports (Tadesse *et. al.* 2011; Allison, *et. al.* 2013). This agrees with the results of the current study. For instance, higher mosquitos' population is being observed in site 3 compared to the other three locations. This may be justified by the abundance of broad-leaved plants specifically of the family Cucurbitaceae and Aracea which shade the containers (vector trap) from direct heat of the sun and thereby regulate the temperature at that site. Beyound the shading effects, plants leave serve as vector hide out from predators and resting places during the day. This synchronizes the reports of Tadesse *et al.*, (2011). Hence low vector population in other sites corresponds with sites with low species diversity, frequent clipping activities and fumigation activities around the hostel area. The existence of an open concrete reptile pond and drainage carnal around station 3 favor the massive breeding and proliferation of mosquitoe population. This agrees with the work of Knio *et al*. (2005), Ammar *et al*., (2012) and El-Zeiny and Sowilem, (2016a) who reported that pools of water associated with human activities favours the proliferation of mosquitoes.

5. Conclusion and Recommendation

In conclusion, it is obvious that the abundance of malaria vector as well as the flora in the study area vary distinctively with locations. These gaps portray with the natural and anthropogenic conditions prevailing in different sites within the campus. It is noted that vector population increased with plant species diversity especially in sites with broad-leaved herbaceous vegetation. It confirms the possibility of an integration scheme which could employ geographic information systems (GIS) techniques for effective management of malaria and other vector borne diseases. In line with this research efforts could be geared towards identifying the influence of specific abiotic factors on vector spread and the use of remote sensing and GIS technique to report such over a wider area.

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References

Allison, M., Gardner, T., Anderson, K., Hamer, L., Johnson, D. E., Varela, K. E., Walker, D. E. and Marilyn, O. R. (2013). Terrestrial Vegetation and Aquatic Chemistry Influence Larval Mosquito Abundance in Catch Basins, Chicago, U.S.A. *Parasites & Vectors*; 6: 1-9.

Ammar, S. E., Kenawy, M. A., Abdel-Rahman, H. A., Ali, A. F., Abdel-Hamid, Y. M. and Gad, A. M. (2012). Characterization of the mosquito breeding habitats in two urban localities of Cairo Governate, Egypt. *Greener Journal of Biological Science*, 3(7): 268-275.

Anosike, J.C., Nwoke, B. E., Okere, A. N., Oku, E. E., Asor, J. E., Emmy-Egbe, I. O. and Adimike, D. A. (2007). Epidemiology of tree-hole breeding mosquitoes in the tropical rainforest of Imo State, South-East Nigeria. *Ann. Agric. Environ. Med*., 14: 31-38.

Berger, F. Flamand, C. Musset, L. Djossou, F. Rosine, J. and Sanquer, M. A. (2012). Investigation of a sudden malaria outbreak in the isolated Amazonian village of Saul, French Guiana. *American Journal of Tropical Medicine and Hygiene*, 86(4):591-597.

Bloom, D. E., and Sachs, J. D. (1998). Geography, demography, and economic growth in Africa. *Brookings Pap. Econ. Act.*; 207–295.

Burkett-Cadena, N., Graham, S. P., and Giovanetto, L. A. (2013). Resting Environments of some Costa Rican Mosquitoes. *J Vector Ecol.*; (1):12-9.

Burkett-Cadena; N. D., Eubanks, M. D. and Unnasch, T. R. (2008). Preference of female mosquitoes for natural and artificial resting sites. *J. Am. Mosq. Contr. Assoc.* **24**: 228–235.

Connelly, C. R and Carlson, D. B (Eds.). (2009). Florida Coordinating Council on Mosquito Control. Florida Mosquito Control: The state of the mission as defined by mosquito controllers, regulators, and environmental managers. Vero Beach, FL: University of Florida, Institute of Food and Agricultural Sciences, Florida Medical Entomology Laboratory.

Darsie, R.F. and R.A. Ward. (2005). *Mosquitoes of North America, North of Mexico*. University of Florida Press, Gainesville. 383 pp.

Desowitz, R. (1999). Milestones in the history of malaria. In: Wahlgren M, Perlmann P, eds. *Malaria.* Amsterdam: Harwood Academic.

El-Zeiny, A. M. and Sowilem, M. M. (2016a). Environmental Characterization for the Area under Risk of Mosquito Transmitted Diseases, Suez Canal Zone using Remote Sensing and Field Surveys. *Journal of Environmental Sciences*; 45(3-4): 283-297.

