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Ecological factors favouring mosquito breeding in Ifedore local government area of Ondo State, Nigeria

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The physico-chemical and biological characteristics affecting the breeding ecology of mosquitoes in Ifedore local government area of Ondo State, Nigeria was investigated. Mosquito larvae were collected from 33 breeding sites using standard plastic dippers, transported to the laboratory and reared to adulthood. Physico-chemical characteristics, distance of each breeding site to the nearest residence and other biotic and abiotic features were determined per site. 2051 imagoes were morphologically identified including *Anopheles gambiae* s.l. (n=348), *Aedes* spp. (n=394), *Culex* spp. (n=1270), *Mansonia* spp. (n=7), *Toxorhynchite* spp. (n=20) and *Coquillettidia* spp. (n=12). Distance of breeding sites to the nearest residence ranged from 0.5 to 300 m. Temperature in all breeding sites ranged from 20.80 to 32.60°C; dissolved oxygen, 2.70 to 7.80 mg/L; total dissolved solids, 043 to 1933 ppm and pH was between 5.30-8.50. Temperature and dissolved oxygen had significant effect on all the species' larvae, as higher values increased their presence. Each of the other physico-chemical parameters had effects on some of the mosquito species. Adequate knowledge of the physico-chemical and biological factors may help in modifying the breeding environments to curb their proliferation. Similarly, the attention of the government to provide basic amenities that would reduce the temporary breeding sites suffices.

Key words: Breeding, ecological factors, Ifedore local government area, mosquitoes, Ondo State, Nigeria.

INTRODUCTION

Various species of mosquitoes are found all over Nigeria and are not restricted by change in topography across the country (Awolola et al., 2002). Many species act as vectors of diseases such as malaria, yellow fever, West Nile virus, dengue fever, filariasis, and other arboviruses (Gatesnote, 2015). 3,500 species of mosquitoes grouped into 41 genera have been identified and many are vectors of diseases (CDC, 2015). Good understanding of the breeding ecology of these organisms including, the types and preferences for larval habitats as well as, the physical, biological and chemical characteristics of the habitats are required to make vector control measures successful (Olayemi et al., 2010). Of note is that convenient breeding sites for certain mosquito species may be inconvenient for other species (Adebote et al., 2008). All types of lentic aquatic habitats can be used for breeding and mosquito larvae have been found to thrive in aquatic bodies such as fresh or salt

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water marshes, swamps, plantations, grassy ditches, streams, lakes and rivers and small, temporary rain pools. Some breed in habitats with vegetation cover while some breed in open, sunlit pools. Kitching (2001) reported that some species breed in tree holes or the leaf axils of some plants. Various studies of larval habitats of mosquito fauna in Nigeria found that abandoned vehicle tyres, used and abandoned containers, stagnant pools, unused septic tanks etc. contained high number of these nuisance organisms that act as vectors of debilitating diseases (Adeleke at al., 2008, 2013; Afolabi et al., 2013; Idowu et al., 2014). According to Okorie (1978) and Mutero et al. (2004), mosquitoes show preference to water with suitable pH, optimum temperature, dissolved oxygen, concentration of ammonia and nitrate. These physico-chemical parameters have been found to affect larval development and survival in breeding water. A study done in northern Nigeria indicated that physico-chemical characteristics such as habitat type, floating debris and emergent plants were key factors determining the presence of *Anopheles* larvae in the habitats (Oguoma and Ikpeze, 2008). The oviposition preferences of gravid females and the ability of immature stages of mosquito to survive both biotic and abiotic environmental conditions of a given aquatic habitat determine the abundance and distribution of mosquito larvae (Okogun et al., 2014). The latter will dictate endemicity of, or predisposition to, infectious agents in any locale. In Ifedore local government area of Ondo state, the ecology of breeding sites of mosquitoes was investigated to identify larva preferences of different mosquitoes across the study area.

