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Assessment of Water Quality, Fish Population Health, and Plankton Dynamics in River Yobe, Nigeria: Implications for Fishery Productivity

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ABSTRACT

This study assessed the ecological status of River Yobe, Nigeria, by evaluating its physicochemical water quality, the health of two key fish species (*Oreochromis niloticus* and *Clarias gariepinus*), and the structure of plankton communities across three sites with varying anthropogenic pressures. Water and biological samples were collected monthly over an 18-month period (November 2021 – April 2023). Physicochemical analysis revealed significant seasonal variations; while key parameters like temperature (19.41–29.48°C), pH (5.57–7.71), and dissolved oxygen (2.60–13.67 mg/L) were generally within acceptable ranges, elevated ammonia (up to 0.927 mg/L) and nitrate (up to 0.930 mg/L) levels indicated nutrient loading from agricultural runoff and domestic waste. Length-weight relationship analysis showed negative allometric growth ($b < 3$) for both fish species, with condition factors ranging from 0.65–4.24 for *O. niloticus* and 0.82–4.15 for *C. gariepinus*, reflecting fluctuating wellbeing linked to environmental stress. Plankton analysis identified 17 phytoplankton and 16 zooplankton species, with Chlorophyceae (*Cladophora oligoclonus*) and Rotifera (*Branchionus* sp.) dominating, respectively. Highest plankton abundance was recorded at sites with the most intense anthropogenic activities, correlating with elevated nutrient levels. The study concludes that while River Yobe's basic water quality supports aquatic life, it is under significant stress from anthropogenic eutrophication, which impacts fish health and drives shifts in plankton communities, underscoring the need for integrated watershed management for long-term fishery sustainability.

Keywords: Plankton, Dynamics, Population, Health

INTRODUCTION

Water covers 71% of the earth's surface. It is vital for all known forms of life. On Earth, 96.5% of the planet's water is found in the sea and oceans, 1.7% in groundwater, 1.7% in glaciers and ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001% in the form of air as vapour and precipitation. Only 2.5% of the earth's water is fresh water. Less than 0.3% of all freshwater is in rivers, lakes, and the atmosphere (Molden, 2007). The common indicators for assessing water quality in Nigeria are Temperature, Transparency, Dissolved Oxygen, (DO) free Carbon dioxide, total phosphorus, total nitrogen, total ammonia, hydrogen ion concentration (pH), conductivity, biochemical oxygen demand (BOD) amongst others. (Oluwande, *et al.*, 1983). The quality of water in any ecosystem provides significant information about the available nutrients supporting life within and around that ecosystem and determines the trophic dynamics of the water (Usman *et al*., 2014). Changes in physicochemical properties can be as a result of several factors which include anthropogenic activities, climatic variability, and eutrophication (Omorinkoba *et al.*, 2011). However, the abundance of chemical ions needed for the interconversion of energy and production of organic minerals present in a lake can provide information on the health status of a lake (Usman *et al.*, 2014; Mustapha, 2013; Bhatnagar and Devi, 2013).

Fish performance is directly affected by the physicochemical properties of the water body in which the fish live (Moody and Folorunsho, 2006). Variations in water quality have been explained in terms of precipitation chemistry, bedrock chemistry or evaporation, and the crystallization process within the reservoir and its entire basin (Kolo and Tukura, 2007). Fish, like every other organism, depend on their aquatic environment for food, growth, reproduction, and health. Physicochemical parameters of water are important in the evaluation of a host of interactions between physical and chemical factors that influence the level of primary productivity, trophic structure, and total biomass throughout the aquatic food web (Wetzel, 1975).

Water quality parameters (physicochemical characteristics) are primary determinants of aquatic life, influencing fish physiology, reproduction, and survival (Mangi, 2024). Concurrently, biological indicators such as fish population health (through length-weight relationships and condition factors) and plankton community structure provide integrated measures of ecosystem integrity and stress (Kefas, 2016; Tian *et al*., 2021). Plankton, as the base of the aquatic food web, is highly sensitive to environmental change and serves as a bioindicator of water quality (Essa *et al*., 2024).

Despite its importance, a holistic assessment linking human activities, water quality, and biological responses in River Yobe is lacking. This study, therefore, aimed to assess the water quality, fish population health, and plankton dynamics in River Yobe, Nigeria

MATERIALS AND METHODS

Study Area

The study was conducted on River Yobe in northeastern Nigeria. River Yobe is situated in the Sudan Sahel zone of northeast. It covers a total area of 148,000km^2 (International Union for Conservation of Nature [IUCN], 2009). The river originates from the flood plain overlaying the lake sediment of the Lake Chad formation (plateau and Kano states) and flows through northeastern Nigeria and forms part of the border between Nigeria and Niger (Jajere *et al.*, 2022). River Yobe is coordinated at latitude 10°30'01"N 13°30'04"E and longitude 11°30'09"N 13°20'08"E and the river flows from Hadeja to Lake Chad (Descloitres *et al.*, 2013)

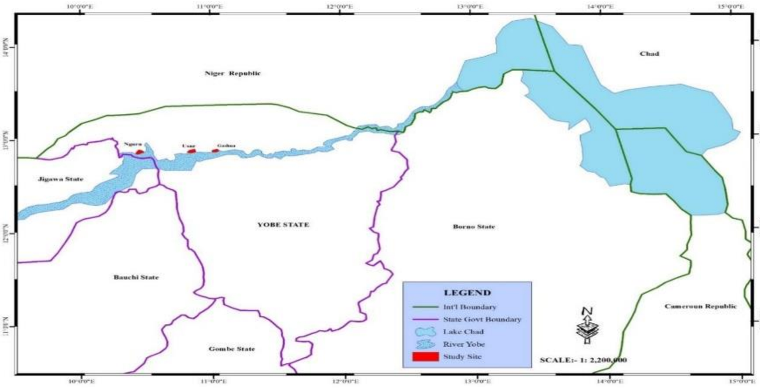

Figure 1: Map of River Yobe Showing the Three Study Sites

Sampling Sites

Three sampling sites, as shown in figure 1, were identified during the studies based on the activities at each site. Site I (Mashayan Bade) in Gashua is coordinated at 12°52'41"N 11°03'26"E and longitude 12°51'44"N 11°02'19"E and has an intensive agricultural activity (dry and rainy season farming and rearing of animals), dumping of domestics wastes and open defecation; Site II (Usur) is coordinated at 12°52'06"N 10°58'55"E and longitude 12°52'03"N 10°58'41"E and in addition to domestics' wastes, open defecation there is an indiscriminate fishing activities and Site III (Nguru) in Nguru, is coordinated at 12°52'34"N 10°28'15"E and longitude 12°51'18"N 10°26'28"E and the site experience discharge of waste dump, open defecation, agricultural activities, indiscriminate fishing activities and it is a grazing site for livestock. The sites were selected based on the human activities observed at each location following preliminary studies.

