**MODELLING OF HABITAT SUITABILITY FOR LARVA MOSQUITOES**

Introduction

The qualities of water in breeding sites play a crucial role in both the laying of eggs and the growth of mosquitoes. The number of mosquito larvae is contingent on several factors, including vegetation, temperature, turbidity, acidity, and the concentrations of various substances, including ammonia, nitrite, nitrate, sulfate, phosphate, chloride, calcium, and hardness of the water (Nikookar et al., 2017). Even more, habitat types and ecozones are critical to mosquito survival and reproductive success.

While many researchers study a single population, there is a paucity of studies showing the multiple effect of physicochemical properties on multiple mosquito populations simultaneously. These factors may not equally affect every mosquito larva due to species physiology differences and environmental growth requirements. Not much data currently exists regarding the physiochemical characteristics of mosquito larval habitats for multiple species in Nigeria.

**RESULT**

In total, 642 larva mosquitoes were collected across all sites and habitats. This included 91 *Anopheles*, 200 *Culex* and 351 *Aedes* species. Correspondence analysis (CA) biplot showed that *Aedes* was most associated with containers and puddles, Culex with used tyres, and anopheles with Tyre tracks. Overall, most mosquitoes were collected from used tyres (320), puddles (210) and containers (43) (see Tabe 1).

According to the Principal component analysis (PCA), the first two axes explained 55.5% of total variation. The first axis accounted for 41.2% of data variance, with total solid, suspended solid, colour, magnesium, sulphate, hardness, chloride, turbidity and Nitrate as the variables that most contributed to explaining the dataset variation. TDS, Conductivity, Alkalinity, pH, phosphate and turbidity were the main variables explaining the second component (accounting for 14.3% of the variance).

PCA of the habitats and ecozones is represented in Figure \_ Puddles and tyre tracks had the most heterogeneous clusters. Containers and used tyres were the most homogenous, with great overlap in their clustering (Figure \_). Furthermore, the PCA ordination did not show much disparity in the characteristics of each habitat in the ecozones.

The correlation matrix of physicochemical properties of the habitats is represented in Figure \_. Pearson’s correlation matrix (Figure\_) depicts that turbidity was strongly positively correlated (r >=0.7) with colour, suspended solids and Total solids. DO was negatively correlated with all assessed physicochemical variables, except pH and water depth. A similar observation was seen with Depth.

Table 1: Mosquito larvae collected at the sampling locations and their abundance.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Habitat (n) | Anopheles (%) | Culex (%) | Aedes (%) | Mean ± SD | Total (%) |
| Containers (6) | 0 (0) | 4 | 39 | 7.17±11.29 | 43 (100) |
| Gutters (3) | 21 | 12 | 2 | 11.67±17.62 | 35 (100) |
| Puddles (5) | 25 | 25 | 160 | 42.00±70.03 | 210 (100) |
| Tyre track (5) | 34 | 0 | 0 | 6.80±6.49 | 34 (100) |
| Used tyres (13) | 11 | 159 | 150 | 24.61±20.78 | 320 (100) |

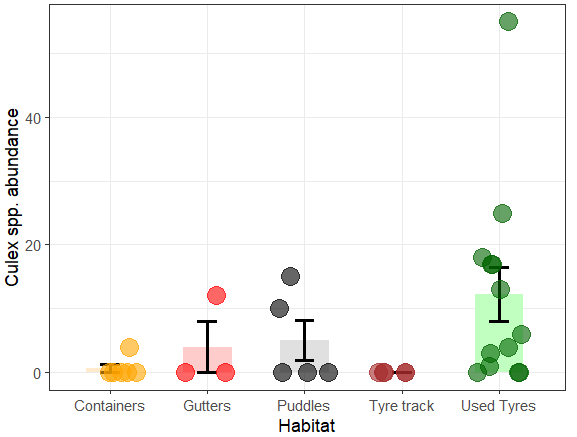
n= number of samples; SD= Standard Deviation

