EVALUATION OF ZOOPLANKTON COMMUNITY OF OKERENKOKO ESTUARY, NIGER DELTA, NIGERIA

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Abstract

Okerenkoko Estuary (OE - 62.79 Km) plays very crucial roles to its surrounding communities. But in recent times, its fauna abundance has been impaired due to anthropogenic activities. Studies on OE fauna abundance are limited. Hence, this study was under taken to investigate OE Zooplankton community abundance. The OE was spatially stratified into five stations (Z 1 – Z 5) based on proximity to major anthropogenic sources. In each station, three sampling points were randomly selected.Water and zooplankton samples were collected monthly for 12 months in wet (March – October) and dry (November – February) Seasons according to standard methods. Water samples were analysed for Temperature (℃)and Dissolved Oxygen (DO, mg/L), while Zooplankton were identified to species level by using standard keys. Abundance (%) was calculated according to standard method. Data were analysed by using descriptive statistics and ANOVA at α0.05. Spatially, Temperature ranged from 24.45±1.67) to 31.86±2.12 in Z 1 and Z 5, highest (29.50±2.65) and least 26.80±5.87 were obtained in dry and wet seasons, respectively. Highest (6.12±1.03) and least (3.97±0.24) of DO occurred in Z 5 and Z 3, it ranged from 3.85±0.43 to 4.80±0.41wet and dry seasons, respectively. A total individual number of 258zooplankton belonging to 8 orders 7 families and 12 species were identified. *Brachionus caudatus* and *Calanus* sp. recorded the highest 54 (20.9 %) and least 3 (1.2 %) zooplankton species abundance. Spatially, Shannon recorded 2.51 and 1.01 as highest and least in Z 2 and Z 5, Margalef ranged from 1.19 to 2.72 in Z 5 and Z 4. Temporally, Shannon ranged from 1.5 to 1.68; Margalef (1.81, 2.02) in wet and dry seasons, respectively. Zooplankton species abundance and diversity of Okerenkoko Estuary could be under stress.

Keywords: Water quality, Fauna abundance, Anthropogenic effluents, Zooplankton diversity.

Introduction

The zooplankton community is an essential component of the aquatic food chain because it acts as intermediary species,serves as intermediary food component between phytoplankton and fishes (Ewutanure and Olaifa, 2020). In surface water, plankton exhibit significant roles in fish foods production to man and in the determination of pollution status of the aquatic environment (Kwen *et al.* 2019). Zooplankton help in energy transfer from primary producers (planktonic algae) to larger invertebrate predators (*Hesperocorixa castanea, Gerris remiges Ephemerella doris*) and fish that eventually feed on them (Ukaonu *et al.*2015).

The appearance of the developmental stages and matured species of zooplankton could serve asindicators of availability of food for fish survival and growth (Ukaonu *et al*. 2015). and the ability of such an aquatic ecosystem to support its flora and fauna species (Ovie *et al.* 2015). Zooplankton feed on phytoplankton (primary producers) and organic matter in water, hence infusing an essential role in the aquatic trophic level relationship (Kigbu *et al.* 2015).

Zooplankton abundance are useful indicators of water quality parameters and fish health(Ewutanure and Olaifa, 2020). The biological status of an aquatic system can be assessed using some indices like species composition, abundance, distribution and diversity of plankton (Ekwu and Udo, 2013). According to Ezekiel *et al.,* (2011) zooplankton control algae and microbial productivity of surface water ecosystem through their foraging capability thereby transferring productivity to fishes and other aquatic fauna species.

Zooplankton move from deeper strata of surface water to the surface at night and at dawn in response to sunlight and in search for foods (Ewutanure *et al*. 2022a &b). The abundance and diversity of zooplankton species of a water body could be altered by the concentrations dynamics of its physico – chemical parameters and river flow rate (Kwen *et al*. 2012).

It has been reported that there is close link between zooplankton species diversity and water qualities parameters of surface waters (Nwoji *et al*. 2010). Several studies have been carried out on the zooplankton compositions, abundance and species diversity of various water bodies in Nigeria(Ewutanure and Olaifa, 2020; Kwen *et al.* 2019; Kigbu *et al*. 2015; Ukaonu *et al*. 2015; Ekwu and Udo, 2013; Ezekiel *et al.* 2011; Ekwu and Sikoki, 2005), but there is dearth of information on the zooplankton community and species diversity of Okerenkoko Estuary, Niger Delta, Nigeria. This study therefore aimed at providing required information on the abundance and species diversity of zooplankton of community of Okerenkoko Estuary for the assessment and management of its productivity and aquatic living resources.

