



International Journal of Fisheries and Aquatic Studies

E-ISSN: 2347-5129

P-ISSN: 2394-0506

(ICV-Poland) Impact Value: 5.62

(GIF) Impact Factor: 0.549

IJFAS 2021; 9(2): 19-28

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www.fisheriesjournal.com

Received: 02-01-2021

Accepted: 11-02-2021

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Spatial and temporal variations in the Physico-chemical parameters and abundance of macro invertebrate in Gurara reservoir, Kaduna state

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DOI: <https://doi.org/10.22271/fish.2021.v9.i2a.2435>

Abstract

The spatial and temporal variations in the Physico-chemical parameters and the abundance of macro-invertebrates in Gurara Reservoir, Kaduna State were evaluated monthly for 6months from February-July, 2018 using standard water sampling and modified kick sampling techniques, respectively. From the results, the water temperature ranged from 25.6-29.1°C, Air temperature ranged from 23.7-32.9 °C, pH ranged from 8.8-9.8, Electrical Conductivity ranged from 37-114µS/cm, Total Alkalinity ranged from 24-44mg/L, BOD ranged from 1.0-2.2mg/L, DO ranged from 2.0-4.8mg/L in all the stations. A total of 1801 individual species of macro-invertebrates in 12 families from 3 orders were collected from 3 stations during the research. The most dominant species are *Melanooides tuberculata*, followed by *Corbicula nitens* and *Union mancus*. The abundance of macro invertebrate was high during the dry season than raining season. The marginal high nutrient levels (Phosphate and nitrate) obtained at these stations during wet season are indication that the water body is stressed with organic input and increased high levels of anthropogenic activities. This study revealed that macro invertebrates communities responded to changes in habitat quality of the reservoir.

Keywords: Spatio-temporal variations, Gurara reservoir, macroinvertebrates, Physico-chemical parameters, anthropogenic activities

1. Introduction

The assessment of water quality in freshwater ecosystems has over the years been through the measurement of physicochemical variables; but such measurements alone cannot provide ecological information in its totality. This is because taxons respond differently to a variety of pollutants and are able to provide an indication of water quality over varying time periods ^[6, 17]. Water is the most indispensable requirement for all living organisms and any alterations in water quality may be detrimental to the survival of organisms. Water of adequate purity which is the life blood of our species, is of vital importance to the existence of life ^[23]. Water resources are declining day by day at a fast rate due to rapid urbanization and population load. This important source of life has been polluted to a point of crisis ^[22]. When waste from different sources are discharged without proper treatment into water the physical, chemical and biological characteristics of water are altered in such a way that they are not useful for the purpose for which they are intended ^[16]. Increasing water pollution causes not only the change of water quality but also threatens human health and the balance of aquatic ecosystems, the development of the economy, and social prosperity. Assessing the ecological status of rivers, creeks and streams is a fundamental and increasingly important water management issue worldwide ^[5]. The physicochemical characteristics of water is important determinant of the aquatic system, their characteristics are influenced by climatic vegetation and general composition of water. Healthy growth of organisms in water body is determined by dissolved oxygen, hardness, turbidity, alkalinity, nutrients, temperature, etc. Conversely, parameters like biological oxygen demand (BOD), and chemical oxygen demand (COD) indicate pollution level of a given water body.

Macroinvertebrates are of great diversity and ecological importance. These consist of These consist of invertebrates of macroscopic size normally more than 1mm, living permanently or during certain periods of their life cycle linked to the aquatic environment. They include insects, crustaceans, annelids, mollusks, leeches, etc. Different groups of macroinvertebrates are excellent indicators of human impacts, especially contamination. Most of them have quite narrow ecological requirements and are very useful as bio-indicators in determining the characteristics of aquatic environments [19]. Studies on macroinvertebrates of African lotic waters until recently had not received much attention in Nigeria [11]. Their use as biomonitoring tool is mainly as a result of their diversity, life cycle, sedentary nature and convenient size for field examination [22]. The composition, distribution and diversity of aquatic insects in a river system can be influenced by anthropogenic activities [2]. Despite the efforts of water and environmental managers, to stop water pollution, conserve and protect water bodies, pollution of the aquatic environment as a result of different anthropogenic activities, degradation and misuse of water as a natural resource has been on the increase in our environment. These do not only influence the physicochemical composition but also affect the biotic community most especially macroinvertebrates, which are major bio-indicators for monitoring the health of any water body. There is also paucity of information on the combined Physico-chemical and macroinvertebrate techniques in the monitoring and management of river resources of Gurara Reservoir. In the face of increasing human activity in catchments of rivers, there is need to assess the water quality and the benthic aquatic insects' assemblage and their diversity as tool for biomonitoring in future planning. This present study therefore, serves as baseline information on the biomonitoring of the Gurara reservoir that can be used in

planning and improving development around the studied river course.

2. Materials and Methods

2.1 Description of Study Area and Stations

The study area covers the upper Gurara falling along Latitudes $9^{\circ}39'N$ and Longitudes $7^{\circ}26'E$ and $7^{\circ}42'E$, and an area of approximately 150km^2 . The vegetation type is savannah (Southern Guinea Savannah Zone) grassland interspersed with tropical forest remnants. The reservoir has six tributaries namely river Ik, River Gurara, River Layi, River Rudu, River Kwohu, River Tapa and many streams, which are also tributaries of the Gurara Rivers that flow North South dropping gently from the Kuku hill ranges. (Fig. 2.1).

Kwantan Mallam (station 1) is located upstream of the reservoir between latitude $N09^{\circ}38.84N$ longitude $E7^{\circ}47.33E$ at 626m elevation. Commonly grown crops at the bank of the river are maize and guinea corn. Main settlers are Hausa farmers and fishermen. Spill-Way (station 2) is located at the upstream by the generating house of the reservoir. There are no human activities, no crops and little or no vegetation; it has sandy shore with shells of mussels of different types. It is situated between latitude $N9^{\circ}38.72$, $E7^{\circ}44.79$ at 625m elevation. Atara (station 3) is a small community of indigenes of Kadara tribe in Kachia Local Government Area of Kaduna State located between two hills. The station is located between latitude $N9^{\circ}41.98$, $E7^{\circ}42.97$ at 625m elevation. Common features are the concentration of fishermen and their canoes and a commercial fish farm/hatchery at the bank of the river. Timber cutting is a common practice. Other activities are farming, washing of cloths and bathing. The shoreline is sandy with clear water and visible shells of bivalves and snails.

