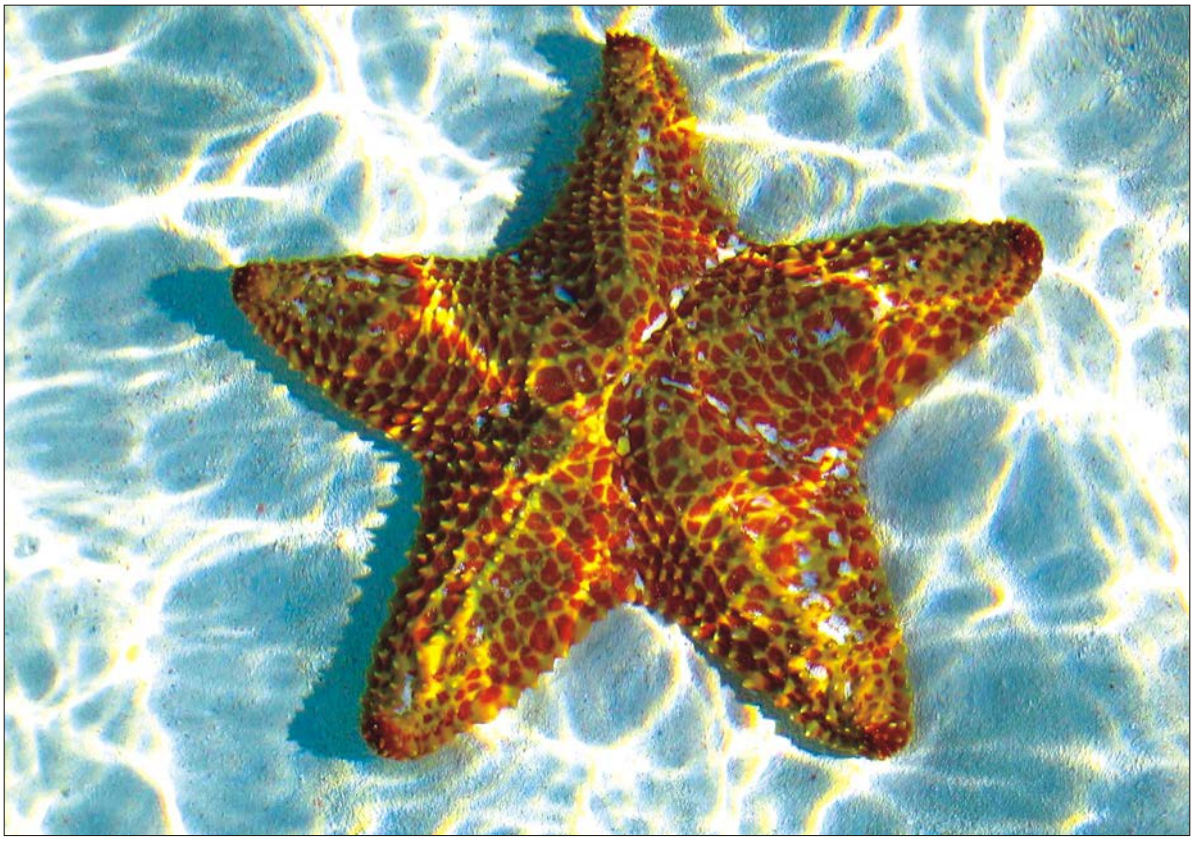

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Research Article
Assessment of the Effect of Anthropogenic Activities on Aquatic Life in Ugbo-Aiyetoro Water-way, Southwestern Nigeria

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Abstract

Background and Objective: The health of a water body is hindered by anthropogenic activities which lead to excess nutrient loading; invariably changing the physicochemical properties of the water. This study investigated the effect of eutrophication on the biodiversity of phytoplanktons and zooplanktons in Ilaje community, Ondo coastal region located in the South-western region of Nigeria in May, 2016. **Materials and Methods:** The physicochemical parameters and nutrient loading of the water were determined at eight pre-established sampling stations (M1-M8) of approximately 200 m equidistance. A 63 μm mesh plankton net was used to isolate planktons at each sample station. Shannon-Weiner index analysis was done to understand specie evenness and diversity. **Results:** The physicochemical parameters determined include temperature (30.08-3.89°C), pH (6.26-7.2), dissolved oxygen (DO, 3.26-4.26 mg L^{-1}), turbidity (18-60 NTU), conductivity (764-4397 μS cm^{-1}), phosphate (0.11-1.17 mg L^{-1}) nitrate (17.0797-46.6954 mg L^{-1}), sulphate (36.6-247.1 mg L^{-1}), salinity (0.37-2.25 ppt), depth ranges between (1.0-1.8 m), respectively. Eighty eight organisms were identified. Some of the organisms identified include *Prorocentrum micans* (phytoplankton), *Cyclopoid copepod* (zooplankton) and *Haematococcus* spp. (phytoplankton). On aggregate, sample stations M2 and M4 had the highest (14) and lowest (2) numbers of organisms per mL of water, respectively. The correlation analysis of nutrients against phytoplanktons and zooplanktons were weakly negative and weakly positive, respectively. **Conclusion:** Results implies that the environment is within the mesotrophic range of pollution. The assessment of Ugbo waterway supports the generalization that light intensity and nutrient are crucial to phytoplankton growth in this region. Conclusively, the diversity index of the study area shows that the environment was moderate to less diverse, hence, it is slight to moderately polluted.

Key words: Eutrophication, biodiversity, phytoplankton, zooplankton, species diversity, specie evenness

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

By definition, marine pollution is the introduction (directly or indirectly) of substances or energy into the marine environment by man (GESAMP)[1]. This results in deleterious effects such as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities, GESAMP[1]. All forms of pollution pose serious threat to biodiversity but in particular nutrient loading (primarily of nitrogen and phosphorus) which is a major, increasing cause of biodiversity loss and ecosystem dysfunction, European Union[2]. In many coastal waters, light attenuation by suspended sediments confines the photic zone to a small fraction of the water column, such that light limitation is a major control on phytoplankton production and invariably, mixing rate.

The coastal area is strongly influenced by the anthropogenic activities within its vicinity. Water eutrophication is one of the most profound challenges in the world[3]. The need to evaluate and monitor water quality cannot be overemphasized. The mechanisms of water eutrophication are not fully understood but excessive nutrient loading into surface water system is considered as one of the major factors, Fang *et al.*[4]. The nutrient level of many lakes and rivers has increased dramatically over the past 50 years in response to increased discharge of domestic wastes and non-point pollution from agricultural practices and urban development, Mainstone and Parr[5]. For more than 30 years, nutrient enrichment, especially phosphorus (P) and nitrogen (N), has been considered as a major threat to the health of coastal marine waters, Andersen *et al.*[6]. Eutrophication causes a body of water to lose its primary functions, invariably affecting sustainable development of economy and society[7]. Coastal regions throughout the world are affected by eutrophication. In ecology, primary production helps indicate eutrophication and the synthesis of organic compounds from atmospheric or aqueous carbon dioxide, Ghosal *et al.*[8].

