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Primary Production estimation in the euphotic zone of a Tropical Harbour Ecosystem, Nigeria

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Abstract- Primary productivity and selected relevant associated physico-chemical parameters in the euphotic zone of Lagos Harbour, a tropical Harbour was monitored at NIOMR Jetty station (Latitude 6º 25΄ 14, 88º N, Longitude 3º 24΄ 24, 42º E) on a monthly basis from October, 2012 to March, 2013. Air and surface water temperature ranged from 23.5^{0}C to 28^{0}C and between 27 ^{0}C and 30^{0}C respectively. Alkaline pH ranged (7.81 to 8.45). Brackish salinity varied from 6.2 to 35.4PSU while Electrical conductivity minimum and maximum values were 11200 and 53300µS/cm respectively. Moderate dissolved oxygen ranged between 5.0mg/l and 6.4mg/l, slightly lower than 6.8mg/l standard suggested by FEPA. Total dissolved solid ranged from 7504 to 35711mg/l while Low Alkalinity varied between 12 and 20mg/l. Rainfall minimum and maximum values were 8.8 and 229mm respectively. Gross primary production (GPP) varied from 0.22 to 0.46gC/m^2/day. The corresponding Net primary production (NPP) and Community respiration (CR) ranged from 0.07 to 0.3gC/ m^2/day and 0.144 to 0.31gC/m^2/day respectively. GPP correlated positively with NPP (r = 0.69), Dissolved Oxygen (r = 0.56) and significantly correlated negatively with Alkalinity (r = -0.86) at $P < 0.05$. NPP also correlated positively with Dissolved Oxygen (r = 0.80).

This investigation revealed that the productivity of Lagos Harbour is impacted by various factors such as sand mining and dredging, industrial effluents, sewage water and other anthropogenic activities.

The information and observation of this study will be very useful as baseline data against which future changes can be measured.

Index Terms- Primary production, tropical harbor, Physicochemical parameters, euphotic zone

I. INTRODUCTION

Productivity is of great importance in ecosystem as it integrates the cumulative effects of many physiological processes, which occurs simultaneously within the ecosystem (Jordan, 1985). Primary productivity of aquatic ecosystems is essential for a proper assessment of the biological potential of that habitat. Primary productivity refers to the fixation of inorganic carbon and the gross or net production of organic matter by the photosynthesis process (Tundisi, 1976). Productivity of any ecosystem depends upon both the flora and fauna of a particular ecosystem but the main factor controlling the productivity of aquatic ecosystem is the phytoplankton population dynamics. The primary role of phytoplankton is to fix solar energy by photosynthesis and make it available to other organisms.

Primary production studies are of paramount interest in understanding the effect of pollution on system's efficiency and because all the organic production of an ecosystem depends on the photosynthetic organisms. The light intensity and nutrient availability are important factors to primary productivity in aquatic ecosystems, because they constitute a limiting factor of photosynthesis. However, there are certain physico-chemical and biological factors which control the rate of production in a marine ecosystem. Higher production is not governed by a single factor (Singh and Singh, 1999).

Lagos Harbour is one of the three main segments of Lagos Lagoon Complex; other segments are Metropolitan and the Epe Division Segments. The 2 km wide harbour receives inland waters from the Lagos Lagoon in the north, and from Badagry Creek in the west. Apart from providing the only opening to the sea for the nine lagoons of South Western Nigeria, the Harbour is used as a route to transport goods and subsistence fishing takes place on the water body by artisanal fishermen.

In order to obtain the knowledge and analysis of support capacity of a tidal Harbour ecosystem, an attempt has been made in this present investigation to study primary productivity of this water body. Furthermore, apart from seeking a greater knowledge about current conditions of this environment, the study will be serving as basis for further work.

