RELATIONSHIPS BETWEEN THE PHYSICO-CHEMICAL WATER PARAMETERS AND ZOOPLANKTON FAUNA OF TIGA LAKE, KANO, NIGERIA

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ABSTRACT
This study investigated the relationships between zooplankton fauna and physico-chemical water parameters of Tiga Lake, Kano, Nigeria from March 2009 to March 2011. Water transparency, pH, Cl^-, SO_4^{2-} and dissolved oxygen (DO) showed significant positive correlations ($p<0.05$) with species occurrence, while total solids (TS), total suspended solids (TSS), turbidity, NO_3^- and PO_4^{3-} showed significant negative correlations ($p<0.05$) with species occurrence. There were significant positive correlations ($p<0.05$) between zooplankton abundance and conductivity, total alkalinity, total dissolved solids (TDS), Ca^{2+}, Na^+ and K^+. The general chemical characteristics (pH, total alkalinity, conductivity and TDS) and major ions (Ca^{2+}, Na^+ and K^+) were all within the permissible limits for aquatic life, and they showed direct relationships with the zooplankton fauna of the lake. Physical parameters (water transparency, turbidity, TS and TSS) and nutrient content (NO_3^- and PO_4^{3-}) were considered to be limiting on the occurrence and distribution of zooplankton in Tiga Lake. The ecological relationship between zooplankton and physico-chemical parameters of the lake is an indication of its suitability for aquatic life.
Keywords: Tiga Lake; relationship; water parameters; zooplankton fauna

INTRODUCTION

Plankton are normally found in different types of aquatic environments and their occurrence and distribution are influenced by ambient physical factors such as wind, temperature, salinity, dissolved oxygen *etc* (Pilkaityte and Razinkivas, 2006). Chemical factors such as high saline levels can be stressful for all organisms, including plankton because of the coupled effects of osmotic stress and ionic stress resulting from high concentrations of ions (Marcarelli *et al.*, 2006). The metabolic rate of aquatic organisms is related to temperature and in warm waters, respiration rates increase leading to increased oxygen consumption and increased decomposition of organic matter (Chapman and Kimstach, 2006). Fish, insects, zooplankton, phytoplankton and other aquatic organisms all have optimum temperature ranges. As temperature gets too far above or below this optimum range, the number of individual species decreases until finally there are few or none (Moore, 1989; Michaud, 1991). The pH of an aquatic ecosystem is also important because it is closely linked to biological productivity (Carr and Neary, 2006). Most surface waters have a pH between 6.0 and 8.5, and values below 6.0 can be hazardous to aquatic life (Mohan and Kumar, 1998) while the optimum value is between 7.5 and 8.5 (Boyd, 1979).

Zooplankton constitute an important link in the aquatic food web through the transfer of chemical energy from the autotrophic phytoplankton to higher trophic organisms such as macroinvertebrates and fish. Their distribution, occurrence and abundance can also be used to assess the productivity of an aquatic ecosystem. Being part of the biotic community, their occurrence and abundance is closely linked to the physico-chemical water condition of the system in which they are found. This study was motivated by the need to establish an ecological relationship between the physico-chemical water condition and the biotic component of Tiga Lake, using its zooplankton fauna as an index. The physico-chemical water parameters studied included: water temperature, water transparency, turbidity, dissolved oxygen, biochemical oxygen demand (BOD_5), nitrate, phosphate, pH, conductivity, total dissolved solids (TDS), total suspended solids (TSS), total solids (TS) and total alkalinity. Others were Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^- and SO_4^{2-}.

MATERIALS AND METHODS
The Study Area

The study area was Tiga Lake, Nigeria's second largest artificial lake (based on volume) which is located some 70 km south of the ancient city of Kano. It is impounded by a large dam with a height of 48 m, crest length of 6 km and $1,974 \times 10^6$ Km^3 reservoir capacity (HASKONING, 1978). The Lake lies between longitudes $008^o18'E$ and $008^o35'E$, and latitudes $11^o18'N$ and $11^o27'N$. It is located some 70 km south of the metropolitan city of Kano.