MATERIALS AND METHODS

Ondo State is situated in the south western part of Nigeria with geographical coordinates of 5° 45 ˈ N, 4° 20ˈ E and 7° 52ˈ N, 6° 05ˈ E (Wikipedia, 2014). The state lies in the tropical rainforest biome with lush vegetation that spawns almost all year round, indicative of good breeding environment for all sorts of fauna and flora. Aside the state capital, Akure, and a few other towns where dwellers are largely civil servants, a good number of inhabitants engage in one form of agricultural activity or the other. Ifedore local government area (5° 21ˈ N, 5° 04ˈ E) (Maphill, 2018) is one of the eighteen (18) local government areas in the state with eleven (11) towns including Owode-Owena, Ibuji, Igbara-Oke, Isarun, Eroo, Ilara, Ipogun, Ibule, Aaye, Ijare and Irese. They are all largely rural and agrarian communities with cocoa and kolanut being the main cash crops apart from lumbering, which also thrives in the area. Three (3) different breeding sites/habitats were selected in each of the eleven towns with the assistance of local guides, and these ranged from open water bodies, streams aid, puddles to tyre tracks, discarded containers, rock pools and footprints. The coordinates were recorded using GPS (eTrex©, Garmin International Inc., Olathe, USA). Before larval evacuation at each site, the physico-chemical parameters were determined using H19813-6 multi-meter (Hanna, USA) for pH, total dissolved solid, electrical conductivity and temperature while a portable dissolved oxygen meter (H196732, Jenway, United Kingdom) was used to measure the dissolved oxygen at each of the collection points. The fauna and flora found at each site were recorded and predators amidst them noted.

Subsequently, immature stages of mosquitoes were collected using standard plastic dippers, ten dips were done per site and contents emptied into collection containers (each specific for a site) and transported to the laboratory where the larvae were reared to adulthood. The emerging adults were preserved in 1.5 ml Eppendorf tubes containing silica gel. All specimens were identified morphologically using Standard keys (Gillett, 1972; Gillies and Coetzee, 1987; WHO, 2013). Mean of physical factors and mosquito species among different breeding sites were determined using one-way analysis of variance (ANOVA), and where there were significant differences, Tukey test at $p<0.05$ was used to separate the means using SPSS 16.0 version. Correlation of physico-chemical factors with the number of larvae was done using the Pearson correlation coefficient test.

RESULTS

2051 imagoes reared from the 33 breeding sites were morphologically identified. The identified mosquitoes were *Anopheles gambiae* s.l. 348 (194 males and 154 females) (16.97%), *Aedes* spp. 394 (248 males and 146 females) (19.21%), *Culex* spp 1270 (740 males and 530 females) (61.92%), *Mansonia* spp. 7 (1 males and 6 females) (0.34%) *Toxorhynchite* spp. 20 (14 males and 6 females) (0.98%) and *Coquillettidia* spp 12 (3 males and 9 females) 0.59%. Breeding sites where these larvae were recovered include gully, tyre tracks, discarded containers, streams, open water bodies, puddles, artificial holes, discarded truck tyre, blocked drainage system, used tyres and concrete hole. The study encountered high number of mosquito larvae especially at Igbara-oke site 3 (dominated by culicines), while the lowest larvae collection was at Owena site 2, which was dominated by *Anopheles* species as described in Table 1. The males were more than the females except for the *Coquillettidia* spp and *Mansonia* spp. and various predators were recorded in the sites including, tadpoles, damsel flies, dragon flies and anurans. The recorded flora was majorly grasses and a few trees like Pride of Barbados, bamboo and orange trees. The distance of the breeding sites to the nearest residence ranged from 0.5 to 300 m. The larvae density ranged from 0.01 to 0.10 and there were significant differences in the larvae density at Isarun and Irese breeding sites. The temperature in all breeding sites ranged from 20.80 to 32.60°C as shown in Table 2, dissolved oxygen ranged from 2.70 to 7.80 mg/L across investigated sites. Total dissolved solid ranged between 043 and 1933 ppm and pH range was between 5.30 and 8.50.

DISCUSSION

Most of the mosquito breeding sites were exposed to direct sunlight and turbid. According to Minakawa et al. (1999), gravid females use open and turbid habitats for oviposition because such sites are warm and reduce larva and pupal development time. Majority of the sites encountered were temporary breeding sites and

Table 1. Physical characteristics of sampled habitats.