II. MATERIALS AND METHODS

Study Area:

Lagos is located in south-western Nigeria on the West Coast of Africa and is undoubtedly the commercial nerve-center of Nigeria. Lagos Harbour (figure 1) situated in Lagos, is Nigeria's most important seaport and the first inlet from the Atlantic Ocean beyond the Republic of Benin. The Harbour is one of the three main segments of Lagos Lagoon Complex; other segments are: Metropolitan and the Epe Division Segments. The 2 km wide harbour receives inland waters from the Lagos Lagoon in the north, and from Badagry Creek in the west. Apart from oil depots located along the shore of western parts of the Harbour coupled with the proliferation of urban and industrial establishments on the shore of eastern part of the Harbour, the Harbour is used as a route to transport goods. NIOMR jetty station (Latitude 6º 25΄ 14, 88º N, Longitude 3º 24΄ 24, 42º E) is located in the commodore channel of Lagos Harbour with Jetty facilities awaiting rehabilitation. Subsistence fishing takes place at this part on the water body by artisanal fishermen (Balogun and Ladigbolu, 2010).

This study was carried out at monthly interval from October, 2012 to March, 2013 covering a typical dry season in Nigeria.

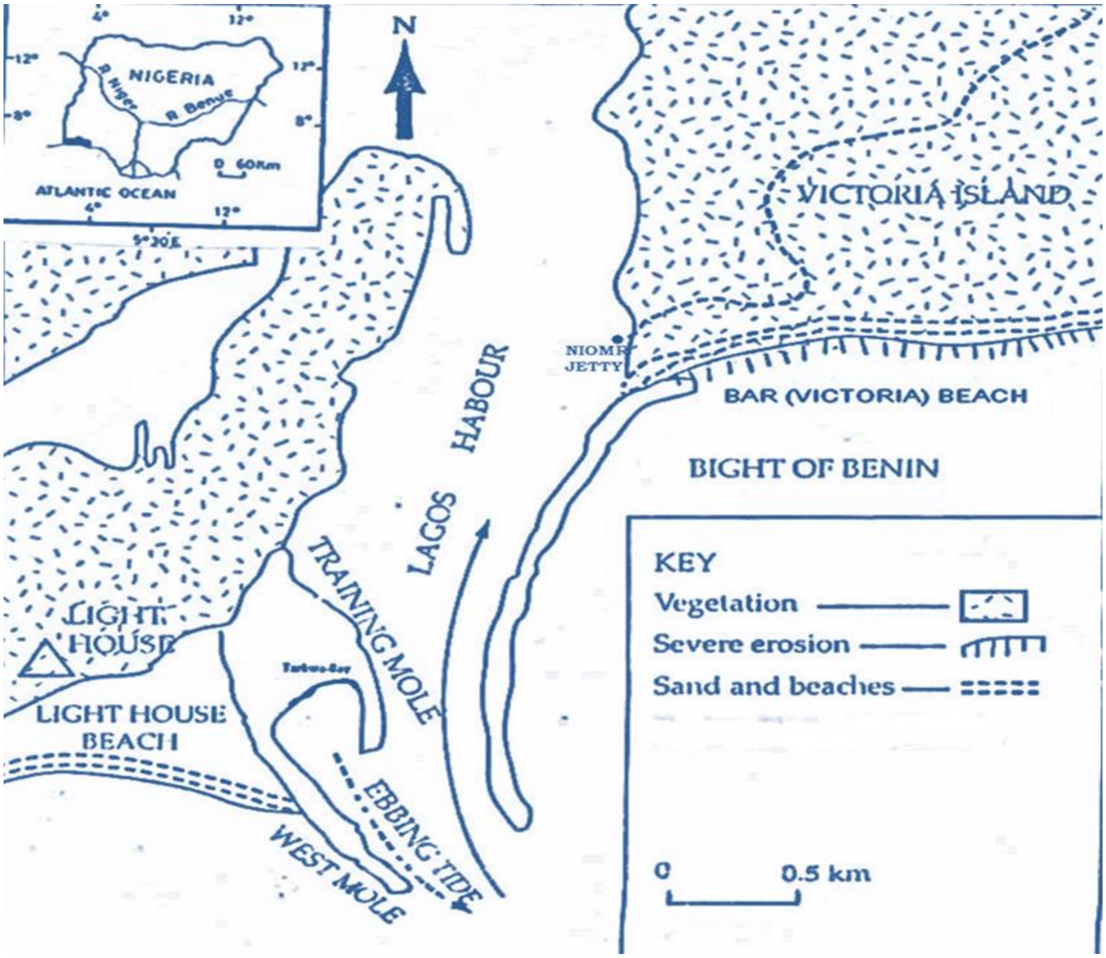

Figure 1: Map of Lagos Harbour showing NIOMR Jetty sampling station denoted by •

Primary production and Physicochemical Parameters measurements:

