International Journal of Biosciences (IJB)
ISSN: 2220-6655 (Print) 2222-5234 (Online)
Vol. 1, No. 4, p. 68-73, 2011
http://www.innspub.net

INNSPUB

RESEARCH PAPER

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

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Received: 22 June 2011
Revised: 5 July 2011
Accepted: 6 July 2011

Key words: Etche, primary production, oligotrophic, community respiration, phytoplankton

Abstract

Dynamics in spatial yields of primary production in the middle course of the Imo River in Etche, South-eastern Nigeria has been investigated. 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. The light and dark bottle technique was used to measure primary production. Wide variations were observed in turbidity (11.0-279.0, mean = 96.7 ± 9.3 NTU), DO (4.50-8.81, mean = 6.96 ± 0.14mg/l), and sulphate (0.90-8.10, mean = 4.35 ± 0.25mg/l) across the sampling locations. Gross and net primary production (GPP & NPP) as well as community respiration (CR) ranged from 0.10-11.2 (0.9 ± 0.2), 0.1-1.0 (0.4 ± 0.03), and 0.02-0.5 (0.2 ± 0.02) $mgO_2l^{-1}d^{-1}$, respectively. Sampling location 1 showed the highest GPP, NPP, and CR of 0.9, 0.6, and 0.3 $mgO_2l^{-1}d^{-1}$, respectively while location 7 showed the least GPP of 0.6 $mgO_2l^{-1}d^{-1}$, and locations 2-7 the least CR of 0.2$mgO_2l^{-1}d^{-1}$each. At $P<0.01$, GPP correlated negatively with turbidity (r=-0.322) and sulphate (r=-0.297), NPP correlated negatively with turbidity (r=-0.592), nitrate (r=-0.435), phosphate (r=-0.365), and sulphate (r=-0.594) and CR correlated negatively with turbidity (r=-0.547), nitrate (r=-0.405), phosphate (r=-0.304), and sulphate (r=-0.551). Marked variance in means of primary production attributes at $P<0.05$ was mostly observed in sampling locations 1 and 4.The observed oligotrophic production of the river was most probably due to low nutrient levels and high turbidity, which blankets off sunlight necessary for photosynthesis.

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Introduction

All life forms depend on primary production, a biochemical synthesis of organic compounds (reduced carbohydrate such as glucose and other sugars) by autotrophs (Hall and Rao, 1994), 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 (Spaak and Bauchrowitz, 2010), thus, energizing the entire biosphere.

Primary production proceeds through the process of photosynthesis, with chemosynthesis being much less important (Global Change, 2008).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 (Guildford and Hecky, 2000; Simmons *et al*., 2004); though temperature and seasonal variations in light intensity also exert influences on the distribution of phytoplankton (algae) (Vaillancourt *et al*., 2003). 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 objectives aimed at the determination of some physicochemical characteristics, spatial variability in gross and net primary production (GPP and NPP) as well as community respiration (CR), as well as the relationships existing between primary production variables and the physicochemical regime of the river.

Materials 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 (Fig. 1). The river is an integral part of the lowland drainage basin of the 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 mining in this river.

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).

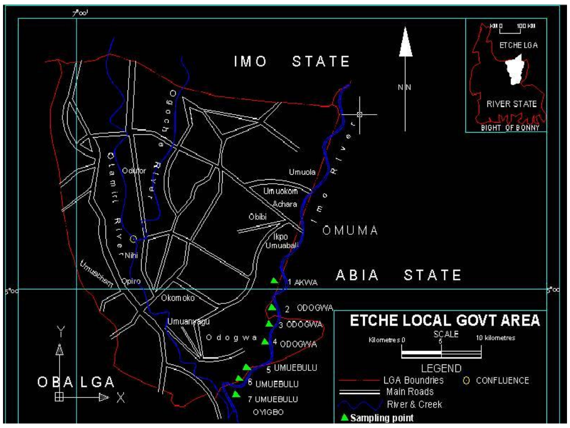

Fig. 1. Map of Etche showing the sampling locations.

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 (APHA, 1998).

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_2concentration, 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 (i.e. transparent; light bottle). The setup was allowed to stand for 4 hours in sunny afternoons (Ikenweiwe and Otubusin, 2005). 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

The relevant primary production variables were calculated and expressed as mg of O_2 produced per litre per day using the following formula:

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 (Simmons *et al.*, 2004).

Statistical analysis

The interaction of the physicochemical variables with primary production was established with the Pearson Product Moment Correlation (r), while the single factor analysis of variance (ANOVA) was used to determine variance equality in means of spatial yields in productivity. Structure detection of group means for the identification of variant productivity variable(s) was further made using means plots.

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 0.1 and 11.2 (0.9±0.2) and 0.1 and 1.0 (0.4±0.03) $mgO_2l^{-1}d^{-1}$respectively.CR ranged between 0.02-0.5 (0.23±0.02) $mgO_2l^{-1}d^{-1}$.

Table 1. Physicochemical characteristics and primary production of Imo River at 7 sampling locations.