Town	Site No. (Coordinate)	Habitat type	Nearness to residential building (m)	Mean nearness to residential building (m)	Mean larvae density	Colour and appearance	Fauna and flora found around breeding site
Owode Owena	1 (7.40413101 and 5.0158392)	Gully	5	17.17 ± 14.48^{a}	0.03 ± 0.16^{ab}	Turbid	Tadpoles, lizards, midges, dragon flies,damsel flies and grasses.
	2 (7.40413101 and 5.015839)	Tyre track	46			Turbid	Elephant grass, grasses.
	3 (7.04043403 and 5.0075186)	Discarded containers	0.5			Greenish	Green algae.
Ibuji	1 (7.4463251 and 5.0626339)	Stream	10	9.33 ± 1.76^{a}	0.04 ± 0.01^{ab}	Greenish	Damsel flies, dragon flies, tadpoles, midges, lizards and water spiders. Grasses and green algae.
	2 (7.4268265 and 5.0590556)	Open water bodies	6			Turbid	Damsel flies, dragon flies, tadpoles and anurans, midges, water spiders and fishes. Green algae, bromeliad plants, trees and grasses.
	3 (7.4455370 and 5.0637899)	Stream	12			Turbid	Dragon flies, damsel flies, grasses, bamboo trees.
Igbara-Oke	1 (7.4348889 and 5.0610074)	Puddle	4.6	5.87 ± 3.24^{a}	0.04 ± 0.01^{ab}	Greenish	Dragon flies, tadpoles, lizards with grasses.
	2 (7.4029373 and 5.0571038)	Tyre track	1			Greenish	Tadpoles, dragon flies and damsel flies and green algae.
	3 (7.3603494 and 5.1023863	Puddle	12			Turbid	Tadpoles, dragon flies, green algae.
Isarun	1 (7.4025111 and 5.0597061)	Marsh	1	13.00 ± 6.03^{a}	$0.01 \pm .000^{a}$	Greenish	Tadpoles, anurans, lizards, midges, water spiders, damsel flies dragon flies, grasses and pride of barbados trees.
	2 (7.3966387 and 5.0638127)	Artificial holes	18			Turbid	Damsel flies, dragon flies. brown algae, bamboo trees, grasses and stubborn grasses.
	3 (7.3976025 and 5.0650115)	Stream	20			Clear	Lizards, midges, water spiders, damsel flies, dragon flies, pride of barbados and bamboo trees.
Ero	1 (7.3991562 and 5.0639352)	Tyre track	300	160.00 ± 83.87^{b}	0.02 ± 0.01^{ab}	Turbid	Midges.
	2 (7.381727 and 5.0867100)	Discarded containers	170			Clear	Grasses.
	3 (7.38643 and 5.095697)	Puddle	10			Turbid	Dragon flies.
Ilara	1 (7.3568315 and 5.1046776)	Discarded truck tyre	12	5.33 ± 3.33^{a}	0.07 ± 0.02^{ab}	Greenish	Dragon flies, pride of barbados trees.
	2 (7.344503 and 5.1052663)	Open water body	2			Greenish	Green algae, green grasses, bromeliad plants. Water spiders, midges, damsel flies and dragon flies.
	3 (7.346225 and 5.1091159)	Blocked drainage system	2			Greenish	Damsel flies, dragon flies, tadpoles and adult anurans, midges, lizards and water spiders.

Table 1. Contd.

Ipogun	1 (7.2888774 and 5.1460546)	Blocked drainage system	5	13.67±6.33[a]	0.03±0.02[ab]	Clear	Dragon flies.
	2 (7.3023612 and 5.0833001)	Discarded container	26			Greenish	Midges and dragon flies. Green algae.
	3 (7.315477 and 5.078567)	Used tyres	10			Greenish	Green algae.
Ibule	1 (7.3095428 and 5.1321278)	Puddle	5	3.50±0.76[a]	0.09±0.03[ab]	Turbid	Green algae, full of anuran's eggs.
	2 (7.3139539 and 5.1244894)	Discarded container	2.5			Clear	Trees.
	3 (7.3240689 and 5.1171348)	Discarded container	3			Clear	Midges.
Aaye	1 (7.3118911 and 5.2024889)	Tyre track	5	2.52±1.32[a]	0.05±0.01[ab]	Turbid	Tadpoles and dragon flies. Trees and grasses.
	2 (07.3203745 and 5.1582515)	Concrete hole	2.05			greenish	Dragon flies, tadpoles and adult anurans, midges, lizards and water spiders. Green algae.
	3 (7.3129921 and 5.21030121)	Discarded container	0.5			Clear	Tadpoles.
Ijare	1 (7.360816 and 5.1641861)	Artificial pool	60	5.33±17.37[a]	0.05±0.03[ab]	Greenish	Algae and dragon flies.
	2 (7.3636545 and 5.1665048)	Discarded tyres	6			Greenish	Green algae, mallophaga and midges.
	3 (7.3622923 and 5.1614825)	Open water body	10			Greenish	Midges and damsel flies. Grasses.
Irese	1 (7.3118911 and 5.2024889)	Discarded tyre	1	6.33±10.14[a]	0.10±0.01[b]	Greenish	Dragon flies larvae and green.
	2 (7.308335 and 5.1975811)	Discarded tyre	13			Clear	Midges, damsel flies and dragon flies. Orange tree.
	3 (7.3066596 and 5.2374935)	Tyres	5			Greenish	Dragon flies.

