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# MONITORING SEASONAL CHANGES IN ENVIRONMENTAL VARIABLES AND CHIRONOMID DIVERSITY AT SHIRORO LAKE, NIGER STATE, NIGERIA

**Auta. Y. I*., Arimoro. F. O., Mohammed, A. Z., and Ayanwale, A. V.**

Applied Hydrobiology Unit, Department of Biological Sciences, Federal University of Technology, Minna, Niger State, Nigeria.

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## ABSTRACT

Freshwater chironomids are considered to be ideal bioassay organisms since they spend most of their larval stages in surface sediments. This study was carried out with the aim of identifying taxa assemblages and analyzing their response to water quality parameters in Shiriro Lake. Chironomid larvae samples were collected in three stations along tributary of Shiroro Lake using the kick sampling technique over a six-month period (August, 2013 to January, 2014). A total of 14 Chironomid species comprising 480 individuals were collected with richness at individual station ranging from 3 to 10 taxa. Two Chironomid taxa; *Chironomus* (a) spp and *Dicrotendipes* spp were preponderant and present in all the three stations. The most abundant taxon was *Chironomus* (a) spp with relative abundance of (56%) followed by *Polypedilum* spp (10%) and *Ablabesmyia* spp (8%). Taxa richness calculated as *Margalef* index did not show any significant difference ($p>0.05$) among the sampling stations. Similarly, diversity indices (*Shannon-Wiener, Simpson dominance indices*) did not detect any significant difference between the stations examined. Lower values of diversity and evenness indices were recorded at station 3. Water quality parameters showed that Sodium (0.001-0.58mg/g) and Potassium (2.9-3.51 mg/g) levels in the water were considerably high as a result of anthropogenic activities in the catchment. Other parameters such as Dissolved Oxygen (2.1-5.6 mg/l), Biochemical Oxygen Demand (1.0-9.6mg/l), Conductivity (25-135µS/cm), pH (6.4-8.11) and Transparency (92-188cm) indicate that the water body is increasingly polluted. Canonical Correspondence analysis (CCA) was adopted for the analysis of environment and biota data indicated that *Chironomus* sp., *Polypedilum* sp., *Clinotanypus* sp., *Ablabesmyia* sp. and *Dicrotendipes* sp, showed a positive relationship with most of the environmental variables. Since chironomid larvae are tolerant to poor water quality conditions, they should be considered as indicators of pollution in Shiroro Lake, Niger State.

**Key words:** Environmental variables, *Chironomid* Larvae, Abundance.

***Corresponding Author:** auta.iliya@futminna.edu.ng

## INTRODUCTION

The Chironomidae, Family of Diptera, commonly called the non-biting midges, are seen in several aquatic systems, and often are the dominant group of the benthic invertebrates' fauna of streams, both in numerical abundance and in species richness (Coffman and Ferrington, 1984). Recently, efforts to identify the effects of exposures of Chironomids to toxic sediment have been focused on deformities in benthic Chironomids living in contaminated sediments. In lentic and lotic environments, the analysis of benthic animals, particularly Chironomidae has played an assertive role (Saether, 1979). However, the use of communities of Chironomidae in terming and monitoring lotic ecosystems still lacks deducing power due to lack of knowledge on their ecological roles and their species distribution (De Bisthoven & Gerhardt, 2003).

Freshwater Chironomids are thought to be perfect bioassay organisms since they pass most of their larval stages in surface sediment, their relatively sedimentary falsifying behaviour ensures that their home ranges are localized areas and have an abundant distribution (Arimoro, 2011). Chironomids are a useful collection for describing abundance-distribution relationship due to their ecological importance to applied facets. Besides indicative of pollution in aquatic environment, Chironomids also present a sort of life history that differs evidently, for example, in life-span, locomotion, habits and physiological tolerance to oxygen deficit (Pinder, 1986) This Chironomid population structure is an index of environmental quality (Bird *et al.,* 1995). The aim of this research is to monitor seasonal changes in environmental variables in relation to chironomid diversity and abundance at Shiroro Lake, Niger state, Nigeria to add to the gradual growing pool of data on their use as water quality indicators.