Water Sampling Methods

Water samples were collected using transparent plastic bottles by submerging the bottle into the river water carefully to avoid disturbing the bottom sediments to prevent contamination. The bottles were filled, leaving minimal air space to avoid alteration of gases within the water. In order to prevent changes in the chemical composition of the water, the bottles were wrapped inside black leather-bagco and placed in a cooler, ice packs were used to keep the bottles cool until transported to the biological science laboratory of Yobe State University in Damaturu. Sampling bottles were labeled for identification. The water quality parameters such as temperature, dissolved oxygen, pH, conductivity, transparency, ammonia, nitrate, phosphorus and carbon dioxide will be determined using AOAC procedures

Sampling of Phytoplankton

Phytoplankton samples were collected with one litter transparent plastic bottle by dipping the container bottle, sliding over the upper surface of the water with its mouth against the water current to permit undisturbed passage of the water into the bottle using Yamaguchi and Bell, (2007) sampling protocols. Samples were preserved with Lugol's solution and brought to the laboratory. Slides were prepared and observed under a binocular microscope with various magnifications. Taxonomic identification of plankton was carried out by using taxonomic keys (Emi and Andy, 2007; Edward and David, 2010; Steve *et al.*, 2013). The phytoplanktons were counted from the left top corner of the slide to the right corner by moving the slide horizontally

Sampling of Zooplankton

Zooplankton grab samples were collected using plankton net mesh size 70µm. It was towed vertically a distance of one meter and hauled out of the water. The sample was collected into a plastic bottle tied at the end of the net and then was emptied into the closed labeled 100ml vial bottle for identification and counting of the zooplanktons. The samples were preserved with 4% formalin and were transported to the laboratory. The zooplankton sample collection after condensation by sedimentation was taken for sorting and counting. A binocular microscope is used for zooplankton. Identification to genus level was performed using Yamaguchi and Bell, (2007) protocols, through which Zooplankton density (abundance) was computed

Determination of Length-Weight Relationship and Condition Factor

Oreochromis niloticus and *Clarias gariepinus* are the most abundant fish species in River Yobe (Lami *et al.*, 2022) and their high population densities make them ideal representatives for studying overall fish health and productivity, as they are likely to reflect the broader aquatic ecosystem's condition. This also provides a comprehensive understanding of the River Yobe's fish health and productivity, as these species frequently interact with the environment and other species.

The length-weight relationship was determined using the conventional formula Kefas and Abubakar (2010) adopted.

$W = {}_aL^b$

The equation and the data were transformed to logarithm before determination was made. The equation was therefore transformed into;

$\log W = \mathrm{Log}a + b\mathrm{Log}L$

Where, W = Weight of the fish in grams, L = Standard length of the fish in cm, a = constant, b = an exponent

The graphs log of the weight of the fish versus the log of the standard length of the fish species was plotted.

The condition factor (k) was determined for individual fish using the conventional formula adopted by Ja'afaru and Tashara (2009). The ratio of the length to the weight of the fish was determined as:

$$K = \frac{W \times 100}{L^3}$$

Where, K = Condition factor, W = weight in grams, L = length in cm

Data Analysis

Data generated from the study was analyzed using Statistical Package for Social Science (SPSS) version 26, Excel and Graph pad distant window 2010. Physicochemical parameters of River Yobe were analysed using both Mean and standard deviation, and two-way Analysis of Variance (ANOVA). Regression analysis was used to analyze data related to length-weight relationship of *Oreochromis niloticus and Clarias gariepinus* at 0.05 level of significance. Frequency count and percentage were used to analyzed for both Phytoplankton and Zooplankton monthly diversity and abundance for each study site

RESULTS AND DISCUSSION

Physicochemical Characteristics of River Yobe

Monthly mean water temperature fluctuated between 19.41±0.586°C - 29.48±1.518°C which was within the recommended ranged of Federal Ministry of Environment (FMEnv). The pH values ranging between 5.570±0.403 - 7.710±0.072 obtained from this study were within the recommended ranged of WHO and FMEnv for culturing tropical fish species and for drinking water. The conductivity values obtained from this study (123.673.786±µS/cm - 263.67±178.691µS/cm) in the river were within the recommended values of 10 - 1000µs/cm for tropical inland water bodies. Low transparency was recorded during the rainy season and it was high during the dry season (4.03±0.586cm to 28.87±20.865cm in the months of August 2022 and April 2022 and respectively). Dissolved oxygen recorded values were within the recommended range for supporting aquatic production. The highest values of ammonia were higher than the recommended value of 0.025mg/L. Phosphorus recorded (0.042±0.003mg/l - 0.840±0.092mg/l) for this study were within the safety limits of 1mg/l recommended by USEPA. Nitrate values obtained were not within the recommended ranged (WHO, 2012), and this might be attributed to the intensive application of fertilizers, pesticides, herbicides, insecticides for farming and the indiscriminate waste dump such as open defecations which goes into the water ways as a result of runoff. Free CO_2 values obtained (0.101±0.270mg/l - 0.887±0.114mg/l) were within the maximum permissible limits of 6.0mg/L for freshwater fish as recommended by WHO guidelines.