Materials and methods

Description, climate and vegetation of the study area

Okerenkoko Estuary (Figure 1) with a total length and mean depth of 62.79 Km and 35 m is located on latitudes 5°30′0″N and 5°50′0″N of the Equator and Longitudes 5°10′0″ E and 5°40′0″ E of the Greenwich meridian(Ewutanure *et al*. 2022a).The study area has its source from the Eschravos River located in the Niger Delta Region of Nigeria (Ewutanure and Olaifa, 2021a). The Okerenkoko Estuary is severely impacted by the effluents emanating from the anthropogenic activities of oil and gas industries situated within it (Ewutanure and Olaifa, 2018).

The major seasons associated with the study area are the wet (March – October) and dry (November – February) seasons

(Ewutanure *et al.* 2022b).The climate of the study area is controlled by the South – West monsoon wind from the Atlantic Ocean and the North – East trade wind from the Sahara Desert. Both wind types are responsible for wet and dry seasons, respectively (Ewutanure and Olaifa, 2018). Okerenkoko Estuary is located in a mangrove swamp forest with alluvials soil type (Ewutanure and Olaifa, 2021c; Ewutanure and Binyotubo, 2021a). Mean annual rainfall and temperature of the study area were 2869.7 mm and29.3℃(Ewutanure and Olaifa, 2021b). The major species of mangrove identified were the *Rhizophora racemose* (red) and *Avicennia africana* (white),while the major occupation of the Okerenkoko inhabitants is fishing with the aid of hook – line, gill net, lift net and beach seine net (Ewutanure and Binyotubo, 2021). Oil wells and flow stations operated by Chevron Nigeria Limited are in multiple locations within the estuary.

Sampling techniques

Okerenkoko Estuary was spatially stratified into five stations (Z1, Z2, Z3, Z4 and Z5) based on proximity to key anthropogenic activities. The exact locations of all sampling stations were determined byusing Garmin GPSMAP eTrex 10 type sensors. Three sampling points per station were randomly selected to ensure that there are replicates, while temporal stratification covered wet (March – October) and dry (November – February) seasons (Ewutanure *et al*. 2022a).

Determination of physico – chemical parameters

Collection of water samples for the evaluation of physical chemical parameters wasdone monthly for station for 12 months (June, 2021 to May, 2022) and analyzed by following standard methods (APHA, 1992).

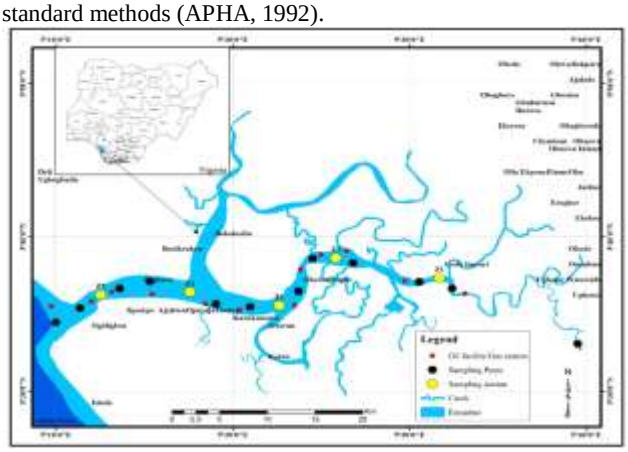

Figure 1. Map of Okerenkoko Estuary, Delta State, Nigeria
Source: Ewutanure*et al.* (2021a)

Collection and analysis of zooplankton samples

Horizontal hauling method was adopted for zooplankton samples collection for 3 minutes by using 0.2 mm mesh size net at a depth of 0 – 15 cm (Jeje and Fernado, 1986) in towing boat. Collected samples were fixed and preserved in 5% formalin within the recommended time of 5 minutes after collectionto avoid damage to animal tissue by microbial action and autolysis. Samples were labeled, dated and taken to the laboratory for further analysis and identification.

