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Spatial Distribution and Diversity of Phytoplankton and Zooplankton and Status of Physico-chemical Parameters in White Nile, Blue Nile and River Nile

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to estimate the distribution of phytoplankton, zooplankton and their correlation with physico-chemical conditions of water for White Nile, Blue Nile and River Nile, April – May 2022. Some of the important physico-chemical factors of the research stations have been analyzed and the water temperature (°C) were (22.00±1.00, 21.00±0.00 and 21.00±0.00), pH (8.47±0.31, 7.6.00±0.35 and 8.07±0.12) and Transperancy (cm) (34.67±11.06, 85.33±4.16 and

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47.00±8.54) for White Nile, Blue Nile and River Nile respectivley. The results revealed that there are 18 species of phytoplankton and 18 species of zooplankton were recorded from all the stations. Among these Bacillariophyceae was the most dominant class in phytoplankton 5 genus, followed by 4 genus Chlorophyceae, 3 genus Cyanophyceae, 3 genus Zygnematophyceae, 2 genus Xanthophyceae and 1 genus Coscinodiscophyceae. While zooplankton, 18 different genera, the genus are represented by 6 genus Rotifera, 2 genus for (Crustacea, Rhizopoda, Lobosea and Eurotatoria), 1 genus for (Adenophorea, Phylactolemata, Secernetea and Ciliata). Statistically, phytoplankton showed significat result with zooplankton (r^2 = 0.81) and with water temperature and PO_4 (r^2 =0.43); non-significant different with transperancy (r2 = 0.01); for zooplankton the results showed that the positive relation between zooplankton and turbidity (r^2 =0.27) and non-significat with other parameters.

Keywords: Phytoplankton; zooplankton; physico-chemical parameter; river nile; blue; white nile.

1. INTRODUCTION

Aquatic surfaces play important role as they serve not only the purpose of water supply for domestic, industrial, agricultural and power generation but also utilized for the purpose of sewage and industrial waste and therefore are put under tremendous pressure (Subin and Husna, 2013). Most rivers have been used for the disposal and discharging of the domestic and industrial effluents [1]. The estimation of temporal and spatial variability in aquatic systems is important for understanding the ecology of biota [2]. Variability it can be used to assesment and understanding of the aquatic ecosystem [3]. Aquatic scientists have conduccted different researches by sampling different aquatic system for many [4].

Aquatic organims (Phytoplankton, Zooplankton, macrophytes, macro invertrates and vertbrates consist more that 75% of fresh water fish’s feed during their life stage Rusak et al. [4]. Measuring primary and secondary production is important for estimating fish production [1]. Plankton and nekton are the large community in the water bodies. Phytoplankton consider as primary procuders in fresh and sal water, fish and other aquaric organism depend on it [5,6]. Plankton's lifestyle, suspension and drifting water. Living in the surface searching for beter physico-chemical properties [7]. Phytoplankton consist of <1% of whole world's photosynthetic biomass, but accounts for about 50% of the world's net primary production and is the primary source of energy for aquatic ecosystems [8] and the fate of this process is crucial. phytoplankton community composition.

Zooplankton is one of the most important biological components affecting all the functions of water bodies, including food sources, energy flows and materials. They occupy important positions in pelagic food webs [9-14].

Environmental factors are also important; for example, water temperature affects the growth and development of organisms and affects their mortality [15]. Different aquatic organisms show different sensitivities to increase or decrease in temperature, and particularly sensitive individuals are removed from them [16-18].

1.1 Justifications

1. The importance of zooplanktons and Phytoplanktons in nutrition of aquatic animal specially fish nutrition.
2. The noticeable attention that has been paid at natural food in order to reduce the costs of fish feed in aquaculture sector in Sudan so that there is need for estimation of zooplanktons and Phytoplanktons in addition; the characterization of water quality for White Nile, Blue Nile and River Nile in Sudan.

1.2 Objective

The objective of this work is to investigate the distribution of phytoplankton, zooplankton and their correlation with physico-chemical conditions of water for White Nile, Blue Nile and River Nile.

2. MATERIALS AND METHODS

2.1 Time and Place of the Study

The present study results from limnological investigation undertaken during the dry season (April-May 2022) on three different locations in White Nile, Blue Nile and River Nile, and every station was divided into three sub-stations (A, B and C) as shown in (Table 1) by using GPS.

Table 1. Locations of the samples collection

	White Nile	Blue Nile	River Nile
A	N" 15˚.31125 E" 32˚.30011	N" 15˚.6125840, E 32˚.58454	N" 15˚.707589, E" 32˚.5356880
B	N" 15˚.31625 E" 32˚.30011	N" 15˚.36351 E 32˚. 43540	N" 15˚.707590, E" 32˚.5365680
C	N" 15˚.31´464 E" 32˚.30011	N" 15˚. 63351 E 32˚.34244	N" 15˚.7094830, E" 32˚.5392930

2.2 Phyisco-Chemical Parameters

The water samples were collected from selected sites during morning hours into two liters polythene bottles for physico-chemical parameters between 7:00 A.M. to 11:00 A.M. Water temperature using (Portable Digital Thermometer), turbidity (cm) (Sacci disk), pH, NO_2-N, NO_3-N, NH_3-N and PO_4 were determined by standard methods of APHA, [19].

