ISSN No:-2456-2165

Effect of Tides on Zooplankton in Great Kwa River, Calabar, Nigeria- A Comparative Study

James, Emmanuel M. and Ajah, Paul O.
Department of Fisheries and Aquaculture
University of Calabar, Calabar, Nigeria

Abstract:- The effect of three tidal levels- ebb, mid and flood tides- on the composition, abundance, distribution, and diversity of zooplankton species in the Great kwa River, a major tributary of Cross River, Nigeria were investigated every forthright beginning from July to September 2019 and compared to 1997 study. A total of 59 zooplankton species belonging to 41 taxa (genera) and 16 classes were identified and recorded during the present study. The zooplankters comprised 199 individuals of which 49 were recorded in low tide, 95 at mid tide and 55 during high tide. Generally, the class Rhizopoda (37.19%) were dominant, followed by Copepods (25.13%) while invertebrate, Lepidoptera and Malacostracan were each less than 1%. While the Copepoda dominated at low tide, the Rhizopoda was dominant at both mid-tide and high tide. Shannon Weiner index (H) showed that zooplankton species were high at low tide (3.95), followed by high tide (2.95) and least at mid tide (2.22). The absence of some zooplankton species at mid-tide and high tide suggest that zooplankton species had migrated vertically downwards prior to the onset of mid tide and high tide. Despite the highest number of individuals recorded at mid-tide, an evenness value of 0.49 compared to 0.74 (high-tide) and 0.85 (low-tide), suggests that the numerical abundance was less evenly distributed among species. Results are compared with 1997 findings.

***Keywords**:- Tides, Zooplankton, Abundance, Vertical Migration, Succession.*

I. INTRODUCTION

Plankton constitute the most important component of the food chain in every water body. They do not only provide food for higher trophic levels, but produce oxygen, cycle nutrients and process pollutants (Suthers *et al.*, 2019). Plankton may also serve as bioindicators to monitor the water environment for pollution and monitoring fish population dynamics (Nwankwo, 2004). Zooplankton being animal-like include many kinds of protozoa, micro-crustaceans and other micro invertebrates that are planktonic in aquatic ecosystems (Omudu & Odeh, 2006). Some eggs and larval stages of some animals also constitute the zooplankton. Zooplankton play important roles in the transfer of energy from producers to carnivores. They serve as food for carnivorous and omnivorous fish (Thurman, 1997; Adeyemi, *et al*., 2009). Natural factors such as current variations, tides, and man-made factors such as river dams strongly affect zooplankton abundance, which can in turn strongly affect fish larval survival (Abo-Taleb, 2019). Tides are changes in sea levels caused by gravitational interactions between the sun, moon, and earth (Hicks, 2006). Tides cause obvious mid-term (spring-neap cycles) and short-term (low-high water cycles) variations in the abiotic and biotic characteristics of these systems (Villate, 1997). Nutrient concentration, salinity, and suspended particulate matter of an estuary or water body are influenced by tidal activities (Montani, *et al*. 1998; Davies & Ugwumba 2013). Several studies have been documented on the zooplankton diversity and ecology in the Great Kwa River and other similar water bodies in Nigeria (Ajah, 2002; Ekwu & Sikoki, 2005; Offem, Samson, Omoniyi, & Ikpi 2009; Ikomi & Anyanwu, 2010; Eyo, Andem, & Ekpo, 2013). The influence on tides on zooplankton in the Great Kwa River was last measured in 1997 (Ajah,2002) which is quite a while for such a dynamic aquatic ecosystem hence the need for re-evaluation. We hereby undertake to update the changes tidal effects would have had on the composition, diversity, abundance and distribution of zooplankton species this River post dredging that took place in 1998 and restoration of the system.

II. MATERIALS AND METHODS

STUDY AREA

The Great Kwa River is one of the major tributaries of the Cross River Estuary. It is located around latitudes 4°45'N and longitudes 8°20'E (Akpan, 2000, Ajah, 2002). The River takes its raise from the Oban Hills of South-Eastern Nigeria (Simoneit, *et al.*, 2017) and meanders Southwards through an estimated 30 km of thick forest before discharging into the Cross River estuary near Calabar, South-South Nigeria. The lower Great Kwa River is characterized by semi-diurnal tides and extensive mud flats. (Moses, 1979).

The climate of the study area is defined by fairly distinct wet and dry seasons. The dry season spans November to March, or sometimes April and the wet season between June and October. A short dry period of about two weeks known as August break occurs in August. There is usually a cold dry and dusty wind that blows from the Sahara and prevailing on the Atlantic coast of West Africa between December and January, referred to as the harmattan season. According to Akpan and Ofem (1993), and Ama-Abasi, Holzloehner and Enin, (2004) temperatures generally range from 22 °C in wet seasons to 35 °C in the dry seasons with relative humidity generally above 60% at all seasons and close to 90% during wet season.

