ABUAD INTERNATIONAL JOURNAL OF NATURAL AND APPLIED SCIENCES
ISSN: 2955-1021; e-ISSN: 1115-5892
AIJNAS Volume 4, Issue 1, 2024 pp 18-26
https://doi.org/10.53982/aijnas.2024.0401.03-j

https://journals.abuad.edu.ng/index.php/aijnas

Characterization of *Anopheles* Mosquitoes Larvae Breeding habitats in Selected Six Local Government Areas in Ekiti State South-West Nigeria

Adejumoke Adelanke Adejayan[1], [1] Hilary Iwegbunem Okoh, [1]Segun Isaac Oyedeji

[1]Department of Animal and Environmental Biology, Faculty of Science, Federal University Oye-Ekiti, Ekiti State, Nigeria
Corresponding author email: *adejayan.adejumoke@yahoo.com*

Abstract
This study explored the spatial distribution and attributes of Anopheles mosquito larvae breeding sites in six local government areas of Ekiti State, Nigeria. It employed a cross-sectional design, randomly sampling larvae habitats across three distinct locations, resulting in the assessment of a total of 18 breeding sites. The assessment of habitat characteristics and physico-chemical parameters of larvae breeding water-bodies was conducted through visual inspection and laboratory procedures, adhering to the standard protocol outlined by the World Health Organization (WHO). The objective of this study is to characterize Anopheles mosquito larvae breeding habitats in six selected local government areas in Ekiti State using WHO protocols. Two local government areas were selected each from the three senatorial districts in the state and a survey was conducted to identify dams, rivers, swamps, marshlands, and temporary water ponds within each zone for Anopheles mosquito larvae using WHO protocols. Measurements of water temperature and pH were conducted twice in a week using a multi-parameter meter (PHB500-WW portable pH meter). Anopheles mosquito larvae were collected across the eighteen breeding sites in the selected six local government areas (LGAs) in Ekiti using standard dipper, pasteur pipettes and scooping techniques and reared to adult in the laboratory. Most of the larvae habitats encountered were stagnant water bodies 10 (56%) with the mean of 122.2 ± 41.20 followed by Tyre track 4 (22%) with the mean of 129.8 ± 41.20, slowly flowing 2 (11%) with the mean of 186.0 ± 16.97 and gutter 2 (11%) with the mean of 170.0 ± 98.9. Types of breeding site across the six study area were all temporary sites 18 (100%), more than half 13 (72%) of the habitats origin of water were natural, 11 (61%) of the breeding habitats' specific water body were stagnant water bodies. Furthermore, majority 14 (78%) of the water bodies were polluted, 16 (89%) were exposed to sunlight and it was also discovered that all the breeding habitats across the six study area were around settlements (houses). Physicochemical characteristics such as Temperature (r=0.896, p=0.016), pH (r=0.865, p=0.026) and Electrical conductivity (r=0.865, p=0.045) were significantly associated with larvae abundant with a strong positive correlation while the physicochemical characteristics such as DO and TDS were not significantly associated with larvae abundance .
***Key words**: Anopheles larvae, Temperature, pH, Electrical conductivity, Ekiti state.*

INTRODUCTION

Members of the Culicidae family, commonly known as mosquitoes, pose significant challenges as both nuisances and grave public health threats. Their females feed on human blood, and thus, facilitating the transmission of severe diseases such as malaria, yellow fever, and filariasis (Nebbak *et al.,* 2022). Each year, mosquitoes are believed to transmit diseases to over 700 million individuals and are accountable for approximately 1 out of every 17 deaths (WHO, 2020, Bamou *et al.,* 2021). The efficient transmission of mosquito-borne diseases hinges on the successful interaction between female mosquitoes and their hosts (Onen *et al.,* 2023). Within the *Anophelinae* subfamily, the genus *Anopheles* is renowned for its global significance in transmitting diseases such as malaria and filariasis (Adugna *et al.,* 2021, Djihinto *et al.,* 2022). Malaria, stemming from the Plasmodium parasite, stands as one of the most lethal diseases globally (Zekar *et al.,* 2022). The disease accounted for about 247 million clinical cases which resulted in over 619 thousand deaths globally in the year 2021 (World malaria report, 2023). In 2021, Sub–Saharan Africa accounted for 95% of malaria cases and 96% of malaria deaths, with children under 5 years accounting for about 80% of all malaria deaths in the region (DPDM, 2022). Four African countries accounted for half of all malaria deaths worldwide in 2021: Nigeria (31.3%), Democratic of the Republic of Congo (12.6%), United Republic of Tanzania (4.1%), and Niger (3.9%) (WHO, 2022). The distribution, transmission, and intensity of the disease rely on the level of urbanization and the proximity to breeding sites of the vector (Mathania *et al.,* 2020). Mosquitoes typically breed in various water bodies, both natural and man-made. Different mosquito species exhibit preferences for specific breeding sites, often influenced by the location and conditions of the water bodies. The endemicity of malaria in a given area is dictated by indigenous *Anopheles* mosquitoes, encompassing factors such as their abundance, feeding habits, resting behavior, and infectivity with Plasmodium, among other variables (Thomas *et al.,* 2017). The elevated transmission rate and prevalence of malaria stem from