Water samples for phytoplankton primary productivity were collected with water sampler from a selected point (NIOMR Jetty station) on the Lagos Harbour during morning time (Between 9 am and 10am), in the third week of every month. The water collected were poured into triplicate bottles (one dark and two light bottles) The sample in one of the light bottles was fixed immediately according to Winkler's method using Manganese Sulphate solution and Alkaline Potassium iodide reagents to determine the initial level of dissolved oxygen content (APHA, 1998), while the other light and dark bottles were then suspended in a vertical position under water in the euphotic zone of the sampling station for twenty four hours. After incubation time, the bottles were taken out and fixed prior to Dissolved Oxygen determination in the laboratory. Water samples for determination of Physico-chemical parameters such as pH, Salinity, Electrical conductivity, total dissolved solids (TDS) and Alkalinity were collected with a 1dm^3 water sampler and store in 1 litre screw-capped plastic container and refrigerated at 4^0C ± 1^0C prior to analysis. Air and surface water temperature (^{0}C) were measured *in situ* using Mercury in glass thermometer.

In the Laboratory, physico-chemical variables (pH, Conductivity and Salinity) were determined using a multi-meter water checker (Horiba U – 10). TDS reading was automatically measured with a Cole Palmer TDS meter. Alkalinity was determined by titrating dilute HCL against 100ml of the water sample using methyl orange as an indicator (APHA, 1998). Dissolved oxygen was estimated using iodometric Winkler's method (Stirling, 1999). The light and dark bottles method (Trivedi and Goel, 1986) was used for measuring the primary productivity (GPP, NPP and Community respiration). Gross primary production, Net primary production and Community respiration were calculated based on this formula (NOAA, 2000).

Calculation:

NPP (mg/l) = *Final DO in light bottle (mg/l) – Initial DO in light bottle (mg/l)*

CR (mg/l) = *Initial DO in dark bottle (mg/l) – Final DO in dark bottle (mg/l)*

GPP (mg/l) = *CR (O_2 consumed by respiration in mg/l) + NPP (Net O_2 production in mg/l).*

The conversion factor 0.375 represents a constant to convert oxygen value (mg/l) to (productivity) carbon value ($gC/m^2/h$) (Thomas *et al.*, 1980). This value was derived on the assumption that one atom is assimilated for each molecule of oxygen (32g) released for each molecule of carbon (12g) fixed (APHA, 1998). Per hour values were multiplied by 24 to derive the productivity values per day (Michael, 1984).

Monthly Rainfall data measured in mm of the study environment were obtained from Nigerian Meteorological marine office at the Nigerian Institute for Oceanography and Marine Research, Victoria – Island, Lagos.

Statistical Analysis:

All descriptive statistics and graphs were executed using Statistical 12 software and Microsoft office Excel 2010. Data were further subjected to Correlation test to find significant relationship between the measured variables at 0.01 and 0.05 levels of significant.

III. RESULTS AND DISCUSSIONS

The trends in physico-chemical parameters measured in Lagos Harbour at NIOMR Jetty station is tabulated in Table 1. Air temperature during the study period ranged from 23.5^{0}C in December, 2012 to 28^{0}C (Oct, 2012 and March, 2013) while water temperatures were between 27^{0}C (December, 2012) and 30^{0}C (March, 2013). The Air and water temperatures values were typical for the tropics and similar patterns have been reported by various authors (Ajibola *et al.*, 2005; Balogun and Ladigbolu, 2005). The temperature of surface waters are influenced by latitude, altitude, season, time of day, air circulation, cloud cover and the flow and depth of the water body. In turn, temperature affects physical, chemical and biological processes in water bodies and, therefore, the concentration of many variables. pH ranged were found alkaline in nature (7.81 to 8.45) throughout the study period (Table 1). This alkaline and fairly stable pH may be due to the buffering effects of the seawater. Similar opinion has been reported (Oyewo, 1998). The biological activity of the coastal zone ensures stable pH, a notable feature of the marine environment, where conditions are remarkably constant over certain areas.