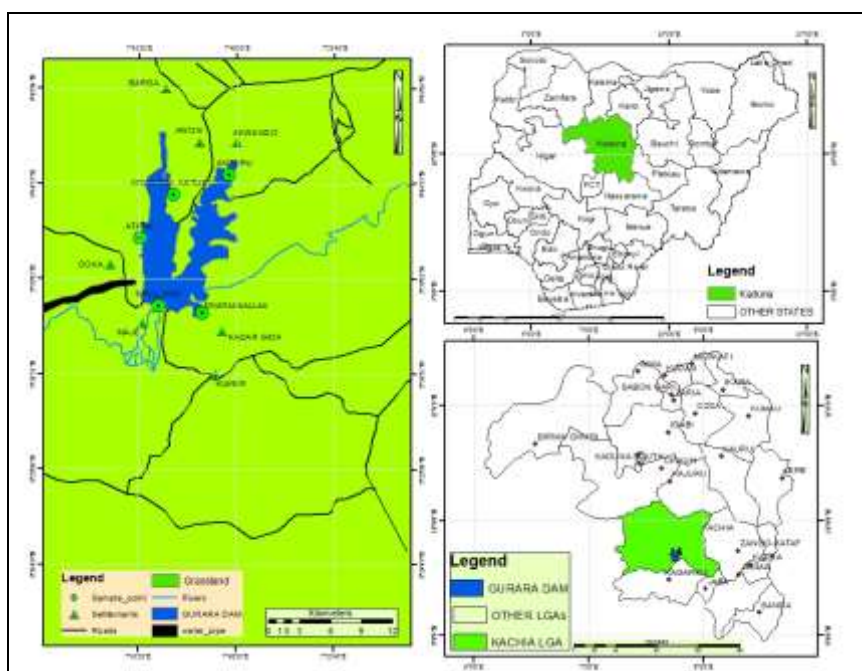


Fig 2.1: Map of Nigeria, Kaduna State and Gurara Reservoir and the three sampling stations

2.2 Water Sampling and Analyses

Monthly sampling of the three study stations were carried out from February to July, 2018 between 7am to 12pm every sampling day due to the difficulty of the terrain. Sampling was designed such that samples were collected in both dry

(February - April) and wet seasons (May-July). Air temperature, water temperatures, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), pH, depth and flow velocity were measured on site. Water samples were collected in 1-l plastic acid- washed bottles and

transported to the River Basin Institute Laboratory, Minna for the analysis of other parameters not determined directly on site.

Air and water temperature were taken using a mercury-in-glass thermometer calibrated in units of °C. For the water temperature, the thermometer was slightly immersed under the surface of water for five minutes until mercury stood at one place.

The DO was determined using a portable Dissolve Oxygen Analyzer, (model JPB-607). The probe was rinsed thoroughly before inserting it into water sample beneath the surface for five minutes until the unit stabilized and then, read in mg/L.

Water samples collected from the same three sampling sites in 250ml stopper bottles were incubated for 5 days in the dark before the titration for oxygen using Winkler Azide method. $BOD_{mg/L} = DO_{on\ day\ 1} - DO_{on\ day\ 5}$ [1].

The pH of the water samples from the three sites were determined using pre-calibrated pH, TDS and conductivity metre *in-situ* (Hanna microprocessor, pH/EC/TDS).

To determine the Electrical conductivity and TDS of the river from the three sites the probe was immersed in the water samples for 5 minutes for each parameter. The readings (in $\mu S/cm$ and mg/L, respectively) were taken when the probe was stable.

The Nitrate- nitrogen was determined using ultraviolet spectro-photometric method [1]. Brief standard nitrate solution

containing 0 to 350 μg was prepared and used to plot the standard curve. The colour of the water sample was removed by adding 4ml of aluminum hydroxide suspension to 100ml of the water sample. There after 1ml of 0.1M hydrochloric acid was added to 50ml of clear water samples. The optical density was read at 220nm. The optical density was converted to nitrate equivalent by reading the nitrate value from standard curve measured in mg/L.

Phosphate was determined by stannous chloride method [1]. A drop of phenolphthalein indicator was added to 100mL of the sample. To each sample, 4ml of ammonium molybdate reagent (1) and 0.5mL or drops of stannous chloride reagent was added, after both reagents have been thoroughly mixed together. A blue colour was developed as result of the mixture. The mixture was allowed to stand for 11 minutes for colour development and thereafter the absorbance was measured with a Gallenkamp Bausch and lamp spectromic 20 at a wavelength of 690nm using distilled water as blank. The phosphate concentration of the water sample in mg PO_4-P was read from the prepared phosphate standard calibration curve.

Sodium, potassium, total alkalinity and total hardness were also determined according to standard methods.

2.3 Macro-Invertebrate Collection and Identification

Macro-invertebrate samples were collected from three sampling stations of the study areas using a Suber sampler, for each sampling station the kick sampling technique was used. Samples were also collected monthly with D-frame net

(500- μm mesh) within an approximately 25m wadable portion of the river. Three different samples were taken at each sampling site which cover all the different substrata (vegetation, sand and gravel biotypes) and flow regime zone. Each sediment sample was diluted with water and sieved with mesh sizes 0.5mm [13]. All samples were fixed in 4% formaldehyde and kept in 70% alcohol before laboratory sorting. In the laboratory, preserved macro invertebrate samples were gently spread on a white tray and all were sorted, under a hand-held magnifying glass, using fine forceps. Sorted macro-invertebrates were preserved in specimen vials containing 70% ethanol. The macroinvertebrates were mounted on stereo microscope for taxonomic identification using mouth parts and other structures according to the keys described by Cranston [9] and other available keys [4, 10].

