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Estimation of primary production along gradients of the middle course of Imo River in Etche, Nigeria

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ABSTRACT

The authors investigated the dynamics in spatial yields of primary production in the middle course of the Imo River in Etche, South-eastern Nigeria. At seven sampling locations along the course of the river, *in situ* measurements for water temperature, pH, turbidity, and dissolved oxygen (DO) were made with HORIBA U-10 Water Quality Checker. Water samples were collected in 500 ml sterile containers for further laboratory analysis using standard methods. The light and dark bottle technique was employed in the measurement of primary production. Correlation coefficient (r) was used to establish relationships between physicochemical variables and primary production while the One-Way ANOVA was used to determine variance equality of means in spatial yields. Means were further separated for the identification of variant productivity variables using the means plot. Wide variations were observed in turbidity (11.0-279.0, mean = 96.7 ± 9.3 NTU), DO (4.50-8.81, mean = 6.96 ± 0.14 mg/l), and sulphate (0.90-8.10, mean = 4.35 ± 0.25 mg/l) across the sampling locations. Gross and net primary production (GPP & NPP) as well as community respiration (CR) ranged from 0.01-1.12 (0.09 ± 0.02), 0.01-0.10 (0.04 ± 0.003), and 0.002-0.05 (0.02 ± 0.002) $gCm^{-2}d^{-1}$, respectively. Sampling location 1 showed the highest GPP, NPP, and CR of 0.09, 0.06, and 0.03 $gCm^{-2}d^{-1}$, respectively while location 7 showed the least GPP of 0.06 $gCm^{-2}d^{-1}$, and locations 2-7 showed the least CR of 0.02 $gCm^{-2}d^{-1}$ each. At $P<0.01$, GPP correlated negatively with turbidity (r=-0.322) and sulphate (r=-0.297), NPP correlated positively with pH (r=0.404) and negatively with DO (r=-0.567), turbidity (r=-0.592), nitrate (r=-0.435), phosphate (r=-0.365), and sulphate (r=-0.594) and CR correlated positively with pH (r=0.363) and negatively with DO (r=-0.510), turbidity (r=-0.547), nitrate (r=-0.405), phosphate (r=-0.304), and sulphate (r=-0.551). Variances in means of primary production variables showed inequality at $P<0.05$ at sampling locations 1 and 4. The observed oligotrophic production of the river was most probably due to low water nutrient levels, high turbidity and high relative humidity prevalent in the area.

KEYWORDS

Etche;
Primary production;
Oligotrophic;
Community respiration;
Phytoplankton.

INTRODUCTION

All life forms depend on primary production, a biochemical synthesis of organic compounds (reduced carbohydrate such as glucose and other sugars) by autotrophs, which form the base of the trophic chain. These autotrophs, which are mainly algae in aquatic ecosystems, capture energy in the form of electromagnetic radiation from the sun and synthesize complex organic molecules from simple inorganic compounds such as carbon (IV) oxide and water, and convert them to chemical forms. The product of primary production may then be used to synthesis further more complex molecules such as protein, complex carbohydrates, lipids, and nucleic acids, or be respired to release energy for work. These organic molecules and their potential energy are moved up the food chain through trophic relationships, thus, energizing the entire biosphere.

Primary production proceeds through the process of photosynthesis, with chemosynthesis being much less important[10]. A very tiny fraction of primary production is driven by organisms utilizing the chemical energy of inorganic molecules. In aquatic ecosystems, the major limiting factors to primary production are light (solar energy) and nutrients[4,8] though temperature and seasonal variations in light intensity also exert influences on the distribution of phytoplankton (algae)[9].

There exist paucity of primary production studies and their documentations in Nigerian rivers such as the Imo River; a major aquatic ecosystem in the Niger Delta area, even as the river serves both domestic and food uses. It is in this regard that the authors investigated the spatial variability in primary production of the middle course of the Imo River. We set out with the following objectives.

Determination of some physicochemical characteristics (temperature, pH, dissolved oxygen, turbidity and nutrients) of the river.

Measurement of spatial variability in its gross and net primary production (GPP and NPP) as well as community respiration (CR).

Determination of spatial relationships between primary production and the physicochemical characteristics.

