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Seasonal variation in macroinvertebrate community of river Okpokwu

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Abstract
Seasonal variation in the macroinvertebrate community of River Okpokwu was determined for a period of two seasons. Different macroinvertebrate species were observed from River Okpokwu during this study. The macroinvertebrate species include *Lanestis libycus*, *Bulinus globosus*, *Anaxipha exigua*, *Nepa cinerea*, *Penaeus monodon*, *Cambridge campus*, *Lumbricus terrestris*. Of the macroinvertebrates, *L. libycus* was most abundant at Station B (78.40%) and Station C (68%) in dry and rainy season respectively while *B. globosus* was most abundant at Station A in both seasons. *A. exigua* was highest at Stations A (71.35%) and B (61.82%) in dry and rainy seasons respectively while *N. cinerea* was highest at Station B and Station C in dry and rainy seasons. *P. monodon* had the highest percentage abundance at Station A. There is correlation matrices (r) between macroinvertebrate species and physicochemical parameters in dry and rainy seasons for all stations from River Okpokwu. There was no significant difference in all the physicochemical parameters across the stations for dry and rainy seasons.

Keywords: Seasonal variation, macroinvertebrate community

Introduction
Environmental variability in time and space is known to shape the distribution of organisms, their interactions and their adaptations (Wiens 1986) [50]. Such spatiotemporal variability is a basic characteristic of running water systems (Minshall 1988; Poff and Ward 1990) [27, 34]. Flow fluctuations and extreme conditions such as floods are primary sources of variability and disturbance (Cowell *et al*. 2004) [12]. High discharge events can cause severe population losses and changes in the community composition and structure (Hart and Finelli 1999; Lytle *et al*. 2008) [16, 24].

Throughout the world freshwater macroinvertebrates are commonly used as an indicator of urban stream ecosystem condition (Beavan *et al.* 2001; Paul and Meyer 2001; Walsh *et al.* 2001) [27, 30, 45]. This has been based on the relative ease of collection, identification of specimens and the sensitivities to pollution and environmental disturbance that many invertebrate taxa display (Chessman 2003) [11].

Seasonal variability is well known to influence the distribution and abundance of various invertebrate taxa and the composition of communities (Brooks 2000; Leung *et al.* 2012; Sporka *et al.* 2006) [9, 23, 38]. For example in many parts of the northern hemisphere where cold winters are followed by short warm summers, significant seasonal variation in both invertebrate community structure and the abundance of many invertebrate taxa has been documented (Sporka *et al.* 2006) [38]. Similarly, invertebrate communities in tropical monsoonal streams have been shown to exhibit strong seasonal variation due to flow variation resulting from the cyclical wet and dry nature of these ecosystems (Leigh 2012; Mesa 2012) [22, 26].

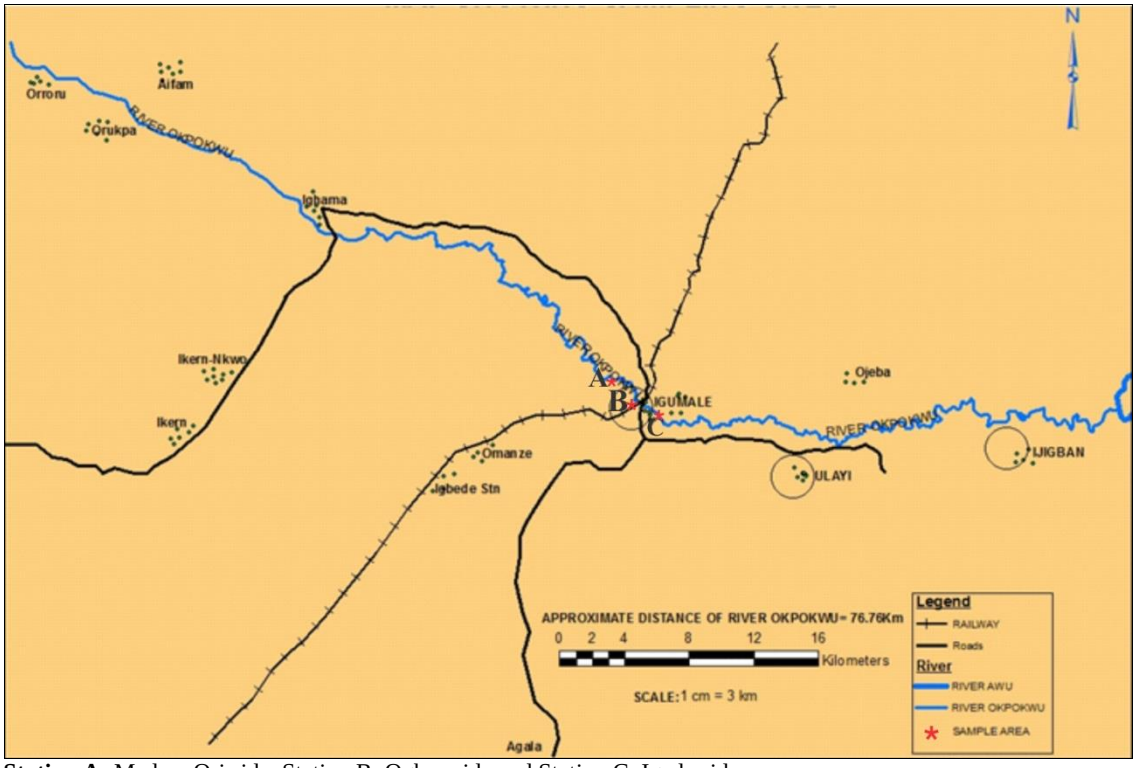
Relative species abundance describes how common or rare a species is relative to other species in a given community and usually described for single trophic level (Lawson and Olusanya, 2010) [21]. Species richness and related abundance are key elements of biodiversity. Lawson and Olusanya (2010) [21] reported that, species richness relates to the number of different species in a given area and it is the fundamental unit used to access homogeneity of an environment. They are commonly used in conservation studies to determine the sensitivity of ecosystem and their species. The objective of this study therefore is to determine seasonal variation of aquatic macro-invertebrates species of River Okpokwu with a view to providing information on the species abundance in the river.

