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What influence does removal of Riparian Vegetation have on Primary Productivity of a River

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ABSTRACT

The impact of removal of riparian vegetations on primary productivity of the Otamiri River in the Federal University of Technology, Owerri, Nigeria was investigated in early 2013. Two sampling locations (OL 1 & OL 2) sited at vegetated segments and 3 others (OL 3, OL 4 and OL 5) sited about 50m apart within a de-vegetated segment of the river were studied. The light and dark bottle technique was used for the estimation of primary productivity and in situ measurements made with the HANNA HI 9828 pH/ORP/EC/DO meter for pH, water temperature, electrical conductivity, total dissolved solids (TDS) and salinity. Other parameters were determined using standard methods. The descriptive statistics, single factor ANOVA, means plots, student's t-test, Pearson correlation (r) and linear regression were used to analyse data. Maximum gross (2.82mgC$L^{-1}d^{-1}$) and net primary productivity (2.52mgC$L^{-1}d^{-1}$) (GPP & NPP) as well community respiration (CR) (0.30mgC$L^{-1}d^{-1}$) were all recorded in the non-de-vegetated OL 2 while highest temperatures (28.34 ± 0.269 °C) were recorded in the de-vegetated segments of the river. There was marked heterogeneity in yields of productivity across the sampling locations [$F_{(17.63)} > F_{crit(4.20)}$], and GPP contributed the difference most at $P<0.05$. Temperature, with insignificant spatial correlationship (Sig, r=0.953) however differed markedly between the vegetated and de-vegetated locations (Sig. t=0.023) at $P<0.05$. Temperature also exerted very significant limiting influence on GPP (r=-0.961) and NPP (r=-0.971) at $P<0.01$, even as the linear regression model revealed that a unit increase in temperature regime of the de-vegetated segment of the river would result in about 48.899 times decrease of yields in GPP. Results underpin the importance of riparian covers in watershed management of a tropical river system.

Keywords: De-vegetation, riparian vegetation, Otamiri River, primary productivity, FUTO

INTRODUCTION

Though water is vital to the existence of all living organisms, this indispensable resource is increasingly being threatened as human populations grow and the demands of infrastructure and landscape increase. According to the UNEP GEMS [1], water abstraction for domestic use, agricultural production, mining, industrial production, power generation, and forestry practices can lead to deterioration in its quality and quantity that impact both the availability of safe water for human consumption and the aquatic ecosystem.

The direct and indirect impacts of man on the ecosystems [2] and the aquatic component to be particular could be diverse. For example, in early 2013, the works department of the Federal University of Technology, Owerri (FUTO), Nigeria embarked on the removal of the riparian vegetations of the segment of the Otamiri River (a major river system in Owerri metropolis that courses through the university campus for "aesthetic" intents. This exercise exposed the segment of the river to direct solar irradiations and so became an issue of concern to conservation biologists and ecologists in some departments of the institution. This concern gleans from the fact that direct solar irradiations could impact the temperature regime of the river and so, alter not only the basic physical and chemical processes necessary for the survival of aquatic biota [3, 4] but also several other physicochemical attributes of the river [5].

For example, other than nutrients [6], solar irradiation and temperature variations are major limiting factors to primary productivity by phytoplankton [7]. Sequel to this, the current study assessed the primary productivity and other related quality parameters of the de-vegetated corridor of the river as to estimate the impact of the anthropogenic activity on the autotrophic biota responsible for primary production in the aquatic ecosystem. In doing this, a longitudinal spatial association approach was utilized to infer scientific conclusions.

MATERIALS AND METHODS

Study Area

The Federal University of Technology, Owerri (FUTO) is sited in Owerri, a metropolitan city located between latitudes 05° 29' 06s and longitude 07° 02' 06s (Figure 1) in the southeastern part of Nigeria. The area experiences mean daily minimum temperature range of 19-24°C and maximum range of 28-35°C, average relative humidity of up to 80%, and a longer wet season which lasts from April-November [8]. The vegetation, though dominated by semi-deciduous forest has been altered by