the multitude of mosquito breeding sites, encompassing virtually any receptacle capable of holding water. These sites include items such as tins, cans, old tires, tree holes, cisterns, swamps, open pools, drainage areas, streams, and ponds (Nabatanzi *et al.,* 2022). The *Anopheline* group encompasses a variety of species with broad geographical distribution, which varies from one location to another. Among these, the primary subgroups are *Anopheles gambiae* and *Anopheles funestus. Anopheles gambiae*, *Anopheles funestus and Anopheles arabiensis* are the three major vectors of malaria in Nigeria (Awolola *et al*., 2018, Akeju *et al*., 2022). Species complexes exist within the genus *Anopheles* (Harbach, 2004) with *Anopheles gambiae* having about seven sibling species and *Anopheles funestus* having about eleven (Derua, 2015). It is difficult to differentiate sibling species of *Anopheles* mosquitoes morphologically since they all look alike with similar behaviour, but different in vectorial capacity hence the need for molecular identification using polymerase chain reaction (PCR). Proper identification of sibling-species of *Anopheles* mosquitoes is crucial in order to understand specific behaviours and ensure that scarce resources are used for controlling the malaria vectors only. The identification of the malaria vectors ranges from the use of morphological keys (Coetzee, 2020) and molecular techniques using species specific polymerized chain reaction (PCR) (Scott *et al*., 1993; Favia *et al*., 1997; Fanello *et al*., 2002; Singh *etal*., 2020). *Anopheles* habitats include irrigation canals, seepage from water pipes, neglected wells, artificial containers, pools, swampy areas, stagnant water and man-made ditches. Individuals residing in impoverished rural regions face numerous obstacles when attempting to access malaria prevention measures, particularly regarding their understanding of vector biology and ecology, among other factors. Mapping malaria vectors holds significant importance in malaria control efforts. This is because the species composition, distribution, and various biological characteristics of mosquitoes remain inadequately understood across different ecological zones in Nigeria and many malaria-endemic regions. Challenges in morphological identification of certain complex species contribute to this lack of knowledge, which is crucial for designing effective vector control programs and addressing disease prevalence in endemic areas. PCR is frequently employed with primers targeting all members of the complex species to determine the presence of specific species in a given area. Nevertheless, it's plausible to detect multiple species in an area, indicating transmission involving multiple species. Each species typically exhibits distinct behaviors and transmission dynamics. Efficient control and potential elimination of the disease necessitate accurate identification of malaria vectors to distinguish between major vectors, minor vectors, and non-vectors. This differentiation ensures that limited resources are not squandered on controlling less significant vectors (Hadebe *et al.,* 2023). Current knowledge about the features of *Anopheles* mosquito breeding sites and the species groups present in Ekiti State is lacking. Thus, this research aims to characterize the breeding habitats and identify the physicochemical parameters that supports *Anopheles* breeding habitats in Ado, Efon, Ise-Orun, Ido-Osi, Oye, and Ikere LGAs of Ekiti State. This information will help determine the most effective vector control method to adopt, considering the constraints of limited resources.

METHODOLOGY

Study sites

The study was carried out in the three senatorial districts in Ekiti State, South-West, Nigeria (Fig 1). Ekiti state is situated within the tropics and located between longitudes $40^{o}51^{"}$ and 50^{0} 451" East of the Greenwich meridian and latitudes $70^{0}151$" and $80^{0}51$" North of the Equator. The State comprises of 16 LGAs of which 13 are rural, 2 are peri-urban and 1 is urban (Babalola *et al.,* 2023). The state comprises of three senatorial districts namely Ekiti Central, Ekiti South and Ekiti North (Government of Ekiti state, 2023). The state covers a total land mass of 6,353km^2 and a density of 514/km^2. The population of the state is approximately 2.4 million people according to the 2006 population census but the 2016 estimates put the number of people in the state at 3.3 million (actionable info 2022). The State capital is Ado-Ekiti which is both the commercial and political hub of the State (NBS, 2012). Most part of the state is located in a highland area at about 250 meters above sea level and situated on a bedrock of metamorphic rock.

Selection of sites

This is a cross-sectional study. The study areas were selected based on their unique characteristics, with two LGAs from each senatorial district. The selection included: Ado LGA (urban: Latitude: 7.621111; Longitude: 5.221389) as it is the state capital and most populous LGA, Oye LGA (rural: Latitude: 7.798266; Longitude: 5.2214493) as it hosts the Federal University Oye-Ekiti campus, Efon LGA (rural: Latitude: 7.65649, Longitude: 4.92235) as it is a hilly town, Ikere LGA (peri-urban: Latitude: 7.499126, Longitude; 5.231888) is a significant urban center, Ido-Osi LGA (peri-urban: Latitude: 7.843093; Longitude: 5.182314) is strategically located and has a unique demographic profile and Ise-Orun LGA (rural: Latitude: 7.232837, Longitude: 5.196718) represents a typical rural setting in Ekiti State The population of the LGs was put at : Ado-Ekiti 536,000,Oye-Ekiti 206,300, Efon-Alaaye 410,000, Ikere-Ekiti 222,400, Ido-Osi 239,600 and Ise-Orun 113,754

respectively according to city population (city population, 2022). The study sites were randomly selected within each study location and their respective coordinate were taken accordingly as indicated in the map.

