International Journal of Fisheries and Aquatic Studies 2019; 7(2): 139-145

E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2019; 7(2): 139-145

www.fisheriesjournal.com
Received: 25-01-2019
Accepted: 28-2-2019

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Primary production and some limnological aspects of Nasarawa reservoir Katsina, Nigeria

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Abstract
Primary production, and some limnological aspects of Nasarawa reservoir was investigated from February to November, 2018 weeks to ascertain the health of the reservoir's ecological system. Sampling was conducted on five sites near the dam wall on a monthly basis, at a one meter interval depth profile. The phyico-chemical parameters were analysed using standard techniques. Dark and light bottle dissolved oxygen method was employed for the analysis of Net primary productivity, Gross primary productivity and Community respiration. pH, temperature, conductivity, transparency, dissolved oxygen, nitrate nitrogen, phosphate phosphorus and net primary productivity shows seasonal variation while biochemical oxygen demand and community respiration showed no seasonal variation. The parameters analysed were higher in dry season. Net primary productivity and gross primary productivity was highest in site C while community respiration was highest in site E. The low productivity of the reservoir in the wet season might be due to high suspended solids in the flood water which restrict light penetration into the reservoir and thereby results in less photosynthetic activities. Primary production in Nasarawa reservoir in all the stations was probably because of the rate of photosynthesis caused by seasonal fluctuations in water temperature, transparency and nutrients experienced.

Keywords: Community respiration, gross primary productivity, net primary productivity, nutrients, physico-chemical.

Introduction

Limnology is the study of the physical, chemical, and biological interactions within inland waters. Limnological studies include the movements and biogeochemical changes that occur as water moves through drainage basins and within lakes and reservoirs. Relatively static lake and reservoir waters (collectively referred to as lentic waters) are functionally linked with the surrounding landscape, including the flowing waters in streams (collectively referred to as lotic waters) [26]. The maintenance of water quality standards in Lakes and reservoirs is necessary in order to avoid excessive growth of aquatic flora which is a problem to aquatic biota and humans. In many tropical lakes, temporal and spatial changes in the physico-chemical parameters are common in response to surface water runoff, direct precipitation, ground water recharge, rate of evaporation and human interference. These changes have impacts on the flora and fauna by imposing physiological and behavioural adaptations [13]. The flow of energy through any ecosystem starts with the fixation of sunlight by plants and other autotrophic organisms. In this way the plants accumulate which is called primary production. The rate at which this energy accumulates is called primary productivity. The total energy accumulated is gross primary production; however, since plants use some of this energy themselves, it is not available for the food web [14]. Estimation of primary productivity is essential to understand food chain and food web [6], water quality [25] and pollution study [19]. The primary productivity of the aquatic ecosystem is adversely affected by anthropogenic activity. The primary productivity of a water body is the manifestation of its biological production. It forms the basis of the ecosystem functioning. It plays an important role in any ecosystem as it makes the chemical energy and organic matters available to the entire biological community [2]. Although freshwater ecosystems cover a much smaller area in the world in comparison to other ecosystems, they have a crucial place especially in the lives of humans [26]. The aim of the research is to investigate some aspects of limnology and primary productivity of Nasarawa Reservoir, Katsina State Nigeria.

Materials and Methods
Study Area
Nasarawa reservoir is located at latitude 12°59' 33'' North and longitude 7° 30' 48'' East at Nasarawa village Jibia local government Katsina state. From the results of the preliminary visit to the reservoir, five sampling stations were established for the purpose of sample collection (Figure 1).

Sample Collection
Water samples were collected at the five sampling sites from February to November, 2018. A water Sampler was used in the collection of water samples. The sampler was lowered into the water with aid of a graduated rope. Some parameters were measured in the field while other parameters were transported to the laboratory for analysis.

Fig 1: Map of the Study Area Showing the Sampling Sites (Source: Google Map)

Determination of physico-chemical parameters
Analysis for the physicochemical parameters of the water samples was made following the standard methods for the examination of water and waste water [3]. Temperature, pH, electrical conductivity, total dissolved Solids were determined using the Hanna instrument of model (H198129). Transparency was determined using Secchi disc painted black and white was tied with strong, thin rope. Dissolved oxygen and Biochemical Oxygen Demand were determined using a dissolved oxygen meter, total alkalinity by titration method using hydrochloric acid and methyl red and brocresol green solutions as indicators, total hardness by ethylene diamino tetra acetic acid (EDTA) titration method using eriochrome black-T dye.

