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# Phytoplankton biomass and primary production dynamic in Porto-Novo lagoon (Republic of Benin)

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## Abstract

*Porto-Novo lagoon is eutrophical water on which more than 500,000 persons depend. The study of primary production tied to some relevant environmental physico-chemical parameters was carried out in order to build an exploitable data base on the potentialities of this lagoon. Measurements were carried out in relation to seasons in six sites divided in twelve areas with different hydrologic scheme, from June 2015 to February 2016. The AFNOR NFT 90 – 117 norm was used for chlorophyll-a measurement though primary production valuation was carried out through prior established general equations. The water temperature varied between 27.58 and 32.28°C. Salinity and pH ranged respectively between 6.33 – 7.03 and 0.00 – 2.93mg/L though the maximum and minimum conductivity values were respectively 9170 and 67.6µsem$^{-1}$. Dissolved oxygen value fluctuated between 1.09 – 2.98 mg/L which are lower than standard normal suggested by FEPA. TDS varied between 107.80 and 3703.00mg/L with turbidity ranging between 2.50 and 54.67mg/L though maximum and minimum transparence were 2.52 and 0.68m respectively. Total Phosphorus (TP) and Total Nitrogen (TN) showed fluctuating values 1.85 – 5.25mg/L and 1.13 – 2.59mg/L respectively. Primary production varied between 840.10 and 3324.24mg C/m$^2$.J. It was globally higher in the central area than in bank area. Primary production was significantly correlated with transparence (r= 0.81 and p=0). The current study shows that phytoplankton production in Porto-Novo lagoon is influenced by many factors such as geographical position that delimit lotic and lenthic area; climate; presence of macrophytes and human activities on the side basin.*

**Keywords:** Primary production, lagoon, Porto-Novo, physico-chemical parameters, phytoplankton.

## Introduction

Productivity is a very important aspect for ecosystems because of its involving in many physiological processes[1]. In a given ecosystem, productivity depends on the dynamic of phytoplankton population. The main role of phytoplankton is to capture solar energy by photosynthesis and make it available for the other organisms[2]. The estimation of primary production in aquatic ecosystems is essential for the valuation of biological potential of these ecosystems. Studies based on primary production are also very important in the understanding of pollution effect on the system efficiency as all organic productions in the ecosystem depend on photosynthetic organisms.

In West Africa, lagoons are important aquatic ecosystems not only ecologically but also economically[3]. Porto-Novo lagoon in southern Benin communicates with Ouémé River, Lake Nokoué and Atlantic Ocean in Lagos with more than 500,000 economically dependent persons through sand exploitation, transport and trading but especially fishery and associations «acadja». Ryther[4] explained the close relationship that could exist between primary production and fishery production through phytoplankton height variation and consumers growth.

In order to collect data on the potential of this hydro-system, experiment was carried out through the current study on the primary production of this water plan. Apart from the knowledge of ecological conditions, this study might help mediate further research for optimal management of the ecosystem.

## Material and methods

**Sampling sites, sampling and measurement methods:** Sampling sites were chosen considering eutrophication features on the one hand and speed gradient on the other hand; this later enabled to divide the water plan in two areas. The first with lotic scheme has relatively the highest flow that corresponds to the central zone though two stations $C_1$ and $C_2$ were identified. The second area with lenthic scheme was more influenced by human activities and has its surface almost entirely covered by macrophytes is made of four stations $R_1$, $R_2$, $R_3$ and $R_4$. The sites location is shown in Figure-1.

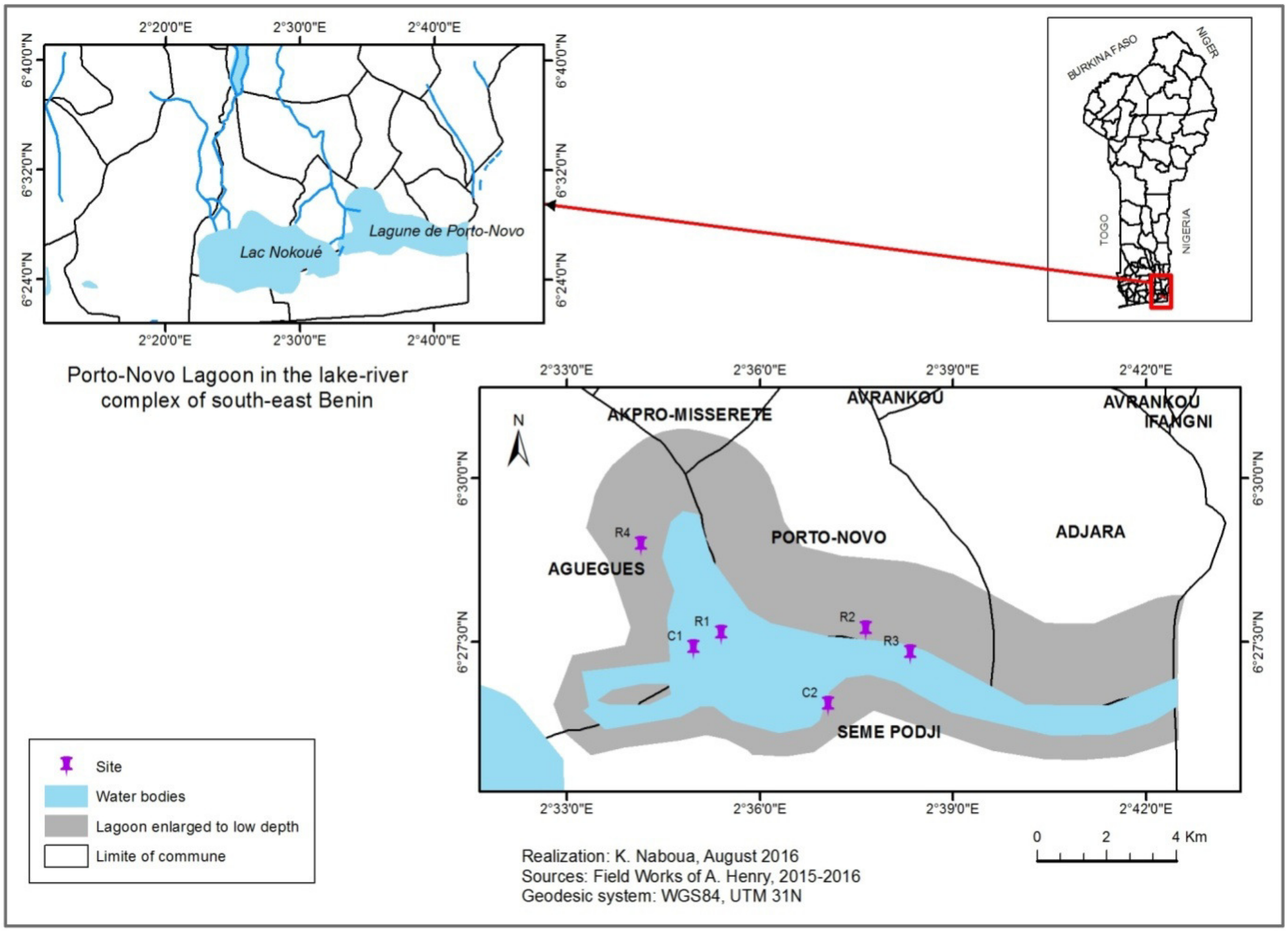

**Figure-1:** Geographical location and sampling sites.

Before water sampling, certain parameters were measured *in situ*. It concerns pH that was measured with a pH-meter WTW 3110 SET 1, dissolved oxygen (DO) and saturation rate measured with oxymeter WTW Tetra Con 325, electrical conductivity (EC), salinity (Sal), temperature (Temp) and total dissolved solids (TDS) measured by using a multi-parameter apparel WTW Cond 3210. A disk of Secchi served to transparence and water depth measurement. Total Nitrogen (NTK) and Total Phosphorus (TP) were measured in laboratory.

