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In-Stream Sand Mining and Primary Productivity of Otamiri River in Owerri, South-East Nigeria

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ABSTRACT: *Sand mining involves the excavation of inland dune or river beds for the purpose of economic, developmental, constructional, etc., activities. Primary productivity therefore, is the frequency at which energy is transformed to organic substances by photosynthesis producers (photoautotrophs), which obtain energy and nutrients by requisite sunlight. Probable influence of sand mining on primary productivity of the mined ponds along the banks of the river was considered. The study undertakes an experimental research approach. Six (6) sampling locations were identified as WC1-WC6 along the course of the river. WCI-WC3 was established in area where active mining had ceased (unperturbed) whereas WC4-WC6 was established in area where active sand mining is ongoing (perturbed). The study utilized the light and dark technique to estimate primary productivity, and the set-up was incubated for four (4) hours in a sunny day. In situ measurement was carried out with HANNA 1H9828 pH/ORP/EC/DO meter and the average of the triplicate results obtained was recorded. Descriptive statistics, analysis of variance (ANOVA), student's t-test and the structure detection of group mean were utilized for the organization of data. Results inter alia revealed that the actively mined ponds of the river had higher GPP ($12.781*10^{-1}$ $MgCL^{-1}d^{-1}$) than the location where mining had ceased (i.e., GPP $5.986*10^{-1}$ $MgCL^{-1}d^{-1}$). The average GPP was $18.767*10^{-1}MgCL^{-1}d^{-1}$ while NPP and CR had $10.914*10^{-1}$ $MgCL^{-1}d^{-1}$ and $15.453*10^{-1}MgCL^{-1}d^{-1}$ respectively. The annual GPP of the study was $1144.800*10^{-1}MgCL^{-1}yr^{-1}$ which define low productivity. Thus, it was recommended that an enforcement of various environmental laws as it affects the preservation, maintenance and the sustenance of the aquatic environment be made in a bid to secure aquatic lives.*

KEY WORDS: Gross primary productivity, Net primary productivity, Community respiration, Biomass, Photosynthesis, Sunlight, Aquatic Ecosystem, Carbohydrate.

INTRODUCTION

Ecosystem emphasises the movement of energy and nutrients among biotic and abiotic components of the environment. The ecosystem is the largest level of biological organisation and all concept can be set within its framework [1, 2, 3. 4]. An ecosystem must include at least an autotroph (primary producer), and a decomposer, water and a source and sink of energy, and all chemical elements required by autotrophs and decomposers [5, 6]. The autotrophs capture energy in form of electromagnetic radiation from simple inorganic compound such as carbon (iv) oxides and water, and convert them into chemical forms. The product of primary production may then be used to synthesize further more complex molecules such as protein, complex carbohydrates, lipids and nucleic acids, or be respired to release energy for work [7, 8, 9, 10]. These organic molecules and their potential are moved by the food chain through trophic relationship [11] and thus energising the entire biosphere.

Primary production proceeds through the process of photosynthesis [3]. The major limiting factors to primary production in an aquatic system are light (solar radiation) and nutrients [12, 13, 10]. Albeit, temperature and seasonal variations in light intensity also exert influences on the distribution of phytoplankton (algae) [14]. Consequently, one of the anthropogenic causes of increased turbidity in water bodies could be traceable to sand mining activities [10]. According to [15], sand mining could exercise both disadvantageous and beneficial effects to include alterations of hydrological regime, sediments suspension, increase turbidity, impact on flora and fauna, improvement of navigational channels, land reclamations, flood mitigations, socio-economic development among others. More so, it forces the river to change course, erode banks, alters river bed, and lead to flooding, destroy habitat of aquatic animals and micro-organisms beside affecting groundwater recharge [16].

Nevertheless, in an aquatic ecosystem, the main aim of productivity measurements is to have a better understanding of the relationships between food web and the functioning of these ecosystems. Still, the ability to bind carbon differ due to differences in productivity [17].

