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Monthly variation in physicochemical parameters of Ebonyi river system

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The objectives of the study were to analyze the monthly physic-chemical properties of Ebonyi river system and to make necessary recommendations for the general improvement of fish management in the study area. Stratified random sampling was carried out in each water body. The fishes were caught, identified, counted, graded, measured and weighed according to species. The species for chemical and histological analysis were taken immediately after weighing to the laboratory. It was observed that the mean water temperature of study areas ranged from25.03±0.44 to 29.35±0.44°C. Mkpume River (29.35±0.44°C) had the highest water temperature when compared to that of other study areas ($p<0.05$). The water temperature of Ameka dam, Enyigba river and Ebonyi river were statistically similar ($p>0.05$) but their water temperature were significantly lower than that of pond water ($p<0.05$). Enyigba river had the highest pH (7.65 ±0.05) but the pH of this River does not differ significantly from that of Ebonyi river (7.49±0.08) ($p>0.05$). There was also not significant difference in the pH of Ameka dam, Mkpuma river and Ebonyi river. The pH of the aforementioned study areas were significantly higher that of pond water ($p<0.05$). Mkpuma had the highest DO content but its value does not differ significantly from that of Ebonyi river and Ameka dam ($p>0.05$). The DO of Enyigba river was significantly lower ($p<0.05$) than those of other study areas. Mkpuma river had significantly higher CO_2 concentration while there was no significant difference ($p<0.05$) in the CO_2 of Ameka dam and Pond water, and Enyigba river, Ebonyi river and Pond water. Enyigba had significantly higher transparency than those of other areas studied. This was followed by Mkpuma river but the transparency of Mkpuma does not differ significantly from those of Ebonyi river and pond water ($p>0.05$). Based on the research findings, the following policy recommendations were therefore proffered. World health/bank should please assist the state Government in making available good quality refined urban tap water to the villages and subborbs so as to save the lives of both Urban and Rural dwellers.

Key words: Ebonyi State, transparency, dissolved oxygen, carbon (iv) oxide, temperature

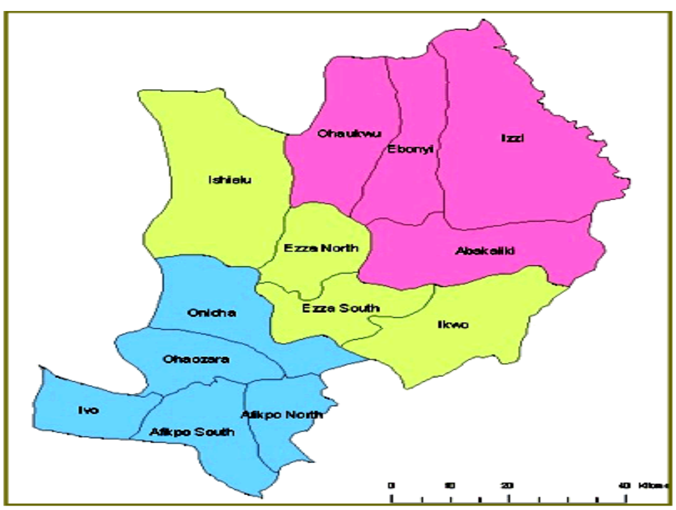
INTRODUCTION

According to D Balakrishna (2015), Water is one of the most abundant substances on the earth. It is essential for survival of any plant and animal, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities. Protecting the lake ecosystems is crucial not only to protecting this country's public and economic health, but also to preserving and restoring the natural environment for all aquatic and terrestrial living things. Pawale RG (2014), observed that hydrobiology simply put is the study of different life in water whereas Limnology deals with the study of the physical, chemical, geological and biological aspects of all natural fresh waters available in the ecosystem. Ecology relates mainly to the biological section of limnology but is different from freshwater biology including the feature of the freshwater environment as well.

Pawale (2014) in Goldman *et al* (1983) observed that freshwater habitats are mainly water bodies like; lakes, ponds dams, and reservoir are known as lentic (still), whereas water habitats and rivers, mountain streams are running water known as lotic (flowing) water habitats. (Mahesh, 2014), observed that the inland water bodies in India such as lakes, tanks and ponds do exhibit distinct monthly fluctuations in their physico-chemical and biological features. Physico-chemical and biological parameters play very important roles in the assessment of water quality. There is need to study different water bodies since the study is very important if one must understand the metabolic events as well as the distribution of fishes in aquatic ecosystem. The parameters influence each other and also play paramount role in governing the abundance and distribution of flora and fauna. The need for this research in the study area arose from the fact that there are a lot of rivers in Ebonyi state and these rivers and water bodies play the role of housing fishes collected over time by fishermen in the study area. The researcher tries to study and understand the monthly variations in the physic-chemical parameters like Temperature, pH, Free CO_2, Dissolved Oxygen and Transparency, among others.

MATERIALS AND METHODS

The Study Area



The study area is Ebonyi State of Nigeria. The State lies approximately 7°3' N and longitudes 5°4' E and 6°45' W. It is located in the Eastern part of Nigeria. The state is made up of thirteen (Nadal *et al*, 2004) local government areas, which are divided into three (Ibe, 2011) agricultural zones, namely: Ebonyi North, Ebonyi Central and Ebonyi South. It has a landmass of approximately 5,932 square kilometers. It is bounded in the East by Cross River State, in the North by Benue State, in the West by Enugu State, and in the South by Abia State (NPC, 2006).

Ebonyi State has a population of 2.1 million people [NPC, 2006]. The vegetation of the state is a mixture of savanna and semi-tropical forest with agriculture and mining as the mainstay of the economy. It lies in an area of moderate relief of between 125 meters and 245 meters above sea level. The soil is texturally clay loam, fairly to poorly drained, with gravely subsoil in some locations especially the upland adjacent to lowland areas (Gado, 2003) Crops grown in the area include; rice, yam, cassava, cocoyam, groundnut, cowpea and vegetables. Livestock farming, especially the extensive system of rearing sheep, goats and native cattle, is also practiced by the people. Fishing activities are predominant in all the zones of the state.