About 50 mL of the water sample containing the zooplankton samples was introduced into a plastic conical centrifuge tube in the laboratory (Gupta, 2001). The mixture was allowed to sit undisturbed in a dark cupboard for four days. Thereafter, 40 mL of the supernatant was carefully decanted leaving 10 mL of the concentrated sample. About 1 mL of the concentrated sample was then pipetted into the Sedgwick – Rafter counting chamber of the Microscope, while the glass cover was gently adjusted over the chamber without forming air bubbles. Later, the counting chamber was placed in its position in the microscope.

A magnification of X 400 was chosen. Counting and identification of zooplankton seen within the ocular micrometer grid was done, while direct enumeration method was used for the identification of zooplankton as described by Lynne, (2006). Zooplankton were identified to species levels by using standard keys such as Jeje and Fernando, (1986); Lynne, 2006; Bouchard, (2004).Calculation was done using this formula:

$$Number\ of\ zooplankton\ per\ mL = (T)\frac{1{,}000{,}000\ x\ volume\ of\ concentrate\ (mL)}{A\ x\ N\ x\ volume\ of\ sample\ (mL)}$$

Where:
T = total number of plankters; A = area of grid in square millimeters; Number of grids used and 1000 = area of counting chamber in square millimeters

Results and Discussion

Physico – chemical parameters

Results of physical and chemical parameters of Okerenkoko Estuary among stations and betweenseasons are presented in Tables 1 and 2, respectively. Mean Temperature obtained were within the recorded range (25 – 32 ℃) for fish growth (Boyd, 1979) in Z1. Lower level recorded in Z1 could be attributed to higher level of rainfall and surface run – off.

Higher surface water temperature recorded in Z5 as compared with the other stations could be associated with itsnearness to gas flaring station that heats up the water temperature. Results from this study are in consonance with earlier findings on Okerenkoko Estuary by Ewutanure *et al.* (2022a); Ewutanure *et al.* (2022b); Ewutanure and Binyotubo, (2021); Ewutanure and Olaifa, (2021) and with the results from other water bodies within the Niger Delta Region bySeiyaboh *et al.* (2016); Ewutanure and Olaifa, (2018); Seiyaboh *et al*. (2016) and Abowei, (2012). The result obtained in Z 5 as compared with other stations showed that anthropogenic activities (gas flaring and oil exploration) could negatively impact surface water and its biota (Ajuonu*et al*. 2011).

Little deviation in Salinity concentration obtained recorded during this study could be attributable to tidal action, rainfall and dilution effects from storm water run – off (Ewutanure *et al.* 2022b). Decrease rainfall, high temperature and increase evaporation could raise the Salinity level of water bodies (Ewutanure and Olaif, 2021c). Results from this study showed that the salinity of Okerenkoko Estuarine oscillates between mesohaline (5 – 18 ‰) and hypherhaline (18 – 50 ‰) (Ewutanure *et al.* 2022b).

Concentrations of electrical conductivity (EC) recorded among stations and between seasons were less than the established limits of 50 - 500 µS/cm (Boyd, 1979; ASTM, 2006). The low concentration recorded could be as a result of dilution effect from the surrounding freshwater sources (Ampon and Taeng-On 2014). The level of dissolved salt content could also influence EC level in inland waters (Abowei, 2012).
Dissolved oxygen concentration was highest in Z2 compared with other stations and season. This result is in agreement with Ewutanure and Olaifa, (2021a); Ewutanure andOlaifa, (2018a); Abowei, (2010); Boyd, (1979). Increased degradation of organic matter andtotal suspended solids associated from

increase level of surface run – off could cause areduction in DO level (Ewutanure and Olaifa, 2021b). Low levels of DO recorded in Z 3 andin Wet Season could be attributed to increased anthropogenic activities. It has been reportedthat a decline in DO concentration could inhibits fish eggs hatchability, fry survival and theabundance of a fish stock (Ewutanure and Binyotubo, 2021c).

Generally, higher concentration of total suspended solids (TSS) than the recommended levels of 10 mg.L^{-1}(Boyd, 1979) and 30mg/L (FEPA, 1991) were obtained among stations and between wet and dry seasons. Higher concentration of TSS in surface water could impair light penetration within the photic zone thereby causing low production reduction in its fishery abundance (Seiyaboh *et al*. 2016; Ekwu and Sikoki, 2006).