Table 1: Monthly Mean Variation of Temperature (°C) of River Yobe

S/N	Month	Site I	Site II	Site III	Mean	Standard Derivation
1	Nov, 2021	25.06	25.27	27.33	25.89b	1.254
2	Dec, 2021	22.10	22.27	23.63	22.67d	0.839
3	Jan, 2022	20.01	18.84	19.38	19.41fe	0.586
4	Feb, 2022	21.83	20.10	18.24	20.06e	1.795
5	Mar, 2022	23.43	23.23	22.57	23.08ed	0.450
6	Apr, 2022	28.60	31.23	28.60	29.48a	1.518
7	May, 2022	28.33	28.13	28.53	28.33a	0.200
8	Jun, 2022	27.93	27.67	28.43	28.01a	0.386
9	Jul, 2022	26.67	28.10	27.57	27.45a	0.723
10	Aug, 2022	26.10	26.03	25.93	26.02b	0.085
11	Sep, 2022	26.41	27.03	25.02	26.15b	1.029
12	Oct, 2022	25.90	26.10	24.57	25.52b	0.832
13	Nov, 2022	21.40	21.10	20.90	21.13e	0.252
14	Dec, 2022	21.27	21.10	20.90	21.09e	0.185
15	Jan, 2023	23.57	22.97	22.70	23.08ed	0.445
16	Feb, 2023	22.97	24.33	24.93	24.08e	1.004
17	Mar, 2023	23.63	23.77	22.87	23.42ed	0.484
18	Apr, 2023	29.17	28.73	28.67	28.86a	0.273

Means followed by the same letters are not significantly different (P>0.05)

Table 2: Monthly Mean Variation of pH in River Yobe

S/N	Month	Site I	Site II	Site III	Mean	Standard Derivation
1	Nov, 2021	5.86	5.74	5.11	5.570d	0.403
2	Dec, 2021	5.96	5.84	5.21	5.670d	0.403
3	Jan, 2022	6.52	6.20	5.64	6.120c	0.445
4	Feb, 2022	6.06	6.23	6.00	6.097c	0.119
5	Mar, 2022	6.87	7.06	7.63	7.187ba	0.396
6	Apr, 2022	6.91	7.34	7.89	7.380a	0.491
7	May, 2022	6.72	6.61	6.84	6.723b	0.115
8	Jun, 2022	7.11	7.11	7.07	7.097ba	0.023
9	Jul, 2022	7.73	7.63	7.77	7.710a	0.072
10	Aug, 2022	7.73	7.60	7.20	7.510a	0.276
11	Sep, 2022	7.91	7.08	7.11	7.367a	0.471
12	Oct, 2022	7.01	6.89	6.88	6.927ba	0.072
13	Nov, 2022	6.73	6.87	6.88	6.857b	0.121
14	Dec, 2022	6.80	6.83	7.03	6.887bc	0.125
15	Jan, 2023	7.43	7.50	7.30	7.410a	0.105
16	Feb, 2023	7.47	7.23	7.10	7.267a	0.188
17	Mar, 2023	7.02	7.00	7.00	7.007ba	0.012
18	Apr, 2023	6.99	7.23	7.12	7.113ba	0.120

Means followed by the same letters are not significantly different (P>0.05)

Table 3: Monthly Mean Variation of Conductivity (µS/cm) of River Yobe

S/N	Month	Site I	Site II	Site III	Mean	Standard Derivation
1	Nov, 2021	156	195	113	154.67a	41.016
2	Dec, 2021	156	169	117	147.33a	27.062
3	Jan, 2022	154	154	187	165.00a	19.053
4	Feb, 2022	140	140	139	139.67a	0.577
5	Mar, 2022	172	176	371	239.67a	113.756
6	Apr, 2022	161	470	160	263.67a	178.691
7	May, 2022	162	161	410	244.33a	143.472
8	Jun, 2022	145	178	357	226.67a	114.072
9	Jul, 2022	159	154	458	257.00a	174.089
10	Aug, 2022	109	95	373	192.33a	156.618
11	Sep, 2022	129	119	388	212.00a	152.502
12	Oct, 2022	59	103	412	191.33a	192.365
13	Nov, 2022	107	110	275	164.00a	96.141
14	Dec, 2022	116	123	182	140.33a	36.254
15	Jan, 2023	174	132	148	151.33a	21.197
16	Feb, 2023	123	140	220	161.00a	51.798
17	Mar, 2023	121	122	128	123.67a	3.786
18	Apr, 2023	155	134	136	141.67a	11.590
Mean		138.78b	159.72a	254.11a	184.20	
Standard Deviation		29.059	82.171	123.752		99.564

Means followed by the same letters are not significantly different (P>0.05)

Table 4: Monthly Mean Variation of Transparency (cm) of River Yobe

S/N	Month	Site I	Site II	Site III	Mean	Standard Derivation
1	Nov, 2021	5.5	9.5	11.7	8.90bc	3.143
2	Dec, 2021	14.1	11.4	14.6	13.37bc	1.721
3	Jan, 2022	11.3	12.6	16.7	13.53bc	2.818
4	Feb, 2022	12.3	12	27.5	17.27b	8.864
5	Mar, 2022	17.4	15.6	30.4	21.13ab	8.075
6	Apr, 2022	14.5	19.3	52.8	28.87a	20.865
7	May, 2022	11.5	8.9	5.5	8.63bc	3.001
8	Jun, 2022	10	9.5	8.7	9.40bc	0.656
9	Jul, 2022	8.4	6.3	7.5	7.40bc	1.054
10	Aug, 2022	3.8	3.6	4.7	4.03c	0.586
11	Sep, 2022	8.5	12	13	11.17bc	2.363
12	Oct, 2022	6.2	6.8	7.5	6.83c	0.651
13	Nov, 2022	7.9	6.7	7.6	7.40bc	0.625
14	Dec, 2022	5.8	7.4	10.5	7.90bc	2.390
15	Jan, 2023	11.6	10.3	9.8	10.57bc	0.929
16	Feb, 2023	11.2	9.6	10.6	10.47bc	0.808
17	Mar, 2023	15.6	13	8.5	12.37bc	3.592
18	Apr, 2023	10.6	8.4	15.2	11.40bc	3.470

Means followed by the same letters are not significantly different (P>0.05)

