UMYU Scientifica, Vol. 3 NO. 1, March 2024, Pp 015 – 028
https://doi.org/10.56919/usci.2431.002
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
*A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina*

**ORIGINAL RESEARCH ARTICLE**

# Assessment of Surface Water Physicochemical Variables and Macrophytes Diversity in Sokoto and Rima Rivers, Nigeria

Ibrahim Muhammad Magami[1]* and Yusuf Muhammad Sanyinna[2,3].

[1]Department of Biology, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University, P.M.B. 2346, Sokoto, Sokoto State, Nigeria
[2]Department of Biology, Faculty of Natural and Applied Sciences, Nigerian Army University Biu, P.M.B. 1500, Biu, Borno State, Nigeria
[3]Department of Animal and Environmental Biology, Faculty of Life Sciences, Kebbi State University of Science and Technology, P.M.B. 1144, Aliero, Kebbi State, Nigeria

## ABSTRACT

The Sokoto and Rima Rivers are vital water bodies in Nigeria, supporting local ecosystems and communities. This study aimed to investigate various physical and chemical parameters of the water, as well as the diversity of macrophytes present in the Sokoto and Rima Rivers. Standard methods of determining physicochemical parameters and surveys of macrophytes were adopted. Results obtained revealed that temperature and depth were found to be the most influential factors on macrophytes distribution. In Sokoto River, average temperature ranged from 27.00℃ to 27.30℃, and average depth from 285 to 295 meters at both stations A and B. In Rima River, average temperature varied from 25.85℃ to 26.50℃, and average depth ranged from 730 to 735 meters at both stations A and B. Emergent species were dominant among the 20 identified macrophyte species, with 18 species, while free-floating and submerged species each represented one species. This research contributes to understanding the ecological health of the Sokoto and Rima Rivers, guiding conservation efforts, informing water resource management, and identifying potential impacts on human activities in these areas. Ultimately, the goal is to support sustainable development and protect these valuable natural resources for the long term.

**ARTICLE HISTORY**

Received August 13, 2023.
Accepted November 18, 2023.
Published February 16, 2024.

**KEYWORDS**

Diversity, Macrophytes, Physicochemical Parameters, Rima, Sokoto



## INTRODUCTION

Aquatic macrophytes have been identified as submerged or floating plants that grow in or near water (Adigun, 2005; Gijo and Alagoa, 2022; Munyai and Dalu, 2023). These macrophytes could comprise a diverse group of organisms including angiosperms, ferns, mosses and liverworts (Lacoul and Freedman, 2006). Aquatic macrophytes are normally found growing in association with both standing and flowing water whose level is at or above the surface of the soil (Keddy, 2010). They can also be defined as plants that have adapted to living in aquatic environments, both in fresh waters or in salt waters (Sculthorpe, 1985). The most common adaptation is aerenchyma, but floating leaves are finely dissected leaves which are also common (Hutchinson, 1975). They are very important parts of the food chain where they serve as food for fish and maintain balance in nutrient cycle of aquatic bodies (Thomaz *et al.,* 2008). The spread and occurrence of these macrophytes on some Nigerian waterways were earlier reported by Kio and Ola (1987) where they generated high national interests. A lot of environmental factors other than nutrient concentrations could explain some of the observed variations in macrophyte species distribution and composition (Wetzel, 2001). However, these plants are highly productive and play important structuring roles in aquatic environments (Jeppesen *et al.,* 2000). Therefore, ecological studies carried out in aquatic environments are not complete if aquatic macrophytes' communities are not as essential components for ecosystem functioning and aquatic biodiversity conservation, as well as the physical parameters that influence or affect their growth.

Furthermore, aquatic macrophytes have the physiological potential to remediate heavy metals from polluted water bodies thereby regarded as the corner stone of aquatic environments (Chukwuka and Uka, 2007). Changes in physicochemical parameters can affect the growth and distribution of submerged macrophytes and other macrophytes (Strand and Weisner, 2001), and the structure of communities (Wantzen *et al.,* 2008). For example, the reported effects of water depth on the growth of the submerged species *Myriophyllum spicatum*

**Correspondence:** Ibrahim Muhammad Magami. Department of Biology, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University, P.M.B. 2346, Sokoto, Sokoto State, Nigeria. ✉ yusufmuhammadsanyinna@gmail.com. Phone Number: +234 706 756 4095.

**How to cite**: Magami, I. M., & Sanyinna, Y. M. (2024). Assessment of Surface Water Physicochemical Variables and Macrophytes Diversity in Sokoto and Rima Rivers, Nigeria. *UMYU Scientifica*, 3(1), 15 – 28. https://doi.org/10.56919/usci.2431.002

(Strand and Weisner, 2001; Zhu *et al.,* 2012; Zhu *et al.,* 2015), *Potamogeton pectinatus* (Bucak *et al.,* 2012), *Potamogeton maackianus* and *Potamogeton malaianus* (Zhu *et al.,* 2012; Zhu *et al.,* 2015), and on the community composition of submerged macrophytes (Dong *et al.,* 2014) demonstrate that water depth plays a vital role in aquatic ecosystems. Light, which is one of the most important variables for photosynthesis during the growth of submerged plants, can be strongly influenced by the characteristics of the water column in an aquatic ecosystem (Bornette and Puijalon, 2011). Water transparency can be affected by coloured dissolved organic matter (CDOM) and the concentrations of both suspended solids and plankton in water (Kirk, 1994). As is true of all organisms, the distribution and abundance of aquatic plants are influenced by variations in environmental factors. This fact can be used to identify species and communities that are reliable indicators of important changes in their ecosystem, including ones that may serve as gauges of ecological integrity (Fennessy *et al.,* 1998; Mack *et al*., 2000; Aznar *et al*., 2002). The high density of water makes aquatic organisms more buoyant, so aquatic plants invest fewer resources in supporting tissues, than terrestrial plants (Oyedeji and Abowei, 2012). Because macrophytes are in water, water loss is not a problem.

Thus, submerged aquatic macrophytes lack the structural and productive structures produced by terrestrial plants (Oyedeji and Abowei, 2012). Emergent aquatic macrophytes are defined as plants that are rooted in shallow water with vegetative parts emerging above the water surface (Westlake *et al*., 1998). Many species of aquatic macrophytes are invasive species and as such make particularly good weeds because they reproduce vegetatively from fragments (Oyedeji and Abowei, 2012). Macrophytes constitute the primary producers of aquatic ecosystems. They convert the incident radiating energy of the sun to chemical energy in the presence of nutrients like iron, nitrogen, manganese, molybdenum, phosphorous and zinc. In the aquatic environment, phytoplanktons are the foundation of the food web, providing a nutritional base for zooplankton and subsequently for other invertebrate shellfish and finfish (Emmanuel and Onyema, 2007). The productivity of any water body is determined by the amount of planktons it contains as they are the major primary and secondary producers (Davies *et al.,* 2009).

Water level fluctuations can affect the growth, distribution, and the survival of submerged macrophytes (Sousa *et al.,* 2010; Zhu *et al*., 2012) both directly and indirectly (Raulings *et al.,* 2010; Zhang Liu *et al.,* 2014). Hyacinth is not new in the ecological history of man (Chukwuka and Uka, 2007). Its extensive growth and multiplication have created problems associated with navigation, irrigation and fishing, among others (Chukwuka and Uka, 2007).

