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The Limnological Status of an Old Intermitent Pond during the Wet Season in Ekpoma, Southern Nigeria

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Abstract

The limnological status of an intermitent borrow pit pond in Ekpoma, Edo State of Nigeria was studied between June and September 2005 (wet season). In situ measurements of temperature, pH, electrical conductivity, transparency and total dissolved solids (TDS) were recorded together with the dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total suspended solids (TSS), primary productivity and the phytoplankton species *composition for the pond water. The study revealed that the pond was slightly alkaline (pH 7.9 – 8.4) and fresh with low electrical conductivities of 91.8 – 114.1µS/cm and TDS of 46.4 – 57.2mg/l. Water temperature ranged from 26.0 – 32.1^{0}C and the pond was well oxygenated (DO values = 6.0 – 9.23mg/l) but slightly polluted with high BOD_5 values (4.33 – 7.43mg/l) and highly turbid (TSS = 13.4 – 20.0mg/l). The high TSS was associated with run-offs and allochthonous inputs from the surrounding environment. The Gross Primary Productivity was low and ranged from 2.47 – 6.60mgO_2/m^3/day while the respiratory activities ranged from 1.8 – 5.23mgO_2/m^3/day. The distribution of phytoplankton was irregular but characterized by high densities and species diversity. The phytoplankton population was dominated by the Bacillariophyceae. These attributes are typical of an intermitent pond.*

Key words: Limnological status, intermittent pond, physicochemistry, phytoplankton, productivity.

Introduction

Investigations on African rivers and ponds include assessment of the hydrobiological features, and it has been found that their physico-chemical characteristics follow a seasonal pattern. Kelley and Alli (1993) studied the effects of organic pollution on algal communities in a tropical stream and observed that the algal population increased with increased organic pollution. Hall *et al*. (1977) worked on Zambezi River in Mozambique with particular emphasis on physico-chemical status of the middle and lower Zambezi prior to closure of the Gabora Bassa dam. Ufodike and Garba (1992) studied the seasonal variation in limnology and productivity of a tropical highland fish pond in Jos Plateau, Nigeria and found that water temperature and rainfall affected primary productivity, plankton abundance as well as the physico-chemistry of the pond. Tenabe (1993) carried out limnological investigation of Eruvbi stream, a tributary of Ikpoba River in South Western Nigeria, and observed that the nutrient level markedly affected the algal population. Hydrobiological studies of water bodies within Okomu forest reserves (sanctuary) in Edo State of Nigeria by Ogbeibu and Victor (1995) revealed that the dissolved oxygen (DO) level was markedly lower in the lentic (pond) than the lotic (stream) which are characterized by lower nutrient levels, alkalinity and electrical conductivity.

The pond studied (70m long and 33m wide) is a seasonal one with an area of about 0.6 hectare at Ekpoma, along the Benin City-Auchi road on latitude

$6^0$44' and longitude $6^0$09' in Edo State, South-western Nigeria. It was created from a borrow pit which was used during the construction of the Benin City Auchi road in the 1970s. The immediate vicinity of the pond consists of bush, farmland, and human settlement. Some of the plants around provide an annual input of leaf litter to the pond. Decomposition of leaf litter,= and dead aquatic macrophytes during most of the years cause the bottom sediment to remain anaerobic (Byars 1960, Barclay 1966; Dineen 1953). During the wet season, the borrow pit is fed by run-offs. According to Heartel (1976) run-offs are direct consequences of rainfall. The water is fetched mainly during the dry season by the nearby settlers for domestic purposes like washing of clothes and rice as well as preparation of palm oil which they do by adding a coagulant (Calcium hypochlorite or alum) to the collected pond water to precipitate suspended/dirt particles before usage. Due to this and also evapotranspiration from the floating macrophytes (mainly *Pistia stratiotes* and *Lemna minor*), the pond dries out by the end of the dry season. No limnological study has been carried out on this pond; and limnological information on ponds from Edo State (Southern Nigeria) is generally lacking despite their socio economic and ecological importance. This work was therefore carried out to provide information on some physico-chemical characteristics as well as the productivity and phytoplankton abundance and diversity of the pond during the wet season, since normally there is no water in the pond during the latter parts of the dry season.