2.4 Data analysis

The Physico-chemical parameter data generated from the study were subjected to one-way analysis of variance (ANOVA) using SPSS version 20 at $P \leq 0.05$. Bar charts were used in each case to indicate the seasonal variation. Macro-invertebrate species abundance and distribution were determined with PAST statistical package.

3. Results and Discussions

3.1 Monthly Variations in Physico-chemical Parameters of the Sampling Stations of Gurara Reservoir, Kaduna State

3.1.1 Water and Air Temperature (°C)

The highest water temperature was recorded in station 3 with 30.5 °C in the month of April and the lowest was recorded at station 2 with 25.6 °C in the month of May. (Table 3.1, Fig.3.1A). Similarly, the highest air temperature was recorded in station 3 with 36.8 °C in the month of April and the lowest was recorded at station 2 with 23.7°C in the month of May (Table 3.1, Fig. 3.1 B)

3.1.2 DO and BOD

The highest dissolved oxygen was recorded in station 1 with 4.8mg/L in the month of May and the lowest was recorded at station 3 with 2.3mg/L in the month of July. (Table 3.1, Fig. 3.2 A). The highest BOD was recorded in station 2 with 2.3mg/L in the month of April and the lowest was recorded at station 3 with 1.2mg/L in the month of March. (Table 3.1, Fig. 3.2 B).

3.1.3 TDS and Electrical Conductivity

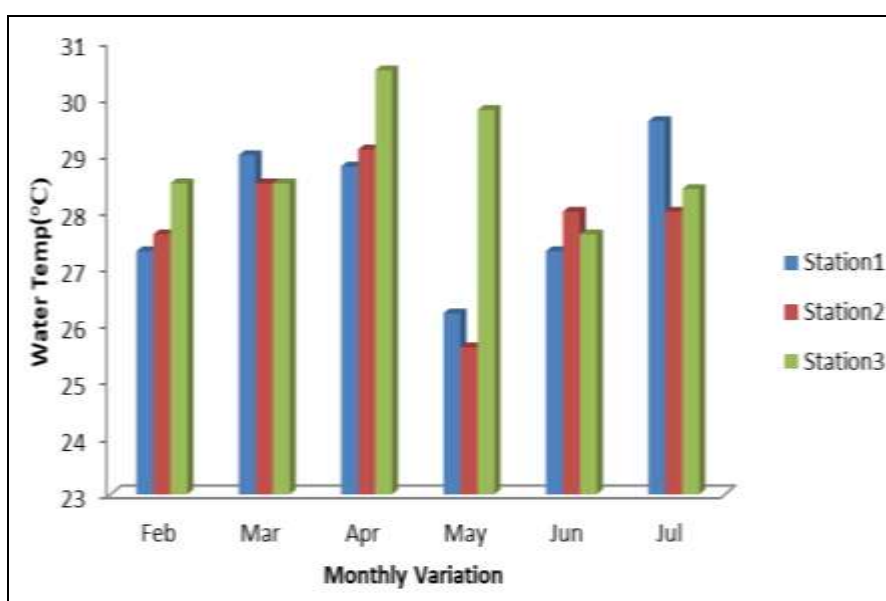
The highest Total dissolved Solid was recorded in station 3 with 68mg/L in the month of February and the lowest was recorded at station 1 with 11mg/L in the months of March and April. (Table 3.1, Fig. 3.3A). The highest Electrical Conductivity was recorded in station 1 with 114 $\mu S/cm$ in the month of April and the lowest was recorded at station 3 with 37 $\mu S/cm$ in the months of June. (Table 3.1, Fig. 3.4 A).

Table 3.1: Summary of the Spatio-temporal Physico-chemical parameters of Gurara Reservoir Sampled from February to July, 2018.

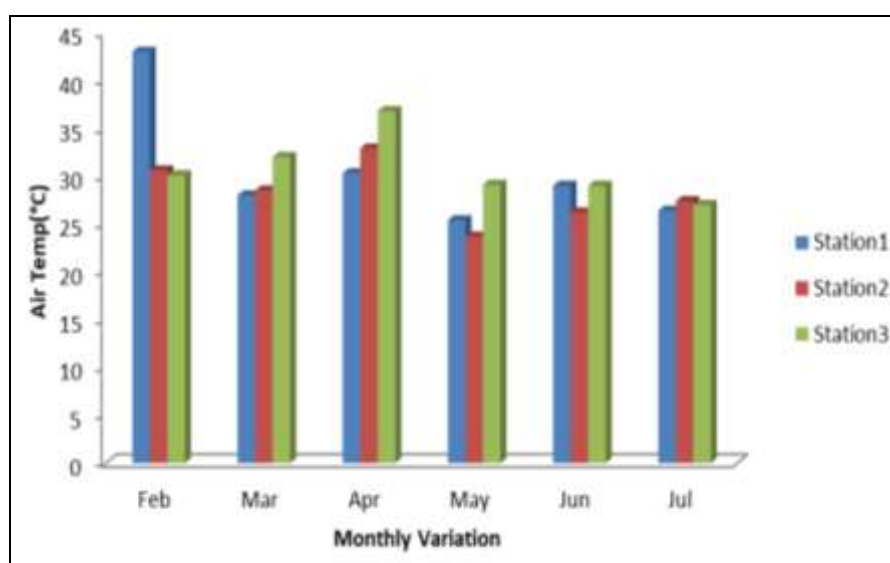
Parameters	St1	St2	St3		F-Values	P-Values	
K ⁺ (mg/l)	1.67±0.39 (0.98-3.88)	1.55±0.23 (0.75-2.5)	1.79±0.43 (0.18-3.2)	1.84	0.06	0.26	0.82
PO ₄ (mg/l)	0.21±0.13 (0.04-1)	0.36±0.27 (0.04-2.0)	0.76±0.45 (0.05-3.0)	0.89	0.93	0.54	0.39
E.Cond($\mu S/cm$)	84.5±14.4 (39-114)	75.17±10.21 (38-106)	64.5±12.7 (37-105)	3.44	2.01	0.13	0.23
Total Alkalinity(mg/l)	32.67±2.86	30.67±2.47	31.33±2.39	6.09	0.04	0.05	0.86