SAMPLING STATION

The study was conducted at Obufa Esuk (Fig. 1) along the Great Kwa River.

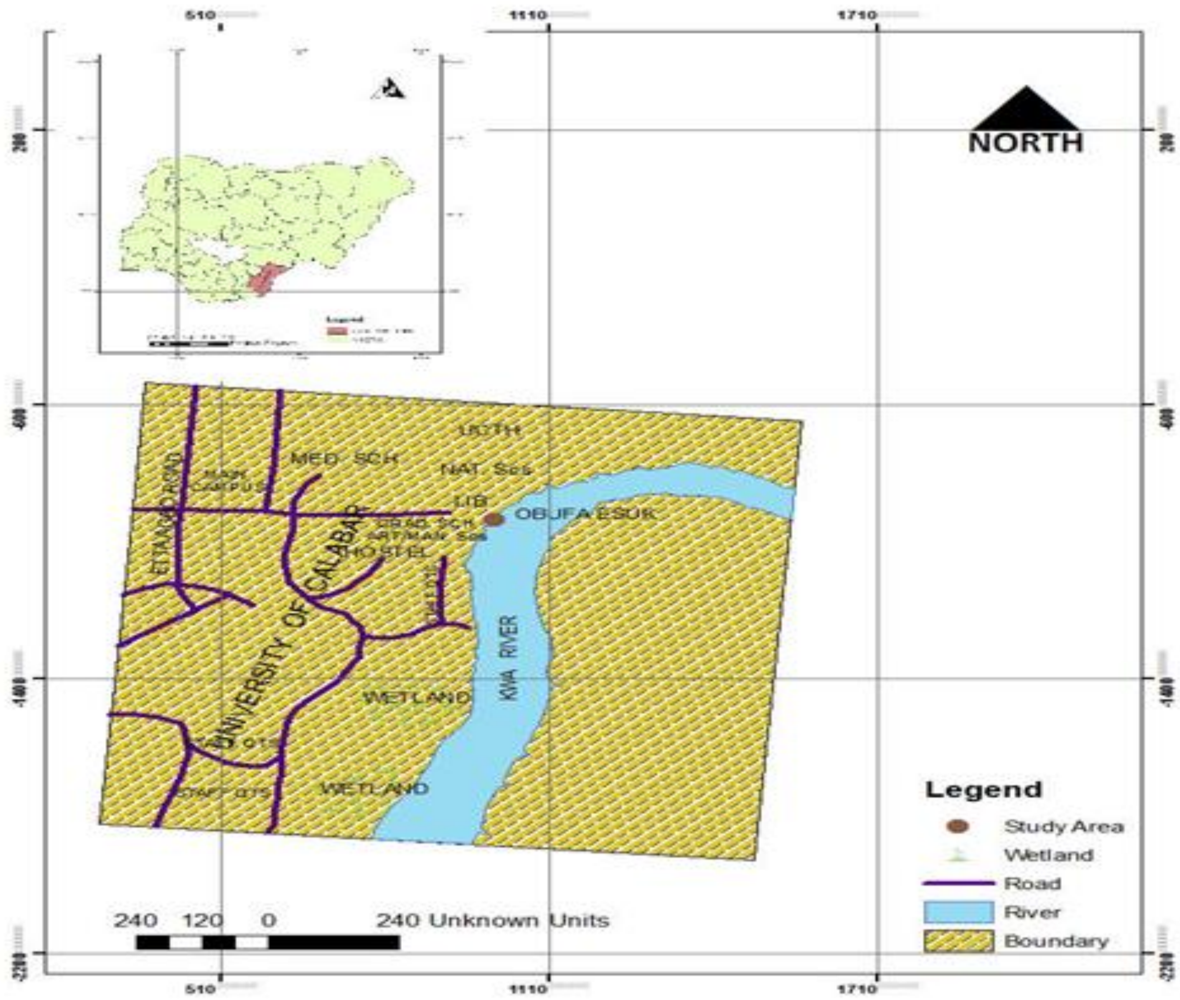

Fig. 1 Map showing the study area

SAMPLE COLLECTION AND ANALYSIS

Water samples were collected between July and September 2019 at different tidal regimes (low, mid and high tides) using 10-litre plastic container. The water was filtered through a plankton net of 55 µm pore size according to the methods of Boyd (1981) and Ajah (2002). The filtrates were transferred into 20 ml properly labelled sterile plastic containers with screw caps, fixed in 4% formalin and transported to the laboratory for analysis following Nkwoji, Ugbana and Ina-Salwany (2020). The filtered plankton were taken to the laboratory for plankton count using Sedge-wick Rafter (Model: Ajah 001) following Ajah, (1995). The analysed zooplankton were thereafter classified taxonomically using standard schemes and guides of Newell and Newell (1977), Jeje and Fernando (1978) and Waife and Frid (2001). Identification was done to the nearest taxon possible.