Materials and Methods

Water samples were collected at two weeks interval from the pond during the wet season months of June to September in the year 2005.A total of three replicates were taken from the two ends and the center across the length of the pond. These were pooled together to form a composite sample for analysis. All analyses were carried out in triplicates and the means are reported. Measurements for parameters such as temperature, electrical conductivity, total dissolved solids (TDS), pH and transparency were taken *in situ*. Samples for dissolved oxygen (DO) were fixed in the field using Winkler’s solutions A & B and taken to the laboratory for analysis. Other physico-chemical parameters measured were biochemical oxygen demand (BOD) and total suspended solids (TSS). All physico-chemical analysis were undertaken following the methods of APHA (1985) using appropriate instrumentation and procedures.

Primary productivity was measured by determining the oxygen concentration of the pond using the Winkler's method using the light and dark bottles technique (Odum 1971, Vallenweider, 1974). Oxygen bottles (transparent bottles) were filled with water samples from the pond and covered with air tight stoppers to avoid trapping air bubbles. These together with the dark bottles also filled with the pond water samples were incubated *in situ* by leaving them inside the pond for 24h. There were two replicate set-up in each case. After the 24h incubation, the oxygen in each bottle was fixed using Winkler solutions A and B and titrated for DO following APHA (1985). The productivity was determined by using the oxygen concentrations determined in the light and dark bottles in the following equation according to Vallenweider (1974).

Gross primary productivity (GPP) = $C_3 - C_2$ = mg O_2 $m^{-3}day^{-1}$

Respiratory activity per unit area = $C_1 - C_2$ = mg $O_2m^{-3}day^{-1}$

Net photosynthetic activity = $C_3 - C_1$ mg $O_2m^{-3}day^{-1}$

Where

C_1 = oxygen concentration of the pond water

C_2 = oxygen concentration of pond water in dark bottle

C_3 = oxygen concentration of pond water in light bottle

The phytoplankton samples were collected using a sweeping plankton hand net (55µm mesh). The samples were preserved in 130ml plastic bottles using 4% formalin solution. The phytoplankton composition, abundance, density, diversity and evenness were determined following the methods of Brower and Zar (1977).

The Shannon – Weiner diversity index (H^1) was considered appropriate to use for species diversity since random samples for species from a large aggregation (random samples for an entire phytoplankton community) were being considered. The Shannon-Weiner diversity index (H^1) was given as follows: Evenness and Taxa richness were also calculated thus:

$$H^1 = \frac{(N\log N - \Sigma ni \log ni)}{N}$$

$$\text{Evenness} = \frac{H^1}{\textit{Log S}}$$

Taxa richness (d) = (S-1)/log N

Where

ni = individual cases

S = species

N = Total number of individuals.

Results and Discussion

The results of the physico-chemical analysis obtained from the pond are presented in Table 1. There were variations in water temperature ranging from 25.6-32.1^{o}C. The variability in the water temperature was governed by the local climatic conditions, depth of water, the degree of approach of the sampling site to sunlight and the time of the day for sampling. Generally the temperature of the surface water is influenced by the substrate composition, turbidity, vegetation cover, run-off and heat exchange with air (Awachie, 1981; Umehen, 1989). The moderating effect of the wet season was partially responsible for the low temperatures recorded in the pond. Generally, the pond waters recorded high temperature in this study when compared with results of ponds in the temprate regions of Southern England and Northern India (Barclay, 1966; Zutshi and Khan 1977). These differences are due to water substrate, water depth in the pond, and its exposure to sunlight in terms of its intensity around the pond and its positions on the globe (tropical or temperature environment) according to King and Nkata (1991) and Byars (1960). The pond water was slightly alkaline (pH 7.9 – 8.4) with very narrow fluctuations, fresh with low electrical conductivity (91.8 – 114.1µS) and TDS (46.4 – 57.2mg/l) values. The water was also well oxygenated with DO values ranging from 6.0-9.23mg/l but slightly polluted with high BOD_5 values (4.33-7.43mg/l) and highly turbid (TSS = 13.4-20.0mg/l). Narrow fluctuations in pH and maximum turbidity values of lentic water bodies have also been reported by Khan and Chandrima (2002). The high TSS values during the study period may be attributed to an increase in silt load and suspended particles brought into the pond by run-offs. The transparency values of 12.0-21.0cm were low and this could be attributed to the presence of suspended particles carried with the inflow of water from the catchment area and plankton population. Similar observations have been made by