Determination of Primary Productivity
The light and dark bottles method [24] was used for measuring the primary productivity (GPP, NPP and Community respiration). Gross primary production, Net primary production and Community respiration were calculated based on the formula below:

NPP (mg/l) = Final DO in light bottle (mg/l) – Initial DO in light bottle (mg/l)

CR (mg/l) = Initial DO in dark bottle (mg/l) – Final DO in dark bottle (mg/l)

GPP (mg/l) = CR (O2 consumed by respiration in mg/l) + NPP (Net O2 production in mg/l).

Statistical analysis
The data collected was analysed and any significant differences between seasons was tested using T test while spatial and monthly variations were assessed using one way analysis of variance (ANOVA). Pearson Correlation Analysis was used to determine the relationship between physico-chemical parameters and primary productivity. Bray-Curtis cluster analysis which is the most common approach of CA, which provides intuitive similarity relationships between any one sample and the entire data set and is typically illustrated by a dendrogram (tree diagram), will be applied to determine the similarity in the environmental conditions of Nasarawa reservoir during the study period.

Results
Physicochemical parameters
The lowest mean monthly temperature value of (24.16±0.74°C) was recorded during the dry season in the month of February while highest value of (32.2 ± 1.14°C) was recorded in the month of September. Mean transparency values showed a peak of 0.80 cm ± 0.47 in May and lowest values of 0.14cm ± 0.04 in September, thus showing a general

decrease in transparency towards the rainy season. Site A recorded the highest transparency, with a value of 1.4 recorded in May. Site D recorded the lowest transparency in September with a value of 0.08.

The pH fluctuated between slight acidity to moderate alkalinity. The lowest pH recorded was 6.74 ±0.15 in June while the highest was 8.52 ±0.20 in March. Across the sampling sites, Site A and C recorded the lowest pH of 6.6 in June, while the highest pH of 9.3 was recorded in April from site D.

The conductivity varied from the lowest value of 100 µS/cm ± 3.96 in May to the highest of 338.8 µS/cm ±49.12 in July. The lowest specific conductance of 96 µS/cm was recorded at site A in July a while the highest values of 432 µS/cm was recorded from site A in July. Conductivity tends to be higher in all the stations during the dry than in the wet periods. The range of the TDS was from the lowest value of 51.6mg/l ±4.67 recorded in July, to the highest of value of 161 mg/l ± 19.98 recorded in May. Site A recorded the lowest and highest TDS value of 46 mg/l in August and 270 mg/l in June respectively. Total dissolved solids were observed to be higher in all the stations during the dry season than in the rainy season. The lowest value of DO was recoded (3.01 ± 0.08 mg/L) in September and highest (6.78 ± 0.62 mg/L) in February. Site E recorded the highest DO value of 7.8 mg/l in February while minimum DO value of 2.92 mg/l was recorded from site B in September. Dry season DO values were higher than wet season values. Biochemical oxygen demand values varied between 2.34 mg/l ±0.62 and 0.87 mg/l ±0.50. The highest value was recorded in June, and the lowest value was obtained in September. Across the sampling sites, site E recorded the highest value of 2.88 mg/l in March and the lowest value of 0.13 in September. Biochemical oxygen demand was higher in the dry season than in the rainy season.

The mean monthly NPP varied from 1.72±0.66 g/cm^3 in May to 0.38±0.05 g/cm^3 in September. On seasonal basis, maximum NPP was observed during dry season and minimum NPP was obtained in rainy season at all the five sampling sites. Across the sampling sites, Site C recorded the highest NPP of 2.9 g/cm^3 in May, while the lowest NPP of 0.23 g/cm^3 was recorded in August from site E. Monthly mean concentration of community respiration of Nasarawa reservoir varied from 0.93 g/cm^3 ±0.14 in June to 0.39 g/cm^3 ±0.13 in August as shown in Figure 4.10 .The concentration of the CR was highest in site E with a peak of 1.1 g/cm^3 recorded in May and June and it was lowest at 0.24 g/cm^3 during the dry period of February at site B. The concentration of GPP ranged between 2.53 g/cm^3 ±0.6 in May and 0.83 g/cm^3 ±0.10. The highest GPP across the sampling sites was 3.53 g/cm^3 recorded from site C and the lowest GPP was 0.78 g/cm^3 recorded from site A. The GPP concentration was significantly higher in the dry season than in the wet season.