The problem posed by eutrophication is usually addressed scientifically[9]. This is so because it inhibits primary productivity which principally occurs through photosynthesis. Also, it occurs through chemosynthesis, a phenomenon whereby oxidation or reduction of inorganic chemical compounds serves as source of energy. Since almost all life forms depend on primary productivity (either directly or indirectly), there is a pressing need to curb activities that initiate or propagate eutrophication. In addition, phosphorus from atmospheric deposition and domestic wastes represents a major threat to Ugbo inland water[10]. It has caused an imbalance in biodiversity, resulting in a challenge for the conservation of natural habitats and species in some areas. Therefore, this research was carried out to access the effect of nutrient loading on a body of water in Ondo coastal region of Ilaje and to show how this affects the biodiversity of organisms in the body of water. Since biodiversity is an important key to the health of a water body, we investigated some limiting parameters to eutrophication in an environment.

There is paucity of study regarding pollution in the study area, a development that underscores the need for this research. However, several publications exist for pollution studies for similar environments.

The plants striving in Cauvery river and its tributaries at Arasalar (Kumbakonam area) were examined by Annalakshmi and Amsath[11]. They carried out studies on the use of phytoplanktons as 'index organisms' in biomonitoring. Their investigation underscored the need to assess the quality of river waters. They assessed two plant species: *Chlorophyceae* and *Cyanophyceae* for their composition, occurrence and diversity, abundance and frequency. They concluded that the Cauvery river is one of the most useful riverine systems of Tamil Nadu as an indicator for pollution in the area. Their findings showed that some algal species are forbearing to organic pollution in Kumbakonam area. In the Cauvery river and its tributaries, Arasalar (which is contaminated downstream) shows large quantity of this taxa. Their presence in the polluted habitats puts forward their possible utilization as "bio-indicators".

Chakrapani *et al.*[12] compared the zooplankton diversity with the physicochemical analysis of urban and non-urban lakes. For this purpose, they selected two sampling points and analysis was carried in two seasons (winter and summer). The obtained values of the various parameters, were compared against WHO standards. It was observed that the standard limits prescribed by the significant authorities (such as WHO) had been breached, severally. They found the water unfit for household consumption and aquatic life. He reported a higher density of zooplankton during the rainy season, with copepods forming the dominant group followed by *Cladocera*, *Rotifera* and *Ostracoda*. Five species of *Rotifera*, four species of *cladocera* and three species each of *ostracoda* and *copepod* were recorded. The *Ostracods*, though tolerate wide range of ecological factors, were abstent in polluted waters. The lower density of zooplankton that occur during

the summer months than in the rainy months was attributed to higher temperature, decrease in the nutrients, leading to a drop in the phytoplankton population. The samples were dominated by *Rotifera*, followed by *cladocera* and *copepoda*. *Rotifera* showed a negative correlation with pH, dissolved oxygen and transparency and *copepods* showed negative correlation with water temperature, nitrate and phosphate. The *cladocerans* also revealed negative correlation with pH, transparency and phosphate. This implies that several abiotic factors exert a considerable influence on the zooplankton abundance and point at phytoplanktons being the best organisms to use as indices for polluted water. However, the presence of certain species of zooplanktons could also reflect the health of that environment.

Mahajan[13] made preliminary studies of the identification of species among the zooplankton community, which could serve as indicators of different types of pollution. Species of zooplankton which are indicators of thermal pollution and stress pollution, eutrophication, heavy metal pollution, pesticidal pollution and miscellaneous pollution activities were studied. Toxicity tests conducted for the selected species indicate, different groups of zooplankton were found to be sensitive to different types of pollutants.

Sunkad and Patil[14] assessed the water quality of Fort lake Belgaum, Karnataka. Zooplanktons were represented by four groups, which include *Rotifers*, *Cladocerans*, *Copepods* and *Ostracods. Rotiferas* were found to contribute to the zooplankton richness of the Fort Lake accounting 52.38% followed by copepoda 26.5%, *Cladocerans* 16.45% and *Ostracods* 4.67%. The dominance of *Rotifers* in the lake was due to the continuous supply of food material which in turn indicates the eutrophic nature of the lake. The level of phosphates in the lake was high (7.2-13.6 mg L^{-1}) due to the entry of sewage into the lake and hence supported the cause of eutrophication.

MATERIALS AND METHODS

This study was conducted in March, 2016. The study area lies between latitude 6.11536°N and longitude 4.78810°E. About 1000 people live in hamlets arranged linearly along the banks of the estuary. The Ugbo estuary is a linear water system with an average depth of 1.6 m. Its abundant natural resources are the primary source of livelihood for people in the area (i.e., fishing). Some areas along the estuary are also cordoned off by villagers to raise fingerlings. Through their daily practices, water hyacinth is introduced to the cordoned area so fingerlings from the wild could strive. This is done with the intent of harvesting when mature.

A 2000-horse powered boat was used to tug the plankton net while a Hanna multi-parameter auto water analyzer equipped with an in-built Global Positioning System (GPS) was used for simultaneous chemical data collection and coordinates determination. A Furuno 6 single beam echo sounder (model LS-6100 dual frequency 50 and 200 kHz) with pole-mounted transducer used for depth measurement. Data collection was done on the 23rd of March, 2016 which corresponds to the onset of the rainy season. *In-situ* physicochemical analysis and data sampling were taken between 4:30-5:45 pm when traffic along the estuary was low this was done in order to ensure minimal mixing during sampling. The *in-situ* physicochemical parameters were measured (using Hana hand held water analyzer) include temperature, salinity, pH, total dissolved solid (TDS), dissolved oxygen (DO), resistivity, surface pressure and electrical conductivity (EC) was done for each sample station along a pre-determined profile (Fig. 1).

One litre, white organic plastic bottles were labelled and filled with water samples taken at each station and stored in a cold box to reduce spontaneous reactions. The samples were collected for nutrient analysis, turbidity measurements, anions and cations. After collection the water samples were preserved using 3 drops of H_2SO_4 and transferred to a refrigerator to ensure the nutrients of interest were fixed in the water samples.

A plankton net of mesh size 0.65 µm was rinsed in fresh water a used the skim the water surface around each sample station. The residue collected in the stopper is then emptied into a labelled amber bottle and 2 drops of 4% ethanol is then added. Identification of the sampled organisms was done by making reference to standard books, Ward and Wipple[15]. Calcium and magnesium were measured using Buck Scientific Atomic Absorption Spectrophotometer Model 210 VGP. Sodium and potassium were determined using Atomic flame photometer PfP7. Nitrate, phosphate and chloride were determined using Shimadzu 1800 UV spectrophotometer. The sample stations occupied were georeferenced to produce the profile map of the area showing the sampling stations (Fig. 1) using ordinary point kriging algorithm, which produces exact data interpolations.