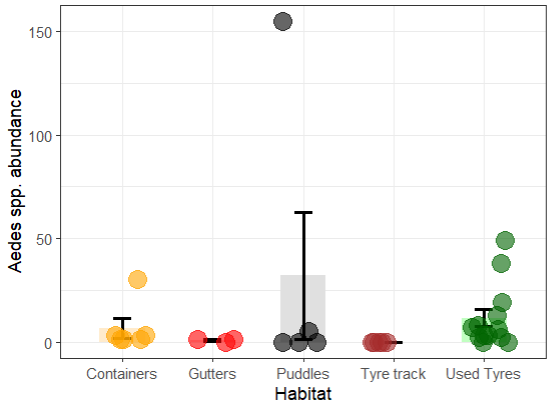
Culex larvae were more prevalent in used tyres compared to other environments, with a density of 12.23 ± 15.38. Aedes larvae showed significantly higher densities in both used tyres and puddles compared to other habitats, having mean densities of 11.54±15.34 and 32.00±68.79, respectively.

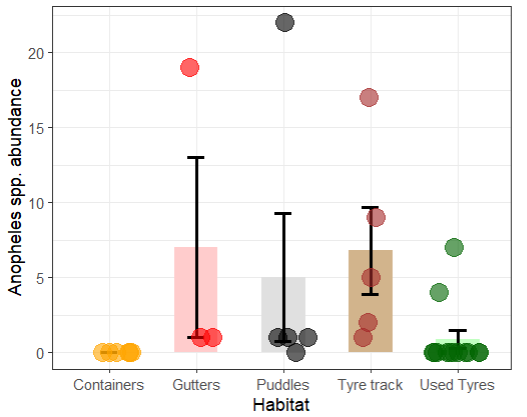
Used tyres harbored the highest density of Culex larvae (12.23±15.38), significantly differing from other habitats (P<0.05), while Culex larval abundance was highest in used tyres and absent in Tyre tracks.

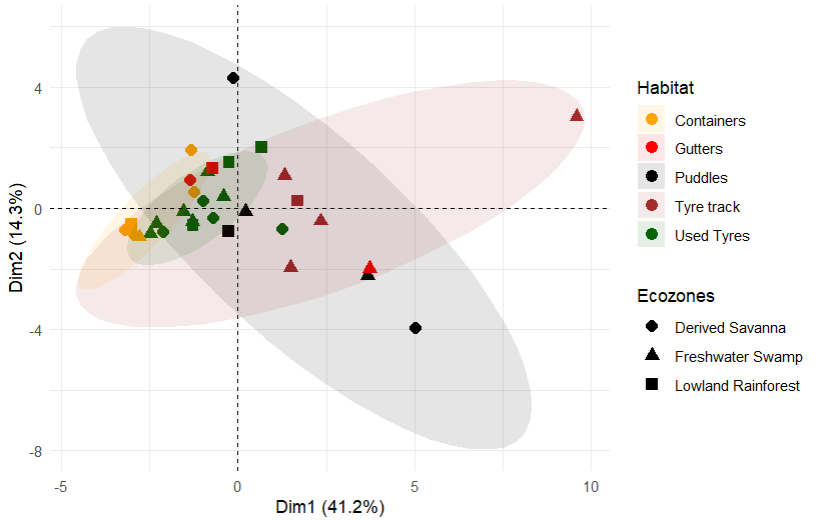
For Anopheles, larval mosquito abundance did not significantly (P>0.05) differ between gutters (7.00±10.39), puddles (5.00±9.51), and tyre tracks (6.80±6.49). However. Containers had no presence of Anopheles larvae and did not significantly differ from used tyres which had a density of 0.84±2.15.

Culex and Aedes larvae were not observed in tyre tracks, while Aedes larvae were absent in containers.









Figure\_: PCA of habitat and their ecozones. Ellipse was set to a 95% confidence interval (CI). However, CI could not be calculated for “Gutters” due to few data points.