PRIMARY PRODUCTION

Carbon (iv) oxide, water, nutrients, and sunlight are needed by plants through the process of photosynthesis. During this process, light energy is converted into stored energy within the plant tissues, and the energy fuels the metabolic machinery of the plant. The most important key in this process is chlorophyll- a unique green molecule that absorbs light energy and uses it to create high energy chemical bond in compounds that serves as the fuel for all subsequent cellular metabolism [9, 8, 18]. The molecular presentation of the process is hereunder defined as;

$$12H_2O + 6CO_2 + 7O4K_{cal} \underset{\text{sunlight}}{\xrightarrow{\text{chlorophyll enzymes}}} \underset{\text{Carbohydrate}}{C6H12} + 6O_2 + 6H_2O \quad (1)$$

$$CO_2 + O_2 + 4H_2S \rightarrow CH_2O + 4S + 3H_2O \quad (2)$$

Equation (1) and (2) are simplified illustration of photosynthesis. Specifically, equation (1) define photosynthesis while equation (2) defines chemosynthesis. The end-point of these two processes is a polymer of reduced carbohydrate $(CH_2O)_{n,}$ characteristically molecules exemplified as glucose or other sugars. These comparatively simple molecules might be used to further synthesize more complicated molecules such as protein, lipids, nucleic acids, and complex carbohydrates, or be respired to perform work. At that point, heterotrophic organisms (consumers of primary producers) for example animals, transfers these organic molecules up the food web (and the energy stored in them) which fuel all the earth's living system [19, 20, 21, 22, 23].

According to [9], the general equation can be represented as:

$$CO_2 + H_2O \longrightarrow (CH_2O)_n + O_2 \qquad (3)$$

MATERIALS AND METHODS

Study Area

The Otamiri River rises from Egbu in Owerri Local Government Area of Imo State, South-East, Nigeria, appeared to be one of the major surface water bodies that transverse the city. This water body serves as domestic source of water and piscatorial activities including artisanal and sand mining by the locals. According to [8], the city lies between latitude $5^{\circ}\ 29^{/}$ 06S and longitude $7^{\circ}\ 02^{/}$ 06s with seasonal characteristics of wet season (April to November) and dry season (last for the rest of the year). The study area has a deciduous forest with gross interference by man [24]. Mean daily average temperature ranged from 28° to 35°C with an average humidity up to 80%.

Collection of Water Samples

Six sampling stations were identified and designated as water column (WC1-WC6) along sand mined ponds at the middle of the Otamiri River in Owerri. WC1-WC3 were cited in unperturbed (derelict) while WC4-WC6 were cited at an active perturbed (where sand mining is ongoing.) Water samples was collected at the pelagial level of the river and was stoppered while submerged. Samples for laboratory analysis were collected in 1ml sterile containers and were fixed with 2 drops of HNO_3 and transported to the laboratory in ice packed cooler.