Chidobem and Ejike (1985) for Shen Reservoir in Plateau State,Karlman (1982) for Kainji lake in Nigeria and Ali (1996) for Chenderoh Reservoir in Malaysia. The results of the present study are also in line with the observations made by Akpan (1995) for some freshwater ponds in Uyo, Nigeria.

The variations recorded in the pH is expected and influenced primarily by metabolic activities of the organisms such as phytoplankton, zooplankton and benthos. The pond had a high pH range of 7.9-8.4 which indicates alkalinity during the sampling period (wet season) similar to the observations of Tassaduqe *et al* (2003) of the Indus River in Pakistan during the wet season. The Bewas pond in New Zealand (Barclay, 1966) and the Radly pond in India (Zutshi and Khan 1977) and fish ponds in Cip Fish Production centre in Elazig Turkey.Sen and Sonmez (2006) also recorded high pH values (alkaline). This is also similar to the findings of Lind (1938) in her study of the Sheffied pond in England. According to Lind (1938), alkaline pH may be accounted for by the nature of run-offs from adjacent agricultural lands and photosynthetic activities of phytoplankton and macrophytes in the pond. The pond under study had a high population of *Pistia stratiotes* and *Lemna minor*.

The fluctuations in the DO concentrations could be due to variations in water temperature as primary productivity increased or decreased (Khan and Zutshi, 1980; Akpan, 1995). The high levels of dissolved oxygen recorded in the present study (6.47-9.23mg/l) indicate that the pond was well oxygenated. These high DO values agree with the findings of Eborge (1971), Hall *et al.* (1977) and King and Nkanta (1991) who reported that increase in photosynthetic activity of aquatic organisms during rainy season, results in high DO values. Similarly, the BOD_5 values of 4.33-7.43mg/L were high due to organic input from the surrounding environment. Variations in parameters like transparency or light penetration,pH, electrical conductivity, and dissolved oxygen observed in the present study are similar to the findings of Mahboob and Zahid (2002) on seasonal variations of limnological characteristics of Rakh Branch canal in Pakistan.

Electrical conductivity which indicates the amount of electrolytes in the pond was generally low indicating that the pond water is fresh. However, there was gradual increase in electrical conductivity during the study period (Table 1) which supports the view of Jutshi and Vass (1973). The increase in electrical conductivity in the pond indicates an increase in the amount of electrolytes in the water possibly due to leaching or allochthonous materials input into the pond as a result of human activities around the pond. These observations are in agreement with the findings of Bishop (1973) for Malayan river, and Ogbeibu and Victor (1995) for Okhomu River in Southwestern Nigeria. The TDS followed the same pattern as the conductivity and may be mutually inter-related and influenced.

The Gross Primary Productivity (GPP) of the pond fluctuated between 2.47 and 6.60mg$O_2$$m^{-3}$$day^{-1}$ during the sampling period whereas the Net Primary Productivity (NPP) ranged from 0.70-1.63mg $O_2$$m^{-3}$$day^{-1}$ and respiratory activity from 1.48-5.23mg $O_2$$m^{-3}$$day^{-1}$ (Table 2). The minimum values of GPP recorded coincided with periods immediately after a spell of heavy rainfall which is also similar to the findings of Mahboob and Zahid (2002). The GPP values recorded generally appear low indicating that the pond under study is low in productivity compared to the GPP of 1443.75-3662.5 and 2171.25-3512.00mg$O_2$$m^{-3}$$day^{-1}$ recorded in Rabindra Sarovar and Subhas Sarovar waters respectively in Calcutta, West Bengal, India, by Khan and Chandrima (2002). This pattern is similar to what was observed for primary productivity in the radly pond in Northenr India (Jutshi and Vass, 1973) and could be attributed to low phytoplankton density and also probably low nutrient level. Primary productivity is associated with the total suspended solids, thus the higher the transparency (low TSS), the higher the gross primary productivity. The results obtained from this seem to agree with Cooper (1975) that highest rate of gross primary production is realized when the population of phytoplankton is not so high as to generate a reduced photosynthetic activity.