Table 5: Monthly Mean Values of Dissolved Oxygen (DO) in River Yobe

Month	Site I	Site II	Site III	Mean	Standard Derivation
Nov, 2021	2.10	2.90	2.80	2.60b	0.436
Dec, 2021	2.40	3.80	4.50	3.57b	1.069
Jan, 2022	6.80	6.80	6.83	6.81b	0.017
Feb, 2022	8.75	8.37	8.43	8.52b	0.204
Mar, 2022	6.70	7.20	8.40	7.43b	0.874
Apr, 2022	5.80	11.00	6.50	7.77b	2.822
May, 2022	3.40	4.00	4.10	3.83b	0.379
Jun, 2022	4.00	7.70	6.80	6.17b	1.930
Jul, 2022	8.40	6.80	9.10	8.10b	1.179
Aug, 2022	2.50	6.30	14.10	7.63b	5.914
Sep, 2022	10.50	4.20	9.90	8.20b	3.477

Oct, 2022	7.50	8.00	8.20	7.90b	0.361
Nov, 2022	5.10	4.70	8.80	6.20b	2.261
Dec, 2022	10.70	7.80	12.50	10.33a	2.371
Jan, 2023	6.60	13.20	21.20	13.67a	7.311
Feb, 2023	5.60	15.70	13.20	11.50a	5.260
Mar, 2023	6.60	13.20	21.20	13.67a	7.311
Apr, 2023	5.60	15.70	13.20	11.50a	5.260

Means followed by the same letters are not significantly different (P>0.05)

Table 6. Monthly Mean Values of Ammonia in River Yobe

S/N	Month	Site I	Site II	Site III	Mean	Standard Derivation
1	Nov, 2021	0.05	0.07	0.064	0.061c	0.010
2	Dec, 2021	0.27	0.24	0.11	0.207b	0.085
3	Jan, 2022	1.18	0.73	0.77	0.893a	0.249
4	Feb, 2022	0.86	0.71	0.94	0.837a	0.117
5	Mar, 2022	0.95	0.86	0.97	0.927a	0.059
6	Apr, 2022	0.57	0.056	0.087	0.238b	0.288
7	May, 2022	0.917	0.86	0.877	0.885a	0.029
8	Jun, 2022	0.082	0.094	0.057	0.078c	0.019
9	Jul, 2022	0.091	0.09	0.097	0.093bc	0.004
10	Aug, 2022	0.87	0.97	0.78	0.873a	0.095
11	Sep, 2022	0.76	0.69	0.72	0.723a	0.035
12	Oct, 2022	0.082	0.089	0.974	0.382b	0.513
13	Nov, 2022	0.887	0.74	0.8	0.809a	0.074
14	Dec, 2022	0.986	0.656	0.646	0.763a	0.193
15	Jan, 2023	0.887	0.74	0.8	0.809a	0.074
16	Feb, 2023	0.833	0.786	0.676	0.765a	0.081
17	Mar, 2023	0.91	0.656	0.553	0.706a	0.184
18	Apr, 2023	0.63	0.61	0.94	0.727a	0.185
Mean		0.656a	0.536a	0.603a	0.599	
Standard Deviation		0.371	0.325	0.351		0.346

Means followed by the same letters are not significantly different (P>0.05)

Table 7: Monthly Mean Values of Phosphorus in River Yobe

S/N	Month	Site I	Site II	Site III	Mean	Standard Derivation
1	Nov, 2021	0.05	0.07	0.064	0.061c	0.010
2	Dec, 2021	0.05	0.07	0.08	0.067c	0.015
3	Jan, 2022	0.57	0.76	0.66	0.663ab	0.095
4	Feb, 2022	0.74	0.74	0.87	0.783ab	0.075
5	Mar, 2022	0.10	0.11	0.08	0.097c	0.015
6	Apr, 2022	1.21	0.127	0.07	0.469b	0.642
7	May, 2022	0.044	0.043	0.038	.042c	0.003
8	Jun, 2022	0.79	0.70	0.89	0.793	0.095
9	Jul, 2022	0.86	0.74	0.92	0.840a	0.092
10	Aug, 2022	0.91	0.68	0.92	0.719ab	0.136
11	Sep, 2022	0.76	0.87	0.89	0.704ab	0.070
12	Oct, 2022	0.516	0.936	0.704	0.464b	0.210
13	Nov, 2022	0.66	0.883	0.57	0.704ab	0.161
14	Dec, 2022	0.483	0.536	0.373	0.821a	0.083
15	Jan, 2023	0.66	0.883	0.57	0.720ab	0.161
16	Feb, 2023	0.883	0.936	0.643	0.821a	0.156
17	Mar, 2023	0.756	0.87	0.533	0.720ab	0.171
18	Apr, 2023	0.42	0.90	0.81	0.710ab	0.255

Means followed by the same letters are not significantly different (P>0.05)

Table 8: Monthly Mean Values of Total Nitrate in River Yobe

S/N	Month	Site I	Site II	Site III	Mean	Standard Derivation
1	Nov, 2021	0.064	0.077	0.06	0.067d	0.009
2	Dec, 2021	0.064	0.077	0.066	0.069d	0.007
3	Jan, 2022	0.58	0.33	0.19	0.367c	0.198

4	Feb, 2022	0.65	0.54	0.71	0.633b	0.086
5	Mar, 2022	0.076	0.106	0.833	0.338c	0.429
6	Apr, 2022	0.037	0.084	0.314	0.145cd	0.148
7	May, 2022	0.057	0.052	0.07	0.060d	0.009
8	Jun, 2022	0.71	0.54	0.92	0.723ab	0.190
9	Jul, 2022	0.71	0.89	0.92	0.840ab	0.114
10	Aug, 2022	0.59	0.81	0.65	0.683ab	0.114
11	Sep, 2022	0.61	0.59	0.60	0.600b	0.010
12	Oct, 2022	0.784	0.933	0.627	0.781ab	0.153
13	Nov, 2022	0.056	0.093	0.08	0.076d	0.019
14	Dec, 2022	0.083	0.066	0.086	0.078d	0.011
15	Jan, 2023	0.056	0.093	0.08	0.076d	0.019
16	Feb, 2023	0.44	0.74	0.836	0.672b	0.207
17	Mar, 2023	0.36	0.633	0.493	0.495bc	0.137
18	Apr, 2023	0.99	0.81	0.99	0.930a	0.104