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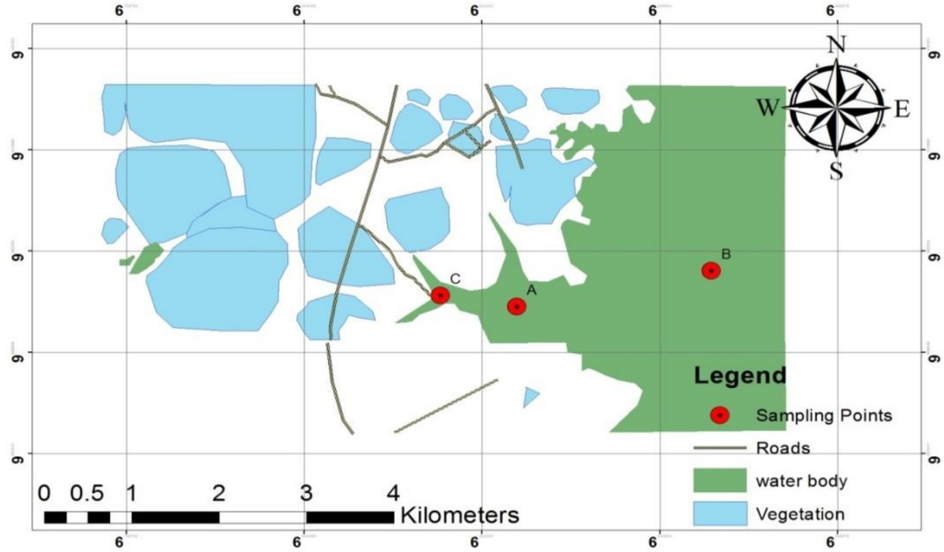


**Fig 1: Shiroro Lake Showing Sampling Stations.**
**Source:** Geography Department, Federal University of Technology, Minna.

## MATERIALS AND METHODS

### The Study Area

Shiroro Dam is located on latitude 9 58˚ 25' North and Longitude 6 50˚ 6`` East and situated 550 meters downstream of the confluence of Kaduna River and its tributaries. There are about 15 tributaries within the Shiroro watershed, the major among them being Rivers Dinya, Sarkin Pawa, Guni, Erina, and Munyi. The tributaries flow in the North South direction and few in the North-west to Southeast direction. The storage areas do not sustain the River during extended dry season. This explains the seasonality characteristics of these rivers, since they depend on rainfall. It is obvious therefore, that the volume of the rivers swell in volume with ranging torrent while in the dry season they dwindle to dry up (Kolo and Oladimeji, 2004).

The inhabitants of Shiroro community, residing along the River floodplains depend on the Kaduna River as a source of irrigation and for their household use and for drinking. Fishing activities is a daily affair in the lake. Another activity noticed at the lake is the weekly market that contribute to the pollution of the lake with a lot of waste materials and the grazing activity of Nomadic herdsmen around the shoreline of the lake was a prominent feature throughout the period of this study.

### Water Quality Parameters Analyses

Water quality analysis was carried out Monthly between August, 2013 and January, 2014. At each sampling site, the following physical and chemical parameters were measured: dissolved oxygen (DO), conductivity, turbidity, temperature, pH, BOD, Potassium and Sodium. Water samples used for the analysis of chemical variables, except for five days biochemical oxygen demand ($BOD_5$), were collected in 250 ml plastic bottles; water samples for $BOD_5$ were collected in sterilized 500 ml glass bottles. Prior to each field trip, the sampling bottles were acid-washed according to the Institute for Water Research Glassware Acid Wash Protocol (Dickman and Rygiel, 1996). In addition, bottles used for the collection of water samples for $BOD_5$ were sterilized in an autoclave set to 120°C and heated for 15 minutes. Water samples were collected facing upstream of the river as recommended in APHA (1992) and the bottles for DO were filled to the neck allowing no head space and Winkler solutions A and B was added using pipette to avoid trapping air bubbles. This was transported to the laboratory in an ice-filled cooler box. Samples were preserved at 4°C in the laboratory for chemical analysis. All chemical analyses were performed within 24 hours of sample collection.