Chlorophyll-a was measured according to the norm AFNOR NFT 90 – 117 December 1984. Water was filtered in laboratory by using GF/C 0.45mm filter laid in a tube containing 10mL acetone 90%. After mixing till filter dissolution and extract centrifugation for 10 minutes, the liquid was treated in spectrophotometer waved at 665nm and 750nm. A regular acidification (hydrochloric acid five times normal) was carried out after reading of absorbance Ao, until reaching the maximum Aa. With Lorenzen[5] formula we can calculate chlorophyll-a concentration:

$$[\mathrm{Chla}] = 27 * [(\mathrm{Ao}\ 665 - \mathrm{Ao}750)\ (\mathrm{Aa}\ 665 - \mathrm{Aa}\ 750)] * \frac{v}{L * V} \qquad (1)$$

Ao 665 and Ao 750 are respectively the absorbance at 665nm and 750nm before acidification; Ao 665 and Ao 750 are respectively absorbance at 665nm and 750nm after acidification; V the filtered water volume (L); L the optic distance of the used vat (cm) and 27 an experimentally determined coefficient.

**Valuation method of the primary production:** Primary production measurements and water sampling were carried out according the four seasons of the year: long rainy season (GSP), short dry season (PSS), short rainy season (PSP) and long dry season (GSS). The estimation method described by Tailling[6], and Descy[7] was used for the determination of primary production:

$$\mathrm{Pd}\ (\mathrm{mg\ C\ ou\ mg\ O_2\ m^{-2}\ j^{-1}}) = \mathrm{n\ Pmax}/k * \mathrm{Ln}\ (2\ I_0/I_k) * \Delta t * 0.9 \qquad (2)$$

Pd is the daily production, n the phytoplankton biomass (mg chla $m^{-3}$), Pmax the photosynthetic capacity of phytoplankton (in mg C or mg $O_2$.mg Chl $a^{-1}$ .$h^{-1}$), K the extinction coefficient ($m^{-1}$), $I_0$ the mean light intensity of the day (in µE $m^{-2}$ $S^{-1}$), $I_k$ the intensity of saturation threshold (in µE $m^{-2}$ $S^{-1}$), Δt the mean duration of the day (12 hours in tropical area) 0.9 is the coefficient of correction.

According to Talling[6], in tropical area, we often record constant values (between 2 and 3) for Ln (2 $I_0$ /$I_k$), either a mean value of 2.5 for African Lakes.

The light extinction coefficient k was estimated from the Secchi depth (m). Indeed, according to Descy[7], k=2/Sd. Pmax values influenced by temperature are higher in tropical areas and estimated to about 25± 5mg $O_2$ .mg Chl $a^{-1}/h^7$.

**Statistical analysis:** Data collected were subjected to analysis of variance among seasons and stations. The Pearson analysis of correlation was used to test relationships among physico-chemical and biological variables. These analyses were carried out thanking the MINITAB software.

## Results and discussion

Parameters responsible to primary production and biomass (chlorophyll-a) are mentioned in Table-2; it concerns global calculated values and representative to the water column. Transparence and dissolved oxygen are determinant factors to the primary production. They are influenced by temperature, salinity, electrical conductivity, TDS, turbidity and pH. Seasonal variation of these factors in relation to sampling sites and the analysis of variance are shown in Figures-2 to 11 and Table-1.

**Variation of environmental parameters in the lagoon**: The water temperature didn't vary significantly among sites (Figure-2). It presented the highest mean value in the GSS (32.28±1.15°C) and the lowest in the PSS (26.73±0.75°C) with a maximum at 33.80°C and a minimum at 25.70°C. These temperature values correspond to those of tropical regions and similar results were recorded by many other authors[8,9]. Temperature at the water surface was influenced by diverse atmospheric and hydrological factors. Temperature also affects many physical, chemical and biological processes in the water and consequently the concentration several variables[2]. The limit of variation in this lagoon could have an incidence on the metabolic activity that is photosynthesis if it happens spontaneously[10]. The lack of thermic stratification in this lagoon also contributes to least influence of temperature on the primary production.

DO concentration indicates the water health and capacity for self-purification throughout biochemical processes. Thus, it constitutes a very important component for water quality. Solar radiations determine its daily variation in the medium[11]. In the current study, DO and saturation present similar seasonal variation (Figures-3 and 4). They are higher in the GSS with 2.98±1.75mg/L (DO) and 39.53±23.12mg/L (Sat DO) and lower in PSP with respectively 1.09±0.69mg/L and 14.15±9.12mg/L.

The pick is obtained in site $C_2$. These DO value is (6.8mg/L) lower than standard normal suggested by FEPA[12] for fish survival and other aquatic organisms.

The water salinity during experiment period was almost null in the PSP and PSS (Figure-5) and presents the highest value (2.93±1.37) during the GSS. This high concentration is due to the high evapotranspiration that concentrate salt in the water. The water salinity is also high in the rainy seasons; this observation is in accordance with those of Adesalu[13]. TDS and EC (Figures-7 and 8) also present the highest values during the GSS with respectively 3703±643mg/L and 7398±1277µsem$^{-1}$ though the least ones during the SDS are 107.80±40.80mg/L and 107.80±40.80µsem$^{-1}$. Maximum values (4600mg/L and 9170µsem$^{-1}$) were recorded in site C2 during the GSS though minimum ones (67.6mg/L and 67.6µsem$^{-1}$) in site R2 during the PSS. Similar observations were reported about Korodu stream that flows in Lagos lagoon[14]. We noticed a certain link among salinity, EC and TDS. Indeed, a high positive correlation was observed between EC and salinity (r=0.835 and p=0) according to Pearson correlation (Table-3). Similar relationship was also observed between salinity and TDS (r=0.76 and p=0). Consequently, there is a positive significant correlation between EC and TDS (r=0.92 and p=0). This observation seems to those of on the lagoon complex of Harbourin Nigeria[2]. Onyema and Nwankwo[3] through their studies on Lagos lagoon reported that EC and salinity are associated factors.

The water pH (Figure-6) shows neutral values during the GSP and GSS with respectively 7.01±0.11 and 7.03±0.16. The PSS and PSP make water acid though pH values are 6.33±0.31 and 6.80±0.14 respectively. Values of pH ranging from 6 to 7.5 as typical to West African water[15]. Persistence of acidity recorded in the lagoon from the GSS to PSP is the result of rain water preponderance on marine water through Lake Nokoué. PH regulates the origin, mobility and availability of ions and their different forms in water[16]. Nutrients consumption is significantly high with acid pH[17] that increases productivity in the medium. Gradual increase of pH by the end of water cycle coincides with a high primary production[18]. Consequently, seasonal variation in pH observed in Porto-Novo lagoon could result from variation in photosynthetic activities of phytoplankton and other macrophytes.

