PLANKTONS DIVERSITY AND WATER QUALITY OF RIVER OSE, ONDO STATE, SOUTHWEST NIGERIA.

**Abstract**

This study was conducted to investigate the plankton diversity and physico-chemical characteristics of River Ose in providing information that can be used for proper management and conservation of the water body. Plankton samples and water quality parameter were observed for 12 months (February, 2022 to January, 2023). Plankton net of 55µm mesh size was used for collection of plankton using stranded method. Plankton abundance was estimated using Shannon-wiener diversity index (H). Physico-chemical parameters which include: pH, Temperature, Conductivity, Dissolved Oxygen, Salinity and Total Dissolved Solid were determined *insitu* using a multi-parameter probe meter. The species composition of phytoplankton was dominated by five phyla, Chlorophyta, Ochrophyta, Bacillariophyta, Cyanobacteria and, Myzozoa while that of zooplankton were the Ciliophora, Rotifera and Arthropod groups. *Spirogyra* sp.which belongs to the phylum Chlorophyta had the highest relative abundance (8.31%) while *Thalassionema* sp.which belong to phylum Ochrophyta had the lowest relative abundance (0.83%). Higher abundance of plankton was recorded during the dry season (61.13%) when compared with the raining season (38.38%). Shannon-Wiener diversity index (H) and Evenness (E) were 3.25 and 0.93 respectively. The results of the physico-chemical parameters were within the acceptable range across the 12 months of study. All the water parameters measured except pH showed significant difference (P<0.05) across the months.

**Keyword**: Plankton Abundance Plankton Diversity, Water quality, River Ose

**Introduction**

Plankton (phytoplankton and zooplankton) plays a crucial role in terms of health of the aquatic environment as pollution indicators (Ukaonu *et al.,* 2015). Phytoplankton is dissolved oxygen producer in the water as well as a natural food for various fishes that inhabits the first level of producer in energy flows. The existence of phytoplankton in the waters can be seen on the basis of their abundance influenced by several environmental parameters and their physiological characteristics. It will change at various levels as a response to the changes in physical, chemical and biological environmental conditions (Evi *et al.*, 2014).

Zooplankton is weakly swimming microscopic animals that drift with water currents. Examples include: fish larvae, insect larvae, Crustacea, Protozoa and Rotifera. Zooplankton in association with phytoplankton makes up the planktonic food supply. The presence of adult and developmental stages of planktonic organisms in any water body reveals the suitability of the environment to support aquatic life. Zooplankton feed on the primary producers and organic debris in water thereby performing a significant role in the trophic relationship in the ecosystem (Kigbu *et al.,* 2015; Ovie *et al.,* 2015). These organisms are useful indicators of water quality and fisheries health as they serve as food sources to organisms at higher trophic level (Davies *et al.,* 2008). Biological productivity of a water body depends on the abundance of the plankton.

Water quality monitoring is deemed to be an important task in water resource management around the world (Barcellos, 2022). Phytoplankton and zooplankton diversity depends on water quality and hydrological conditions. Plankton is small, fast-growing, widely distributed, and sensitive to changes in the water environment (Li *et al.,* 2016; Arulraj *et al.,* 2019; Duong *et al.,* 2019 and Song *et al.,* 2020). Therefore, they are often used as indicator species to monitor river ecosystems (Hoang *et al*., 2018 and Ha *et al.,* 2020) and surface water quality (Yen *et al.,* 2019 and Van *et al.,* 2020). Several studies have recognized the effects of temperature, water clarity, pH, DO, and electrical conductivity (EC) on plankton (Arulraj *et al.,* 2019; Song *et al.,* 2020; Mironova *et al.,* 2022 and Nguyen *et al.,* 2022). The combination of physicochemical characteristics and plankton diversity will provide better information of the current state of the River. Therefore, this study was conducted to assess surface water quality and the biodiversity index of plankton in River Ose. These approaches can provide important information in water quality monitoring and assist in predicting biological changes when the environment is altered.