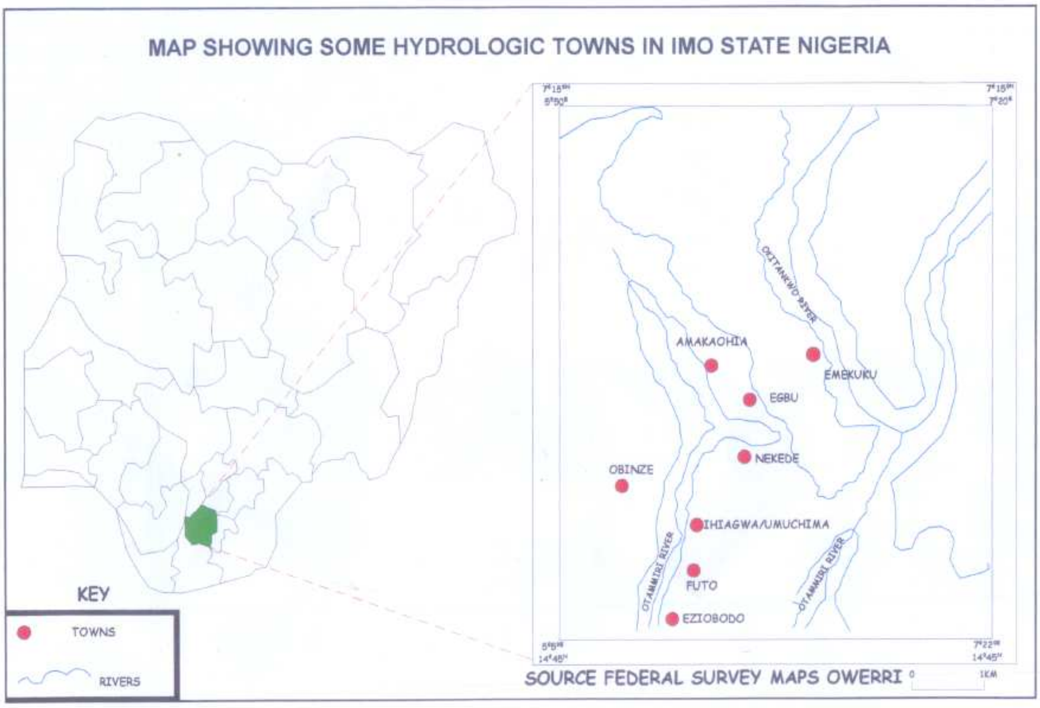

Figure 1. Hydrological map of Owerri showing FUTO, the study location

agriculture and other anthropogenic activities [9], with dominant top-soil of moderate humus composition.

The Otamiri River, a major river in Owerri which serves for domestic, fisheries and artisanal sand mining courses through the university campus, onto the suburbs and then to the neighbouring Rivers State where it first confluences with the Oge-ochie, and then Imo Rivers before emptying into the Atlantic Ocean.

Sampling locations

Two sampling locations designated as OL 1 and OL 2 were sited within the vegetated segments of the river 50m before and 50m after the de-vegetated section and 3 others, designated as OL 3, OL 4, and OL 5 established about 50m apart within the de-vegetated section of the river in the FUTO.

***In situ* Measurements**

pH, temperature, electrical conductivity, total dissolved solids (TDS), and salinity of surface water were determined electrometrically *in situ* with the HANNA HI 9828 pH/ORP/EC/DO meter. The other physicochemical parameters were measured using standard methods of APHA, [10].

The Light and Dark Bottle technique [11] for the estimation of primary productivity was applied. Three identical transparent 1-litre bottles; 1 covered with black polythene (Dark bottle) and the other not (Light bottle) were filled with the river water and stoppered while still submerged. The dissolved oxygen (DO_1) content of the first light bottle was determined immediately with the HANNA HI 9828 pH/ORP/EC/DO meter, while the other two bottles were suspended in the pelagial zone where the water had been taken with the aid of an inextensible rope for about 4 hours in a sunny afternoon [12]. The two bottles were however harvested immediately after the incubation period and their dissolved O_2 contents (DO_L & DO_D) determined. The experimental setup was done in replicates.

Primary productivity was calculated in mg of O_2 produced per litre of water per day according to the formula:

$$\mathbf{GPP\ (MgO_2L^{-1}d^{-1}) = NPP\ (mgO_2L^{-1}d^{-1}) + CR\ (mgO_2L^{-1}d^{-1})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{i}$$

Where GPP = gross primary productivity,
NPP = net primary productivity, and
CR = community respiration.

