INTRODUCTION
Mosquitoes, under favorable environmental conditions of the tropics, are successful and cause several diseases of medical and veterinary concerns such as malaria, lymphatic filariasis, dengue fever, amongst other infections (WHO, 2020). With the continued increase in climate change, case reports of these diseases have skyrocketed especially in Africa where insecticide resistance has become a major challenge to vector control (Muhammad et al., 2021). This necessitated the ongoing search to unravel better approaches to tackle the mechanisms involved in insecticide resistance in species, establish efficient larvicides and repellents in plant materials, as well as the scale up of interventions involving treated nets and indoor spraying to reduce the scourge of mosquito-borne infections (WHO, 2016).

The use of insecticides has, therefore been recommended for use by the World Health Organization either in impregnating bed nets or indoor sprays (WHO, 2016). But this intervention alone cannot help reduce the morbidity and mortality caused by the Anopheles mosquitoes. Between 2000 and 2020, vector control using insecticide has helped reduce case report from malaria below 45% (WHO, 2020). Even with the decrease in death tolls, Nigeria, amongst other countries in Central and West Africa were marked as major endemic countries with high malaria cases, thus, accounting for 70% of the world’s malaria burdens (WHO, 2020). Malaria infection burdens the Nigeria populace where about half of the disease has been ascribed to it from the 50% burdens reported in Africa (WHO, 2020). In Nigeria, the disease reached 60% in patients visiting medical facilities, and mortality reached 30% in infants (WHO, 2017). The prevalence of malaria could be as a result of the poor environmental hygiene that encourages abundance of potential breeding sites.

The malaria disease caused by Anopheles mosquitoes have been reported in most part of the world where over 700 million persons are at risk annually (Adelke, et al., 2010). Anopheles can exploit varieties of breeding habitats containing water either natural or artificial sites near human dwelling (Klinkenberg et al., 2008). According to Aigbodion and Anyiwe, (2005), a number of factors relating to environment and climate directly influence the abundance and distribution of mosquitoes. These factors such as the habitat size, water characteristics, intensity of sunlight, water salinity, turbidity, and presence of emergent or floating vegetation greatly influence the aquatic habitats suitability for the different stages of development of the Anopheline vectors. Human-influenced activities that changes the landscape, including irrigated fields and land settlements, consequently may influence the temporal and spatial distribution of mosquitoes (Zhou et al., 2011). The chemical properties of breeding site equally has a direct impact on habitat selection by gravid female mosquitoes, growth and development of immature stages, and thus mosquito distribution (Noutcha and Anumudu, 2009).

A study by Ciota and Kramer (2013) has shown that human activities such as international trading, climate and urbanization may influence mosquito availability in Afro-endemic areas and environs. With potential breeding sites of mosquitoes thriving everywhere, colonization of newer
geographic areas and the incidence of mosquito-borne diseases of public health concerns would be experienced. According to observation made by Rakotomanana et al. (2010), urban expansion have influenced the epidemiology of malaria diseases through the availability of suitable breeding environment for vectors. Most studies have established the susceptibility of mosquitoes to various insecticides (Chukwuekezie et al., 2020; Muhammad et al., 2021; Ojianwuna et al., 2021). However, no information on the exact determination of physicochemical parameters of mosquito breeding site is available as an avenue to estimate the abundance and distribution of mosquitoes in endemic areas. It is, therefore, necessary to determine the physicochemical parameters of Anopheles breeding site, and their abundance and distribution in a selected Local Government Area in Delta State.

MATERIALS AND METHOD

Study Area
The research was conducted in Ukwani Local Government Area of Delta State. Ukwani borders Ndokwa West to the East, Ethiope East to the west and Isoko North to the south. Over 110,000 people live in the LGA (Nigerian National Bureau of Statistics, 2006). Ukwani is under Delta North Senatorial District, Delta State (Figure 1). Three communities were mapped out to obtain data on the abundance and distribution of Anopheles mosquitoes in Obiaruku (5.836465°N and 6.159439°E), Umutu (5.915783°N and 6.225577°E) and Umukwata (5.808901°N and 6.240219°E).

Fig. 1. Map showing study area

Umutu; Obiaruku; Umukwata

MATERIALS
Ladles, transparent buckets, mosquito net caps, collapsible cages, larval trays, scooping spoons, pipette, and thermo-hygrometer and larval recording sheets were the materials used for the collection of mosquitoes in the study.