Five sampling stations (A, B, C, D & E) were established on the Lake covering both the riverine and the lacustrine sections (Figure 1). Station A was established close to Babuha Village, at the River Kano axis of the lake. Station B was in the lacustrine section of the lake, downstream of Station A and adjacent to Bature house, Rurum village. Station C was also in the lacustrine section, downstream of both Stations B and E, but upstream of Station D (dam site). Station E was established at River Duku axis of the lake close to Yaryasa village.
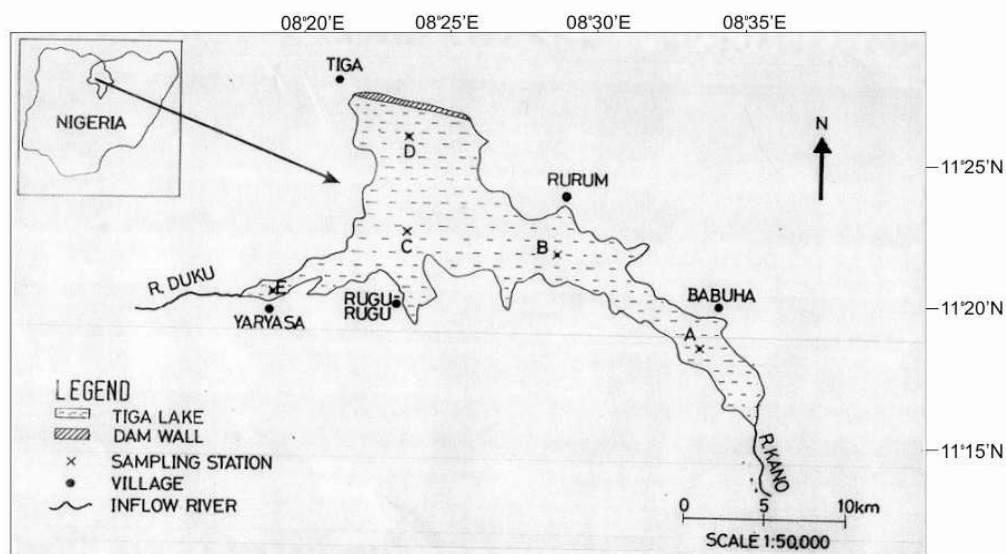
Figure 1: Tiga Lake showing the sampling stations

Sample Collection and Field Determinations
Water samples were collected on monthly basis from March 2009 to March 2011 from the limnetic zone of the lake. Water samples for physico-chemical analyses were collected in sterile plastic containers which had been rinsed with distilled water and water from the site. Water temperature, water transparency and pH were determined *in-situ* by using mercury-in-glass thermometer, calibrated Secchi disc and calibrated field pH meter (pH Testr2) respectively. Samples for dissolved oxygen analysis were also fixed *in-situ* with Winkler's reagents A ($MnSO_4$) and B (alkali iodide). BOD_5 samples were collected in dark bottles (250 ml) and kept inside a dark cupboard in the laboratory over a five-day period. Zooplankton samples were collected by filtering 20 litres of water through plankton net of 60 µm mesh size and reducing them to concentrate volume of 30 ml which were later preserved in 5 % formalin.

Laboratory Analyses
Turbidity was determined by nephelometric method using a turbidity meter at 540 nm (APHA *et al.* 1995). TS, TSS and TDS were determined by gravimetric method (APHA *et al.,* 1995), while DO and BOD_5 were determined by iodometic titration (Goltermann *et al,* 1978). Total alkalinity was determined by acid-base titration method while chloride ion was determined by Mohr titration method. Complexiometric titration method was employed in determining both calcium and magnesium ions (Goltermann *et al.,* 1978). SO_4^{2-} was determined by turbidimetric method while NO_3^- and PO_4^{3-} were determined spectrophotometrically. Flame emission spectrophotometer was used for determining Na^+ and K^+ (Goltermann *et al.,* 1978).