2.3 Sampling and Collection of Plankton

Plankton samples were collected by filtering 40 liters of water through plankton net of 20µ pore size filtering cloth and concentrated up to 100 ml. The concentrated plankton samples were preserved immediately by 2 ml of formalin solution (10%) [20]. The samples were observed under the microscope and identified phytoplankton using standard keys and published literature. The phytoplankton species has been identified using keys Edmondson [20]. Counting was made by putting one drop of concentrate on a slide and observing the content under inverted microscope (Metzer). Results were expressed in No. /ml.

Diversity index Shannon -Weaver [21] and correlation coefficient were also calculated. Shannon Weaver diversity index (H') was calculated using the following formula:

$$\text{Shannon - Wiener Index (H)} = \Sigma ni/N \ \text{In} \ ni/N \quad (1)$$

Where:

H = Shannon -Weaver index of diversity;
ni = total numbers of individuals of species,
N = total number of individual of all species.

2.4 Data Analysis

2.4.1 Spatial and temporal distribution

One aspect of the dynamics of phytoplankton is the spatial and temporal distribution of PO_4, NO_3 and density of phytoplankton. Spatial aspects than is location, i.e. White Nile, Blue Nile and River Nile, while the temporal aspect is the dry. The analysis used two way multivariate analysis of variance [22].

If the parameters of a functional relationship between the dependent variable with more than one independent variable estimated, then the regression analysis with respect to the regression (multiple regression). To determine the relationship between (X_1), (X_2) and (X_3), to perform structural equation modeling and diagram using SPSS® (V. 16), then the general multiple linear regression model as:

$$Y = \beta 0 + \beta 1 X_{1i} + \beta 2 X_{2i} + \ldots\ldots + \beta k\ Xki + \varepsilon i \quad (2)$$

Where:

Y = observation to i on the dependent variable
Xik = Observations to i on the independent variables
β0 = intercept parameter
β1, β2, .. .βk = parameter regression coefficient independent variable
εi = observations to the i variable error

2.4.2 Functional relationship between plankton and abiotic factors

Plankton functional relationship with the abiotic environment was done to form multiple regression approach:

$$f\ \text{Plankton} = f\,(\text{Turbidity}; Po_4 - P; No_3 - N) \quad (3)$$

$$Y_{\text{plankton}} = f(X\,Trans\,;\ X\,PO_4 - P\,; X\,No_3 - N)$$

(4) Linear Multiple Regression

3. RESULTS

3.1 Physico-Chemical Parameters

The measurements of these characteristics provide valuable information about the aquatic environment. Some of the important physico-chemical factors of the research stations (White Nile, Blue Nile and River Nile) have been analyzed as in (Table 2 and Fig. 1).

Table 2. The average of physico-chemical parameters in water

	White Nile	Blue Nile	River Nile
Temperature (°C)	22.00±1.00	21.00±0.0	21.00±0.0
pH	8.47±0.31	7.6.00±0.5	8.07±0.12
NO_2 (mg L^{-1})	0.00±0.01	0.00±0.00	0.00±0.00
NO_3 (mg L^{-1})	0.00±0.01	0.00±0.00	0.00±0.00
NH_3 (mg L^{-1})	0.00±0.00	0.00±0.00	0.00±0.00
PO_4 (mg L^{-1})	1.33±0.01	0.00±0.00	0.00±0.00
Turbidity (cm)	34.67±11.06	85.33±4.1	47.00±8.5