TABLE 1: Physico-chemical parameters of Lagos Harbour, Nigeria at NIOMR Jetty station

Parameters	Oct., 2012	Nov., 2012	Dec., 2012	Jan., 2013	Feb., 2013	March., 2013	Mean ± S.E
Air Temperature (^{0}C)	28	26	23.5	27	26	28	26.42 ± 0.69
Water Temperature (^{0}C)	28	28	27	29	29	30	28.5 ± 0.43
pH	8.09	7.81	8.45	8.07	8.41	8.3	8.19 ± 0.09
Salinity (PSU)	6.2	28.3	27.9	32.5	33.6	35.4	27.32 ± 4.39
Conductivity (µS/cm)	11200	43800	43100	49400	51000	53300	41966.7 ± 6367.98
Dissolved Oxygen (mg/l)	6.4	5.2	6	5	5.2	6.4	5.7 ± 0.26
TDS (mg/l)	7504	29346	28877	33098	34170	35711	28117.7 ± 4266.54
Alkalinity (mg/l)	18	16	12	14	20	12	15. 33 ± 1.33
Rainfall (mm)	229	71.8	8.8	60.7	55.5	64.1	81.65 ± 30.85

Salinity of the study station was between 6.2 and 35.4psu while electrical conductivity minimum and maximum values were 11200 and 53300µS/cm respectively (Table 1). The lowest salinity observed (October, 2012) was probably due to dilution from rainfall as the month also recorded maximum rainfall (Table 1). The high values of Electrical conductivity were an indication of more dissolved solids. The highest electrical conductivity of the environment study occurred in March, 2013 while the lowest was observed in October, 2012. Total dissolved solid ranged from 7504 (October, 2012) to 35711mg/l (March, 2013). Meanwhile, Conductivity and salinity have been reported as associated factors (Onyema and Nwankwo, 2009). Conductivity for a given water body is also related to the concentrations of total dissolved solids and major ions (Chapman, 1996). Conductivity values obtained in this investigation increase with rise in Salinity and Total dissolved solids. Furthermore, a highly significant positive correlation was established between salinity and conductivity ($r= 0.99$, $P < 0.01$, $n = 6$) (Table 2). Salinity and TDS also showed a similar relationship ($r = 0.99$, $P < 0.01$, $n = 6$) Table 2. Consequently, there was strong significant positive correlation between conductivity and TDS ($r= 0.99$, $P < 0.01$, $n = 6$). This finding is in agreement with the view of several authors that there is a close correlation between salinity and other ecological factors in Lagos Lagoon including the rainfall of the region (Oyewo, 1998; Hill and Webb, 1958). Dissolved Oxygen content indicates the health and ability of the water body to purify itself through biochemical processes. Furthermore, the concentration of the oxygen in aquatic environments is a very important component of water quality. The measurement of the DO concentration of a body of water is often used to determine whether the biological activities requiring oxygen are occurring and consequently, it is an important indicator of pollution. Lowest value of Dissolved oxygen recorded was 5.0mg/l while the highest value was 6.4mg/l. These DO values were within the minimum 5.0mg/l suggested (Eroudu, 1991) and slightly lower than 6.8mg/l standard suggested (FEPA, 1991) for the survival of fish and other aquatic organisms. The Alkalinity of water is controlled by the sum of the titratable bases. It is mostly taken as an indication of the concentration of carbonate, bicarbonate and hydroxide, but may include contributions from borate, phosphates, silicates and other basic compounds. Low Alkalinity recorded in this study varied between 12 and 20mg/l. Water of low alkalinity (< 24mg/l as $CaCO_3$) have a low buffering capacity. The average rainfall of Lagos Harbour during the period of study was 81.65mm. Rainfall minimum and maximum values were 8.8 and 229mm respectively (Table 1). The highest rainfall was recorded in October, 2012 while December, 2012 had the least value. A significant negative correlation was established between Rainfall and Salinity ($r= - 0.88$, $P < 0.05$, $n = 6$), Rainfall and Conductivity ($r = -0.89$, $P < 0.05$, $n = 6$) and Rainfall and Total dissolved solids ($r = - 0.89$, $P < 0.05$, $n = 6$) (Table 2).