Mean monthly phosphate concentration ranged from the lowest of 0.08 mg/l ±0.03 obtained in February to the highest of 0.30 mg/l ±0.15 obtained in June, 2003. Spatially, the concentration of phosphate phosphorus was highest in site B with a value of 0.3 mg/l obtained in September and lowest in site A with a value of 0.05 mg/l obtained in February. The wet season had significantly higher phosphate concentration than the dry season. The concentration ranged between 6.12 mg/l ±0.74 in May and 26 mg/l ±1.3 in August. The highest amplitude across the sites was recorded from site E with a value of 28 mg/l and the lowest was recorded from site A with a value of 5.1 mg/l. The nitrate concentration was significantly higher in the rainy season than in the dry season.

The Physico-chemical parameters studied showed no significant difference across the sampling sites except biochemical oxygen demand and community respiration that was significant. Based on seasons all the physico-chemical parameters were highly significant except BOD and CR that show no significant difference.

Correlation analyses (Table 2) were carried out between all the parameters measured. Water temperature significantly correlated negatively with DO. Transparency showed significant positive correlation with pH, EC, TDS, DO, NPP, and GPP but showed significant negative correlation with phosphate-phosphorus and nitrate-nitrogen. A significant positive correlation was recorded between pH with EC, TDS, DO, NPP and GPP, while a significant negative correlation was observed between pH with phosphate-phosphorus and nitrate-nitrogen.

There was a significant positive correlation between EC with NPP, GPP, TDS and DO while also a significant negative relationship existed between EC with nitrate-nitrogen. A high significant positive relationship was observed between TDS with DO, NPP and GPP while a highly significant negative correlation was observed with nitrate-nitrogen. DO show a significant positive correlation with NPP and GPP but showed significant negative correlation with phosphate-phosphorus and nitrate-nitrogen. A significant positive correlation existed between BOD with CR. Correlation coefficient analysis for NPP and other physic-chemical parameters exhibited a highly significant positive correlation with GPP, DO, pH and EC while a significant negative correlation was observed between NPP with phosphate-phosphorus and nitrate-nitrogen Community respiration exhibited a significant positive correlation with GPP. GPP revealed a highly positive significant correlation with DO, pH, EC and NPP but showed significant negative correlation with nitrate-nitrogen. A significant positive correlation was seen between phosphate-phosphorus with nitrate-nitrogen.

The dendrogram of similarity from the cluster analysis (Figure 1) showed that months of February to June formed one cluster, which represented the dry season and the early onset of rainy season period. July to November which represents the rainy season and the onset of the dry season of this locality formed another cluster, which showed that there existed a similarity in environmental conditions of the lake during these months. These observations showed that the reservoir's environment is significantly affected by the dry and wet season, which is active in this part of Nigeria (Table 1, 2 and 3).

Table 1 Mean Monthly (±SD) Values of Some Physico-chemical Parameters in Nasarawa Reservoir during the Period of Study (Feb 2018- Nov. 2018)