Concerning TP and TN (Figures-10 and 11), the highest values were recorded in the GSS with respectively 5.25±0.88mg/L and 2.59±0.74mg/L and the lowest (1.85±0.93mg/L and 1.13±1.07 mg/L) respectively in the GSP and PSP. They are upper than those of Fresco lagoon in Ivory Coast that varied from 0.07 to 0.09mg/L and than those surface water concerning TP[10]. The increase in TP concentration in the GSS can be attributed to natural causes such as evaporation, domestic influx load toward the water plan especially the releasing of phosphorus by sediments[19]. The rate of released phosphorus in water may double when sediments are frequently disturbed[20]. A significant positive correlation was observed between TP and EC (r=0.78 and p=0). When associated to TDS, this correlation suggested that phosphorus is mostly on particle form. Mean on these parameters according to season are summarized in the Table-1 with their maximum and minimum.

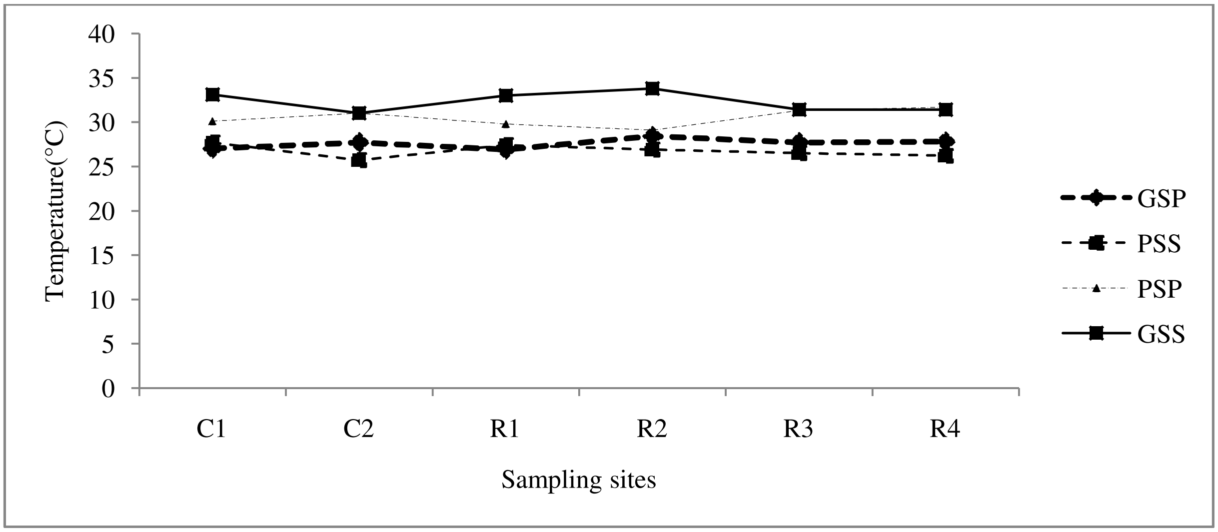

**Figure-2:** Variation of temperature in relation to sites and seasons.

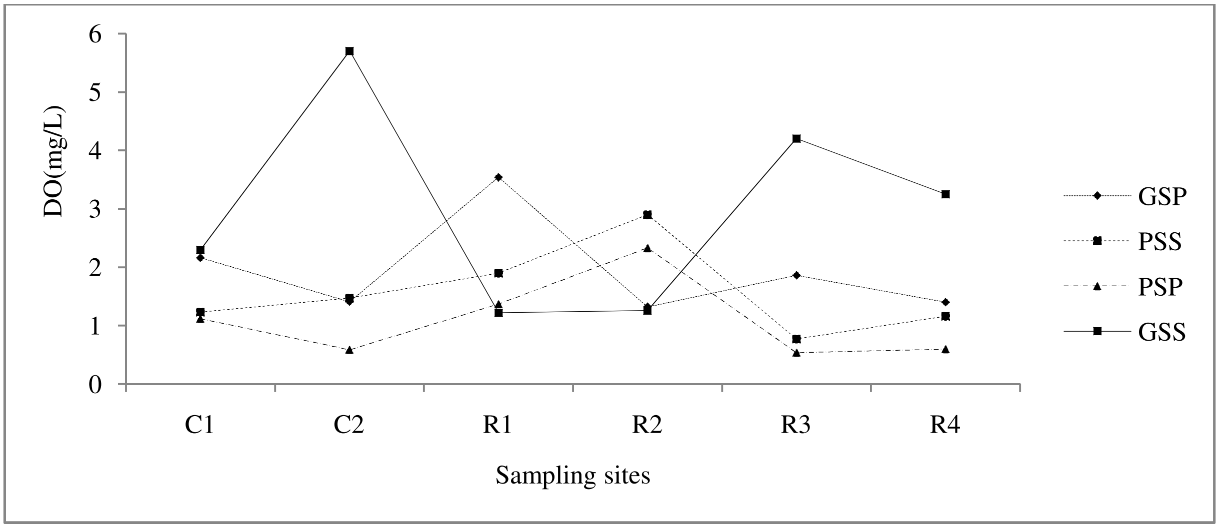

**Figure-3:** Variation in DO concentration in relation to sites and seasons.

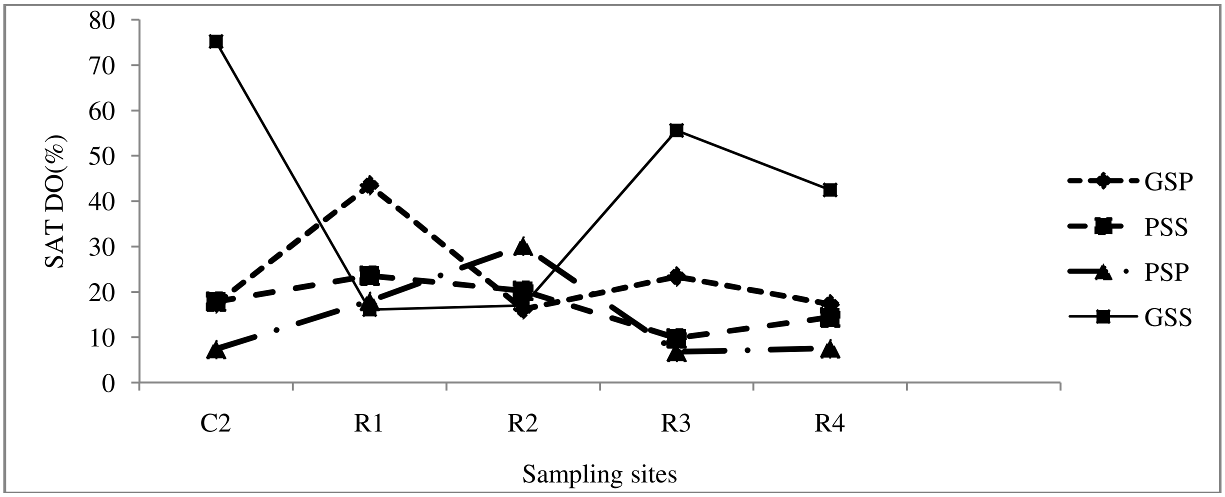

**Figure-4:** Variation in saturation DO concentration in relation to sites and seasons.

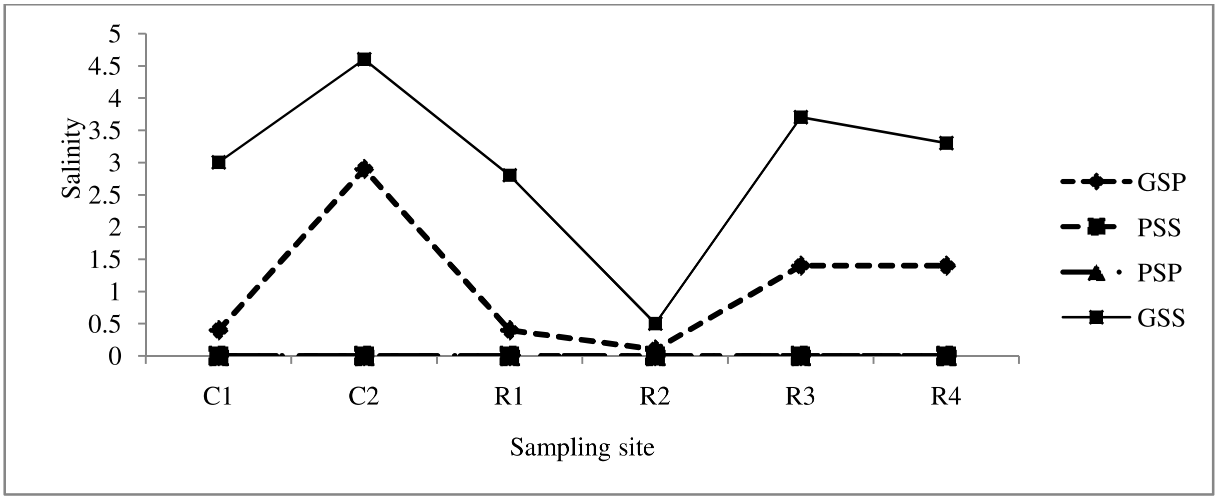