**Materials and Methods**

**Geography of River Ose**

River Ose is a major perennial river in south western Nigeria. Its source is in the Apata hills and it flows through savannah, rainforest and mangrove forest before discharging into the Atlantic Ocean through a series of creeks and lagoons. The river lies between longitudes 5°20 E to 6°10 E and latitudes 6°20N to 8°00N. It flows approximately 300 km from its source before breaking into a series of creeks and lagoon. The water is used for agriculture, transportation, human consumption, various industrial activities, and domestic purposes.

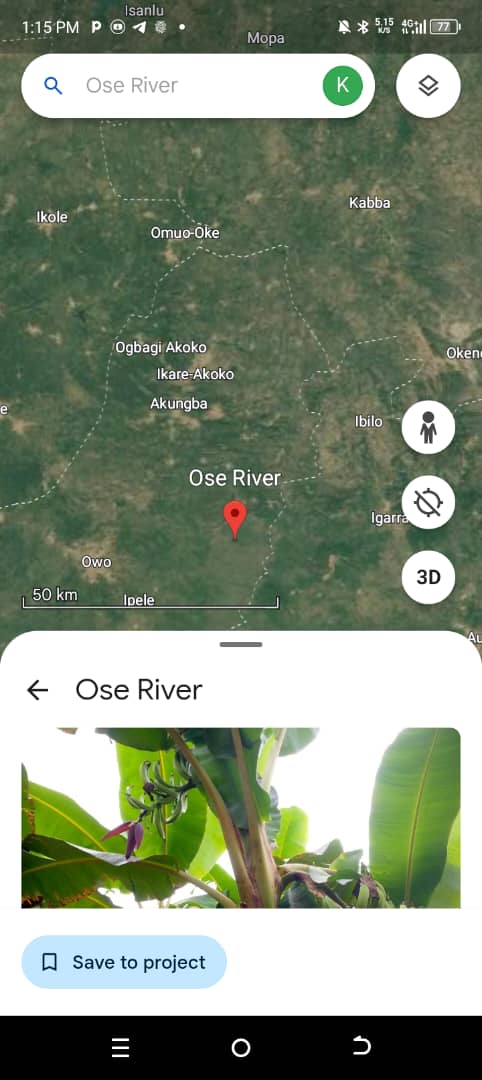


Figure 1: Map of River Ose

**Collection and identification of plankton**

About 50 Litres each, of water were collected from 3 sampling points at 2-3feet below and filtered through silk plankton net of 55 μm (Kwen *et al.,* 2019)*.* The filtrate was transferred to another bottle and preserved immediately in 10% formalin on the field. Qualitative and quantitative analysis of both phytoplankton and zooplankton were done following drop count method (APHA, 1995). The preserved plankton samples were allowed to settle first and 0.1 mL of the sample was withdrawn using a pipette and observed under compound microscope. Identification was done using key literatures by Jeje and Fernando (1986), Egborge (1995) and Janse *et al*. (2006). Plankton was identified and total number per species counted and recorded.

**Water sample collection for physico-chemical analyses**

Dissolved oxygen (DO), Salinity, Total dissolved solids (TDS), Conductivity Temperature and pH were measured using Hanna-HI928 multi-parameter water analysis meter (made in

Romania). All the parameters were investigated *insitu.*

**Statistical analysis**

Relative abundance (RA) = Number of specimens of particular species x100/Total number of specimens of all species. Shannon Wiener Diversity Index (H) = -Σ *iP* Log *iP* (Shannon and Wenier, 1963) was used to estimate the plankton diversity of the river while E (Evenness) =H/Hmax was used to estimate the evenness. Water parameters namely, Dissolved oxygen, Total dissolved solid, pH, Salinity, Temperature and conductivity were subjected to one-way analysis of variance (ANOVA) test and the means from the various treatments were compared for significant differences (P>0.05) using SPSS (statistical package for social scientists) software version 20.