The following physicochemical parameters were measured during the study period- pH, conductivity, dissolved oxygen, temperature, salinity and total dissolved solute (TDS) using the appropriate measuring instruments.

III. ECOLOGICAL DIVERSITY INDICES

Ecological diversity indices evaluated in this study included Shannon Weiner index, Simpson's index of diversity, Margalef's index and Evenness. They were analysed using PAST (version 3) and also calculated according to formulae adopted from Ogbeigbu (2005) as follows:

Margalef's index (d)

This index is dependent on sample size (Margalef, 1965; Ogbeigbu, 2005; Isibor, *et al.*, 2020). It is based on the relationship "S" and the total number of individuals observed (N) and is generally known to increase with increase in sample size The index is given by the formula:

ISSN No:-2456-2165

$$d = \frac{s-1}{\ln N}$$

(Ogbeigbu, 2005; Eyo, *et al*., 2013).

Where: S= total number of species
N = total number of individual samples and
ln = the natural logarithm (Log_e).

Shannon-Wiener index (H)

Shannon-Weiner index sensitive to the number of species present and how evenly the individuals are distributed in the sample (Shannon-Wiener, 1949; Ogbeigbu, 2005; Ajah 2010), and is given by the formula:

$$H = \frac{N \log N - f \log fi}{N}$$ (Baul, Tiwari, Ullah & McDonald, 2013)

Where N = total number of all individuals in the sample
fi = total number of individual species or group of species.

Evenness index (E)

Evenness of the zooplankton was determined by dividing the number obtained from Shannon-Weiner index (H), by the maximum possible value of H (i.e H_{max}) (if every species was equal) using the formula:

$$E = \frac{H}{H_{max}}$$ (Pielou, 1966, 1984; Ogbeigbu, 2005; Ajah 2010).

Simpson's Dominance index (D)

Simpson's dominance index was determined using the formula:

$$D = \frac{ni(ni-1)}{Ni\,(Ni-1)}$$ (Ogbeibgu, 2005)

Where ni = the number of individual species
Ni = the total number of all species from each group or family.

IV. RESULTS AND DISCUSSIONS

The overall zooplankton composition, distribution, abundance and frequency of occurrence in the different tidal intervals are shown in Table 1. A total of fifty-nine (59) species and forty-one (41) taxa (genera) of zooplankton belonging to sixteen class groups recorded during the study included Copepoda (11 species, 9 taxa), Rhizopoda (8 species, 5 taxa), (Rotifera (7 species, 6 taxa), Cladoceran (6 species, 5 taxa), Protozoa (5 species, 5 taxa), Actinopoda, Nemata and Ostracoda (4 species, 4 taxa each), Coleoptera, Echinodermata, Ephemeroptera, Invertebrata, Lepidoptera and Malacostraca each had one species and one taxon and 2 unidentified species. The total of 59 species of Zooplankton is higher than the 44 species recorded by Eyo, *et al*., (2013), 38 species and five zooplankton taxa (Ajah 2002) and 23 species of zooplankton recorded by Antai and Joseph, (2015). Thus, over the years, there have been increase in both species composition and taxa groups. This agrees with dos Santos, Abra and Castilho-Noll (2021). Rosinka, Brzozowska and Goldyn (2019) attributed zooplankton changes during bottom-up and top-down control to sustainable restoration. Ewa-Oboho, Oladimeji and Asuquo (2008) reported lower phytoplankton and zooplankton due to reduction in light penetration, the physical smothering of benthic algae and disruption of benthic habitat. With reduced efficiency in energy transfer from primary production to copepod production, 8% post-dredging from January to August 1998 and 15% (January to September 1997) before dredging which took place between 8th October to 20th November 1997. Twelve years down the line Great Kwa River has witnessed unprecedented increase in zooplankton densities and diversities as seen from our report due to increased nutrient load, restoration, regeneration, and rejuvenation of the aquatic ecosystem.

A summary of the relative percentage composition of the major taxonomic groups to the overall zooplankton population at the different tidal intervals (Fig. 2) revealed that Great Kwa River was dominated by Rhizopoda (37.19%) and Copepoda (25.13%). This is contrary to Ajah (2002), who found Ciliata as the dominant group of zooplankton in same River depicting complete succession of Rhizopoda over Ciliata. 1997 sampling recorded six classes of zooplankton, namely, Ciliata, Protozoa, Copepoda, Cladoceran, Rotifera and Ostracoda whereas in 2019 fifteen (15) prominent classes were observed (Table 1).

Low tide recorded the highest (33 species) number of species, followed by high tide (26 species) while the least (22 species) was at Mid-tide. Density of zooplankton species, however, was highest at Mid-Tide with 95 individuals/ml, followed by High-Tide with 55 ind/ml and 49 ind/ml at Low-Tide. Compared to other waters body in the South-South and South-East geopolitical zones, Ekwu and Sikoki, (2005) identified 66 taxa, with Copepod (17 taxa) dominant and a population density ranging from 40 ind/l to 1,660 ind/l.