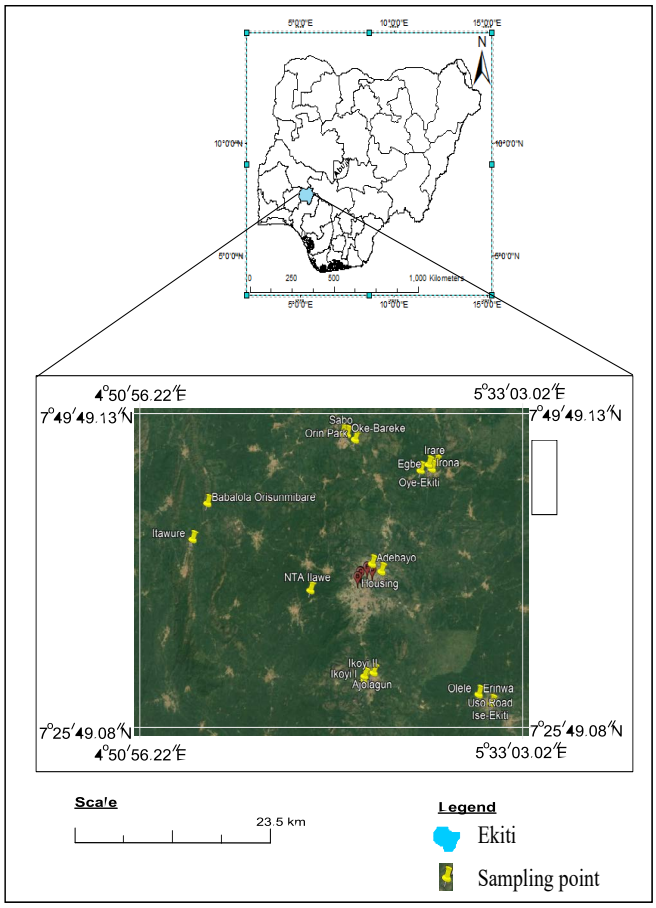

Fig. 1: Map of Ekiti State showing the study LGAs from the three senatorial districts.

Larval sampling and identification

Larva sampling took place twice in a week at designated locations from April 2022 to July 2023 in which a total of 3600 *Anopheles* mosquito larvae were collected. During each sampling visit, the habitat was initially examined for the presence of *Anopheles* mosquito larvae, and their coordinates were documented using a GPS device (Garmin 20.0 etrex). Additionally, the location and type of breeding sites were recorded for each habitat sampled, and few images (plate 1-5) were captured using a mobile phone camera.

Plate 1: *Anopheles* breeding site in Ado LG

Plate 2: *Anopheles* breeding site in Efon LG

Plate 3: *Anopheles* breeding site in IdO-Osi

Plate 4: *Anopheles* breeding site in Ise-Orun

Plate 5: *Anopheles* breeding site in Oye

Larval habitat characterization

An initial assessment of potential breeding sites for *Anopheline* mosquitoes was conducted to identify areas with suitable environmental conditions that could support the development of these species by visual inspection and

a systematic process to identify and describe the physical, chemical and biological features of the environment where *Anopheles* mosquito breeds was carried out (WHO, 2013). Site selection was done to identify potential breeding sites based on factors like proximity to human settlements, water sources and vegetation. Physical characterization like Temperature was recorded. Water flow, turbidity and presence of Vegetation were observed. Physicochemical characterizations like pH, electrical conductivity, dissolved oxygen, total dissolved solids and salinity were all measured on site using a multi-parameter meter (PHB500- WW portable pH meter). The larvae were scooped into plastic buckets and well labeled before transferring them to the laboratory (Entomology unit department of Animal and Environmental Biology, Federal University Oye-Ekiti) for rearing and proper identification.

DATA ANALYSIS

All statistical analyses were performed using SPSS version 27, with a significance level of ≤0.05. The findings were expressed as percentages, and the relationship between the abundance of mosquito larvae and the environmental characteristics of their habitat was examined using a chi-square test. To consider the impact of physicochemical variables on the abundance of *Anopheles* larvae at each breeding site, a one-way ANOVA was conducted. Additionally, a Pearson correlation analysis was employed to evaluate the association between larvae densities and the physicochemical properties of the larval habitat.