	WTR T(◦C)	0	pH	EC (µS/cm)	TDS (mg/l)	DO (mg/l)	BOD (mg/l)	NPP (g/cm³)	CR (g/cm³)	GPP (g/cm³)	PHP P (mg/l)	NRT T (mg/l)
FEB	24.2±2.23^{a}	0.676±0.32^{ac}	8.34±0.19^{a}	253.4±51.09^{ab}	117.6±27.85^{ab}	6.78±0.62^{a}	1.13±0.89^{a}	1.37±0.54^{a}	0.40±0.11^{ab}	1.77±0.44^{a}	0.08±0.03^{a}	9.78±1.06^{a}
Mar	26.38±1.81^{a}	0.67±0.34^{ac}	8.52±0.20^{a}	257.2±54.52^{ab}	119.2±28.72^{ab}	6.83±0.44^{a}	1.19±0.96^{a}	1.28±0.50^{a}	0.42±0.11^{ab}	1.70±0.44^{a}	0.10±0.02^{a}	10.04±0.97^{a}
Apr	30.5±1.62^{ab}	0.69±0.29^{ac}	8.32±0.53^{a}	334.8±49.13^{ab}	157.8±25.25^{a}	6.45±0.47^{a}	1.29±0.94^{a}	1.54±0.64^{ab}	0.64±0.23^{ab}	2.18±0.53^{a}	0.13±0.03^{a}	6.38±0.78^{b}
May	31.48±1.38^{ab}	0.80±0.30^{ac}	8.32±0.47^{a}	338.8±49.12^{ab}	161.2±24.86^{a}	5.9±0.39^{a}	1.52±0.94^{a}	1.72±0.66^{ab}	0.81±0.22^{b}	2.53±0.61^{a}	0.17±0.03^{a}	6.12±0.74^{b}
Jun	31±1.50^{ab}	0.15±0.02^{ab}	6.74±0.15^{b}	221.4±26.78^{a}	106±19.98^{a}	4.3±0.14^{ab}	2.34±0.62^{a}	1.1±0.30^{a}	0.93±0.14^{b}	2.03±0.40^{a}	0.30±0.15^{b}	14.92±0.74^{c}
Jul	28.96±1.10^{ab}	0.30±0.15^{ab}	6.8±0.09^{b}	110.8±13.96^{ba}	51.6±4.67^{b}	4.32±0.52^{ab}	1.25±0.81^{a}	0.84±0.15^{a}	0.61±0.20^{b}	1.45±0.18^{a}	0.09±0.04^{c}	13.54±1.33^{c}
Aug	30.62±1.95^{ab}	0.18±0.01^{ab}	6.940.10^{b}	140.4±5.82^{ba}	64.6±3.20^{b}	3.768±0.12^{b}	1.05±0.60^{a}	0.48±0.15^{b}	0.39±0.13^{c}	0.87±0.06^{b}	0.23±0.03^{ac}	26±1.33^{ab}
Sep	32.02±1.14^{ab}	0.14±0.04^{ab}	7.24±0.08^{b}	181.2±12.54^{bc}	86.4±7.23^{ab}	3.01±0.08^{b}	0.87±0.50^{a}	0.38±0.05^{b}	0.45±0.05^{c}	0.83±0.10^{b}	0.26±0.03^{ac}	22.7±1.41^{ab}
Oct	26.84±0.99^{ac}	0.20±0.06^{ab}	7.14±0.14^{b}	188.6±13.82^{bc}	92±6.72^{ab}	3.8±0.14^{b}	1.18±0.77^{a}	0.50±0.12^{b}	0.57±0.13^{ab}	1.06±0.23^{b}	0.23±0.02^{ac}	15.8±0.75^{ac}
Nov	24.16±0.74^{a}	0.31±0.12^{ab}	7.28±0.07^{b}	201.4±13.25^{bc}	100.2±4.58^{ab}	6.28±0.37^{a}	1.720.88^{a}	0.63±0.14^{ab}	0.69±0.13^{ab}	1.32±0.25^{a}	0.2±0.02^{a}	14.2±0.98^{ac}

Mean ±standard deviation with the same letter on the same column are not significantly different from each other (Least Significant Difference P<0.05)

Table-2 Pearson Correlation showing the Relationship between the Physico-chemical Parameters of Nasarawa Reservoir

	WTR T	TRPC	Ph	EC	TDS	DO	BOD	NPP	CR	GPP	$P0_4$ P	$N0_3$ N
WTR T	1.00											
TRPC	-0.19	1.00										
Ph	-0.23	0.94**	1.00									
EC	0.07	0.82**	0.82**	1.00								
TDS	0.06	0.80**	0.80**	1.00**	1.00							
DO	-0.55*	0.85**	0.81**	0.68*	0.67*	1.00						
BOD	0.04	-0.10	-0.25	0.19	0.22	0.14	1.00					
NPP	0.03	0.89**	0.76**	0.85**	0.82**	0.74*	0.26	1.00				
CR	0.30	-0.01	-0.21	0.30	0.34	0.02	0.87**	0.33	1.00			
GPP	0.12	0.75**	0.58*	0.81**	0.81**	0.64*	0.50*	0.95**	0.60**	1.00		
PHP P	0.45	-0.71**	-0.62*	-0.23	-0.19	-0.67*	0.38	-0.52*	0.36	-0.32	1.00	
NRT T	0.24	-0.85**	-0.72**	-0.78**	-0.77**	-0.80**	-0.26	-0.88**	-0.38	-0.87**	0.61*	1.00

*****Significant at P<0.05 **Significant at P<0.01

Table 3: Seasonal Variation of the Physico-chemical Parameters of Nasarawa Reservoir