	(24-44)	(24-40)	(24-38)				
Na ⁺ (mg/l)	6.01±0.63	6.4±0.31	5.84±0.22	0.97	0.93	0.51	0.39
	(4.39-8.9)	(5.22-7.23)	(5.3-6.71)				
Total Hardness (mg/l)	47.67±2.99	56.17±2.51	55.83±2.34	2.61	0.04	0.19	0.86
	(34-54)	(44-60)	(46-61)				
TDS(ppm)	50.51±7.94	58.67±1.20	60.17±1.89	1.33	0.85	0.39	0.41
	(11-61)	(56-64)	(55-68)				
BOD(mg/l)	1.73±0.23	1.85±0.18	1.58±0.16	1.95	2.28	0.27	0.21
	(1-2.2)	(1.2-2.3)	(1.2-2.2)				
DO(mg/l)	3.57±0.45	3.3±0.24	2.97±0.28	1.03	0.57	0.49	0.49
	(2-4.8)	(2.4-4.2)	(2.3-4.3)				
Air Temp(°C)	30.35±2.63	28.22±1.33	30.67±1.39	10.29	10.04	0.02	0.03
	(25.4-43)	(23.7-32.9)	27-36.8				
Water temp(°C)	28.03±0.53	27.8±0.49	28.88±0.43	0.84	1.84	0.57	0.25
	(26.2-29.6)	(25.6-29.1)	(27.6-30.5)				
NO ₃ (mg/l)	0.43±0.28	0.43±0.25	0.17±0.03	0.97	0.93	0.51	0.39
	(0.02-1.83)	(0.3-1.65)	(0.08-0.29)				
pH	9.28±0.14	9.32±0.12	9.17±0.14	3.69	1.07	0.12	0.36
	(8.8-9.7)	(8.9-9.8)	(8.8-9.6)				

The Range of values of Physico-chemical parameters obtained from Gurara Reservoir from Feb-July, 2018 are indicated in parenthesis.

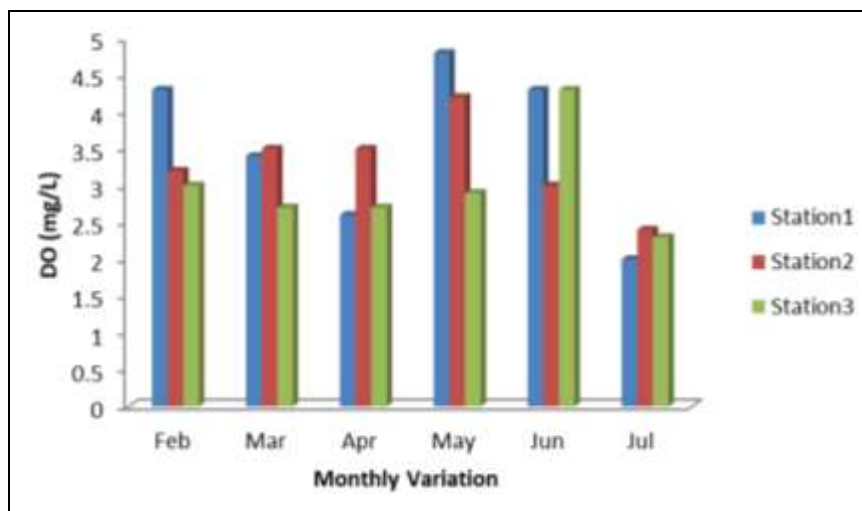


A

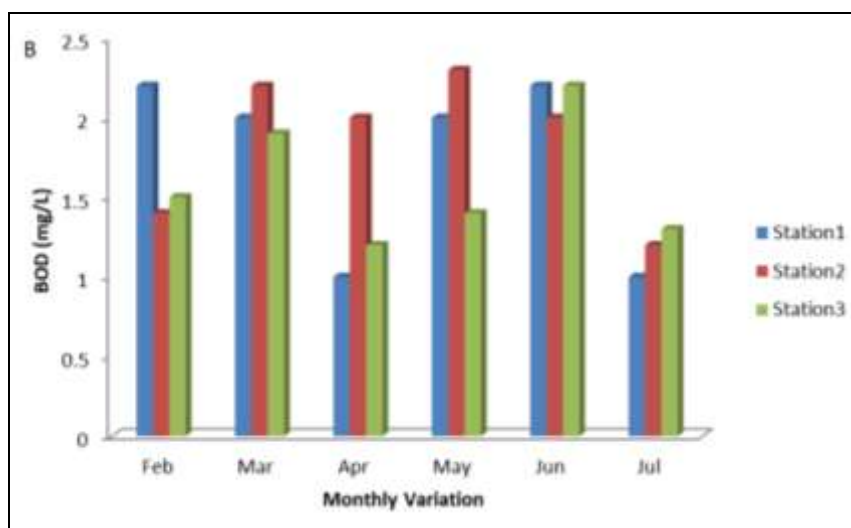


B

Fig 3.1: Seasonal variations in the A) water temperature and B) Air temperature sampled from Gurara reservoir from Feb. to July, 2018.



A



B

Fig 3.2: Seasonal Variations in the A) Dissolved Oxygen and B) BOD Sampled from Gurara Reservoir from Feb. to July, 2018.

3.1.4 pH

The highest pH was recorded in station 2 with 9.8 in the month of February and the lowest was recorded at station 3 with 8.8 in the months of March; and stations 1 and 3 in the month of April. (Table 3.1, Fig. 3.3B).

3.1.5 Sodium

The highest Sodium was recorded in station 2 with 7.23mg/L in the month of February and the lowest was recorded at station 3 with 5.3mg/L in the months of March. (Table 3.1, Fig. 3.4 B)

3.1.6 Potassium

The highest Potassium was recorded in station 1 with 3.88mg/L in the month of April and the lowest was recorded at station 3 and 1 with 0.18mg/L, respectively in the months of February and March. (Table 3.1, Fig. 3.5 A).