**Figure-5:** Variation of salinity in relation to sites and seasons.

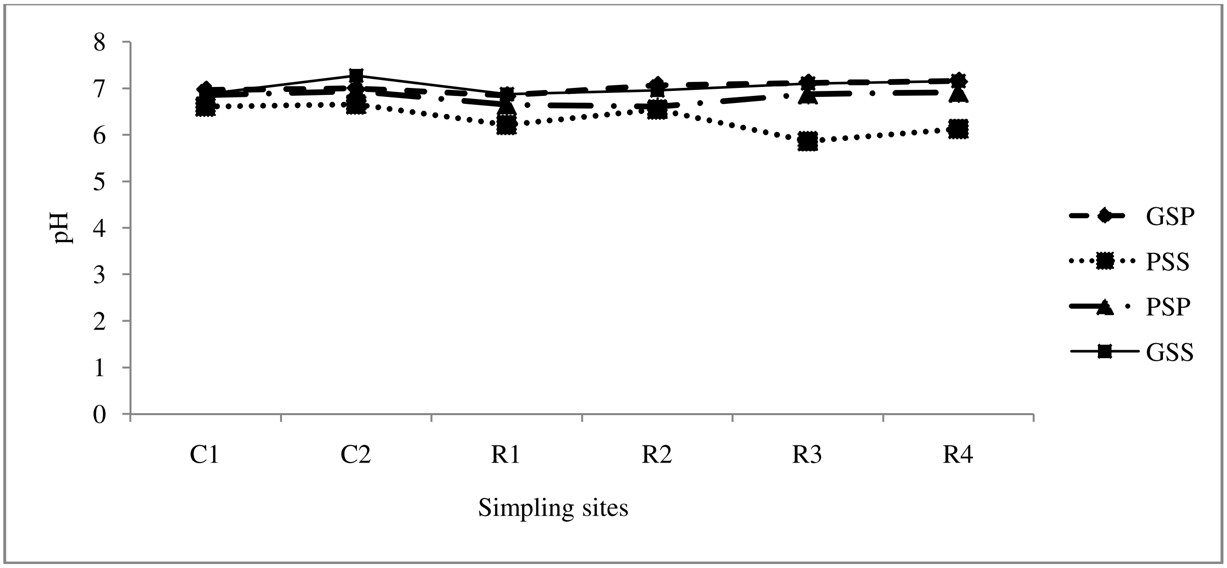

**Figure-6:** Variation of pH in relation to sites and seasons.

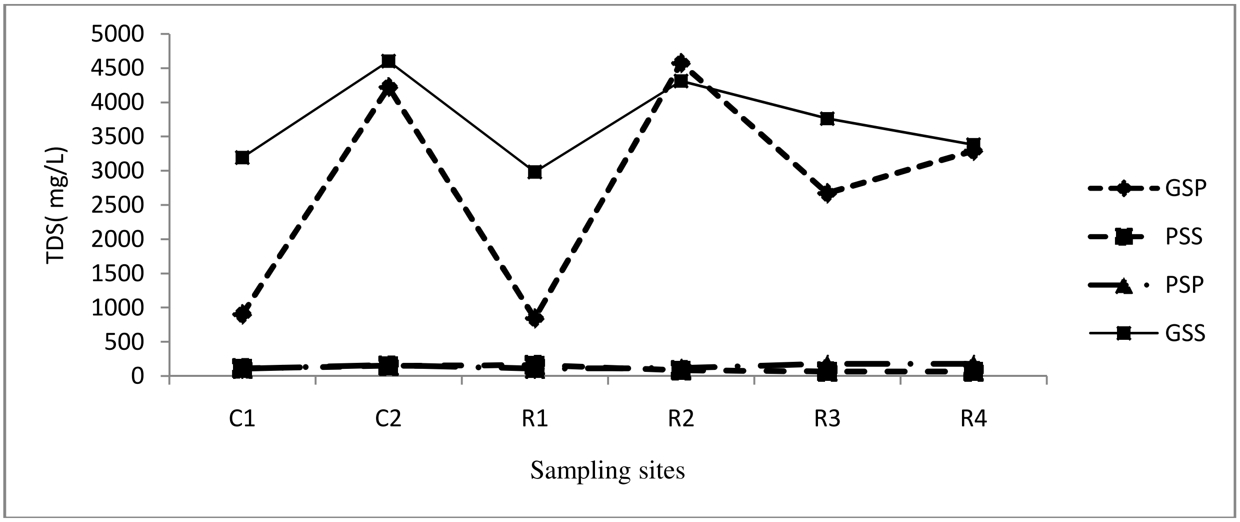

**Figure-7:** Variation of TDS in relation to sites and seasons.

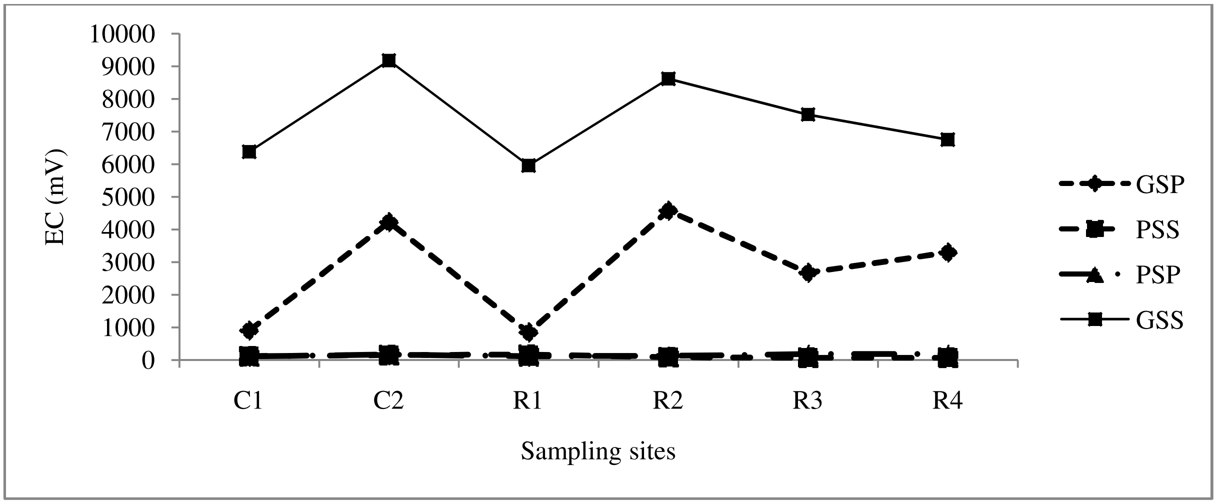

**Figure-8:** Variation of EC in relation to sites and seasons.

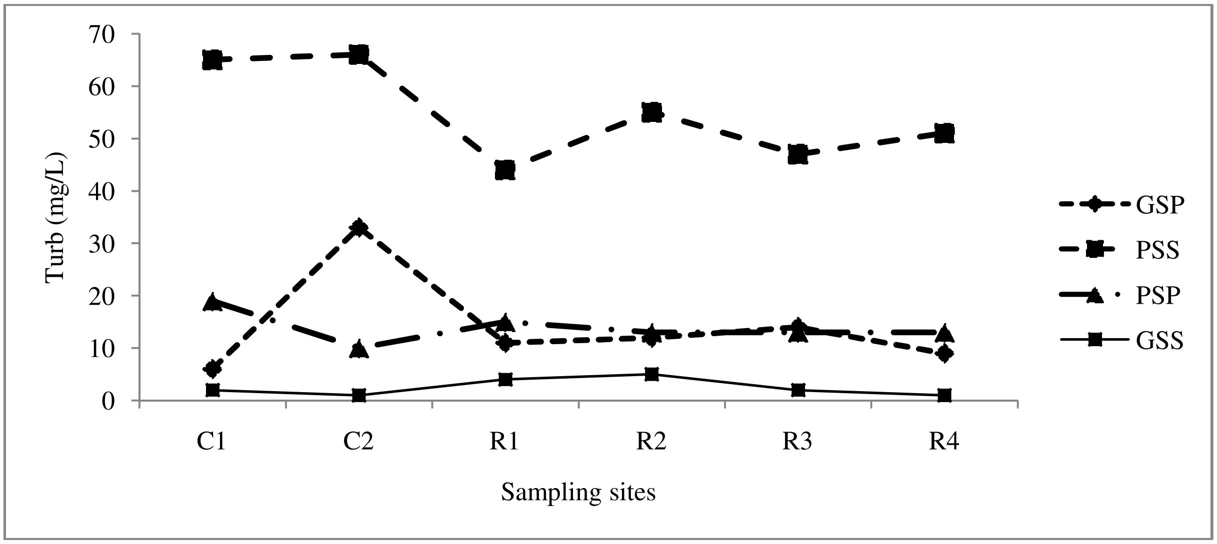

**Figure-9:** Variation of turbidity in relation to sites and seasons.

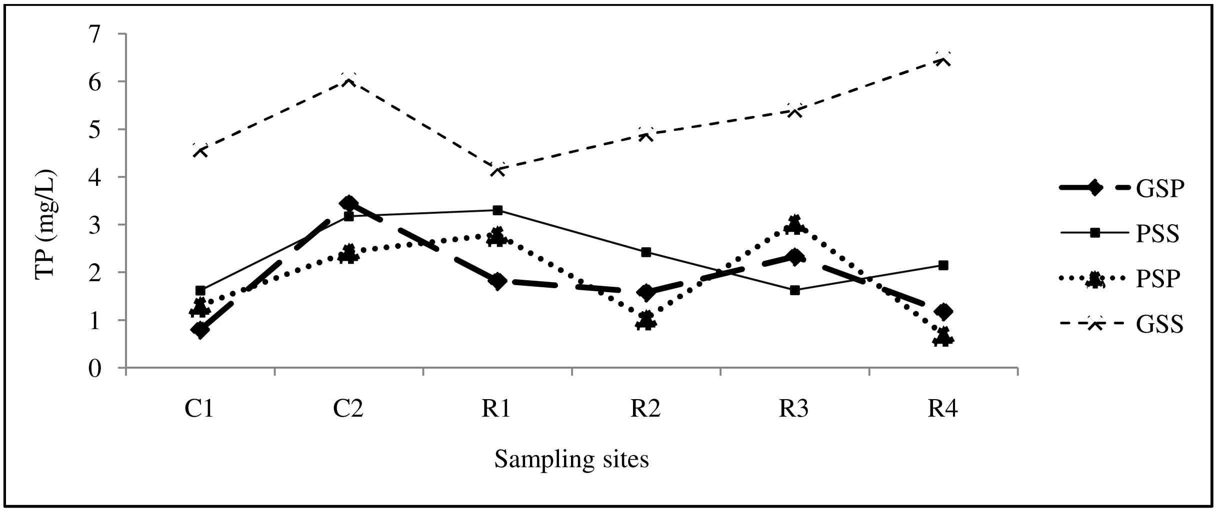

**Figure-10:** Variation of TP in relation to sites and seasons.

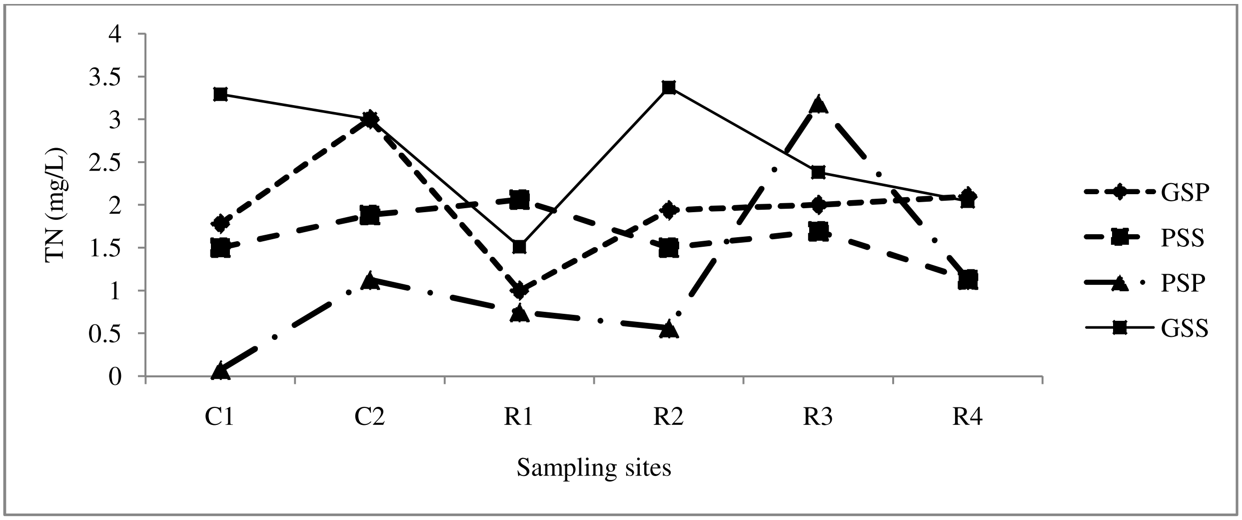

**Figure-11:** Variation of TN concentration in relation to sites and seasons.

**Table-1:** Variation of environmental parameters of Porto-Novo lagoon water in relation to seasons.

| Parameters | GSP(Moy±SD) | PSS (Moy±SD) | PSP (Moy±SD) | GSS (Moy±SD) | Maxi | Mini |
|---|---|---|---|---|---|---|
| DO (mg/L) | 1.94±0.84 | 1.57±0.75 | 1.09±0.69 | 2.98±1.75 | 5.70 | 0.54 |
| Sat DO (%) | 24.15±10.37 | 16.87±4.84 | 14.15±9.12 | 39.53±23.12 | 75.20 | 6.80 |
| Temp (°C) | 27.58±0.55 | 26.73±0.75 | 30.50±0.99 | 32.28±1.15 | 33.80 | 25.70 |
| pH | 7.01±0.11 | 6.33±0.31 | 6.80±0.14 | 7.03±0.16 | 7.27 | 5.86 |