MATERIAL AND METHODS

Study area

The study was conducted on the middle course of the Imo River between longitude 06° 05' and 07°14′E and latitude 05° 08' and 04°45′N (Figure 1). The river is an integral part of the lowland drainage basin of the

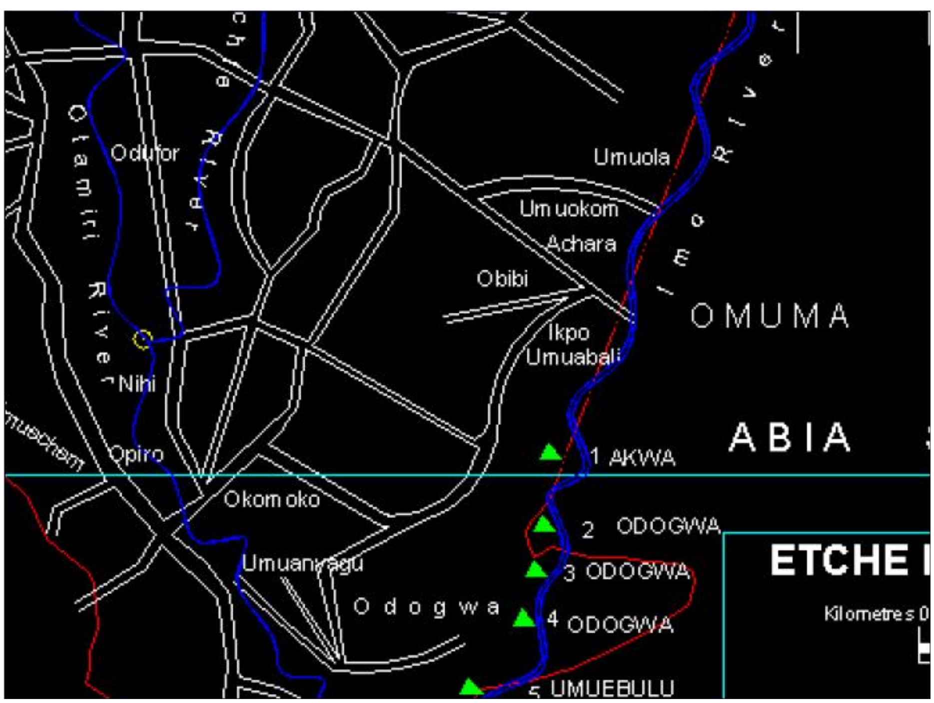

Figure 1 : Map of Etche showing the sampling locations

TABLE 1 : Physicochemical characteristics of Imo River

Parameter	Minimum	Maximum	Mean	SE
Water temperature (°C)	24.00	28.10	26.89	0.12
pH	6.00	6.70	6.40	0.02
DO (mg/l)	4.50	8.81	6.96	0.14
Turbidity (NTU)	11.0	279.0	96.7	9.3
NO_3^- (mg/l)	0.10	1.35	0.54	0.04
PO_4^{2-} (mg/l)	0.07	0.23	0.13	0.01
SO_4^{2-} (mg/l)	0.90	8.10	4.35	0.25
GPP ($gCm^{-2}d^{-1}$)	0.01	1.12	0.09	0.02
NPP ($gCm^{-2}d^{-1}$)	0.01	0.10	0.04	0.003
CR ($gCm^{-2}d^{-1}$)	0.002	0.05	0.02	0.002

DO = dissolved oxygen, NO_3^- = nitrate, PO_4^{2-} = phosphate, SO_4^{2-} = sulphate, GPP = gross primary production, NPP = net primary production, CR = community respiration

Niger Delta region, where wet season generally lasts for about 300 days per year between March and November.

Atmospheric temperature ranges from between 24 and 38°C and humidity could reach as high as 90%, usually during the wet season. The major activity of inhabitants of the area is farming, though some also engage in petty trading, palm wine tapping, fishing, hunting and sand dredging.