3.1.7 Nitrate

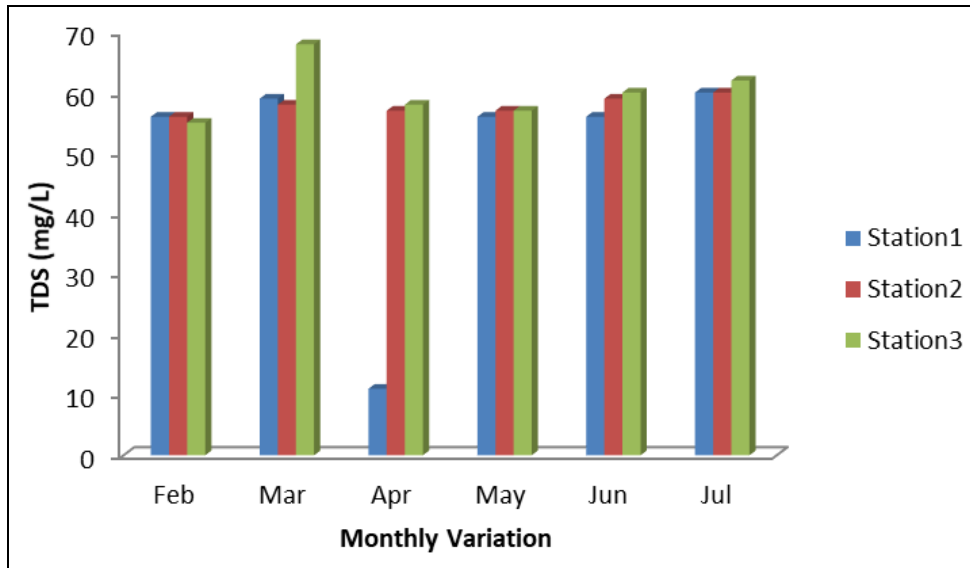
The highest and the lowest Nitrate were recorded in station 1 with 1.83mg/L and 0.02mg/L in the months of July and April, respectively. (Table 3.1, Fig. 3.5 B).

3.1.8 Phosphate

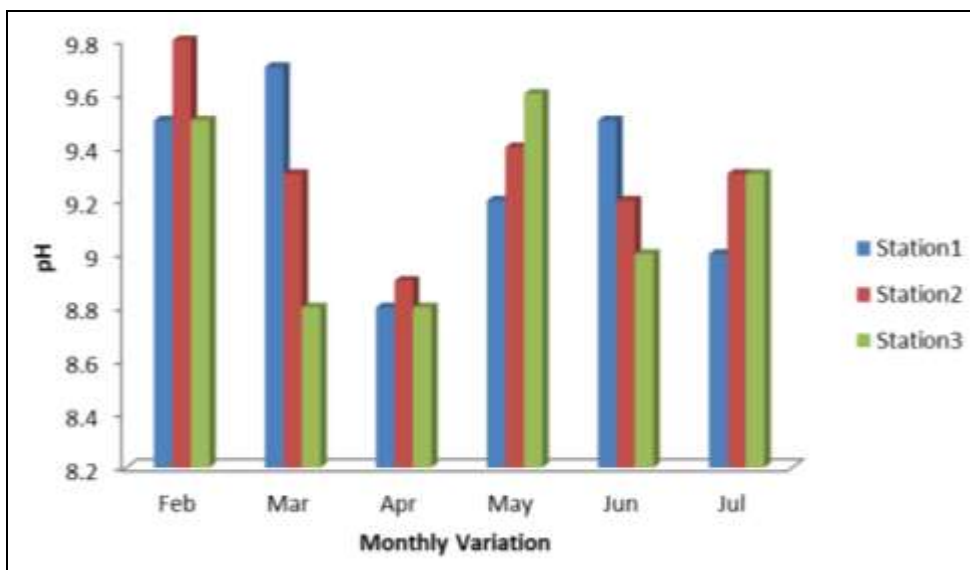
The highest Phosphate was recorded in station 3 with 0.15mg/L in the month of May and the lowest was recorded at station 3 with 0.1mg/L in the month of June. (Table 3.1, Fig. 3.6 A).

3.1.9 Total Alkalinity and Total Hardness

The highest total alkalinity was recorded in station 1 with 44mg/L in the month of July and the lowest value was recorded in all the stations with 24mg/L in the month of April. (Table 3.1, Fig. 3.6 B). On the other hand, the highest total hardness was recorded in station 3 with 61mg/L in the month of May and the lowest was recorded in station 1 with 34mg/L in the month of February. (Table 3.1, Fig. 3.7 A).

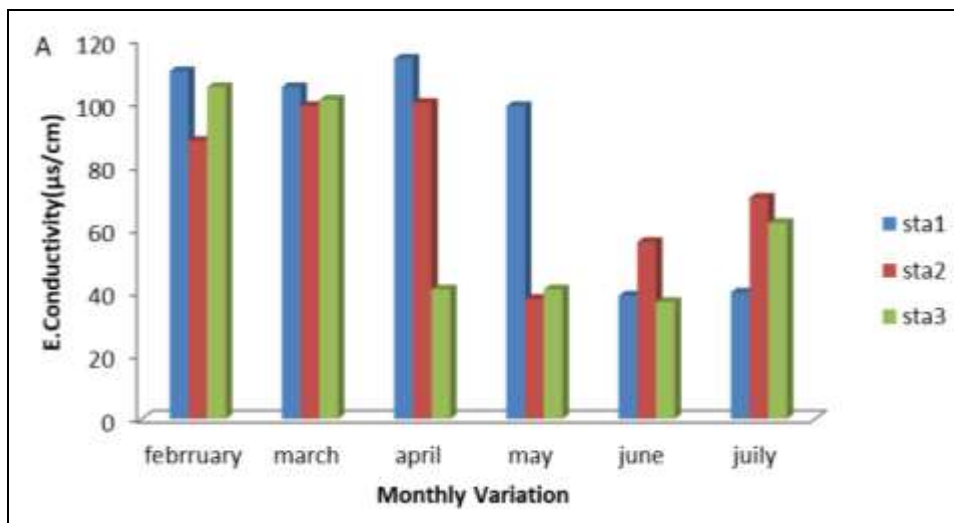


A.