Description of study area

River Okpokwu transverses Ogbadibo, Ohimini, Okpokwu and Ado Local Government Areas of Benue State, to Ogoja Local Government Area of Cross River State. There is a coal deposit in Owukpa, Ogbadibo Local Government Area which is upstream of River Okpokwu in Igumale, Ado Local Government Area of Benue where the sampling stations are located. The river is used for irrigation, recreation, sewage disposal, fishing etc.

The study area is the only portion of the river where there are true riparian communities, with settlements on both banks of the river. The area is located between latitude 6º 48' 0" N and longitude 7º 58' 0" E. It contains mineral and natural resources in commercial quantities such as limestone, kaolin, petroleum and coal. The river covers about 76.76km. The climate is characterized by two distinct seasons, the dry season (November – April) and Wet season (May – October).

The three sampling stations (figure 1) were located at Igumale (Station A, known as Madam Ori side, Station B, known as Ogbee side and station C known as Igede side), all in Ado Local Government Area of Benue State. These stations were selected considering the riparian nature and activities of the settlers.



Station A: Madam Ori side, Station B: Ogbee side and Station C: Igede side
***Source*:** Benue State Ministry of Land and Survey (2016).

Fig 1: Map of River Okpokwu showing the sampling stations

Physicochemical parameter analysis

Temperature was determined on the field by using a PHT-027 Multi-parameter water quality checker, the degree of transparency of sampling points was obtained using a secchi disc with graduated rope. The transparency of the water body was computed as follows:

$$\frac{d1+d2}{2}$$

Where d_1 = depth at which secchi disc disappears, d_2 = depth at which secchi disc reappears

Hydrogen ion concentration (pH) was determined on the field using a PHT-027 Multi-parameter water quality checker, Dissolved oxygen was determined on the field using dissolved oxygen meter model: DO-5509, Biological oxygen demand was determined using a dissolved oxygen meter model: DO-5509 and Freshwater aquaculture test kit (MODEL AQ-2)**.** Sampling bottle was rinsed with water sample, Alkalinity was determined by using a Freshwater aquaculture test kit (MODEL AQ-2), Total dissolved solids were determined in situ using a PHT-027 Multi-parameter water quality checker, Free carbon-oxide was determined by using a Freshwater aquaculture test kit (MODEL AQ-2)**,** Nitrate was determined using APHA (1985) [5], Total hardness was determined using a Freshwater aquaculture test kit (MODEL AQ-2)**,** Chloride was determined by using a Freshwater aquaculture test kit (MODEL AQ-2) while phosphate was determined according to APHA (1985) [5] using spectrophotometer (spectromi 21D) at wavelength of 882 mm.