Higher levels of TSS concentration than recommended limits could cause clogging in fish gill, mortality of hatchlings and fry (Seiyaboh *et al*. 2013). This could lead to instability in fish stock abundance (Adeleke and Babalola, 2014). Result from this study agrees with those obtained from Gbalegbe River (Ewutanure and Olaifa, 2021b).

Concentration of pH obtained in Okerenkoko Estuary varies slightly. This is a common phenomenon in tidal brackish water environment (Ewutanure and Olaifa, 2021c). With the exception of Z4 and dry season, pH levels obtained were within the recommended limit by Boyd, (1979). The relatively lower level of pH obtained in Z4 could be attributable to the decay of anthropogenic wastes upstream (Ogamba *et al*. 2015).

Table 1. Mean physico – chemical parameters of Okerenkoko Estuary among stations

	Stations				
Parameters	**Z1**	**Z2**	**Z3**	**Z4**	**Z5**
Temp ((°C)	24.85±1.66^{c}	30.50±3.98^{a}	29.5±2.91^{a}	27.34±1.98^{b}	31.86±2.12^{a}
Salinity (‰)	18.99±0.77^{b}	18.57±0.35^{b}	21.37±1.13^{a}	18.45±0.17^{b}	20.56±3.23^{a}
DO (mg.L^{-1})	5.45±0.07^{a}	6.05±0.26^{a}	3.97±0.24^{b}	4.34±0.98^{b}	6.12±1.03^{a}
TSS (mg.L^{-1})	45.87±6.98^{c}	41.54±1.7^{c}	60.86±1.33^{b}	70.17±3.9^{a}	59.89±3.23^{b}
EC (µScm^{-1})	58.27±2.65^{a}	49.93±2.09^{b}	50.09±5.91^{b}	46.67±3.55^{c}	65.4±6.98^{a}
pH	7.26±0.78^{a}	6.98±0.93^{a}	7.11±0.67^{a}	5.83±0.89^{b}	6.97±1.29^{a}

Source: Ewutanure *et al*. 2022b

Note: Z1 – Z5 = Stations 1 to 5.

Table 2. Mean physico – chemical parameters among stations in Okerenkoko Estuary between wet and dry seasons

Physico-chemical Parameters	Wet season	Dry season	P – values	Boyd, (1979)&Whitfield *et al.* (1981)
Temperature (°C)	26.80±5.87	29.50±2.65	0.11**	25 – 32
Salinity (‰)	17.95±0.88	21.76±0.71	0.08**	0 – 90
DO (mg.L^{-1})	3.85±0.43	4.80±0.41	0.77**	5 – 10
TSS (mg.L^{-1})	75.05±0.64	50.76±4.97	0.62*	< 10
EC (µScm^{-1})	39.98±1.49	59.92±1.11	0.76**	50 – 500
pH	7.90±0.23	6.30±0.75	0.45**	6.5 – 8.9

Source: Ewutanure *et al*. 2022b

Note: * = There are significant differences ($p<0.05$) between means along rows;
** = There are no significant differences ($p>0.05$) between means along rows

Composition, distribution and abundance of zooplankton species

The composition, distribution and abundance of zooplankton species among stations and between wet and dry seasons are shown in Tables 3 and 4. The total individual number of zooplankton recorded during the study was 258, comprising 8 orders, 7 families and 12 species. Highest 85 (32.9 %) and least 23 (8.9 %) individual number of zooplankton were recorded in Z 2 and Z 5, while Z 5 recorded 63 (24.45 %).

Spatially, *Branchianus caudatus* 54 (20.9 %) and *Calanus* sp. 3(1.2 %) were recorded as highest and least. *Branchianus caudatus* 30 (11.6 %) and *Alona davidi* 11 (4.3 %) were obtained as highest and least during wet and dry seasons, respectively. Individual species number of zooplankton recorded in this study were more than the 37 recorded for Taylor Creek, Bayelsa State (Kwen *et al*. 2010) but less than that recorded for Gbalegbe River, 1071 (Ewutanure and Olaifa, 2020).

Higher zooplankton species diversity recorded than in other water bodies within the Niger Delta during the study could be associated with Okerenkoko Estuary close proximity to the open seas which give rise to diadromous migration of various species of zooplankton and constant mixing of the Estuary with the Atlantic Ocean(Onuoha *et al*. 2010; Offem *et al*. 2014).