Means followed by the same letters are not significantly different (P>0.05)

Table 9: Monthly Mean Variation of Free CO_2 in River Yobe

S/N	Month	Site I	Site II	Site III	Mean	Standard Derivation
1	Nov, 2021	0.553	0.529	0.154	0.412b	0.224
2	Dec, 2021	0.604	0.716	0.299	0.540ab	0.216
3	Jan, 2022	0.579	0.669	0.676	0.641ab	0.054
4	Feb, 2022	0.054	0.706	0.059	0.273b	0.375
5	Mar, 2022	0.081	0.114	0.199	0.131b	0.061
6	Apr, 2022	0.770	1.131	0.639	0.847a	0.255
7	May, 2022	0.744	0.607	0.902	0.751ab	0.148
8	Jun, 2022	0.068	1.056	0.732	0.619ab	0.504
9	Jul, 2022	0.745	1.020	0.895	0.887a	0.138
10	Aug, 2022	0.601	0.997	0.818	0.805a	0.198
11	Sep, 2022	0.889	0.567	0.964	0.807a	0.211
12	Oct, 2022	0.618	0.747	0.268	0.544ab	0.248
13	Nov, 2022	0.610	0.850	0.237	0.566ab	0.309
14	Dec, 2022	0.607	0.870	0.281	0.586ab	0.295
15	Jan, 2023	0.680	0.792	0.815	0.762ab	0.722
16	Feb, 2023	0.086	0.122	0.094	0.101b	0.019
17	Mar, 2023	0.109	0.136	0.134	0.126b	0.015
18	Apr, 2023	0.558	0.453	0.185	0.399b	0.315

Means followed by the same letters are not significantly different (P>0.05)

Length-Weight Relationship and Condition Factors of Fish

In assessing the wellbeing of fish species; the ‘b’ values for both *O. niloticus* and *C. gariepinus* at sites I, II and III showed that, the two species showed negative allometric growth pattern. Allometric growth experienced during this study in the two species fish might be attributed to high ammonia and nitrate. The results of the condition factor which recorded 0.65±0.072 - 4.24±0.440 and 0.82±0.092 - 4.15±0.044 for the *O. niloticus* and *C. gariepinus* was an indication that the fishes were in stabled condition throughout the period of this study. Smaller fish in *O. niloticus* exhibited higher condition factor, while the larger fish in *C. gariepinus* exhibited higher condition factor. Values of the condition factor differ significantly (p<0.05) between season and month, but showed no significant differences between sites.

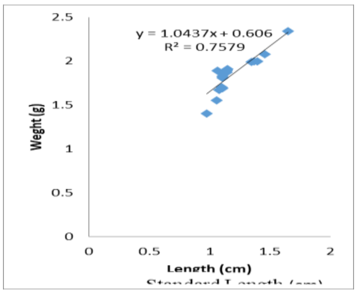

Figure 2: Length-weight relationship of *Oreochromis niloticus* in Mashayar Bade (site I)

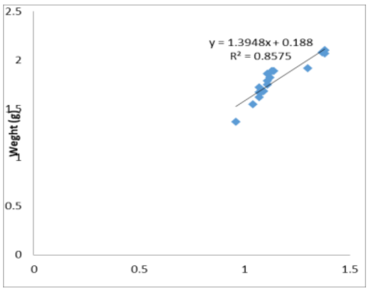

Figure 3: Length-weight relationship of *Oreochromis niloticus* in Usur (site II)

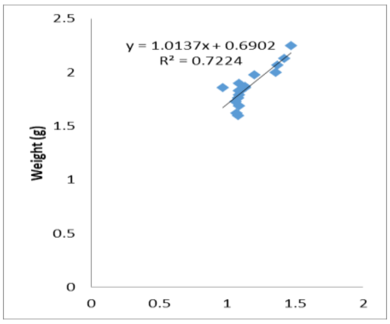

Figure 4: Length-weight relationship of *Oreochromis niloticus* in Nguru (site III)

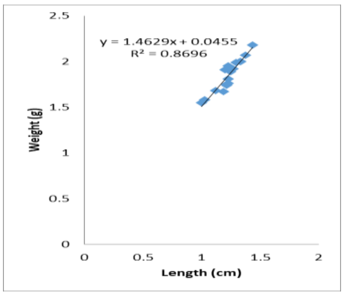

Figure 5: Length-weight relationship of *Clarias gariepinus* in Mashayar Bade (site I)

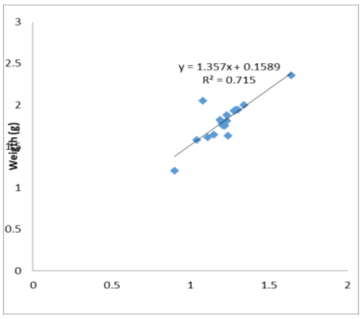

Figure 6: Length-Weight Relationship Of *Clarias Gariepinus* in Usur (site II)

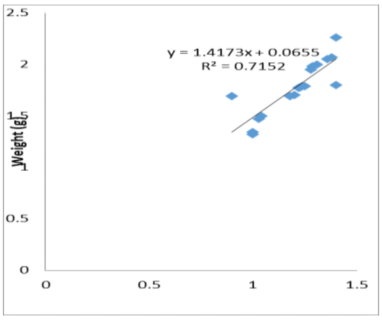

Figure 7: Length-Weight Relationship Of *Clarias Gariepinus* in Nguru (site III)

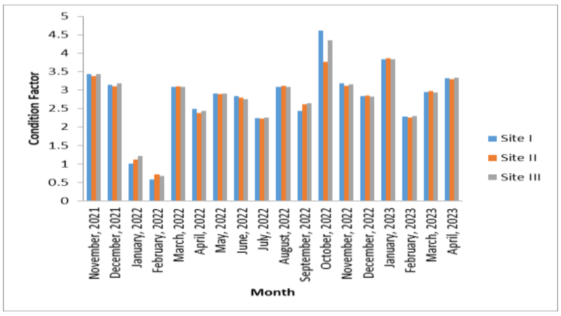

Figure 8: Monthly Condition Factor of *Oreochromis niloticus* from River Yobe (November, 2021-April, 2023)