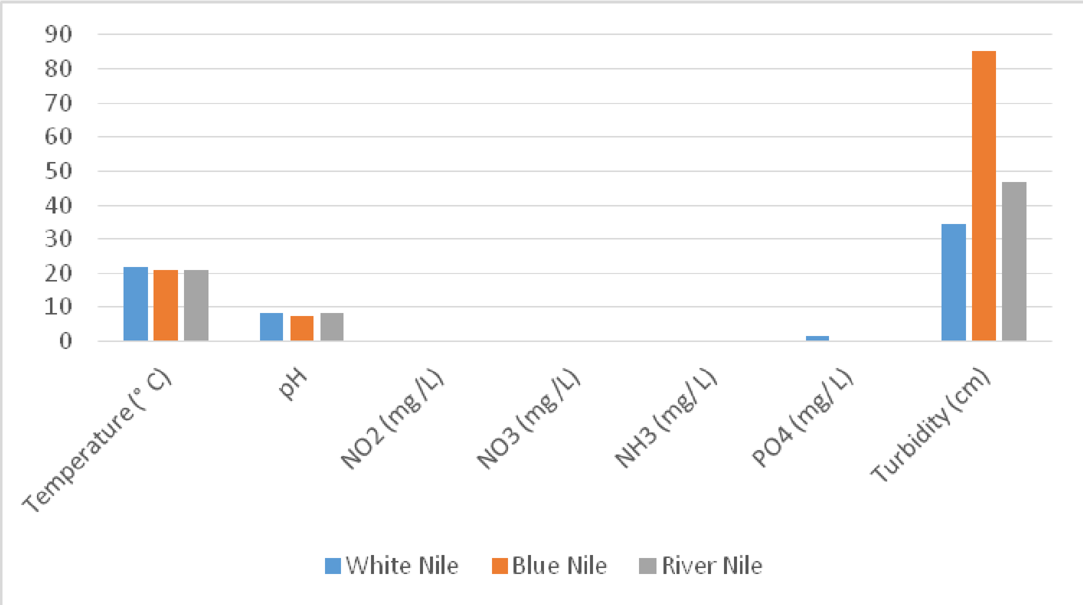


Fig. 1. Physico-chemical parameters of water

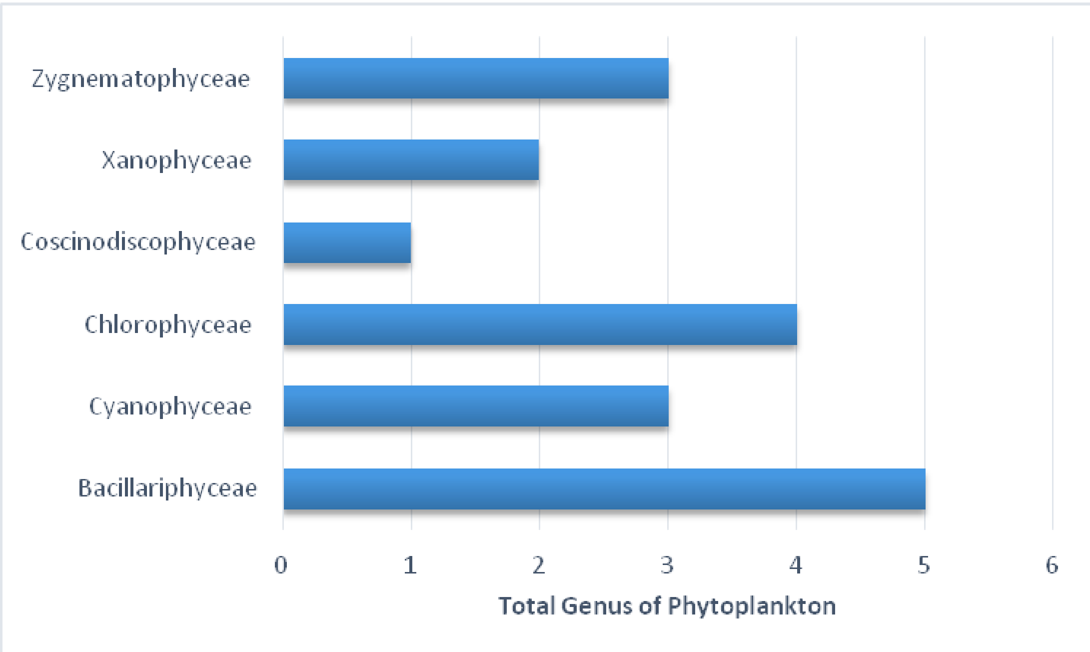


Fig. 2. Total genus of phytoplankton during the study

3.2 Phytoplankton

The results showed that, the total number of phytoplankton classes were 6 in nine different stations studied which comprises 18 different genera, the genus are represented by 4 genus Chlorophyceae, 5 genus Bacillariophyceae, 3 genus Cyanophyceae, 1 genus Coscinodiscophyceae, 2 genus Xanthophyceae and 3 genus Zygnematophyceae (Table 3; and Fig. 2).

The environmental variation in the species diversity index (H') have been calculated and presented in (Fig. 3) for all the nine stations. The abundance of phytoplankton during this study ranged from 73, 101 and 210 Cell L^{-1} for White Nile, Blue Nile and River Nile respectivley.

3.3 Zooplankton

The results showed that, the total number of zooplankton classes were 9 in nine different stations studied in White Nile, Blue Nile and River Nile, which comprises 18 different genera, the genus are represented by 6 genus Rotifera, 2 genus for (Crustacea, Rhizopoda, Lobosea and Eurotatoria, 1 genus for (Adenophorea, Phylactolemata, Secernetea and Ciliata) (Table 3 and Fig. 4). Simpson (D) and diversity index (H') have been calculated and presented in (Table 4; Fig. 5) for all the nine stations. The abundance of zooplankton during this study were 125, 97 and 202 (ind./L) for White Nile, Blue Nile and River Nile respectivley (Fig. 5).

Table 5 and Figs. 6 showed significat result between phytoplankton and zooplankton (r^2 = 0.81) and with water temperature and PO4 (r^2 =0.43); non-significant different with turbidity (r^2 = 0.01); for zooplankton the results showed that the positive relation between zooplankton and turbidity (r^2 =0.27) and non-significat with other parameters.