The floating mat of vegetation covers available sunlight from the water surface. The direct effect of this is the low production of natural fish food (phytoplankton and zooplankton species) thus resulting in overall low fish productivity (Chukwuka and Uka, 2007). The bloom of vegetation also results in massive fish kills due to high oxygen demand and competition for nutrients available. These invasive aquatic weeds affect both biodiversity and water quality (Chukwuka and Uka, 2007). The effect of the presence of aquatic weeds in water bodies on water loss through evapotranspiration is a subject of controversy but most experimental data indicate an increase in water loss from surfaces covered by aquatic weeds (Obot and Mbagwu, 1988).

Aquatic macrophytes form an important part of the biota of the littoral zones of lakes and reservoirs and are considered one of the most productive communities on Earth (Ondiviela *et al*., 2014). Many ecological functions have been assigned to them (Jeppesen *et al*., 1998; Kotta *et al*., 2014). These mainly include: their role as primary producers in trophic food chains; the source of habitats and refuges for algae, periphyton, zooplankton, invertebrate and vertebrate species; their role in nutrient cycling in aquatic systems; their influence on microclimate and hydrochemical processes in littoral zones; and their influence on the sediment dynamics of freshwater ecosystems. Besides these, many macrophyte species have been regarded as sites of carbon sequestration and they potentially support carbon dioxide ($CO_2$) mitigation (Marba *et al*., 2015). Generally, a certain level of water depth can provide the opportunity for plant growth (Gafny and Gasith, 1999), which is clearly conducive to the maintenance of stable macrophyte communities (Geest *et al.,* 2005). However, extremely low or high water levels that are beyond the suitable water depth range of certain species are both unfavourable for the growth of this aquatic vegetation (Coops *et al.,* 2003; O'Farrell *et al.,* 2011; Zhu *et al.,* 2012). Therefore, there is a need for adequate assessment of the effects of some physico-chemical parameters on the diversity of macrophytes. The present study aims to investigate the status of some physico-chemical parameters and their influences on the distribution of macrophytes in seasonal wetland ecosystem in the River Rima and River Sokoto of Sokoto State, Nigeria.

## MATERIALS AND METHODS

### Description of the Study Area

River Rima is situated in the North-Western region of Sokoto State, Nigeria. The area is located between longitude 4°E and 6°54'E and latitude 12°N and 13°54'N (Mamman, 2000). Rainy season is usually between May/June to early October/November (Umar and Ipinjolu, 2001). The Rima River is a river in the northern part of Nigeria. At its northernmost point, it is joined by the Goulbi de Maradi River. It runs southwest and joins the Sokoto River near Sokoto, then continues south to the Niger River. The upper Rima is a seasonal river and flows only during the rainy season (Umar and Ipinjolu, 2001). The Zauro polder project, a major irrigation scheme, has been planned for many years. It would irrigate 10,572 hectares (26,120 acres) of farmland in the Rima floodplain between Argungu and Birnin Kebbi (Tosin, 2009).

River Sokoto (formerly known as Gulbin Kebbi) is a river in North-West Nigeria and a tributary of the River Niger. The river's source is near Funtua in the south of Katsina State, some 275 kilometers (171 mi) in a straight line from Sokoto. It flows north-west passing Gusau in Zamfara State, where the Gusau Dam forms a reservoir that supplies water (Akané and Jurgen, 2005). Further downstream, the river enters Sokoto State where it passes by Sokoto and is joined by the River Rima, then turns south and flows through Birnin Kebbi in Kebbi State. About 120 kilometers (75 mi) south of Birnin Kebbi, it reaches its confluence with the Niger River. The plains around the rivers are widely cultivated and the water is used as a source of irrigation. The rivers are also used as a source of transportation. Bakalori Dam, about 100 kilometers (62 mi) upstream from Sokoto is a major reservoir on the Sokoto River. It has had a significant impact on downstream floodplain cultivation (Akané and Jurgen, 2005).

**Sampling Points**

In River Rima and River Sokoto, there are two sampling points A and B which were studied based on the differences in their partition by bridge overhead.

Sampling Point A: The right hand side of the rivers as partitioned by the bridge.

Sampling Point B: The left hand side of the rivers as partitioned by the bridge.