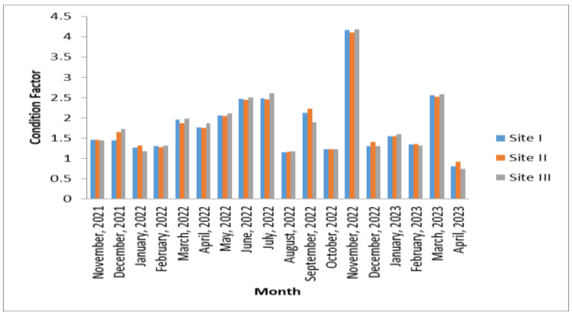

Figure 9: Monthly Condition Factor of *Clarias gariepinus* from River Yobe (November, 2021-April, 2023)

Plankton Species Diversity and Abundance

A total of 1,714 phytoplankton individuals from 5 classes and 1,781 zooplankton individuals from 3 classes were identified. The phytoplankton community was dominated by Chlorophyceae (Green algae), with *Cladophora oligoclonus* being the most abundant species (17.97%). Zooplankton was dominated by Rotifera, primarily *Branchionus* sp. (13.36%).

Spatial analysis showed the highest abundance of both phytoplankton and zooplankton at Sites II and III. These sites correspond with the areas of highest reported anthropogenic activity (indiscriminate fishing, waste dumping, agriculture). The proliferation of Chlorophyceae and nutrient-tolerant Rotifera like *Branchionus* is a classic bioindicator of eutrophic conditions (Steve *et al*., 2013; Zira and Edward, 2021). The significant correlation between sites of high human activity, elevated nutrient levels (ammonia, phosphate), and high plankton abundance confirms that anthropogenic inputs are driving primary productivity shifts in River Yobe. While this may temporarily boost food for filter-feeders, it destabilizes the ecosystem and can lead to harmful algal blooms and oxygen depletion.

Table 10: Monthly Diversity and Abundance of Phytoplankton

Species	**2021 Nov**	**Dec**	**2022 Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**2023 Jan**	**Feb**	**Mar**	**Apr**	**T**	**% Comp**
Cyanophyceae																				
Oocystis solitaria	4	3	2	4	6	3	5	3	2	2	4	5	6	3	2	5	7	3	69	4.03
Microcystis aerugynosa	3	5	4	2	6	5	7	4	3	2	4	5	5	3	2	4	5	4	73	4.26
Oscillatoria	5	6	7	5	8	7	9	6	5	4	5	4	6	7	5	6	8	7	110	6.42
Microcystis incerta	7	9	8	8	10	9	6	8	7	6	7	5	8	6	8	7	6	6	131	7.64
Cholorophyceae																				
Spirogyra	5	9	7	10	11	8	7	8	6	9	8	8	11	8	7	8	11	8	149	8.69
Cladophora oligoclonus	18	14	9	19	25	17	15	20	21	8	20	17	16	23	18	17	19	12	308	17.97
Chlorella	2	4	5	3	7	6	5	3	4	2	3	4	2	3	6	4	3	5	71	4.14
Mongeotia	7	4	5	3	8	6	5	3	4	2	3	5	1	3	6	4	3	5	77	4.49
Euglenophyceae																				
Euglena caudate	4	4	3	2	5	8	6	4	5	7	6	5	3	5	6	7	5	4	98	5.19
Euglena viridis	2	3	5	6	3	6	4	5	4	6	4	7	5	2	5	6	4	3	80	4.67
Bacillariophyceae																				
Synedra	7	5	3	4	3	5	4	8	6	7	7	5	8	6	6	4	6	5	99	5.78

Species	2021 Nov	Dec	2022 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2023 Jan	Feb	Mar	Apr	T	% Comp
Fragillara	2	4	7	6	3	5	8	9	8	7	5	4	3	5	5	6	4	6	97	5.66
Nitachia	4	2	3	3	0	3	6	3	1	2	4	3	2	3	4	5	4	5	57	3.33
Aulacoseira	4	4	9	8	5	10	8	7	4	6	8	4	6	5	3	2	5	4	102	5.94
Melosira	3	3	1	2	0	4	5	2	1	4	5	3	0	1	1	3	2	4	44	2.57
Diatoma	3	4	5	5	4	6	5	3	1	5	6	3	0	2	4	5	6	7	74	4.32
Rhodophyceae																				
Batrachospermum	3	5	4	3	7	6	4	7	3	5	3	4	6	4	5	4	4	5	84	4.90
Total	86	86	88	94	107	115	111	100	89	82	104	90	86	91	92	98	102	93	1714	100
%Composition	5.02	5.02	5.13	5.48	6.24	6.71	6.48	5.83	5.19	4.78	6.07	5.25	5.02	5.31	5.37	5.72	5.95	5.43	100	

Table 11: Diversity and Abundance of Phytoplankton according to Sites

Class	Species	Site I	Site II	Site III	Total
Cyanophyceae	*Oocystis solitaria*	25	26	18	69
	Microcystis aeruginosa	11	33	29	73
	Oscillatoria sp.	37	10	63	110
	Microcystis incerta	44	29	58	131
Cholorophyceae	*Spirogyra sp.*	45	32	72	149
	Cladophora oligoclonus	67	89	152	308
	Chlorella sp.	35	19	17	71
	Mongeotia sp.	24	37	16	77
Euglenophyceae	*Euglena caudate*	24	37	28	89
	Euglena viridis	20	39	21	80
Bacillariophyceae	*Synedra sp.*	43	45	11	99
	Fragillaria sp.	27	30	40	97
	Nitachia sp.	9	32	16	57
	Aulacoseira sp.	33	38	31	102
	Melosira	8	19	17	44
	Diatoma	6	45	23	74
Rhodophyceae	Batrachospermum	5	48	31	84
Total abundance		463	608	643	1714
Percentage Composition (%)		27.02%	35.47%	37.51%	100%

