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Status of Phytoplankton Community of Kisumu Bay, Winam Gulf, Lake Victoria, Kenya

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----------ABSTRACT----------
Lake Victoria has undergone remarkable and diverse ecological perturbations which are as a result of physical, chemical and biological processes, together with human activities that take place in the watershed area and within the lake itself. The most observed effects include increases in phytoplankton biomass and frequent algal blooms. In this study species composition, abundance, spatial and temporal distribution of phytoplankton as well as total phytoplankton biomass of Kisumu Bay, (Winam Gulf), Lake Victoria, Kenya was studied for six months in the wake of climate change. Sampling was done every two weeks using a Van Dorn Water sampler to take water samples and algal cells were counted under an inverted microscope with the help of a Sedge-Wick Rafter Cell in order to determine density. Phytoplankton biomass indicated by chlorophyll-content was determined through cold extraction in acetone and subsequent quantification by spectrophotometry. Physico-chemical parameters were measured *in situ* using respective meters, while plant nutrient levels were determined by spectrophotometric methods following standard methods of APHA 1985 and Gems (1992) Handbook. ANOVA test was used to determine any temporal and spatial variability in the biological factors. Regression and Pearson's correlation analyses were done to establish relationships between these factors. LSD test was done to determine means which were significantly different. The results indicated that a total of 36 genera of algae belonging to Cyanophyta, Bacillariophyta, Chlorophyta and Pyrrophyta were present, with dominance of the classes in terms of number of species being in that order. *Chroococcus* species was the most abundant and its density was significantly different from all the others. Most algal species were more or less homogenously distributed in the bay ($p=1.0000$) and over the study period ($p=1.0000$), but their densities varied significantly between different species ($p<0.0001$). From these results, it can be concluded that the phytoplankton community within the bay is becoming very dynamic and could possibly portray the status in the whole lake. Diatoms are becoming increasingly dominant. There is continual increasing trend in physico-chemical factors. The information obtained from this work contributes to the understanding of ecological changes in the bay in response to climate change and variability and thus the threat to biodiversity. This information is therefore important for ecological and management purposes of the lake and understanding effects of climate change on ecosystem structure, functioning and productivity.

Keywords: *Phytoplankton, algae, Lake Victoria, biodiversity, climate change*

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I. INTRODUCTION

Lake Victoria and hence Winam Gulf is an important resource upon which millions of people in the basin either directly or indirectly depend for their livelihood. Winam Gulf is also animal habitat with a rich biodiversity of fish species and other aquatic organisms whose life cycles and contributions to the lake ecosystem functioning are largely unknown. During the last few decades Lake Victoria has undergone remarkable and diverse ecological perturbations which are as a result of physical, chemical and biological process together with anthropogenic activities that take place in the watershed area and the lake itself. Palaeontological studies indicate that there have been repeated past climatic changes with a trend towards a drier regime [1]. A rise in air temperatures has been reflected in higher water temperatures in the lake in the early 1990s and could have caused substantial impacts on the aquatic ecosystem [2]. Increases in eutrophication and pollution have occurred from various sources, including deforestation, agricultural run-off and urban and industrial discharges [3]. The destruction of riparian vegetation and reclamation of wetlands which act as sieve for pollutants has aggravated the situation further. The most observed effects include increases in phytoplankton biomass and frequent algal blooms [4]. Continued degradation of the environment in the basin may lead to more destruction of habitats and loss of biodiversity. One of the latest developments with undesirable effects is invasion by the water hyacinth (*Eicchonia crassipes*). The fishery is currently dominated by the exotic nile perch (*Leteus niloticus*) and Nile Tilapia (*Oreochromis niloticus*) and the indigenous 'omena' (*Rastrineobola*