Zooplankton samples were examined under a calibrated Olympus 504161 compound light microscope microscope fitted with an ocular micrometer. Observed zooplankters were drawn to scale and their photomicrographs were also taken. Standard identification guides (Egborge and Chigbu, 1988; Akinbuwa, 1999; Egborge, 1994; Fernando, 2002) were used in identifying the observed zooplankton. The abundance of zooplankton was determined from the count records of the final concentrate volume in relation to their original volume of water strained through the plankton net, using the formula given below

$$A = (ad/bc) \times 1000$$

Where, A = organism/m^3 of original water
a = Number of a particular species in the counting chamber
b = Original volume of water (20 litres)
c = Total concentrate volume of water viewed (4.5ml)
d = Final concentrate volume (5ml)

Statistical Analyses
Descriptive statistics as well as regression and correlation analysis were employed in relating the physico-chemical parameters with zooplankton occurrence and abundance.

RESULTS
Zooplankton fauna
Observed zooplankton groups in this study were protozoans, rotifers, cladocerans, copepods, ostracods and insects. A total of 28, 35, 37, 40 and 32 species were recorded in Stations A, B, C, D and E respectively with abundance values of 31,482 organisms/m^3, 36,252 organisms/m^3, 38, 160 organisms/m^3, 77,220 organisms/m^3 and 181,390 organisms/m^3. The classification and composition of the observed zooplankton is given in Table 1.

Table 1: Classification and composition of zooplankton in Tiga Lake, Kano, Nigeria (March 2009-March 2011)

Phylum	Class	Order	Family	Genus/Species
Protozoa	Sarcodina	Amoebida	Amoebidae	*Amoeba radiata*
	Tubulinea	Arcellinida	Arcellinidae	*Arcella sp.*
Rotifera	Eurotatoria	Ploima	Asplanchnidae	*Asplanchna brightwelli*
				A. priodonta
			Brachionidae	*Anuraeopsis racenensis*
				Brachionus angularis
				Brachionus bennini
				Brachionus calyciflorus
				Brachionus falcatus
				Brachionus plicatilis
				Brachionus quadridentatus
				Keratella cochlearis cochlearis
				Keratella lenzi
				Keratella tropica
				Notholca sp.
			Colurellidae	*Lepadella patella*
				Lepadella ovalis
			Dicranophoridae	*Dicranophorus sp.*
				Encentrum felis
			Euchlanidae	*Euchlanis dilatata*
			Gastropodidae	*Ascomorpha sp.*
			Lecanidae	*Lecane leontina*
			Synchaetidae	*Polyarthra sp.*
			Trichocercidae	*Trichocerca cylindrica*
			Trichotriidae	*Macrochaetus collinsi*
		Flosculariacea	Filinidae	*Filinia opoliensis*
				Filinia terminalis
			Testudinellidae	*Testudinella patina*
Arthropoda	Copepoda	Cyclopoida	Cyclopidae	*Halicyclops korodiensis*
				Halicyclops troglodytes
				Eucyclops macrurus
				Microcyclops varicans
				Thermocyclops crassus
				Thermocyclops neglectus
		Calanoida	Calanoidae	*Thermodiaptamus yabensis*
	Brachiopoda	Cladocera	Bosminidae	*Bosmina longirostris*
			Chydoridae	*Camptocercus rectirostris*
				Alona holdeni
				Alona karua
				Alona pulchella
				Alona rectangula
			Daphnidae	*Scapholeberis kingi*
			Macrothricidae	*Macrothrix laticornis*
			Moiniidae	*Moina micrura*
				Moinodaphnia macleayi
			Sididae	*Diaphanosoma excisum*
	Ostracoda	Podocopida	Candonidae	*Physocypria crenulata*
			Cyprididae	*Chrissia humilis*
				Hemicypris ovata
			Enthocytheridae	*Entocythere columbia*
	Insecta	Diptera	Ceratopogonidae	Ceratopogonid sp.
			Chaoboridae	*Chaoborus sp.*
			Chironomidae	Chironomid sp.