Table 3. The average of phytoplankton in selected locations

Phytoplankton	White Nile	Blue Nile	River Nile	Total
Bacillariphyceae				
Navicula sp	1	2	-	3
Fragilaria robusta	-	2	2	4
Synedra sp	-	4	-	4
Bacillaria paradoxa	1	-	-	1
Diatoma sp	1	-	-	1
Cyanophyceae				
Phormidium sp	24	37	104	165
Oscillatoria sp	1	2	6	9
Chamaesiphon sp	7	6	12	25
Chlorophyceae				
Chaetophora sp	14	7	8	29
Scenedesmus sp	-	4	-	4
Pediastrum boryanum	1	1	-	2
Eudorina sp	-	1	-	1
Coscinodiscophyceae				
Melosira sp	7	26	17	50
Xanophyceae				
Tribonema sp	6	6	51	63
Euglena sp	5	-	3	8
Zygnematophyceae				
Spondylosium sp	1	2	-	3
Euastrum sp	4	-	3	7
Cosmarium sp	-	1	4	5
Total	73	101	210	384
Simpson Index (D)	0.24	0.22	0.59	
Shannon wiener index (H)	4.2	4.6	1.7	

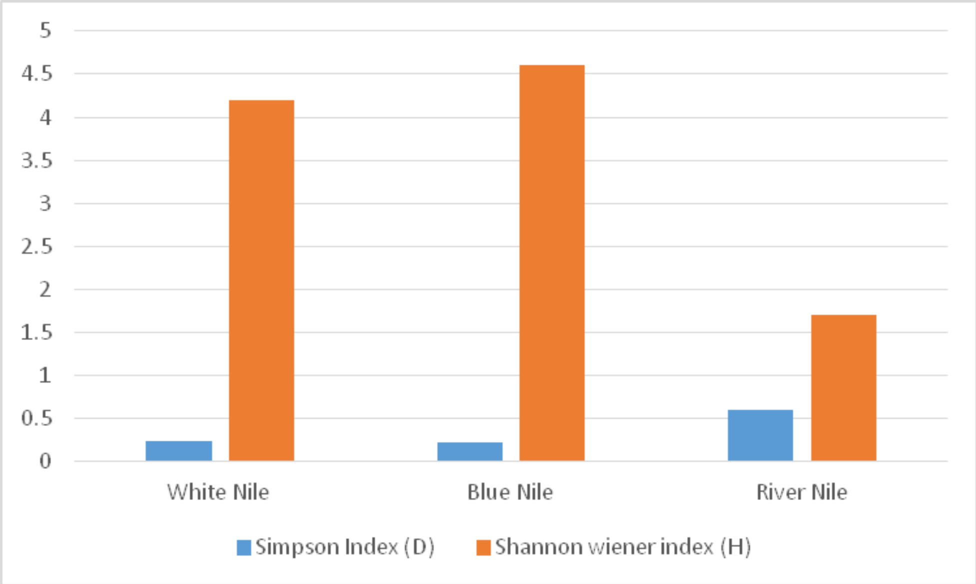


Fig. 3. Phytoplankton diversity index

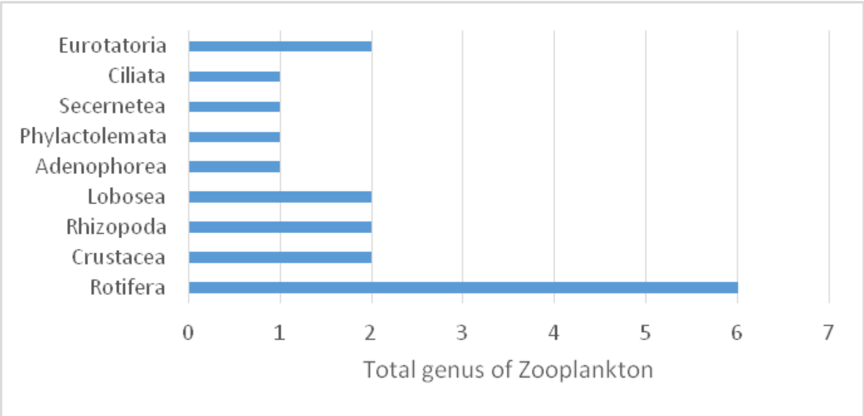


Fig. 4. Total genus of zooplankton in studied locations

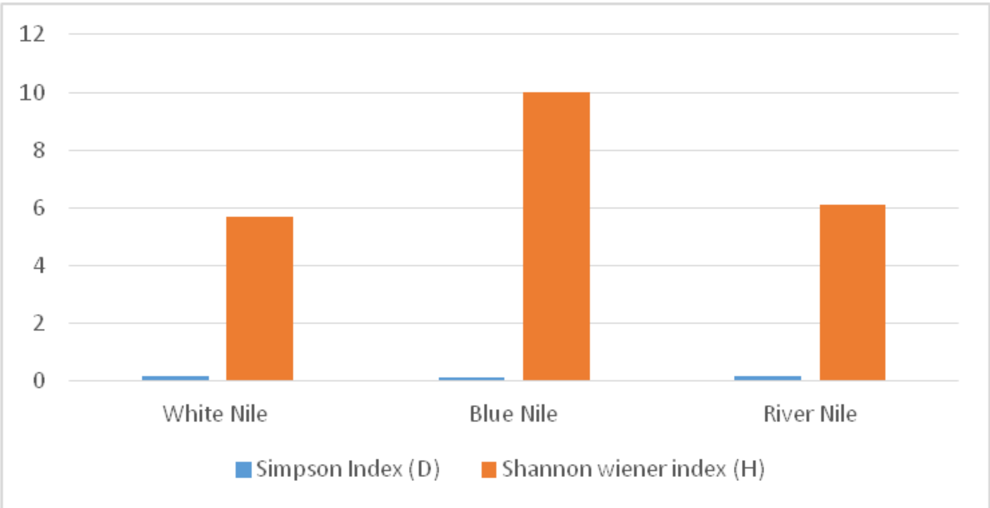