| Sal (mg/L) | 1.10±1.03 | 0.00±0.00 | 0.00±0.00 | 2.93±1.37 | 4.60 | 0.00 |
| TDS (mg/L) | 2749±1601 | 107.80±40.80 | 143.30±33.90 | 3703±643 | 4600 | 67.6 |
| Turb (mg/L) | 14.17±9.62 | 54.67±9.18 | 13.83±2.99 | 2.50±1.64 | 66.00 | 1.00 |
| Transp (m) | 1.07±0.36 | 1.49±0.84 | 1.26±0.53 | 1.40±0.70 | 2.52 | 0.68 |
| EC ($\mu sem^{-1}$) | 2749±1601 | 107.70±40.80 | 143.30±33.90 | 7398±1277 | 9170 | 67.6 |
| TP (mg/L) | 1.85±0.93 | 2.38±0.73 | 1.88±0.99 | 5.25±0.88 | 6.47 | 0.70 |
| TN (mg/L) | 1.97±0.64 | 1.62±0.32 | 1.13±1.07 | 2.59±0.74 | 3.37 | 0.075 |

**Table-2:** Primary production parameters, chlorophyll-a and transparence in the lagoon.

| Year Periods | $TDS_{(m)}$ -C- | $TDS_{(m)}$ -R- | Chl a ($mg/m^3$) -C- | Chl a ($mg/m^3$) -R- | Pmax ($mgO_2.mg$ Chl $a^{-1}.h^{-1}$) | Ln ($2I_0/I_k$) | Pd (mg $C/m^2.J$) -C- | Pd (mg $C/m^2.J$) -R- |
|---|---|---|---|---|---|---|---|---|
| GSP | 0.85 | 1.18 | 4.55±1.14 | 2.62±0.46 | 25± 5 | 2.5±0.5 | 1305.28±2.85 | 1043.41±1.14 |
| PSS | 0.85 | 1.81 | 6.75±0.722 | 5.44±0.32 | 25± 5 | 2.5±0.5 | 1936.40±1.80 | 3323.16±0.80 |
| PSP | 0.98 | 1.41 | 2.54±1.35 | 3.24±0.27 | 25± 5 | 2.5±0.5 | 840.10±3.37 | 1541.83±0.67 |
| GSS | 1.52 | 1.34 | 6.48±0.617 | 3.99±0.88 | 25± 5 | 2.5±0.5 | 3324.24±1.54 | 1804.47±2.22 |