The estimation of sodium and potassium was based on the emission spectroscopy, which deals with the excitation of electrons from ground state to higher energy state and coming back to its original state with release of energy in the form of light (Kruis, 2005).

**Chironomid Sampling**

Chironomids samples were collected between August, 2013 and October, 2013 (Rainy season) and November, 2013 to January, 2013 (dry season) in accordance with Dicksen and Graham (2002) protocol for the South African scoring system (SASS) version, 5. The protocol requires the collection of Chironomids from three biotopes, the stone biotope (stone in and out of current), the vegetation biotope (marginal and aquatic vegetation) and the gravel, sand and mud (GSM) biotopes. Chironomids collection was done using a D-frame net of mesh size 110 µm and a Surber sampler. The Surber sampler was draged inside the water for at least 20 meters at each station and the contents were discharge on a tray with a white background using clean water to reduce decay organic matter. Chironomid larvae were sorted out using forceps and sampling tubes containing 70% ethanol. A total of nine replicates (three per biotope) were collected and pooled. Collected Chironomid larvae were preserved in 70% ethanol and transported to the Biological Sciences Laboratory of Federal University of Technology, Minna for further analysis.

**Screening, sorting and identification of Chironomid Larvae**

In the laboratory, preserved chironomid samples were gently spread on a white tray and all Chironomid larvae sorted, under a hand-held magnifying glass, using fine forceps. Sorted chironomid larvae were preserved in specimen vials containing 70% ethanol. The chironomid larvae were mounted for taxonomic identification using mouth parts and other structures according to the keys described by Wiederhilm (1983) and Cranston (1996).

**Data Analysis**

Canonical correspondence Analysis, (CCA) was used to demonstrate relationship between chironomid larvae and physical variables in water using PAST statistical package (Dickman & Rygiel, 1996). Taxa richness (Margalef indices), diversity (Shannon and Simpson dominance indices) and evenness indices were calculated using the computer BASIC programme sp DIVERS (Ludwig and Reynolds, 1988).

## RESULTS AND DISCUSSION

The summary of physicochemical parameters obtained for the three sampling stations of the lake is shown in Table 1. Dissolved oxygen (DO), Biochemical oxygen demand (BOD), air temperature, transparency, conductivity, and sodium showed higher significant differences ($p<0.05$) among the months sampled. Also, pH and potassium were significantly higher ($p<0.05$) with moderate variation among the stations.

Canonical correspondence Analysis, (CCA) was used to demonstrate relationship between chironomid larvae and physical variables in the surface water and the result is presented in Figure 2. It is well established that multivariate analysis methods such as CCA have the potential to explain the interaction between Chironomids community and Environmental stressors (Mausavi *et al*., 2004; Marziali *et al*., 2010). In the present study, the CCA facilitated identification of the influence of various environmental variables on the distribution of Chironomid larvae in the Shiroro Lake. *Chironomus* sp., *Polypedilum* sp*.*, *Clinotanypus* sp*.*, *Ablabesmyia* sp. and *Dicrotendipes* sp., showed positive relationship with most of the environmental variables. These species were considered as tolerant species because they have the ability to survive in extreme environmental conditions with low amount of dissolved oxygen and high concentration of pollutants. The finding of Mausavi *et al*., (2004) that *Chironomus* sp, and *Polypedilum* sp. were very tolerant to pollutants further supported this categorization. As displayed in the CCA output, the Tanypodinae, *Micropelopia* sp and other species favoured habitats with higher level of DO content, Na, pH and water temperature during the wet seasons, but could not survive at low dissolved oxygen concentration. *Tanytarsus* species preferred environmental conditions with relatively moderate to high water temperature, DO and pH.

There were fourteen (14) Chironomid taxa at the three stations with richness at individual station ranging from 3 to 10 taxa. Two Chironomid taxa, *Chironomus* sp. and *Dicrotendipes* sp. were found in all the three stations (Table 2). Some sensitive Chironomid species, *Polypedilium*, *Clinotanypus* were found in stations 1 and 2, while tolerant species *Cladotanytarsus* sp was restricted to station 1 only. *Chironomus* sp (a) was the major taxa with a relative abundance of 54 (56%) followed by *Polypedilium* sp. 9 individuals (10%) and *Ablabesmyia* sp. 7 individuals (8%).