argentea). Thus the increasing pressure on the ecosystem of the lake will continuously change its structure and function. A recent development that already has undesirable effects on the lake's ecosystem is the invasion by the water hyacinth (*Eicchonia crassipes*) and the long term impacts of this notorious weed are not yet known. The findings of this study therefore contribute towards knowledge in understanding phytoplankton dynamics and the controlling phsico-chemical factors in Kisumu Bay, Lake Victoria. Rational management and optimal exploitation of inland fisheries depends upon fundamental knowledge of the ecology of the various food resources [5]. A detailed knowledge of ecosystem structure, functioning and production is a requirement in the utilization and management of any water body. One major way to acquire this knowledge is through study of the plankton in the water by a taxonomic species inventory, which is a prerequisite to any ecological study. Growth of phytoplankton has direct or indirect effects on other organisms in the ecosystem and on water quality. They are food sources for fish and data on them can be used to assess fish yields. Data from studies on phytoplankton can also be used in assessment of primary productivity as they are a main contributor to primary productivity in water bodies. Their response to physical and chemical factors in water is of great value in biological monitoring. Ecological consideration of an aquatic ecosystem for management purposes include temporal and spatial abundance, community structure and composition, productivity of aquatic primary and secondary producers as well as factors controlling their dynamics. Limnological information can also be analysed to prove background data for fisheries management and information on hydrographic factors to enhance fish products. The response of biota such as plankton and nekton (e.g. fish) to physical and chemical factors in water is of great value in biological monitoring. The findings of this study have added knowledge in understanding phytoplankton dynamics within this bay, and hence Winam Gulf and managing anthropogenic factors in Kisumu town and its environs. This information forms a basis for ecological monitoring of the lake in response to observed climate change and variability in the region. It is recommended that primary productivity of the Gulf be assessed in regard to various anthropogenic factors within the lake basin for purposes of managing these factors.

Hypothesis

There is no variability in phytoplankton community and physico-chemical factors within Kisumu Bay of Winam Gulf.

Objectives

General Objective: To establish status of phytoplankton community within Kisumu Bay and relate to prevailing physico-chemical factors.

Specific objectives:

1. To determine the phytoplankton biomass, species composition and diversity.
2. To analyse spatial and temporal abundance of phytoplankton within Kisumu Bay
3. Relate phytoplankton community structure to physico-chemical factors of the lake.

II. STUDY APPROACH

2.1 Study Area

This study was carried out in Kisumu Bay. Kisumu Bay is part of the Nyanza (Winam) Gulf, which forms the Kenyan part of Lake Victoria. It is a considerably shallow enclosed bay with average depth of 4m, while the depth of the inner bay has been varying between 1.8 and 2.0m [6]. The gulf has a surface area of 1400km^2 [7], a shoreline of 500km [8], maximum length, 60km and maximum width of 30km, although width varies between 6-30km. It lies at an altitude of 1134m above sea level, at latitudes 00 05S and 011S and longitude 34^{0}44'E and 34^{0}46'E [9]. The catchment area is characterized by a lot of agricultural activities and many industries in Kisumu town including slaughter houses, textile mills, feed mill and many small scale industries. Much of the shoreline is infringed with papyrus which may extend into swamps, sandy beaches and rocky exposures while other shoreline habitats are sandy beaches and rocky exposures.

Selection of Study sites

Four sampling stations were established in the bay, thereby referred to as station (STNS) I, II, III and IV. Selection of these sites was based on physico-chemical characteristics. Station I is at point of entry of River Kisat into the bay, a major point source pollution, STN II is Kisumu railway pier, STN III entry of storm water and runoff from town while STN IV open offshore waters. Physical parameters were biweekly measured in situ for surface and bottom waters at sampling stations using respective meters. Dissolved Oxygen (DO) was determined using digital DO meter (WTW exi 320) in mg/l, Conductivity using micron Meter LF 96 in ms/cm, Turbidity using NTU turbiditimeter, Temperature with Mercury thermometer, Transparency using 20cm diameter black and white metal secchi disk and pH was measured with a pH meter (NTM pH 320).

Plant nutrient levels in water samples were determined by spectrophotometric methods following standard methods [10, 11].

2.2.0 Materials and Methods

2.2. 1 Collection of Samples and Preparation for Subsequent Laboratory Treatment

Triplicate surface and bottom water samples were taken biweekly for a period of 6 months using a Van Dorn Water sampler of 5-litre capacity.

Water samples for qualitative and quantitative phytoplankton analysis were fixed with Lughol's solution in 500mls sampling bottles and labeled. Samples for nutrient analysis were preserved using mercury chloride solution, filtered using membrane filters in the laboratory and stored in 500ml glass bottles under refrigeration at 4^0C before analysis. Samples for alkalinity and hardness analyses were carried in plastic bottles.

For chlorophyll-a analysis 150mls of water sample was filtered through whatman GF/C glass fibre filters using a manual vacuum filter pump after addition of magnesium carbonate solution. The filters were wrapped in aluminium foil, placed in dark bottles and put in ice-cooler box and transported to the laboratory for further analysis.

2.2.2 Phytoplankton Laboratory Analyses

Species composition and abundance

Algal cells were identified and counted under an inverted microscope at x 400 magnification with the aid of a Sedge – Wick Rafter Cell. The number of algal filaments or cells or colonies per ml of lake water was calculated from the formula:

N= (1000/30)n

Where,

N=Total number of cells, colonies or filaments of each species per ml of water,

n=number of algae counted per species.