Table 2: Physicochemical properties of mosquito larva habitats, represented as mean ± standard deviation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Habitat | Container | Gutters | Puddles | Tyre tracks | Used tyres |
| pH | 6.15±0.35 | 7.03±1.21 | 6.94±0.67 | 7.3±1.01 | 6.6±0.88 |
| Colour | 81.16±36.82 | 1878±2877.07 | 3139.6±2781.72 | 4153.4±31 | 608.15±797.83 |
| Turbidity | 12.333±7.94 | 436.33±661.42 | 817.4±842.95 | 855.8±484.35 | 77.92±89.82 |
| TDS | 57.42±67.32 | 81.27±46.31 | 108.12±104.37 | 106±64.04 | 70.94±30.94 |
| Suspended Solid | 8.33±5.98 | 250.67±378.77 | 374±324.79 | 776±687.10 | 129.92±278.72 |
| Total Solid | 65.75±67.47 | 331.93±370.20 | 482.12±287.72 | 882±730.19 | 200.86±273.88 |
| Conductivity | 108.33±127.03 | 153.33±87.37 | 204±196.93 | 200±120.83 | 133.85±58.39 |
| Chloride | 14.12±6.31 | 32.94±4.07 | 50.832±40.06 | 39.536±22.66 | 22.81±16.34 |
| Alkalinity | 29.33±21.75 | 86±72.58 | 57.6±15.71 | 87.2±66.19 | 53.85±35.11 |
| Hardness as CaCO3 | 25.67±29.59 | 53.33±41.05 | 83.6±66.31 | 116.4±68.31 | 54.15±36.28 |
| Phosphate | 0.49±0.40 | 3.67±2.49 | 36.082±74.12 | 5.046±3.51 | 1.13±0.99 |
| Sulphate | 17.5±18.98 | 88.67±101.93 | 35±26.63 | 119.8±128.26 | 29.46±14.40 |
| Nitrate | 5.94±7.43 | 28.73±37.18 | 28.538±25.68 | 27.14±17.71 | 10.75±11.95 |
| DO | 7.38±1.58 | 4.8±4.42 | 2.62±1.64 | 3.82±2.49 | 4.08±1.82 |
| BOD | 2.56±1.42 | 16.03±20.67 | 10.282±6.69 | 12.54±17.42 | 9.09±14.66 |
| Calcium | 7.61±11.61 | 18.95±15.45 | 26.934±21.08 | 28.70±19.31 | 16.28±13.40 |
| Magnesium | 1.38±1.08 | 1.62±1.13 | 3.988±3.64 | 10.79±9.70 | 2.62±1.65 |

Table : Results of the generalized linear mixed model (GLMM) of the number of immature Anopheles in larval habitats.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Dependent variable** | **Effect** | **Term** | **Estimate** | **SE** | **Z-Value** | **p-value** |
| Anopheles Count | Fixed | Intercept | -0.1065 | 0.9494 | -0.112 | >0.05 |
|  |  | Turbidity | -0.8887 | 0.2863 | -3.104 | <0.01 |
|  |  | DO | -2.6321 | 0.4059 | -6.485 | <0.001 |
|  |  | *Culex* count | -0.5686 | 0.2636 | -2.157 | <0.05 |
|  |  | *Aedes* count | -1.0627 | 0.2632 | -4.037 | <0.001 |
|  |  | Depth | 1.3394 | 0.3687 | 3.633 | <0.001 |
|  |  | Magnesium | -0.6989 | 0.1834 | -3.810 | <0.001 |
|  | Interaction | Turbidity \* DO | 1.2109 | 0.2756 | 4.394 | <0.001 |

Turbidity, DO, Depth, Magnesium, Culex and Aedes count influenced the Anopheles density. There was an interactive effect between turbidity and DO which had a positive relationship with Anopheles density. The Depth was also positively related to *Anopheles* density.

Table : Results of the generalized linear mixed model (GLMM) of the number of immature Aedes in larval habitats.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Dependent variable** | **Effect** | **Term** | **Estimate** | **SE** | **Z-Value** | **p-value** |
| Aedes Count | Fixed |  | -0.7078 | 1.6976 | -0.417 | P >0.05 |
|  |  | Anopheles Count | -0.9053 | 0.2375 | -3.812 | P<0.001 |
|  |  | Suspended Solid | 2.1395 | 0.6143 | 3.483 | P<0.001 |
|  |  | TDS | -1.9979 | 0.1691 | -11.813 | P<0.001 |
|  |  | Chloride | 0.2304 | 0.1486 | 1.550 | P >0.05 |
|  |  | Colour | -3.7158 | 0.3981 | -9.334 | P<0.001 |
|  |  | BOD | -1.9126 | 0.4001 | -4.781 | P<0.001 |

The GLMM model was utilized to predict the prevalence of Aedes larvae. It was constructed with six independent factors (Anopheles population, suspended solids, total dissolved solids (TDS), chloride levels, color, and biological oxygen demand (BOD)), all of which except Chloride showed notable impact. Anopheles density, TDS, color, and BOD displayed a negative correlation with Aedes abundance, whereas suspended solids and chloride exhibited a positive correlation with Aedes density.