Macro invertebrate analysis

The macro-invertebrates were sampled every month from May, 2015 to April, 2017 at three selected stations of River Okpokwu to compare and evaluate the macro-invertebrates seasonal variation. Ten (10) litres (at a time) of water was obtained from each station every month and Macro-invertebrates were collected by sieving. Each animal was then brush picked and preserved in 5% formaline and were identified according to Ward and Whipple (1992) [46], APHA (1998) [4] and Pennack (1978) [31] up to the genera level. Species richness has been calculated on the basis of number of species available at each station. By using the method of least squares and Karl Pearson, the regression equation,

coefficient of correlation and standard deviation values between species richness and abiotic factors were calculated using SPSS (version 20).

Results

Results of the mean water quality parameters in dry and rainy seasons from the three stations are presented in Table 1. The DO was highest at station C (9.03±0.14 and 7.80±0.30) while it was lowest at station A (8.99 ± 0.16 and 7.72±0.28) for dry and rainy seasons respectively. The highest BOD was recorded at station B (3.19±0.13 in dry season) and A (2.62±0.09 in rainy season) while the lowest (3.09±0.15 and 2.53±0.13 respectively) were recorded at station C for both seasons. The highest CO_2 (17.06±0.24 and 17.35±0.22) were recorded at station C in the two seasons while the lowest was recorded at station B (16.66±0.31) and A (17.15±0.23) in dry and rainy seasons respectively. Air temperature was highest at station C (21.81±0.46) and B (23.51±0.46) in dry and rainy seasons respectively and lowest (21.54±0.47 and 23.14±0.47) at station A in both seasons the highest water temperature (24.99±0.43 and 26.52±0.48) were recorded at station C while the lowest (24.33±0.39 and 26.08±0.44) were recorded at station A in both seasons respectively. The highest TDS (46.48±2.36 and 33.43±2.03) were recorded at station C for both seasons. Transparency was highest (51.51±3.75 and 27.06±1.75) at stations A and B while it was lowest (51.04±3.91 and 26.62±1.70) at stations C and A in dry and rainy season respectively. The highest pH (7.10±0.10 and 6.85±0.08) were recorded at stations C and B in dry and rainy seasons respectively while the lowest (6.95±0.10 and 6.81±0.09) were recorded at station A for both seasons. Alkalinity was highest at stations B (59.69±1.12) and A (46.03±1.84) while it is lowest at stations A (58.68±1.30) and C (45.70±1.72) in dry and rainy seasons respectively. Water hardness recorded the highest at stations B (26.28±0.76) and C (22.20±0.68) in dry and rainy seasons respectively while it was lowest at station A (26.23±0.75 and 22.06±0.64) for both seasons. The highest Chloride (12.08±0.18 and 11.55±0.22) were recorded at station C while the lowest (12.03±0.12 and 11.50±0.17) was recorded at station A for both seasons. Nitrate was highest at stations C (0.82±0.02) and A (0.85±0.03) in dry and rainy seasons respectively and Phosphate was highest (0.19±0.00) at station A in rainy season and lowest (0.14±0.01) at station A in dry season.

However, there was no significant difference ($p>0.05$) between Chloride and Nitrate in the dry and rainy seasons while there was significant difference ($p< 0.05$) between the other parameters in both seasons throughout the period of study.

Table 1: Mean water quality parameters obtained from river Okpokwu at different stations in dry and rainy season