Roy (2002), noted that three main seasons prevail in the area - the rainy (wet) season, which spans from early April to early November, the harmattan period which lasts between mid-November to late January and the dry season, which lasts from late January to early April. However, a short dry spell is usually experienced during the month of August, and this is termed the August break. Lowland areas popularly called, FADAMA are largely available and serve as good sites for rice and fish farming during the rain and dry season vegetable farming. Some non-farm activities prevalent in the State include: quarrying, petty trading, pottery, weaving etc. Medium to large-scale industries also exist in the state. Notable among them are the Abakaliki rice milling industry, the fertilizer blending plant and the building materials industry. Large deposits of solid mineral resources such as lead, gold, gellena, zinc, iron, oxide, quartz, grease, gypsum, limestone, marble stone, common salt and others are found in Ebonyi State.

Field Sampling

Three locations within the river systems in Ebonyi State, lying close to mine sites were sampled on monthly bases for two years beginning from March 2011 to February 2013. Then a river system which does not lay close to any mining site was used to serve as control 1. Then culture pond water using urban tap water to culture *Clarias albopunctatus* was used as control 2. Specimen of *Clarias albopunctatus* were collected from the Ebonyi state university earthen pond and acclimatized to the laboratory conditions for fifteen days. The fishes were fed with industrial coup hen industrial feed at the 3% body weight twice daily. The fishes, measuring 4 to 6cm in length and weighing 8 to 10gm were selected for the experimental purpose. The physiochemical parameters of the water were estimated according to (Das *et al*, 2001). The test specimen was stocked in a concrete pond supplied with urban tap water. The water was changed bimonthly. The experiment was sampled monthly, for onward processing and preservation for analytical purpose. Samples for water quality were taken and analyzed in IITA according to Fishers Standard Methods (FSM standards) for sediments samples.

Multi-mesh gillnets were used to monitor the abundance and structure of the fish fauna (Goyer, 1992). Stratified random sampling was carried out in each water body. The fishes were caught, identified, counted, graded, measured and weighed according to species. The species for chemical and histological analysis were taken immediately after weighing to the laboratory.

Data Analysis

Water Body Analysis

Temperature: A 0.01 graduated centigrade thermometer in °C was employed for recording the water temperature at the sites. pH (Hydrogen ion concentration): WTW (wissenchaft lieh-technische werk-statten) multiline-p_4 (merk) made in Germany was used. Procedure**:** The probe was cleaned and calibrated by switching on and was directly inserted into the water and the value recorded after 10 minutes. Dissolved Oxygen: WTW multiline –p_4 was used for disolved oxygen estimation but must be inserted up to 25cm depth and the value recorded in mg/l. Free Carbondioxide (CO_2): Immediately the sample was collected with a Nessler's tube, 2 (two) drops of phenolphtalein reagent were added and the number of drops calculated thus: N/10 NaOH required x 20 = ppm of free carbondioxide. Transparency: The water transparency was measured by using Secchi disc. The Secchi transparency is the mean depth of the point where emergent white disk disappears or match with the water physically. Hence, the exact depth or point of disappearance of the disk from the surface level of water was recorded as the transparency of the existing water at a particular time.

RESULT PRESENTATION

Physico-chemical Parameters of the Water Bodies

Variation in the water temperature °C of the five water bodies ranging from March 2011 to February 30th 2013 is as follows. Water temperatures varied from 18.2°C to 35°C which is from the coolest period of November to the warmest dry season February, March and April in 2011-2012 and 22°C during harmattan (Nov/Dec) to 36°C of dry season which ranges from February-April of 2012-2013. The pattern of temperature variation in water temperature followed a similar trend in all the lakes showing lowest value in December /January 2012 and December 2012. Water gradually became warmer from February onwards with maximal temperature in April. Gradually, the variation in water during both years was marginal only.