Table 3. Abundance and distribution of zooplankton species in Okerenkoko Estuarine among Stations

Families	Species	Stations					Total	% Abundance
		Z 1	Z2	Z 3	Z 4	Z 5		
Cyclopoidae	*Cyclops* sp.	1	3	0	5	9	18	7.0
Calanidae	*Calanus*sp.	0	3	0	0	0	3	1.2
	Dphnia magna	3	1	5	1	0	10	3.9
	Cyclotellastriata	0	0	5	8	2	15	5.8
Diaptomidae	*Diaptomus*sp.	0	0	1	3	4	8	3.1
Harpacticoidae	*Harpacticoid copepod*	12	5	2	0	1	20	7.8
Chydoridae	*Chydorus*sp.	1	4	23	1	0	29	11.2
Chydoridae	*Alona davidi*	1	5	7	3	1	17	6.6
	Bosminalongirostris	4	10	0	4	1	19	7.4
Chydoridae	*Alonamonacantha*	32	2	1	5	0	40	15.5
Brachioniidae	*Brachionuscaudatus*	5	43	0	5	1	54	20.9
Moinidae	*Moinamicrura*	4	9	8	0	4	25	9.7
	Total	63	85	52	35			
	% Abundance	24.4	32.9	20.2	13.6	8.9		

Note: Z1 – Z5 = Stations 1 to 5.

Table 4. Abundance and distribution of zooplankton species in Okerenkoko Estuary between wet and dry seasons

Families	Species	Wet season	% Abundance	Dry season	% Abundance
Cyclopoidae	*Cyclops* sp.	11	4.3	7	2.7
Calanidae	*Calanus*sp.	2	0.8	1	0.4
	Dphnia magna	4	1.6	6	2.3
	Cyclotellastriata	9	3.5	6	2.3
Diaptomidae	*Diaptomus*sp.	5	1.9	3	1.2
Harpacticoidae	*Harpacticoid copepod*	14	5.4	6	2.3
Chydoridae	*Chydorus*sp.	16	6.2	13	5.0
Chydoridae	*Alona davidi*	6	2.3	11	4.3
	Bosminalongirostris	12	4.7	7	2.7
Chydoridae	*Alonamonacantha*	17	6.6	23	8.9
Brachioniidae	*Brachionuscaudatus*	30	11.6	24	9.3
Moinidae	*Moinamicrura*	16	6.2	9	3.5
	Total	142		116	
	% Abundance		55.0		45.0

Diversity index obtained for zooplankton of Okerenkoko Estuary among stations and between wet and dry seasons are presented in Tables 9 and 10, respectively. Dominance ranged from 0.17 to 0.64 in Z2 and Z 5; Simpson (0.36, 0.83); Shannon (1.01, 2.51) in Z 5 and Z 2; Evenness (0.41, 0.91) in Z 1 and Z 3), while Margalef (1.19, 2.72), respectively. Seasonally, highest (0.73) and least (0.34) Dominance and Evenness (0.61, 0.56) occurred during wet and dry seasons, while Simpson (1 – D) ranged from 0.27 to 0.51; Shannon (1.51, 1.68) and Margalef (1.81, 2.02) in wet and dry seasons, respectively.

Table 5. Diversity indices of zooplankton species of Okerenkoko Estuarine among stations

Parameters	Z1	Z2	Z3	Z4	Z5
Individuals (N)	63	85	52	35	23
Dominance	0.33	0.17	0.37	0.51	0.64
Simpson (1-D)	0.67	0.83	0.63	0.49	0.36
Shannon (H)	2.14	2.51	2.31	1.89	1.01
Evenness (E)	0.41	0.71	0.91	0.46	0.73
Margalef	1.41	1.95	2.41	2.72	1.19

Note: Z1 – Z5 = Stations 1 to 5.

Table 6. Diversity indices of zooplankton species of Okerenkoko Estuarine between seasons

Parameters	Wet season	Dry season
Individuals (N)	142	116
Dominance	0.73	0.34
Simpson (1 – D)	0.27	0.51
Shannon (H)	1.51	1.68
Evenness (E)	0.61	0.56
Margalef	1.81	2.02

The main taxonomic groups of zooplankton recorded during this study were *Cyclopoida, Anomopoda, Harpacticoida, Ploimida* and *Cladocera*. *Brachionus caudatus* (*Ploimida*) recorded the most abundant zooplankton species throughout the duration of the study. The highest population of zooplankton recorded at Z 5 during this study could be attributed to minimal anthropogenic activities because of the maintenance of some of the oil facilities around it and dilution effect from storm water. It has been reported that Ploimida shows good survival and flourish in relatively undisturbed water condition (Ekwu and Udo, 2013; Ovie *et al.* 2015).