Sample collection and identification
Larvae and pupae of Anopheles mosquito were collected from various communities as well as the physical components of the mosquito breeding habitat. Ladle (350 ml) and scooping spoons were used to collect larva in large water bodies and shallow habitats such as tyre marks and puddles respectively. A total of 35 sites were sampled. Field collections were transported to the Insectary of the Department of Animal and Environmental Biology, Delta State University, Abraka for breeding. Larvae were transferred into trays and kept in insectary with temperature and relative humidity maintained at 28±3°C and 78±3% respectively. Net caps made from mosquito net were used to tightly cover the tray to avoid the escape of emerging adult mosquitoes. Emerging adult mosquitoes were transferred to the adult cages using aspirator and later killed using ethyl acetate in the killing jar before identification using standard key described by Harbach, (2008) and Harbach and Kitching (2016).

Mosquito density
The density of mosquitoes was calculated after 20 dips using ladles in each of the sampled community and the abundance of the larva recorded. Percentage density of Anopheles mosquitoes was calculated as:

\[ \text{Density of Anopheles} = \frac{\text{Number of Anopheles in the ladle}}{20 \text{ dips}} \times 100 \]

Determination of physicochemical parameters
These were carried out in accordance with procedures reported in ASTM, (2012).

**pH**

The pH is the negative logarithm of hydrogen ion concentration. It was measured electronically using a pH meter, the electrode was washed with de-ionized water and later standardized, then the standardized electrode was introduced into the water sample contained in 100ml Beaker and the reading was taken.

**Temperature**

Air and water temperature can be measured using a mercury-in-glass thermometer. Water temperature was measured by suspending the thermometer into the water and held for 1-2mins for stability, then the readings were taken. Air temperature was measured using thermohygrometer in the air for few minutes and the reading was taken.

**Dissolved oxygen**

Water samples were collected with a DO bottle and covered while under the water. The wrinkler solution A & B was added to the sample to trap the oxygen using a syringe. In the laboratory, 100ml of sample was measured using a measuring cylinder and turned into a conical flask, 2ml of H2SO4 was added to the sample, this gave it a yellowish colour. Then a few drop of starch indicator was added, and the solution turned black. It was then Titrated using Na2S2O3 until solution became colourless.

\[ \text{Do} = \text{Titre of value of N x N of Na2S2O3 / 100ml} \]

The S.I unit = mg/l

**Electrical conductivity**

Conductivity (specific conductance) is the numerical expression of the water's ability to conduct an electric current. It is measured in micro Siemens per cm and depends on the total concentration, mobility, valence and the temperature of the solution of ions.

**Results**

Summary results of some physicochemical parameters of the Anopheles breeding sites in Ukwani LGA, Delta State is shown in Figure 2. The monthly variation in the density of mosquitoes (Table 2). The monthly variation in the density of mosquitoes. Hydrogen ion concentration (pH), and dissolved oxygen were higher in Obiaruku compared to the other communities. The differences were significant (p <0.05) within the sampled months and communities except for pH. Similarly, salinity, conductivity, total dissolved solids and flow velocity were higher in Obiaruku and Umukwata respectively when compared to Umutu. There was also significant differences in most of the physicochemical parameters and the sampled months (p< 0.05) (Table 1).

**Physicochemical parameter correlation with Density of Anopheles**

The percentage density of Anopheles mosquitoes sampled from Ukwan LGA, Delta State is shown in Figure 2. The density of species in Obiaruku was higher (p= 0.0025) compared to other sampled communities while species density was lowest in Umukwata. All physicochemical parameters were positively correlated with density of the mosquitoes and water temperature had the highest correlation (0.485) compared to other parameters (Table 2). Air temperature positively influenced electrical conductivity and total dissolved solids. Water temperature was also influenced by air temperature which in turn influenced electrical conductivity, total dissolved solids, flow velocity and the density of mosquitoes. Hydrogen ion concentration (pH) and dissolved oxygen affected all other parameters.