The productivity results were however converted to their carbon equivalents by multiplying the O_2 values by 0.375 [13].

Statistical analysis

The test of homogeneity in mean primary productivity variables across the sampling locations was conducted with the single factor ANOVA and post-hoc structure of group means detected with means plots at P<0.05. The Pearson correlation (r) was used to establish possible relationships between productivity and physicochemical variables, while linear regression was used to further explore the association between productivity and water temperature. The student's t-test of significance was used to establish marked variations in levels of the parameters between the vegetated and de-vegetated locations.

RESULTS AND DISCUSSION

Spatial variations in productivity and physicochemical variables

GPP, NPP and CR varied from 0.43-2.82 (1.608 ± 0.485), 0.38-2.52 (1.386 ± 0.447) and 0.05-0.30 (0.222 ± 0.046) $mgCL^{-1}d^{-1}$ respectively. Minimum GPP, NPP and CR were all recorded in OL 5 (a de-vegetated sampling location, while their maximums were all recorded in OL 2 (a non-de-vegetated location) (Figure 2). However, water temperature, total suspended solids (TSS), turbidity, NO_3^-, PO_4^{2-} and SO_4^{2-} ions concentrations varied from 27.50-28.80 (28.34 ± 0.269) °C, 1.05-2.75 (1.980 ± 0.347) mg/L, 1.95-4.10 (3.120 ± 0.444) NTU, 0.57-3.50 (1.943 ± 0.570) mg/L, 0.18-1.55 (0.866 ± 0.280) mg/L and 3.20-6.48 (4.785 ± 0.625) mg/L respectively. Correspondingly higher temperatures were recorded in the de-vegetated sampling locations where the least productivity were also recorded, even though higher levels of the other limiting factors of primary productivity- turbidity and TSS [4, 7] were recorded in the non-de-vegetated OL 2.

There was significant heterogeneity [$F_{(17.627)}>F_{crit(4.196)}$] in productivity yields across the sampling locations at P<0.05, and post-hoc structure of group means revealed that GPP (2.70) contributed the difference most in all the locations (Figures 3-6).

The levels of the nutrients (NO_3^-, PO_4^{2-} & SO_4^{2-}), with significant spatial correlationships (Sig. r=0.000 each) did not differ significantly (Sig. t=0.149, 0.249 & 0.059) at P<0.05. Conversely, water temperature which had no significant spatial correlation (Sig. r=0.953) differed markedly between the vegetated and de-vegetated segments of the river

(Sig. t=0.023) at the 95% confidence limit. These thus indicate that temperature was the major influencing factor in this study. The removal of riparian covers obviously exposed the segment of the river to direct irradiation and consequent temperature elevations.

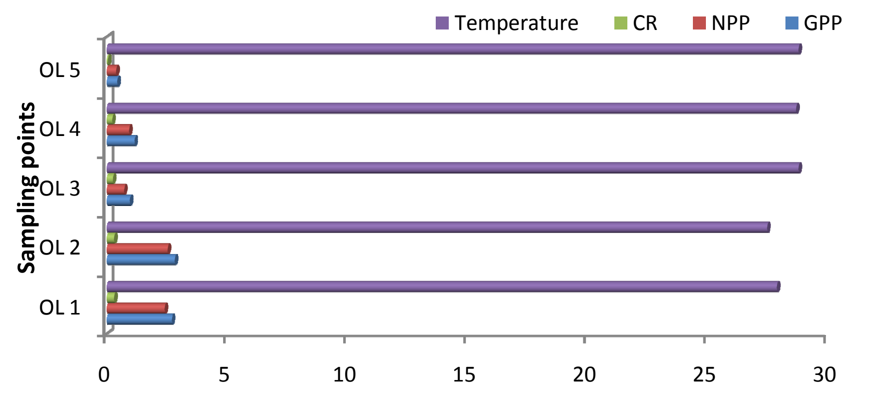

Figure 2. Spatial variations in gross and net primary productivity, community respiration and temperature of the vegetated and devegetated segments of the Otamiri River in FUTO