Zooplankton Fauna in Relation to Physico-chemical Water Parameters

The mean values of the investigated physico-chemical water parameters in the five stations are given in Table 2. The relationship between each physico-chemical water parameter and zooplankton species occurrence/abundance is provided in Table 3. Water transparency, pH, sulphate, Cl⁻ and dissolved oxygen showed significant positive correlation with species occurrence. Nitrate, phosphate and three hydro-physical parameters (TS, TSS and turbidity) showed significant inverse correlations with species occurrence. Water transparency and pH showed significant correlation (p≤0.05), while TS, TSS, turbidity, Cl⁻ and PO_4^{3-} showed highly significant correlation (p≤0.01) with species occurrence. Sulphate, dissolved oxygen and nitrate showed very highly significant correlations (p≤0.001) with species occurrence.

Conductivity, total alkalinity, TDS, Ca^{2+}, Na^+ and K^+ all showed significant positive correlations with zooplankton abundance. Na^+ showed significant correlation (p ≤ 0.05) with abundance; conductivity, total alkalinity, TDS and Ca^{2+} showed highly significant correlation (p ≤ 0.01) with abundance, while K^+ alone showed very highly significant correlation (p ≤ 0.001). There were no significant inverse correlations between physico-chemical water parameters and zooplankton abundance.

Table 2: Mean Values of Physico-chemical Water Parameters in Five Selected Stations of Tiga Lake (March 2009-March 2011)

Water Parameter	Sampling Station					
	A	B	C	D	E	RSSF
Water Temp. (°C)	25.3	26.7	27.7	27.9	28.0	-
Water Transparency (m)	0.26	0.41	0.53	0.58	0.14	<30.0°C*
Turbidity (NTU)	107.9	39.1	21.2	18.6	50.8	<25 NTU**
TS (mg/L)	312	126	115	104	273	-
TSS (mg/L)	258	84	73	63	157	-
TDS (mg/L)	54	42	42	41	116	-
pH	7.07	7.28	7.31	7.41	7.34	6.0-8.5*
Conductivity (µS/cm)	94.4	74.2	73.7	73.0	209.9	<1000 µ/Scm*
Total Alkalinity (mgCaCO₃/L)	34	24	25	26	78	10-120 mg/L**
Ca^{2+} (mg/L)	8.17	6.25	6.44	6.32	13.34	<15 mg/L*
Mg^{2+} (mg/L)	2.34	1.17	1.13	1.35	0.87	1-100 mg/L*
Na^+ (mg/L)	6.24	4.06	3.99	3.91	7.07	<50 mg/L*
K^+ (mg/L)	3.02	2.51	2.57	2.52	9.09	<10 mg/L*
Cl⁻ (mg/L)	7.43	4.54	4.45	4.40	11.7	<10 mg/L*
SO_4^{2-} (mg/L)	3.66	4.83	5.11	5.75	4.05	2-80 mg/L*
DO (mg/L)	5.8	7.4	7.6	7.9	6.2	5.0-9.0 mg/L*
BOD₅ (mg/L)	2.4	2.2	2.4	2.4	3.3	3.0-6.0 mg/L*
PO_4^{3-} (mg/L)	0.29	0.18	0.18	0.18	0.21	0.1 mg/L**
NO_3^- (mg/L)	1.33	0.61	0.51	0.39	0.77	5 mg/L NO_3^-N *

Source: * Chapman and Kimstach, 2006; ** Moore, 1989 and Michaud, 1991
Key: RSSF = Recommended Standard for Surface Freshwaters

Table 3: Relationship between Physico-chemical Parameters and Zooplankton Fauna of Tiga Lake (March 2009-March 2011)