C = Central area, R = Bank area

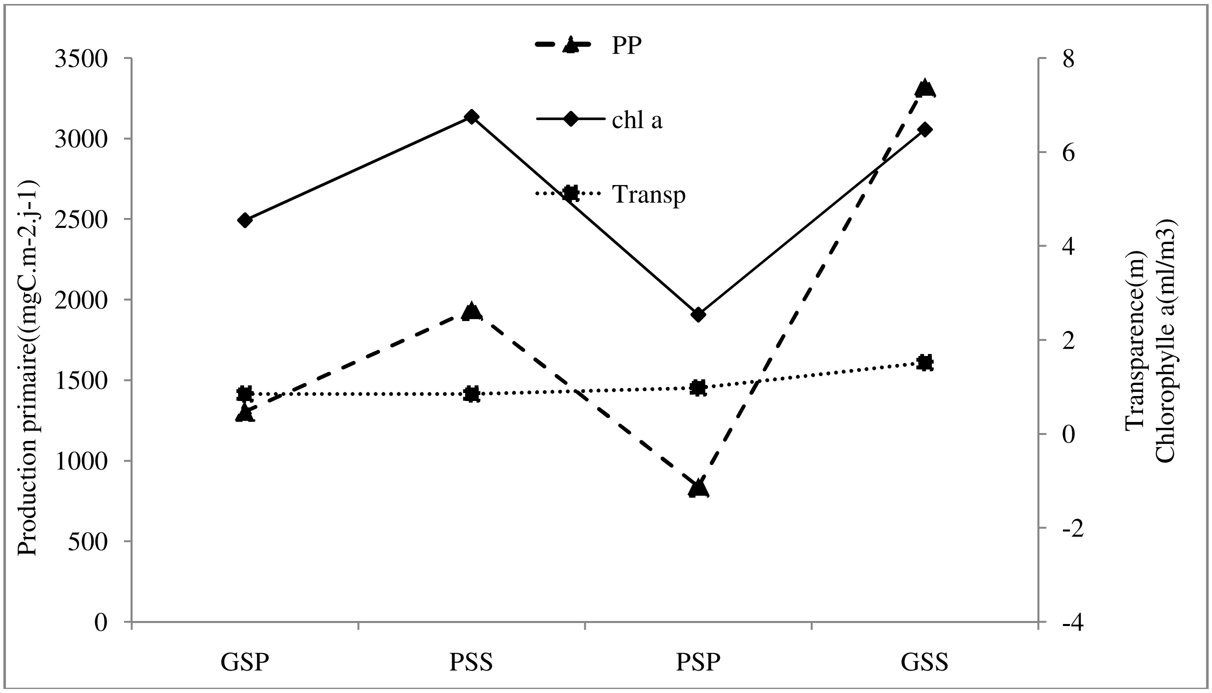

**Figure-12:** Seasonal variations of the daily production, chlorophyll-a and transparence in the central area.

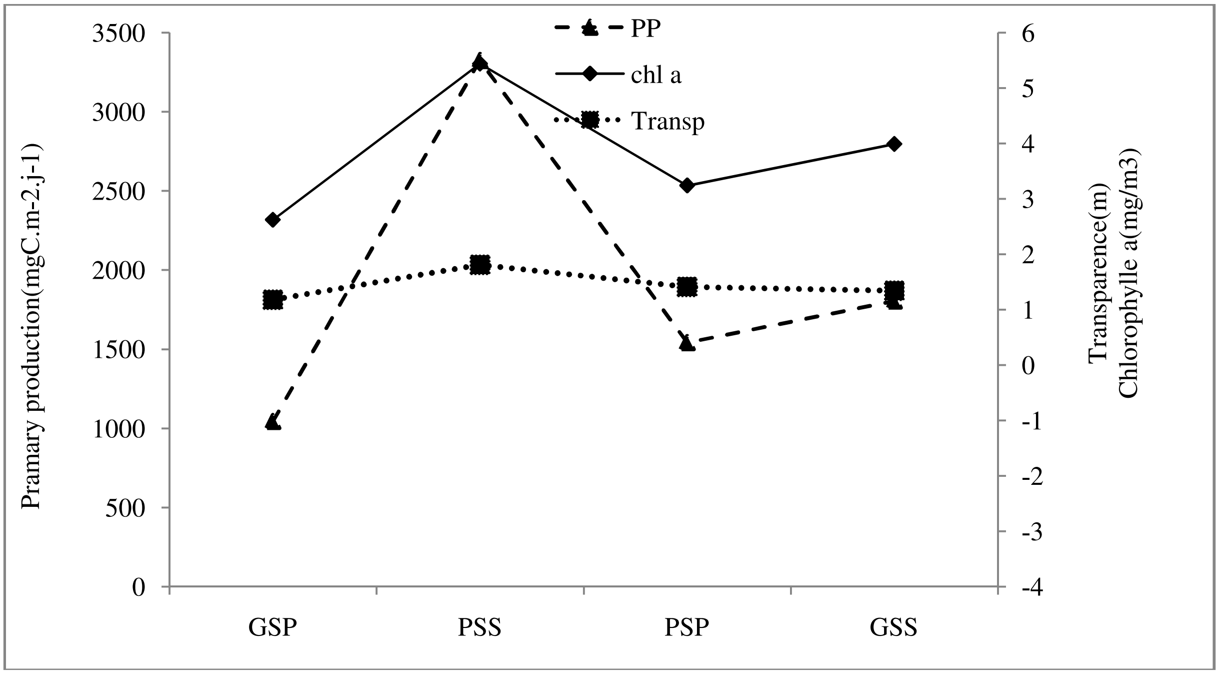

**Figure-13:** Seasonal variations of the daily production, chlorophyll-a and transparence in the bank area.

Water transparence varied in relation to seasons. It was generally higher in the bank area (R) than in the central one and relatively high during dry seasons with 1.49±0.84m in the PSS and 1.40±0.70m in the GSS though it’s lower (1.07±0.36m) during the GSS. It strongly influenced the primary production that showed the significant correlation (r=0.81 and p=0). Contrary to transparence, the biomass (chlorophyll-a) presented high value in the central area compared to the bank area throughout all seasons except the PSP. For this eutrophical medium, nutrients are essential but also available for the development of primary producers. Such development should be more remarkable in the bank area where nutrients are more concentrated than in the central area. That could be explained by shade occasioned by macrophytes that could prevent light penetration.

Primary production directly depends on sun light conditions and is subject to quick variations. Season frequency doesn't allow us to appreciate all the variations that can happen during the year. However, it allows us (Figures-10 and 11) to distinguish variations among seasons and areas. Indeed, during the PSP and GSP, primary production was lower than those recorded in dry seasons and reached 840.10mg C/m$^2$.J. It was generally higher in the central area than bank area. The low value of primary production in rainy seasons and in bank area would result from sun light variation, as light is the determinant factor for primary producers. Sun light variation varied from a microsecond till climate cycle variations due to wave's movements at the air-water interface[21]. Indeed, when conditions are optimal regarding temperature and nutrients, primary production and photosynthetic capacities are directly tied to sun light intensity[22]. In low light shine, autotrophe organisms proceed to photo-acclimatization by modifying their photosynthetic apparel[23], an increase in pigment concentration associated to membrane reorganization in thylakoïds that provokes shade in chloroplasts and so a decrease in light absorption[24]. Thus, the variation of photosynthetic activity depends essentially on light variation as phytoplankton is homogen with depth[25]. This depth can contribute to sun light variation in deep water plans. In order to show depth influence, Talling[6] proposed a mathematical model based on Smith[26] semi-empiric equation by using optimal photosynthetic capacity (Pmax) and the beginning photosynthetic saturation equation (Ik) as essential parameters.