RESULTS

Characterization of *Anopheles* mosquito larvae breeding sites

Most of the larvae habitats encountered (Table 3) were stagnant water bodies 10 (56%) followed by Tyre track 4 (22%), slowly flowing 2 (11%) and Gutter 2 (11%). Types of breeding site across the six study area were temporary sites 18 (100%), more than half 13 (72%) of the habitats origin of water were natural, 11(61%) of the breeding habitats' specific water body were stagnant water bodies. Furthermore, majority 14 (78%) of the water bodies were polluted, 16 (89%) were exposed to sunlight and it was also discovered that the all the breeding habitats across the six study LGAs were around settlements (houses). There were no significant associations between characteristics of mosquito breeding sites and sampling areas ($p > 0.05$)

Anopheles Mosquitoes' Breeding Habitat Characteristics

Characterization was done accordingly as presented in Table 1 and Table2. All the parameters studied were not significantly different across the six study LGAs. The pH across the six study LGAs is between the range of 7.17 to 8.76 with a mean of 7.88 ± 0.5129, Temperature across the six study area is between the range of 28.2℃ to 29.9℃ with a mean of 28.65 ± 0.5863, DO across the six study area is between the range of 1.3 mg/I to 1.45 mg/I with a mean of 1.33 ± 0.068, EC across the six study area is between the range of 178 µS/cm to 347 µS/cm with a mean of 261 ± 63.485, TDS across the six study area is between the range of 15 to 28ppm with a mean of 20.67 ± 4.885 and salinity across the six study areas is between 0.01 to 0.04psu with a mean of 5.58 ± 0.93. Dissolved oxygen was not signifcantly correlated with Anopheles larvae population (r= −0.734 and−0.789 , respectively), there was no significant difference across the study area (P>0.05). Temperature was significantly correlated with the abundance of Anopheles larvae (r=0.74). Anopheles larvae increase as the temperature increases (R2=0.582).

Table 1: Physicochemical Parameters of Water Samples collected from the Breeding Sites across the Six Study LGAs.

Physico-chemical parameters	Ado	Oye	Efon	Ikere	Ise-Orun	Ido-Osi
Temperature (°C)	28.6	28.7	28.5	28.2	29.9	28.9
pH	7.17	7.70	7.90	7.82	7.91	8.76
Electrical conductivity (µS/l)	234	284	212	178	347	308
Dissolved oxygen (mg/l	1.28	1.30	1.26	1.45	1.32	1.35
Total dissolved solids (ppm)	15	20	18	28	25	28

Table 2. The distribution of *Anopheles* species larva based on different habitat characteristics in the six studied LGAs

		N	Mean	Std Deviation	Std Error	95% Confidence Interval for the mean		Minimum	Maximum
						Lower bound	Upper Bound		
Ph	Oye	3	7.70	0.3848	0.2221	5.7885	8.6557	7.26	7.95
	Ado	3	7.17	0.6764	0.3095	5.4898	8.8502	6.47	7.82
	EfonAlaye	3	7.86	0.2523	0.1457	7.7410	7.9789	7.69	8.15
	Idoosi	3	8.77	0.3512	0.0203	-7.8976	9.6424	8.4	9.1
	Ikere	3	7.67	0.6768	0.3907	5.9889	9.3512	7.11	8.4
	IseOrun	3	7.9	0.7	0.4041	-6.1612	9.6388	7.2	8.6
	Total	18	7.88	0.5129	0.2094	-7.3383	8.4149	7.17	8.76
Do	Oye	3	1.3	0.1	0.5778	0.7516	0.3484	1.2	1.4
	Ado	3	1.28	0.4508	0.2603	0.1602	2.3998	1	1.8
	EfonAlaye	3	2.77	1.4571	0.8412	2.08301	3.4569	1.1	3.8
	Idoosi	3	1.35	0.05	0.0289	-1.2258	1.4742	1.3	1.4
	Ikere	3	1.32	0.1311	0.076	-0.9942	1.6459	1.2	1.46
	IseOrun	3	1.45	0.1323	0.0764	-1.1214	1.7786	1.6	1.35
	Total	18	1.33	0.068	0.0278	-1.2253	1.3978	1.3	1.45
Temp	Oye	3	28.77	1.1239	0.6489	25.9773	31.56	27.8	30
	Ado	3	28.47	1.4189	0.8192	24.9452	31.9947	27.2	30
	EfonAlaye	3	28.53	6.7039	3.8705	34.2097	40.5303	28.0	29.6
	Idoosi	3	28.87	0.3512	0.2028	-26.2607	31.3793	27.8	29.9
	Ikere	3	28.73	1.1676	0.6741	-25.8295	31.6305	27.7	30
	IseOrun	3	29.93	0.1155	0.0667	-29.364	30.2618	29.8	30
	Total	18	28.65	0.5865	0.23944	-28.184	29.415	28.2	29.9
EC	Oye	3	210	5.0	2.8868	197.5793	222.4207	205	215
	Ado	3	234	6.5064	3.7565	217.5072	249.8328	227	240
	EfonAlaye	3	206	10.4083	6.0092	185.8104	237.5224	200	220
	Idoosi	3	217	7.6376	4.4096	-197.6971	235.6429	210	225
	Ikere	3	215	5	2.8868	-202.5793	277.4207	210	220
	IseOrun	3	237	30.5505	17.6383	-161.1083	312.8917	210	270
	Total	18	261	63.485	25.916	-195.623	327.623	178	347
TDS	Oye	3	20.00	3.6056	2.0817	28.9567	11.0344	17	24
	Ado	3	15.00	2.0000	1.1547	10.0317	19.9683	13	15
	EfonAlaye	3	18.00	2.0000	1.1547	13.0317	22.9683	16	20
	Idoosi	3	28.00	1.0000	0.5774	-25.5159	30.4841	27	29
	Ikere	3	25.00	3.0000	1.7321	-17.5476	32.4524	22	28
	IseOrun	3	28.00	1.0000	0.5774	-25.5159	30.4841	27	29
	Total	18	20.67	4.8853	1.9944	-15.5339	20.6667	15	28
SAL	Oye	3	0.02	0.0115	0.0067	-0.0087	0.0486	0.01	0.03
	Ado	3	0.27	0.0058	0.0033	-0.2524	0.2811	0.02	0.03
	Efon-Alaye	3	0.48	0.2026	0.1169	-0.3846	0.5754	0.25	0.64
	Ido-osi	3	0.02	0.0058	0.0033	2.4641	2.5041	0.02	0.03
	Ikere	3	0.02	0.0058	0.0033	0.0057	0.0343	0.02	0.03
	Ise-Orun	3	0.02	0.0058	0.0033	0.0057	0.0343	0.02	0.03
	Total	18	0.02	0.0078	0.0018	-0.0161	0.0239	0.02	0.04