Fig. 5. Zooplankton diversity index

Table 4. The average of phytoplankton in the studied locations

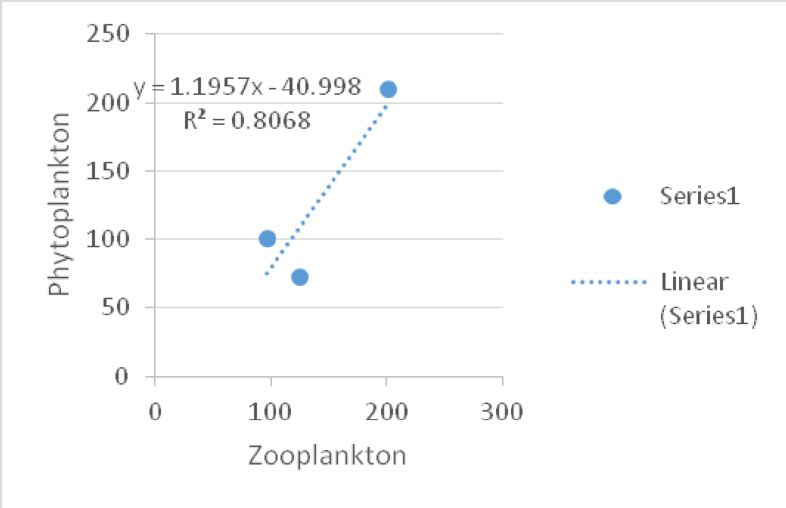
Zooplankton	White Nile	Blue Nile	River Nile	Total
Rotifera				
Brachionus sp	1	-	-	1
Brachionus bidentate	-	-	3	3
Brachionus falcatus	-	1	-	1
Notholca sp	-	4	1	5
Philodina sp	17	13	13	43
Keratella sp	1	4	-	5
Crustacea				
Cyclops sp	-	2	1	3
Moina sp	-	3	1	4
Rhizopoda				
Arcella sp	25	3	25	53
Difflugia sp	12	8	41	61
Lobosea				
Centropyxis sp	19	9	11	39
Centropyxis aculeate	5	6	23	34
Adenophorea				
Rhabdolaimus sp	8	10	35	53
Phylactolemata				
Plumatella sp	11	4	4	19
Secernetea				
Panagrolaimus sp	5	4	3	12
Ciliata				
Epistylis sp	9	16	17	42
Eurotatoria				
Rotaria sp	10	6	15	31
Monostyla sp	2	4	9	15
Total	125	97	202	424
Simpson Index (D)	0.18	0.1	0.16	
Shannon wiener index	5.7	10	6.1	

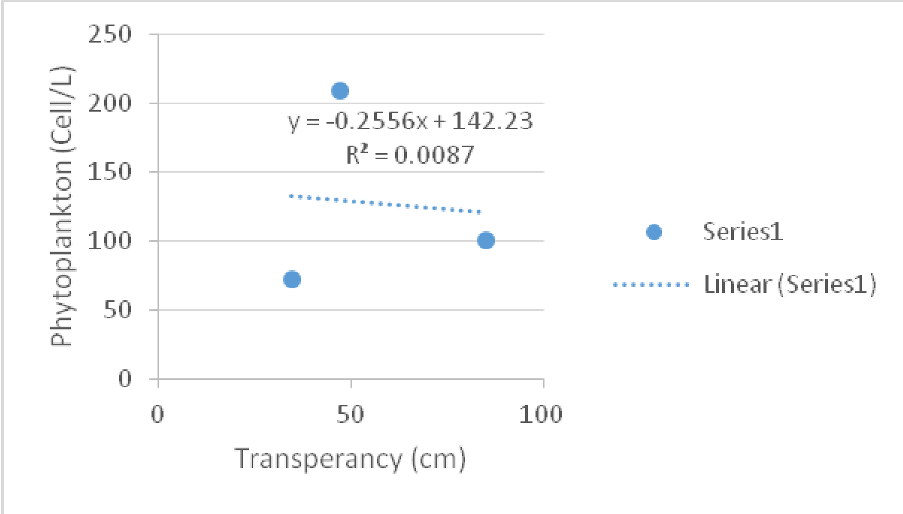
Table 5. The equation of regression relationship between biotic and abiotic components