The biological samples collected were concentrated in 100 mL using 63 µm mesh sieve. The sample was then allowed to settle. Samples were later decanted so as to concentrate the sample, 1 mL was used in a Sedgwick-Rafter Cell, of which

Fig. 1: A georeferenced Google earth map showing the sample stations in the study area. Note sediment plumes usually laden with leached nutrients and effluents

Table 1: *In-situ* physico-chemical parameters of all sample stations

Locations	Temperature (°C)	TDS (mg L^{-1})	Salinity (%)	DO (mg L^{-1})	pH	Conductivity (µS cm^{-1})	Depth (M)
M1	31.20	393	0.39	3.95	7.20	817	1.8
M2	30.96	383	0.37	3.94	6.83	765	1.3
M3	30.72	385	0.37	3.93	6.61	764	1.2
M4	30.56	396	0.38	3.55	6.51	803	1.8
M5	30.29	444	0.43	4.26	6.43	889	2.2
M6	30.51	402	0.38	3.30	6.41	822	1.7
M7	30.08	402	0.39	3.43	6.26	803	1.7
M8	31.89	2156	2.25	3.26	6.34	4397	1.0
	*0-30°C	*1000 mg L^{-1}		*4.0 mg L^{-1}	*6.5-9.5		

DO: Dissolved oxygen, TDS: Total dissolved solids

microscopic cells were captured using a camera. The camera was mounted on a microscope and used to identify major species according to Wetzel and Likens[16]. Identification and counting was made based on a key guideline of Yamaguchi and Gould[17] and Blomqvist and Olsen[18] and abundance of each species of phytoplankton was calculated based on Shannon wiener index of diversity and evenness.

Statistical analysis: The number of isolated organisms per mL of sample/station was subjected to statistical analysis in order to calculate the Shannon-Wiener index (H'). A correlation plot phytoplankton and zooplanktons against nutrient was done using SPSS (Statistical package for social sciences) software version 19.0 (released 2010)[19]. For all correlations by default were run at the 5% significance level. Plots of specie distribution, diversity, evenness were presented using Microsoft excel, 2017.

RESULTS

Eight sample stations (M1-M8) were chosen for this study. The physico-chemical parameters measured *in-situ* are shown in Table 1. All sample stations M1 to M8 exceed World Health Organization (WHO) limits for estuaries for temperature (°C). Station M8 exceeds WHO limits for total dissolved solids (TDS mg L^{-1}). Station M5 exceeds WHO limits for dissolved oxygen (DO mg L^{-1}) and all sample stations fall in range for pH.

The water way is deepest at M5 2.2 metres (m) and shallowest at M8 1.0 m with an average thickness of 1.6 m. The trend shown by TDS and conductivity, salinity conforms with existing principle of proportionality (Table 1).

Anion and cation analysis (Table 2) showed nitrate, potash and turbidity exceeds WHO limits across all sample stations is in excess for all stations. Sulphate is in excess at

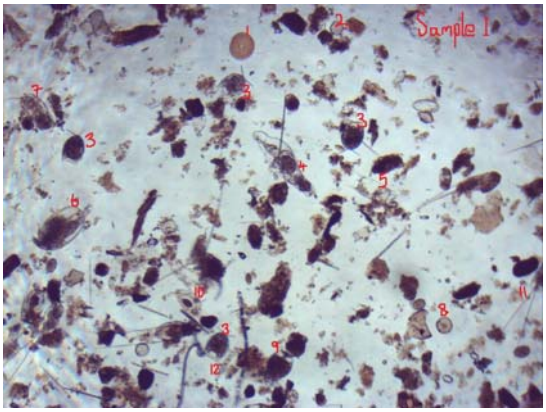

Fig. 2: Organisms captured at location M1 mL^{-1} of water, 1: *Coscinodiscus* sp., 2: *Hemidiscus cuneiformis*, 3: *Haematococcus* sp., 4: *Chlorogonium* sp., 5: *Odontella* sp. (Zooplankton), 6: *Copepod* sp. (Zooplankton), 7: *Ochromonas* sp. (*Chrysophyceae* {Golden-brown algae}), 8: *Coscinodiscus* sp., 9: *Dinophysis fortii*, 10: *Cryptomonas* sp., 11: *Ditylum brightwelli* and 12: *Leptocylindricus danicus*

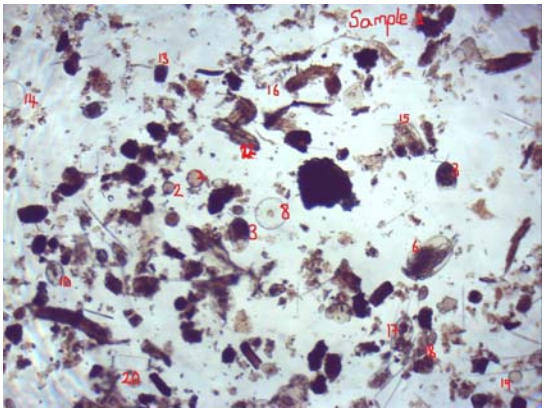

Fig. 3: Organisms captured at location M2 mL^{-1} of water, 10: *Cryptomonas* sp., 13: *Pavlova* sp., 14: *Thallassiosira subtilis*, 15: *Cryptochrysis fulva*, 16: *Calanoid copepod* (Zooplankton), 17: *Noctiluca miliaris*, 18: *Ditylum brightwelli*, 19: *Coscinodiscus stellari*, 22: *Bacillaria* sp. 2: *Hemidiscus cuneiformis*, 3: *Haematococcus* sp., 8: *Coscinodiscus* sp., 6: *Copepod* sp. (Zooplankton) and 20: *Ditylum brightwelli*

station M8 while all other stations fall within the permissible limits of WHO. All sample stations with the exception of M6 and M7 exceed the WHO limits for phosphate. For chloride, only station M3 falls within permissible range. Stations M1, M5 and M8 has excess sodium by WHO standards. The trend

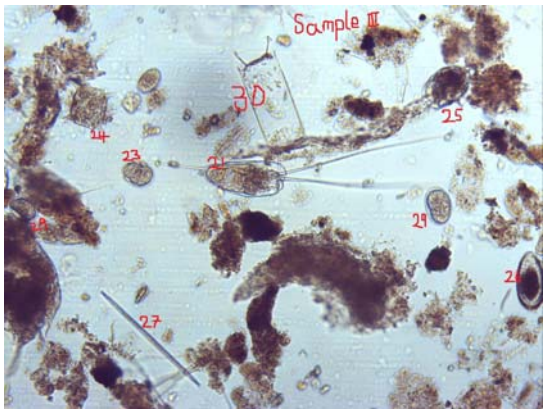

Fig. 4: Organisms captured at location M3 mL^{-1} of water, 21: *Chlorogonium* sp., 24: *Protoperidinium pyriforme*, 23: *Protoperidinium conicoides*, 27: *Pseudo-nitzschia pungens*, 25: *Dinophysis fortii*, 30: *Rhizosolenia* sp. and29: *Hemidiscus cuneiformis*

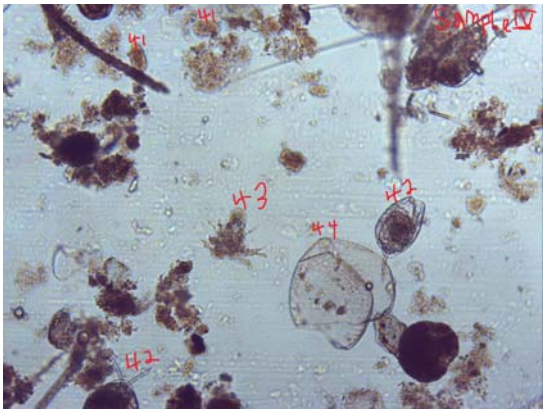

Fig. 5: Organisms captured at location M4 mL^{-1} of water, 41: *Protoperidinium conicoides*, 42: *Prorocentrum micans*, 43: *Copepod naupulius* (cyclops spp.) (zooplankton) and 44: *Leptocylindricus danicus*

shown in turbidity values across sample locations corresponds with that of TDS. The anion values also corroborate salinity values (Table 1).