Table 3: Characterization of mosquitoes breeding Habitats across the eighteen study sites

VARIABLE	FREQUENCY (N=18)	PERCENTAGE
Type of site		
Temporary site	18	100
Origin of water		
Manmade	5	28
Natural	13	72
Specific water body		
Gutter	2	11
Stagnant	10	61
Slowly flowing	2	11
Tyre track	4	22
Characteristic of water body		
Polluted	14	78
Clear	4	22
Exposure to sunlight		
Yes	16	89
Partial	2	11
Presence of settlement (houses) around the sampling area		
Yes	18	100
Presence of vegetation		
Yes	13	72.2
No	5	27.8
Presence of algae		
Yes	15	83.3
No	3	16.7
Mosquitoes species		
Culicine Anopheles	10	56
Anopheles	8	44

Table 4: Association between Physicochemical parameters and larva abundance in the study areas.

				1	*Mean	2	Temp	3	pH	4	EC	5	DO	6	TDS
7	*Mean abundance of *An mosquitoes*	8	Pearson Correlation	9	1										
		10	Sig. (2-tailed)												
		11	N	12	6										
13	Temp	14	Pearson Correlation	15	0.445	16	1								
		17	Sig. (2-tailed)	18	0.376										
		19	N	20	6	21	6								
22	pH	23	Pearson Correlation	24	0.424	25	0.207	26	1						
		27	Sig. (2-tailed)	28	0.402	29	0.694								
		30	N	31	6			32	6						
33	EC	34	Pearson Correlation	35	0.253	36	0.896	37	0.387	38	1				
		39	Sig. (2-tailed)	40	0.629	41	0.016	42	0.449						
		43	N	44	6	45	6	46	6	47	6				
48	DO	49	Pearson Correlation	50	-0.326	51	0.387	52	0.284	53	-0.269			54	1
		55	Sig. (2-tailed)	56	00.528	57	0.449	58	0.586	59	0.607				
		60	N	61	6	62	6	63	6	64	6			65	6
66	TDS	67	Pearson Correlation	68	0.388	69	-0.284	70	0.865	71	0.778	72	0.165	73	1
		74	Sig. (2-tailed)	75	0.447	76	0.586	77	0.026	78	0.045	79	0.755		
		80	N	81	6	82	6	83	6	84	6	85	6	86	6

DISCUSSION

Significant temperature variations across study areas can influence the breeding sites of *Anopheles* mosquitoes. Sunlit environments offer more favorable conditions for optimal egg development compared to shaded habitats. Consequently, in tropical regions, stagnant water bodies commonly facilitate the breeding of mosquito larvae due to their exposure to sunlight. Mosquito larvae were discovered in breeding habitats distinguished by differing levels of sunlight and shade, with 16 (89%) found in areas exposed to sunlight and 2 (11%) in shaded locations. Abundance of *Anopheles gambiae sensu lato* and *An. funestus* has also been observed in habitats exposed to sunlight in a study carried out in rural south eastern Tanzania by Nambunga *et al.* (2020) and Graca *et al.* (2023) in southern Mozambique.

Algae were present in 83.3% of the sites and in habitats with vegetation, conversely, algae were absent in 16.7% of the sites, while vegetation was absent in 27.8% of sites. The presence of extensive permanent water bodies adorned with vegetation significantly contributes to the prevalence of larvae (Awolola *et al.,* 2007). Nevertheless, in locations experiencing algae blooms and dense emergent aquatic vegetation, surface coverage of the habitat could serve as a barrier, reducing the density of mosquito larvae by deterring egg-laying females. Additionally, they might induce microbial proliferation and foster a diverse array of predators.