**Results**

**Plankton abundance and diversity**

Table 1 shows the abundance of phytoplankton and zooplankton in River Ose from the month of February, 2022 to January, 2023. A total of 265 plankton members were recorded throughout the study period. Phyla of phytoplanktons that were recorded: Chlorophyta, Ochrophyta, Bacillariophyta, Cyanobactria and Myzozoa. Zooplankton also recorded while the sampling periods Ciliophora, Rotifera and Arthropoda. *Spirogyra* sp. which belongs to phylum Chlorophyta had the highest relative abundance (8.31%)while *Thalassionema* sp.which belong the phylum Ochrophyta had the least relative abundance (0.38%).

Figure 2 represent the monthly relative abundance of plankton of River Ose during the study period. Highest relative abundance was recorded in the month of February with 17.36% while the least recorded in August (3.77%). Table 2 represent the seasonal abundance of plankton in River Ose. Higher abundance of plankton was recorded during the dry season (61.13%) when compared with the raining season (38.38%). Shannon wiener diversity index (H) of the plankton was estimated to be 3.25 while Evenness was 0.93.

**Physico-chemical parameters**

Table 3 shows the values of physic-chemical parameters of pH, Temperature, Conductivity, Dissolved Oxygen, Salinity, and Total Dissolved Solid. pH ranged from 6.50-7.00 and there was no significant deference (P>0.05). Highest Value of the Temperature was recorded in May (30.10 0C) with the least in January (27.30 0C) and there were significant differences across the months (P<0.05). The value of conductivity ranges from (138-196µs/cm) with significant difference across the months. Highest value of DO was recorded in the month of May (7.36 mg/l) with while the lowest value was recorded in the month of February (5.27 mg/l)). There was significant difference in the values of DO across the months. TDS ranges from (77-101 ppm) with significant deference across the months.