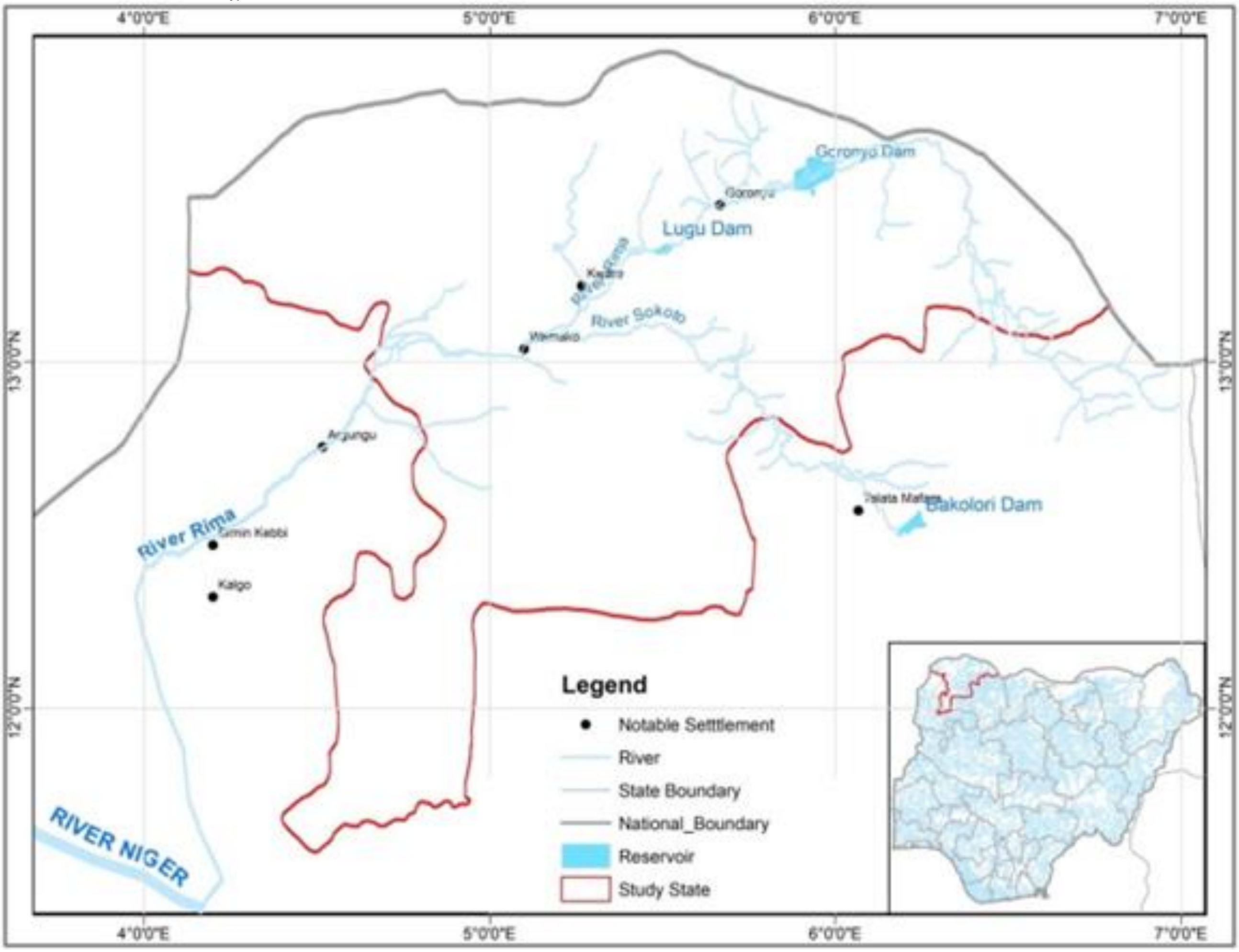


**Plate 1: A Map Showing River Rima and River Sokoto**

**Sample Size Determination**

The sample size requirements were estimated using resampling techniques as described by Quist *et al.* (2007). The presence and relative abundance of the macrophytes were estimated along each transect. The relative abundance of the macrophytes was recorded as the percentage cover of the macrophyte per species above the substrate when viewed from above (Environmental Protection (Water) Policy EPP 2009 – Monitoring and Sampling Manual, 2018).

**Macrophytes Sampling Techniques**

Two (2) methods were adopted for the macrophytes sampling in this study: point sampling method and transect sampling method (Madsen, 1999; Kolada *et al.*, 2009). The point sampling method was employed in shallow regions of the Rivers where the vegetation cover was very high. The belt transect method was employed in this study according to the procedure described by Environmental Protection (Water) Policy EPP 2009 – Monitoring and Sampling Manual (2018). Belt transects were randomly selected (without replacement) from both Rivers.

**Location and Frequency of Macrophytes Sampling**

The macrophytes community was collected from River Rima and River Sokoto for the period of 2 weeks in the month of August at each sampling point i.e. sampling points A and B in both Rivers Sokoto and Rima as partitioned by the bridge.

**Sample Collection and Determination of Physico-Chemical Parameters**

Water samples were collected from the rivers in 60 cl capacity sample bottles in the hours of 08:00 a.m. to 09:00 a.m. and were taken to laboratory for physico-chemical analysis. The samples (for both physico-chemical and biological analyses) were collected for a period of two weeks in the month of August. The physico-chemical parameters measured at the field were Temperature (Adeyemo *et al.,* 2008), Turbidity (Cole, 1994) and Depth, as well as Dissolved Oxygen (Huang *et al.,* 2017), Nitrate ($NO_3$) (SMEWW, 1999), Phosphate ($PO_4$) (Niemi *et al.,* 1990), pH and Biochemical Oxygen Demand (BOD) (Huang *et al.,* 2017), while biological analysis which includes identification of macrophytes was conducted at both field and laboratory.

**Macrophytes Counting and Identification**

The macrophytes community was collected from River Rima and River Sokoto for the period of 2 weeks at each sampling point i.e. sampling points A and B in both Rivers Sokoto and Rima as partitioned by the bridge. Macrophytes species were identified on the field while unidentified species were collected in a leather bag and transported to the laboratory for identification. Based on their morphological features, the collected samples were sorted and identified by comparing with identification charts (African glossary), plates and preserved macrophytes in the Biological Science Herbarium, Usmanu Danfodiyo University, Sokoto, Nigeria.

**Statistical Analysis**

Means and standard deviation were calculated for the physicochemical parameters for all the sampling points. Analysis of variance (ANOVA) was employed to determine the variability between means of the measured physicochemical parameters. Tukey's Honestly Significant Difference (HSD) Test was also employed to separate means where significant differences exist ($P < 0.05$). Version 20 of Statistical Package for the Social Sciences (SPSS) software was used to aid the statistical analysis. Tables were used to depict the average physicochemical parameters and list of macrophyte species for the two Rivers. Pie chart was used to show the percentage of occurrence of macrophytes in both Rivers.

## RESULTS

**Surface Water Physicochemical Variables**

The results of the analysis of the surface water physicochemical variables of the Sokoto and Rima Rivers are presented in Table 1 and 2. In Sokoto River, average temperature ranged from 27.00℃ to 27.30℃, and average depth from 285 to 295 meters at both stations A and B. In Rima River, average temperature varied from 25.85℃ to 26.50℃, and average depth ranged from 730 to 735 meters at both stations A and B. The results obtained in this study revealed that temperature and depth were found to be the most influential factors on macrophytes distribution.

Table 1 and 2 shows the values for weekly variation in physicochemical parameters in relation to sampling points of River Sokoto and River Rima from week one to the second week. There was fluctuation within the weeks between the sites in average Temperature, Depth, Turbidity, Nitrate, pH, DO, $BOD_5$ and Phosphate from 27.00 - 27.30 ℃, 285 - 295 cm, 26.50 - 30.00 NTU, 1.10 - 1.40 mg/L, 6.85 - 6.88, 4.80 - 5.70 mg/L, 22.70 - 25.05 mg/L and 0.238 - 0.243 mg/L in River Sokoto and from 25.85 - 26.50 ℃, 730 - 735 cm, 31.50 - 32.00 NTU, 1.20 - 1.55 mg/L, 6.81 - 6.82, 4.35 - 5.50 mg/L, 23.50 - 25.35 mg/L and 0.214 - 0.215 mg/L in River Rima, respectively.

**Diversity of Macrophytes**

The diversity of macrophytes in both River Sokoto and River Rima as shown in Table 3, emergent life forms occurred the most with 18 emergent species while free floating and submerged species are identified as one each.

Figure 1 illustrates the percentage of life forms of macrophytes where emergent species occurred the most with 90% occurrence while free floating and submerged species have 5% occurrence each.

Figure 2 and 3 depicts the density of macrophytes occurrence in both stations A and B of River Sokoto. Station A was seen to have higher species richness of 14 compared to Station B with 11 species richness. *Eichhornia crassipes, Cymbopogon schoenanthus, Mimosa pigra, Rottboellia cochinchinensis*, *Ricinus communis, Amaranthus viridis, Corchorus olitorius, Commelina* spp., *Pennisetum purpureum, Paspalum* *scrobiculatum* and *Digitaria debilis* all occurred the most throughout the study weeks at 8% while *Alcea rosea, Triumfetta cordifolia* and *Dicoma tomentosa* all occurred the least throughout the weeks of the study at 4% in station A of River Sokoto. *Eichhornia crassipes, Cymbopogon schoenanthus*, *Mimosa pigra*, *Rottboellia cochinchinensis*, *Pennisetum purpureum, Paspalum scrobiculatum, Digitaria debilis* and *Zea mays* occurred the most throughout the study weeks in station B of River Sokoto at 10.5% of occurrence while *Cynodon dactylon, Commelina* spp. and *Corchorus olitorius* occurred the least throughout the weeks of the study with 5.3% of occurrence in station B of River Sokoto.