Figure 1: Variations in Water Temperature (°C) of Ebonyi River System

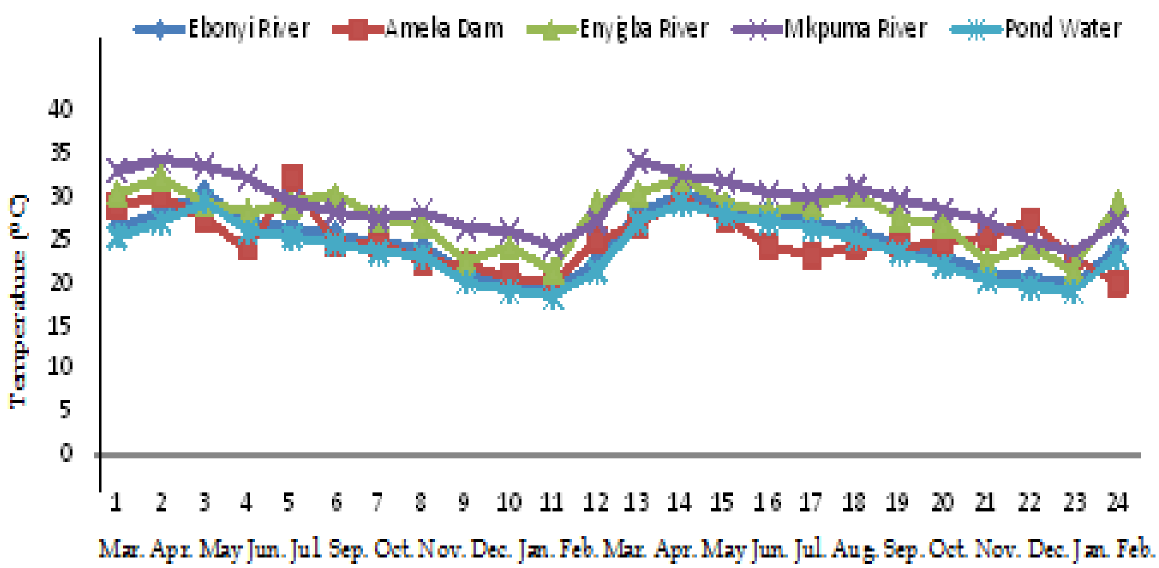
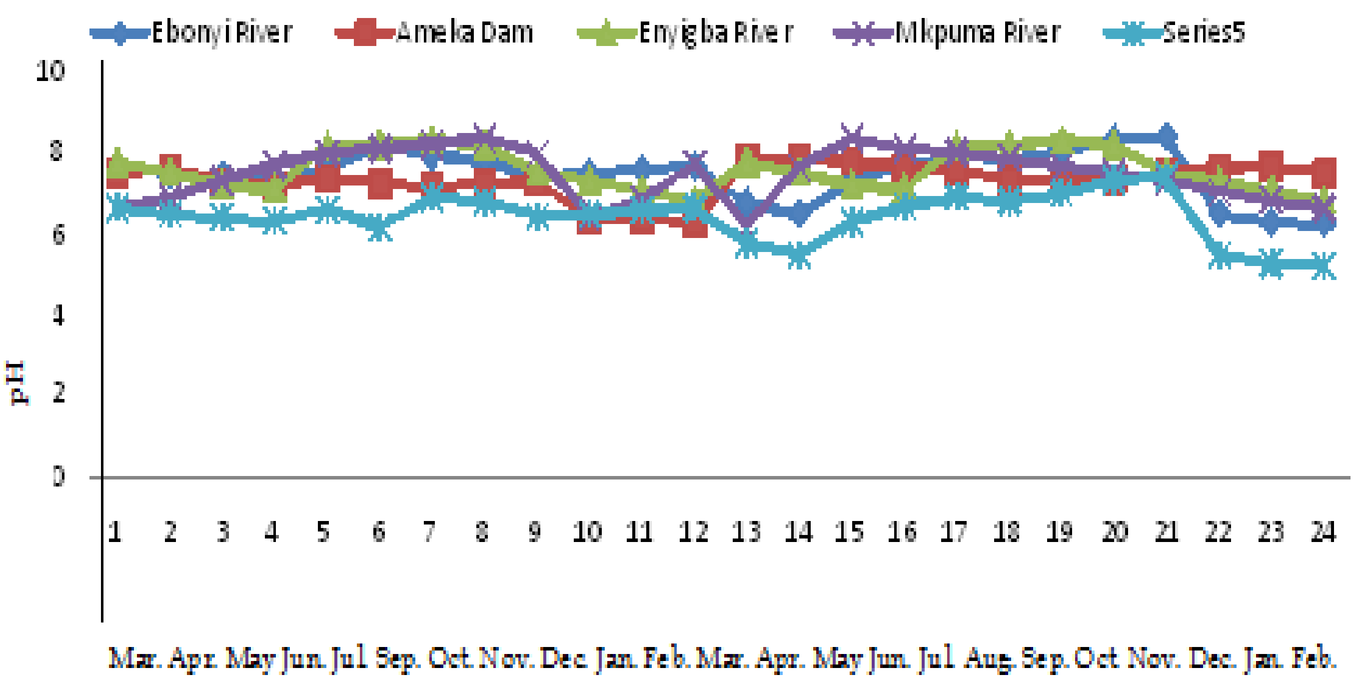


Figure 2: Variation In Hydrogen Ion Concentration (pH) of Ebonyi River System



Variation in pH in the five water bodies ranging from March to February of the two years. The pH of water varied from 6.3-8.5 in November, December and January 2011 at Mkpuma and Mkpuma river and February, March at Enyigba and Ebonyi rivers. During both years of observations all lakes showed bimodial seasonal variations. Generally the pH of water was lower during the period of harmattan and dry season which was November -February with a highest value obtained in August, September and October 2012. The pond water showed slightly varied pH compared to the other water bodies. The pattern of hydrogen ion concentration varied considerably among the stations.

Dissolved oxygen fluctuated in the range of 5.80-12.00ppm during the first year of observation: 2011-2012, with an average of 7.3 and 8.2 ppm respectively. The fluctuation in Dissolved Oxygen level remained marginal during the period under study. Dissolved Oxygen content of Ebonyi, Mkpuma and Enyigba were high during year 2011 and 2012 but that of the Pond and the Dam were low within the period of study. The pattern of temperature variation was more or less uniform in all the water bodies; even though minor deviation was observed within stagnant waters than flowing waters. The trend of dissolved oxygen were different in all the water bodies.Free CO_2 was in the range of 1.0- 7.1 in year 1and 2.3-8.0 in year 2 with an average of 4.05 and 5.15 ppm respectively. The fluctuation in free CO_2 level was comparatively high during the entire period of study. The pattern of seasonal variation showed considerable deviations at different months in the lakes, maximal CO_2 was recorded in September 2011 and December 2012 in Mkpuma river. Relatively, lower concentrations of free CO_2 were recorded in the pond and Ebonyi river during the harmattan period (December to January 2011) and below the detectable levels.

Transparency varied from 45.2 to 250 cm during year 2011 and 88.0 to 103cm in year 2012 with an average of 147.5 and 94.5 respectively. The variation of Sechi disc depth was relatively higher in Enyigba as compared to others in year 2011 but in year 2012, the trend of transparency was the same in all the water bodies. There was observed drop in transparency within the period of an onset of rain at this time the water bodies became muddy. High transparency was observed within the period of the end of rain.