Conclusion

The abundance and diversity of zooplankton species could be used as indicator of aquatic productivity and index of its fish stock abundance (Davies *et al*. 2008). In most aquatic ecosystems, *Brachionus caudatus* could be highly abundant among the zooplankton community probably due to the presence of food, conducive environment and high reproductive ability (Dejen *et al.* 2004). The compositions and distribution of zooplankton varies with regards to location and seasons due to the dynamic of the aquatic ecology (Ewutanure and Olaifa, 2020).

Variation in zooplankton diversity is very important to research scientists in delineating water bodies (Ukaonu *et al.* 2015). The productivity and stability of any aquatic ecosystems with respect to fish production is a function of the quality and quantity of planktonic organisms present in it (Ewutanure and Olaifa, 2020). Margalef indices > 3 indicate clean water condition; < 1 indicates heavy pollution, while values ranging from 1 – 3 indicate moderately polluted water conditions (Popoola and Otalekor, 2011).

Inspite of the visible presence oil sleeks in the Estuary,the range of Margalef indices obtainedindicated that Okerenkoko Estuary is moderately polluted.This could be attributed to its constant flow which reduces pollutant concentrations along its course and downstream, respectively. It is therefore recommended that, urgent management measures be taken to ameliorate the decline in its quality and to preserve the diversity of its zooplankton community and other aquatic organisms.

References

Abowei, J.F.N., Ezekiel, E.N. and Hansen, U. (2012). Effects of Water Pollution on Phytoplankton Species Composition in Koluama Area, Niger Delta Area, Nigeria. *International Journal of Fisheries and Aquatic Sciences* 1.2: 134 – 139.

Adeleke, T.A. and Babalola, A.F (2014). Estimate of primary production in Ologe Lagoon, Lagos. In S.G Solomon (Ed.). Proceedings of the 29th Annual Conference of the Fisheries Society of Nigeria, Makurdi, Benue State. Pp. 266 – 271.

Ajuonu, N., Ukaonu, S.U., Oluwajoba, E. O., Mbawuike, B. E., Williams, A. B., Myade, E. F. (2011). Crude oil pollution in the Bonny Estuary, Nigeria. *Agriculture and Biology Journal of North America* 2.6: 1032 – 1037.

American Public Health Association(APHA). (1992). Standard methods for the examination of water and waste water. 18th edition, Washington DC. Pp. 15 – 218.

American Society for Testing and Materials (ASTM). (2006). Standard guide for conducting laboratory toxicity tests with freshwater mussels. E2455-06, Philadelphia. *Annual Book of America Society for Testing and MaterialsStandards* 11.6: 1393–1444.

Ampon, P and Taeng-On, P. (2014). Aquatic insects biodiversity and water quality Parameters of Receiving Water body.*Current World Environment* 9.1: 53 – 58.

Bouchard, R.W., Jr. (2004). *Guide to aquatic macro – invertebrates of the Upper Midwest*. Water Resources Center, University of Minnesota, St. Paul, MN. 200 – 208.

Boyd, C.E. (1979). *Water quality in warm water fish ponds*. 4th ed. Auburn University, Uburn.

Davies, O.A, A.A A. Ugwumba and Abolude, D.S. (2008). Physico-chemistry quality of Trans-Amadi (Woji) Creek, Port Harcourt, Niger Delta, Nigeria. *Journal of Fisheries International*, 3 (3): 91-97.

Dejen, E., Vijverberg, J., Nagelkerke, L.A.J. and Sibbing, F.A. (2004). Temporal and spatial distribution of micro-

crustacean's zooplankton in relation to turbidity and other environment factors in large lake (L. Tana, Ethiopia). *Hydrobiologia*, 513:39-49.

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

Ekwu, A. O. and Sikoki, F. D. (2006). Phytoplankton diversity in Cross River estuary. *Journal of Applied Sciences and Environmental Management*. 10 (1): 89-95.