Table 12: Monthly Diversity and Abundance of Zooplanktons

Species	2021 Nov	Dec	2022 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2023 Jan	Feb	Mar	Apr	T	.%com
Cladocera																				
Leptodora sp.	2	3	2	4	5	3	2	1	2	1	2	3	2	3	2	3	4	3	47	2.64
Simocephalus	4	6	3	5	8	6	4	7	5	3	4	3	1	5	7	6	5	4	86	4.83
Chydonis	6	6	7	5	8	6	9	3	5	4	2	3	6	5	4	8	9	7	103	5.78
Daphnia	8	9	7	11	12	14	10	8	7	6	7	5	4	6	8	7	6	5	140	7.86
Sida	3	1	3	2	4	3	1	2	1	2	3	1	2	1	2	3	2	1	37	2.08
Copepoda																				
Diaptomus	2	5	3	2	6	5	4	1	2	1	3	6	8	4	2	1	5	4	64	3.59
Cyclops	6	4	1	3	1	2	5	3	4	2	3	5	1	3	6	4	3	1	57	3.20
Nauplius larvae	8	7	11	8	6	10	15	9	7	6	13	6	8	14	9	12	7	10	166	9.32
Metacydops	6	4	9	7	5	8	6	4	8	7	6	10	4	5	11	8	6	4	118	6.63
Rotifera																				
Trichocerca	7	6	7	6	7	8	9	5	4	7	8	10	6	7	5	6	4	7	119	6.68
Filinia	1	1	3	2	3	5	4	1	0	1	3	5	3	6	4	4	2	5	53	2.98
Branchionus	14	11	12	12	7	13	17	10	8	12	19	15	11	16	15	18	15	13	238	13.36
Euclanis	8	5	11	9	6	12	9	8	6	7	9	8	7	6	5	5	6	5	132	7.42
Notholca	10	9	7	8	6	10	13	9	8	9	15	8	7	16	9	13	10	11	178	9.99

	2021		2022												2023					
Species	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**T**	**.%com**
Testidunella	6	9	11	10	7	12	11	8	6	7	10	8	5	7	7	9	10	9	152	8.53
Monostyla	7	4	6	5	4	8	7	5	5	4	6	3	4	6	3	5	4	5	91	5.11
Total	98	90	103	99	95	125	126	84	78	79	113	99	79	110	99	112	98	94	1781	100
% Comp		5.5	5.1	5.78	5.56	5.33	7.02	7.07	4.72	4.38	4.43	6.34	5.56	4.43	6.17	5.56	6.28	5.5	5.27	100

Table 13: Diversity and Abundance of Zooplanktons according to Sites

Class	**Species**	**Site I**	**Site II**	**Site III**	**Total**
Cladocera	*Leptodora sp.*	17	18	12	47
	Simocephalus	36	28	22	86
	Chydonis sp.	25	42	36	103
	Daphnia	39	58	43	140
	Sida sp.	5	25	7	37
Copepoda	*Diaptomus*	14	33	17	64
	Cyclops	11	32	14	57
	Nauplius larvae	32	61	73	166
	Metacydops sp.	34	58	26	118
Rotifera	*Trochocerca sp.*	27	53	39	119
	Filinia sp.	14	23	16	53
	Branchionus sp.	78	95	65	238
	Euclanis sp.	43	66	23	132
	Notholca sp.	26	69	83	178
	Testidunella	39	62	51	152
	Monostyla sp.	40	31	20	91
Total Abundance		480	754	547	1781
		26.95%	42.34%	30.71%	100%

Discussion

Water Quality of River Yobe

The monthly mean water temperature of River Yobe varies between 19.41±0.586 ºC in January 2022 to 29.48±1.518 ºC in April 2022 during the period of the research. The low water temperature recorded in the January, might be due to the characteristic cool dry North-East trade wind known as Harmattan between November and February while the high-water temperature in April was due to characteristic of hot weather from the North East (Abowei, *et al.*, 2010). This pattern of variation has similarly been reported in River Benue and River Taraba at Makurdi and Bali by Akaahan, Araoye and Azua (2015) and Danba *et al.* (2023) who reported a temperature range of 23 ^{O}C – 33 ^{O}C. The values of monthly mean temperature observed were within the normal permissible limits of 35 ºC and 30 ºC recommended by Federal Ministry of Environment (2001) and WHO (2012) for tropical fish. The result was higher than the recommended 8 – 30 ºC set by WHO (2012). Monthly mean variation of the pH values ranged from 5.570±0.403 in November 2021 to 7.710±0.072 in July 2022. This fall within the result reported for River Taraba by Danba *et al.,* (2023) who reported 7.5±0.53 to 10.6±1.03 respectively. The recorded value falls within the EU recommended range of 6 to 9 for fisheries and aquatic life (Akindele, Adeniyi and Indabawa, 2013) and the WHO (2012), 6.0-8.5 pH guideline for drinking water and culturing tropical fish species. Low mean pH recorded in July 2022 could be due to the influx of water during the rainy season. Generally, the pH values did fall within the acceptable limit of 6.5-8.5 by WHO (2012).