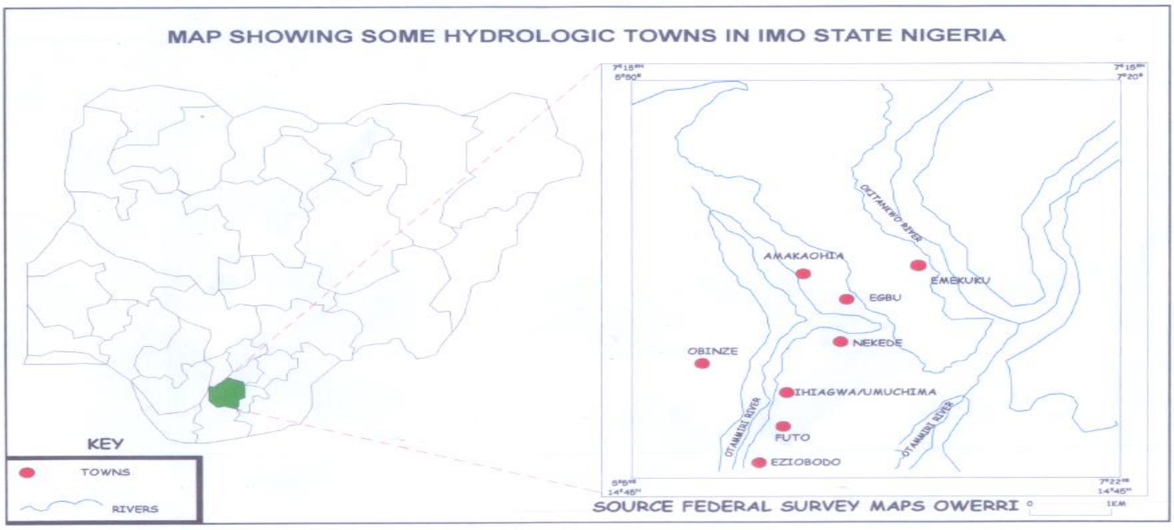

Figure 1: Hydrological Map of Imo State Showing the study Area

Field Measurement

In aquatic ecosystems, primary productivity measurement is typified by three main techniques according to [21], which include:

1. Variation in oxygen concentration within a sealed bottle.
2. Incorporation of inorganic C^{14} (in the form of sodium bicarbonate - $NaCO_3$ into organic matter.)
3. Fluorescence kinetics

Therefore, this study makes use of the technique developed by Gaarder and Gran in 1927, which observes the variation in oxygen concentration. The dark and the light bottle technique was applied. The first bottle while submerged, was stoppered and brought out to be analysed immediately representing the initial oxygen (O_2) concentration while the other two bottles were suspended at the pelagic water zone aided by a rope. One of the two bottles was covered with black polythene (dark) while the other remain being transparent (light). The set-up was incubated for four (4) hours in a sunny afternoon [25, 5]. Immediately after the incubation period, the bottles were brought out and the O_2 concentrations in them were measured with the aid of HANNAH1 9828 PH/ORD/EC/DO meter. The experiment was done in triplicates and the average recorded. The dark bottle provided respiration and photosynthesis.

Model for Primary Productivity

The relevant primary productivity variables were computed and expressed as mg of O_2 produced per litre of water per day using the following model:

$$GPP\ (Mg\ O_2\ L^{-1}d^{-1}) = NPP\ (Mg\ O_2L^{-1}d^{-1}) + CR\ (MgO_2L^{-1}d^{-1}) \quad (4)$$

According to [13] and [5] the acronyms as enshrined below simply means:

GPP: Gross Primary Productivity (Photosynthesis)

NPP: Net Primary Productivity (Photosynthesis)

CR: Community Respiration

According to [23], Gross primary production (GPP) simply refers to the total rate of organic carbon production by autotrophs, whereas Net primary production (NPP) is the rate at which the full metabolism of phytoplankton produces biomass, and Respiration is the energy-yielding oxidation of organic carbon back to carbon dioxide. However, NPP is GPP minus the autotrophs' own rate of respiration and is represented stoichiometrically [8, 23, 26] as:

$$NPP = GPP - CR \quad (5)$$

Again, the carbon equivalents of productivity variables were computed by multiplying the O_2 value by 0.375 and expressed as $MgCL^{-1}d^{-1}$ [3].

RESULTS

Spatial Variations in Primary Production

There were variations across the sampling locations of the primary productivity parameters. The maximum GPP ($6.413*10^{-1}$) $MgCL^{-1}d^{-1}$ was recorded in sampling location 6 (WC6) whereas the minimum GPP ($1.800*10^{-1}$) $MgCL^{-1}d^{-1}$ was recorded in 1 (WC1). Furthermore, maximum NPP ($3.150*10^{-1}$) $MgCL^{-1}d^{-1}$ was recorded in WC4 whereas the minimum productivity NPP ($5.180*10^{-2}$) $MgCL^{-1}d^{-1}$ was recorded in WC6. Finally, maximum CR ($5.895*10^{-1}$) $MgCL^{-1}d^{-1}$ was recorded in WC6 while minimum CR ($1.350*10^{-2}$) $MgCL^{-1}d^{-1}$ was recorded in WC5 (Table 1).