Eighty eight organisms were identified from the sampled water (Table 3, Fig. 2-9). Sample station M2 has the highest number of organisms per mL of water, M4 has the lowest (3). Some of the organisms identified include *Calanoid copepod* (zooplankton), *Protoperidinium conicoides* (phytoplankton), *Prorocentrum micans* (phytoplankton), *Cyclopoid copepod* (zooplankton) and *Haematococcus* spp. (phytoplankton). Some organisms were found common to more than one sample station e.g., *Haematococcus* spp.

Table 2: Various nutrients, anions and cations analyzed for all sample stations

Locations	NO^{-}_{3} (mg L^{-1})	SO^{-}_{4} (mg L^{-1})	PO^{-}_{4} (mg L^{-1})	Na^{2+} (mg L^{-1})	K^{+1} (mg L^{-1})	Cl^{-1} (mg L^{-1})	HCO_{3}^{-} (mg L^{-1})	Turbidity
M1	17.24138	38.20690	8.974359	207	12	227.9293	11396.47	24.0
M2	17.09770	47.31034	7.692308	192	14	209.9349	10496.75	11.1
M3	43.39080	43.72414	8.974359	187	12	191.9405	9597.024	18.0
M4	46.69540	36.55172	5.128205	180	15	210.9346	10546.73	37.1
M5	31.60920	42.48276	7.692308	202	19	233.9275	11696.37	59.8
M6	23.13218	36.82759	2.564103	196	17	237.9262	11896.31	46.0
M7	39.94253	34.75862	2.564103	190	17	215.9330	10796.65	44.5
M8	38.07471	247.17240	6.410256	458	82	7597.6440	9497055	60.0
	*10	*100	*5.0	*200	*10	*200		*5 NTU

*WHO standard

Table 3: Summary of identified phytoplanktons and zooplanktons for all sample stations

Species	M1	M2	M3	M4	M5	M6	M7	M8	Total
Coscinodiscus sp. (phytoplankton)	**	*							3
Hemidiscus cuneiformis (phytoplankton)	*	**	*						4
Haematococcus sp. (phytoplankton)	****	**							6
Chlorogonium spp. (phytoplankton)	*		*						2
Odontella sp. (Zooplankton)	*								1
Copepod sp. (Zooplankton)	*	*							2
Ochromonas sp. (*Chrysophyceae* {Golden-brown algae}	*								1
Dinophysis fortii (phytoplankton)	*		*						2
Cryptomonas sp. (phytoplankton)	*	*							2
Ditylum brightwelli (phytoplankton)	*	*				*			3
Leptocylindricus danicus sp. (phytoplankton)	*								1
Pavlova sp. (phytoplankton)		*							1
Thallassiosira subtilis (phytoplankton)		*							1
Cryptochrysis fulva (phytoplankton)		*							1
Calanoid copepod (Zooplankton)		*			**	*	*		5
Noctiluca miliaris (Zooplankton)		*							1
Coscinodiscus stellaris (phytoplankton)		*							1
Bacillaria sp. (phytoplankton)		*							1
Cryptomonas sp. (phytoplankton)		*							1
Brachionus falcatus sp. (Zooplankton)			*						1
Protoperidinium pyriforme (phytoplankton)			*						1
Pseudo-nitzschia Pungens (phytoplankton)			*						1
Rhizosolenia sp.			*						1
Copepod naupulius (Zooplankton)				*					1
Protoperidinium conicoides (phytoplankton)			*	**					3
Pseudo-Nitzschia australis (phytoplankton)					*				1
Proboscia alata (phytoplankton)					*				1
Prorocentrum micans (phytoplankton)				**	*				3
Protoperidinium excetricum (phytoplankton)					*				1
Nitzschia sp. (phytoplankton)					*				1
Cyclopoid copepod (Zooplankton)					*		**		3
Pseudo-nitzschia delicatissima (phytoplankton)					*				1
Licmophora ehrebergii (phytoplankton)						*			1
Rotifer (Zooplankton)						*	*		2
Eucampia zoodiacus (phytoplankton)						*			1
Coscinodiscus granii (phytoplankton)							*		1
Melosira cf. *spaerica* (phytoplankton)							*		1
Dinophysis rotundata (phytoplankton)							*		1
Chaetoceros sp. (phytoplankton)							*		1
Amphora liniolata (phytoplankton)							*		1
Harpacticoid copepod (Zooplankton)							*		1
Crustacean cypris larvae (Zooplankton)								*	1
Zoea larva of an *Anomuran* Crab (Zooplankton)								**	2
Crustacean nauplius larvae (Zooplankton)								*	1
Biddulphia mobiliensis (phytoplankton)								*	1
Rhizosolenia sp. (Zooplankton)								*	1
Brachionus plicatitlis (Zooplankton)								**	2
Stephanopyxis sp. (phytoplankton)								*	1
Early Fish embryo (Zooplankton)								*	1
Number of planktons	15	16	8	5	9	5	10	10	78

M1-M8 denotes various sample stations

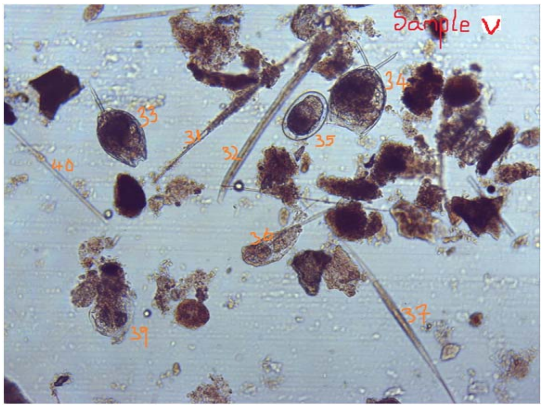

Fig. 6: Organisms captured at location M5 mL^{-1} of water, 31: *Pseudo-Nitzschia australis*, 32: *Proboscia alata*, 33: *Prorocentrum micans*, 34: *Calanoid copepod* (Zooplankton), 35: *Protoperidinium excentricum*, 37: *Nitzschia* sp., 36: *Cyclopoid copepod* (Zooplankton), 39: *Calanoid copepod* (Zooplankton) and 40: *Pseudo-nitzschia delicatissima*