Figure 3: Variation in Dissolved Oxygen Content (ppm) of Ebonyi River System

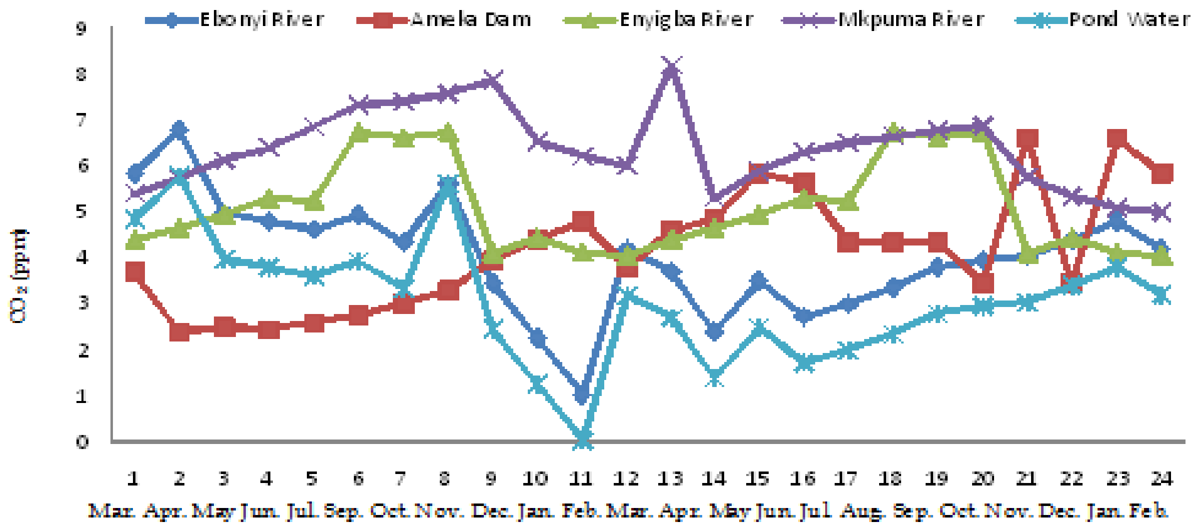
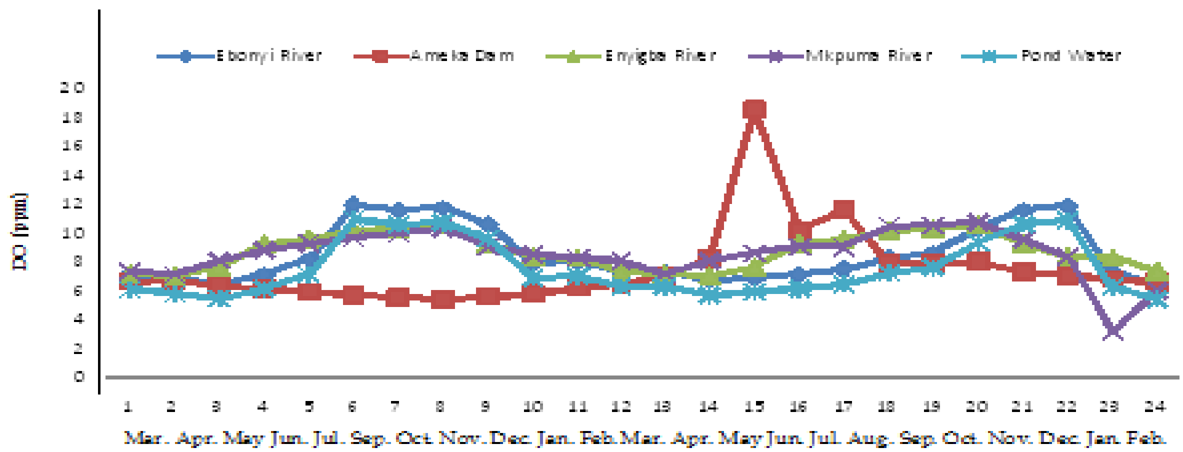