Table 1: Primary Productivity of Otamiri River across Sampling Locations

Location: Water Column (WC)		Productivity ($MgCL^{-1}d^{-1}$)	
	GPP	NPP	CR
WC1	$1.800*10^{-1}$	$7.880*10^{-2}$	$1.013*10^{-1}$
WC2	$2.093*10^{-1}$	$1.800*10^{-1}$	$2.930*10^{-1}$
WC3	$2.093*10^{-1}$	$1.800*10^{-1}$	$2.290*10^{-1}$
WC4	$3.375*10^{-1}$	$3.150*10^{-1}$	$2.250*10^{-1}$
WC5	$2.993*10^{-1}$	$2.858*10^{-1}$	$1.350*10^{-2}$
WC6	$6.413*10^{-1}$	$5.180*10^{-2}$	$5.895*10^{-1}$

GPP=Gross Primary Productivity, NPP=Net Primary Productivity, CR=Community Respiration, *=Multiplication sign (x)

The test for homogeneity in the mean variant of the primary productivity variables across the sampling locations utilizing the single factor analysis (ANOVA) revealed that there was a significant heterogeneity **[**$F_{(62.47)} > Fcrit$ (4.13)**]** at $P<0.05$ (Table 2).

Table 2: Analysis of Variance (ANOVA)

Source of Variation	SS	df	MS	F	P- Value	F_{crit}
Between Groups	47.5041	1	97.5041	62.47103	3.32	4.130018
Within Groups	53.06683	34	1.560789			
Total	150.5709	35				

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A further structure detection of group means that utilised WC1 as predictor variables revealed that in WC2, WC3, WC4, and WC5 respectively, NPP ($7.880*10^{-2}$) $MgCL^{-1}d^{-1}$ and GPP ($1.800*10^{-2}$) $MgCL^{-1}d^{-1}$ were most responsible for the observed homogeneity (Figure 2,3,4, and 5). Nonetheless, in WC6, CR ($1.013*10^{-1}$) $MgCL^{-1}d^{-1}$and GPP ($1.800 * 10^{-1}$) $MgCL^{-1}d^{-1}$ were most responsible for the observed heterogeneity.