Figure 4 and 5 depicts the density of macrophytes occurrence in both stations A and B of River Rima. Station A was seen to have higher species richness of 17 compared to Station B with 11 species richness. *Oryza sativa, Eichhornia crassipes, Cymbopogon schoenanthus, Rottboellia cochinchinensis*, *Cleome viscosa, Mimosa pigra, Alcea rosea, Amaranthus viridis, Triumfetta cordifolia, Corchorus olitorius, Commelina* spp., *Pennisetum purpureum, Paspalum scrobiculatum, Digitaria debilis, Pennisetum glaucum, Spinacia oleracea* and *Cynodon dactylon* all have 5.88% of occurrence in station A while *Oryza sativa, Cymbopogon schoenanthus, Cleome viscosa, Alcea rosea, Triumfetta cordifolia, Corchorus olitorius, Paspalum scrobiculatum, Pennisetum glaucum, Spinacia oleracea* and *Cynodon dactylon* all have 9.52% of occurrence and *Eichhornia crassipes* has 4.76% of occurrence in station B of River Rima.

**Table 1:** Weekly Variation of Physicochemical Parameters of River Sokoto

| Parameters | Site A | | Site B | |
|---|---|---|---|---|
| | **Week 1** | **Week 2** | **Week 1** | **Week 2** |
| Temperature (℃) | 26.00 | 27.00 | 28.00 | 27.60 |
| Depth (cm) | 300 | 300 | 290 | 270 |
| Turbidity (NTU) | 26.00 | 30.00 | 27.00 | 30.00 |
| Nitrate (mg/L) | 1.00 | 1.40 | 1.20 | 1.40 |
| pH | 6.83 | 6.85 | 6.87 | 6.90 |
| DO (mg/L) | 4.40 | 5.10 | 5.20 | 6.30 |
| $BOD_5$ (mg/L) | 23.60 | 20.20 | 26.50 | 25.20 |
| Phosphate (mg/L) | 0.229 | 0.245 | 0.257 | 0.231 |

**Key:** °C = Degree Celsius; cm = Centimeter; NTU = Nephelometric Turbidity Scale; mg/L = Milligrams per Liter

**Table 2:** Weekly Variation of Physicochemical Parameters of River Rima

| Parameters | Site A | | Site B | |
|---|---|---|---|---|
| | **Week 1** | **Week 2** | **Week 1** | **Week 2** |
| Temperature (℃) | 25.40 | 26.00 | 26.30 | 27.00 |
| Depth (cm) | 750 | 750 | 720 | 710 |
| Turbidity (NTU) | 29.00 | 32.00 | 34.00 | 32.00 |
| Nitrate (mg/L) | 1.00 | 1.30 | 1.40 | 1.80 |
| pH | 6.80 | 6.79 | 6.82 | 6.85 |
| DO (mg/L) | 5.00 | 5.90 | 3.70 | 5.10 |
| $BOD_5$ (mg/L) | 21.60 | 24.20 | 25.40 | 26.50 |
| Phosphate (mg/L) | 0.230 | 0.215 | 0.199 | 0.213 |

**Table 3:** List of Macrophytes Found in Both River Sokoto and River Rima during the Study Period

| S/N | Scientific Name | Common Name | Local Name | Family | Life Form (Group) |
|---|---|---|---|---|---|
| 1 | *Oryza sativa* | Rice | Shinkaafa | Poaceae | Emergent |
| 2 | *Eichhornia crassipes* | Water Hyacinth | Kainuwa | Pontederiaceae | Free Floating Leaves |
| 3 | *Cymbopogon schoenanthus* | Lemon Grass | Dangaye | Poaceae | Emergent |
| 4 | *Cleome viscosa* | Asian Spiderflower | Yarunguwi | Cleomaceae | Emergent |
| 5 | *Rottboellia cochinchinensis* | Itchgrass | Daawadawa | Poaceae | Emergent |
| 6 | *Mimosa pigra* | Giant Sensitive Tree | Gumbii | Fabaceae | Emergent |
| 7 | *Commelina* spp. | Dayflowers | Balaasayaa | Commelinaceae | Emergent |
| 8 | *Pennisetum glaucum* | Pearl Millet or Bulrush Millet | Hatsi/Dauroo | Poaceae | Emergent |
| 9 | *Alcea rosea* | Hollyhock | Garmagami | Malvaceae | Emergent |
| 10 | *Amaranthus viridis* | Pig Weed | Halifa/Rukubu | Amaranthaceae | Emergent |
| 11 | *Spinacia oleracea* | Spinach | Alayyahuu | Amaranthaceae | Emergent |
| 12 | *Digitaria debilis* | Finger-Grass | Harkiyaa | Poaceae | Emergent |
| 13 | *Ricinus communis* | Castor Bean or Castor Oil Plant | Zuruman | Euphorbiaceae Emergent | Emergent |
| 14 | *Corchorus olitorius* | Nalta Jute, Jute Mallow or Bush Okra | Laalo | Malvaceae Emergent | Emergent |
| 15 | *Dicoma tomentosa* | Woolly Dicoma | Daudawa | Asteraceae | Emergent |
| 16 | *Zea mays* | Maize | Masaraa/Bagwariiyaa | Poaceae | Emergent |
| 17 | *Triumfetta cordifolia* | Burbark | Dangeree | Malvaceae | Emergent |
| 18 | *Paspalum scrobiculatum* | Rice Grass, Kodo Millet or Koda Millet | Tumbin Jaakki | Poaceae | Emergent |
| 19 | *Pennisetum purpureum* | Elephant Grass, Napier Grass or Uganda Grass | Ciyaawar Giwaa | Poaceae | Emergent |
| 20 | *Cynodon dactylon* | Bermuda Grass, Dog's Tooth Grass, Dubo or Bahama Grass | Tsarkiyar Damoo | Poaceae | Submerged |

From the table (Table 3) above, emergent species of macrophytes occurred the most (18) out of 20 species, while submerged and free-floating only have one species each.