Physico-Chemical Parameters	Dry	Wet	Mean	t	df	P value
WTR T(◦C)	27.34	29.89	29.89	2.96	48.00	0.004**
TRPC (cm)	0.63	0.19	0.19	6.94	63.00	0.000**
Ph	8.16	6.97	6.97	9.61	48.00	0.009*
EC (µS/cm)	277.12	168.48	168.48	6.45	51.00	0.000**
TDS (mg/l)	131.20	80.12	80.12	6.18	48.00	0.000**
DO (mg/l)	6.45	3.84	3.84	16.14	48.00	0.000**
BOD (mg/l)	1.37	1.34	1.34	0.12	48.00	0.900ns
NPP (g/cm³)	1.31	0.66	0.66	4.05	48.00	0.000**
CR (g/cm³)	0.59	0.59	0.59	0.05	48.00	0.962ns
GPP (g/cm³)	1.90	1.20	1.20	4.15	49.00	0.000**
PHP P (mg/l)	0.14	0.22	0.22	3.60	48.00	0.001**
NRT T (mg/l)	9.30	18.59	18.59	7.78	48.00	0.000**
Mean	38.33	30.04	30.04			
STD	70.39	44.19	44.19			

Key: ** highly significant at p<0.01, * significant at p<0.05, ns significant at p>0.05

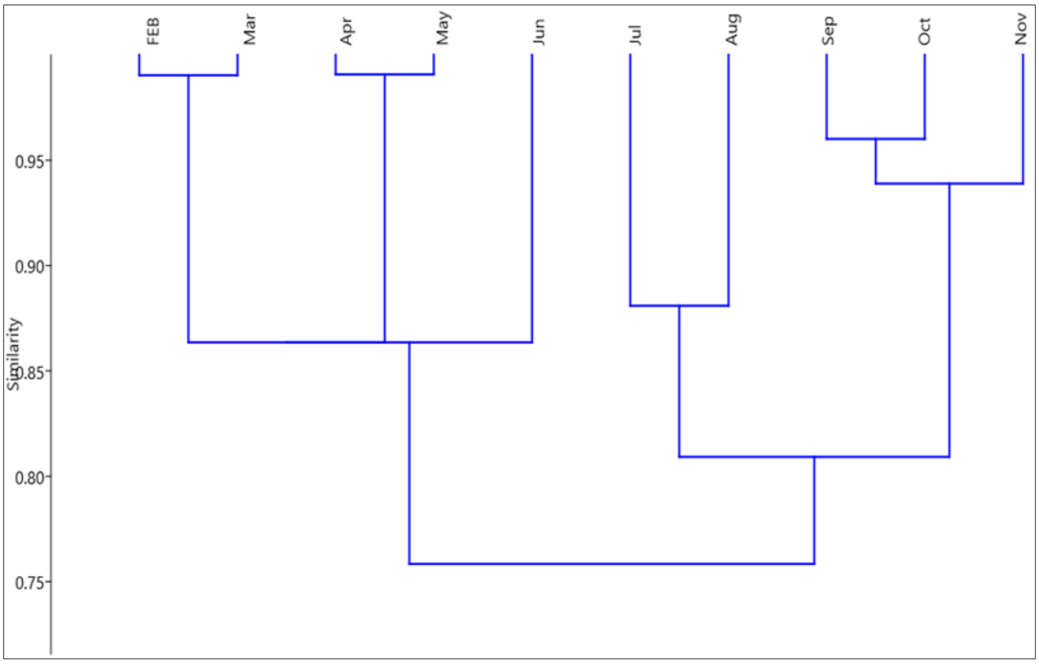

Fig 1: Bray-Curtis Cluster Analyses of the Overall Environmental Factors of Nasarawa Reservoir