Pmax varied in relation to seasons in temperate regions, water flow, temperature, trophic level of water and the nature of phytoplankton. Pmax can reach 3 and 12mg C/mg Ch.a/h for mesotrophical and eutrophical lakes in temperate regions. It was 8.4±2.1mg C/mg Ch.a/h in the Lot River[25] corresponding to high photosynthetic activity. Pmax values were higher in tropical Lakes and Descy[7]estimated it to about 25± 5mg $O_2$ .mg Chl a$^{-1}$ .h$^{-1}$. Concerning Ik, its value remained relatively constant like the logarithm of $I_0$/Ik especially in tropical area corresponding to Porto-Novo lagoon.

**Table-3:** Correlation among some physico-chemical and biological parameters.

| | Sat O | Temp | Sal | CE | TDS | Turb | Transp | pH | PT | NT | Chl a | P Primaire |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OD | | | | | | | | | | | | |
| Sat O | 0,976<br>0,000 | | | | | | | | | | | |
| Temp | 0,064<br>0,766 | 0,147<br>0,492 | | | | | | | | | | |
| Sal | 0,656<br>0,001 | 0,714<br>0,000 | 0,438<br>0,032 | | | | | | | | | |
| CE | 0,529<br>0,008 | 0,595<br>0,002 | 0,606<br>0,002 | 0,835<br>0,000 | | | | | | | | |
| TDS | 0,411<br>0,046 | 0,468<br>0,021 | 0,414<br>0,045 | 0,762<br>0,000 | 0,924<br>0,000 | | | | | | | |
| Turb | -0,289<br>0,171 | -0,382<br>0,065 | -0,698<br>0,000 | -0,484<br>0,016 | -0,576<br>0,003 | 0,540<br>0,006 | | | | | | |
| Transp | 0,020<br>0,928 | -0,053<br>0,807 | 0,045<br>0,834 | 0,089<br>0,678 | -0,020<br>0,926 | -0,085<br>0,695 | 0,070<br>0,744 | | | | | |
| pH | 0,359<br>0,085 | 0,404<br>0,050 | 0,484<br>0,017 | 0,560<br>0,004 | 0,603<br>0,002 | 0,669<br>0,000 | -0,708<br>0,000 | -0,211<br>0,321 | | | | |
| PT | 0,547<br>0,006 | 0,589<br>0,002 | 0,538<br>0,007 | 0,765<br>0,000 | 0,787<br>0,000 | 0,593<br>0,002 | -0,304<br>0,148 | 0,073<br>0,734 | 0,334<br>0,111 | | | |
| NT | 0,220<br>0,301 | 0,252<br>0,236 | 0,319<br>0,128 | 0,530<br>0,008 | 0,653<br>0,001 | 0,649<br>0,001 | -0,203<br>0,342 | 0,209<br>0,327 | 0,333<br>0,112 | 0,609<br>0,002 | | |
| Chl a | 0,182<br>0,393 | 0,194<br>0,363 | 0,135<br>0,531 | 0,169<br>0,431 | 0,209<br>0,326 | 0,087<br>0,686 | 0,153<br>0,475 | -0,083<br>0,700 | 0,151<br>0,482 | 0,254<br>0,230 | 0,295<br>0,162 | |
| P Primaire | 0,134<br>0,532 | 0,084<br>0,698 | 0,188<br>0,379 | 0,225<br>0,290 | 0,149<br>0,486 | 0,030<br>0,889 | 0,052<br>0,809 | 0,816<br>0,000 | -0,081<br>0,706 | 0,236<br>0,267 | 0,368<br>0,077 | 0,455<br>0,026 |

Cell Contents: Pearson correlation, P-Value, pH= potential Hydrogen; Transp=Transparence; Cond= electrical Conductivity; Sal= Salinity; $O_2$= dissolved Oxygen; Temp= Temperature; TP= Total Phosphorus; NT= Kjedahl Nitrogen; Chl a =Chlorophyll-a; P.Primaire= primary Production.