Figure 4: Variation of Free Carbon Dioxide. (ppm) of Ebonyi River System



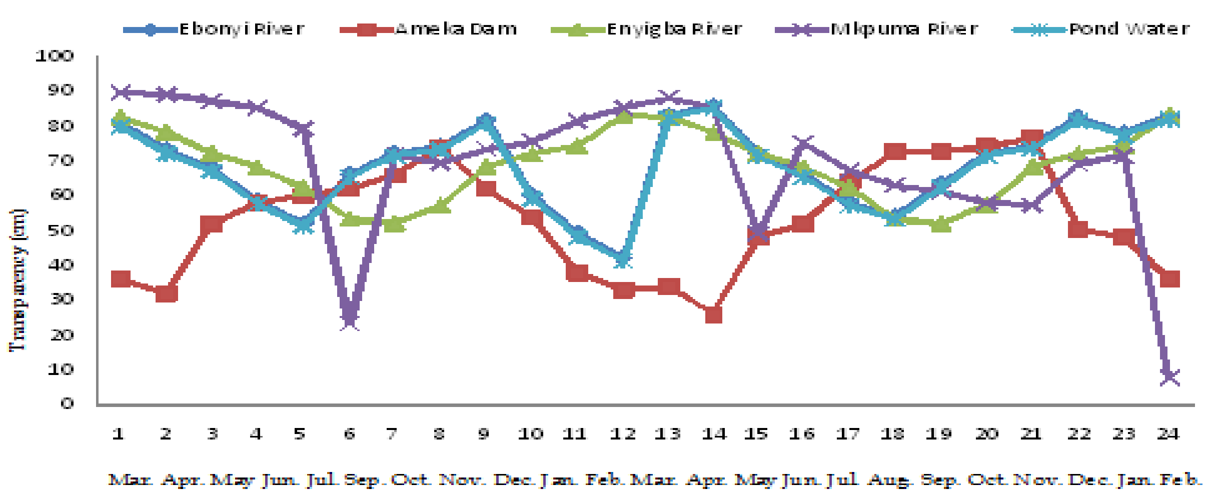


Figure 5: Variation of Transparency Content (Cm) of Ebonyi River System

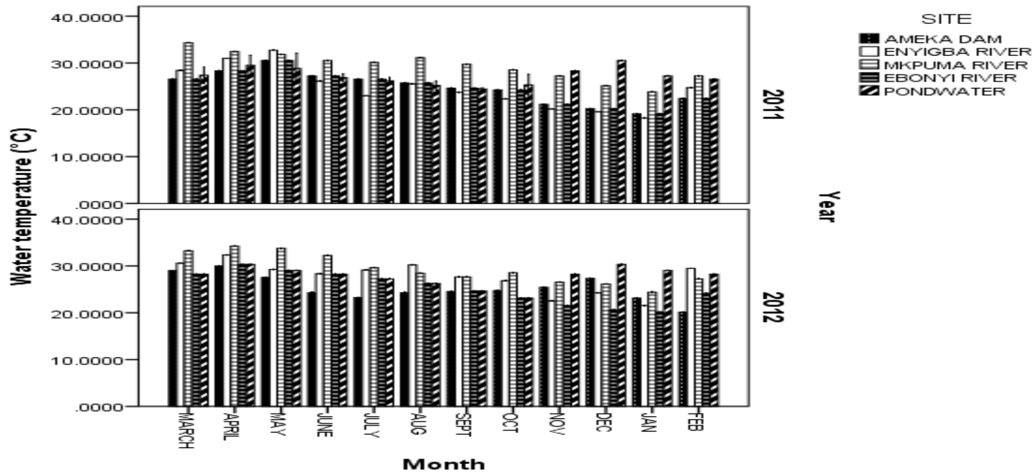


Figure 6: Monthly variation in water temperature in study areas

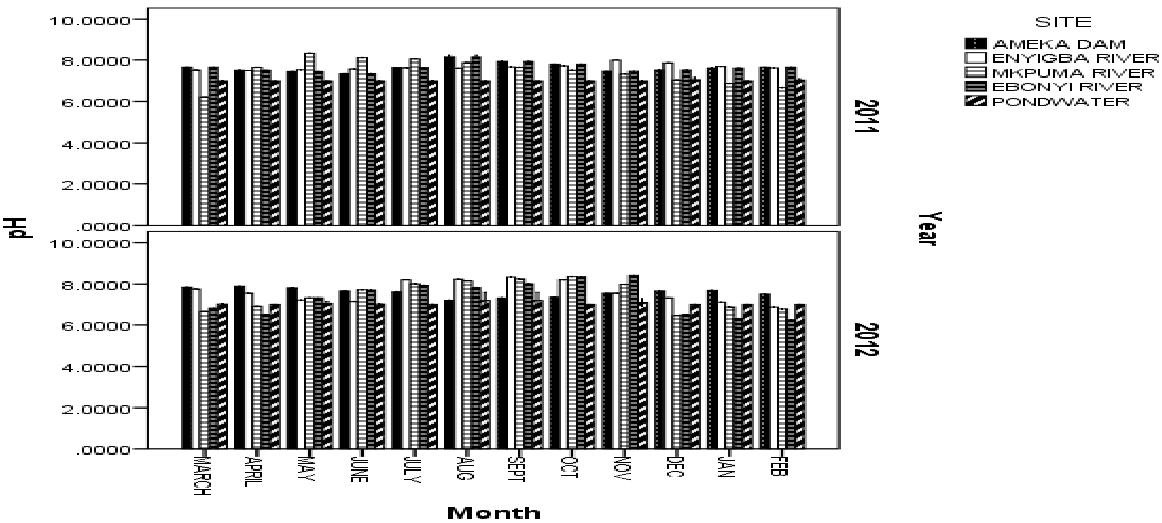


Figure 7: Monthly variation in pH in study areas

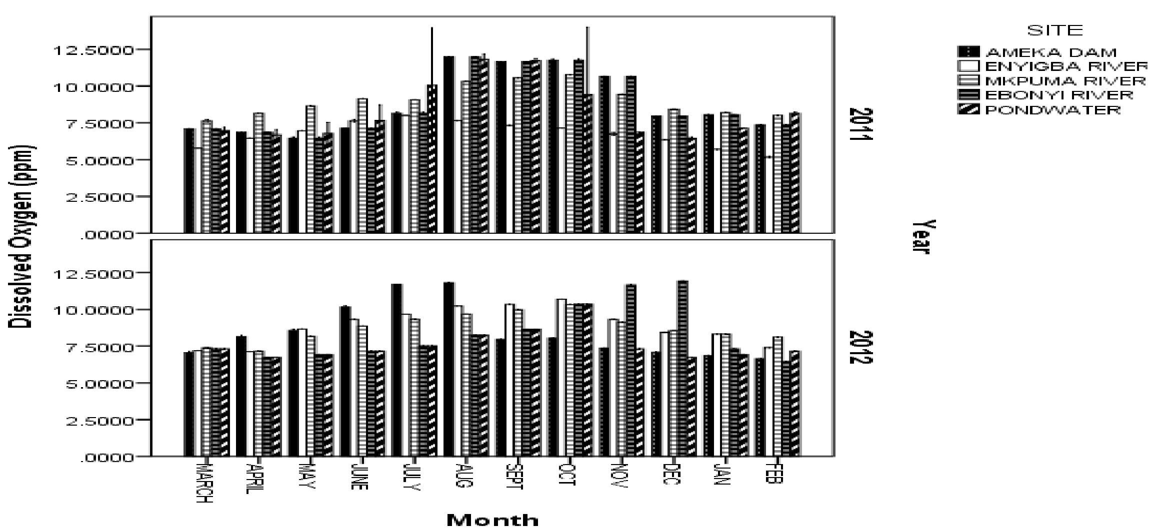


Figure 8: Monthly variation in dissolved oxygen concentration in study areas

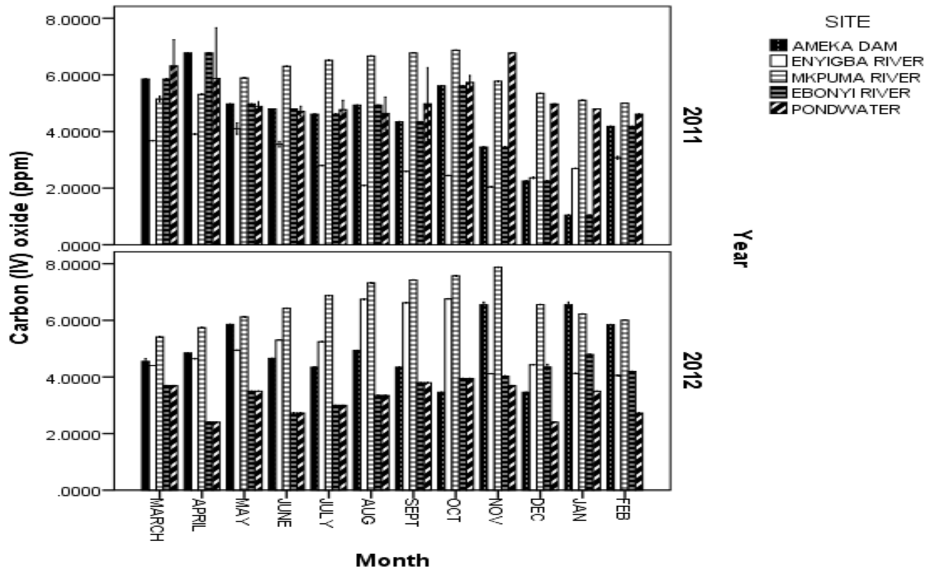


Figure 9: Monthly variation in CO_2 concentration in study areas

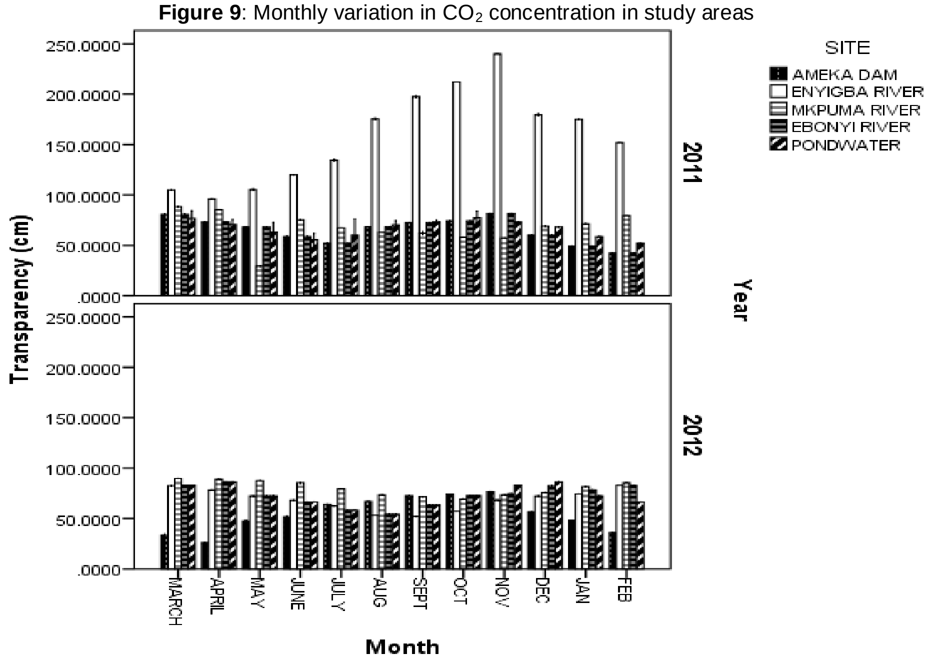


Figure 10: Monthly variation in transparency in study areas

The mean water temperature of study areas ranged from25.03±0.44 to 29.35±0.44°C. MkpumeRiver (29.35±0.44°C) had the highest water temperature when compared to that of other study areas ($p<0.05$). The water temperature of AmekaDam, EnyigbaRiver and EbonyiRiver were statistically similar ($p>0.05$) but their water temperature was significantly lower than that of pond water ($p<0.05$). EnyigbaRiver had the highest pH (7.65 ±0.05) but the pH of this River does not differ significantly from that of EbonyiRiver (7.49±0.08) ($p>0.05$). There was also no significant difference in the pH of AmekaDam, MkpumeRiver and EbonyiRiver. The pH of the aforementioned study areas were significantly higher that of pond water ($p<0.05$). Mkpume had the highest DO content but its value does not differ significantly from that of EbonyiRiver and Ameka Dam (p>0.05). The DO of EnyigbaRiver was significantly lower (p<0.05) than those of other study areas. MkpumeRiver had significantly higher CO_2 concentration while there was no significant difference (p<0.05) in the CO_2 of Ameka Dam and Pond water, and EnyigbaRiver, EbonyiRiver and Pond water. Enyigba had significantly higher transparency than those of other areas studied. This was followed by MkpumeRiver but the transparency of Mkpume does not differ significantly from those of EbonyiRiver and pond water (p>0.05) (Table 1).

Table 1: Mean comparisons of physicochemical parameters of study areas