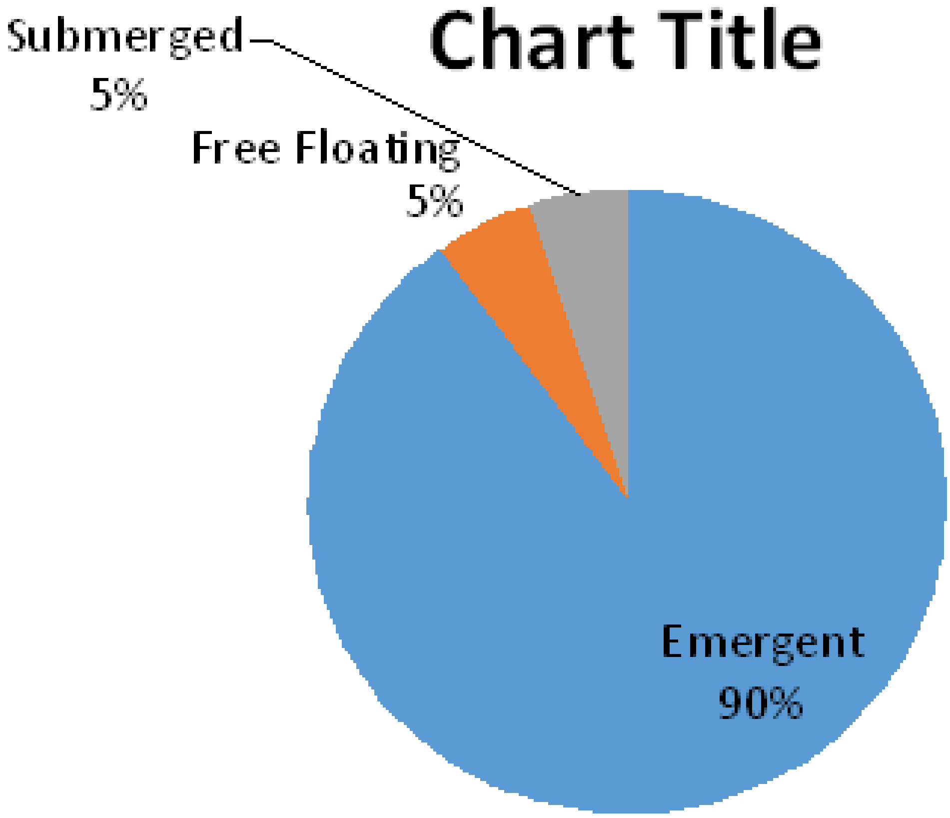


**Figure 1:** Pie Chart Showing the Percentage of Macrophytes Live Forms during the Study Period

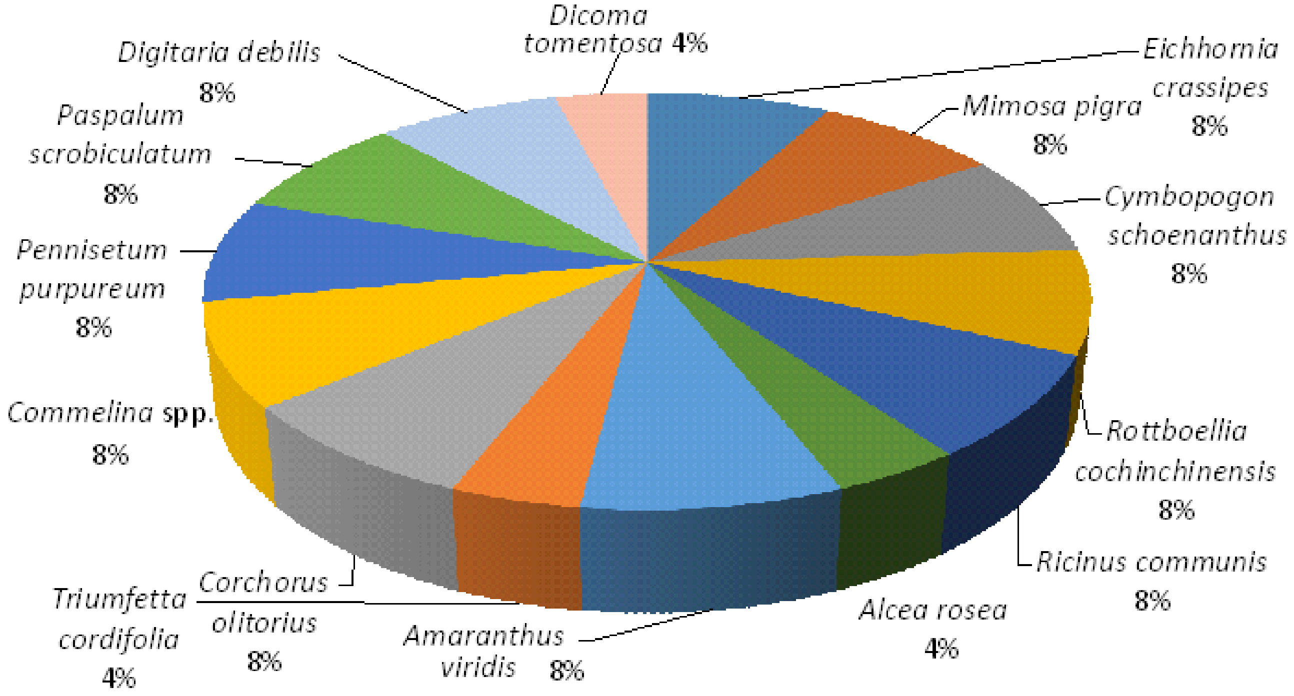


**Figure 2:** Pie Chart Showing the Percentage of Occurrence of Macrophytes in River Sokoto Partition A during the Study Period

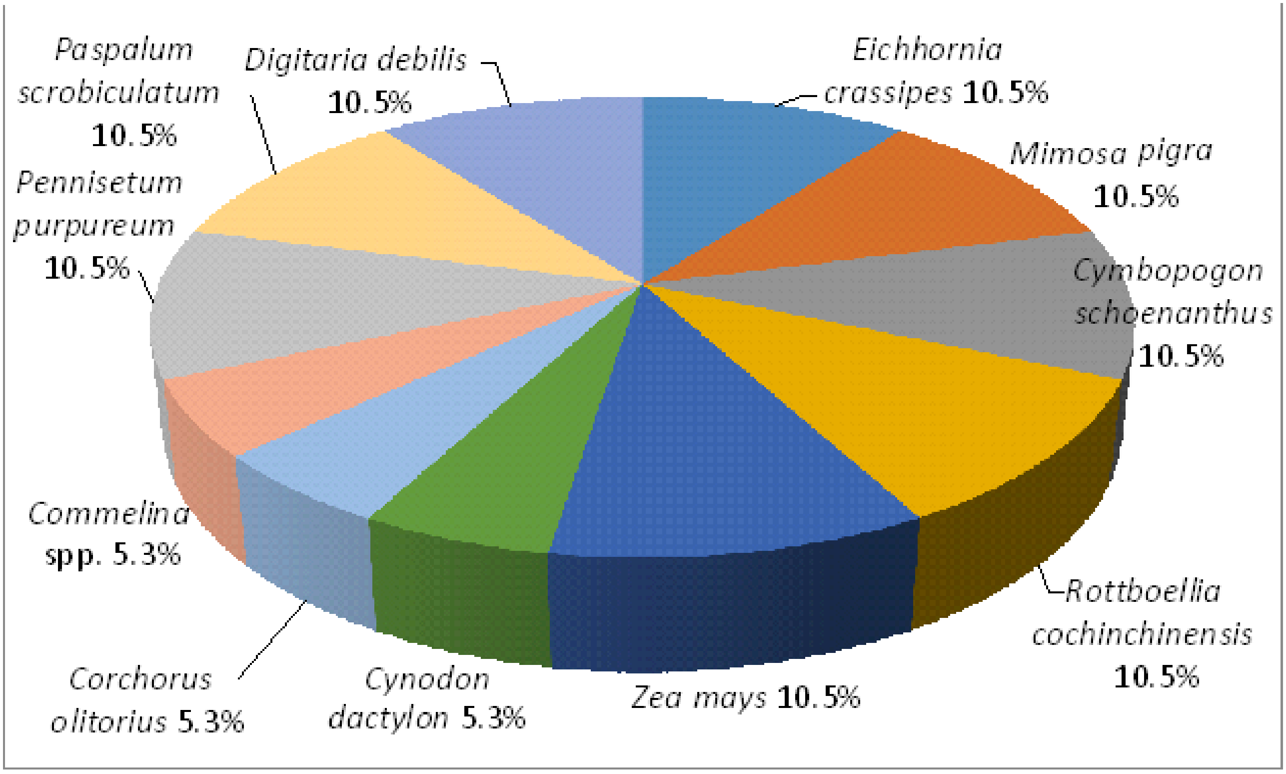


**Figure 3:** Pie Chart Showing the Percentage of Occurrence of Macrophytes in River Sokoto Partition B during the Study Period