Table 1. Distribution of Maximum and Minimum Physico-chemical Parameters of Shiroro Reservoir from August, 2013 to January 2014.

| | | | | F-value | | p-value | |
|---|---|---|---|---|---|---|---|
| | Station 1 | Station 2 | Station 3 | MONTHS | STATIONS | MONTHS | STATIONS |
| Dissolved oxygen(mg/l) | 3.7 ±1.16<br>(2.1-4.7) | 3.95± 1.22<br>(2.0-5) | 4.31± 0.94<br>(3.3-5.6) | 5.04 | 1.09 | 0.15 | 0.37 |
| B.O.D( mg/l) | 4.26±2.93<br>(1.0-9.6) | 2.78±1.60<br>(1.0-5.0) | 2.9±1.81<br>(1.0-5.7) | 1.47 | 0.98 | 0.28 | 0.41 |
| Air Temperature(°C) | 24.83±0.75<br>(24-26) | 25.33±1.21<br>(24-27) | 25.83±1.69<br>(24-27) | 1.29 | 1.45 | 0.34 | 0.28 |
| water Temperature(°C) | 23±1.10<br>(21-24) | 22.67±0.52<br>(22-23) | 21.83±0.75<br>(21-23) | 0.91 | 3.1 | 0.52 | 0.09 |
| Transparency(cm) | 150±38.47<br>(95-185) | 151.5±39.47<br>(96-188) | 149±36.61<br>(92-186) | 309.94* | 0.68 | 1.26E-10 | 0.53 |
| Conductivity(µs) | 68±44.79<br>(26-133) | 69±44.15<br>(25-132) | 67±.68<br>(27-135) | 646.58* | 0.67 | 3.26E-12 | 0.53 |
| pH | 7.38±0.51<br>(6.66-8.11) | 7.28±0.66<br>(6.5-8.1) | 7.29±0.68<br>(6.4-8.11) | 20.6* | 0.39 | 5.67E-05 | 0.69 |
| Sodium(mg/g) | 0.21±0.28<br>(.001-.58) | .20±.27<br>(.002-.57) | .20±.27<br>(.001-.57) | 1888.44* | 1.48 | 1.55E-14 | 0.27 |
| Potassium(mg/g) | 17.65±18.47<br>(2.9-47.9) | 17.77±18.73<br>(3.0-48) | 23.62±18.98<br>(3.3-51) | 17.17* | 1.36 | 0 | 0.3 |

Note: $p< 0.05$ indicates that the parameter is significantly different.
Values in parenthesis are minimum recorded for therespective parameter.

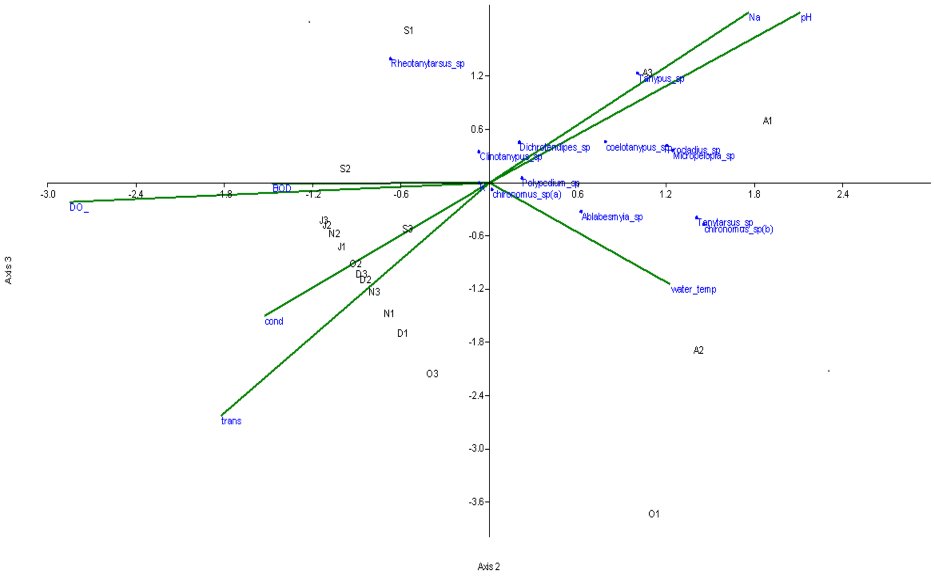


Fig 2. Canonical correspondence Analysis, (CCA) of the different species of chironomid larvae and physical variables in the surface water of Shiroro Lake.