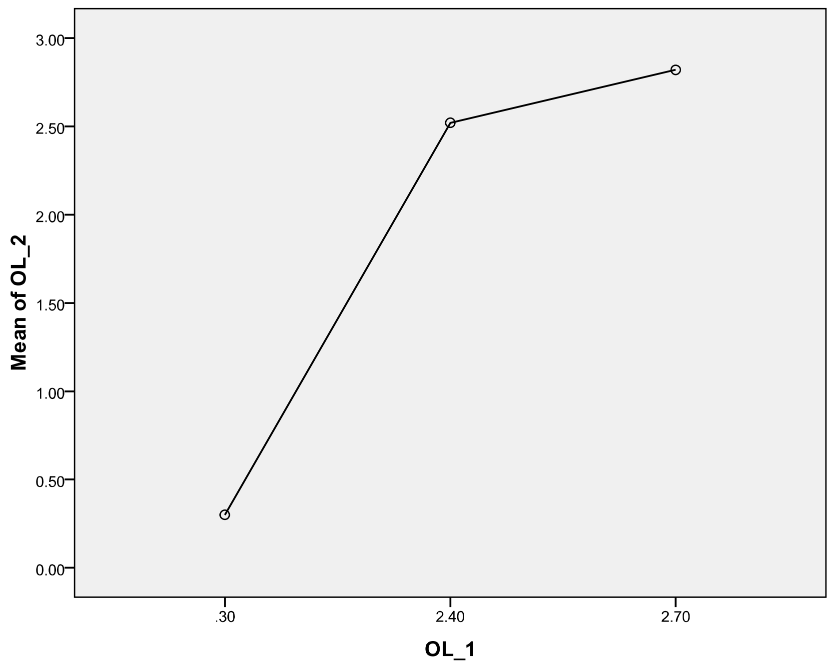

Figure 3. Means plot in primary productivity between vegetated (OL 1) and de-vegetated location (OL 2)

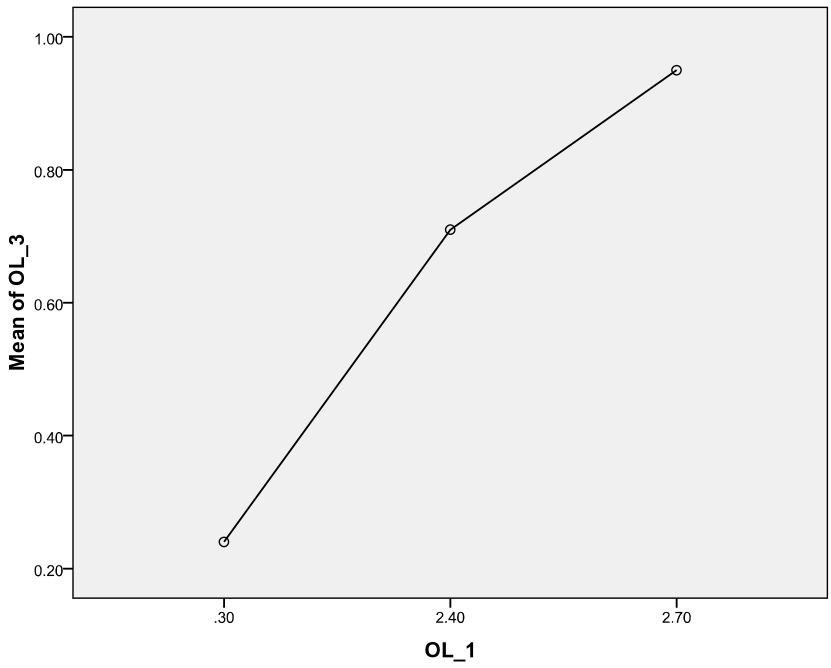

Figure 4. Means plot in primary productivity between vegetated (OL 1) and de-vegetated location (OL 3)