Ekwu, A. O. and Udo, N. D. (2013). Plankton communities of Ikpa River, South East Nigeria exposed to sand-dredging activities. In: P. E. Ndimele (Ed.). Proceedings of the 29th Annual Conference of the Fisheries Society of Nigeria (FISON), 25th -29th, November, Abuja. Pp. 273-276.

Ewutanure, S.J., Eyo, V.O., Binyotubo, E.T. and Eriegha, O.J. (2022). Heavy metal and total petroleum hydrocarbon concentrations in water, sediment and fauna of Okerenkoko Estuarine, Delta State, Nigeria. *Journal of Digital Innovations and Contemporary Research in Science, Engineering and Technology*, Vol. 10, No. 2. Pp 1-12.

Ewutanure, S.J., Eyo, V.O., Binyotubo, E.T. and Eriegha, O.J. (2022). Phytoplankton abundance and diversity of Okerekoko Estuarine, Delta State, Nigeria. *Advances in Multidisciplinary and Scientific Research*, Vol. 8. No. 1, Pp 63-74 DOI: dx.doi.org/10.22624/AIMS/V8N1P6.

Ewutanure, S.J. and Binyotubo, T.E. (2021). Impacts of Anthropogenic Activities on the Fish Compositions and Diversity of Okerenkoko Estuarine, Delta State, Nigeria. Proceedings of the Accra Bespoke Multidisciplinary Innovations Conference. University of Ghana/Academic City University College, Accra, Ghana. December 2021. Pp 9-8 www.isteams.net/ghanabespoke2021. DOI https://doi.org/ 10.22624/AIMS/ABMIC2021-V2-P2.

Ewutanure, S.J. and Olaifa, F.E. (2021). Spatial and Temporal Fluctuations of PhysicoChemical Parameters, Nutrients and Primary Productivity of Gbalegbe River, Delta State, Nigeria Proceedings of the 28th iSTEAMS Intertertiary Multidisciplinary Conference. American International University West Africa, The GambiaSeries 28, Vol 3 October, 2021. Pp 137-1 www.isteams.net/gambia2021. DOI - https://doi.org/ 10.22624/AIMS/iSTEAMS-2021/V28N3P11.

Ewutanure, S.J. and Olaifa, F.E. (2021). Temperature, Salinity, Dissolved Oxygen, Total Suspended Solids and pH Conditions in Okerenkoko Estuarine, Delta State, Nigeria. Proceedings of the Accra Bespoke Multidisciplinary Innovations Conference. University of Ghana/Academic City University College, Accra, Ghana. December 2021. Pp 133-140 www.isteams.net/ghanabespoke2021. DOI https://doi.org/ 10.22624/AIMS/ABMIC2021P10.

Ewutanure, S.J. and Olaifa, F.E. (2021). Effects of effluents from Gbalegbe River, Delta State, Nigeria on the breeding performance of *Clarias gariepinus* (Burchell, 1822). Proceedings of the Accra Bespoke Multidisciplinary Innovations Conference. University of Ghana/Academic City University College, Accra, Ghana. December 2021. Pp 163-178 www.isteams.net/ghanabespoke2021. DOI https://doi.org/ 10.22624/AIMS/ABMIC2021P13

Ewutanure, S.J. and Olaifa, Flora. E. (2020). Zooplankton Species Compositions, Abundance and Diversity of Gbalegbe River, Delta State, Nigeria. *Advances in Multidisciplinary Research Journal*. Vol. 6. No. 1, Pp 105–120 Article DOI: dx.doi.org/10.22624/AIMS/V6N1P11.

Ewutanure, S.J. and Olaifa, F.E. (2018). Phytoplankton Species Composition, Distribution, Abundance and Diversity in Gbalegbe River, Delta State, Nigeria. Proceedings of 6th NSCB Biodiversity Conference; Uniuyo, 164 - 170 Pp.

Ewutanure, S.J. and Olaifa, Flora. E. (2018). Phytoplankton Species Composition, Distribution, Abundance and Diversity in Gbalegbe River, Delta State, Nigeria. Proceedings of 6th NSCB Biodiversity Conference; Uniuyo, 164 – 170.

Ezekiel, E.N., Ogamba, E.N. and Abowei, J.F.N. (2011). The distribution and seasonality of zooplankton in Sombreiro River, Niger Delta, Nigeria. *Current Research Journal of Biological Sciences*, 3(3): 234-239.