More so, electrical conductivity negatively affected water temperature and dissolved oxygen, total dissolved oxygen affected air temperature, pH and electrical conductivity. Flow velocity and salinity also negatively affected air, water temperature, pH, dissolved oxygen and total dissolved solids. Flow velocity and salinity positively correlated with density of mosquitoes (Table 2). The monthly variation in the density of Anopheles showed that more species were recorded in

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**Table 1. Summary of some physical and chemical parameters of the Anopheles breeding sites in Ukwani LGA, Delta State from September to November, 2020.**

| S/N | Parameter | Obiaruku | Umukwata | Umutu | F-ANOVA months | F-ANOVA Sites | P-value months | P-value Sites |
|-----|-----------|----------|----------|-------|----------------|--------------|---------------|---------------|
| 1.  | Air temperature (°C) | 33.63±0.67 | 32.45±0.41 | 34.55±0.40 | 20.32*<0.05 | 4.32*<0.05 | 0.0041<0.05 | 0.027<0.05 |
| 2.  | Water temperature (°C) | 30.00 ± 0.37 | 29.91±0.45 | 30.95±0.12 | 14.3*<0.05 | 2.841<0.05 | 0.0091<0.05 | 0.083<0.05 |
| 3.  | pH | 6.12 ± 0.02 | 6.09±0.02 | 6.13±0.03 | 1.36 | 1.266 | 0.263<0.05 | 0.626<0.05 |
| 4.  | Dissolved oxygen (mg/l) | 7.8±1.1 | 7.4±0.7 | 8.1±0.91 | 34.53*<0.05 | 27.83*<0.05 | 0.0013<0.05 | 0.0043<0.05 |
| 5.  | Conductivity (µS/cm) | 583±6.26 | 424±6.52 | 462±12.4 | 0.1004<0.05 | 87.6*<0.05 | 0.762<0.0001 | <0.0001<0.05 |
| 6.  | TDS | 11.25±1.17 | 51.3±0.92 | 51.13±0.65 | 15.21*<0.05 | 462.2*<0.05 | 0.008<0.0001 | <0.0001<0.05 |
| 7.  | Salinity (ppm) | 276.5±4.14 | 190.3±5.85 | 149.6±18.7 | 0.579 | 5.002*<0.05 | 0.475<0.0167 | 0.0167<0.05 |
| 8.  | Flow velocity (mV) | 198.0±4.69 | 287.4±1.68 | 226.3±3.99 | 0.204 | 88.99*<0.05 | 0.668<0.0001 | <0.0001<0.05 |
September and in Obiaruku than in other sampled months and communities (Figure 3). Although, the differences was not significant (p > 0.05).

**Fig. 2.** Showing the percentage density of anopheles mosquitoes sampled from Ukwani LGA, Delta State. (F (density) = 12.59, P= 0.0025)

**Table 2:** Summary of the physiochemical correlation against the density of anopheles mosquitoes sampled at Ukwani LGA, Delta State.

|         | AT     | WT     | pH    | DO    | EC    | TDS   | FV     | SAL    | DEN   |
|---------|--------|--------|-------|-------|-------|-------|--------|--------|-------|
| AT      | 1      | 0.0011 | 0.007 | 3.72E-05 | 0.381 | 0.629 | 0.031  | 0.067  | 0.012 |
| WT      | 0.708  | 1      | 0.245 | 0.003 | 0.615 | 0.427 | 0.154  | 0.095  | 0.485 |
| pH      | 0.532  | 0.247  | 1     | 0.006 | 0.484 | 0.687 | 0.015  | 0.186  | 0.074 |
| DO      | 0.739  | 0.578  | 0.546 | 1     | 0.389 | 0.163 | 5.17E-05 | 0.016  | 0.149 |
| EC      | 0.187  | -0.108 | 0.150 | -0.184 | 1    | 3.36E-10 | 0.505  | 0.795  | 0.001 |
| TDS     | -0.104 | 0.170  | -0.088 | 0.294 | -0.916 | 1    | 0.151  | 0.110  | 0.001 |
| FV      | -0.442 | -0.300 | -0.429 | -0.730 | 0.143 | -0.302 | 1     | 0.003  | 0.374 |
| SAL     | -0.380 | -0.348 | -0.279 | -0.485 | 0.056 | -0.335 | 0.573  | 1     | 0.358 |

**Note:** AT= air temperature, WT= water temperature, pH= hydrogen ion concentration, DO= dissolved oxygen, EC= electrical conductivity, TDS= total dissolved solids, FV= flow velocity, SAL= salinity, DEN= density of mosquitoes.