Cell counting was done in 30 squares while the rafter cell has total of 1000 squares. Identification was done based on microscopic identification keys for lakes Victoria, Tanganyika, George and other tropical and temperate lakes developed by Talling [12]. Species Diversity was determined using Shannon Wienner Diversity Index.

Chlorophyll-a determination

Phytoplankton biomass was determined through cold extraction in acetone and subsequent quantification by spectrophotometry using standard analytical methods [10, 11]. The filter papers with their algal contents were placed in 10mls of 90% acetone and put in a refrigerator for at least 24 hours during which extraction of chlorophyll-a occurred. The pigment extract was centrifuged at 3500 revolutions per minute (rpm) for 15-30 minutes, the supernatant liquid decanted into spectrophotometric cuvettes and its absorbance measured spectrophotometrically at 630nm, 645nm, 665nm, and 750nm against 90% acetone blanks. The value at 750nm is for turbidity correction. Chlorophyll-a concentration was determined using approximate relations of [13] according to the equation:

Chl-a (mg/l)=Ca x 1/d x v/V x 1000

Where: $Ca=11.6A_{665}-1.31A_{645}-0.14A_{630}$

A=Absorbance

v=volume of solvent (acetone) in mls

V= volume of water filtered in mls

D=wavelength/pathlength (1cm)

2.3 Data Analysis

ANOVA test was used to establish variability in biological and physico-chemical factors with respect to sampling stations, months of sampling and depth of water at which samples were taken. Regression and Pearson's correlation analysis was done to establish relationships between the various factors. LSD test done to determine significantly different means.

III. RESULTS

3.1 Physico-chemical parameters

The parameters had significantly high values in the waters as shown in (table 1). These factors had significant spatial and temporal variations. Temperature recorded significantly varied both in time and space during the period of study, highest being in March (Dry Season) and lowest in May (rainy season) Turbidity ranged between 30.76 NTU $\pm$ 16.16 TO 80.2 NTU ($\pm$107.6) with significantly spatial differences but not significant temporal. Offshore sites recorded highest turbidity values in dry months while inshore sites recorded highest values in rainy seasons. pH was generally high with values ranging between 7.2 ($\pm$ 0.384) and 8.4 ($\pm$0.332). This was notably different for different sampling sites but not with time. DO was generally high during day spell (e.g March) and low in rainy period e.g. May. It was also noted to be higher in offshore sites (6.006 mg/l

±2.997) but lowest in inshore station I (0.613mg/l ± 0.668) representing a river mouth. Observed electrical conductivity ranged between 168.8us/cm ±20.3 and 983us/cm ±367.6, with both spatial and temporal variations. Hardness and Alkalinity values recorded were generally high throughout the study period, variations being significant both in space and with time.

Table 1: Variation in Physico-Chemical Parameters of Kisumu Bay (Values are means -+ sd)

Sampling Station	Temp.(^{0}C)	pH	Cond(µs/cm)	Transp.(cm)	DO(mg/l)	Alk(mg/CO^3/l)	Hard.(mg$CaCO^3$)	Turb(NTU)
I	23.6-+0.601	7.2 -+0.384	983-+367.6	1.2-+0.005	0.613-+0.668	569.9-+307.1	214.3-+91.9	42.28-+43.9
II	26.9-+0.624	7.7-+0.352	168.8-+20.03	2.5-+0.070	3.797-+2.425	130.5-+34.98	56.50-+4.92	30.76-+16.1
III	26.9-+0.890	8.1-+0.576	182.6-+20.02	2.4-+0.083	6.006-+2.977	126.2-+25.65	54.04-+5.62	37.8-+25.86
IV	26.1-+0.786	8.4-+0.332	170.3-+10.94	27-+0.089	5.990-+1.290	123.6-+27.61	52.07-+5.15	80.2-+107.6
F-Date P	10.82* <0.0001	1.81 NS 0.1359	3.62* 0.0097		19.25* <0.0001	8.41* <0.0001	5.22* 0.0011	2.04 NS 0.0973
F-Station P	141.17* <0.0001	34.18* 0.0001	109.43* <0.0001		60.99* <0.0001	55.40* <0.0001	72.06* <0.0001	3.12* 0.0309
F-Depth P	6.06* 0.0163	6.16* 0.0155	0.00 NS 0.979		2.96NS 0.0898	0.000NS 0.893	0.000NS 0.9705	9.21* 0.0034

*Value significant; (n=80, df=70,NS:Not Significant; P<0.05)

Nutrient levels were generally high, varying significantly on spatial and temporal scales. High concentrations of plant nutrients such as ammonia (NH_4^+-N), nitrates (NO_3^--N), Silicates (SiO_2) and phosphates (PO_4^{3-}-P) were observed throughout the study period.