Table 1: Plankton composition of River Ose from February 2022 to January 2023

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Phylum | Plankton species | Feb | Mar | Apri | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Total | RA% |
| Chlorophyta | *Spirogyra sp* | 4 | 3 | 3 | 1 | 3 | - | - | 4 | - | - | 1 | 3 | 22 | 8.31 |
|  | *Zygnema sp* | 1 | - | 1 | - | - | - | - | - | 2 | - | - | 1 | 5 | 1.89 |
|  | *Chlorella sp* | - | - | - | 1 | - | - | - | - | - | 2 | - | - | 3 | 1.13 |
|  | *Oedogonium sp* | 2 | - | 2 | 1 | 1 | 3 | - | - | 2 | - | - | - | 11 | 4.15 |
| Ochrophyta | *Dinobryon divrgens* | 1 | - | - | 1 | - | 2 | - | - | - | 1 | 1 | - | 6 | 2.26 |
|  | *Hetosigna akashiwo* | - | - | - | - | - | - | 1 | - | - | 1 | - | - | 2 | 0.75 |
|  | *Fragilaria sp* | 2 | 1 | 3 | - | 4 | - | - | - | 2 | 1 | 1 | 2 | 16 | 2.26 |
|  | *Navicula sp* | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 2 | 0.75 |
|  | *Melosira sp* | 3 | 1 | 4 | - | 3 | - | - | 2 | 2 | 3 | - | 1 | 18 | 6.79 |
|  | *Bacillaria sp* | - | - | - | - | - | - | - | - | 1 | - | 1 | - | 2 | 0.75 |
|  | *Biddulphia sp* | 1 | 2 | - | - | 1 | - | - | - | 3 | - | - | - | 7 | 2.64 |
|  | *Thalassionema sp* | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.38 |
|  | *Chaetoceros sp* | 4 | - | 2 | - | - | 1 | - | 3 | - | 4 | - | 2 | 16 | 6.04 |
|  | *Pseudo-nitzshia sp* | - | 1 | - | - | 1 | - | 2 | - | - | 1 | - | - | 6 | 2.26 |
| Bacillariophyta | *Odontella sp* | - | 1 | 2 | - | - | 2 | - | 2 | 1 | - | - | 1 | 9 | 3.40 |
|  | *Coscinodiscus sp* | - | - | 2 | - | - | 1 | - | - | - | - | - | - | 3 | 1.13 |
|  | *Aulacoseira sp* | 3 | - | 2 | - | 1 | 1 | 1 | - | - | - | 2 | - | 10 | 3.77 |
| Cyanobacteria | *Microcystis flo-aquae* | 6 | 2 | 4 | 3 | - | 1 | - | - | 3 | - | 1 | - | 20 | 7.55 |
|  | *Microcystis aeruginosa* | 3 | 1 | 3 | - | 2 | - | - | - | 1 | - | 2 | - | 12 | 4.53 |
|  | *Cupsidothrix issatasheenkoi* | - | - | 2 | - | - | - | - | - | - | 1 | - | - | 3 | 1.13 |
|  | *Planktothrix sp* | 1 | - | - | 1 | - | 2 | - | - | - | 1 | - | - | 5 | 1.89 |
|  | *Cylindrosperm opsisraciboski* | - | - | 2 | - | 2 | - | - | - | 1 | - | 3 | - | 8 | 3.03 |
| Myzozoa | *Boreadinium* | 1 | 1 | - | - | - | - | 1 | - | - | - | - | 1 | 4 | 1.51 |
| Ciliophora | *Paradileptus sp* | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 0.38 |
|  | *Paramecium sp* | 1 | 2 | - | - | - | 1 | - | - | - | 1 | - | - | 5 | 1.89 |
| Rotifera | *Polyarthra vulgaris* | 2 | 4 | 1 | - | - | 1 | - | - | 1 | - | 5 | - | 14 | 5.28 |
|  | *Filiniaopoliensis* | 4 | 2 | - | 6 | - | - | 2 | - | - | 1 | - | - | 15 | 5.66 |
| Arthropoda | *Pleuroxus sp* | - | - | 1 | - | - | - | 1 | 1 | - | - | - | - | 3 | 1.13 |
|  | *Culicidae larva* | 3 | - | 2 | 1 | - | - | 2 | - | - | 2 | - | 1 | 11 | 4.15 |
|  | *Cytocyclops sp* | 2 | - | - | 2 | - | 1 | - | - | 1 | - | 2 | - | 8 | 3.02 |
|  | *Naupilius larva* | - | 1 | 1 | - | - | 2 | - | - | - | 4 | - | - | 8 | 3.02 |
|  | *Calanoid sp* | 2 | - | - | - | 2 | - | - | 1 | 1 | 1 | - | - | 7 | 2.64 |
|  | *Mysida sp* | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 2 | 0.75 |
| Total |  | 46 | 22 | 37 | 18 | 20 | 20 | 10 | 14 | 21 | 24 | 19 | 14 | 265 |  |
| Monthly RA (%) |  | 17.36 | 8.30 | 13.96 | 6.79 | 7.55 | 7.55 | 3.77 | 5.28 | 7.92 | 9.06 | 7.17 | 5.28 |  |  |

Table 2: Seasonal variation in the relative abundance (%) of plankton species of River Ose from February 2022 to January 2023

Dry Season Wet Season Dry Season

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Months | Feb | Mar | Apr |  | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan |
| Ra (%) | 17.36 | 8.30 | 13.96 |  | 6.79 | 7.55 | 7.55 | 3.77 | 5.28 | 7.92 | 9.06 | 7.17 | 5.28 |
| Ra (%) in dry season | 61.13% |  |  |  |  |  |  |  |  |  |  |  |  |
| Ra (%) in wet season | 38.86% |  |  |  |  |  |  |  |  |  |  |  |  |

Figure 2: Monthly relative abundance of plankton of River Ose from February 2022 to January 2023.