**Fig. 3.** Monthly variations in the density of anopheles mosquitoes in Ukwani LGA, Delta State. (F (density) = 2.84, P= 0.136)

**Abundance and distribution of Anopheles mosquitoes**

The abundance and distribution of *Anopheles* mosquitoes sampled from various habitat in Ukwani LGA, Delta State is shown in Table 3. Only *Anopheles gambiae* was encountered in puddles, tyre-marks, ponds, and ditches. Anopheles mosquitoes were preponderant in ponds. Puddles equally had high Anopheles larvae while ditches recorded low species (Table 3). **Table 3.** Effect of physiochemical parameters on the abundance and distribution of *Anopheles* mosquitoes sampled from various habitat in Ukwani LGA, Delta State.

| Mosquito habitats | Mosquito species collected | No. of mosquito species collected (%) |
|-------------------|----------------------------|--------------------------------------|
| Puddles           | *An. gambiae*              | 271 (32.6)                           |
| Tyre-marks        | *An. gambiae*              | 152 (18.3)                           |
| Ponds             | *An. gambiae*              | 350 (42.1)                           |
| Ditches           | *An. gambiae*              | 59 (7.1)                             |
| Total             |                            | 832 (100.0)                          |

**Note:** habitats with – signifies absence of mosquito species.

**Discussion**

In this study, we aimed to determine the abundance and distribution of *Anopheles* mosquitoes in Ukwani L.G.A., Delta State with reference to the physicochemical characteristics of their breeding sites. The appropriate estimation of mosquito species abundance and distribution is...
prerequisite to developing an effective control approach in the prevailing malaria and disease in Nigeria. Similar to this study, Kipyab et al. (2015) confirmed that the density of mosquito species in breeding sites is a function of some physiochemical parameters. More so, Kwka et al. (2012), and Garba and Olayemi (2015) established that there is a link between physiochemical parameters of mosquito breeding sites and mosquito abundance and distribution, as well as the prevalence of the diseases they transmit. Notable studies have implicated Anopheles mosquitoes in clean fresh water (Kevin et al., 2014; Manguin, 2013; Kudom, 2015). However, only recently Anopheles mosquitoes have been found in polluted waters of their breeding sites (Satller et al., 2005; Awolola et al., 2007). In some cases Anopheles and Culex mosquitoes inhabit same habitat even with the disparity in the ecology of habitat, but Anopheles species are more likely to be found as noted in studies of (Kweka et al., 2012; Dejenie et al., 2011).

The present study encountered Anopheles mosquitoes in clear and turbid water of breeding habitats. Clear waters with associating vegetation were majorly observed in the breeding habitats in this study. Sometimes waters were turbid and perceived to have little organic matter mixed (Kudom, 2015). Physiochemical parameter survey in various breeding sites revealed temperature to be between 29.9 and 34.6°C, pH between 6.09 and 6.14. Dissolved oxygen between 7.4 and 8.1 mg/l, conductivity between 424 and 583 µS/cm, TDS between 11.3 and 51.3, salinity between 149.6 and 276.5 ppm, and flow velocity between 198 to 287.4 mV. Water temperature of the sampled communities were within acceptable limits for larvae survival. Various studies have confirmed that larvae density corresponds to temperature between 28°C and 32°C (Kabula et al., 2011; Kweka et al., 2012; Munga et al., 2013; Imam and Deeni, 2014). Though, air temperature in Umutu was high and probably had influenced the increasing temperature of water in the breeding habitats. It may connote that increased air temperature influenced increased water temperature which thus affects mosquito abundance and distribution in the sampled communities. Air temperature, water temperature, conductivity and total dissolved solids was highest in Umukwata, as pH and DO were highest in Obiaruku and Umutu respectively compared to the other locations. The high conductivity reported in this study must have supported the high density of mosquito larvae in Obiaruku. This observation is in agreement with previous studies of (Kabula et al., 2011; Dejenie et al., 2011) which reported salinity and conductivity supports abundance of Anopheles larvae compared to culicine larvae. Higher records of conductivity is linked to run offs contaminated with pesticides, chlorine, phosphoric and nitrous ions other than associating solids in the waters of breeding habitats (Kevin et al., 2014).