Mean followed by the same letter along the column are not significantly different (p>0.05) using Tukey test.

supported mosquito larvae breeding, only 10 of the 33 sites were permanent/semi-permanent water bodies as illustrated in Table 1, and were populated with different kinds of predators. Similar reports are found in other works (Vince et al., 1976; Coen et al., 1981; Stav et al., 1999; Dida et al., 2015). A good number of the tyre tracks were made by lumber trucks driven through farms and forest and had become more or less permanent breeding sites for mosquitoes. Physical description of each of the sites showed that larvae were found in shallow and muddy habitats. The various predators recorded in Table 1 feed on mosquito larvae. Grasses were present in some of the sampled sites, these plants facilitated breeding by slowing down water current, blocking water flow and providing shade and points for laying eggs(Asaeda et al., 2005). The observed larvae density ranged from 0.01 to 0.10, the larvae were equally distributed across breeding sites in 9 of the 11 towns, with significant differences observed only at the sites in Isarun and Irese. The observed distance between the breeding sites and residential abodes ranged between 0.5 to 300 m, a distance that can easily be covered by the vectors, and can allow effective transmission of mosquito borne diseases in the local government area.

Temperature, total dissolved solids, electrical conductivity and dissolved oxygen were found to be the main variables influencing the abundance and distribution of mosquito larva and predators in the habitats investigated. These abiotic factors could inhibit adult mosquitoes' oviposition (Minakawa et al., 1999, 2012).

The temperature in all breeding sites ranged from 20.80 and 32.60°C, mosquito larvae were seen in breeding sites with temperature as low 20.8°C at Igbara-Oke, although relatively higher than the value observed by Kleinschmidt (2001). Temperature had significant effect on all the mosquito species larvae as higher temperature values increases the presence of these species. Mean temperature from all the sites showed that sites at Owode-Owena, Ero, Ilara and Ipogun were

Table 2. Physico-chemical parameters of larvae collected per site.

Town/village	Site number	Total dissolved solid (ppm)	Dissolved oxygen (mg/L)	pH	Temperature (°C)	Electrical conductivity (mS/cm)	Dominant species
	1	543	6.70	5.70	31.12	0.65	*Anopheles* species
OwodeOwena	2	510	5.90	8.50	31.80	0.48	*Culex* species
	3	540	6.50	5.30	32.30	0.51	*Culex* species
	1	1691	2.70	6.40	23.20	2.26	*Culex* species
Ibuji	2	1147	4.50	7.20	22.60	1.50	*Culex* species
	3	578	7.20	6.50	23.50	0.80	*Culex* species
	1	375	5.90	8.00	25.80	0.50	*Culex* species
Igbara-Oke	2	543	6.10	7.10	29.30	0.73	*Culex* species
	3	620	5.30	7.40	20.80	0.87	*Culex* species
	1	778	5.60	6.20	24.70	1.07	*Anopheles* species
Isarun	2	505	7.00	6.60	21.20	0.77	*Aedes* species
	3	1029	6.10	6.70	28.90	1.47	*Culex* species
	1	1099	4.60	6.40	28.90	1.51	*Aedes* species
Ero	2	615	5.10	6.60	29.30	1.01	*Culex* species
	3	1085	3.20	6.30	31.20	4.30	*Culex* species
	1	513	6.00	7.20	32.20	0.71	*Culex* species
Ilara	2	352	3.00	6.50	31.20	0.49	*Culex* species
	3	781	4.00	7.30	31.80	1.09	*Culex* species
	1	257	7.80	6.30	31.70	0.36	*Culex* species
Ipogun	2	400	5.30	7.10	32.60	0.55	*Culex* species
	3	1423	4.50	6.50	29.90	1.14	*Culex* species
	1	520	6.10	7.20	29.90	0.71	*Culex* species
Ibule	2	1933	4.99	6.90	29.30	2.59	*Culex* species
	3	1868	7.11	7.30	29.00	2.49	*Aedes* species
	1	277	5.60	6.50	29.20	0.38	*Anopheles* species
Aaye	2	488	5.10	6.50	27.40	0.49	*Anopheles* species
	3	131	5.30	6.70	28.20	0.17	*Culex* species
	1	043	7.40	6.90	27.80	0.05	*Culex* species
Ijare	2	261	6.00	6.40	28.80	0.37	*Culex* species
	3	256	6.30	6.70	29.40	0.63	*Culex* species
	1	074	6.40	6.20	25.50	0.09	*Culex* species
Irese	2	126	5.69	6.70	25.60	0.17	*Culex* species
	3	262	6.15	6.30	26.00	0.36	*Culex* species