Table 2: Variation of Plant Nutrient of Kisumu Bay (Values are means-+sd)

Sampling Station	NH^+_4-N(mg/l)	NO_3^-_N(mg/l)	PO_4^3--P(µg/l)	SiO_2(mg/l)
I	945-+1577	0.0438-+0.0877	983-+465	4541-+8.08
II	80.2-+57.8	0.0135-+0.0163	115.2-+180.9	33.79-+852
III	83.2-+90.2	0.0961-+0.1478	85.0-+118.8	32.17-+9.55
IV	65.35-+32.71	0.009-+0.00064	107.0-+180.8	28.28-+6.65
F-Date P	2.72* 0.0360	3.31* 0.0154	1.22NS 0.3119	7.71* <0.0001
F-Station P	6.61* 0.0006	4.82* 0.0043	5257* <0.0001	21.76* <0.0001
F-Depth P	0.01NS 0.9299	0.15NS 0.9677	0.000NS 0.9677	0.12NS 0.7277

*Value Significant; (n=80, df=70,NS: Not Significant; P<0.05); Confidence Limit=95%

3.2 Biological Factors

A total of 36 genera, falling into 4 classes: Cyanophyta (13 genera), Bacillariophyta (12 genera), Chlorophyta (9 genera), and Pyrrophyta (2 genera) were identified (Table 3). This indicates that diatoms have become abundant as compared to previous studies. Distribution of most species had spatial and temporal homogeneity (P=1.0000) probably due to little or no variations in the physico-chemical parameters, but with significant variations between different species (p<0.0001). The density differences between species could be attributed to variations in reproductive patterns, growth rates, microhabitat preferences and algal physiology.

Table 3: Variation in relative abundance of various algal species in each class

Species	**Relative abundance (%)**
Cyanophytes (blue-green algae)	
Chroococus sp.	72
Anabaena sp.	09
Microcystis sp.	06
Lyngbya sp.	04
Merismopedia sp.	02
Others	07

Bacillariophytes (Diatoms)	
Navicula sp.	29
Synedra sp.	17
Phyto 1	16
Nitzschia sp.	13
Melosira sp.	06
Phyto 2	05
Thallasosira sp.	03
Cymatopleura sp.	03
Surirella sp.	02
Rhizosolenia sp.	01
Others	05
Chlorophytes (Green algae)	
Tetraspora sp.	28
Pediustrum sp.	25
Chlamydomonas sp.	12
Phyto 3	12
Oocystis sp.	10
Chlorella sp.	06
Scenedesmus sp.	04
Ankistrodesmus sp.	03
Pyrrophytes (Desmids)	
Straurustrum sp.	62
Closterium sp.	35
Gomphonema sp.	03

High algal densities were observed throughout the study period, probably due to high nutrient inputs, shallowness of the gulf, together with mixing of the lake, which makes available high nutrient concentrations in the water column [4]. Algal standing crop varied significantly with respect to stations, and dates. Station I, representing point of inlet from industrial and domestic waste discharges had lowest value, all others not different. Algal crop was highest in January, then February and lowest in March, April and May which were not different from each other.

Table 4: Variation in Chlorophyll-a Concentration of the Kisumu Bay (Mean Concentrations -+sd)

Sampling Station	**Concentration of Chl-a in µg/l**
I	7.71-+4.49
II	40.60-+27.53
III	40.92-+21.91
IV	37.10-+17.77

Months/Dates		**F-Value**	**P-Value**
Jan	55.01-+34.38	F-Station-25.98*	(P<0.0001)
Feb	39.81-+22.91	F-Dates-19.71*	(P<0.0001)
Mar	17.71-+5.50	F-Depth-1.13NS	(P<0.2919)

*Value Significant; n=80; df=70; NS=Not Significant

Species diversity index trend, represented by Shannon-Wienner Diversity Index was observed to be significantly different both among sampling stations and sampling months. It was lowest in May.

Table 5: Species Diversity Trend of Kisumu Bay

Sampling Station	Dec	Jan	Feb	Mar	April	May
I	14	--	12	6	7	8
II	12	14	12	10	16	11
III	11	18	17	9	14	9
IV	15	6	16	14	14	14
Species Diversity (Shannon Wienner Index)	--	1.4594	1.3351	1.4494	1.6093	0.8020
Species Diversity by Stations	--	STN I	STN II	STN III	STN IV	
		1:6423	0:9385	1:2202	1:5231	

F-Value; F-Station=4.65*; P=0.0223; F-Month=3.61*; P=0.0375

- Value Significant (n=80; df=70;P<0.05); -no sampling

Relationships between different species with environmental factors were weak, most species not affected by these environmental factors.