As shown in Fig. 3, The most dominant groups at Low tide were Copepoda (21.21%) mostly represented by *Microcyclops varicans* and Rhizopoda (18.18%) mostly represented by *Centropyxis sp*. Other sub-dominant groups were Actinopoda (9.09%), Ostracoda (9.09%), Rotifera (9.09%), Nemata (6.06%), and Protozoa (6.06%). Cladoceran, Coleoptera, Ephemeroptera, Invertebrata, Lepidoptera, Malacostracan and Polychaeta were the rare groups, each recording a relative percentage composition of 3.03%.

At mid tide, Rhizopoda (46.32%) and Copepoda (30.53%) were the most dominant groups of zooplankton. Other groups observed during this tidal interval include Actinopoda, Cladoceran, Ephemeroptera, Nemata, Protozoa, and Rotifera.

Rhizopoda, mostly represented by *Paraquadrula irregularis*, was the most dominant zooplankton group at High tide with a relative percentage composition of 34.55%. Copepoda (16.36%), Cladoceran (10.91%), Protozoa (10.91%), Nemata (9.09%), an unidentified group (7.27%) and Rotifera (3.64%) were the sub-dominant groups of zooplankton observed at this tidal interval. Actinopoda, Echinodermata, Ostracoda, and Polychaeta were the rare groups, each recording a relative percentage composition of 1.82%.

The indices of diversity; Shannon Weiner (H), evenness (E) and dominance calculated for the three stations are presented in Table 2. Shannon Weiner index was observed to be higher at Low and High-tides than Mid-tide, with values ranging between 2.22 and 3.95. Despite the highest number of individuals being recorded at Mid-Tide, an evenness value of 0.49 compared to 0.74 at High-Tide and 0.85 at Low-tide, suggested that the numerical abundance was less evenly distributed among species.

Table 1: The Overall Composition, Distribution and Abundance of Zooplankton in the Great Kwa River

Species Composition	Low Tide	Mid Tide	High Tide
ACTINOPODA			
Euglypha tuberculate	2	2	-
Heterophrys myriopoda	1	-	-
Phromis sp	-	-	-
Placosida spinose	-	2	-
CLADOCERAN	-	-	-
Alona intermedia	-	-	-
Alonella excigua	-	-	-
Chydorus ovalis	-	-	3
Chydorus sphaericus	-	2	-
Daphnia lacustris	-	-	1
Dunhevedia serata	-	-	1
COLEOPTERA			
Promoerescia sp	2	-	-
COPEPODA			
Bryocamptus besteinii	1	20	2
Calanoids sp	1	-	-
Copepod Nauplius	-	-	-
Diaptomus augustensis	-	-	-
Enhydrosoma uniaticulatus	1	-	-
Ergasilus centridadum		1	-
Microcyclops varicans	6	7	5
Phalacrocera sp	-	1	-
Thermocyclops kamaruwai		-	1
Thermocyclops sp	1	-	-
Tropocyclops longabdominal	1	-	-
ECHINODERMATA			
Echinodea sp	-	2	1
EPHEMEROPTERA			
Ephonon sp	1	2	-
INVERTEBRATA			
Hydrochnid sp	1	-	-
LEPIDOPTERA			
Unidentified	1	-	-
MALACOSTRACAN			
Gramarus sp	1	-	-
NEMATA			
Anaplectus granoluscus	1	1	-

ISSN No:-2456-2165

Anonchlus monlystera	1	-	3
Prismatolaimus stenurus	-	-	1
Trilobus longus	-	-	1
OSTRACODA			
Candona sp	-	1	-
Candonocypris serata	***3***	-	-
Ostracod sp	***1***	-	-
Physiocypria inflate	***3***	4	1
POLYCHAETA			
Glycerid larva	1	-	-
Polychaeta sp		-	1
PROTOZOA			
Arcella radiates	-	-	2
Paramecium caudatum	1	-	-
Stentor polymorphis	-	-	1
Strombidinopsis sp		-	3
Tintinnopsis sinensis	1	-	-
RHIZOPODA			
Arcella vulgaris	1	5	2
Centropyxis aculleata	1	-	1
Centropyxis arcelloides	3	3	7
Centropyxis ecormis	3	-	-
Difflugia lebes	-	1	-
Paraquadrulla irregularis	2	35	8
Penarduchlamys arcelloides	1	-	-
Phrygenella sp		-	1
ROTIFERA			
Asplanchna priodonta	1	1	-
Brachionus quadridentata	-	-	1
Lecane luna	-	1	-
Lecane ohiensis	1	-	-
Notholca sp	1	-	-
Platyias quadricormis		-	1
Scaridium longicaudum	-	1	-
OTHERS			
Heptagenia sp	-	-	4
Similium larva	-	1	-
Total No. of Organisms	**49**	**95**	**55**
Total No. of Species	**33**	**22**	**26**