A total of 22 phytoplankton genera belonging to 4 families were recorded from the pond. The common phytoplankton species recorded from the pond are listed in Table 3. The algal species recorded from the pond belong to the families Cyanophyceae (blue green algae), Euglenophyceae (Euglenoid), Chlorophyceae (green algae) and the Bacillariophyceae (diatoms). *Oscillatoria, Lyngbia* (of the family Cyanophyceae) and *Nitzschia* (of the family Bacillariophyceae) were the most widely distributed during the period of study. Sen and Sonmez (2006) also observed *Nitzschia* spp. as the most conspicuous member of the Bacillariophyceae in the Cip Fish Production centre ponds in Turkey. *Nitzschia* together with *Navicula* and *Cymbella* have been recorded as the genera represented with most numerous species in the region of the Cip Fish Production Centre near Cip Dam Lake in Elazig, Turkey by Sen and Pala (2001) and Alp (1996) which is similar to the observations in the present study. Among the lowest distributed phytoplankton taxa, are the *Dactylococcopsis fasciculan* and *Microcystis aeruginosa* (both of the family Cyanophyceae), *Penium cylindrus* and *Hylotheca dissiliens* (Chlorophyceae).Cyanophyceae and Bacillariophyceae had a wider range of distribution than Euglenophyceae and the Chlorophyceae (Table 3) which is also similar to the findings of Sen and Soumez (2006). Some of the phytoplankton species encountered in this study have also been encountered in the Indus River in Palestine by Tassaduque *et al*. (2003).

Phytoplankton density of the pond fluctuated during the period of study June-Sept. with the highest phytoplankton density of 660cells/ml recorded towards the end and of the wet season sampling and the lowest (306cells/ml) at the beginning of 2nd week sampling in July (Table 4). *Oscillatoria, Fragillaria and Nitzschia* spp had the highest phytoplankton density representing the Cyanophyceae and Bacillariophyceae families respectively.*Spirogyra* sp and *Chlorella* sp had the highest phytoplankton density for the families of Chlorophyceae. *Microcystis aeruginosa* (Cyanophyceae) and *Cosmarium askenasyi* (Chlorophyceae) had the least phytoplankton density (Table 4) having 18 and 4 cells/ml respectively.

Results obtained from the density index (Shannon Weiner) and evenness (or relative abundance as it is sometimes called) showed that the density ranged from 0.75-1.06 (low diversity index) in the pond with the maximum value recorded at 7th week of sampling. The evenness or relative abundance, ranged from 0.73 to 1.25 which were recorded at 4th and 5th weeks of sampling respectively (Table 5).

The diatoms were the dominant species of the phytoplankton population in the pond in wet season. It constituted 28.0% to 59.0% of the phytoplankton abundance in the wet season. The total Bacillariophyceae taxa recorded was 6. This group was represented mostly by *Fragillaria, Navicula,, Pinnularia, Synedra, Nitzschia and Cyclotela.*

Chlorophyceae constituted 24.0% to 59.0% of the phytoplankton abundance during the wet season.

The Cyanophyceae (blue-green algae) constituted 5.0% to 33.0% during the wet season. The common genera recorded were *Oscillatoria, Gloetrichia, Lyngbia, Dactylococcopsis* and *Microcystis.*

Euglenophyceae was represented by 1 genus, *Euglena* sp.Its abundance varied from 4.0% to 11.0% in the wet season.