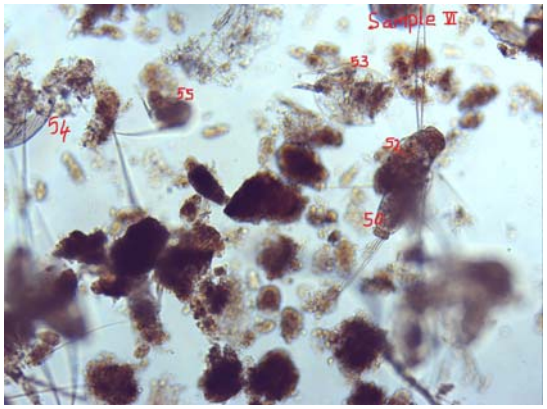

Fig. 7: Organisms captured at location M6 mL^{-1} of water, 50: *Ditylum brightwelli*, 52: *Licmophora ehrenbergii*, 53: *Rotifera* (Zooplankton), 54: *Calanoid copepod* (Zooplankton) and 55: *Eucampia zoodiacus*

(6 stations) while others were found in only one station e.g., *Stephanopyxis* sp. (Fig. 2-9).

The number of organisms per mL of water was counted for all sample stations. The M8 has the highest zooplankton count per mL of water (8) and M1 and M2 has the highest number of phytoplankton per mL of water (13) (Fig. 10, 11). Species diversity is highest at M2 while specie evenness is highest at M2 (Table 4). The Shannon diversity index (SDI) is used to indicate pollution level in an environment based on comparisons with a standard range. It shows moderate diversity level for all sample stations except M4 and M6 which

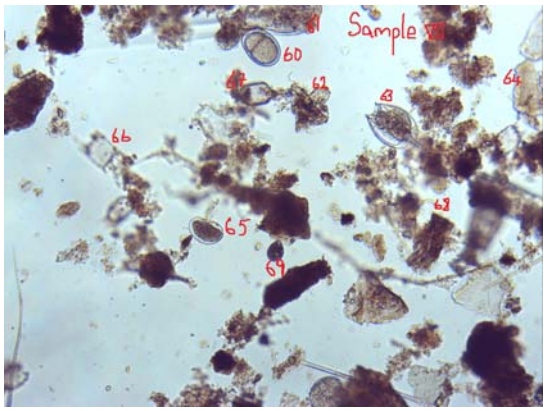

Fig. 8: Organisms captured at location M7 mL^{-1} of water, 60: *Coscinodiscus granii* (Phytoplankton), 61: *Cyclopoid copepod* (Zooplankton), 62: *Calanoid copepod* (Zooplankton), 63: *Rotifera* (Zooplankton), 64: *Melosira cf. Spaerica*, 65: *Dinophysis rotundata*, 66: Chaetoceros sp., 67: *Cyclopoid copepod* (Zooplankton), 68: *Amphora liniolata* (Phytoplankton) and 69: *Harpacticoid copepod* (Zooplankton)

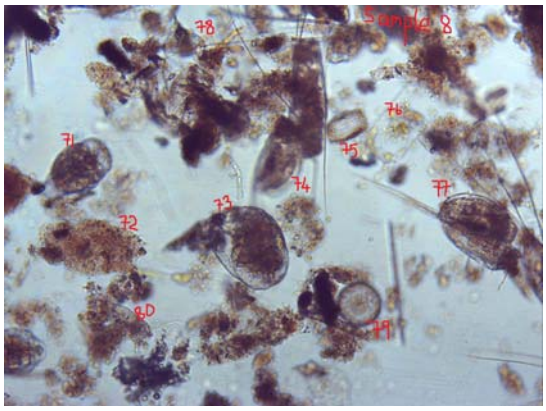

Fig. 9: Organisms captured at location M8 mL^{-1} of water, 71: *Crustacean cypris larvae* (Zooplankton), 72: *Zoea* larva of an *Anomuran* Crab (Zooplankton), 73: *Crustacean nauplius larvae* (Zooplankton), 74: *Zoea larva* of an *Anomuran Crab* (Zooplankton), 75: *Biddulphia mobiliensis* (Phytoplankton), 76: *Rhizosolenia* sp. (Zooplankton), 77: *Brachionus plicatitlis* (Zooplankton), 78: *Stephanopyxis* sp. (Phytoplankton), 79: *Early Fish embryo* (Zooplankton) and 80: *Brachionus plicatitlis* (Rotifer) (Zooplankton)

showed less. The SDI range is between 2.0-3.0 implying (mesotrophic) slight pollution level except at M4 and M6 (1.0- 2.0) which shows moderate pollution.

Plots of correlation (Fig. 12-19) for TDS and zooplankton shows a strongly positive correlation (0.855), for phytoplankton and TDS is a low negative correlation (-0.438). Sulphate and phytoplankton show a low negative correlation (-0.400), with zooplankton shows a high positive correlation (0.849). Nitrate and phytoplankton shows a moderate negative correlation (-0.698) and with zooplankton is low positive correlation (0.156). Phosphate and phytoplankton shows a moderate positive correlation (0.589) while with zooplankton is low negative (-0.148).

Plots of zooplankton versus depth shows low negative correlation (-0.499), that of phytoplankton against depth shows a strong positive correlation (0.819). For pH and sulphate is a low negative correlation (-0.288), pH and phosphate is a moderate positive correlation (0.670). The pH and nitrate shows a moderate negative correlation (-0.632).

Table 4: Relationship between Shannon diversity index and pollution level

Locations	NOS	Phytoplankton	Zooplankton	Diversity	Eveness	T.N.P. D.L S.D.I P.L
M1	11	13	2	2.245952	0.936635	15 Moderate 2.0-3.0 slight
M2	14	13	3	2.599302	0.984936	16 Moderate 2.0-3.0 slight
M3	8	6	2	2.197225	1	8 Moderate 2.0-3.0 slight
M4	3	4	1	1.054920	0.96023	5 Less 1.0-2.0 Moderate
M5	8	6	3	2.043192	0.982568	9 Moderate 2.0-3.0 slight
M6	5	3	2	1.609438	1	5 Less 1.0-2.0 Moderate
M7	9	5	5	2.302585	1	10 Moderate 2.0-3.0 slight
M8	8	2	8	2.025326	0.973976	10 Moderate 2.0-3.0 slight
Total	66	52	26			78

*DL: Diversity level, *TNP: Total number of planktons, *PL: Pollution level, *SDI: Shannon diversity index