Table 2: Diversity of zooplankton in the Great Kwa River			
Indices	**Low Tide**	**Mid Tide**	**High Tide**
No. of Taxa	33	22	26
Individuals	49	95	55
Margalef Index (D)	8.22	4.61	6.24
Shannon-Weiner Index (H)	3.32	2.22	2.95
Evenness (E)	0.85	0.49	0.74
Simpson Index	0.95	0.81	0.93

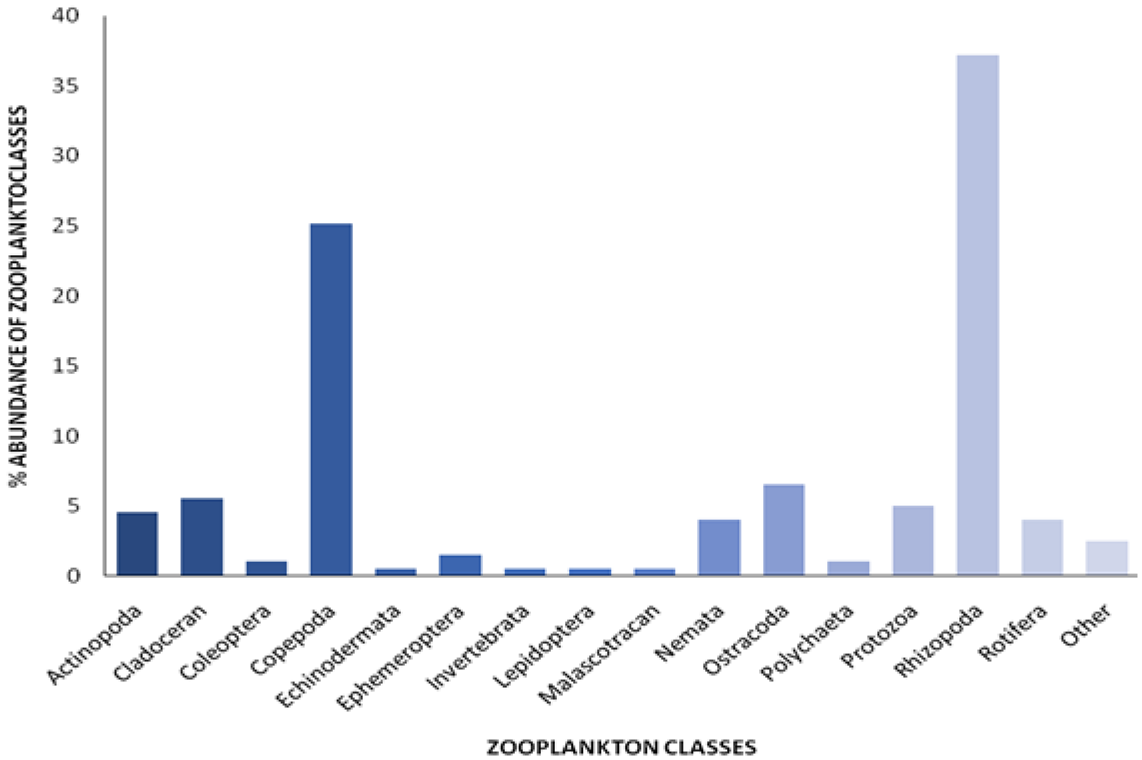

Fig. 2: Graph showing relative abundance of Zooplankton classes.

Physicochemical parameters of water for the three tidal cycles

Table 3 shows mean results for analyses of different water quality parameters carried out in the study area at different tidal intervals. In the month of July, August, and September, mean pH ranged between 5.11±0.04 and 6.72±0.00 across the three tidal intervals. Conductivity ranged between 18.70±0.20 µS and 37.95±1.05 µS. Dissolved Oxygen was observed to be higher in the month of July with a mean value of 4.00±0.60 mg/l at low tide. The lowest value (2.60±0.00mg/l) observed in the month of August was at low tide. Water temperature was within the range of 25.50±0.50 °C and 27.00±0.00 °C across both the tidal intervals and the three months. Salinity level never exceeded 0.03±0.01 mg/l or lower than 0.01±0.00mg/l across the three tidal intervals during the study. Total dissolved solid (TDS) ranged between 23.19±0.25mg/l and 47.06±1.30 mg/l.

TABLE 3
Mean physico-chemical parameters of water samples at the sampling station at the different tidal intervals.