Sampling locations

Seven sampling locations were established along the course of the river in Etche Local Government Area, Rivers State. Location 1 was situated upstream at Akwa, locations 2, 3, and 4 were situated about 1 km apart in Odogwa, with location 2 situated about 2km from 1. Location 5, 6, and 7 were also situated about 1km apart in Umuebulu, with location 5 situated about 3km from 4. Odogwa and Umuebulu communities house oil and gas facilities belonging to the Shell Petroleum Development Company of Nigeria (SPDC).

Field measurements

The HORIBA U-10 Water Quality Checker was used to measure water temperature, pH, turbidity, and dissolved oxygen (DO) *in situ*. Water samples for laboratory analysis were collected in 500ml sterile containers and taken to the laboratory in iced-cooler.

Laboratory analysis

Nitrate was determined by the cadmium reduction method, sulphate by the barium chloride (turbidometric) method, and phosphate by ascorbic acid method[3].

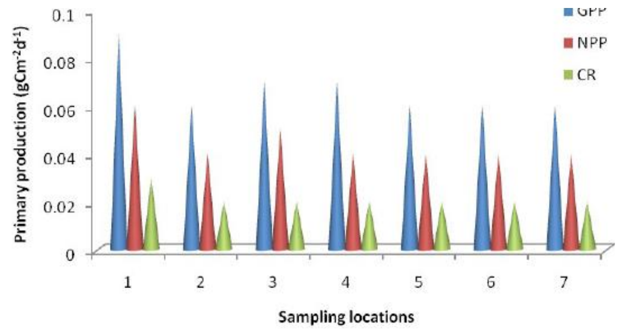

Figure 2 : Spatial variation in mean primary production of Imo River

Primary production measurements

Three identical transparent 1-litre bottles were filled with the river water and stoppered while still submerged. The first bottle was analyzed immediately and used to determine the initial O_2 concentration, while the other two bottles were suspended in the pelagial water zones where the water had been taken, with the aid of a rope; one covered with black polythene(dark bottle) and the other not covered (ie transparent; light bottle). The setup was allowed to stand for 4 hours in sunny afternoons[5]. Immediately after the incubation period, the bottles were brought out and the O_2 concentrations in them measured with HORIBA U-10 Water Quality Checker. This experimentation was done in replicates and the average recorded.

As photosynthesis would not have taken place in the dark bottle, it provided a measure of respiration while the light bottle that permitted both photosynthesis and respiration provided a measure of net photosynthesis.

Calculation

GPP ($mgO_2l^{-1}d^{-1}$) = NPP ($mgO_2l^{-1}d^{-1}$) + CR ($mgO_2l^{-1}d^{-1}$)

where GPP is gross primary production (photosynthesis), NPP is net primary production (photosynthesis), and CR, community respiration[10].

Relevant productivity estimates so obtained were converted to $gCm^{-2}d^{-1}$ according to APHA[3] as adopted by Ikenweiwe and Otubusin[5].

Statistical analysis

The interaction of the physicochemical variables with primary production was established with the Pearson Product Moment Correlation (r), while the One-Way

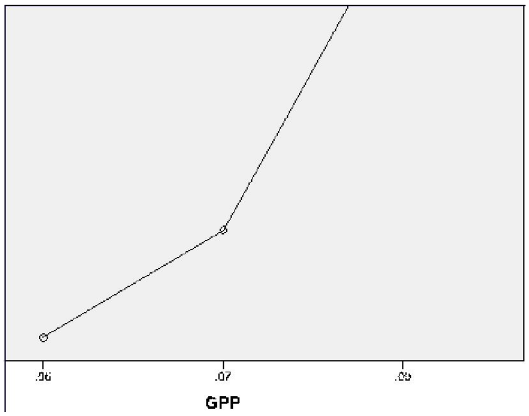

Figure 3a : Mean separation of primary production variables across the sampling locations

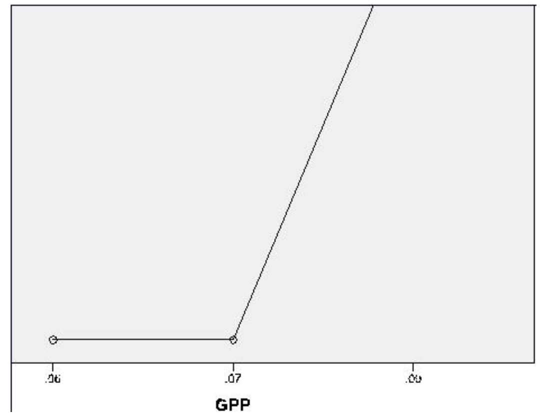

Figure 3b : Mean separation of primary production variables across the sampling locations