Anopheles mosquito larvae were predominantly found in polluted habitat 14, accounting for 78% of the total, as opposed to the 22% found in clear breeding sites. The predominance of Anopheles mosquito larvae in polluted habitat can be attributed to several factors. Polluted habitat creates favorable water conditions for the thriving of *Anopheles* mosquito larvae, while the elevated nutrient levels in polluted water enhance their growth and development. Additionally, the reduced presence of predators in polluted habitats allows for the unhindered proliferation of mosquito larvae. Furthermore, specific microbial activity in polluted water bodies may attract mosquitoes or create suitable breeding conditions. Environmental factors such as temperature, pH levels, and sunlight exposure also play a role in influencing the distribution of mosquito larvae between polluted and clear habitats (Awolola *et al.,* 2007). Temperature across the eighteen breeding sites is between the range of 28.2 ℃ to 29.9 ℃ with a strong positive correlation mean of 28.65 ± 0.5863. The ideal temperature range is crucial for successful egg hatching, but temperatures beyond certain limits can negatively impact larval development. For example, temperatures exceeding 40°C have been found to hinder the growth and survival of *Anopheles* larvae (Agyekum *et al.,* 2022). Enzymes play a crucial role in facilitating growth and development, but their activity decreases as temperature rises, hindering the catalysis of reactions essential for these processes. The temperature recorded in this research was in line with that of Asare *et al*., 2016 in which on a daily time scale, recorded the mean, maximum and minimum water temperatures were 27.2, 29.2 and 24.0°C, respectively. This was also supported by the results of Okoh *et al*., 2020 in which temperature range of 24 - 28^0 C was recorded.

The physicochemical parameters encountered in this research was closely corresponds with recent research by Akeju *et al.* (2022) in which the study found that the physicochemical parameters in *Anopheles* mosquito habitats showed minimal variation across the different study areas. The pH levels ranged from 6.05 to 8.23, with a mean value of 6.92 ± 0.06, indicating a slightly acidic to neutral environment. Electrical conductivity values ranged from 140 to 557µS/cm, with a mean of 250.52 ± 14.52, suggesting moderate levels of dissolved ions. Temperature readings spanned from 23.1 to 28.7°C, with a mean of 26.04 ± 0.19, indicating a warm environment. Dissolved oxygen levels ranged from 7.67 to 8.56 mg/L, with a mean of 8.09 ± 0.03, indicating adequate oxygen levels. Total dissolved solids ranged from 10 to 27 ppm, with a mean of 16.60 ± 0.06, indicating relatively low levels of dissolved substances. Overall, the parameters showed minimal significant differences across the study areas. The slight difference in conductivity range in the case of Akeju *et al*. 2022 may be due to difference in minerals in the surrounding soil, organic matter, pollutants, and atmospheric deposition. All the parameters study was not significantly different across the study area. The salinities across the six study LGAs is between the range of 0.01 to 0.04psu with a mean of 5.56 ± 0.93. The low salinity might be due to the local environmental. Factors such as rainfall patterns, soil composition, and vegetation cover. This findings was similar to the research carried out by Laura Cristina Multini in Green Belt of the City of São Paulo, Brazil, 2021 where more abundant larvae were discovered in aquatic water with low salinity and as the salinity increases the number of larvae reduces.

Temporary breeding sites can contain water for several weeks but normally dry up after the rainy season while permanent breeding sites can contain water even after the rainy season. The study revealed the types of breeding site across the six study area were temporary sites 18(100%), more than half 13 (72%) of the habitats origin of water were natural, 11(61%) of the breeding habitats' specific water body were stagnant water bodies. which implies that the six study area had more mosquito breeding sites like ground pools (ponds, stagnant water) and man-made containers (discarded tins, tyres, drums,

plastic buckets) compared to other communities. The descriptive statistics align with Emidi *et al.* (2017), where the mosquito breeding sites were temporary, meaning that the main sources of water for these breeding sites were rainfall. Similar findings were reported in another study where five mosquito breeding sites were identified: motor tyres, gutters, containers, water pools, and block holes (Amawulu, 2020).

Most of the larvae habitats encountered were stagnant water bodies 10(56%) with the mean of 122.2 ± 41.20 followed by Tyre track 4(22%) with the mean of 129.8 ± 41.20. Similarly, Tarekegn et al. (2022) predominantly encountered larval habitats were rain pools (17.6% (n = 19)), and river pool (17.6% (n =19). Furthermore, majority 14(78%) of the water bodies were polluted, 16(89%) were exposed to sunlight and it was also discovered that all the breeding habitats across the six study area were around settlements (houses).

In this study, greater proportion of the mosquitoes species across the study area were Culicine *Anopheles* 10 (56%). In contrast to Auta *et al*. (2020) in which the most abundant species encountered was *Culex quinquefasciatus* 1280 (80.45%), *Aedes aegypti* 217 (13.64%), Culexdecens 60 (3.77%), *Aedes vittatus* 24 (1.51%), Culextigripes 10 (0.63%) and there was no record of *Anopheles* species encountered during the sampling period.