Study areas	Water temperature (°C)	pH	Dissolved oxygen (DO)	Carbon(iv) oxide	Transparency
AmekaDam	25.03 ± 0.44^{c}	7.62 ± 0.03^{b}	8.60 ± 0.27^{ab}	4.68 ± 0.19^{b}	59.78 ± 2.22^{c}
EnyigbaRiver	26.17 ± 0.59^{c}	7.64 ± 0.05^{a}	7.82 ± 0.05^{c}	4.03 ± 0.20^{c}	113.17 ± 8.01^{a}
MkpumeRiver	29.35 ± 0.44^{a}	7.45 ± 0.08^{b}	8.89 ± 0.14^{a}	6.26 ± 0.81^{a}	73.63 ± 1.94^{b}
EbonyiRiver	25.03 ± 0.48^{c}	7.49 ± 0.08^{ab}	8.55 ± 0.28^{ab}	4.03 ± 0.18^{c}	69.00 ± 1.71^{bc}
Pond water	27.49 ± 0.29^{b}	7.04 ± 0.09^{c}	7.94 ± 0.24^{bc}	4.24 ± 0.18^{bc}	69.37 ± 1.46^{bc}

Mean values in a column with different alphabets as superscripts are significantly different (p<0.05)

DISCUSSION

Variation in the water temperature in ^{o}c of the five water bodies ranging from March 2011 to February 30th 2013 is as follows. Water temperatures varied from 18.2^{o}c to 35^{o}c which was from the coolest period of harmattan to the warmest dry season of February, March and April in 2011-2012 and 22^{o}c during harmattan (Nov/Dec) to 36^{o}c of dry season which ranged from February-April of 2012-2013. The pattern of variation in water temperature followed a similar trend in all the lakes showing lowest value in December/January 2012 and December 2012. Water gradually became warmer from February onwards with maximal temperature in April (fig.1). Gradually, the variation in water temperature during both years became marginal. This agrees with earlier findings reported by Egborge (2001) in the Warri river. temperature also differed significantly between seasons. The mininium and maximium temperatures of 18.2^{o}c to 35^{o}c obtained in Ebonyi river was normal for tropical waters for optimal growth of aquatic organisms. Okayi (2003) made similar findings in river Benue, Markudi. FEPA reported that 25^{0}c is the recommended limit for no risk water quality guideline for domestic use while 40^{0}c is the recommended upper limit for who based on these guidelines, the temperature of the effluent did not appear to pose any threat to the homeostatic balance of the receiving water bodies. This is in conformity with the report of Jaji *et al*., (2007).