Gupta, P. K. (2001). *Methods in environmental analysis: Water, Soil and Air*. AGROBIOS (India) Publisher. 1 – 408.

Jeje, C.Y. and Fernando, C.H. (1986). *A practical guide to the identification for Nigeria zooplankton (Cladocera, Copepoda and Rotifera)*. 1st ed. Published and printed by Kainji Lake Research Institute. 1 – 141.

Kigbu, A. A., Lawee, A. Y. and Jatau, A. M. (2015). Studies on the plankton diversity and physico-chemical parameters of Shabu Stream in Nasarawa State, Nigeria. In K. E. Lelei (Ed.). Proceedings of the 30th Annual Conference of the Fisheries Society of Nigeria (FISON), 22nd – 27th, November, Delta State. Pp. 27-32.

Kwen, K., Davies, O.A. and Okaeme, A.N. (2012). Temperature, dissolved oxygen, hydrogen ion concentration and transparency conditions in the Upper Nun River, Niger Delta. *Journal of Aquatic Sciences*, 2(2): 135-145.

Kwen, K., Ewutanure, J. S. and Binyotubo, T. E. (2019). Zooplankton species diversity and physico-chemical parameters in the Lower Taylor Creek Area, Bayelsa State, Nigeria. American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN : 2320-0936 Volume-8, Issue-6, pp-94-99.

Lynne, M.W. (2006). *Practical guide to identifying freshwater crustaceans and zooplankton*. Cooperative freshwater ecology unit. 2nd ed. Department of biology, Laurentian University, 935 Ramsey Lake Road, Sudbury, Ontario, Canada, P3E2C6, https://coopunit.laurentian.ca. p. 1 – 50.

Margalef, R. (1968). *Perspectives in ecological theory*. The University of Chicago Press, Chicago. 1 – 111.

Nwoji, J.A., I.C. Onyema and Igbo, J. K. (2010). Wet season spatial occurrence of phytoplankton and zooplankton in Lagos Lagoon, Nigeria. *Science World of Journal* 5.5: 7 – 14.

Offem, B.O., Ayotunde, E.O, Ikpi, G.U., Ochange, S.N. and Ada, F.B. (2014). Influence of seasons on water quality, abundance of fish and plankton species of Ikwori Lake, South-Eastern Nigeria. *Fish. Aquat. J.*, Vol. 2 (7): 442-446.

Ogamba, E. N., Izah, S. C. and Oribu, T. (2015). Water quality and proximate analysis of Eichhorniacrassipes from River Nun, Amassoma Axis, Nigeria. *Research Journal of Phytomedicine*, 1 (1): 43-48.

Onuoha, P.C., Nwankwo, D.I. and Vyverman, W. (2010). A checklist of phytoplankton species of Ologe Lagoon,

Lagos southwestern Nigeria. *Journal of American Science*, 6(9): 297-302.

Ovie, S. I., Mbagwu, I. G., Adukwu, G. and Ajayi, O. (2015). Preliminary study on the limnology and zooplankton abundance in relation to fish production in Kontagora reservoir. National Institute for Freshwater Fisheries Research, New Bussa, Niger State, Nigeria. Annual Report. Pp. 49.52.

Popoola, K.O.K and Otalekor, A. (2011). Analysis of Aquatic Insects' Communities of Awba Reservoir and its Physico-Chemical Properties. *Research Journal of Environmental and Earth Sciences* 3.4: 422-428.

Seiyaboh, E. I., Inyang, I. R., and Izah, S. C. (2016). Spatial variation in physic-chemical characteristics of sediment from Epie Creek, Bayelsa State, Nigeria. *Greener Journal of Environment Management and Public Safety*, 5 (4): 45-49.

Seiyaboh, E. I., Ogamba, E. N. and Utibe, D. I. (2013). mpact of dredging on the water quality of Igbedi Creek, Upper Nun River, Niger Delta, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 7 (5): 51-56.

Ukaonu, S.U., Williams, A.B., Ajuonu, N., Mbawuike, B.C. and Adejumobi, K.O. (2015). Zooplankton species composition and distribution off Lagos coast, Nigeria. In: K.E. Lelei (Ed.). Proceedings of the 30th Annual Conference of the Fisheries Society of Nigeria (FISON), 22nd -27th, November, Delta State. Pp. 439-445.