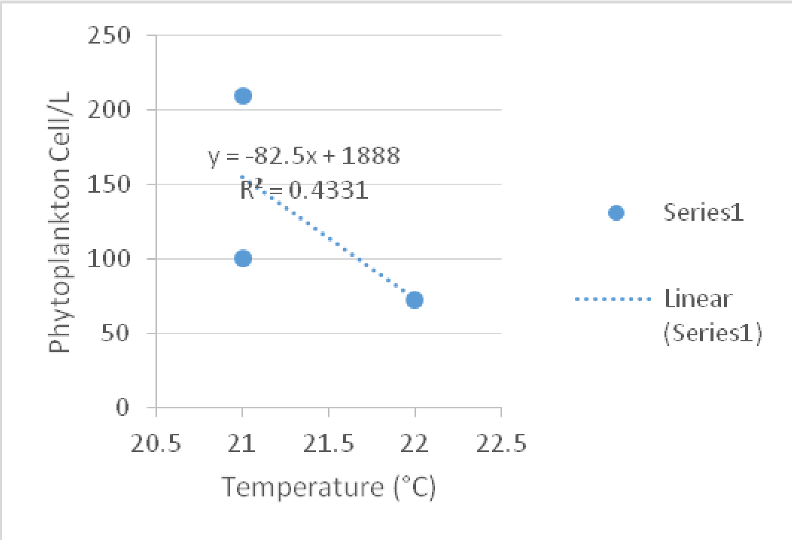
Parameter properties	Regression equations	df	$r_{calcu.}$	r_{table}		L.S
				0.01	**0.05**	
Phyto – Zoo	$y=1,1957.e^{-40,998X}$	10	0.81	0.50	0.48	**
Phyo-Trans.	$y = -0,2556.e^{142,23X}$	10	0.01	0.50	0.48	NS
Phyto-Temp.	$y = -82,5.e^{1888X}$	10	0.43	0.50	0.48	*
Phyto-PO_4	$y = -62,03.e^{155,5X}$	10	0.43	0.50	0.48	*
Phyto – pH	$y = -24,547.e^{325,52X}$	10	0.02	0.50	0.48	NS
Zoo-Trans.	$y = -1,0731.e^{201,07X}$	10	0.27	0.50	0.48	*
Zoo –Temp.	$y = -24,5.e^{664X}$	10	0.07	0.50	0.48	NS
Zoo-PO_4	$y = -18,421.e^{149,5X}$	10	0.07	0.50	0.48	NS
Zoo –pH	$y = 37,713.e^{-162,13X}$	10	0.09	0.50	0.48	NS