This study further shows that physicochemical characteristics such as Temperature (r=0.896, *p=0.016*), pH (r=0.865, *p=0.026*) and Electrical conductivity (r=0.865, *p=0.045*) were significantly associated with larvae abundant with a strong positive correlation indicating that as temperature, pH and electrical conductivity increases, larvae abundance also increases. Warmer temperatures and higher pH levels create an environment conducive to larvae growth and development. This is slightly related to a study carried out by Akeju *et al*. (2022) where the Electrical conductivity was significantly correlated with the abundance of *A. gambiae* and *A. funestus* in the area (r=0.840 and 0.843, respectively).

This is also slightly in agreement with another study by obi and onyali (2018) *A. gambiae* larvae abundance correlates positively and not significantly with pH and surface water temperature ($p>0.05$; r = 0.549 and 0.450) in ground pools. *An. gambiae* larvae abundance correlates positively and highly significantly with dissolved oxygen ($p<0.01$; r = 0.771). It had a weak positive relationship with salinity, total suspended solids and sulphate without significance difference ($p>0.05$; r = 0.284, 0.331 and 0.082) while it correlates weakly and negatively with total dissolved solids (-0.075)

CONCLUSION

This study indicates that both biotic and abiotic factors significantly influence Anopheles mosquito larval breeding habitats. The diverse physico-chemical parameters observed in the breeding sites, along with the type of environment conducive to oviposition, demonstrate the combined impact of biological and non-biological elements on the breeding ecology of Anopheles mosquitoes. The significant positive correlations between larvae abundance and temperature, pH, and electrical conductivity imply that these physicochemical characteristics play important roles in shaping the habitat suitability for larvae in the study areas. However, further research is needed to understand the specific mechanisms underlying these associations and to explore other potential factors influencing larvae abundance.

REFERENCES

Adugna, F., Wale, M., & Nibret, E. (2021). Review of Anopheles mosquito species, abundance, and distribution in Ethiopia. *Volume, Article ID 6726622*. DOI

Akeju, A. V., Olusi, T. A., & Simon-Oke, I. A. (2022). Molecular identification and wing variations among malaria vectors in Akure North Local Government Area, Nigeria. *Scientific Reports, 12*, 7674. DOI

Awolola, S. T., Oduola, A. O., Obansa, J. B., & Chukwurar, N. J. (2007). Anopheles gambiae s.s. breeding in polluted water bodies in urban Lagos, southwestern Nigeria. *Journal of Vector Borne Diseases, 44*(4), 241-244.

Awolola, T. S., Adeogun, A., Olakiigbe, A. K., Oyeniyi, T., Olukosi, Y. A., Okoh, H., Arowolo, T., Akila, J., Oduola, A., & Amajoh, C. N. (2018). Pyrethroids resistance intensity and resistance mechanisms in Anopheles gambiae from malaria vector surveillance sites in Nigeria. *PloS one, 13*(12), e0205230. DOI

Babalola, K. H., Hull, S., & Whittal, J. (2023). Assessing peri-urban land management using 8Rs framework of responsible land management: The case of peri-urban land in Ekiti State, Nigeria. *Land, 12*(9), 1795. https://doi.org/10.3390/land12091795

Bamou, R., Mayi, M. P. A., Djiappi-Tchamen, B., Nana-Ndjangwo, S. M., Nchoutpouen, E., Cornel, A. J., ... & Antonio-Nkondjio, C. (2021). An update on the mosquito fauna and mosquito-borne diseases distribution in Cameroon. *Parasites & Vectors, 14*, 527. DOI

Basiliana, E., William, N.K., Robert, D.K., Robert, M. and Franklin, W.M. (2017). Insecticide susceptibility status of human biting mosquitoes in Muheza, Tanzania. *Tanzania Journal of Health Research, 19*(3).

Coetzee, M. (2020). Key to the females of Afrotropical Anopheles mosquitoes (Diptera: Culicidae). *BMC Malaria Journal, 19*, 70.

Coetzee, M., Hunt, R. H., & Wilkerson, R. (2013). Identification of malaria vectors in the Afrotropical region using morphological and molecular methods. *BioMed Research International, 2013*, 153986. doi:10.1155/2013/153986

Djihinto, O. Y., Medjigbodo, A. A., Gangbadja, A. R. A., Saizonou, H. M., Lagnika, H. O., Nanmede, D., ... & Djogbénou, L. S. (2022). Malaria-Transmitting Vectors Microbiota: Overview and Interactions With Anopheles Mosquito Biology. *Frontiers in Microbiology, 13*, 891573. DOI

Division of Parasitic diseases and Malaria Center for Global Health. (December, 2022).