Parameters	Season	Station A	Station B	Station C	P Value	Mean Total	P Value
DO (m/l)	Dry	8.99 ± 0.16 a	8.99±0.19a	9.03±0.14a	0.98	9.00±0.09	0.00
	Rainy	7.72±0.28a	7.77±0.31a	7.80±0.30a	0.98	7.77±0.17	
BOD (m/l)	Dry	3.14±0.14a	3.19±0.13a	3.09±0.15a	0.87	3.14±0.08	0.00
	Rainy	2.57±0.09a	2.62±0.09a	2.53±0.13a	0.84	2.57±0.06	
CO_2 (m/l)	Dry	16.80±0.19a	16.66±0.31a	17.06±0.24a	0.52	16.84±0.15	0.03
	Rainy	17.15±0.23a	17.30±0.22a	17.35±0.22a	0.81	17.27±0.13	
Air Temp.	Dry	21.54±0.47a	21.64±0.45a	21.81±0.46a	0.91	21.66±0.26	0.00
(°C)	Rainy	23.14±0.47a	23.51±0.46a	24.31±0.59a	0.27	23.65±0.30	
Water Temp.	Dry	24.33±0.39a	24.82±0.46a	24.99±0.43a	0.53	24.71±0.25	0.00
(°C)	Rainy	26.08±0.44a	26.23±0.49a	26.52±0.48a	0.79	26.28±0.27	
TDS (ppm)	Dry	44.63±1.42a	46.48±2.36a	44.56±1.46a	0.70	45.22±1.03	0.00
	Rainy	33.43±2.03a	31.86±2.09a	23.03±1.92a	0.85	32.78±1.15	
Transparency	Dry	51.51±3.75a	50.38±3.54a	51.04±3.91a	0.98	50.98±2.13	0.00
	Rainy	26.62±1.70a	27.06±1.75a	27.01±1.73a	0.98	26.90±0.98	
PH	Dry	6.95±0.10a	7.10±0.08a	7.10±0.10a	0.41	7.05±0.05	0.00
	Rainy	6.81±0.09a	6.85±0.08a	6.82±0.09a	0.95	6.83±0.05	
Alkalinity	Dry	58.68 ± 1.30a	59.69±1.12a	59.66±1.10a	0.79	59.35±0.67	0.00
	Rainy	46.03±1.84a	45.85±1.72a	45.70±1.72a	0.99	45.86±1.00	
Hardness	Dry	26.23±0.75a	26.28±0.76a	26.27±0.73a	1.00	26.26±0.42	0.00
	Rainy	22.06±0.64a	22.15±0.67a	22.20±0.68a	0.99	22.14±0.38	
Chlorine	Dry	12.03±0.12a	12.05±0.20a	12.08±0.18a	0.37	30.02±17.99	0.31
(m/l)	Rainy	11.50±0.17a	11.54±0.12a	11.55±0.22a	0.97	11.53±0.10	
Nitrate	Dry	0.80±0.01a	0.81±0.02a	0.82±0.02a	0.87	0.81±0.01	0.60
(m/l)	Rainy	0.85±0.03a	0.84±0.03a	0.84±0.03a	0.95	0.85±0.02	
Phosphate	Dry	0.14±0.01a	0.15±0.01a	0.15±0.01a	0.97	0.15±0.00	0.00
(m/l)	Rainy	0.19±0.00a	0.18±0.00a	0.18±0.00a	0.94	0.18±0.00	

Mean values with different superscript within rows differed significantly ($p< 0.05$)

Table 2 shows the percentage macroinvertebrate composition and abundance at the various stations in both dry and rainy season. *L. libycus* has the highest percentage at Stations B (78.40%) and C (68%) in dry and rainy seasons respectively while *B. globosus* was highest at Station A in both seasons. *A. exigua* was highest in Station A (137%) and Station B (61.37%) in dry and rainy season respectively while *N. cinerea* was highest at Station B and Station C in dry and rainy season respectively. *P. monodon* has the highest percentage at Station A (55.56) and Station C (55.00) in dry and rainy seasons respectively.

Table 2: Percentage Macroinvertebrate Composition and Abundance by Stations in Dry and Rainy Seasons from River Okpokwu

Macroinvertebrate	Station A		Station B		Station C		% Class	
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)		
Class Gastropoda								
Lanestis libycus	80 (59.70)	48 (56.47)	98 (78.40)	61 (79.22)	56 (77.78)	68 (81.93)	35.98	29.45
Bulinus globosus	54 (40.30)	37 (43.53)	27 (21.60)	16 (20.78)	16 (22.22)	15 (18.07)		
Class Insecta								
Anaxipha exigua	137 (71.35)	85 (71.35)	112 (64.37)	102 (61.82)	103 (65.61)	88 (58.68)	56.85	62.14
Nepa cinerea	55 (28.65)	53 (28.65)	62 (35.63)	63 (38.18)	54 (34.40)	69 (41.32)		
Class Malacostraca								
Penaeus monodon	5 (55.56)	12 (70.59)	4 (26.67)	3 (33.33)	3 (27.27)	11 (55.00)	3.8	5.53
Cambridge campus	4 (44.44)	5 (29.41)	11 (73.33)	6 (66.67)	8 (72.73)	9 (45.00)		
Class Oligochaeta								
Lumbricus terrestris	13 (100)	9 (100)	10 (100)	6 (100)	8 (100)	9 (100)	3.37	2.88
Total Abundance	348	249	248	257	248	269		
Shannon Weinner index	4.45	3.85	4.27	4.05	4.27	4.32		
Margalef index	4.28	3.83	4.1	4.12	4.10	4.17		