PARAMETERS	Month	High-Tide	Mid-Tide	Low-Tide
pH	July	6.72±0.00	6.72±0.04	6.67±0.03
	August	6.36±0.44	6.23±0.42	6.31±0.37
	September	5.11±0.04	5.25±0.02	5.31±0.13
Conductivity (µS/cm)	July	30.9±3.1	30.75±2.25	37.95±1.05
	August	26.05±5.95	26.50±0.50	31.50±10.50
	September	19.51±0.81	27.97±8.03	18.70±0.20
DO (mg/l)	July	3.45±0.25	3.55±0.45	4.00±0.60
	August	2.95±0.25	3.05±0.35	2.60±0.00
	September	3.15±0.45	3.10±0.30	2.65±0.50
Temp (°C)	July	27.00±0.00	27.50±0.50	27.00±0.00
	August	27.00±1.00	25.50±0.50	25.50±0.50
	September	26.50±0.50	26.50±0.50	26.50±0.50
Sal (%)	July	0.02±0.00	0.02±0.00	0.03±0.01
	August	0.02±0.01	0.01±0.00	0.02±0.01
	September	0.01±0.00	0.02±0.01	0.01±0.00
TDS (mg/l)	July	38.32±3.85	38.13±2.79	47.06±1.30
	August	32.30±7.38	26.37±5.87	39.06±13.02
	September	24.18±0.99	34.68±9.96	23.19±0.25

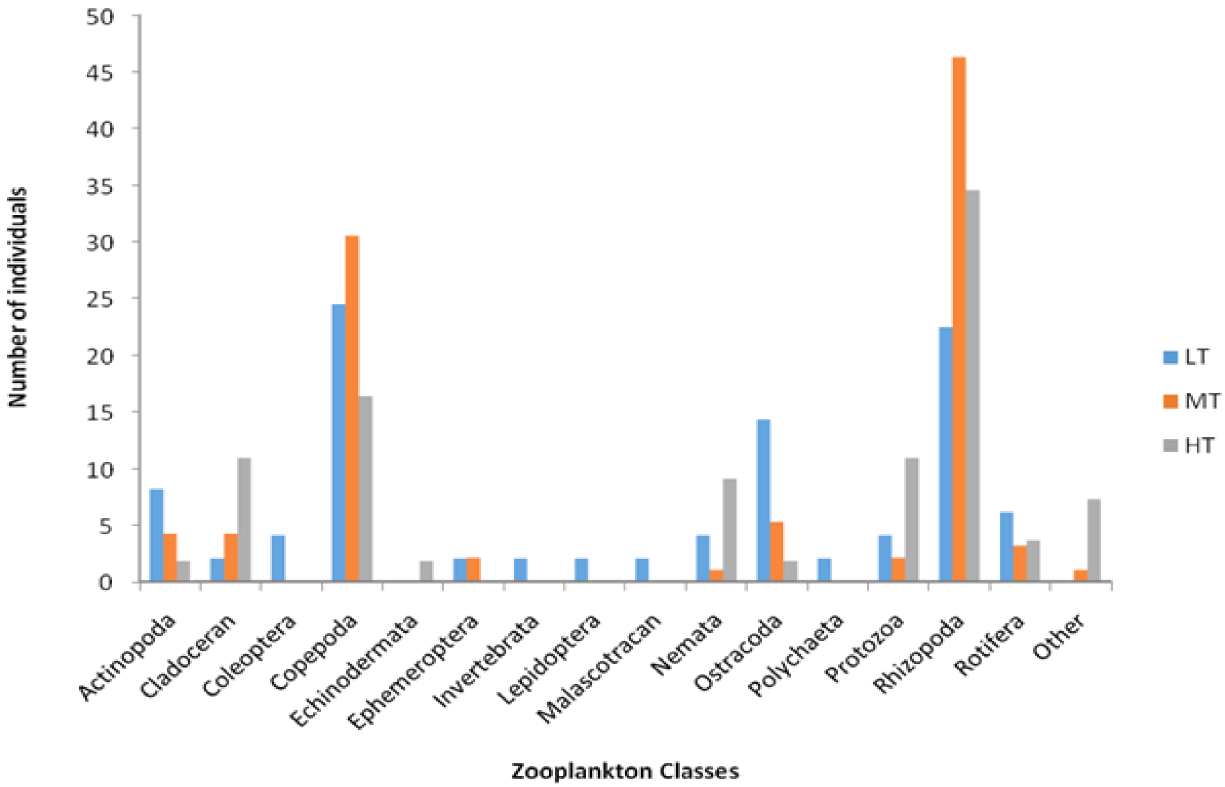

Fig. 3. Zooplankton abundance in relation to tides

Tidal cycles were observed to affect zooplankton density, species diversity indices, composition (species richness) and distribution. Tides induce flow and transport of sediments, animals, plants, other organisms and suspended particles at high tides and leave the sediments and suspended particles behind, but the biota go with the ebbing tide back to the sea (Blondeaux & Vittori, 2005; SlideShare Inc., 2009).

The tidal variations of the zooplankton abundance we observed in this study may be indicative of varying nutrients concentrations. The low species diversity values might be associated with environmental stress. Dominance of copepods in terms of abundance and species composition indicates pollution (Krumme & Liang, 2004). This shows that copepods are resilient to the increased anthropogenic input and high turbidity.