The Monthly variation of gross primary productivity, net primary productivity and community respiration of Lagos harbor is presented in Figure 2. The gross primary productivity was generally low in the study site throughout the study duration. The low gross production may be due to low photosynthetic activity in this water body.

Maximum gross production per day ($0.46gC/m^2/day$) was recorded in the months of December, 2012 and March, 2013, while minimum value ($0.22gC/m^2/day$) was recorded in November. The corresponding maximum ($0.3gC/m^2/day$) and minimum ($0.07gC/m^2/day$) values of Net production were obtained in March, 2013 and November, 2012 respectively (Figure 2). Community respiration was highest in the month of December, 2012 ($0.31gC/m^2/day$) and lowest ($0.144gC/m^2/day$) in November, 2012 and March, 2013. These values were lower than the range reported in Krishnasayer lake (Banerjee and Chattopadhyay, 2008) but higher than range reported in ponds of Otamiri River, Nigeria (Ogbuagu, 2013). The low productivity observed in this present investigation could be probably linked to intense sand mining operation in this harbor for Atlantic City project land reclamation. Sand mining could exert negative influences on the productivity of aquatic ecosystems (Tamuno, 2005). The positive correlation between GPP and NPP ($r = 0.69$, $P = 0.133$) revealed that high GPP is responsible for high NPP. A negative significant correlation between GPP and Alkalinity($r = -0.86$, $P < 0.05$) was established (Table 2). The rate of primary production in NIOMR jetty station of Lagos Harbour was found to be relatively uniform throughout this study probably because of stable rate of photosynthesis due to moderately stable water temperature experienced. The excessive amount of nutrients along with higher temperature favors the maximum growth of aquatic flora, which ultimately favors the primary productivity. Temperature, solar radiation and available nutrients may be important limiting factors for primary production (Sultan et al., 2003).

The productivity of Lagos Harbour in this present investigation was influenced by various factors such as sand mining and dredging, agriculture runoff, industrial effluents, sewage water and other anthropogenic activities.