Results of the monthly percentage abundance of macro invertebrate in the dry and rainy season are presented according to species in Table 3 and Table 4. In dry season, *Lanestis libycus* was most abundant (10.26%) in December 2016 but least abundant (5.56%) in April 2016. *Bulinus globosus* was most abundant (10.31% each) in the months of November 2015 and March 2017 but least in the months of December 2016 and April 2017 (6.19%). *Anaxipha exigua* was most abundant in November 2016 (10.80%) but least abundant (6.53%) in April 2016. *Nepa cinerea* was most abundant in March 2017 and April 2017 (9.94%) but least abundant in February 2016 and January 2017 (5.85%). *Penaeus monodon* was most abundant in March 2017 (41.67%) but least abundant (8.33%) in February 2017. *Cambridge campus* was most abundant (21.74%) in the months of November 2015 and April 2016 but least abundant (4.35%) in the months of December 2015, March 2016, December 2016, March 2017 and April 2017; while *Lumbricus terrestris* was most abundant (29.03%) in November 2016 but least abundant in the months of December 2015 and January 2016 (3.23%).

In rainy season, while *Lanestis libycus* was most abundant (12.99%) in October 2016, it was least abundant (6.21% each) in June and July 2016. *Bulinus globosus* was most abundant (14.71%) in the month of July 2015 but least abundant in the month of May 2016 (2.94%). *Anaxipha exigua* was most abundant in August 2016 (10.24%) but least abundant (6.93%) in September and October 2015. *Nepa cinerea* was most abundant in August 2015 (10.81%) but least abundant in June 2016 (5.95%). *Penaeus monodon* was most abundant in July 2016 (23.08%) but least abundant (3.85%) in the months of July 2015, August 2015, and August 2016. *Cambridge campus* was most abundant (30.00%) in the month of July 2016 but least abundant in the months of June 2015, June 2016 and August 2016 (5.00%) respectively; while *Lumbricus terrestris* was most abundant (20.83%) in October 2016 but least abundant in the months of August 2015, June 2016 and August 2016 (4.17%) respectively.

The correlation matrices (r) between macroinvertebrate species and physicochemical parameters in dry and rainy season for all stations from River Okpowu are show in Table 5 and Table 6 respectively. In the dry season, *Lanestis libycus* exhibited a high degree of positive correlation with DO, CO_2, pH, chloride and nitrate but showed high degree of negative correlation with air temperature, TDS, nitrate and phosphate. *Bulinus globosus* exhibited a high degree of positive correlation with DO, CO_2, pH and chloride but showed high degree of negative correlation with air temperature, water temperature, TDS, transparency, hardness, nitrate and phosphate; *Anaxipha exigua* exhibited a high degree of positive correlation with DO, CO_2 and pH but showed high degree of negative correlation with, air temperature, TDS, alkalinity, nitrate and phosphate. *Nepa cinerea* exhibited a high degree of positive correlation with DO, CO_2 and water temperature, but showed high degree of negative correlation with air temperature, TDS, nitrate and phosphate. *Penaeus monodon* exhibited a high degree of positive correlation with BOD and CO_2 but showed high degree of negative correlation with air temperature, water temperature, TDS, pH, alkalinity, hardness, chloride, nitrate and phosphate. *Cambridge campus* exhibited a high degree of positive correlation with DO, BOD, transparency and chloride but showed high degree of negative correlation with air temperature, water temperature, TDS, pH, alkalinity, hardness, chloride, nitrate and phosphate while *Lumbricus terrestris* exhibited a high degree of positive correlation DO, BOD, CO_2, transparency, pH and chloride but showed high degree of negative correlation with air temperature, water temperature, TDS, alkalinity, hardness, nitrate and phosphate.

Whereas, in rainy season, *Lanestis libycus* exhibited a high degree of positive correlation with BOD, CO_2, water temperature, transparency and chloride but showed high degree of negative correlation with TDS, pH, nitrate and phosphate. *Bulinus globosus* exhibited a high degree of positive correlation with DO, BOD, TDS, alkalinity, hardness and chloride but showed high degree of negative correlation with, air temperature, water temperature, transparency, pH, nitrate and phosphate. *Anaxipha exigua* exhibited a high

degree of positive correlation with BOD, CO_2, water temperature, transparency and chloride but showed high degree of negative correlation with, air temperature, nitrate and phosphate. *Nepa cinerea* exhibited a high degree of positive correlation with BOD, CO_2 and chloride but showed high degree of negative correlation with air temperature, TDS, alkalinity, nitrate and phosphate. *Penaeus monodon* exhibited a high degree of positive correlation with BOD, CO_2, TDS, PH and chloride but showed high degree of negative correlation with DO, air temperature, water temperature, transparency, alkalinity, nitrate and phosphate. *Cambridge campus* exhibited a high degree of positive correlation with CO_2 but showed high degree of negative correlation with DO, BOD, air temperature, water temperature, TDS, transparency, alkalinity, hardness, chloride, nitrate and phosphate while *Lumbricus terrestris* exhibited a high degree of positive correlation BOD, CO_2 and chloride but showed high degree of negative correlation with air temperature, water temperature, TDS, transparency, alkalinity, hardness, nitrate and phosphate.