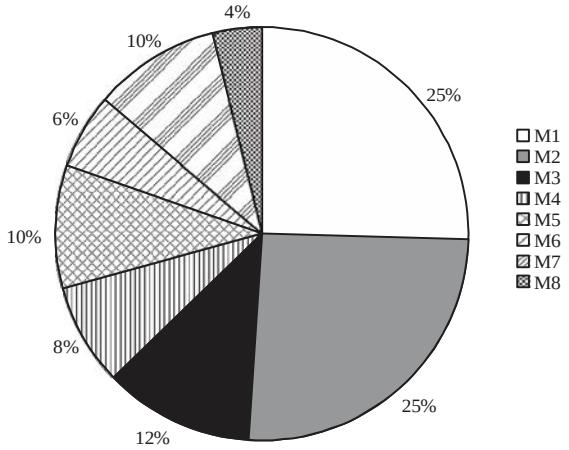

Fig. 10: Distribution of phytoplankton for all sample stations

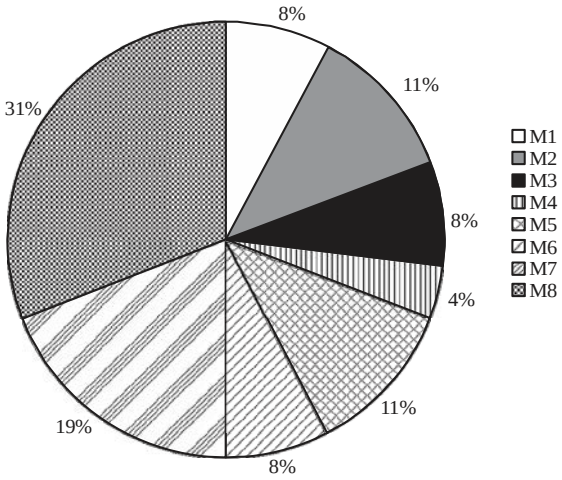

Fig. 11: Distribution of zooplankton across all sample stations

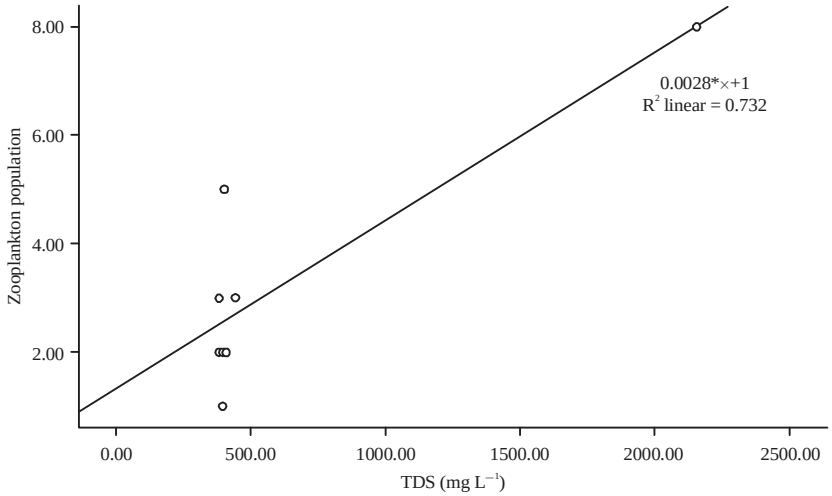

Fig. 12: A highly positive correlation of zooplanktons with the TDS in the study area

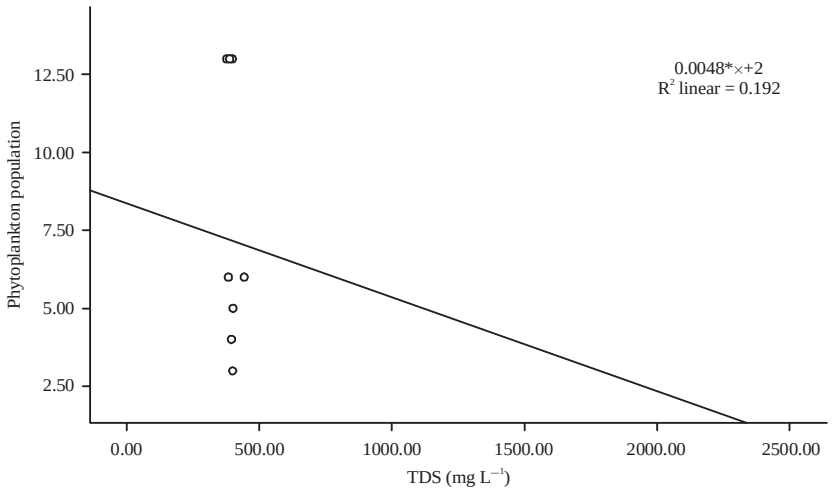

Fig. 13: A low negative correlation of phytoplankton distribution with TDS across sample stations

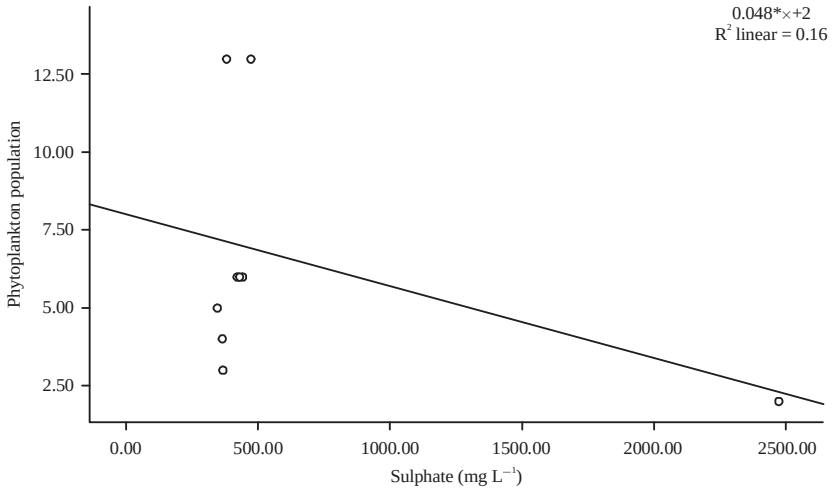

Fig. 14: A low negative correlation of phytoplankton and sulphate across the study area

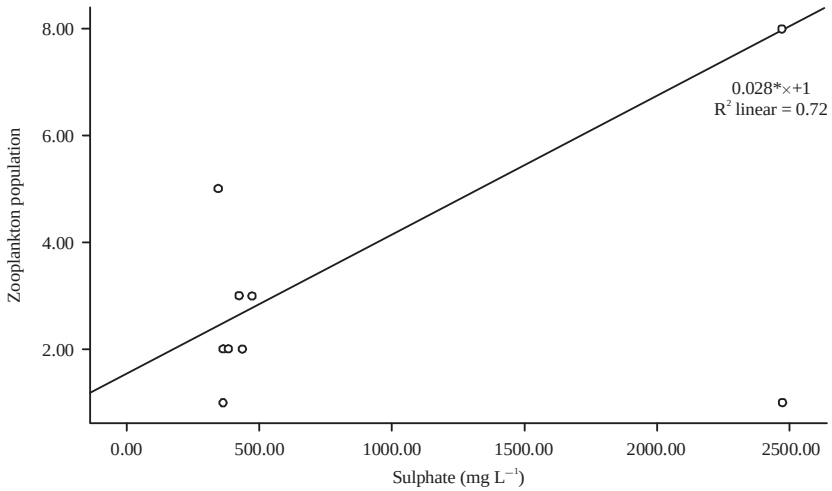

Fig. 15: A highly positive correlation of zooplanktons with sulphate across sample stations