Parameter (n= 5)	Species occurrence		Zooplankton abundance	
	Cc (r)	Regression equation	Cc (r)	Regression equation
Water temp. (°C)	0.7149	Y= 1.2489-73.859x	0.5894	Y=58.875-1519.3x
Water transp. (m)	0.8433*	Y= 24.845+24.852x	-0.5917	Y=217.35x-366.25
TS (mg/L)	-0.9320**	Y= 43.138x-0.0470	0.3562	Y=0.6925-52.207x
TSS (mg/L)	-0.9482**	Y= 41.518x-0.0562	0.0617	Y=0.8290-28.324x
Turbidity (NTU)	-0.9411**	Y= 40.454x-0.1274	-0.1006	Y=165.85x-1.878
pH	0.8479*	Y= 35.541-224.37x	0.4405	Y=523.92-3738.2x
Conductivity (µS/cm)	-0.4225	Y= 42.587x-0.0779	0.9337**	Y=1.1481-44.083x
Total alkalinity (mgCaCO₃/L)	-0.4322	Y= 41.822x-0.1982	0.9321**	Y=2.9225-32.813x
TDS (mg/L)	-0.4283	Y= 42.942x-0.1437	0.9321**	Y=2.1183-49.325x
Calcium (mg/L)	-0.5144	Y=46.801x-1.5251	0.8960**	Y=22.482-106.22x
Magnesium (mg/L)	-0.5598	Y=45.582x-8.1483	-0.5444	Y=241.43x-120.12
Sodium (mg/L)	-0.6623	Y=45.911x-2.1243	0.8020*	Y=31.316-93.096x
Potassium (mg/L)	-0.3539	Y=40.686x-1.2286	0.9531***	Y=18.111-16.068x
Chloride (mg/L)	0.9152**	Y=53.189x-3.5674	-0.0239	Y=353.58x-52.589
Sulphate (mg/L)	0.9886***	Y=5.5284+8.5347x	-0.2178	Y=457.9x-81.497
DO (mg/L)	0.9591***	Y=4.93+0.0671x	-0.3207	Y=582.72x-72.676
BOD₅ (mg/L)	-0.2948	Y=62.179x-10.952	0.2268	Y=293.49-642.46x
Nitrate (mg/L)	-0.9560***	Y=43.382x-12.375	-0.0990	Y=209x-182.43
Phosphate (mg/L)	-0.9328**	Y=67.326x-166.61	0.0282	Y=2456.1x-408.78

*Significant, p ≤0.05, r= 0.7545, **Highly significant, p≤0.01, r= 0.8745, ***Very highly significant, p≤0.001, r=0.9507, Cc = Correlation coefficient

DISCUSSION

Hydro-physical parameters (water transparency, TS, TSS and turbidity) played a major role in the occurrence of zooplankton species in Tiga Lake during the study period. Water transparency was found to have a direct relationship with zooplankton species occurrence in the lake. High water transparency increases the euphotic zone in an aquatic ecosystem which in turn favours phytoplankton growth and primary productivity. Any factor that enhances the production of phytoplankton is most likely going to enhance the production of zooplankton also, since the latter are nutritionally dependent on the former. Transparency however showed an indirect relationship ($p > 0.05$) with abundance of zooplankton, an account similarly given in the Imo River estuary (Atoma, 2004) and in Onah Lake, Nigeria (Olele and Ekelemu, 2008).

Biological productivity in tropical lakes is mainly limited by the introduction of highly turbid waters and wind-induced turbulence during the wet season (Carr and Neary, 2006). This may be the reason for the inverse relationships that existed between turbidity, TS, TSS and zooplankton species occurrence. Turbidity and TSS are inter-related and they are both capable of extinguishing incident solar radiation in a lake, thereby affecting the phytoplankton primary production and by extension, the zooplankton secondary production. The mean values of turbidity in three out of the five stations were for instance beyond the maximum value of 25 NTU recommended for aquatic life (Moore, 1989; Michaud, 1991).

The pH values of the lake showed positive correlation with zooplankton occurrence. This was probably because the recorded pH values (6.60-7.83) were within the recommended range (6.0-9.0) for aquatic life (Chapman and Kimstach, 2006). pH values outside this range could negatively affect the distribution of zooplankton in the lake.