Table 3: Monthly Percentage Abundance of Macroinvertebrates of River Okpokwu in Dry Season

Months	*L. libycus*	*B. globosus*	*A. exigua*	*N. cinerea*	*P. monodon*	*C. camburus*	*L. terrestris*
Nov. 2015	9.40	10.31	8.52	9.36	25.00	21.74	9.68
Dec. 2015	8.55	7.22	8.24	8.19	-	4.35	3.23
Jan. 2016	8.12	7.22	7.37	8.19	-	-	3.23
Feb. 2016	8.97	8.25	8.24	5.85	-	17.39	9.68
Mar. 2016	7.69	9.28	8.24	8.78	-	4.35	6.45
Apr. 2016	5.56	8.25	6.53	9.36	25.00	-	6.45
Nov. 2016	8.97	8.25	10.80	7.60	-	21.74	29.03
Dec. 2016	10.26	6.19	9.09	9.36	-	4.35	-
Jan. 2017	8.12	9.28	9.38	5.85	-	8.70	6.45
Feb. 2017	6.41	9.28	8.52	7.60	8.33	8.70	9.68
Mar. 2017	9.83	10.31	7.95	9.94	41.67	4.35	6.45
Apr. 2017	8.12	6.19	7.10	9.94	-	4.35	9.68

Table 4: Monthly Percentage Abundance of Macroinvertebrate of River Okpokwu in Rainy Season

Months	*L. libycus*	*B. globosus*	*A. exigua*	*N. cinerea*	*P. monodon*	*C. camburus*	*L. terrestris*
May. 2015	9.04	5.88	8.43	8.65	11.54	15	8.33
Jun. 2015	8.475	7.35	7.83	8.65	0	5	0
Jul. 2015	6.78	14.71	8.13	9.73	3.85	0	0
Aug. 2015	9.60	8.82	9.94	10.81	3.85	10	4.17
Sep 2015	7.34	7.35	6.93	7.03	11.54	0	16.67
Oct. 2015	7.91	10.29	6.93	7.57	7.69	15	12.5
May 2016	7.91	2.94	8.13	6.49	19.23	0	0
Jun. 2016	6.21	8.82	9.34	5.95	7.69	5	4.17
Jul. 2016	6.21	5.88	7.23	7.03	23.08	30	16.67
Aug 2016	9.04	5.88	10.24	9.19	3.85	5	4.17
Sep. 2016	8.47	8.82	9.04	8.65	7.69	15	12.5
Oct-16	12.99	13.24	7.83	10.27	0	0	20.83

Discussion

Temperature being one of the most important ecological factors is intimately related to latitude, altitude, season, and in spring fed or lake fed streams to the distance from the source (Hussain and Pandit, 2006) [17]. The benthic macroinvertebrates have evolved to live within a specific temperature range, which limits their distribution and affects the community structure (Hynes, 1960; Biggs *et al*., 1990) [18, 8]. According to Waziri *et al*. (2015) [47], low water and air temperatures in the dry season were due to the cool dry North East trade wind effect. The assertion in this present work agrees with the reported work of Waziri *et al*. (2015) [47]. Any increase in temperature decreases the DO (Vincy *et al*., 2012) [44]. The range of values recorded for temperature in River Okpokwu falls within the range recommended by the Federal Environmental Protection Agency (FEPA, 2003) [13] in an aquatic environment or ecosystem.

Dissolved oxygen concentration was highest during the dry season as a result of photosynthetic activity by plants, which contributed in oxygenating the water column and at the same time reducing respiration by aquatic organisms and decomposition processes in the river. The low oxygen content of the water body during the rainy season could be as a result of Low transparency and low nutrient load during the season. The Dissolved oxygen concentrations in River Okpokwu were above the value of 5.0 mg L^{-1} recommended by FEPA (2003) [13]. The higher values of Dissolved oxygen concentrations in the river may be due to change in season, and rainfall pattern.

Biological Oxygen Demand (BOD) is a measure of the biological activities of a water body, an indication of the organic load and it is a pollution index especially for water bodies receiving organic effluent. According to the rankings of World Health Organization (WHO, 2005) [49] water bodies with BOD levels between 1.0 and 2.0mg/l are considered clean, 3.0mg/l, fairly clean; 5.0mg/l doubtful, and 10.0mg/l definitely bad and polluted. Seasonal changes in BOD with low values during wet seasons (rainy) may be due to increased surface run-offs, soil erosions and effluents discharge into the receiving water bodies (Sani, 2015) [36]. The BOD value in River Okpokwu was below 7.0 mg L^{-1} value recommended by World Health Organization. The BOD reported in this study is not in agreement with Adjarho *et al.* (2013) [2] findings who reported a high.