Anopheles mosquitoes were highly abundant in September and in ponds than in other sampled months and breeding habitats. The range of water and air temperature reported in this study is in agreement with the study of Mereta et al. (2013). Hydrogen ion concentration (pH) of breeding habitats in Obiaruku was neutral and those recorded in the other habitats were slightly acidic. This must have been the reason for high density of Anopheles mosquito in Obiaruku compared to the other locations with slightly acidic waters. However, the study of Kwasi et al. (2012) noted that hydrogen ion concentration of 10.1 above or 4.4 below would cause larval mortality in breeding sites. The waters of the various breeding habitats in the sampled locations were highly oxygenated following the records presented in this study (Table 1). According to Kenguecha et al. (2005), water temperature, pH, CO₂ and hardness were determining factors of mosquito abundance. However, variation in dissolved oxygen concentration has been reported to be linked to the differences in mosquito larva density in the various habitat (Lancaster and Downes, 2013). The low pH recorded in Umukwata would be due to the mining activity that could have increased acid deposition via sedimentation. In other locations, increase in pH could be due to fertilizer use which ran off into mosquito breeding sites. Dissolved oxygen was at acceptable limits for mosquito survival and it is in line with other studies of Getachew et al. (2020). The record of total dissolved solids reported in this study was remarkable. However, highest concentrations were recorded in Umukwata and were similar to the observations made by the study of Okogun et al. (2005). In laboratory culture, Geller et al. (2000) noted that An. gambiae would thrive well and emerge at stipulated day limits when pH is at tolerable levels and planktons sufficient enough for their consumption. Similar observation was made by Okogun et al. (2005) that cool, still and clear water with suitable pH, temperature and nutrient composition would encourage breeding of Anopheles species and fewer erosion and flooding are enemies of mosquito in their breeding habitats with an observed oxygen depletion and physical harm to the larvae (Mereta et al., 2013).

Considering the density of Anopheles mosquito in the different locations, Obiaruku had the highest (42.3%) and Umukwata the lowest density (21.3%). Dissolved oxygen and hydrogen ion concentration (pH) of waters of breeding sites were positively correlated to the density of mosquitoes. Even though other factors including temperature, total dissolved solids and conductivity showed negative correlation, there is likelihood of these parameters impacting on larva density in the various breeding sites. As evidenced in the study of Noori et al. (2015), positive correlation was observed with temperature, pH, nitrate, and Cx. pipiens, Cx. longiareolata, Cx. antennatus, Cx. caspius, Cx. vagans, Cx. decens, Cx. perexiguus, Cx. unititatus, An. multicolor; turbidity and An. arabiensis; sulphate and An. sinensis; phosphate and Cx. quinquefasciatus. In this present study, Anopheles mosquitoes were present, abundant and distributed in puddles, tyre marks, ponds and ditches with ponds (42.1%) having the highest number of species collected. Contrary to the findings of this study, Mattah et al. (2017) reported that puddles had the highest number of mosquito species. Similarly, the study of Getachew et al. (2020) reported higher Anopheles larvae density in rain pools, pools generally and burrow pits compared to other habitats. The differences between those recorded in this present study and previous study may be ascribed to water chemistry, physical and environmental factors. This study has revealed that due to the presence of Anopheles mosquito in abundance, sustained malaria infections in the communities investigated is possible. The diversity of breeding habitats of mosquitoes is probably due to the abandonment of developmental projects, lack of sanitary activities, poor environmental maintenance and management practices that prevails in several communities in Nigeria.

CONCLUSION
This study has shown that physicochemical parameters reported favoured mosquito abundance and distribution in all sampled habitats especially Obiaruku. Water temperature, pH, conductivity, dissolved oxygen and TDS being at acceptable limit for mosquito survival. Anopheles mosquito density was reportedly high in all locations, positively correlated with all physicochemical parameters and highest
in September. This predicts that habitat of mosquitoes in Obiaruku and Umatu encouraged abundance of mosquito species. Therefore, manipulating the habitat by increasing or decreasing DO and pH would better control species in their local habitat. Mosquito control should be targeted on ponds. This findings could be useful in comprehending the ecology of mosquito larva that may be beneficial in designing and implementing larval control programs.

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