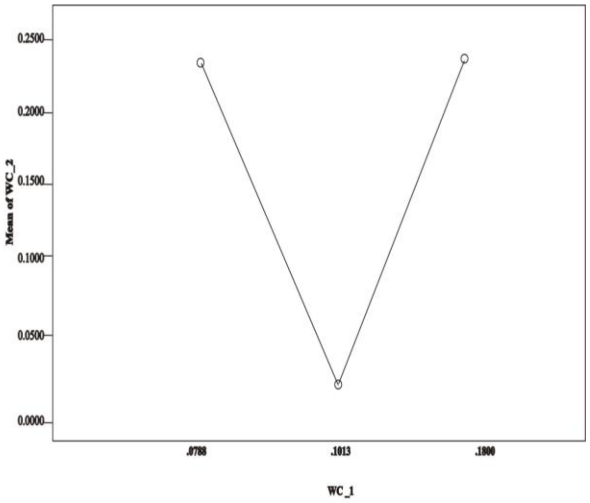

Fig. 4.3. Means plot in Primary Productivity between Sampling Points 1 and 2

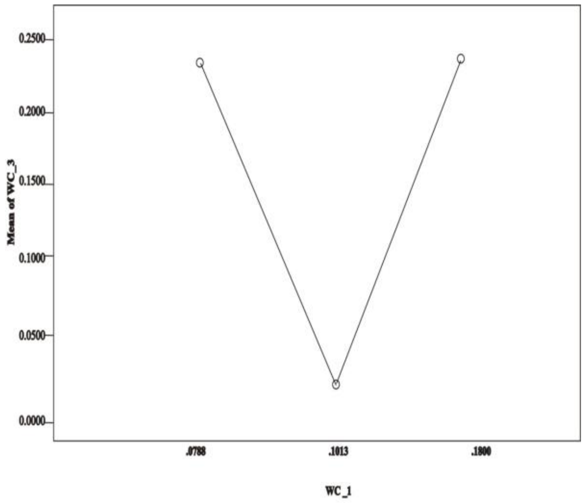

Fig. 4.4. Means plot in Primary Productivity between Sampling Points 1 and 3

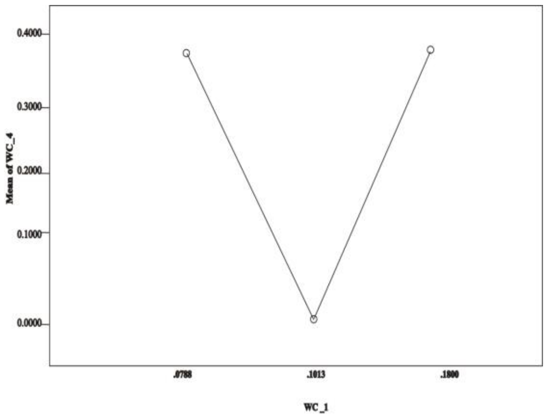

Fig. 4.5. Mean plot in Primary Productivity between Sampling Points 1 and 4

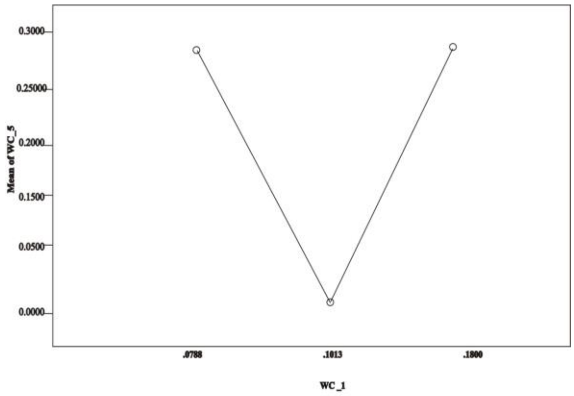

Fig. 4.6. Mean plot in Primary Productivity between Sampling Points 1 and 5

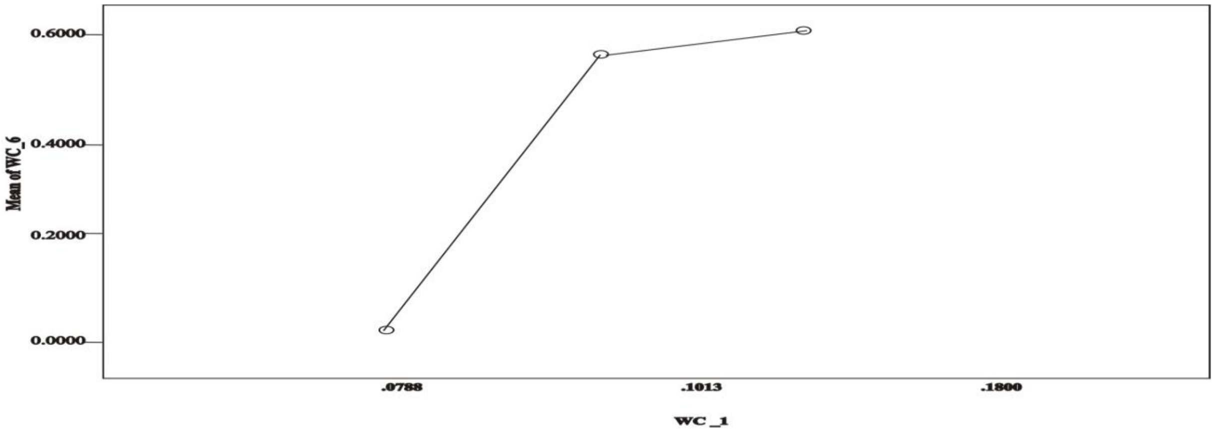

Fig. 4.7. Mean plot in Primary Productivity between Sampling Points 1 and 6

Comparison of Primary Productivity in Mine Ponds

The student's t-test of significance between pooled primary productivity values in the actively mined (WC4 – WC6) and derelict ponds (WC1 – WC3) (Table 3) revealed significant difference (Sig t = 0.009) at P<0.05. However, the variables did not show significant correlation between the ponds (Sig r = 0.158) at P<0.05

Table 3: Comparison of Primary Productivity in Actively Mined and Derelict Ponds on Otamiri River using Student T-Test of Significance (P<0.05).