There is a continuous increasing trend in physico-chemical factors within the bay, showing persistent pressure that is put on the lake from physical-chemical and biological processes in its catchment area and within the lake itself. Temperature, conductivity, dissolved oxygen and alkalinity varied significantly between station and months.

IV. DISCUSSION

The range of temperatures observed were within what has been observed in the Nyanza Gulf during earlier studies [7, 14] though they were higher than observations made between 1960 – 1961 [12]. The higher temperatures suggest a response of the lake water to a possible warming trend of climate of East Africa.

High turbidity values were attributed to high algal densities and suspended solid nutrients in the water column caused mainly by mixing or stirring of the water column by winds [6] and also due to input from runoff. Open waters had low turbidities due to reduced particulate matter in suspension and low algal densities. Lung'aiya [15] noted considerably high turbidities at river mouths within the Nyanza Gulf, which increased substantially during the rainy seasons, and decreased offshore in the open lake stations as a result of dilution of lake water and low algal biomass in the open lake waters.

The water was well oxygenated from the surface to the bottom. High mean oxygen concentrations were attributed to increased algal photosynthetic activity. Oxygen levels of up to 13 mg/l were observed during algal blooms of blue green algae in the Kenyan offshore waters [4].

High electrical conductivities were attributed to large chemical inputs of dissolved ions from towns and runoff from various farm lands in the catchment area.

The waters had higher nutrient levels compared to observations from earlier studies. This was attributed to increased eutrophication resulting from increased industrialization and agricultural activities in the catchment areas arising from increased human population. Nutrient recycling within the shallow water column can also be a contributing factor to this high load. The high temperatures of the lake water may allow for rapid nutrient recycling.

Algal distribution was generally homogenous within the bay and within the water column. This could be due to little variation of physico-chemical parameters during the study period. High light intensities with good light penetration due to shallowness of water and high nutrient loads could offer favorable conditions for algal growth hence the high densities observed. However, spatial and seasonal distribution of phytoplankton are sometimes difficult because of the array of environmental factors involved, the individual physiological properties of each algal species, and the magnitude of change that occur in both [16].

Differences in spatial and seasonal distribution of phytoplankton among different species could be due to individual physiological properties.

Chrococcus species was the most abundant. Blue-green algal were the dominant both in spp and density throughout the study period, in the past when dilations dominated. Dominance by the blue-greens could be explained to be due to different in physiology between them and the dilated or the ecology of the lake. Their abundance is presumably supportably availability of high nutrient t levels, particularly nitrates. An increase in temperature has physiological effects on algae by increasing their growth rates and blue-green are the most favoured by high temperatures [17, 15].

However, the generally higher densities of dilations like *Nitzschia* observed as composed to earlier obsessions is an indication of high levels of silicates present in the water column in the gulf.

Algal standing crop as indicated by results of chlorophyll-a concentrations varied significantly between stations and among months of sampling. The trend of algal standing crop does not exactly follow that of algal densities as would be expected. This could be due to presence of picoplankton which could also be present but could not be identified or counted. Picoplankton have been reported in moderate numbers (3.7 x104 cells/ml) in Nyanza Gulf and to contribute upto 63% of the total chlorophyll, upto 26% of the total phytoplankton carbon and upto 53% of the total photosynthesis [18].

V. CONCLUSION

The findings of this stud indicate that the phytoplankton community in Nyanza Gulf is very dynamic and undergoing changes as depicted by some earlier rare species becoming abundant eg blue-green algae *Chroococcus* species. They indicate changes in phytoplankton community structure hence an indication of ecological changes in the lake, which can be attributed to both anthropogenic and climate change factors. There is an indication of homogenous distribution of phytoplankton within the water column throughout the stud period, the density only changing slightly. No single environmental parameter had complete influence on the

distribution and occurrence of the phytoplankton species. No evidence of relationship between the different species could be established either, could be this requires a more elaborate and comprehensive study.
Findings can be used to design measures for monitoring and mitigating environmental impacts arising from physical, chemical and biological processes within the bay and its catchment area.

VI. RECOMMENDATION

It's recommended that long term investigation be done on relationship between phytoplankton species with one another and with the physico-chemical parameters. Comprehensive evaluation of ecological changes in the bay in relation to anthropogenic activities and climate change factors be investigated. Comprehensive species inventory of the gulf to be done in response to climate change inorder to contribute to formulation of sound management policies. Effective management of watershed is a basic necessity within the basin.

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