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 ($mgO_2l^{-1}d^{-1}$)	0.1	11.2	0.9	0.2
NPP ($mgO_2l^{-1}d^{-1}$)	0.1	1.0	0.4	0.03
CR ($mgO_2l^{-1}d^{-1}$)	0.02	0.5	0.23	0.02

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

Sampling location 1 showed the highest GPP, NPP and CR values of 0.9, 0.6, and 0.3 $mgO_2l^{-1}d^{-1}$respectively, while site 7 showed the least GPP (0.6) $mgO_2l^{-1}d^{-1}$. However, locations 2-7 showed the least CR values of0.2$mgO_2l^{-1}d^{-1}$ (Fig. 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).

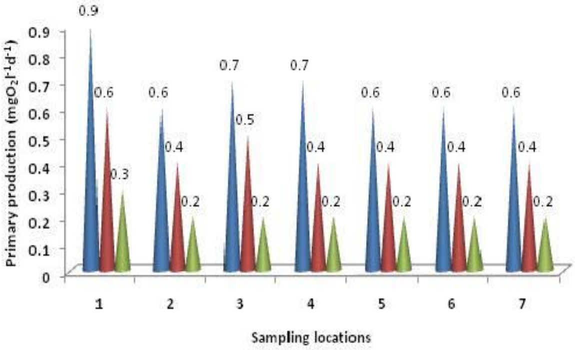

Fig. 2. Spatial variation in mean primary production of Imo river.

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	-0.32**	-0.141	-0.204	-0.29**
NPP	-0.007	0.404**	-0.56**	-0.59**	-0.43**	-0.36**	-0.59**
CR	-0.106	0.363**	-0.51**	-0.54**	-0.40**	-0.30**	-0.55**

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

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).

Table 3. Variance equality in means of 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.

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 post-ANOVA structure detection of group means using means plots (Figs. 3a&b) revealed that observed heterogeneity was accounted for at sampling locations 4 and 1, while between GPP and CR, it was accounted for at sampling location 1.

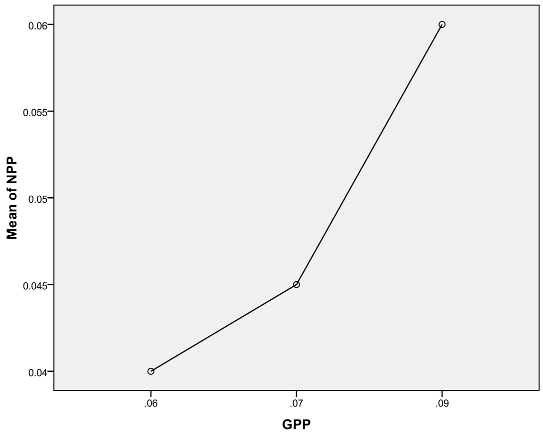

Fig. 3a. Means plot between GPP and NPP across the sampling locations.

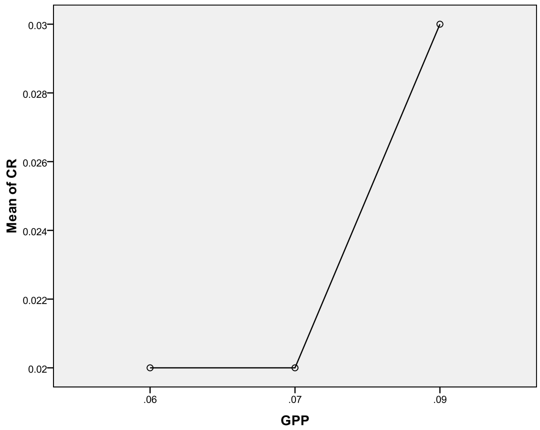

Fig. 3b. Means plot between GPP and NPP across the sampling locations.

Discussion

The GPP of this study was low when compared with the works of Samaan (1971), Mbagwu and Adeniji (1994) and Ikenweiwe and Otubusin (2005) in Nasser, Mariut, and Oyan lakes in Nigeria, respectively. However, it was higher than mean values recorded by Adeniji (1980) in Bakolori Lake, Sokoto State and Adeniji (1990) in Asa Lake, Ilorin, all in Nigeria, as well as values recorded by Simmons *et al.* (2004) in the US Appalachian coal region. This low productivity could be attributed to the observed low nutrient levels (especially of nitrate and phosphate) and high turbidity (which exerts influences on photosynthetic activities of the autotrophs). Ongoing commercial sand mining in the river must have led to the depletion of nutrient stores, especially in the benthal regions of the aquatic system. Guildford and Hecky (2000) had identified phosphate as the nutrient that most commonly limits productivity in freshwater systems. Mining activity also re-suspends particulate matter in water column, thus constituting increased turbidity (Adams, 2003) and low phytoplankton abundance. The significant influences of pH and DO on productivity variables confirm their vital roles in ecosystems processes. Studies have shown that some pollutants (e.g. heavy metals) have greater toxicity towards algae at circumneutral pH (Hargreaves and Whitton, 1976; Campbell and Stokes, 1985; Bortnikova *et al.* (2001) such as in this study.

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

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