Total alkalinity, conductivity, TDS, Ca^{2+}, Na^+, K^+ and SO_4^{2-} all had direct relationships with either abundance or occurrence of zooplankton in the lake, while Cl^- showed inverse relationship. This implies that dissolved salts and minerals are necessary components of good quality water as they help maintain the health and vitality of aquatic organisms that rely on this ecosystem service (Stark *et al.*, 2000). The direct relationships may also be supported by the fact that the mean values of alkalinity exceeded the minimum value of 24 $mgCaCO_3L^{-1}$ recommended for aquatic life, while Ca^{2+}, Na^+ and K^+ did not exceed their recommended limits for aquatic life (<15.0 mgL^{-1}, <50.0 mgL^{-1} and <10.0 mgL^{-1} respectively) (Chapman and Kimstach, 2006). Changes in the ionic composition of water can exclude some species while promoting the population growth of others (Weber-Scannell and Duffy, 2007). This was the probable reason for the direct relationships between zooplankton abundance and various ions (Ca^{2+}, Na^+, K^+ and HCO_3^-) in the lake in spite of the inverse relationship between species occurrence and Cl^-. Chloride ion is one of the major ions that determine the salinity of water body. Its inverse relationship with species occurrence is further supported by the fact

that the diversity of aquatic species declines as osmotic tolerances are exceeded with increasing salinity (Derry *et al.,* 2003). Increases in salinity also cause shifts in biotic communities, limit biodiversity, exclude less-tolerant species and cause acute effects at specific life stages (Weber-Scannell and Duffy, 2007). Magnesium, sodium, potassium and calcium concentrations tend to be influenced by metabolic activities of aquatic organisms and can exhibit marked seasonal and spatial dynamics as a result of biological activity. Chloride concentrations can also be influenced by biological activity, while SO_4^{2-} and HCO_3^- can be driven by production and respiration cycles of the aquatic biota (Wetzel, 2001). These ions have also been reported as being responsible for salinity in a body of water. The level of salinity in aquatic systems is important to aquatic plants and animals as species can survive only within certain salinity ranges (Friedl *et al.*, 2004). The significant positive correlations recorded between zooplankton species occurrence/abundance with Ca^{2+}, Na^+, K^+, HCO_3^-, Cl^- and SO_4^{2-} in this study are further justified by the fact that the ions were within their preferred ranges for freshwater life.

Zooplankton communities respond to a wide variety of disturbances including nutrient loading (Dodson, 1992), and this was evident in the inverse relationships of NO_3^- and PO_4^{3-} with species occurrence. Nutrient compounds in the lake showed the same pattern as the hydro-physical parameters in their relationship with species occurrence. This implies that the concentrations of nutrient compounds were largely determined by the hydro-physical parameters which could in turn have been determined by allochthonous run-off and re-suspended autochthonous sediments in the rainy season. Nutrient compounds are expected to stimulate phytoplankton growth and by extension zooplankton growth, but their positive impacts could have been far outweighed by the high concentrations of hydro-physical parameters which are capable of limiting the euphotic zone, hence the inverse relationships between nutrient compounds and zooplankton species occurrence.

CONCLUSION AND RECOMMENDATION

This study has revealed that zooplankton fauna of Tiga Lake is limited by hydro-physical (turbidity, total solids and total suspended solids) and nutrient (NO_3^- and PO_4^{3-}) parameters, but enhanced by the general chemical characteristics (total dissolved solids, total alkalinity and conductivity) and major ions (Ca^{2+}, Na^+, K^+ and HCO_3^-). The ecological relationships found between zooplankton fauna and physico-chemical water condition of Tiga Lake indicated that the water body is suitable for aquatic life. Its productivity however seems to be threatened by high concentration of suspended solids, especially in the riverine section.

This study has also revealed that Tiga Lake has not been largely impacted by human activities and is under the close watch of the River Basin Development Authority.

It is however important to closely monitor the basin from its inflows in order to slow down the aging process of the entire lake. This lake as well as other inland water bodies in Nigeria should also be accorded the same attention as other nature protected areas like national parks, in order to conserve our freshwater biological resources.

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