Ekiti State Government. (2016). About Ekiti. Retrieved March 4, 2019, from www.ekitistate.gov.ng

Emidi, B., Kisinza, W.N., Mmbando, B.P., Malima, R. and Mosha, F.W. (2017). Effect of physicochemical parameters on Anopheles and Culex mosquito larvae abundance in different breeding sites in a rural setting of Muheza, Tanzania. *Journal of Parasites and Vectors, 10*(1), 304-315.

Fanello, C., Santolamazza, F. and della Torre, A. (2002). Simultaneous identification of species and molecular forms of the Anopheles gambiae complex by PCR-RFLP. *Medical and Veterinary Entomology, 16*, 461-464.

Harbach RE. Culex pipiens: species versus species complex taxonomic history and perspective. J Am Mosq Control Assoc. 2012 Dec;28(4 Suppl):10-23. doi: 10.2987/8756-971X-28.4.10. PMID: 23401941.

Jayeola Oladipo, H. (2022). Increasing challenges of malaria control in sub-Saharan Africa: Priorities for public health research and policymakers. *Annals of Medicine and Surgery, 81*, 104366. DOI

Mathania, M. M., Munisi, D. Z., & Silayo, R. S. (2020). Spatial and temporal distribution of Anopheles mosquito's larvae and its determinants in two urban sites in Tanzania with different malaria transmission levels. *Parasite Epidemiology and Control, 11*, e00179.

Nabatanzi, M., Ntono, V., Kamulegeya, J., Kwesiga, B., Bulage, L., Lubwama, B., ... & Harris, J. (2022). Malaria outbreak facilitated by increased mosquito breeding sites near houses and cessation of indoor residual spraying, Kole district, Uganda, January-June 2019. *BMC Public Health, 22*, 1898. DOI

Nambunga, I. H., Ngowo, H. S., Mapua, S. A., Hape, E. E., Msugupakulya, B. J., Msaky, D. S., ... Okumu, F. O. (2020). Aquatic habitats of the malaria vector Anopheles funestus in rural south-eastern Tanzania. *Malaria Journal, 19*, 219. DOI

Nebbak, A., Almeras, L., Parola, P., & Bitam, I. (2022). Mosquito Vectors (Diptera: Culicidae) and Mosquito-Borne Diseases in North Africa. *Insects, 13*(10), 962. DOI

Neafsey, D. E., Waterhouse, R. M., Abai, M. R., Aganezov, S. S., Alekseyev, M. A., Allen, J. E., ... Besansky, N. J. (2015). Highly evolvable malaria vectors: the genomes of 16 Anopheles mosquitoes. *Science, 347*(6217), 1258522. DOI

Okoh, H. I., Akinsulire, O., Omonijo, A. O., Adeyemo, A., Iyeh, C., Mogaji, H. O., Olorunniyi, O. F., Awe, O. B., Ayeni, A., Arilekolase, O., Adeogun, A., Arowolo, T., & Awolola, S. (2017). Morphological identification and molecular characterisation of Anopheles mosquitoes from Oye Local Government Area of Ekiti State, Nigeria. *Federal Journal of Pure and Applied Sciences, 2*(1).

Okoh, H. I., Akinfemiwa, C. A., Iyeh, C., Mogaji, H. O., Omonijo, A. O., & Awe, O. B. (2020). Spatial distribution and breeding habitat characterisation of Anopheles mosquitoes in Ado-Ekiti, Ekiti State, Nigeria. *FUOYE Journal of Pure and Applied Sciences, 5*(1), 154. ISSN: 2616-1419. Available online at www.fuoye.edu.ng.

Onen, H., Luzala, M. M., Kigozi, S., Sikumbili, R. M., Muanga, C. J. K., Zola, E. N., ... & Memvanga, P. B. (2021). Mosquito-Borne Diseases and Their Control Strategies: An Overview Focused on Green Synthesized Plant-Based Metallic Nanoparticles. [Journal Name], [Volume], [Page numbers], [DOI].

Salomé, G., Riddin, M., & Braack, L. (2023). Species Composition, Seasonal Abundance, and Biting Behavior of Malaria Vectors in Rural Conhane Village, Southern Mozambique. *International Journal of Environmental Research and Public Health, 20*(4), 3597. DOI

Sarpong, E., Acheampong, D. O., Fordjour, G. N. R., Anyanful, A., Aninagyei, E., Tuoyire, D. A., ... Thomford, N. E. (2022). Zero malaria: a mirage or reality for populations of sub-Saharan Africa in health transition. *Malaria Journal, 21*, 314. DOI

Singh, U. S., Amdep, F. L., Kshiar, A., Acharya, P., Karumuthil, T., Kale, S., ... Albert, S. (2023). Characterisation of Anopheles species composition and genetic diversity in Meghalaya, northeast India, using molecular identification tools. *Infection, Genetics and Evolution, 112*, 105450. DOI

Thomas, S., Ravishankaran, S., Justin, N.A.J.A. *et al.* Resting and feeding preferences of *Anopheles stephensi* in an urban setting, perennial for malaria. *Malar J* **16**, 111 (2017). https://doi.org/10.1186/s12936-017-1764-5

World Health Organization. (2023). *World Malaria Report 2023.* WHO, Geneva