Table 5: Correlation Matrices (r) between Macroinvertebrate Species and Physicochemical Parameters in Dry Season for All Stations from River Okpokwu

	DO	BOD	CO_2	Air temp.	Water temp.	TDS	Transparency	pH	Alkalinity	Hardness	Chloride	Nitrate	Phosphate
Lanestis libycus	0.12	0.07	0.23	-0.03	0.08	-0.06	0.04	0.15	0.00	0.04	0.12	-0.34**	-0.11
Bulinus globosus	0.26*	0.01	0.20	-0.06	-0.02	-0.15	-0.06	0.13	0.03	-0.02	0.11	-0.41**	-0.15
Anaxipha exigua	0.17	0.06	0.34**	-0.01	0.05	-0.09	0.03	0.13	-0.01	0.02	0.07	-0.25*	-0.13
Nepa cinerea	0.12	0.02	0.26*	-0.01	0.11	-0.03	0.02	0.07	0.01	0.04	0.07	-0.26*	-0.04
Penaeus monodon	0.05	0.14	0.17	-0.18	-0.07	-0.09	0.07	-0.10	-0.05	-0.04	-0.04	-0.19	-0.13
Cambridge campus	0.12	0.20	0.18	-0.15	-0.03	-0.03	0.21	-0.01	-0.16	-0.08	0.13	-0.20	-0.18
Lumbricus terrestris	0.22	0.14	0.16	-0.17	-0.06	-0.11	0.09	0.09	-0.08	-0.02	0.09	-0.28*	-0.19

*****Correlation is significant at the 0.05 level (2-tailed).

Table 6: Correlation Matrices (r) between Macroinvertebrate Species and Physicochemical Parameters in Rainy Season for All Stations from River Okpokwu

	DO	BOD	CO_2	Air temp.	Water temp.	TDS	Transparency	pH	Alkalinity	Hardness	Chloride	Nitrate	Phosphate
Lanestis libycus	0.06	0.20	0.14	0.03	0.12	-0.01	0.13	-0.06	0.06	0.02	0.18	-0.15	-0.20
Bulinus globosus	0.16	0.30*	0.03	-0.08	-0.04	0.12	-0.08	-0.04	0.19	0.11	0.19	-0.11	-0.04
Anaxipha exigua	0.04	0.29*	0.11	-0.01	0.08	0.06	0.08	0.07	0.05	0.06	0.23	-0.09	-0.18
Nepa cinerea	0.04	0.23	0.15	-0.04	0.05	-0.01	0.07	0.01	-0.00	0.00	0.18	-0.13	-0.17
Penaeus monodon	-0.14	0.08	0.14	-0.13	-0.10	0.12	-0.04	0.20	-0.07	0.07	0.11	-0.16	-0.08
Cambridge campus	-0.05	-0.09	0.17	-0.14	-0.08	-0.08	-0.08	0.06	-0.16	-0.03	-0.04	-0.23	-0.09
Lumbricus terrestris	0.01	0.11	0.13	-0.17	-0.06	-0.01	-0.07	0.00	-0.13	-0.03	0.18	-0.06	-0.08

*****Correlation is significant at the 0.05 level (2-tailed).

value of BOD and dominance of the Chironomus sp. and Melaniodes tuberculata revealed that Ona River at Oluyole Estate is polluted and is not fit for drinking by water quality standard.

pH being one of the most important water quality parameters has been found to have profound effects on the ecology of macroinvertebrates in aquatic systems. Although, benthic macroinvertebrate sensitivities to pH vary (Yuan, 2004) [52], values below 5.0 and greater than 9.0 are considered harmful. Low pH values are associated with lower diversity of benthic macroinvertebrates (Thomsen and Friberg, 2002) [42], and cause decreased emergence rates in them (Hall *et al*., 1980) [15]. Seasonal variation in the pH revealed higher values for the dry season than wet season. The lower pH recorded in rainy season than the dry season could be due to increase in temperature and decreased amount of nitrates and in rainy season. According to WHO normal range of pH for water is 6.5-8.5 (Zaigham *et al*., 2012) [53]. The range of value recorded for pH in River Okpokwu agrees with the range recommended by the World Health Organization (2008) [48] for the culture of fish but disagrees with the reported work of Altaf *et al*., (2013) [3] who reported low pH values in their work. The United States Environmental Protection Agency (USEPA) also indicated that a pH range of 6.5 - 9.0 provides adequate protection for the life of freshwater fish and bottom-dwelling macroinvertebrates (USEPA, 1986) [43]. Thus, the pH range of River Okpokwu recorded during the study period was not considered as a risk factor affecting the macro-invertebrates population diversity of the river. This also agrees with the findings of Adjarho *et al.* (2013) [2]. MacNeil *et al*. (2002) [25] have recognized the concept that macro invertebrate families are very diverse, sensitive to pollution of water a body and may be suitable for assessment of severity of contamination of water pollution.