TABLE 2 : Correlations (r) between the physicochemical characteristics and primary production of Imo River

Parameter	Wtemp	pH	DO	Turb	NO_3	PO_4^2	SO_4^2
GPP	-0.114	0.170	0.206	0.322**	0.141	0.204	0.297**
NPP	-0.007	0.404**	0.567**	0.592**	0.435**	0.365**	0.594**
CR	-0.106	0.363**	0.510**	0.547**	0.405**	0.304**	0.551**

****significant at P<0.01, Wtemp = water temperature, Turb = turbidity, GPP = gross primary production, NPP = net primary production, CR = community respiration**

TABLE 3 : Equality of means in primary production of Imo River using the One-Way ANOVA

Parameter	F-values		Significance (P<0.05)
	Calculated	Critical	
GPP	315.12	3.90	Significant
NPP	324.82	3.90	Significant
CR	328.27	3.90	Significant

GPP = gross primary production, NPP = net primary production, CR = community respiration

Analysis of Variance (ANOVA) was used to determine equality of means in spatial yields in productivity. Means were further separated for the identification of variant productivity variable(s).

RESULTS

Turbidity (96.7 ± 9.3 NTU), DO (6.96 ± 0.14 mg/l), nitrate (0.54 ± 0.04 mg/l), and sulphate (4.35 ± 0.25 mg/l) all showed comparatively wide variations across the sampling locations (TABLE 1). However, pH, temperature, and phosphate did not vary widely. GPP and NPP ranged between 0.01 and 1.12 (0.09 ± 0.02) and 0.01 and 0.10 (0.04 ± 0.003) $gCm^{-2}d^{-1}$ respectively. CR ranged between 0.002-0.05 (0.023 ± 0.002) $gCm^{-2}d^{-1}$.

Sampling location 1 showed the highest GPP, NPP and CR values of 0.09, 0.06, and 0.03 $gCm^{-2}d^{-1}$ respectively, while site 7 showed the least GPP (0.06) $gCm^{-2}d^{-1}$. However, locations 2-7 showed the least CR values of 0.02 $gCm^{-2}d^{-1}$ (Figure 2).

At P<0.01, GPP correlated negatively with turbidity (r=-0.322) and sulphate (r=-0.297) while NPP correlated positively with pH (r=0.404) and negatively with DO (r=-0.567), turbidity (-0.592), nitrate (r=-0.435), phosphate (r=-0.365) and sulphate (r=-0.594) (TABLE 2). CR correlated positively with pH (r=0.363) and negatively with DO (r=-0.510), turbidity (-0.547), nitrate (r=-0.405), phosphate (r=-0.304), and sulphate (r=-0.551) (P<0.01).

The means of all the primary production variables across the spatial gradient showed significant inequalities at P<0.05 (TABLE 3). Between GPP and NPP, the inequality was accounted for at sampling locations 4 and 1, while between GPP and CR, it was accounted for at sampling location 1 (Figure 3a & b).

DISCUSSION

The GPP of this study is low when compared with the works of Samaan[7] in Nasser Lake, Mbagwu and Adeniji[6] in Mariut Lake and Ikenweiwe and Otubusin[5] in Oyan Lake, South-Western Nigeria. However, it was higher than mean values recorded by Adeniji[1] in Bakolori Lake, Sokoto State and by Adeniji[2] in Asa Lake in Ilorin. This low productivity could be attributed to several possible reasons such as low nutrient levels (especially nitrate and phosphate), photoperiodicity (especially considering the high relative humidity prevalent in the area), and high turbidity, which exerts influences on photosynthesis of the autotrophs. The significant influences of pH and DO on productivity variables confirm their vital roles in ecosystems processes.

Sampling locations 1, with the highest primary production also had the least turbidity and highest sulphate and DO concentrations. This highest productivity was responsible for the observed spatial inequality in means of the production variables.

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