The total number of taxa recorded during the period of the study in the wet season was 22. The value of the taxa richness (d) ranged from 2.30 to 4.23 during the wet season.

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Table 1: Changes in physico-chemical characteristics in the pond during the wet season (June – September 2005)

Results are in means ± standard errors

Sampling frequency at 2 weeks intervals (June – Sept.)	**pH**	**Temperature (^{0}C)**	**Transparency (cm)**	**TDS (mg/L)**	**TSS (mg/L)**	**DO (mg/L)**	**BOD_5 (mg/L)**	**Conductivity (µS)**
1.	8.1±0.10	32.1±0.22	12.0±0.35	47.0±1.05	20.0±0.19	6.43±0.38	4.33±0.12	92.2±0.90
2.	8.3±0.15	29.4±0.14	14.4±0.14	46.4±0.80	15.1±0.48	8.97±0.57	6.94±0.30	91.8±1.62
3.	8.0±0.09	28.3±0.20	17.0±0.20	49.8±2.00	14.0±0.91	8.3±0.01	5.23±0.30	100.6±1.88
4.	7.9±0.20	25.6±0.10	14.0±0.27	53.9±1.70	16.0±0.81	7.0±0.76	4.83±0.21	107.1±0.64
5.	8.2±0.14	26.0±0.25	16.3±0.35	51.6±3.00	15.0±0.10	6.0±0.26	5.73±0.11	103.5±2.30
6.	8.4±0.22	31.0±0.20	12.2±0.21	54.0±2.12	19.3±0.28	8.0±0.18	6.84±0.22	109.4±1.55
7.	8.3±0.18	26.5±0.15	21.0±0.10	57.2±3.10	13.4±0.52	9.23±0.92	7.43±0.30	114.1±2.73

Table 2: Changes in Primary Productivity, respiratory activity and net photosynthetic activity with time in the pond during the wet season (June – September 2005)

Results are in means ± standard error

Sampling frequency at 2 weeks intervals (June – September)	**Gross Primary Productivity (mg $O_2m^{-3}day^{-1}$)**	**Respiratory Activity ($mgO_2m^{-3}day^{-1}$)**	**Net Photosynthetic Activity ($mgO_2m^{-3}day^{-1}$)**
1.	6.60 ± 0.13	5.23 ± 0.38	1.37 ± 0.94
2.	2.47 ± 0.94	1.67 ± 0.25	0.84 ± 0.81
3.	3.50 ± 0.81	2.50 ± 0.63	1.00 ± 0.18
4.	2.94 ± 0.76	1.48 ± 0.31	1.46 ± 0.48
5.	3.87 ± 0.11	3.17 ± 0.83	0.70 ± 0.63
6.	3.97 ± 0.34	2.64 ± 0.99	1.33 ± 0.31
7.	5.03 ± 0.56	3.40 ± 0.28	1.63 ± 0.51

Table 3: Changes in distribution of phytoplankton species in the pond during the wet season (June – September 2005)

TAXA	**Sampling frequency at 2-week intervals**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
CYANOPHYCEAE							
Oscillatoria sp.	+	+	+	+	+	+	+
Gloetrichia ecshinulata Smith.		+	+				
Lyngbia majuscula Harvey	+	+	+	+	+	+	
Dactyloccopis fasciculan Lemm..							
Microcystis aeruginosa *Kutz.*			+		+		+
EUGLENOPHYCEAE							
Euglena sp.	+	+	+				
CHLOROPHYCEAE							
Closterium monoliferum (Bory) Ehr.ex Ralfs.			+		+		
Chlorella sp.		+	+		+		+
Penium cylindrus (Ehr.) Breb.ex Ralfs.				+			+
Hylotheca dissiliens (Smith) Breb.in Ralfs..						+	
Gomphomena sp.				+			+
Spyrogyra sp.	+					+	
Cosmarium askenasyi Schmidle..						+	
Tetraedron sp.	+						
Cladophora oligoclona Kutz..		+			+		+
BACILLARIOPHYCEAE							
Fragillaria sp.		+		+	+		
Pinnularia cardinaliculus Cleve.			+			+	+
Navicula sp.	+				+		
Synedra acus Kutz..	+			+			+
Nitzschia sp.	+	+	+	+	+	+	+
Diatoma sp.	+		+		+		+
Cyclotela sp.	+						+
Total No. of Taxa	**10**	**8**	**10**	**7**	**10**	**7**	**11**