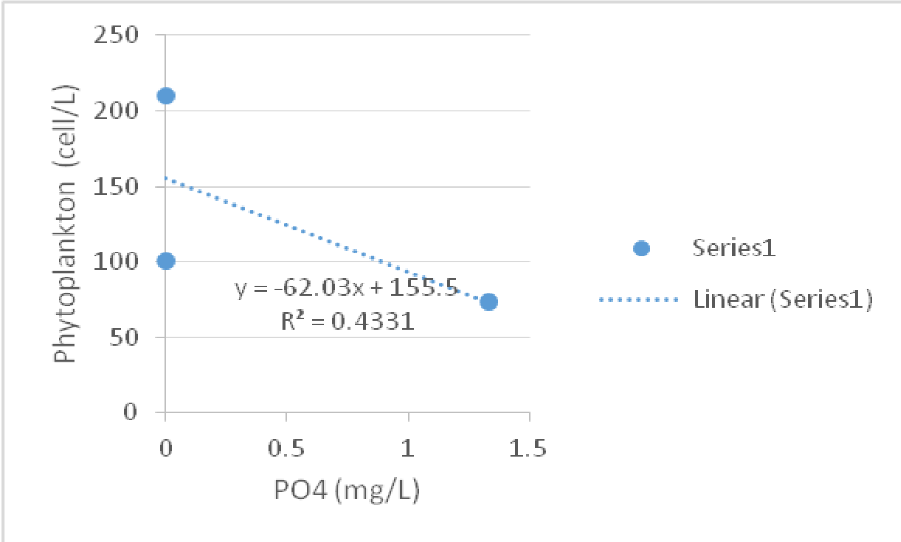
4. DISCUSSION

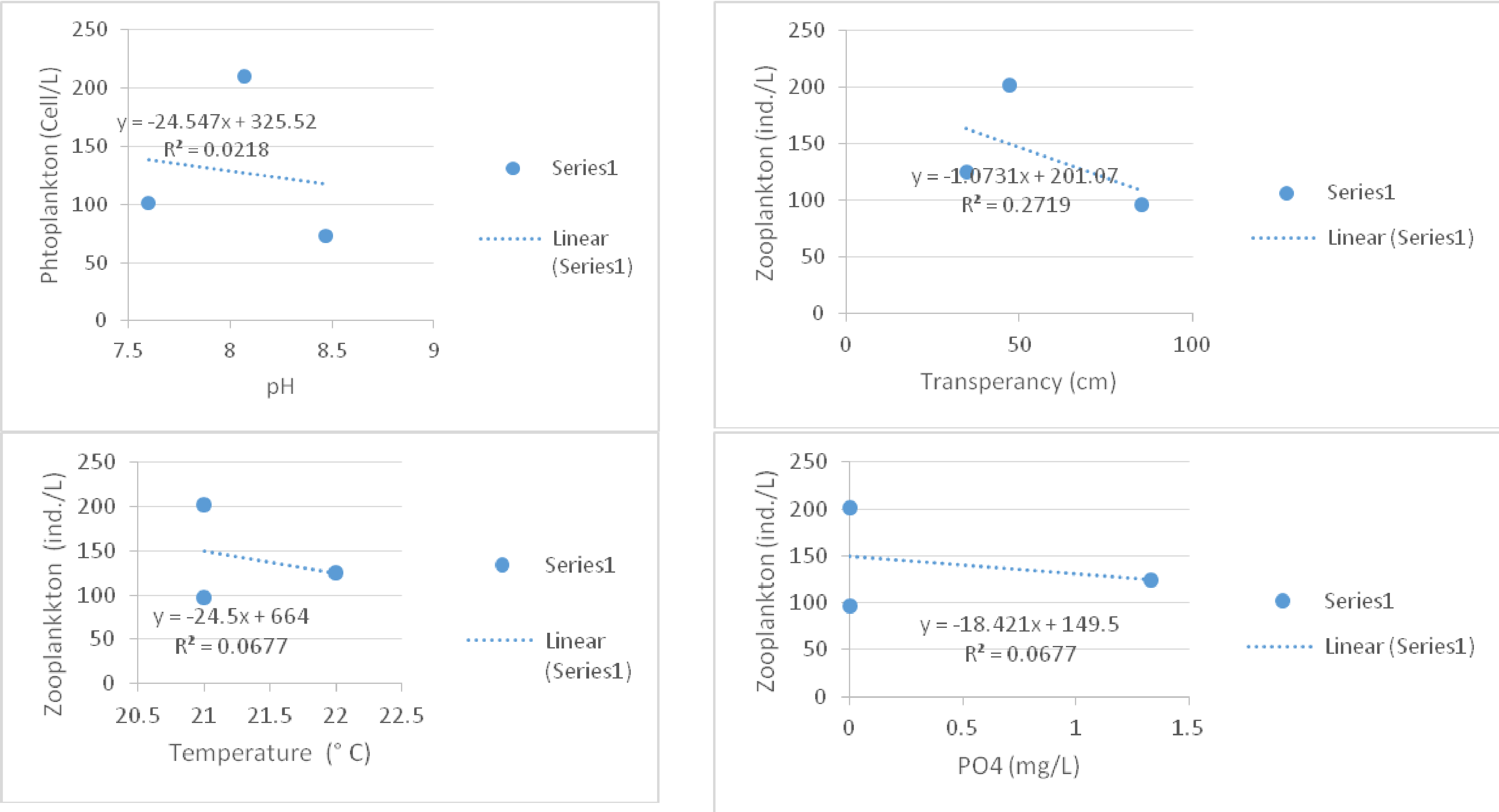
In order to define a particular freshwater body, it is important to analyze accurately as many physical and chemical characteristics of water as possible. The measurements of these characteristics provide valuable information about the aquatic environment. Some of the important physicochemical factors of the research stations (White Nile, Blue Nile and River Nile) has been analyzed and the water temperature (°C) were (22.00±1.00, 21.00±0.00, 21.00±0.00), pH (8.47±0.31, 7.6.00±0.35 and 8.07±0.12) and transparency (cm) (34.67±11.06, 85.33±4.16 and 47.00±8.54) for White Nile, Blue Nile and River Nile respectively.


250
200
150
100
50
0
0
100
200
300
Phytoplankton
Zooplankton
y = 1.1957x - 40.998
R² = 0.8068
Series1
Linear (Series1)


250
200
150
100
50
0
0
50
100
Phytoplankton (Cell/L)
Transperancy (cm)
y = -0.2556x + 142.23
R² = 0.0087
Series1
Linear (Series1)


250
200
150
100
50
0
20.5
21
21.5
22
22.5
Phytoplankton Cell/L
Temperature (°C)
y = -82.5x + 1888
R² = 0.4331
Series1
Linear (Series1)


250
200
150
100
50
0
0
0.5
1
1.5
Phytoplankton (cell/L)
PO4 (mg/L)
y = -62.03x + 155.5
R² = 0.4331
Series1
Linear (Series1)


Phtoplankton (Cell/L)
y = -24.547x + 325.52
R² = 0.0218
pH
Series1
Linear (Series1)
Zooplankton (ind./L)
y = -1.0731x + 201.07
R² = 0.2719
Transperancy (cm)
Series1
Linear (Series1)
Zooplankkton (ind./L)
y = -24.5x + 664
R² = 0.0677
Temperature (° C)
Series1
Linear (Series1)
Zooplankton (ind./L)
y = -18.421x + 149.5
R² = 0.0677
PO4 (mg/L)
Series1
Linear (Series1)