High light intensity or transparency at low tide leads to high primary productivity and this might indicate that these zooplankters fed on microphytoplankton (Davies & Ugwumba 2013). The absence of some zooplankton species at Mid tide and High tide suggests that zooplankton species had vertically migrated downward the river before high tide and mid tide. This vertical migration of species is a behaviour common to all plankton. It can be influenced by several factors including food abundance and availability, predators and other environmental factors such as light, tide, salinity and temperature (Avent, Bollens, & Troia, 1998).

In 1997, zooplankton density stood at 2,144 individuals/100 l which is far less than the present 95, 000/l. These sharp increase over the years is not unconnected with high nutrient load attained within this interval. The higher the nutrient level, the higher the zooplankton population.

V. CONCLUSION

Tides affect the density, species diversity, composition (species richness) and distribution of zooplankton in the Great Kwa River. Rhizopoda and Copepoda were the most dominant groups of zooplankton observed in the study. Copepods were dominant at Low tide, while Rhizopods were most abundant at mid-tide and high-tide. This study provides useful comparative information on the composition and ecology of species in relation to tides and space in the Great Kwa River, which could be used to monitor trends in water quality with time and best periods for fishing.

REFERENCES

[1]. Abo-Taleb, H. (2019). Importance of Plankton to Fish Community. 10.5772/intechopen.85769.

[2]. Adeyemi, S.O., Adikwu, L.A., Akombu. P.M. & Iyala, J.I. 2009. Survey of zooplankton and macroinvertebrates of Gbedikere lake Bassa, Kogi Stae, Nigeria. *International Journal of Lakes and* River, 2(1): 37-44

[3]. Ajah, P.O. (1995). identification and mass production of zooplankton species suitable for early rearing of African clariid catfish. *PhD thesis*, University of Calabar, 164pp

[4]. Ajah, P.O. (2002), Seasonal and tidal influence on nutrients dynamics and plankton cycles in an oligotrophic river –The Great Kwa River, Nigeria. *ROAN*. 1 : 54-79.

[5]. Ajah, P.O. (2013). The Limnology of Ohana Lake, a Potential Manmade Aquaculture System in Nigeria, *Open Journal of Applied Sciences*, 3: 232-246. doi:10.4236/ojapps.2013.32031

[6]. Akpan, E. R, and Ofem, J. O. (1993). Seasonal variation in water quality of Cross River, Nigeria. *Revised Hydrobiologia. Tropical.*, 26: 96-103.

[7]. Akpan, E. R. (2000). Influence of meteorological and hydrological factors on the water quality of Calabar River, Nigeria. *Trop. Environ. Res*. 2(1): 101 – 111.

[8]. Ama-Abasi, D. Holzloehner, S. & Enin, U. I. (2004). The dynamics of exploited population of bonga, *Ethmalosa fimbrata* (Bowdich 1825) in Cross River Estuary and adjacent coastal Gulf of Guinea. *Fisheries Research*, 68(1-3): 225 – 235.

[9]. Avent, S.R., Bollens, S.M. & Troia, S.P. (1998). Diel vertical migration in zooplankton: experimental investigations using video-microscopy and plankton mini-towers. In American Geophysical Union (ed). 1998 Ocean Sciences Meeting, 9-13 February 1998, San Diego, CA. American Geophysical Union, Washington, DC.

[10]. Baul, T.K., Tiwari, K.R., Ullah, K.M. A. & McDonald, M.A., (2013). Exploring agrobiodiversity on farm: A case from Middle-Hill of Nepal, *Small-Scale Forestry*, Doi.10.1007/s11842-012-9234-y.

[11]. Blondeaux, O.J. & Vittori, E.E. (2005). Flow and sediment transport by tide propagation;1. The flat bottom case. *Journal of Geophysical Research*, 110C07020. DOI:101029/2004/JC002532.

[12]. Boyd, C.E. (1981). Water quality in warmwater fishponds. 2nd ed. Alabama: Craftmaster.

[13]. Davies, O. A. & Ugwumba, O. A. (2013). Tidal influence on nutrients status and phytoplankton population of Okpoka Creek, Upper Bonny Estuary, Nigeria. *Journal of Marine Biology*, ID 684739, 16 pp.

[14]. Ekwu, O. & Sikoki, F.D. (2005). Species composition and distribution of zooplankton in the Lower Cross River Estuary. *African Journal of Applied Zoology and Environmental Biology*, 7: 5-10.

[15]. Ewa-Oboho, I., Oladimeji, O. & Asuquo, E.F (2008). Effect of dredging on benthic-pelagic production in the mouth of the Cross River Estuary (off the Gulf of Guinea), S.E. Nigeria. *Indian journal of marine Science*, 37(3) 291-297.

[16]. Eyo, V.O. Andem, A.B. & Ekpo, P.B. (2013). Ecology and Diversity of Zooplankton in the Great Kwa River, Cross River State, Nigeria. *International Journal of Science and Research*. 2(10): 67-71.