Impact	Mean	S. E	R	Sig. r	T	Sig. t
Actively Mined	0.1333	0.04410	0.969	0.158	-10.417	0.009
Derelict	0.3267	0.05783				

S.E = Standard Error of Mean, Sig.=Significance.

DISCUSSION

Ecologically, primary production is the amalgamation of organic compounds either from aqueous carbon dioxide or atmosphere. The amount of plant tissue builds up by photosynthesis over time is known as primary productivity [27, 28]. Net primary production (NPP) is strictly defined as the difference between the energy fixed by autotrophs and their respiration, and it is most commonly equated to increments in biomass per unit of land surface and time [19]. However, the average GPP of 18.767*10^{-1} $MgC^{-1}d^{-1}$ in this study was low and comparable to that obtained by [26]. Nonetheless, values were lower than that obtained by [27, 22, 8] in Imo River Etche but values were higher than that recorded by [29] in Asa Lake, South-western Nigeria. The Net primary productivity had an average of 10.914*$10^{-1}$$MgC^{-1}d^{-1}$ while Community respiration had 15.453*$10^{-1}$$MgC^{-1}d^{-1}$ respectively. On the other hand, values were higher than those recorded by [13] in the United State Appalachian coal region. The present study gives an annual productivity of $1144.85*10^{-1}$ $MgCL^{-1}yr^{-1}$ only. The observed low productivity could be associated with ongoing intense sand mining activities along the river as perturbation of the benthal region give rise to murkiness of the river which explicitly interfere with sunlight, and thereto influence primary productivity negatively. More so, other factors such as nutrients, depth could also inhibit primary production [30].

The primary productivity of actively mined ponds of the river (WC4-WC6) had higher productivity of $12.781*10^{-1}$ $MgCL^{-1}d^{-1}$ than the derelict mined pond of the river (WC1-WC3) i.e., $5.986*10^{-1}$ $MgCL^{-1}d^{-1}$ implying that the productivity varied distinctively within the actively mined and derelict locations. The variability in productivity between the actively mined and the derelict could be associated with the bioavailability of pollutants such as chlorinated hydrocarbon (CHC), heavy metals on one hand and the nutrient factor like phosphate (PO_4^{2-}), nitrate (NO_3^-), sulphate (SO_4^{3-}), carbon (iv) oxide (CO_2) etc., on the other hand. Literatures have indicated that some pollutants like the heavy metals are more bioavailable and thus have greater toxicities toward aquatic lives, including autotrophic algae, at acidic pH [31, 32, 33, 34].

SUMMARY OF FINDINGS

1. The average GPP in this study was low.
2. The annual productivity of this study was low.
3. Ongoing intense sand mining activities encourages murkiness of water column.
4. Turbidity in water column influences photosynthetic activities negatively.
5. Excavation of benthal region of the river could enhances bioavailability of nutrients.
6. Sand mining could lead to biodiversity loss of benthal organism.
7. Actively mind ponds of the river exhibited higher productivity than derelict.

CONCLUSION

In the biosphere, the most basic ecological process is the fixation of photosynthetic energy by green plants (i.e., primary production). Possibly, turbidity, nutrients and heavy metals serves as key driver impact factors of photosynthetic process in an aquatic ecosystem. The observed higher productivity in the actively mined ponds of the river as against the derelict could be due to higher essential nutrients availability which seemed to destabilize a slightly increase turbidity.

RECOMMENDATION

Sequel to the findings in this study, the authors recommended the followings:

1. There should be an integrated organs of governmental agencies saddled with the responsibility to monitor and control artisanal sand mining activities across the length

and breadth of the Imo River in a bid to preserve and promote productivity of the aquatic ecosystem.

2. There should be a sensitization and awareness on the part of the artisanal miners in a bid to encourage mitigation of impact on primary productivity.

3. There should be an enforcement of various environmental laws as it affects the preservation and sustenance of the aquatic environment.

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COMPETING INTEREST

Authors have declared that no competing interest exist.

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