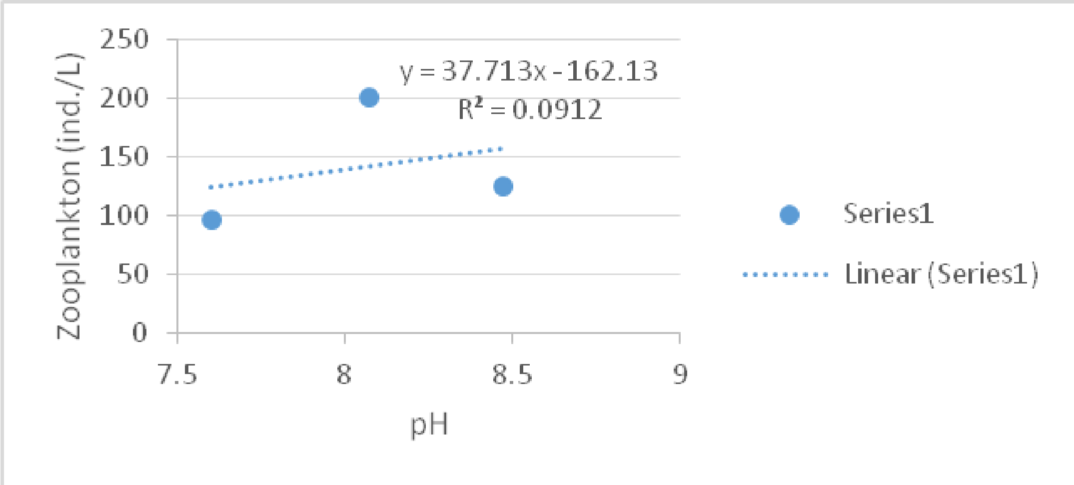


Fig. 6. Regression relationship between biotic and abiotic components

The pH of water affects the solubility of many toxic and nutritive chemicals; therefore, the availability of these substances to aquatic organisms is affected. According to (Mosley et al., 2004), water with a pH > 8.5; most metals become more soluble and more toxic with increase in acidity. A reduction in pH (increase in acidity) also results in an increase in the toxicity of cyanides and sulfides. The content of toxic forms of ammonia to the untoxic form also depends on pH dynamics.

Transparency: The involvement of light in the photosynthetic activities of all chlorophyll-bearing aquatic plants, and consequently for primary production, is a factor of fundamental significance. It frequently acts as a barrier to the spread of aquatic species, especially plankton. The transparency values are given in (Table 2 and Fig. 1) for the nine substations.

There are many sources of phosphorus addition to aquatic systems. In heavily fertilized agricultural regions, and from municipal and industrial wastes is also an important source of phosphorus precipitation, P^{+++} bound to soil particles enters aquatic systems by way of runoff and is a major source of P^{+++} to surface waters. Applications of fertilizers and certain land management practices modify and generally increase the amount of nutrients in runoff. The addition of P^{+++} to water from municipal and industrial wastes is also an important source [23]. Phosphorus is accumulating in the world's agricultural soils. A continuous aspect of intensive agriculture is that it functions with a P surplus, with more P entering the system than leaves in agricultural product [24]. Increased PO_4 inputs can have many negative effects on aquatic ecosystems including: increased biomass of phytoplankton; shifts in phytoplankton to bloom forming species such as cyanobacteria, that may be toxic or inedible; increased biomass of benthic and epiphytic algae; changes in macrophyte species composition and biomass; decreases in water transparency; oxygen depletion; and, decreases in perceived esthetic value of the water body [25]. Increased growth of algae and aquatic weeds interferes with use of the water for fisheries, recreation, industry, agriculture, and drinking.

Strong seasonal influences have an impact on the succession of phytoplankton communities, and the population gradually decreases until at all locations. The temperature variations may be to blame for this. The greater warmth and abundance of vital nutrients during the dry season may be the cause of the high biomass. Predation and grazing may have an impact on changes in the composition of plankton biomass, which makes it more difficult to evaluate the population dynamics of phytoplankton in the White Nile, Blue Nile and River Nile.

Shannon-Wiener diversity index (H’) were calculated by using the data on phytoplankton species and numerical abundance (cell number). Changes in phytoplankton cell numbers and diversity indices are shown in (Table 3). The highest values were 4.6 (in Blue Nile). It was shown that abundance of phytoplankton during the dry season in waters is negatively correlated with nutrient concentration [26,5]. This is attributed to a depletion of nutrients as these were utilized by the phytoplankton for photosynthesis increasing their population size.

Zooplankton, which is also regarded as the biological indicator of water bodies, is a useful predictor of changes in water quality because it is heavily influenced by environmental circumstances, reacts quickly to changes in environmental quality, and is strongly affected by them [27]. The population dynamics of zooplankton are influenced by elements like light intensity, food availability, dissolved oxygen, and predation [28].

5. CONCLUSION

The findings of this study revealed that phytoplankton and zooplankton could be considered as bio-indicators of water quality in several areas subjected to anthropogenic disturbance. The study showed that the physico-chemical (inputs of sewage discharge, urban and agricultural run-off) and natural parameter (rainfall) are significant sources of variation and fluctuations in densities of phytoplankton and zooplankton genera, these biota are considered suitable bio-indicators for environmental changes which may threaten the White Nile, Blue Nile and River Nile. The composition and relative abundance of phytoplankton are determined by environmental factors especially nutrients and light conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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