Conductivity monthly mean values ranged from 123.673.786±µS/cm in the month of March 2023 to 263.67±178.691µS/cm in the month of April 2022. This was a typical fresh water since the electrical conductivity of most fresh water ranges from 8-10000 µS/cm (WHO 2012). The variation in the conductivity values observed may be due to the fluctuation of monthly mean value of pH around the neutral point of 7 recorded in the river. Acidic water (pH < 4.5) or alkalinity (pH >10) appreciate higher conductivity values. The high transparency mean value recorded in April is within the recommended 30-80cm for pond water fishery (Bhatnagar and Devi, 2013). Similar observation was made by Ehigiator and Obi (2015) on the relationship among physical parameters of Ovia River. The high transparency could be due to surface run-offs and settling effect of suspended materials at the beginning of rainfall. The monthly mean variation of the Dissolved Oxygen ranged from 2.60±0.436ppm in the month of November 2021 to 13.67±7.311ppm in the months of January and March 2023. The high oxygen value recorded in January and March coincides with the periods of lowest temperature. The monthly mean total ammonia variations ranged from 0.061±0.010mg/l in November 2021 to 0.927±0.059mg/l in March 2022. This was higher than the recommended 0.025mg/l by Bhatnagar and Devi (2013). These findings were also not in agreement with Edward (2017) who also reported a higher total ammonia of 0.030mg/l to 0.110mg/l in upper Benue River in both dry and rainy season. The monthly mean variation of total phosphorus ranged from 0.042±0.003mg/l in the month of May 2022 to 0.840±0.092mg/l in the month of July and September 2022. This was higher than 0.295±0.0020mg/l to 0.665±0.1061mg/l reported from River Taraba (Danba *et al.,* 2023). The high concentration of phosphorus in River Taraba was due to higher water hardness, thus high co-precipitation of phosphate with calcium carbonate. The monthly mean total nitrate ranges between 0.060±0.009mg/l to 0.930±0.104mg/l in the months of May 2022 and April 2023 respectively. The higher nitrate observed in April could be due to surface run-offs as well as decomposition of organic matter from the early rainfall. Ibrahim *et al.* (2009) stated that a high nitrate concentration is related to inputs from agricultural lands. The monthly mean variation of free CO_2 ranged between 0.101±0.270mg/l to 0.887±0.114mg/l in the months of February 2023 and July 2022 respectively. This fall within the result of 0.9±0.10mg/l in October 2018 and 1.9±0.81mg/l in April 2018 reported for River Taraba (Danba *et al.,* 2023). The low value of free CO_2 observed in the month of February maybe attributed to low light intensity penetrating the clear water leading to photosynthesis while the high CO_2 recorded in July could be as a result of raining season farming activities around the river which washed organic and inorganic chemical to the water body. The value of CO_2 in this study is within the permissible limit (6.0mg/l) as defined by WHO (2012) guidelines.

Length-Weight Relationship and Condition Factors of O. niloticus and C. gariepinus

The result of length-weight regression analysis showed that the "b" values for both Sites I, II, and III of *O. niloticus* and *C. gariepinus* exhibited negative allometric growth pattern for both *O. niloticus* and *C. gariepinus* showed negative allometric growth ($b<3$) at both the three sites. The present study is similar to the observation for different species of fish in Lake Tatabu in Niger State, Kiri Dam and Lake Geriyo in Adamawa State (Akinwande, *et al.,* 2012; Zira, *et al.*, 2019; Kefas and Abubakar, 2010 and Kefas, 2016). From length-weight parameters (a, b), fishes are affected by a series of factors such as season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions (Onome, *et al.*, 2013). Even though the change of b values depends primarily on the shape and fatness of the species, various factors might be responsible for differences in the b value for the length-weight relationships of cichlids (Atama, *et al.*, 2013). These factors might include seasons, water temperature, salinity, food (quantity, quality and size), sex and stage of maturity.

The condition factor expresses the condition of a fish, such as the degree of well-being, relative robustness, plumpness or fatness in numerical terms. *O. niloticus* and *C. gariepinus* recorded monthly mean condition factor ranging from 0.65±0.072 - 4.24±0.440 and 0.82±0.092 - 4.15±0.044 respectively. The current result exceeds the 0.65 - 1.21 range reported for *C. gariepinus* from Kiri reservoir (Zira, *et al.*, 2015) but falls within the 1.85 - 6.81 and 1.81 - 9.47 ranges reported for the same Kiri reservoir (Zira, *et al.*, 2019). This also supports the work (Zira *et al.,* 2015), who reported an increase in condition factor during dry season as a result of water clarity during this period and more light penetrates the water and photosynthetic plants flourish.

Plankton Diversity and Abundance

Most water bodies require significant amount of phytoplankton to have productive and sustainable fisheries. Phytoplankton is usually at the base of aquatic food web and is the most important factor for production of organic matter in aquatic ecosystem. A total of 1714 organisms (phytoplankton) belonging to five (5) taxa were identified at river Yobe. The species *Cladophora aligoclonus* was the most abundance species of phytoplankton recorded from this study in site III (152) followed by site II (89). This is as a result of anthropogenic activities that come from wastes washed, washing of clothes, bathing around the river and agricultural runoff particularly phosphorus and nitrogen which often lead to the proliferation of *Cladophora* species. Steve *et al.* (2013), also made similar observation in their work. Anago, Esenowo and Ugwumba (2013), reported that in lakes where domestic, agricultural and industrial pollution is accelerated, growth of Chlorophyta and Cyanophyta results. Thus, current changes in the phytoplankton composition appear to be directly related to the prevailing environmental conditions. Site III recorded higher distribution and abundance of phytoplankton with a total of 643(37.51%) species than site I and II which recorded 463(27.02%) and 608(35.47%) species respectively. This could be attributed to the nutrient enrichment of site III which record very significant anthropogenic activities in the area.

Zooplanktons are good indicator of water quality. They play a vital role in the food web of aquatic ecosystems. Zooplankton obtained from the current study revealed that, three (3) taxa namely; Clodocera, Copepoda and Rotifera and were represented by sixteen (16) species. Zira and Edward (2021) and Kadam, *et al.*, (2014) reported four taxa namely; Rotifera, Cladocera, Copepoda and Ostrocoda from Kiri reservoir and Pillowa Reservoir District Morena Madhya Pradesh. The dominance of Rotifera in this study agreed with other observation (Zira and Edward, 2021; Dede and Deshmukh, 2015 and Eyo and Paul, 2015) that Rotifera is the most abundant zooplankton. This was in variance with the work (Yakubu *et al.,* 2007; Ajuonu, *et al.*, 2011), who both reported Cladocera and Copepoda as the most dominant in their separate studies.

CONCLUSION

The physicochemical analysis of River Yobe revealed significant seasonal variations in parameters such as temperature, pH, dissolved oxygen, and ammonia levels. For instance, ammonia and nitrate levels were slightly above the WHO permissible limit, indicating periodic stress on aquatic life. The Length-weight regression analysis revealed that both *Oreochromis niloticus* and *Clarias gariepinus* exhibit negative allometric growth across all sampling stations and sampling months, indicating that their weight increases at a slower rate than their length. Additionally, variations in condition factors across sites suggest the influence of habitat quality and fishing pressure. The findings suggest that anthropogenic activities like refuse dumping, farming, and fertilizer usage impacted the plankton diversity and abundance. Plankton serves as a critical component of the aquatic food web, and its decline could adversely affect fish populations.

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