Figure 3: Pie chart showing the relative abundance of plankton of River Ose

Table 3: Water quality parameters of River Ose from February, 2022 to January, 2023

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Sig. |
| pH | 6.50 ab | 7.00 ab | 6.50 ab | 6.50 ab | 6.50 ab | 6.50 a | 7.00 b | 6.50 ab | 7.00 ab | 6.50 ab | 6.00 b | 6.50 a | 0.427 |
| Temperature (0C) | 28.7 f | 29.00 g | 28.60 f | 30.10 i | 27.20 ab | 28.40e | 29.20 h | 27.9 d | 28.40 e | 27.10 a | 27.4 c | 27.3 bc | 0.000 |
| Conductivity(µS/cm) | 142.00 b | 138.00 a | 162.00 f | 174.00 g | 189.00 h | 154.00 d | 139.00 a | 163.00 f | 141.00 b | 196.00 i | 156.00 e | 146.00 c | 0.000 |
| Dissolved Oxygen(Mg/l) | 5.27h | 6.14 c | 5.41b | 7.36c | 6.19a | 7.14 d | 7.22d | 5.64 b | 6.61 a | 5.33b | 6.35c | 6.46 e | 0.000 |
| Salinity (ppt) | 0.06 ab | 0.06 ab | 0.05 a | 0.05 a | 0.07 b | 0.06 ab | 0.06 ab | 0.05 a | 0.05 a | 0.06 ab | 0.06 ab | 0.07 b | 0.010 |
| Total Dissolved Solid (ppm) | 88.00 e | 79.00 b | 98.00 h | 96.00 g | 83 d | 81 c | 92 f | 88 e | 101.00 i | 77.00 a | 82.00 cd | 91.00 f | 0.000 |

**Discussion**

The abundance and diversity of plankton recorded in River Ose were relatively high. Ecological conditions, which include constant water, nutrients, water volume, less turbidity, and the availability of sunlight helps the growth of phytoplanktons in freshwater ecosystem (Shrivastava, 2005). Phytoplanktons are Baciliariophyta, Chlorophyta, Ochrophyta, Myzozoa and Cyanobacteria identified. Similar finding was previously done from different Nigerian Rivers (Egborge, 1970, Aguigwo, 1997; Yakubu *et al.,* 1998). Cyanophyta and Bacillariophyta which were the most abundant reported in this study, same observation was already reported by Janse *et al.* (2006) and Arulraj et al., (2022). The abundance of Bacillariophyta in this study could be due to the protection they got through the high concentration of silicon in their shell which are also glass-like. This result highly match with Arulraj *et al*. (2017).

The Zooplankton phyla identified include Rotifera, Artropoda and Ciliophora. Throughout the study period, phytoplankton generally dominated over the zooplankton at the surface waters due to photosynthetic activity of the phytoplankton (Yakubu *et al.,* 1998). Aboul-Ela and Khali (1989), phytoplankton forms the most stable community in lakes. It has been observed that green algae and diatoms dominate the phytoplankton community of many tropical African waters (Aboul-Ela and Khali, 1989, Ugwumba 1990; Oben, 2000; Arulraj *et al*., 2017). This was the trend observed in the rivers during the period of study. The low phytoplankton abundance observed during wet season throughout the study period could be attributed to heavy rains, runoff water from the catchment areas, and flood. These were unfavourable ecological conditions that increased the suspended solid as well as the turbidity and water dynamics. All these ecological adversities influenced the phytoplankton growth. Higher plankton relative abundance observed in the dry season could possibly be induced by high photosynthetic activity during the dry season (Chapman and Kinstach, 1992; Meybeck *et al.,* 1992).

Shannon-Wiener Diversity Index (3.25) showed that plankton abundance was high in the river which might have contributed to the high dissolved oxygen produced in the river. High diversity Index of plankton is indication of greater species diversity which could be because of suitable ecological conditions of the river.