**Table 2:** Diversity, Distribution and Abundance of Chironomidae larvae in Shiroro Lake

| Species | station 1 | station 2 | station 3 | Species Total | % |
|---|---|---|---|---|---|
| *Chironomus sp* | 60 | 25 | 185 | 270 | 56 |
| *Chironomus sp* | 5 | 0 | 10 | 15 | 3 |
| *Dicrotendipes sp* | 10 | 5 | 5 | 20 | 4 |
| *Tanytarsus* | 0 | 5 | 0 | 5 | 10 |
| *Procladius sp* | 0 | 10 | 0 | 10 | 2 |
| *Coelotanypus sp* | 15 | 5 | 0 | 20 | 4 |
| *Clinotanypus* | 15 | 5 | 0 | 20 | 4 |
| *Polypedilum sp* | 10 | 35 | 0 | 45 | 10 |
| *Ablabesmyia sp* | 15 | 20 | 0 | 35 | 8 |
| *Rheotanytarsus* | 0 | 5 | 0 | 5 | 1 |
| *Microchironomus* | 0 | 5 | 0 | 5 | 1 |
| *Cladotanytarsus sp* | 15 | 0 | 0 | 15 | 3 |
| *Tanypus sp* | 5 | 0 | 0 | 5 | 1 |
| *Macropelopia sp* | 10 | 0 | 0 | 10 | 2 |
| **Total** | **160** | **120** | **200** | **480** | |

Table 3: Taxa Richness, Diversity, Evenness and Dominance Indices of chironomid species at Shiroro Lake

| | 1 | 2 | 3 |
|---|---|---|---|
| No of Taxa | 10 | 10 | 3 |
| No of Individuals | 32.00 | 24.00 | 40.00 |
| Dominance_D | 0.19 | 0.17 | 0.86 |
| Simpson_1-D | 0.81 | 0.83 | 0.14 |
| Shannon_H | 1.99 | 1.99 | 0.31 |
| Evenness_e^H/S | 0.73 | 0.73 | 0.46 |
| Taxa Richness (Margalef index) | 2.60 | 2.83 | 0.54 |

Taxa richness calculated as Margalef index, Shannon diversity, Evenness and Simpson's index for the three stations are presented in Table 3. Shannon index and Evenness index analysis showed that there were no significant differences ($p>0.05$) between station 1 and 2. However, the lowest values were recorded in station 3. Taxa richness was higher in station 2, followed by station 1 and then station 3 in that order. Station 3 values were significantly lower ($p<0.05$) than those of stations 1 and 2.

*Tanytarsus sp*. appeared to be the most reliable bio-indicators of the least polluted sites, whereas sites with higher concentration of organic pollutants in the Lake favoured abundance of tolerant species of *Chironomus* sp. The physico-chemical parameters did not provide a clear distinction between the stations, Dissolved oxygen (DO) is one of the most reliable parameters in assessing the trophic status of an aquatic ecosystem. Its concentration was generally low with a gradual increase within the stations and a slight decrease in January during the study period. The low level of DO is indicative of polluted nature of the water body; such low level of dissolved oxygen was also noted in Dal Lake, Kashmir, (Iqbal *et al*., 2006). Again the low dissolved oxygen at the station could be accounted for by the accumulation of decomposable organic matter which used up the oxygen; this corroborates the finding of Arimoro (2009) who reported that decomposed organic matter could cause depletion of oxygen. The Biochemical Oxygen Demand (B.O.D) values of Shiroro Lake fluctuated throughout the period of the study. The low BOD indicates the low level of biodegradables (Vasumathi, 2009). BOD values above the range of 5mg/l demonstrate the poor water quality as recorded in Tamil Nadul, India, by Chandra *et al*. (2009). The present values were within acceptable limits prescribed by the World Health Organization, (WHO, 1997). The water surface temperature is one of the most significant parameters which control in-born physical qualities of water, the temperature of Shiroro Lake varied from 24°C to 27°C. The water temperature was as usual high in dry and low in wet seasons. The highest water temperature was in the month of October and December and there was a slight drop in January. This is because of the shallowness of the stations and subsequently the volume of water in contact with air. A close relationship exist between atmospheric temperature and water temperature and as such the water is warmer during dry and colder during wet season. Although, the annual amplitude of variation in water temperature was 21.83±0.75°C and