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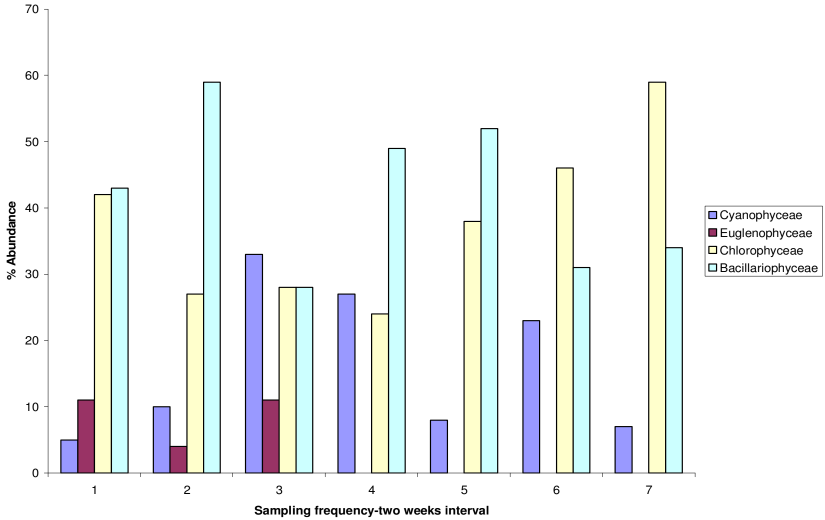
Table 4: Changes in phytoplankton density (cells/ml) in the pond during the wet season (June-September 2005)

TAXA	**Sampling frequency at 2-week intervals**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
CYANOPHYCEAE							
Oscillatoria sp.	14	13	120	100	11	76	29
Gloetrichia ecshinulata Smith.		17	41				
Dactylococcopsis fasciculan Lemm.					38		18
Microcystis aeruginosa *Kutz.*			18				
EUGLENOPHYCEAE							
Euglena sp.	33	12	60				
CHLOROPHYCEAE							
Closterium monoliferum (Bory) Ehr.ex Ralfs			64		82		
Chlorella sp.		30	91		76		105
Penium cylindrus (Ehr.) Breb.ex Ralfs				40			54
Hylotheca dissiliens (Smith) Breb.in Ralfs.						37	
Gomphonema sp.				51			88
Spyrogyra sp.	80					110	
Cosmarium askenasyi Schmidle.						4	
Tetraedron sp.	51						64
Cladophora oligoclona Kutz.		53			39		81
BACILLARIOPHYCEAE							
Fragillaria sp.		120		91	86		
Pinnularia cardinaliculus Cleve .			50			31	70
Navicula sp.	73				63		21
Synedra acus Kutz.	4			81			38
Nitzschia sp.	28	61	85	10	89	70	51
Diatoma sp.	17		17		31		
Cyclotela sp.	12						41
Total No. of cells/ml	**312**	**306**	**546**	**373**	**515**	**328**	**660**

Table 5: Summary of phytoplankton density, diversity, evenness and taxa richness in the pond during the wet season (June – September 2005)

Phytoplankton characteristics	Sampling frequency at 2-week intervals						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Density (Number of organisms/L)	312	306	546	373	515	328	660
Number of Taxa	10	8	10	7	10	7	11
Shannon – Weiner Diversity index (H')	0.88	0.83	0.92	0.77	1.04	0.75	1.06
Evenness	0.87	0.90	0.90	0.73	1.25	0.90	0.97
Taxa Richness (d)	3.89	3.13	3.56	2.30	4.00	2.34	4.23

Fig 1: Percentage abundance of major phytoplankton groups of the pond during the sampling periods.



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