The abundance of phytoplankton in the dry season is higher than in the rainy season in this study. This result is in agreement with the study in Sai Gon River (Nguyen, 2022). One of the primary reasons for this variation is higher light intensity and higher nutrient content, which favours maximum phytoplankton growth (Bellinger and Sigee 2015). In addition, the study of Haque *et al.* (2021) also demonstrated that an increase in precipitation and turbidity in the wet season could be factors responsible for the low abundance.

The physico-chemical parameters in this study were within the acceptable range of tolerance for the survival of aquatic organisms. The pH value which ranged from 6-7in this study is like the findings of Olatunji and Odedeyi (2023) that recorded the pH range of 6-7in River Ogbese, Ondo State. Changes in water pH can significantly impact plankton abundance and community structure. A decline in pH (increasing acidity) can lead to reduced plankton abundance while alkaline conditions can favour specific phytoplankton species and potentially lead to algal blooms. Effendi (2003), stated that certain organism can survive in more acidic water. Temperature significantly impacts plankton abundance, primarily affecting their growth, metabolism, and community structure. Higher temperature can enhance photosynthesis and respiration in phytoplankton, leading to increased growth and reproduction. Temperature changes can also influence the grazing rates of zooplankton, impacting the overall dynamics of the food web.

The values of temperature in this study ranges from 27.20 0C to 30.10 0C which is within the optimum range for plankton growth. These results compared favourably with study of the Upper Nun River around Polakuaxis by Kwen *et al.* (2012) who found temperature range of 25.5 0C to 30.5 0C. These values also agreed with results from other fresh water rivers and creeks in the Niger Delta region. For example, Seiyaboh *et al.* (2017), reported the temperature range of 26.60 0C to 32 0C for Igbedi Creek. A warmer temperature can reduce the abundance and productivity of plankton due to increased stratification, reduced nutrient supply, and shift in species composition.

The dissolved oxygen in the study sites ranged between 5.27 and 7.36 mg/l, while the optimum DO for planktonic organism is 5-10 mg/l. The range of DO in this study was similarssssssss to the value reported by Kwen *et al*. (2012) which was 6.0 to 10.0mg/l in the Upper Nun River, Niger Delta. Ogamba *et al.* (2015) recorded DO values of 3.6 to 7.79mg/l in the Nun River around Amassoma axis. Seiyaboh *et al.* (2017) reported a range of 4.4 to 7.9mg/l in Sagbama Creek, Niger Delta.

Conductivity which is waters ability to conduct current, indirectly affects plankton abundance by influencing water quality, which in turn impacts the availability of nutrient where plankton live. The value of conductivity in this study (138- 196 μS/cm) was within the normal range recommended by Wetzel (1983).

**Conclusion**

The study revealed that River Ose had a diversified group of plankton dominated by Cyanobacteria members followed by Ochrophyta, Chlorophyta, Arthropoda, Bacillariophyta, Rotifera, Ciliophora and Myzozoa groups. Results indicated that the optimum level of Dissolved Oxygen, Temperature, Conductivity, pH, Total Dissolved Solid and Salinity were responsible for diverse group of plankton.

**References**

Aboul-Ela, O. and Khalil, M.T (1989). Ecological studies on the plankton and Benthic of Wadi

Elrayan, a new lake in Egypt. *Tropical Fresh Water Biological*. 2: 101-111.

Aguigwo, J.N. (1997). Studies on Plankton productivity in relation to water quality parameters and

Nutrient levels. *Journal of Aquatic Science.* 12: 15-22.

Arulraj, M.S., Vijayan, S. and Anbalagan, S. (2017). A pilot study of leaf litter associated diatoms in five streams of Southern Western Ghats, India. International Journal of Environmental Biology, 7 (2): 27-31.