[17]. Hicks, S.D. (2006). *Understanding tides*. US Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

[18]. Ikomi, R.B. & Anyanwu, E.D. (2010). "Zooplankton of Ogba River, Benin City, Nigeria", *Bioscience Research Communications*, 22(5), pp. 255-258,

[19]. Isibor, P.O., Imoobe, T.O.T., Dedeke, G.A., Adagunodo, T.A., & Taiwo, O.S. (2020). Health risk indices and zooplankton -based assessment of a tropical rainforest river contaminated with iron, lead, cadmium, and chromium. *Scientific Reports/natureresearch,* 10: 1-16, 16896 https://doi.org/10.1038/s41598-020-72526-1

[20]. Jeje, C.Y., & Fernando, C.F. (1986). A practical guide to the identification of Nigerian zooplankton (Cladocera, Copepoda and Rotifera). Published by Kainji Lake Research Institute, New Bussa p. 742.

[21]. Krumme, U. & Liang, T. (2004). Tidal-Induced Changes in a Copepod-Dominated Zooplankton Community in a Macrotidal Mangrove Channel in Northern Brazil. *Zoological Studies*, 43(2):404-414.

[22]. Montani, S., Magni, P., Shimamoto, M., Abe, N., & Okutani, K. (1998). The effect of a tidal cycle on the dynamics of nutrients in a tidal flat of the Seto Inland Sea, Japan. *Journal of Oceanography*: 54: 65 – 76.

[23]. Moses, B. B. (1979). The Cross River, Nigeria. Its ecology and fisheries. pp. 335-571. In: *Proceedings of the intercontinental Conference of Kainji Lake Research Institute,* New Bussa, Nigeria.

[24]. Newell, G.E. & Newell, R.C. (1977). *Marine plankton*: a practical guide. Hutchinson, London. Reprint, 244Pp

[25]. Nkwoji, J.A., Ugbana, S.I. & Ina-Salwany, M.Y. (2020). Impacts of land-based pollutants on water chemistry andbenthic macroinvertebrates community in a coastal lagoon, Lagos, Nigeria, *Scientific African,* 7: 3-10e00220..

[26]. Nwankwo, D. I. (2004). Studies on the Environmental preference of blue-green algae (Cyanophyta) in Nigeria Coastal waters. *The Nigeria Environmental Society Journal,* 2(1): 44-51.

[27]. Offem, B.O., Samsons, Y.A., Omoniyi, I.T. & Ikpi, G.U. (2009). "Dynamics of the limnological features and diversity of zooplankton populations of the Cross River System SE Nigeria". *Knowledge and Management of Aquatic Ecosystem,* 2: 393,

[28]. Ogbeigbu, A.E. (2005). *Biostatistics*: A Practical Approach to Research and Data Handling. Minex Publishing Company Limited. Benin City, Nigeria 153-155.

[29]. Pielou, E.C. (1966). The Measurement of Diversity in Different Type of Biological Collections. *Journal of Theoretical Science*, 13:131-144.

[30]. Pielou, E.C. (1984). *The interpretation of Ecological data*: a premier on classification and co-ordination. John Wiley and Sons. New York, 263p

[31]. Rosinska, J., Brzozowska & Goldyn, R. (2019). Zooplankton changes during bottom-up and top-down control due to sustainable restoration in a shallow urban lake. *Environmental Science and Pollution Research, 26: 19575-19587.*

[32]. Shannon, C.E. & Weiner, W. (1949). *The mathematical theory of communication*. University of Illinois Press-Urbana. 125pp.

[33]. Simoneit, B.R.T., Pisani, O., Ekpo, B.O., Fubara, E.P., Nna, J.P., & Ekpa, O.D. (2017). Lipid biomarker analysis of suspended particulate matter from the Great Kwa River, SE Nigeria: Origins and Environmental implications of biogenic and anthropogenic organic compounds. *Aquatic Geochemistry,* 23: 89-109.

[34]. Dos Santos, E.F., Abra, J. & Castilho-Noll, M.S. (2021). Does land use influence the localandregional structure of the rotifer assemblage? *Hydrobiologia*, 845(5): Doi:10.1007/s10750-020-04513-6

[35]. SlideShare Inc (2009). Effects of waves, currents, tides-Presentation transcript. Available at http://www.slideshare.net/bosch/effects-ofwaves-currents-tides-presentation.

[36]. Suthers, I., Rissik, D., & Richardson, A. (Eds.). (2019). *Plankton: A guide to their ecology and monitoring for water quality*. CSIRO publishing.

[37]. Thurman, H.V. (1997). Introductory oceanography. New Jersey: Prentice Hall.

[38]. Villate, F. (1997). Tidal influence on zonation and occurrence of resident and temporary zooplankton in a shallow system (Estuary of Mundaka, Bay of Biscay). *Scientia Marina.* 61.

[39]. Waife, G. & Frid, C. L.J. (2001). Marine Zooplankton of West Africa. Darwin Initiative Report 5. 162/7/451. 120p.