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.


Keywords: GIS Based Modelling, Mosquitoe, Population Dynamics, Vegetation Distribution, Public Health, University of Uyo.

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...
2. Material and Methods
2.1 Study Area

This study was carried out within the vicinity 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°C to 29°C. 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:

\[
\text{Abundance} = \frac{\text{Abundance}_o - \text{Abundance}_{\text{min}}}{\text{Abundance}_{\text{max}} - \text{Abundance}_{\text{min}}}
\]

Where:
- Abundance = the rescaled abundance for a particular month
- Abundance$_o$ = the observed abundance for the month
- Abundance$_{\text{min}}$ = the minimum abundance for the month,
- Abundance$_{\text{max}}$ = 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:

\[ H = -\sum (p_i \times \ln p_i) \]
\[ \pi = \frac{\text{number of individual species}}{\text{total number of samples}} \]
\[ D = 1 - \frac{\Sigma n(n - 1)}{N(N - 1)} \]

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, specieis richness; Bd, beta-diversity; H', diversity; Cd, concentration of dominance; E, evenness/equitability).

<table>
<thead>
<tr>
<th>Mean Abundance</th>
<th>Point 1</th>
<th>Point 2</th>
<th>Point 3</th>
<th>Point 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northing:</td>
<td>5° 2' 40.85&quot; N</td>
<td>5° 2' 18.57&quot; N</td>
<td>5° 2' 18.36&quot; N</td>
<td>5° 2' 10.68&quot; N</td>
</tr>
<tr>
<td>Easting:</td>
<td>7° 55' 27.26&quot; E</td>
<td>7° 55' 32.15&quot; E</td>
<td>7° 55' 25.97&quot; E</td>
<td>7° 55' 27.40&quot; E</td>
</tr>
<tr>
<td>Shannon-Weinner</td>
<td>0.993</td>
<td>0.6616</td>
<td>1.797</td>
<td>1.32</td>
</tr>
<tr>
<td>Week 1</td>
<td>5.25±0.21</td>
<td>13.25±2.19</td>
<td>28.5±1.21</td>
<td>11.25±1.06</td>
</tr>
<tr>
<td>Week 2</td>
<td>11.25±2.6</td>
<td>14.5±1.87</td>
<td>29.25±2.20</td>
<td>15.25±1.72</td>
</tr>
<tr>
<td>Week 3</td>
<td>44.75±4.31</td>
<td>41.5±5.22</td>
<td>58.25±2.11</td>
<td>28.0±3.02</td>
</tr>
<tr>
<td>Week 4</td>
<td>19±1.68</td>
<td>20.25±3.12</td>
<td>43±4.21</td>
<td>14.25±3.11</td>
</tr>
<tr>
<td>Point 1 (Long $5^\circ$ 2' 40.05&quot; N; Lat. $7^\circ$ 55' 27.26&quot; E)</td>
<td>Family</td>
<td>Growth habit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td>--------</td>
<td>-------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altenanthera sessils (L.) R.Br. ex DC.</td>
<td>Amaranthaceae</td>
<td>Herb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eleusine indica (Linn.) Gaertn</td>
<td>Poaceae</td>
<td>Grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laportea aestuans (Linn.)</td>
<td>Urticaceae</td>
<td>Herb</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Point 2 (Long $5^\circ$ 2' 18.57&quot; N; Lat. $7^\circ$ 55' 32.15&quot; E)</th>
<th>Family</th>
<th>Growth habit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia auriculiformis A. Cunn. Ex Benth</td>
<td>Fabaceae</td>
<td>Tree</td>
</tr>
<tr>
<td>Eleusine indica (Linn.) Gaertn</td>
<td>Poaceae</td>
<td>Grass</td>
</tr>
<tr>
<td>Setaria verticillata (L.) P. Beauv.</td>
<td>Poaceae</td>
<td>Herb</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Point 3 (Long $5^\circ$ 2' 18.36&quot; N; Lat. $7^\circ$ 55' 25.97&quot; E)</th>
<th>Family</th>
<th>Growth habit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caladium bicolor Vent.</td>
<td>Araceae</td>
<td>Herb</td>
</tr>
<tr>
<td>Chromolaena odorata (L.) R. M. King &amp; H. Rob.</td>
<td>Asteraceae</td>
<td>Shrub</td>
</tr>
<tr>
<td>Commelina benghalensis L.</td>
<td>Commelinaceae</td>
<td>Herb</td>
</tr>
<tr>
<td>Eleusine indica (Linn.) Gaertn</td>
<td>Poaceae</td>
<td>Grass</td>
</tr>
<tr>
<td>Lagenaria breviflora (Benth.)</td>
<td>Cucurbitaceae</td>
<td>Herb</td>
</tr>
<tr>
<td>Solenostemon monostachyus (P. Beauv.) Briq.</td>
<td>Labiatae</td>
<td>Herb</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Point 4 (Long $5^\circ$ 2' 10.68&quot; N; Lat. $7^\circ$ 55' 27.40&quot; E)</th>
<th>Family</th>
<th>Growth habit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ageratum conyzoides Linn.</td>
<td>Asteraceae</td>
<td>Herb</td>
</tr>
<tr>
<td>Caladium bicolor Vent.</td>
<td>Araceae</td>
<td>Herb</td>
</tr>
<tr>
<td>Emilia sonchifolia (L.) DC. ex DC.</td>
<td>Asteraceae</td>
<td>Herb</td>
</tr>
<tr>
<td>Khyllinga erecta Schumach.</td>
<td>Cyperaceae</td>
<td>Sedge</td>
</tr>
<tr>
<td>Ludwigia erecta (L.) H. Hara</td>
<td>Onagraceae</td>
<td>Herb</td>
</tr>
<tr>
<td>Solenostemon monostachyus (P. Beauv.) Briq.</td>
<td>Labiatae</td>
<td>Herb</td>
</tr>
<tr>
<td>Tridax procumbens Linn.</td>
<td>Asteraceae</td>
<td>Herb</td>
</tr>
<tr>
<td>Xanthosoma sagittifolium (L.). Schott</td>
<td>Araceae</td>
<td>Shrub</td>
</tr>
</tbody>
</table>
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 bears 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 mosquito 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. Beyond 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 mosquito 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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