Arulraj, M.S., Anbalagan, S. and Vijayan, S. (2019). Periphytic diatom colonization and litter decomposition in an intermittent stream of South India. Journal of Basic Microbiology, 1, 1-7.

Arulraj, M.S., Rekha, K., Vijayan, S. and Anbalagan, S. (2022). Periphytic microalgae colonization in mosquito breeding stream puddles of Southern Western Ghats. nternational Journal of Mosquito Research, 9(4): 40-48.

Barcellos, D. da S., and Souza, F. T. de. (2022). Optimization of water quality monitoring

programs by data mining. Water Research, 221, 118805. doi:10.1016/j.watres.2022.118805

Bellinger, E. G., and Sigee, D. C. (2015). Freshwater Algae: Identification, enumeration and use

as bio indicators (2nd Ed.). Joh Wiley & Sons, Hoboken, United States. doi:10.1002/9781118917152.

Chapman, D. and Kinstach, V. (1992). Selection of water quality variables. In: Chapman, D. (Ed).

Water quality assessment. 56pp. UNESO/WHO/UNEP.

Duong, T. T., Hoang, T. T. H., Nguyen, T. K., Le, T. P. Q., Le, N. Da, Dang, D. K., Lu, X. X.,

Bui, M. H., Trinh, Q. H., Dinh, T. H. Van, Pham, T. D., & Rochelle-newall, E. (2019). Factors structuring phytoplankton community in a large tropical river: Case study in the Red River

(Vietnam). Limnologica, 76, 82–93.

Effendi, H. (2003). Telaahkualit as air bag ipengelolaansumberdaya dan lingkunganperairan.

*Kanisius, Yogyakarta*, 145 p.

Evi, V., Amin., S. L. and Soemarno, A. (2014). Effect of Water Quality on Phytoplankton

Abundance In Hampalam River and Fish Pond Of Batanjung Village. *Journal of Environmental Science, Toxicology and Food Technology*, 8 (1): 15-21

Ha, N. N. Y., & Tran, M. N. D. (2020). Seasonal variation of zooplankton in Ba Lai River, Ben

Tre province. Science and Technology Development Journal - Natural Sciences, 4(4), First. doi:10.32508/stdjns.v4i4.863.

Egborge, A.B.M. (1970). The sulphate content of Nigeria River. *Archhydro* 70: 67-71.

Haque, M. A., Jewel, M. A. S., Akhi, M. M., Atique, U., Paul, A. K., Iqbal, S., Islam, M. S., Das,

S. K., & Alam, M. M. (2021). Seasonal dynamics of phytoplankton community and functional groups in a tropical river. Environmental Monitoring and Assessment, 193(11). doi:10.1007/s10661-021-09500-5.

Hoang, H. T. T., Duong, T. T., Nguyen, K. T., Le, Q. T. P., Luu, M. T. N., Trinh, D. A., Le, A. H.,

Ho, C. T., Dang, K. D., Némery, J., Orange, D., and Klein, J. (2018). Impact of anthropogenic activities on water quality and plankton communities in the Day River (Red River Delta, Vietnam). Environmental Monitoring and Assessment, 190(2), 1–18. doi:10.1007/s10661-017- 6435-z.

Janse van Vuuren, S., Taylor, J., Gerber, A. and Van, G. C. (2006). “Easy identification of the

most common freshwater algae. A guide for the dentification of microscopic algae in South African freshwaters.” ISBN 0-621-35471-6. School of Environmental Sciences and Development: Botany, North-West University (Potchefstroom Campus), Private Bag X6001, Potchefstroom 2520, South Africa.

Jeje, C.Y and Fernando, C.H. (1986), “A practical guide to the identification of Nigerian

zooplankton.” Kainji Lake Research Institute Press, Kainji, Nigeria.