B.

Fig 3.3: Seasonal Variations in the A) TDS and B) pH Sampled from Gurara Reservoir from Feb. to July, 2018.



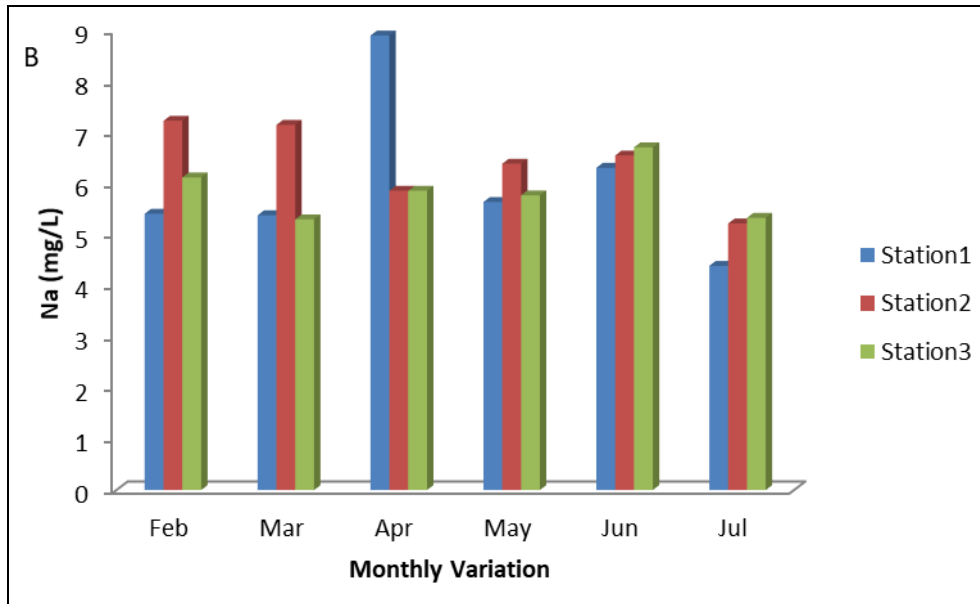
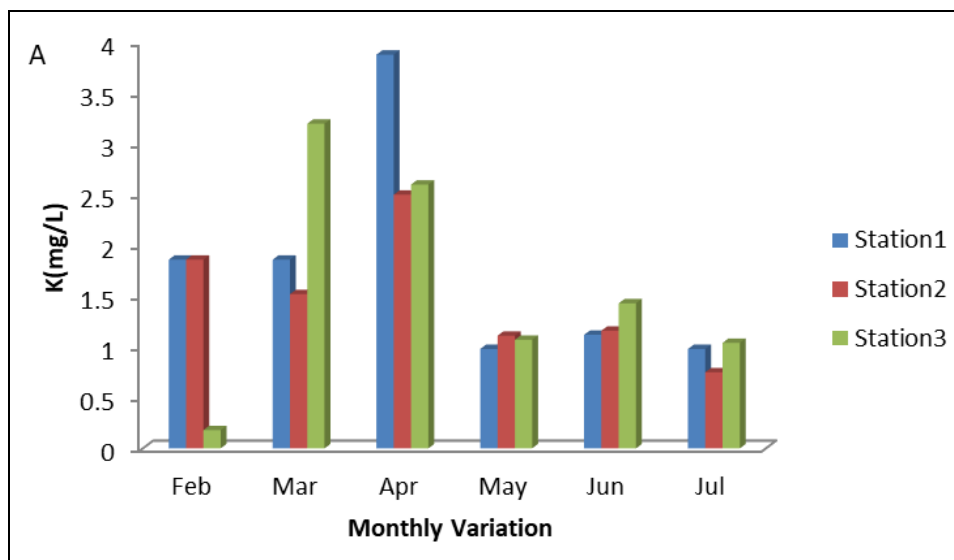
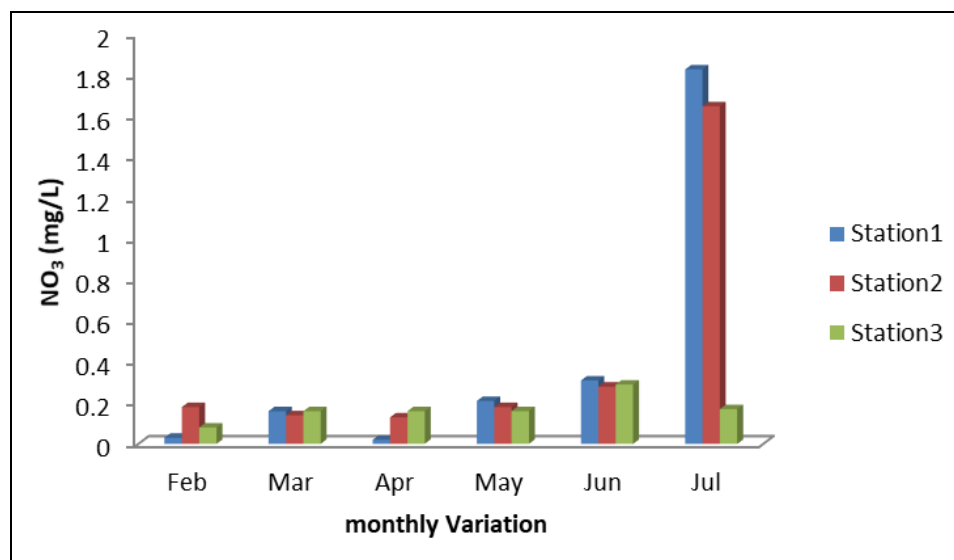


Fig 3.4: Seasonal Variations in the A) Electrical Conductivity and B) Na Sampled from Gurara Reservoir from Feb. to July, 2018.



A.



B.

Fig 3.5: Seasonal variations in the A) Potassium and B) Nitrate sampled from Gurara reservoir from Feb. to July, 2018.