23±1.10˚C during the period of the study, the highest temperature of water bodies is the result of low water depth, low or no watershed and volume of water which remain in contact with air. Similar findings were recorded by Zutshi *et al*. (1980) in some Kashmir Lakes in India. Water transparency is an important factor that controls the energy relationship at different trophic levels. It is essentially a function of reflection of light from the surface and it is influenced by the absorption characteristics both of water and of its dissolved particulate matter (Sankar and Marinal, 2011). Water transparency showed significant differences between the stations throughout the study period. The high values recorded across the stations could be attributed to the following, land-slope, drainage pattern, soil geology, vegetation cover and precipitation. The speed and extent of run-off depend on the sloppy nature of Shiroro Lake, since the lake was constructed on a sloppy gradient. In addition to low vegetation cover and exposure of the land to high level of erosion, flow of water into the lake added to the turbid nature of the water body. This corroborate with findings of Kolo and Oladimeji (2004). The pH values observed during the study period were slightly alkaline in nature. It might be due to the increased decomposition under low water depth (Irshad *et al*., 2012).

The electrical conductivity value indicates that the maximum conductivity was observed in the dry months. The higher values, throughout the period of the study, place this water body in mesotrophic state. This is as a results of availability of various minerals due to the rate of decomposition during the period of the research. Increased electrical conductivity is regarded as pollution indicator in shallow lakes (Das *et al*., 2006). Also, the significantly low dissolved oxygen and high water conductivity level especially in Shiroro shoreline could be attributed to the degradation of some organic materials and the elevated concentration of metal ions and other salt that emanate from the catchment areas. Similar findings were reported by Ochieng *et al*. (2008) in lake Victoria, Uganda. The results of this research indicates that the values of sodium were found to be much lower in all the stations during dry seasons and moderate during wet seasons, contrary to the findings of Zutshi (1968) and Zutsi *et al.* (1980) in various Kashmir lakes. The present investigation also indicates that the lake is undergoing moderate eutrophication. During the present study period, the values of potassium recorded were high in the early months (August- October). The potassium content of this Lake were probably due to agricultural drain waters containing high concentrations of different pesticides, fertilizers, run-off and heavy metals. This is in conformity with the finding of Alne-na-ei (2003); Khallaf *et al*. (2003); Tayel *et al*. (2007); Authman (2008); at the Nile Delta, Egypt.

Sodium and Potassium are two important nutrients in the Lake loading through point and non-point pollution sources such as washing, bathing, Agricultural activities in fringe area, joining of domestic raw sewage, cultivation of trepan and huge amount of aquatic *macrophytes* as recorded in Anchar Lake, *Kashmir*, by Irshad *et al.* (2012).

## CONCLUSION

The present study demonstrates the possible influence of industrial and anthropogenic contaminants on the distribution and diversity of chironomid larvae inhabiting Shiroro Lake. In general, severe levels of pollution appeared to have marked impact on Chironomid community abundance and distribution. This study thus provide baseline data for some physico-chemical conditions prevailing in Shiroro Lake for further reference and to develop a bio-monitoring programme using macroinvertebrate especially the Chironomid larvae as bio-indicators for water quality assessment in Nigeria rivers and African aquatic ecosystem.

However we wish to recommend that more extensive and long period of research be carried out to ascertain the rate of pollution of the lake over some years.

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