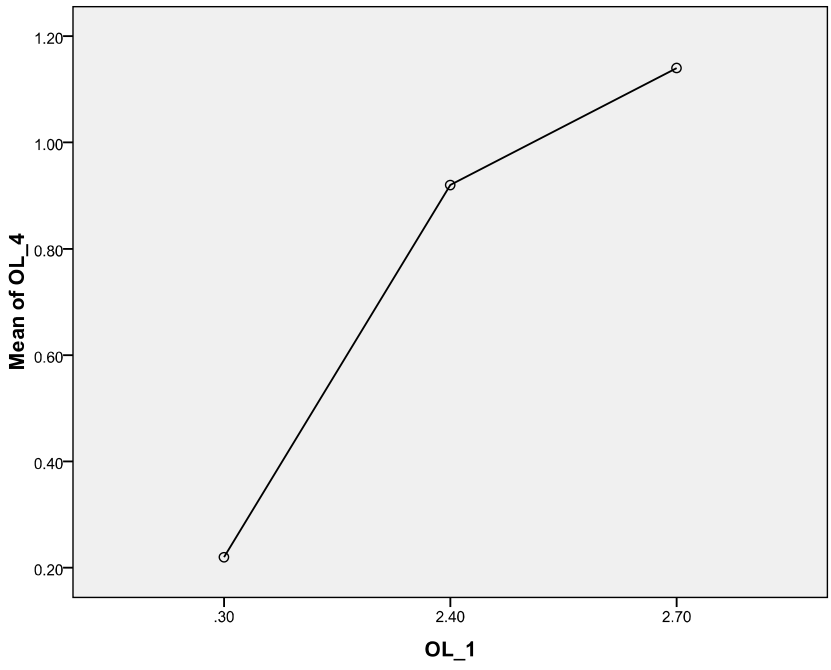

Figure 5. Means plot in primary productivity between vegetated (OL 1) and de-vegetated location (OL 4)

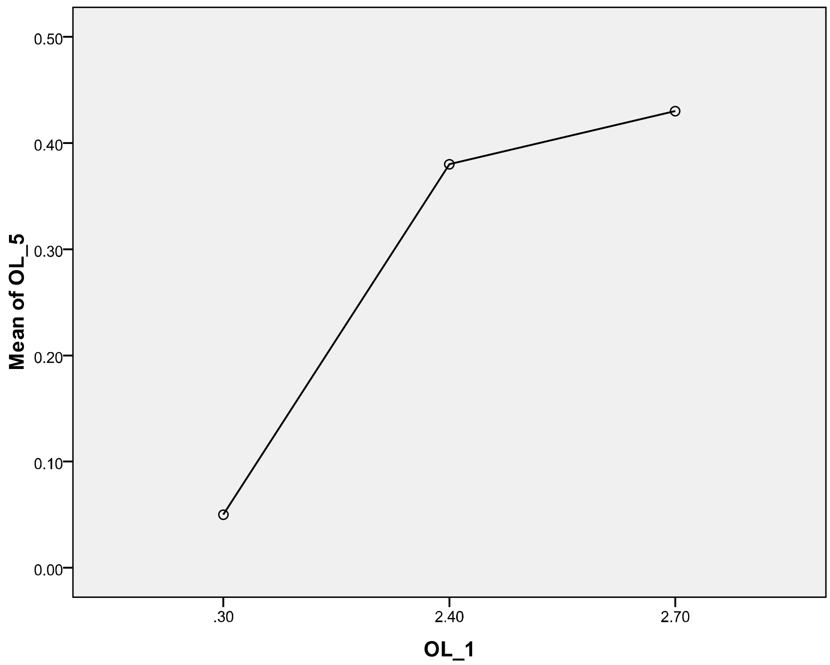

Figure 6. Means plot in primary productivity between vegetated (OL 1) and de-vegetated location (OL 5)

Relationship between primary productivity and physicochemical variables

The Pearson correlation (r) revealed that temperature exerted very significant limiting influences on GPP (r=-0.961) and NPP (r=-0.971) (P<0.01), even as TSS, NO_3^- and SO_4^{2-} ions also exerted significantly direct influences on the productivity variables (Table 1). The UNEP GEMS [1] states that temperature affects the speed of chemical reactions, the rate of photosynthesis by algae and aquatic plants, the rate of metabolism in organisms, as well as the interactions of pollutants, parasites and other pathogens with aquatic residents. It also influences the solubility of dissolved oxygen and other materials (e.g. CO_2) required for photosynthesis (primary production) in water column. This thus implies that higher temperature regimes in water column (such as the one created by the removal of riparian vegetations and subsequent exposure of surface waters to direct solar radiation and heat in this study) could reduce the availability of the all important dissolved CO_2 necessary for primary production.