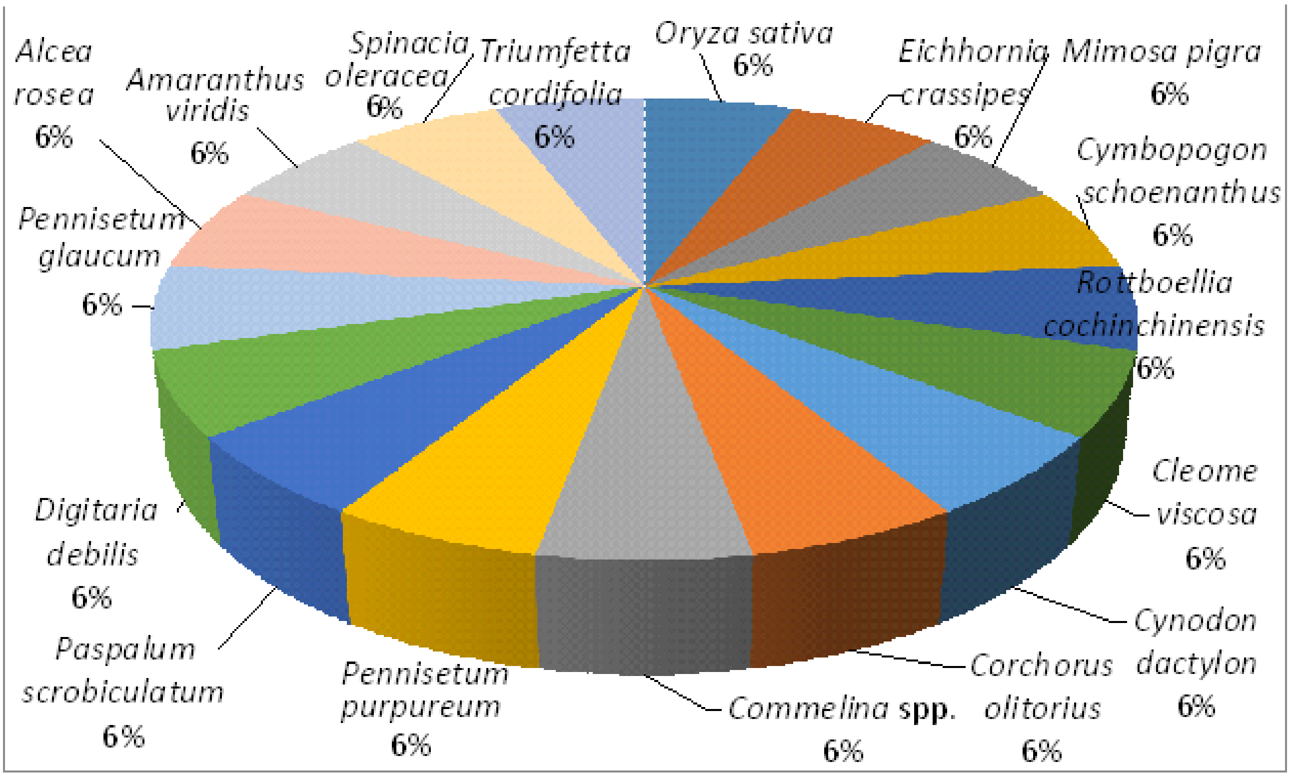


**Figure 4:** Pie Chart Showing the Percentage of Occurrence of Macrophytes in River Rima Partition A during the Study Period

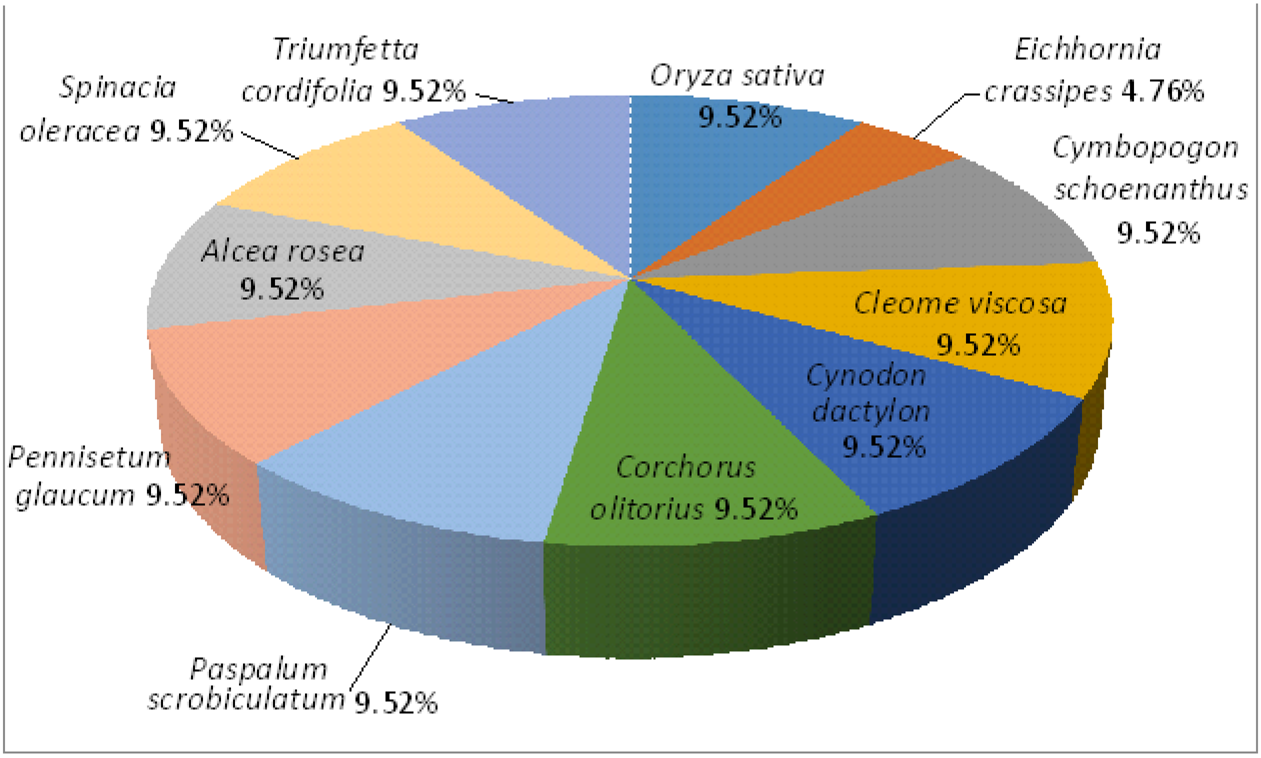


**Figure 5:** Pie Chart Showing the Percentage of Occurrence of Macrophytes in River Rima Partition B during the Study Period

## DISCUSSION

There are six major ecological factors that are important to the life of aquatic organisms (macrophytes). They include water, temperature, pH, light, oxygen and salinity (Sleigh, 1991). Water quality is of paramount importance for an aquatic ecosystem as it maintains all the ecological processes which support biodiversity. The growth and productivity of the aquatic organisms depend on the physicochemical characteristics of the water body (Verma *et al.,* 2012).