Apart from light energy and temperature, nutrients and primary consumers are also regulation factors of primary production and their limitation will affect both photosynthesis and biomass of organisms. Limitation of nutritive salts affects photosynthetic parameters by provoking alteration in the photosynthetic apparel[26,27]. In eutrophical ecosystems rich in nutritive salts, phytoplankton cells have necessary resources to optimize their efficiency and photosynthetic capacity that show high growth rates and biomass accumulation observed in the ecosystems[21].This observation is in accordance with those of Akogbéto[28] that shows phytoplankton density obtained in the same water plan was relatively high ($8.33\ 10^8$ to $1.58\ 10^{10}$). The influence of primary consumers is not null. Indeed, the dynamic of primary production was affected by superior trophic compartments[29,30]. Thus copepods and micro-zooplankton (flagellate and ciliated), main phytoplankton and micro phytobenthos consumers, can limit growth, biomass and regulate primary production[21]. An exhaustive investigation on zooplankton in Porto-Novo lagoon wasn't carried out except Colleuil and Texier [31] that reported the presence of Foraminifers, Ostracoda, Copepods such as *Jadamminapolystoma, Ammonia beccarii* and *Neomonoceratina* sp. However, Nkwodji[32] by his observations on the lagoon of Lagos communicating with Porto-Novo lagoon recorded calanoïd copepods as the most important zooplankton though phytoplankton presented great similitude with those observed in Porto-Novo lagoon[28]. By the same, when diatoms dominate phytoplankton population, copepods predominate among zooplankton[33]. Considering diatoms predominance in Porto-Novo lagoon, we could imagine the dominance of copepods in this lagoon. Further research will confirm or deny this hypothesis. Copepods that are generally omnivorous or carnivorous, could influence primary production by consuming phytoplankton[33].

Primary production scale is not identical in all water plans (Table-4). Primary production rate in lagoon is among the highest in natural ecosystems[35]. The estimated rate in Porto-Novo lagoon similar to those observed in Lake Tchad in Niger[36] ($0.7$-$2.69 g.C.m^{-2}.j^{-1}$) and Lake Taabo[37] ($1.5$-$2.66 g.C.m^{-2}.j^{-1}$) but is lower than those in Lagos lagoon[38] ($5.69 g.C.m^{-2}.j^{-1}$). Besides, it's upper than those observed in some eutrophical Lakes and lagoons such as Lake Kivu[39] ($213 mg.C.m^{-2}.an^{-1}$), Lake Tanganyika[40] ($0.11$–$1.41 g.C.m^{-2}.j^{-1}$), upper than those in Lake Nokoué[41] ($0.0057$–$0.059 mg.C.m^{-2}.j^{-1}$). Apart from regulation factors, variations observed may result from estimation methods used[42]. Indeed, two traditional measurement methods were adopted longtime to estimate primary production. It concerns method of carbon radioactive isotope incorporation $^{14}C$, initiated by Steeman-Nielson[43] and modified by Babin[44] that is the most used. The second method is based on the monitoring of oxygen produced during photosynthesis process. This method requires long hatchery time and is less sensitive. It's most adapted to measurements in laboratory[24]. Long hatchery time doesn't allow appreciation of short term variations of photosynthetic processes. In addition, the confined environment where experiments were carried out can provoke changes in population composition, an increase in bacteria consumption and so a trouble in considered parameters[45]. This second method was used by Groga on Lake Taabo with seven days latency[37]. Other methods were developed from Chlorophyllous fluorescence of photosynthetic cells using oxydo-reduction reactions and enable estimation of photosynthetic parameters at high frequency. However, their yield decreases when light intensity increases and they don't allow direct measurement of carbon[46]. An interesting alternative for high frequency estimation of primary production is couplage of photosynthetic parameters measurement and carbon incorporation methods. However, carbon fixation is spacially and temporally unconstant due to multiple physico-chemical and ecological factors that will influence it and electron flux in microalgae[27,47]. The most simple method of chlorophyll-a and carbon ratio adopted in the current study would slightly influence primary production estimation. In this study, the concentration of chlorophyll-a recorded was $2.62 mg/m^3$ indicating a relative abundance of phytoplankton during these seasons. We noticed that transparence remained low (1.18m). So, light is no longer a limiting factor during this period. Other factors such as taxonomic composition of phytoplankton and their height could explain ratio between chlorophyll-a and carbon through photosynthetic activity[48]. Indeed, in Lake Taboo, phytoplankton are made of 30.5% of chlorophyceans compared to 22% recorded in Porto-Novo lagoon though diatoms proportion is 22% compared to 41%[28,37]. The ratio of primary production noticed in Lake Taboo compared to those in Porto-Novo lagoon results from this high chlorophyceans rate. Aleya and Devaux[49] showed in Lake Aydat (France) that height range 12-45 µm contributes for about 50% to total phytoplankton biomass whatever the biomass describer used and 65% to total photosynthetic activity. These results could be explained by light extinction with an opposite relationship between chlorophyll-a and depth. Light extinction due to planktonic algae is relatively low compared to those due to live suspended matters[50]. Thus, considering high values of turbidity especially in the PSP in Porto-Novo lagoon, this factor may have little influence on primary production. It's also important to notice pigment concentrations per volume unit, were upper in nanoplankton than in big cells[51-53].

## Conclusion

The efficiency of phytoplankton primary production estimation is important for ecosystem and water resource management. The monitoring of phytoplankton primary production in the current study was influenced by many factors such as geographical position that delimit lotic and lenthic areas, climate, macrophytes and human activities on the basin side. Rainy seasons have primary production lower than those of dry seasons and would be due to dilution of macronutrients and micronutrients, weak sun light and low temperature. By the same way, the central area rate was higher than those in bank area and was responsible to hydro-dynamism, water transparence and constitutes an important element to be considered for fisheries improvement.

**Table-4:** Primary production of phytoplankton in Porto-Novo lagoon: comparison with other African Lakes and lagoons.

| Water plan | Values | References |
|---|---|---|
| Lake Nokoué (Benin) | 0.0057 – 0.059 mg.C.m$^{-2}$.j$^{-1}$ | 41 |
| Lake Chad (Niger) | 0.7 - 2.69 g.C.m$^{-2}$.j$^{-1}$ | 36 |
| Lake Taabo (Togo) | 1.5 – 2.66 g.C.m$^{-2}$.j$^{-1}$ | 37 |
| Lake Kivu (DRC) | 213 mg.C.m$^{-2}$.an$^{-1}$ | 39 |
| Lake Tanganyika | 0.11 – 1.41 g.C.m$^{-2}$.j$^{-1}$ | 40 |
| Lagos lagoon (Nigeria) | 5.69 g.C.m$^{-2}$.j$^{-1}$ | 38 |
| Porto-Novo lagoon | 0.84 – 3.32 g.C.m$^{-2}$.j$^{-1}$ | The current study |

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