Discussion

The low water temperatures recorded in February, March and November were attributed to the characteristics of cool, dry north-eastern trade wind popularly called harmattan. Lower temperature values in the dry months are characteristic of the harmattan season in northern Nigeria [4]. The higher water temperature recorded in the dry season may be due to intense heat from solar radiation which was absorbed by the water body [15]. Similar observations have been reported [10, 11]. The lower transparency observed during the rains and flood could be due to high water run-off from the water shed into the reservoir. Higher water velocity recorded during the rainy season was probably due to the high amount of flood which made the water flow faster and became turbulent most especially at site E which was more riverine and site D that was steeper than the other stations. Mustapha (2008) [16] reported similar observations in Isinla and Moro Lakes. The mean pH of Nasarawa reservoir ranges 6.8 – 8.2. This range is good and could allow for the overall survival of the reservoir biota. The recommended pH range for most fish and other aquatic organisms is between 6.0 and 9.0 [23]. Trivedi (1989) [23] reported that most natural waters have pH values within 5 to 10, with greater frequency of values falling within 6.5 to 9. The high pH values during summer may be due to high photosynthesis of micro and macro vegetation, shifting the equilibrium towards alkaline side [24]. The increase in values of conductivity in the dry season could be attributed to decrease in volume or depth of water with time. Comin *et al.* (1983) [6] also observed that high balance of evaporation leads to reduction in water volume with an increase in salt concentration hence the positive significant correlation between conductivity and TDS, Phosphate-Phosphorous and Zinc. Total dissolved solids are also important to aquatic life by keeping cell density balanced [9]. The reservoir has higher value of TDS during the dry season. This could have been due to the higher temperatures observed during the dry season which facilitated dissolution, ion exchange capacity, desorption and weathering processes. This is similar with findings of Zinabu (2002) [24], who reported that higher TDS values during the dry season may be associated with evaporation and the absence of a dilution effect, while the lower values during the wet season are hypothesized to be due to dilution from the tributaries. The high dissolved oxygen concentration recorded during the dry season was due to enhanced photosynthetic activities and reduced turbidity during the dry season. The low DO value in the wet season evinces an increase in the water column respiration caused by the entrance of organic matter by runoff and overflow of water for floodplain [21]. The high positive correlation between NPP, GPP and dissolved oxygen indicates the biologic activity strongly influences the oxygen variation and carbon cycle dynamics through photosynthesis. The larger oxygen concentration was related to the highest values of chlorophyll and water transparency and the smaller concentration of chlorophyll was associated with the lowest oxygen values. Such results indicate a biological control of aquatic oxygen [18]. Low values of BOD in rainy season may be due to lesser quantity of total solids/dissolved solids/suspended solids due to rain and more mixing of fresh water from river.

Decreased value of NPP and GPP during the rainy season might be due to the reason that high suspended solids in the flood water restrict light penetration into the water and thereby results in less photosynthetic activities and productivity [7]. The higher values NPP during the dry season may be due to penetration of more light intensity which facilitates higher rate of photosynthesis and ultimately the productivity of the reservoir system. Photosynthesis is the fundamental process involved in primary production [1]. Mitsch *et al.* [14] reported that reported high primary productivity during summer season may be due to high light penetration while low productivity during monsoon season because of the influx of the turbid water to the reservoir. Radwan (2005) [20] reported that a lake having a dense population of plankton indicating higher productivity and less plankton concentration showed low productivity. The decreased CR during the harmattan season was linked with low water temperature and reduced light which affects the rate of photosynthetic efficiency [1]. The rainy season season CR may be due to increased water temperature that stimulates growth of microbial population which in turn utilize more oxygen for their metabolic activities [2]. The positive correlation between GPP with EC, NPP, and BOD is similar to the findings of Ahmed *et al.*, (2005) [2] where they reported a moderate correlation between EC and GPP and NPP. A positive relationship between GPP and BOD (r=0,428, p=0,037) and NPP with BOD (r=0,549, p=0,005) indirectly demonstrates that the growth of phytoplankton and their increased productivity is due to organic wastes containing high nutrient values.

Surface water runoff, agriculture runoff; washing activities could have also contributed to the high phosphate-phosphorus in the dry season. A similar observation was reported by Balarabe (2001) [4]. The uptake of phosphate by phytoplankton and less agricultural runoffs resulted in the progressive decrease noticed in its concentration in the dry season. This agrees with similar findings by Kemdrim, (2005) [12]. Allochtonous sources of phosphate from fertilizer application on farmlands and the use of phosphate detergents for washing in site C may account for the high concentration of phosphate in the site. Higher wet season nitrate-nitrogen concentrations can be attributed to fertilizers, decayed vegetables and animal matter washed by rain. Anthropogenic activities from the municipal use of the water in site C and D, non-point source of nitrate from nitro phosphate fertilizers leaching into the water body and cow dung washed into the reservoir may be the reason for the significant high nitrate concentration in the sites. Zinabu (2002) [23] has observed this phenomenon and reported cattle manure to be a leading cause of eutrophication in tropical reservoirs.

Conclusion

All the physico-chemical parameters revealed monthly and seasonal variation and were within the recommended standard for fresh water bodies with the exception of biochemical oxygen demand, community respiration and nitrate-nitrogen. The reservoir water is suitable for irrigational and domestic purposes in terms of most of the physico-chemical and biological parameters analysed. However, considering that the reservoir is a source of drinking water, the potential of the anthropogenic inputs gains significance. It can be concluded that, Nasarawa reservoir is a shallow, eutrophic man-made reservoir with short water residence time. Because of its shallow nature, it is subjected to rapid fluctuations in water level. These fluctuations could negatively impact on the fisheries of the reservoir as well as its primary productivity.

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