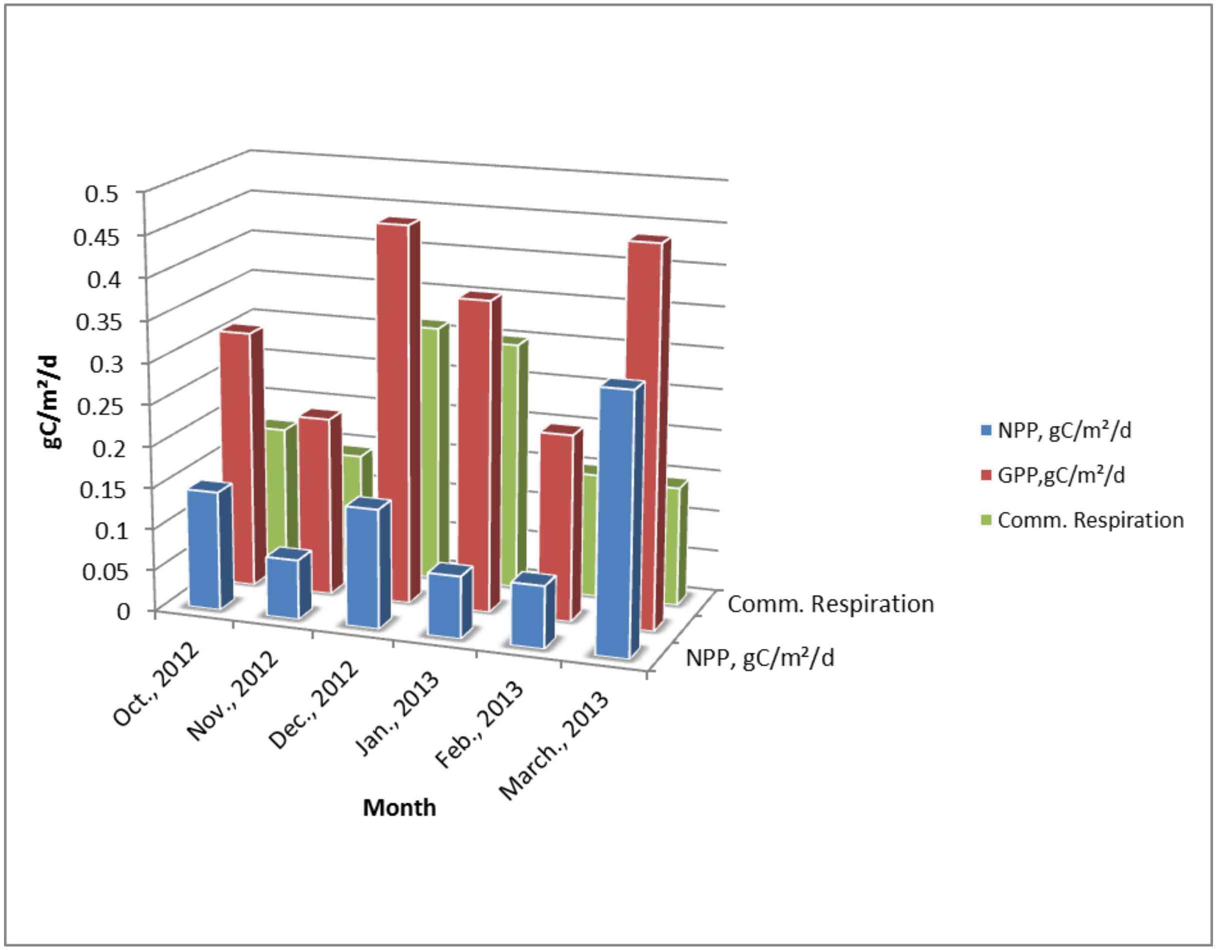

Figure 2: Monthly Variation in Primary Productivity at NIOMR Jetty Station in Lagos Harbour during the study period.

TABLE 2: Pearson Correlation Co-efficient Matrix of all variables measured at NIOMR Jetty station in Lagos Harbour

	Air Temp.^{0}C	Water Temp. ^{0}C	pH	Salinity (psu)	Cond. (µS/cm)	DO (mg/l)	TDS mg/l	Alkalinity (mg/l)	Rainfall (mm)	NPP (gC/m²/d)	GPP (gC/m²/d)	CR (gC/m²/d)
Air Temp.^{0}C	1											
Water Temp.^{0}C	0.707	1										
pH	-0.363	0.051	1									
Salinity (psu)	-0.246	0.479	0.270	1								
Cond. (µS/cm)	-0.261	0.465	0.264	0.999**	1							
DO (mg/l)	0.250	-0.030	0.318	-0.469	-0.477	1						
TDS (mg/l)	-0.261	0.465	0.264	0.999**	0.999**	-0.477	1					
Alkalinity (mg/l)	0.206	0.000	-0.142	-0.354	-0.354	-0.305	-0.354	1				
Rainfall (mm)	0.661	-0.024	-0.381	-0.880*	-0.887*	0.419	-0.887*	0.481	1			
NPP (gC/m²/d)	0.366	0.452	0.345	0.100	0.088	0.798	0.088	-0.556	0.029	1		
GPP (gC/m²/d)	-0.087	0.064	0.485	0.162	0.156	0.556	0.156	-0.864*	-0.274	0.685	1	
CR (gC/m²/d)	-0.537	-0.434	0.250	0.101	0.106	-0.174	0.106	-0.515	-0.399	-0.234	0.547	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
N = 6

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