significantly different from other sites as presented in Table 2. The temperatures of breeding sites at Ibuji were significantly different from other sites at Aaye, Igbara-Oke, Isarun, and Irese. Culicines seemed to adapt to a wide range of temperature as they dominated most of the habitats revealing that temperature is a key factor in the distribution of mosquitoes as also reported (Piyaratne et al., 2005; Henri et al., 2010; Abdel-Hamid et al., 2011).

The range of pH was between 5.30-8.50, pH similar with the observations of Afolabi et al. (2013). pH had a significant effect on the breeding of *A. gambiae* s.l, *Culex* sp, *Toxorhynchites* sp and *Coquillettidia* sp larvae, these species tend to be acidophilic in nature, as higher pH values reduced their presence. pH had no significant effect on the other species, mean pH from all the sampled sites showed no significant difference across settlements. Electrical conductivity (EC) affected the presence of *A. gambiae* s.l., *Toxorhynchites* sp, *Mansonia* sp larvae and *Coquillettidia* sp larvae in the various sites as higher values of EC reduced their presence, but did not seem to affect *Aedes*, and *Culex* species. Mean of electrical conductivity from all the settlements showed that sites at Irese were significantly different from other sites. The range of total dissolved solid (TDS) was between 043 and 1933 ppm as shown in Table 2. TDS had a significant effect on the breeding of *A. gambiae* s.l., *Culex* sp *Mansonia* sp and *Coquillettidia* sp larvae as higher TDS values reduced the presence of these species, but had no effect on the other species. Sites at Ibuji, Aaye, Ijare and Irese had significantly different TDS values from other sites. Tyres had the highest TDS as also reported by Obi et al. (2016). The range of the dissolved oxygen was 2.70-7.80 mg/L, the dissolved oxygen was highest in small water bodies in comparison to larger water bodies due to low usage of free oxygen in the small water bodies. Dissolved oxygen had significant effect on all the mosquito species larvae as higher dissolved oxygen values increased the presence of these species, as also reported by Surendran and Ramasamy (2005), Muturi et al. (2008), Oyewole et al. (2009) and Dejenie et al. (2011). Mean of dissolved oxygen from all the sites showed no significant difference across sites. Culex spp occurred in habitats with wide range of dissolved oxygen levels; Opoku et al. (2007) gave a similar report.

Temperature, total dissolved solids, electrical conductivity and dissolved oxygen were identified to play significant roles in the survival and breeding of these vectors in Ifedore local government area of Ondo state. *Culex* species, arising from its dominance in most of the sites are better breeders being able to tolerate a wide range of physico-chemical variations; though not vectors of malaria, they are incriminated in the transmission of debilitating agents particularly the filariasis parasites. This also predisposes the local government area to *Culex*-vectored pathogens.

Anopheles larvae were dominant in four of the breeding sites, and against previous reports (CDC, 2015), they were not found in clear water but turbid environments. Despite the small number of breeding sites for these malaria vectors, malaria is endemic in the study area which may be indicative of a small number with high vectoral capacity or in-house residual breeding where most transmission takes place. Most malaria vectors in the tropics are anthropophilic and endophilic.

Adequate understanding of these breeding sites is needed to control mosquito particularly in deploying environmental modification of breeding sites. The latter will be advisable over deployment of chemicals into such sites that may also serve other functions to non-target organisms. In conclusion, all the three tiers of government in the country should endeavour to provide adequate social amenities like pipe borne water, proper drainages and good roads so as to prevent the creation of temporary mosquito breeding sites, which were more in number in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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