Variation in pH in the five water bodies ranged from March to February of the two years. The pH of water varied from 6.3-8.5 in November, December and January 2011 at Akpara Dam and Mkpuma River and between February, March at Enyigba and Ebonyi rivers. During both years of observations all lakes showed bimodial seasonal variations. Generally the pH of water was lower during the period of harmattan and dry season which was November -February with a highest value obtained in August, September and October 2012. The pond water showed slightly varied pH compared to the other water bodies. The pattern of hydrogen ion concentration varied considerably among the stations (Fig. 2). Generally, the obtained pH value fell within the World Health Organization Standard of 7.0 – 8.5 and the water quality range of 6.5-8.5 for drinking water and water meant for full contact recreation, respectively. DWAF, 1996b; World Health Organization (WHO) 1984; 1989). The European Union (EU) also sets pH protection limits of 6.0-9.0 for fisheries and aquatic life (Chapman, 1996). The study also revealed that pH value was generally lower than 7.0 during the dry seasons. This was as a result of high quarrying activities during the dry season. The findings of this study is in consonance with the work of Swingle (1961) and Boyd (1985) who obtained pH values of 6.0-9.0 as values most suitable for fish production for maximum productivity.

Dissolved oxygen fluctuated in the range of 5.80-12.00ppm during the first year of observation 2011-2012; with an average of 7.3 and 8.2 ppm respectively. The fluctuation in Dissolved Oxygen level remained marginal during the period under study. Dissolved Oxygen content of Ebonyi, Mkpuma and Enyigba were higher during year 2011 and 2012 but that of the Pond and Dam were low within the period of study. The pattern of temperature variation was more or less uniform in all the water bodies even though minor deviations were observed within stagnant waters than flowing waters respectively. The trend of dissolved oxygen were different in all the water bodies (fig .3). The mean dissolved oxygen fell within the ranges documented by Swingle (1969), Boyd (1979), and Alabaster (1982) for good water quality on fish culture. The DO concentration in unpolluted water normally range between 8-10 mg/L and concentration below 5 mg/L adversely affects aquatic life (DFID, 1999; Rao, 2005). The value for this study fell short of the recommended standard for water quality criteria as set at the minimum acceptable concentration to ensure maintenance of biological function.

Free CO_2 was in the range of 1.0- 7.1 in year 1and 2.3 - 8.0 in year 2 with an average of 4.05 and 5.15 ppm respectively. The fluctuation in free CO_2 level was comparatively high during the entire period of study. The pattern of seasonal variation showed considerable deviations at different months in the lakes. Maximal CO_2 was recorded in September 2011 and December 2012 in Mkpuma river. Relatively, lower concentrations of free CO_2 were recorded in pond and Ebonyi river during harmattan period in December to January 2011 and below the detectable levels (Figure 4).

Transparency varied from 45.2 to 250 cm during year 2011 and 88.0 to 103cm in year 2012; with an average of 147.5 and 94.5 respectively. A distinct pattern of seasonal variation in respect of the variation of Sechi disc depth was relatively higher in Enyigba as compared to others in year 2011 but in year 2012, the trend of transparency was the same in all the water bodies. There is observed drop in transparency within the period of an onset of rain, at this time, the water bodies became muddy. High transparency was observed within the period of the end of rain or on set of dry season. This result is similar to the values documented by Ugwumba and Ugwumba (1993) and Yusuf (2004) who observed low transparency within down stream of the river in Warri Delta State Nigeria. This could be due to colloids, suspended solid in effluent of quarry waste water channels introduced into the Ebonyi river system (fig.5). Similar observation was reported earlier by Pathiratne *et al*.,(2001) by monitoring the environmental influence on outbreak of EUS in fresh water fish.

Temperature is universally accepted density independent factor shaping the biotic communities. Slight change in it may affect the hydrology of the lake ecosystem. It has a pronounced effect on chemical and biological processes (Prasad, 1956). The monthly fluctuation of water temperature in ambient water largely depends on the changes in the solar radiation. Temperature does affect the phytoplankton density (Mathew, 1975) and also the growth and distribution of macrophytes (Dale, 1986). In general, the rate of chemical and biological reactions is being doubled with every 10^oC increase in temperature. Warm water fish grow the best at a temperature range of 25 to 32^oC (Boyd, 1984). The fluctuation in water temperature in floodplain lakes Bihar has been reported as 18.9 to 33.0^oc (Sinha and Jha 1997; Bose and Gorai 1993); 20.3 to 33.0^oc (Bhoumik, 1985); 19.32 to 30.92^oc (Singh, et. al., 1994) which are in agreement with the present findings.

Hydrogen ion concentration (pH) is one of the most important characteristics regulating the life process and nutrient availability in any water body, particularly in floodplain lakes with alternate drying and flooding. the pH of water has a significant role in the survival of aquatic plants (Sculthrupe, 1967).The pH of water in the present investigation showed considerable variation in the range of 7.20 – 8.20, which is in agreement with earlier works (Sinha and Jha 1997; Ghose and Sharma 1988) etc. Apparently, the fluctuation of pH in water phase of floodplain lakes is a function of basin soil and the dense aquatic vegetation (Yadava, et. al., 1987) besides the inflow of surface run-off. a sharp decline in the pH value during March to April Kaithkola lake and April to May in Bishunpur lake was recorded during the present study. It was probably due to the inflow of considerable organic matter from the catchments along with surface run-off. Mixing of bottom water rich in organic matter and their subsequent decomposition might also be responsible for its fluctuation. The pH might undergo appreciable diurnal fluctuation, often exceeding 10.0 in the late afternoon and decreasing below 8.0 during darkness in accordance with the photosynthetic activity of phytoplankton and submerged aquatic macrophytes (Wetzel, 2001). According to Swingle (1976), water having a pH range of 6.5 to 9.0 before daybreak is considered suitable for fish production in freshwater ponds and lakes. Banerjea (1967) observed a neutral ph (6.5 to 7.5) to be the most favorable for productive ponds. Thus, the pH levels recorded in Kaithkola and Bishunpur lakes were in favorable ranges of production.