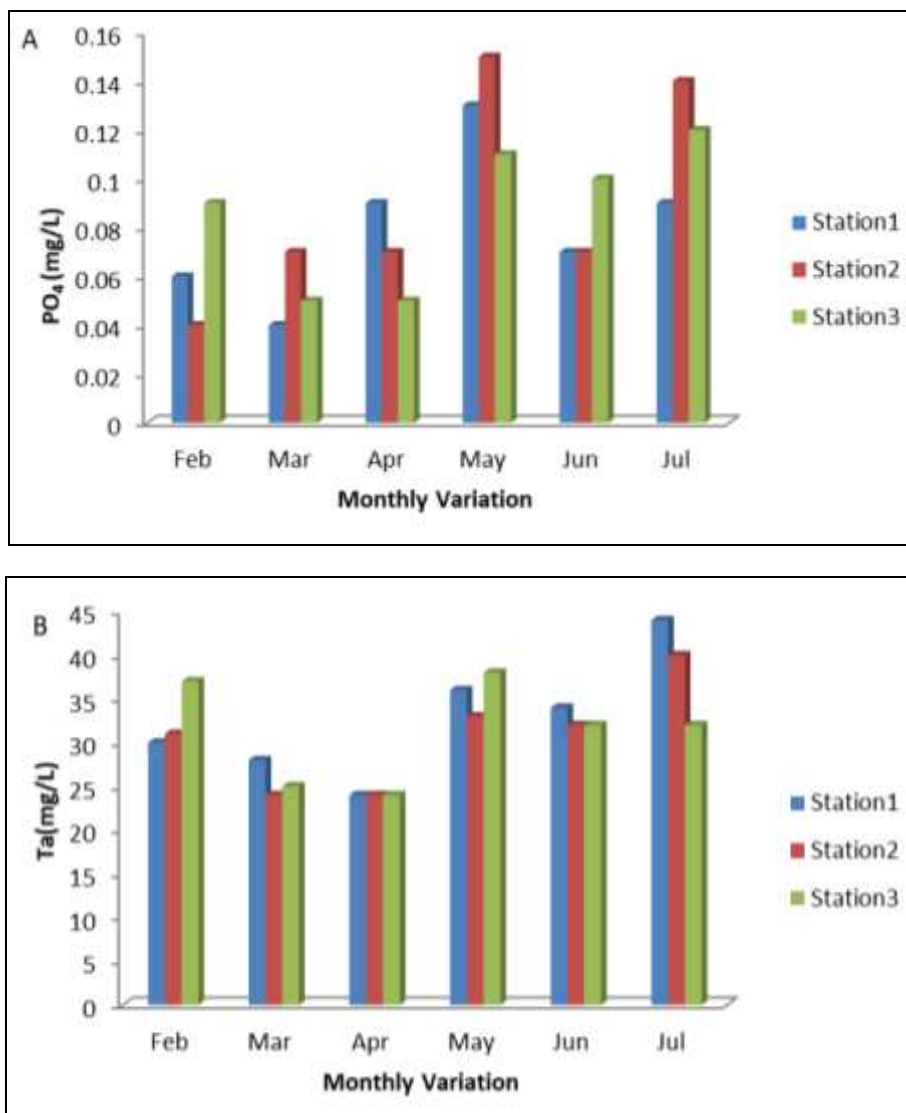


Fig 3.6: Seasonal variations in the A) Phosphate and B) Total alkalinity Sampled from Gurara Reservoir from Feb. to July, 2018.

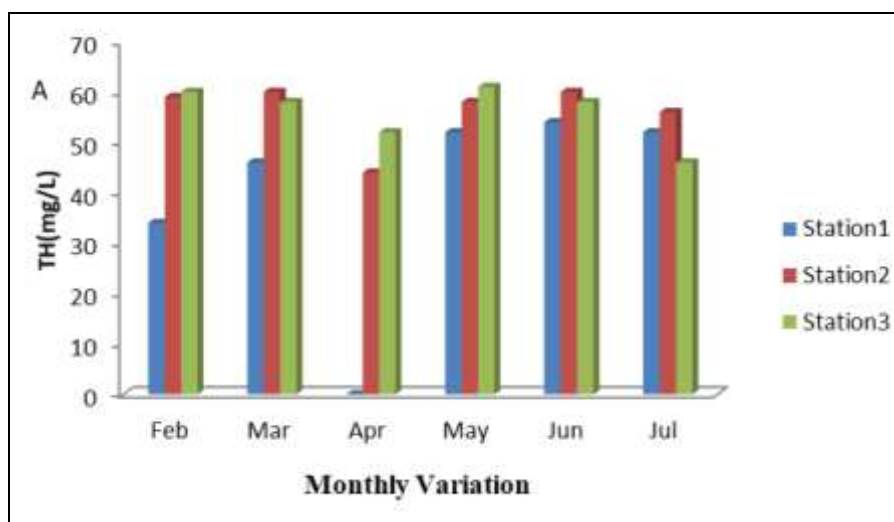


Fig 3.7: Seasonal Variations in the A) Total hardness Sampled from Gurara Reservoir from Feb. to July, 2018.

3.2 Macro-invertebrate Composition and Abundance

The relative abundance of macro invertebrates encountered in Gurara reservoir during the study period is as shown in Table 3.2. A total of 1801 individual species were recorded. The phylum Mollusca was the most abundant accounting for 99.21%; followed by Coleoptera with 0.43% while Crustacean had the least number of individuals with 0.27%.

The highest Taxa richness was recorded in stations 1 and 2 (2.218 and 2.144), respectively. The lowest was recorded in station 3 (1.968). Stations 1 and 3 recorded high evenness values (0.7586 and 0.7232), respectively. The Shannon-Wiener diversity’s highest value was recorded in station 3 (2.449).