Kigbu, A. A., Lawee, A. Y. and Jatau, A. M. (2015). Studies on the plankton diversity and physic

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.1, Ewutanure, K. 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)* 8(6):94-99

Li, Q. P., Dong, Y., and Wang, Y. (2016). Phytoplankton dynamics driven by vertical nutrient

fluxes during the spring inter-monsoon period in the northeastern South China Sea. Biogeosciences, 13(2), 455–466. doi:10.5194/bg-13-455-2016.

Meybeck, M., Friedrich, A., Thomas, R. and Chapman, D. (1992). Rivers in Water quality

assessment; A guide to use of biota, sediments and water in environmental monitoring chapman. D.E.D, *Chapman and Hall, London* 2390316pp.

Mironova, N., Yefremova, O., Biletska, H., Bloshchynskyi, I., Koshelnyk, I., Sych, S., and

Kravchuk, V. (2022). Soil quality evaluation in urban ecosystems during the covid-19 pandemic. HighTech and Innovation Journal, 3, 43-51. doi:10.28991/HIJ-SP2022-03-04.

Nguyen, T. K. L., Au, V. H., Tran, T. G., Vu, N. U., and Huynh, T. G. (2022). Seasonal fluctuation

of water quality parameters and zooplankton composition in the Hau River and its tributaries, Vietnam. AACL Bioflux, 15(3), 1371–1388

Nguyen, A. T., Dao, T. S., Strady, E., Nguyen, T. T. N., Aimé, J., Gratiot, N., & Némery, J. (2022).

Phytoplankton characterization in a tropical tidal river impacted by a megacity: the case of the Saigon River (Southern Vietnam). Environmental Science and Pollution Research, 29(3), 4076–4092. doi:10.1007/s11356-021-15850-x

Oben, B.O (2000). Limnological assessment of the impact of Agricultural and domestic effluent

of three man – made lakes in Ibadan, Nigeria Ph. D Thesis. University of Ibadan.

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.

Olatunji, K E. and Odedeyi, D O. (2023). Macrobenthos diversity and the physico-chemical

parameters of Ogbese River, Ondo State, Southwest Nigeria. *Annals of Animal and Biological Research,* 2023; 3(1).

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.

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.

Shannon, C. E and Wiener, W. (1963). The Mathematical Theory of Communication. University

of Illinois Press, Urbana, Illinois.

Shrivastava, N.P. (2005). Plankton status of Ravisankarsagar reservoir. *Journal of Inland Fish*

*Society, India*, 37 (2): 43

Song, J., Hou, C., Liu, Q., Wu, X., Wang, Y., and Yi, Y. (2020). Spatial and temporal variations

in the plankton community because of water and sediment regulation in the lower reaches of Yellow River. Journal of Cleaner Production, 261, 120972. doi:10.1016/j.jclepro.2020.120972

Ugwumba, A.A.A. (1990). Food and feeding ecology of the Oreochromis niloticus (pisces

osteichthyes) in Awba Reservoir Ibadan, Ph.D. Thesis, University of Ibadan.

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.

Van, L. T. H., and My, T. N. D. (2020). The Zooplankton composition and surface water quality

in some watershed around the aquaculture areas at the Ben Tre province. *Science and Technology Development Journal* - Natural Sciences, 4(1), First. doi:10.32508/stdjns.v4i1.768.

Wetzel, R. G. (1983). Limnology, 2nd edition. *Saunders College Publishing*. 760 pp

Yen, T. T. H., Thai, T. T., Lam, N. L. Q., Quang, N. X., and Luu, P. T. (2019). The planktonic

diatomaceous earth and water quality of Ba Lai and Ham Luong rivers, Ben Tre province. *Science Journal*, 15(9), 144. doi:10.54607/hcmue.js.15.9.84 (2018).

Yakubu, A.S., Sikoko, F.D. and Horsfall, M. (1998). An investigation into physic-chemical

condition and planktonic organisms of the lower reaches of the Nun River, Niger*. Journal of Applied Science and Environmental Management*, 1(3): 38-42