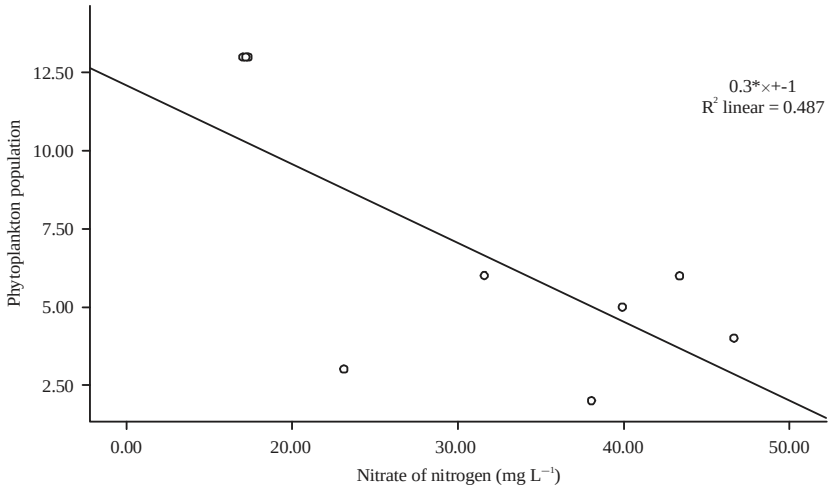

Fig. 16: A moderately negative correlation phytoplankton with nitrate across sample stations

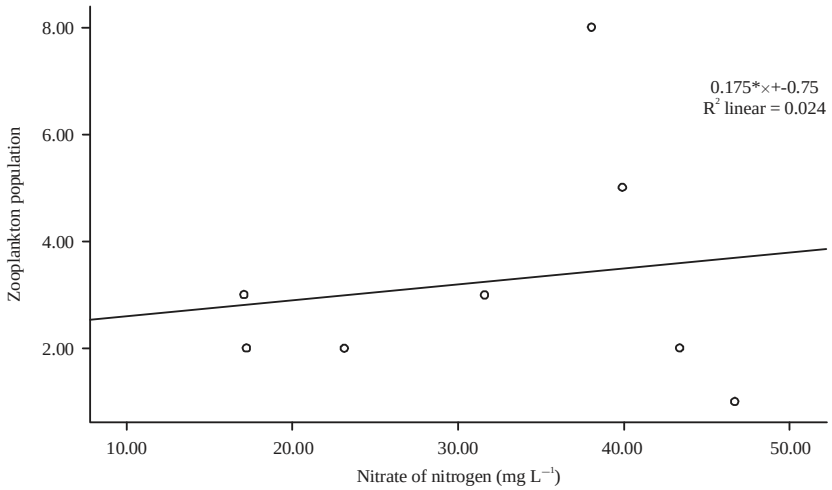

Fig. 17: A low positive correlation of zooplankton with nitrate in the study area

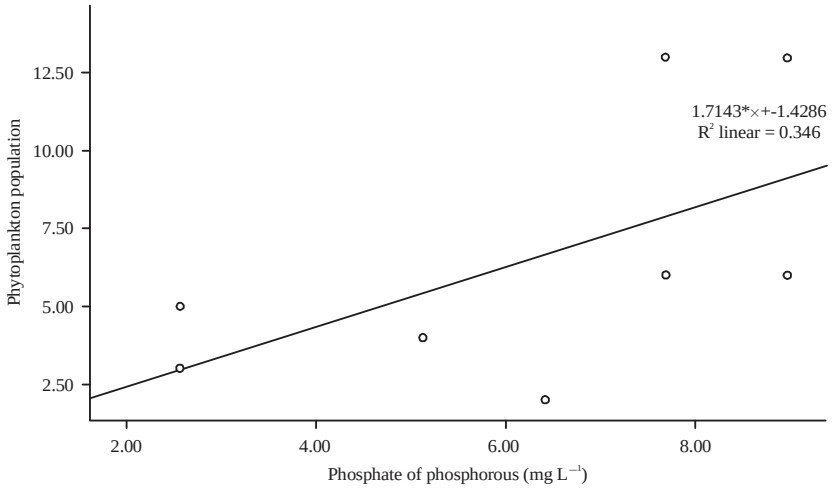

Fig. 18: A moderately positive correlation of phytoplankton with phosphate in the study area

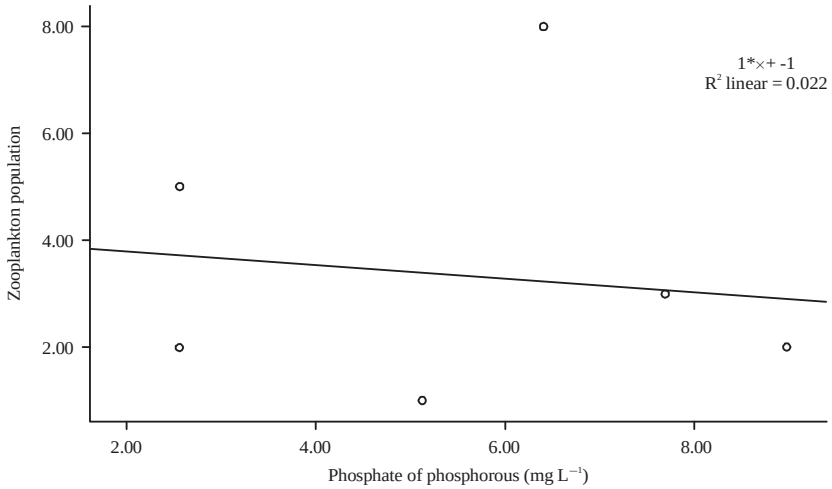

Fig. 19: A low negative correlation of zooplankton with phosphate across the study area

DISCUSSION

From the results, the photic condition of the water body (at all sample stations) is inferred as poor because its turbidity exceeds the WHO limit of 5 NTU. This was considered as the main factor that inhibits the growth of the phytoplankton in this environment despite the availability of the required nutrients. Indicating the water is extremely turbid, inhibiting aquatic life. This statement is corroborated in the specie distribution (Table 3) where M8 has the lowest number of phytoplanktons per mL, the highest TDS and highest turbidity values. The M2 has the lowest TDS, Turbidity and the highest number of phytoplanktons and number of organisms per mL of water.

Zooplankton population per mL of water is highest at M8, then M7 and lowest at M1 (Fig. 11) Phytoplankton population per mL of water is highest is highest at M1, M2 and lowest at M8 (Fig. 10). At these stations, TDS is highest at M7 and M8 and so is Turbidity (Table 1). World Health Organization (WHO) guidelines for TDS is 1000 mg L^{-1} for domestic water and irrigation water. The TDS values measured in-situ mirrors the turbidity values measured in the laboratory. The TDS values higher than 600 mg L^{-1} are regarded as severely contaminated water and this may inhibit the growth of phytoplankton and reduced the light penetration level in this environment.