Table 3.2 Spatial Variation in macro -invertebrate species collected from Gurara Reservoir, Kaduna State from the February to July, 2018

Species	Station 1	Station 2	Station 3	Total	%
Cleopatra. guillemei	52	29	10	91	5.05%
Cleopatra. bulimoides	15	0	0	15	0.83%
Cleopatra. ferrienginea	0	5	0	5	0.27%
Melanoides. tuberculata	213	297	154	564	31.31%
Potadoma. sp	49	32	35	116	6.44%
Union. mancus	105	122	80	307	17.04%
Pila. ovata	22	29	5	56	3.10%
Lanistes. purpureus	21	9	9	39	2.16%
Valvata. nilotica	9	18	10	37	2.05%
Corbicula. nitens	120	152	115	387	21.48%
Bulinus. globasus	49	52	21	122	6.77%
Cerithidea. decollata	30	9	5	44	2.44%
Biomphalaria. smithi	5	0	0	5	0.27%
Philodytes. sp	5	2	0	7	0.38%
Hydrophilus. sp	0	1	0	1	0.05%
Callinectes. sp	0	1	4	5	0.27%
	695	658	448	1801	100%

Table 3.3: Taxa Richness, Diversity, Evenness and Dominance Indices of Macro Invertebrate Species Collected from Gurara Reservoir, Kaduna State from February to July 2018.

	Station 1	Station 2	Station 3
Taxa S	13	14	11
Individuals	695	658	448
Dominance D	0.1048	0.1081	0.102
Simpson_1-D	0.8952	0.8919	0.898
Shannon H	2.432	2.41	2.449
Evenness e [^] H/S	0.7586	0.696	0.7232
Taxa Richness (Margalef index)	1.968	2.144	2.218

4. Discussions

4.1 Physico-chemical Parameters and Macro invertebrates

The water and ambient temperatures were relatively high in the month of April and at station 3. This is probably because of poor vegetation cover at this station relative to other stations and probably because April is the peak of the dry season. Similar observations were reported by Samuel *et al.* [21] in River Galma, Zaria.

The mean dissolved oxygen obtained during the period of the study was low. This could be as a result of polluted nature of water body that could have led to the acidic nature of the water body. This is in line with observations made by Iqbal *et al.* [14] in Dal Lake, Kashmir. The mean dissolved oxygen was lowest in station 3 in the month of July (2.3mg/L). The low mean dissolved oxygen values in the wet season could be due to the turbidity nature of the water at this period due to inflows from run offs and decomposition of organic matter in the water that may have led to low dissolution of oxygen from the atmosphere. Braide *et al.* [7] also had similar low mean values of dissolved oxygen in their study of water quality of Miniweja stream in Eastern Niger delta, Nigeria.

The BOD values indicate the extent of organic pollution in the aquatic system which affects the water quality [15]. Station 2 showed the highest value (2.3mg/L) while station 3 showed the lowest value (1.2mg/L) in the months of April and March, respectively. Based on the BOD classification of APHA [1], the mean BOD value obtained in station 3 was slightly high above the limit of 2.2mg/L. The fluctuations in the BOD of each station and month probably indicate that the water in these stations was moderately polluted. This may also be as a result of anthropogenic activity around the reservoir due to the presence of market at the reservoir site which may have led to organic pollution.

The monthly variations in nitrate level were relatively high in

the sampling stations. Station 1 showed the highest nitrate level (1.83mg/L) in month of July. This could be due to run off of fertilizer residues and animal waste into the water bodies from the neighbouring farms. Slightly lower values were reported by Samuel *et al.* [21] in River Galma, Zaria.

The mean phosphate levels in each station ranged from 0.04-3.0mg/L. The relatively lower pH values at the station 3 (8.8) in April than that at station 2 (9.8) in February, may have resulted from decaying of the domestic and industrial waste litter in station 3. Similar trend was reported by Ekeh and Sikoki [12] in the new Calabar river and also by Ansa [3] in Adoni flats of Niger Delta Area.

The highest value for total dissolved solid (68mg/L) was recorded in the month of February. This is probably as a result of changes in water balance by limiting inflow, increased water use or increased precipitation. High temperature and evaporation tendencies may also have accounted for the variations.

Electrical conductivity (EC) fluctuated between 37 and 114 $\mu\text{S}/\text{cm}$. Station 1 recorded higher values in the month of April. The conductivity of most lake water range from 10 - 1000 $\mu\text{S}/\text{cm}^{-1}$ but may exceed 1000 $\mu\text{S}/\text{cm}^{-1}$ especially in polluted water or those receiving quantities of land run-off [24]. The values obtained in this research are well within this range.

In like manner, the highest value of sodium was recorded in station 2 (7.23mg/L) in the month of February. Station 1 recorded the highest value for potassium (3.8mg/L) in the month of April. These may be due to high rates of evaporations, high temperature variations and other environmental factors during the dry season. The most common source of elevated sodium levels in the lake water are; erosion of salt deposit and sodium bearing rock minerals, infiltration of surface water contaminated by road salt,

irrigation and precipitation of lechate from landfill or industrial sites^[8].

A total number of 12 families of macro-invertebrates were encountered in Gurara reservoir during the study period. This is high when compared to 4 families reported by Ogidiaka *et al.*^[18] in Ogunpa River. The presence of pollution tolerant macro-invertebrates such as *Melanoides tuberculata*, *Bulinus globosus*, *Union mancus* could be attributed to the effects of domestic and municipal waste discharged into the reservoir. These also probably indicated that Gurara Reservoir is moderately organically polluted. According to Shannon-Weiner diversity index, the values obtained during the present study were more than 1.0 in all the station, confirming the pollution level of the reservoir.

5. Conclusions and Recommendations

Station 1 recorded the highest number of species with 695 species; closely followed by station 2 with 658 and station 3 with the lowest number (448) of species. *Melanoides tuberculata* had the highest number of species followed by *Corbicula nitens*, then *Union mancus*. In general, the abundance of macroinvertebrates was higher during dry season than rainy season.

The highest DO was observed in the month of May with 4.8mg/L, the highest electrical conductivity was observed in the month of April with 114 μ S/cm, the highest TDS was observed in the month of February with 68mg/L, the highest BOD was observed in the month of April 2.3mg/L. The variation in the phosphate, Nitrate, Sodium and Potassium indicates that Gurara Reservoir is organically polluted.

From this research it was observed that Molluscs are abundant in Gurara Reservoir which can be of economic benefit to both individuals and governments if sustainably explored.

6. References

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