The temperature ranges of River Rima and River Sokoto are within the range of 16 - 30 °C as reported by Chapman (1992) (Tables 1 and 2). This indicates fluctuation in water temperature within the study period (from week one to week two) in the two Rivers. Adeniyi and Ovie (1982) reported that temperature range for the survival and optimum growth of aquatic organisms (macrophytes) is between 22 °C and 31 °C which corresponds to the range of temperature reported in all the sampling points of both River Sokoto and River Rima. Also, the observed result of water temperature in the Rivers was within FEPA (1991) and WHO (1999) standard maximum limits. But, works by Inuwa (2007) and Mustapha (2008a & b) agreed with the result obtained in this study, that shows fluctuation in the water temperature within the Rivers (Tables 1 and 2).

The importance of water pH to the survival of aquatic macrophytes is great. In river, pH fluctuates based on the metabolic activities as well as the amount of decomposition of organic matter by the microbes. The pH obtained in the current study falls within the FEPA (1991), WHO (1999) and Ragnar (2004) standard range for water quality (Tables 1 and 2). Therefore, the results of the pH obtained in this study are within the limits to support aquatic life for favourable and successful thriving of fish, shrimp and other aquatic organisms as suggested by Deekae *et al.* (2010). It was also in congruence with the findings of Inuwa (2007) and Mustapha (2008a & b). However, it somehow disagreed with the findings of Gijo and Alagoa (2022) who reported a pH range of 7.86 to 8.03 from the three (3) sampled stations.

The DO concentration observed in this study fluctuated throughout the period of sampling in the two Rivers, in which low DO was recorded in the first week in River Sokoto and first week in River Rima which falls below the normal range stated by FEPA (1991). This result agrees with the reports of Inuwa (2007) and Ibrahim *et al.* (2009), which showed that river system that contain high level of inorganic and organic pollutants tend to have low DO (Tables 1 and 2).

$BOD_5$ in this study disagrees with the FEPA (1991) and findings of Ragnar (2004), where the lowest $BOD_5$ was recorded in week two in River Sokoto and second week in River Rima (Tables 1 and 2).

According to Gijo and Alagoa (2022), nitrate is an indispensable factor for water quality assessment in surface water whose presence depend majorly on the activities of nitrifying bacteria, stream currents and catchment characteristics in lotic water systems. The highest nitrate level was in site B of River Rima and site B of River Sokoto (Tables 1 and 2). This result is in agreement with the finding of Gijo and Alagoa (2022) who reported a nitrate concentration that ranged from 0.92 mg/L to 1.62 mg/L from the sampled locations. The high nitrate concentrations could be attributed majorly to anthropogenic activities taking place in the water systems (Gijo and Alagoa, 2022). These anthropogenic activities include water runoff from agricultural farms, discharge of municipal and household refuse and sewage from public places such as markets and schools, and other effluents that contain nitrogen. However, the nitrate concentration result reported in this study is below the permissible limit of 50mg/L in comparison with international and national standards. Although, high nitrate values always signify eutrophication which usually result in the depletion of dissolved oxygen in the receiving water systems (Gijo and Alagoa, 2022).

According to Gijo and Alagoa (2022), phosphate regulates the production of phytoplanktons in the presence of nitrogen which therefore serves as the first limiting nutrient for freshwater plants. In natural waters, it is usually available in the form of phosphate which generally occurs in low and moderate concentrations. Increasing the $PO_4^{3-}$ pollution in water system depends largely on certain activities such as agriculture runoff containing phosphate fertilizers (NPK) and the waste water containing detergents, et cetera. In this study, mean of phosphate level of the Rivers is relatively similar weekly but there was variation in phosphate level at all sampling points in River Sokoto and River Rima (Tables 1 and 2). Therefore, low phosphate values were observed in this study which are inconsistent with the result obtained by Gijo and Alagoa (2022) who reported higher phosphate level which varied from 2.19 mg/L to 10.68 mg/L. However, in comparison with the standard phosphate values, the result obtained in this study is slightly above the permissible limits of 0.1 mg/L indicating that the Rivers are partially polluted by phosphate compounds.

The result of turbidity showed disparate fluctuations of concentrations with respect to location (site) in which site B had the highest turbidity in River Sokoto which is within maximum limits stated by Pandey (1997) (Tables 1 and 2). While the highest turbidity recorded for River Rima was in site B (Tables 1 and 2). The result recorded for turbidity in the two Rivers during the course of this study is also in agreement with that reported by Mustapha (2008a & b) and Wakawa (2008) while studying Challawa River.

In the present study, higher depth value at Site A of River Sokoto and Site A of River Rima may be linked with the abundance of rainfall within the period of study and also because they are the respective inlets of each of the Rivers (Wakawa, 2008) (Tables 1 and 2).

Macrophytes perform many ecosystem functions in aquatic ecosystems and provide services to human society. One of the important functions performed by macrophytes is uptake of dissolved nutrients (Nitrate and Phosphate) from water. These nutrients may be harmful to humans but in turn useful to aquatic macrophytes (Vymazal, 2013), which may be the reason why lower nitrate and phosphate levels were recorded in all sampling sites of the two Rivers during this study (Tables 1 and 2). Aquatic macrophytes are phylogenetically well dispersed across the angiosperms, with at least 50 independent origins, although they comprise less than 2% of the angiosperm species (Pennisi, 2018) (Table 3). Due to their underwater environment, aquatic submerged macrophytes have limited access to carbon and experience reduced light levels (Pederson *et al*., 2013). This may be the reason why the emergent species of macrophytes are dominant in distribution during this study (Table 3). Due to their aquatic surroundings and depth of water, the macrophytes are not at risk of losing water through the stomata and therefore, face no risk of dehydration (Shtein *et al*., 2017) (Tables 1 and 2). As according to van der Valk (2006), in the classification of macrophytes, emergent species are the most abundant and highly distributed throughout the study period both in River Sokoto and River Rima sampling sites with 90% percentage of occurrence (Figure 1). Submerged macrophytes completely grow under water with roots attached to the substrate (e.g. *Cynodon dactylon*) or without any root system (Beentje *et al.,* 2001) (Table 3). Free-floating macrophytes are aquatic plants that are found suspended on water surface with their roots not attached to substrate, sediment, or bottom of the water body. They are easily blown by air and provide breeding ground for mosquitoes. Example include: water lettuce, water cabbage and water hyacinth (Bornette *et al.,* 1998) (Table 3).

According to Westlake *et al.* (1998) Amphiphytes (can live in water or land) were found during the study period but Helophytes (rooted to the bottom and leaves are above the waterline) were the most widely distributed in both River Sokoto and River Rima (Table 3). Habitat complexity provided by macrophytes tends to increase diversity and density of both fish and invertebrates (Thomaz *et al.,* 2007). Mean of temperature in River Sokoto (Table 1) shows why they have lesser macrophytes species distribution of 14 species in the highest site compared to River Rima with lesser temperature (Table 2) which have up to 17 species in site A. However, effects of temperature on macrophytes' growth and distribution depends on the species of the macrophytes (Kotta *et al.,* 2014). With respect to each sites of the respective Rivers, this study agrees with Wrona *et al.* (2006) and Riis *et al.* (2012) that temperature can increase the growth of macrophytes as respiration and photosynthesis increases, this is in favour of emergent species and thus increase by 25% (Buschmann *et al*., 2004; Heikkinen *et al.,* 2009; Rothausler *et al.,* 2011). This may be the reason why emergent species are more distributed compared to submerged species. In a nutshell, warming will favour growth of few species. Hence, the diversity and species richness of macrophytes will decrease (Feuchtmayr *et al.,* 2010) (Table 3).