The pH values for all locations (Table 1) range between 6.26-7.20 which falls within the WHO recommended limits (6.5-9.5) of water for domestic use. The pH is dependent upon many factors including the relative quantities of calcium, carbonates and bicarbonates. The water tends to be more acidic when it contains more carbonates (as observed at location M8). This is a reason why location M8 could hold the

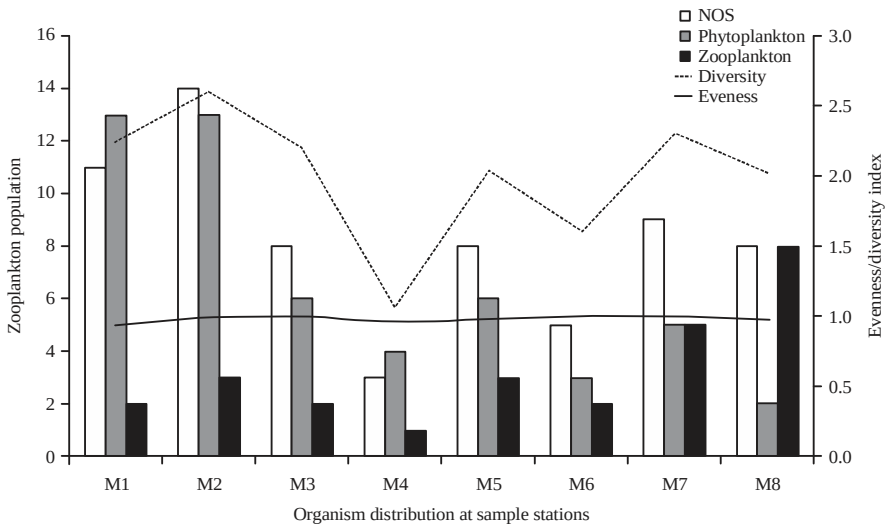

Fig. 20: Distribution of phytoplankton and zooplankton for all sample stations, Phytoplanktons: Number of phytoplanktons mL^{-1} of water, Zooplanktons: Number of zooplanktons mL^{-1} of water, NOS: Number of species

least phytoplankton population. Also, dissolved oxygen (DO), an indicator of organic pollution, is important to the ecological health of a stream and aquatic life, Chang[20]. The WHO sets a limit at 4.0 mg L^{-1} for aquatic life. Only M5 meets this limit though M1-M4 fall within close range of this value. M8 has the lowest DO value for many reasons, which includes high turbidity, low phytoplankton population, onset of organic decomposition.

The sulphate concentration (Table 2) ranges from 34.75-247.2 mg L^{-1}. The maximum value was found in water sample collected from location M8 which can be attributed to the discharge of domestic sewage and organic wastes in the study area. Sulphate was found within the permissible limit for all sample stations except for M8, excess amount of sulphate may have laxative effect. The desirable limit for chlorides is of 200 mg L^{-1} as prescribed by WHO for aquatic life, presence of higher level of chlorides is considered a pollution indicator, Reddy and Venkateswarlu[21]. The chloride concentration ranges from 191.9-7597 mg L^{-1}. Chloride concentration is highest at location M8. Higher values of chloride at this location are also linked to large amounts of sewage discharges. These discharges subsequently increase the rate of decomposition of organic matter. This suggests the onset of eutrophication, which could have been aided by high temperature. The nitrate of nitrogen concentrations ranges from 17.0977-46.6954 mg L^{-1} this value is extremely higher than the permissible limits at all the sample stations. Highest values were observed at location M4 and M3 because of mixing of various effluents from local industries and other waste material.

Within the study area, 78 planktons were identified and all fall under 66 species (Fig. 2-9). This environment is well represented by diatoms and dinoflagellate with the *Haematococcus* spp. (phytoplankton) followed by *Calanoid copepod* (Zooplankton) being the most abundant. The distribution and composition of these organisms depend on varying physicochemical properties of the environments as it suits the requirements of individual organisms and their tolerance ranges. These conditions were correlated with organism population to show dependence on physicochemical parameters and nutrient. Zooplankton population correlates positively with TDS, sulphate, nitrate and phosphate, while phytoplanktons seem unaffected by sulphate and TDS, with moderate dependence on phosphate and nitrate (Fig. 12-19). Zooplanktons correlation with depth is low negative whereas that of phytoplankton is very strong. This corroborates the relationship of phytoplanktons productivity with light intensity (limited by depth and turbidity).

The Shannon-Wiener index (H') was used in assessing the diversity at each sample station and the Pielou's index was used in assessing the specie evenness at each of the sampled stations. The diversity indices are based on two assumptions: (a) Stable communities have a high diversity value and unstable ones a low diversity and (b) Stability in diversity is an index of environmental integrity and wellbeing. As a consequence, the diversity value decreases with environmental degradation Magurran[22]. Shannon Wiener Index is a combination of the number of species and the evenness of distribution of individuals among taxa. It may

function as a sensitivity indicator for pollution, Klemm *et al.*[23] The biodiversity index (Fig. 20, Table 4) is low and the specie evenness at sampling stations in most cases are almost uniform. The correlation graph also reveals that the organisms' growth required for eutrophic condition is not strongly correlated with the organisms' population. The diversity index of the study area shows that the environment is moderate to less diverse. All of these information shows that body of water is moderately polluted and falls within the mesotrophic region of the trophic classification when considering the Shannon wiener analysis (Table 4).

Results from Ugbo water way support the generalization that light and nutrient availability are critical environmental controls for phytoplankton growth in this region. However, the distribution of these organisms implies a polluted environment even though the water quality reveals that parameters measured are within the acceptable limits.

CONCLUSION

This study reveals that pollution could be due to an interplay of many factors as seen in the study area and not necessarily, nutrient loading alone. In view of the findings made in the present study, the following recommendations are made for better water quality management of the Ugbo water way:

- The public has to be educated on proper waste disposal and the implications on the water
- The municipal waste sanitary effluents, domestic sewage and industrial effluents should not be discharged directly into the water but channelled to a central sewage system to be properly treated before being drained out
- City garbage should be dumped into low lying areas to act as landfills but care should be taken to ensure the selected dumpsite is far removed for the water table. Also, proper separation of the biodegradable and non-biodegradable materials should be done
- Regular monitoring of water parameters should be should be done to ensure the sustainability of the environment

Many researchers agree that once there is an excessive input of nutrients there will be eutrophication but the question remains, 'under what condition?' 'In what state must the photic region of the water be?'

SIGNIFICANCE STATEMENTS

Researchers have established the relationship between nutrient loading and eutrophication and finally, pollution. Here, it has been confirmed that the amount of "identified organisms" per mL of water could indicate the degree of eutrophication in a target water body. From this study, it has been established that certain organisms have affinity for polluted waters, thereby, could serve as indicators for pollution.

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