The average monthly fluctuation of temperature and dissolved oxygen (DO) along with average fish and average mortality recorded during the period of experimentation have been shown in table 5 and fig. 1 to 3. It was observed that DO decreases with decline in temperature. However, the minimum temperature 18.2^0C and minimum DO 3.6 ppm were recorded in 9^{th} month (i.e Dec. to Jan). The result revealed positive correlation between temperature and DO.

The experiment was conducted for two years (March to February 2011 to February 2013) the water temperature declined significantly up to 15 Jan 2011 and afterwards started rising gradually. It was observed that the number of infected fish and consequently the mortality increased with the gradual decrease of temperature and DO. When temperature declined from Nov 2012, the number of infected fish and mortality increased significantly and maximum number of infected fish (LC_{50}) and mortality increased with the decrease in temperature.

The physico-chemical parameter like temperature and dissolved oxygen were recorded throughout the investigation period revealed that there is direct correlation between temperature and DO. During the investigation period, the maximum temperature 22.9^0c and DO 6.8ppm recorded in 15^{th} week (i.e 26 Feb 03 to March 03 followed by temperature 21.45^0c and DO 6.5 ppm in 1^{st} week (19-25 Nov 02) and the minimum temperature 9.4 ^0c and DO 3.6ppm were found in 9^{th} week (15-21 Jan 03) after that, when temperature rise gradually, the number of infected fish and mortality decreased considerably). The result of present investigation revealed that the fluctuation of temperature and variation of DO might be one of the disposing stress factor for break out of EUS. The similar observation were also reported earlier by Pathiratne *et. al*.,(2001), Lio-po G.D (1999) and Chinabut et. al., (1995) by monitoring the environmental influence on the breakout of EUS in fresh water fish.

The required quantity of dissolved oxygen in the water is essential for the metabolism of all aerobic aquatic organisms. Dissolved oxygen (DO) in water depends on physical, chemical and biological activities, which play an important role in the distribution and abundance of phytoplanktons. The photosynthetic release, denitrification process of bacteria, wind action and others are responsible for the change in DO concentration. The solubility of oxygen is being affected by atmospheric pressure and water temperature.

According to Boyd (1982), fish do not grow or feed well when dissolved oxygen remains continuously below 4 or 5 $mg1^{-1}$. DO also provides a valuable information on the prevailing biological reactions of the system, which affects the aquatic life and the capacity of water to receive organic matters without causing adverse impact (Wetzel, 1990a). During the present investigation, the levels of DO were above this critical level in both the lakes. Relatively, lower levels of DO were recorded in Kaithkola lake, which may be attributed to the extensive growth of water hyacinth covering the surface and thereby reducing free surface area for diffusion/wind action. Wide fluctuations in dissolved oxygen content of water in the lakes might be due to dense aquatic vegetation, shallow water depth and intense fishing activities, at times (Yadava, et. al., 1987). High dissolved oxygen concentrations were recorded during the late summer and pre-monsoon seasons. The DO concentrations, in both the lakes, support the earlier findings like 4.2 – 7.6 $mg1^{-1}$ (Singh, et. al., 1994a); 1.6-14.0, 0.0 -12.0, 0.05-10.0 and 3.50-13.0 $mg1^{-1}$ in Brahanpura, Manika, Kanti, and Motijheel lakes respectively in north Bihar (Sinha and Jha 1997); 1.7-9.9 and 3.5-13.0 $mg1^{-1}$ (Jha, 1995) and 2.15-6.77 $mg1^{-1}$ (Pandy, et. al., 1994) etc.

Free carbondioxide in water occurs due to respiration of aquatic biota, decomposition of organic matters and also due to infilteration through the soil. Carbon-dioxide is an important component of the buffer system and influences carbonates and bicarbornate concentrations in water. Higher level of free CO_2 observed during summer might be due to the decomposition of organic matters (Chakravarty, et. al., 1959). The fish can tolerate a higher concentration of free CO_2 up to 60 $mg1^{-1}$ with a tendency to avoid as low as 5 $mg1^{-1}$ (Hart, 1944). The present findings were in agreement with sigh and Roy (1995) who reported similar trend in Kawar lake. Besides, Pandy, et. al., (1994) also recorded a maximum of 9.68 mg in Kawar lake during 1993 to 1994.The secchi disc depth (transparency) indicated wide fluctuation besides showing an irregular spatio-temporal variation in both the lakes. Even though the penetration of solar radiation in natural waters is a function of the angle of light falling on the water surface, the geographical location of the water body presence of dissolved and particulate materials are the other interfering factors (Bhat, 1979).

In Kaithkola and Bishunpur lakes, the inflow of surface runoff was found carrying heavy load of inorganic and organic materials washed down from the catchment after pre-monsoon showers, which might have caused a sharp reduction in Secchi disc depth during March to April. considerable decline of Secchi disc depth in June and August may also be inflow silt through surface runoff from the catchment into the lakes following heavy monsoon showers experienced during this periods. Marked decline in the transparency was observed during April in the Kaithkola lake and May in Bishunpur lake, apparently due to the fluctuation in the water level and enhanced algal growth. The depth of visibility in these lakes was considerably higher during winter to early summer, which may be due to settlement of monsoon particulate matter and subsequent increase in solar radiation to deeper layers.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made:

- There should be periodic monitoring of the Ebonyi river system to ensure maintenance of standard values for the physicochemical parameters to avoid loss of fishes over high or low values.
- Safe disposal of domestic wastes and control of industrial effluents should be practiced to avoid introduction of materials that might fluctuate the natural state of the river systems.
- There should be further study to understand the effect of heavy metals on the water bodies.

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