Table 3: Results of the generalized linear mixed model (GLMM) of the number of immature Culicidae in larval habitats.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Dependent variable** | **Effect** | **Term** | **Estimate** | **SE** | **Z-Value** | **p-value** |
| Culex Count | Fixed | Intercept | -0.6317 | 1.1381 | -0.555 | P>0.05 |
|  |  | Turbidity | -4.7911 | 0.6119 | -7.830 | P<0.001 |
|  |  | pH | -0.4662 | 0.1768 | -2.636 | P<0.01 |
|  |  | Nitrate | 1.6897 | 0.2405 | 7.025 | P<0.001 |
|  |  | BOD | 0.3048 | 0.1457 | 2.092 | P<0.01 |
|  |  | DO | -0.7392 | 0.2333 | -3.169 | P<0.01 |
|  |  | TDS | -0.8355 | 0.2097 | -3.985 | P<0.001 |
|  | Interaction | DO\*TDS | 1.2212 | 0.4028 | 3.032 | P<0.01 |

Culex density was most affected by turbidity, pH, Nitrate, BOD, DO and TDS. GLMM showed that turbidity, pH, DO, and TDS had negative relationships with culex density.

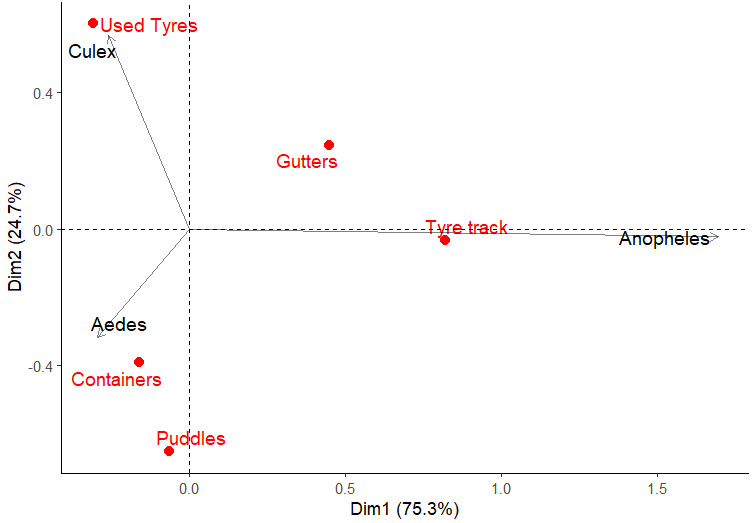


Figure \_ : CA biplot representing the relationship between mosquito larvae and the Habitats.