High concentrations of carbon (iv) oxide may be due to high pH, and decomposition of organic matter which lead to pollution. Low concentrations of carbon (iv) oxide in this study could be due to photosynthetic activity by aquatic plants which releases oxygen to the water during photosynthesis. The result of this study is in agreement with the findings of Ikongbeh *et al*. (2014) who reported free carbon dioxide of Akata Lake in Benue State.

Relationship between macro-invertebrate community structure and environmental variables has been the subject of numerous investigations (Tate and Heiny, 1995; Wright *et al*, 1984; Omerod, 1987; Gower *et al*. 1994) [40, 51, 29, 14]. Poff and Ward (1989) [33] identified streamflow variability as a major factor affecting other abiotic and biotic factors that regulate lotic macrozoobenthic patterns. Brown and Brown (1994) [10] and Richards *et al.* (1993) [35] suggested that many variables, including conductivity, dissolved oxygen, pH, current velocity, substrate type, depth and water temperature affect the invertebrate production in response to changes in flow regime. The finding of this study agree with Pires *et al.* (2000) [32] who concluded that some of the environmental variables like temperature, conductivity, depth and width influenced the invertebrate distribution and abundance within the Guadiana River Basin.

The correlation matrices (r) values of physico-chemical parameters in the present study is similar to that reported by Idowu *et al*., (2013) [19] in Ado Ekiti Reservoir southwestern Nigeria. Sharma and Samita (2011) [37] reported relationships between physico-chemical characteristics and the density of macrobenthic invertebrate fauna in their studies. They reported that Annelida showed a significant positive correlation with air temperature and a negative correlation with bicarbonates and Ca^2. This result agrees with the findings of their study which shows positive correlations in some parameters.

The highest occurrence (56.85% and 62.14%) of class insecta in the present study is similar to the findings of Asibor (2015), Olomukoro *et al*., (2013) [28] and Adeyemi *et al*., (2009) [1] who reported more organisms of the class insecta than any other species and asserted that the source of species was rich in fauna composition. Highest abundance of insecta and Gastropoda in November could be due to the fact that insecta and Gastropoda survive more with little moisture. This work is in agreement with the findings of Tersoo, *et al*., (2017) [41]. According to the authors, the reason for this scenario is that insecta and Oligochaeta species need just little or moderate amount of moisture to survive while Malacostraca and Gastropoda need a lot of water to exist. Callisto *et al*. (2005)

reported that the major dominant groups in Paulo Afonso reservoir were the gastropods and bivalves. This does not agree with the findings of this study.

The findings of this study agrees with Adjarho *et al.* (2013) [2] in their study on the Physico-chemical parameters and macro invertebrate fauna of Ona River, Ibadan Nigeria from November, 2008 to January, 2009. They reported that aquatic insect larvae (Chironomus sp.), gastropods (Physa sp.) and (Melaniodes tuberculata) were the most abundant accounting for 43.5, 27.7 and 20% respectively. Shannon Weiner diversity index as adopted by Tanimu *et al*., (2012) [39] revealed that species diversity and pollution status of aquatic system are classified as follows; >3 clean water, 1-3 moderately polluted and <1 heavily polluted. Based on this classification, the water of River Okpokwu is clean for macroinvertebrates. Shannon-Weaver diversity index did not vary significantly between seasons which are characteristics of stable physico-chemical conditions. This suggests that the river is not under pollution threat presently.

Conclusion

Macro-invertebrates species in River Okpokwu were affected by seasons, as the dry season concentrations were significantly higher than the rainy season concentrations. During the present study, most abundant class recorded are class insect and gastropoda at all stations which indicate good water quality as well as favourable conditions for biotic communities which is in line with the above observation. It is thus concluded that the level of species abundance is dependent on the abiotic factors like temperature, hardness, pH, chlorides, phosphorus and dissolved oxygen.

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