The direct enhancing influences of the nutrients on primary productivity have been noted by Ogbuagu *et al*. [4] in Imo River in Etche, Nigeria and Simmons *et al.* [6] in an acid mine drainage treatment pond in the United States. Since their levels did not differ significantly between the vegetation cover areas of this study, temperature therefore remains the sole impact factor on primary productivity.

Table 1. Correlation (r) matrix between primary productivity and physicochemical variables of Otamiri River impacted by removal of riparian vegetations in FUTO

Parameters	Temperature	TSS	Turbidity	NO_3^-	PO_4^{2-}	SO_4^{2-}	pH	Conductivity
GPP	**-0.961****	**0.932***	**0.846**	**0.893***	**0.870**	**0.976****	**0.423**	**0.339**
NPP	**-0.971****	**0.926***	**0.839**	**0.891***	**0.867**	**0.973****	**0.450**	**0.378**
CR	**-0.693**	**0.818**	**0.756**	**0.747**	**0.741**	**0.824**	**0.085**	**-0.098**

***=significant at P<0.01, TSS=total suspended solids, GPP=gross primary productivity, NPP=net primary productivity, CR=community respiration*

The linear regression scatterplot of GPP by temperature shows that the variability of GPP decreased with increasing temperature (Figure 7). The regression (4.344) and residual sums of squares (0.357) which are unequal indicates that more than ½ of the variation in GPP could be explained by the model. The significant value of the F statistics (0.009) also indicates that the variation explained by the model is not due to chance at P<0.05. The large multiple

correlation coefficient (R=0.961) indicates a strong relationship, even as the coefficient of determination (R^2=0.924) confirms that more than half the variation in GPP is explained by the model.
The model further shows that:

The expected yield in GPP = -1.730 X temperature + 50.629 ………………………….ii

This indicates that a unit increase in temperature variation would result in about 48.899 decreases in GPP of the segment of the aquatic ecosystem.

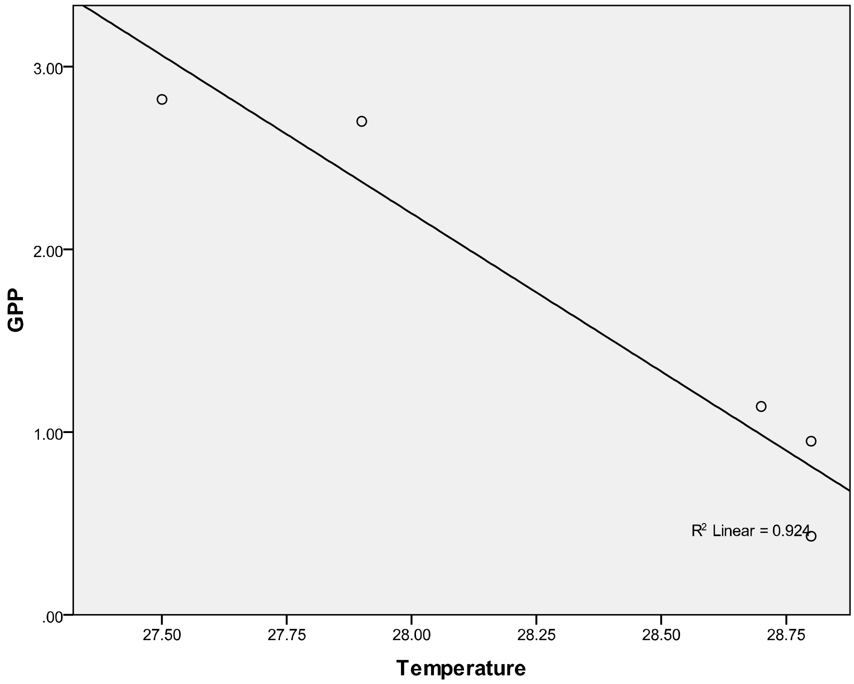

Figure 7. Linear regression scatterplot of GPP by temperature

CONCLUSION

Yields in primary productivity were higher in the segment of the river with vegetation covers. Productivity was greatly limited by temperature imbalance created by the removal of the riparian vegetations of the Otamiri River, even as other limiting factors such as turbidity and suspended solids were higher in the de-vegetated than vegetated segments of the river. The role of nutrients in the vegetated and de-vegetated segments of the river appeared similar, thus, implicating temperature regime as the sole impact factor on primary productivity in this study.

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