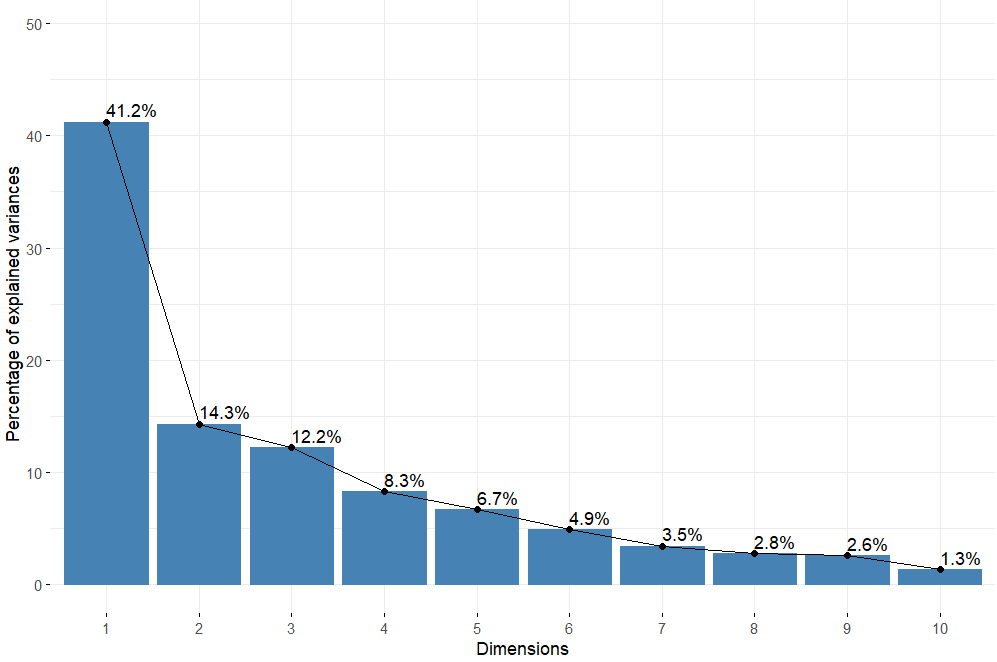
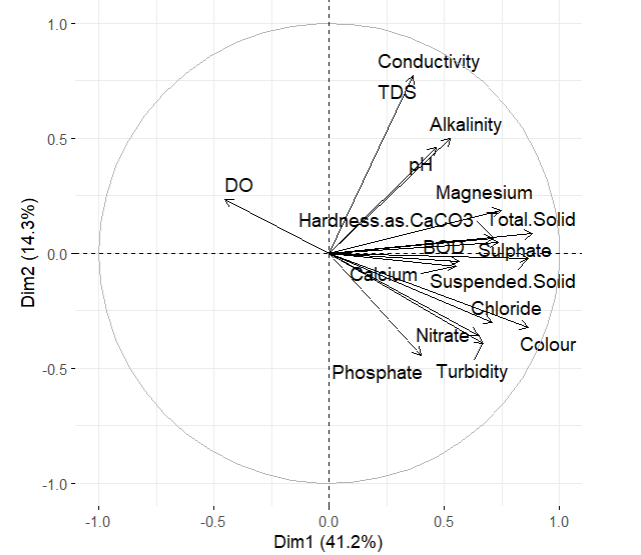
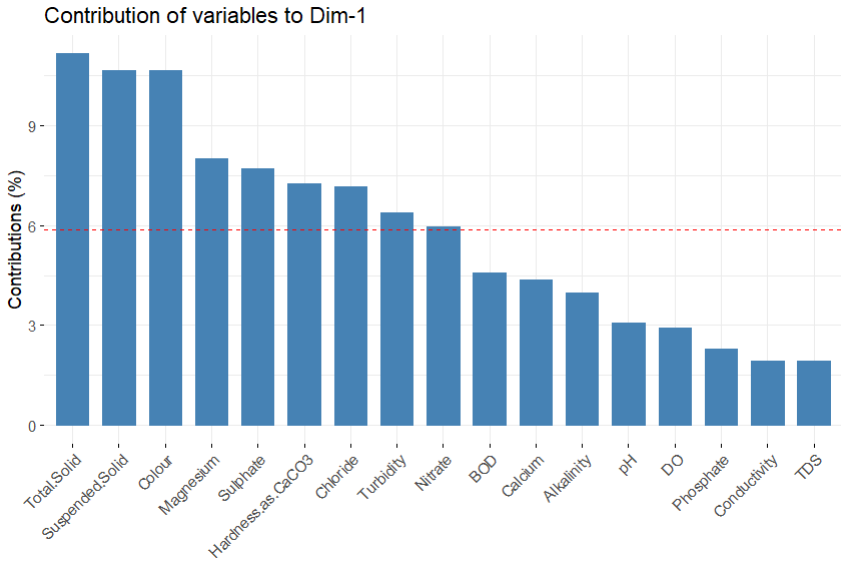
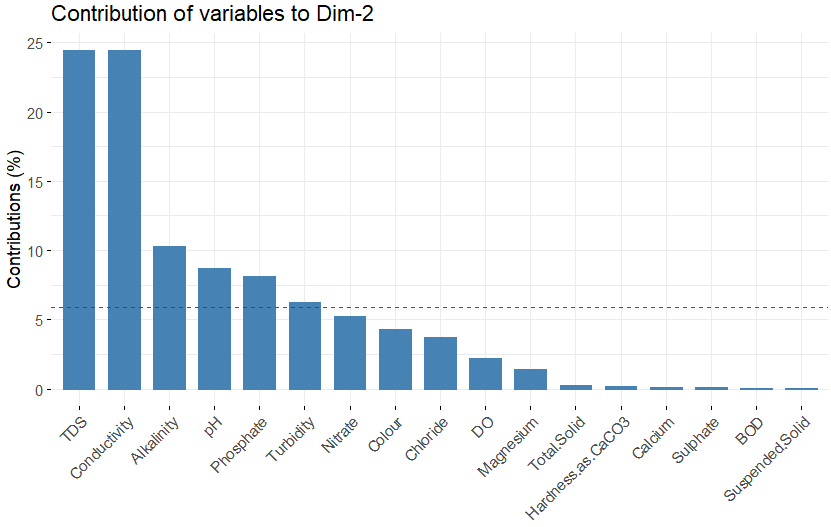
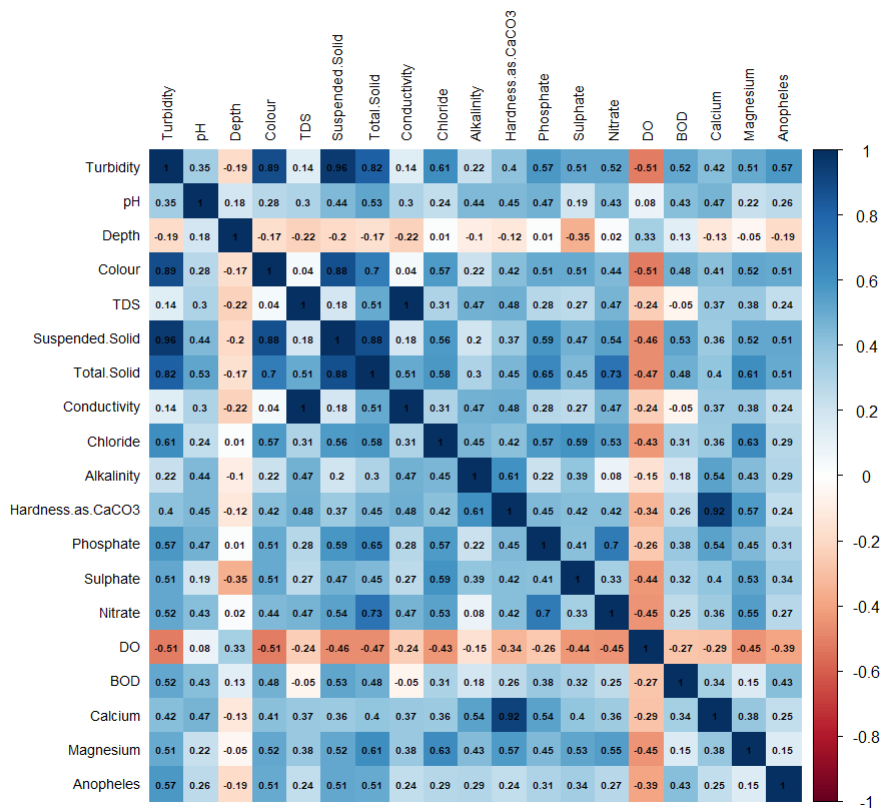


Figure \_ : Scree plot of principal component of physicochemical parameters. It shows that the first and second dimensions were enough to explain \_\_% of the variation in the data.









REFERENCES

Nikookar, S. H., Fazeli-Dinan, M., Azari-Hamidian, S., Mousavinasab, S. N., Aarabi, M., Ziapour, S. P., Esfandyari, Y., & Enayati, A. (2017). Correlation between mosquito larval density and their habitat physicochemical characteristics in Mazandaran Province, northern Iran. *PLOS Neglected Tropical Diseases*, *11*(8), e0005835. https://doi.org/10.1371/journal.pntd.0005835