El-Zeiny, A., El- Hefni, A. and Sowilem, M. (2016b). Geospatial techniques for environmental modelling of mosquito breeding habitats at Suez Canal Zone, Egypt. *Egyptian Journal of Remote Sensing and Space Sciences*, 20: 283-293.

Grillet, M. E. (2000). Factors associated with distribution of Anopheles aquasalis and Anopheles oswaldoi (Diptera: Culicidae) in a malarious area, Northeastern Venezuela. *Journal of Medical Entomology*, 37(2):231-238.

Guruprasad, N. M, Jalali, S. K. and Puttaraju, H. P. (2014). Wolbachia-a foe for mosquitoes. *Asian Pac J Trop Dis*; 4: 78-81.

Hammer, O., Harper, D. A., and Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica, 4(1), 1–9.

Kalluri, S., Gilruth, P., Rogers, D. and Szezur, M. (2007). Surveillance of arthropod vector-borne infectious diseases using remote sensing techniques: a review. *PLoS Pathogen,* 3:16.

Keating, J., Macintyre, K., Mbogo, C. M., Githure, J. I. and Beier, J. C. (2004). Characterization of potential larval habitats for Anopheles mosquitoes in relation to urban land-use in Malindi, Kenya. *International Journal of Health Geographics*; 3: 9-16.

Kenea, O., Balkew, M. and Gebre-Michael, T. (2011). Environmental factors Associated with larval habitats of anopheline mosquitoes (Diptera: Culicidae) in irrigation and major drainage areas in the middle course of the Rift Valley, Central Ethiopia. *Journal of Vector Borne Diseases*; 48(2): 85–92.

Kilpatrick, A. M. (2011). Globalization land use and the invasion of West Nile virus. *Science;* 334(6054): 323-327.

Knio, K. M., Markarian, N., Kassis, A. and Nuwayri-Salti, N. (2005). A two-year survey in mosquitoes of Lebanon. *Parasite,* 12(3): 229-235.

Mbong, E. O, George, U. U. and Edem, E. N. (2021). Phyto-environmental variables, Mosquitoe Abundance and Malaria prevalence in University of Uyo town Campus. Reports and Opinion, 13 (4): 11-18.

Mbong, E. O., Edem, E. N and Sajjad, H. (2020). Awareness and Measures utilized by Pregnant women in the Prevention of malaria in sub-urban communities in Eket local Government Area. *Journal of Environmental Science and Public health*; 4(3):175-183.

Nabarro, D. N and Taylor, E. M. (1998). “The Roll Back Malaria campaign.” Science 280, 2062–2068.

Ogbemudia, F. O. and Mbong, E. O. (2013). Studies on Some Pedological Indices, Nutrient Flux Pattern and Plant Distribution in Metropolitan Dumpsites in Uyo, Akwa Ibom State. Indian Journal of Pharmaceutical and Biological Research, Vol. 1 (1), 40 – 45.

Snow, R. W., Craig, M., Deichmann, U. and Marsh, K. (1999). "Estimating mortality, morbidity and disability due to malaria among Africa's non-pregnant population. *Bulletin of the World Health Organization*; 77(8): 624-40.

Tadesse, D., Mekonnen, Y. and TSEHAYE, A. (2011). Characterization of mosquito breeding sites in and in the vicinity of Tigray microdams. *Ethiopian Journal of* Health Sciences; 10: 57–66.

Tran, A., Ippoliti, C., Balenghien, T., Conte, A., Gely, M., Calistri, P., Goffredo, M., Baldet, T. and Chevalier, V. (2013). A geographical information system-based multicriteria evaluation to map areas at risk for Rift Valley fever vector-borne transmission in Italy. *Transboundary and Emerging* Diseases; 60(2): 14-23.

Walker, E. D., Lawson, D. L, Merritt, R.W., Morgan, W.T. and Klug, M. J. (1991). Nutrient dynamics, bacterial populations, and mosquito productivity in tree hole ecosystems and microcosms. Ecology 72: 1529–1546.

Wamae, P. M. Githeko, A. K. Menya, D. M. and Takken, W. (2010). Shading by napier grass reduces malaria vector larvae in natural habitats in Western Kenya highlands. *Ecological health*; 7(4):485-497.

Weaver, S. C. and Reisen, W. K. (2010). Present and future arboviral threats. *Antiviral Resources*; 85: 328-345.

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