Both Rivers are turbid due to suspension of solids, silts, clays and wastes from various sources and contributories of the Rivers. This results in turbidity of the majority of the water body with transparencies recorded in River Sokoto and River Rima, hence suppressing growth of macrophytes by limiting light (Riis *et al*., 2012). In turbid situations, only floating plants and emergent communities dominate (Table 3). pH of the two Rivers from this study is slightly neutral throughout the weeks and sampling sites during the study period.

## CONCLUSION

This research contributes to understanding the ecological health of the Sokoto and Rima Rivers, guiding conservation efforts, informing water resource management, and identifying potential impacts on human activities in these areas. Ultimately, the goal is to support sustainable development and protect these valuable natural resources for the long term.

## RECOMMENDATIONS

Based on the results obtained in this study, the following recommendations were drawn:

i. Efficient management system is recommended to reduce the rate of water pollution caused by human activities on water bodies of the Rivers.

ii. Sensitization and public education of local people as well as general public on the effect of anthropogenic activities on the water bodies as well as the resultant effect on ecosystem of the Rivers should be encouraged.

iii. Further studies of the two Rivers should be conducted for a longer period in order to obtain more detailed information about the activities taking place around the water and factors that lead to fluctuations of physicochemical parameters of the Rivers.

iv. It is recommended that private agencies contribute to management system of the Rivers or further form synergy with Government agencies to reduce the pollution of the Rivers and reduce anthropogenic activities taking place.

v. Constant monitoring is recommended to avoid depositions of toxic solids from the sources.

## ACKNOWLEDGEMENTS

We are very grateful to the laboratory personnel and staff of Department of Biology, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University, Sokoto, Nigeria for making this research a successful one.

## REFERENCES

Adeniyi, H.A. and Ovie, S.T. (1982). Study and Appraisal for the Water Quality of the Asa Oil and Niger Rivers. *NIFFER Annual Report*. pp 15-20.

Adeyemo, O.K., Adedokun, O.A., Yusuf, R.K. and Adeleye, E.A. (2008). Seasonal Changes in Physico-Chemical Parameters and Nutrient Load of River Sediments in Ibadan City, Nigeria. *Global NEST Journal*. **10**(3): 326-336. **[Crossref]**

Adigun, B.A. (2005). *Water Quality Management in Agriculture and Fresh Water Zooplankton*. Innovation Venture Press, Niger State. pp 1-15.

Akané, H. and Jurgen, S. (2005). Bakolori Dam and Bakolori Irrigation Project – Sokoto River, Nigeria. *Eawag Aquatic Research Institute*. Retrieved from. wikipedia.org.

Aznar, J., Dervieux, A. and Grillas, P. (2002). Association between Aquatic Vegetation and Landscape Indicators of Human Pressure. *Wetlands*. **23**: 149-160. **[Crossref]**

Beentje, H., Hickey, M. and King, C. (2001). The Cambridge Illustrated Glossary of Botanical Terms. *Kew Bulletin*. **56**(2): 505. **[Crossref]**

Bornette, G. and Puijalon, S. (2011). Response of Aquatic Plants to Abiotic Factors: *A Review of Aquatic Science*. **73**: 1-14. **[Crossref]**

Bornette, G., Amoros, C. and Lamouroux, N. (1998). Aquatic Plant Diversity in Riverine Wetlands: The Role of Connectivity. *Freshwater Biology*. **39**: 267-283. **[Crossref]**

Bornette, G., Tabacchi, E., Hupp, C., Puijalon, S., Rostan, J.C. (2008). A Model of Plant Strategies in Fluvial Hydrosystems. *Freshwater Biology*. **53**: 1692-1705. **[Crossref]**

Bucak, T., SaraoĞLu, E.C.E., Levİ, E.E. (2012). The Influence of Water Level on Macrophyte Growth and Trophic Interactions in Eutrophic Mediterranean Shallow Lakes: A Mesocosm Experiment With and Without Fish. *Freshwater Biology*. **7**: 1631-1642. **[Crossref]**

Buschmann, A.H., Vasquez, J.A., Osorio, P., Reyes, E., Filun, L., HernandezGonzalez, M.C. and Vega, A. (2004). The Effect of Water Movement, Temperature and Salinity on Abundance and Reproductive Patterns of *Macrocystis* spp. (Phaeophyta) at Different Latitudes in Chile. *Marine Biology*. **145**: 849-862. **[Crossref]**

Chapman, D. (1992). Water Quality Assessment: A Guide to the Use of Biota, Sediment and Water in Environmental Monitoring. *WHO, Geneva,* p. 585. **[Crossref]**

Chukwuka, K.S. and Uka, U.N. (2007). Effect of Water Hyacinth (*Eichornia crassipes*) Infestation on Zooplankton Populations in Awba Reservoir, Ibadan South-West Nigeria. *Journal of Biological Sciences*. **7**: 865-869. **[Crossref]**

Cole, G.A. (1994). *Textbook of Limnology*. 4th Edition, Waveland Press, Inc., Prospect Heights, IL, 426.

Coops, H., Beklioglu, M. and Crisman, T.L. (2003). The Role of Water-Level Fluctuations in Shallow Lake Ecosystems – Workshop Conclusions. *Hydrobiological*. **506–509**: 23–27. [**Crossref**]

Davies, O.A., Abawei, J.F.N. and Tawari, C.C. (2009). Phytoplankton Community of Elech Creek, Niger-Delta, Nigeria: A Nutrient Polluted Tropical Creek. *America Journal of Applied Sciences*. **6**(6): 1143-1152. [**Crossref**]

Deekae, S., Abowei, J. and Alfred-Ockiya, J. (2010). Seasonal Variation of Some Physical and Chemical Parameters of Luubara Creek, Ogoni Land, Niger Delta, Nigeria. *Research Journal of Environmental and Earth Sciences*. **2**: 208-215.

Dong, B., Qin, B., Gao, G. and Cai, X. (2014). Submerged Macrophyte Communities and the Controlling Factors in Large, Shallow Lake Taihu (China): Sediment Distribution and Water Depth. *Journal of Great Lakes Research*. **40**(3): 646-655. [**Crossref**]

Emmanuel, B.E. and Onyema, I.C. (2007). The Plankton and Fishes of a Tropical South Western Nigeria. *Turkish Journal of Fisheries and Aquaculture Science*. **7**: 105-113.

Environmental Protection (Water) Policy 2009 – Monitoring and Sampling Manual (2018). Aquatic Macrophytes, Collecting Data Along a Belt Transect. *Biological Assessment*. Version: June 2018.

Fennessy, M.S., Geho, R., Elifritz, B. and Lopez, R. (1998). Testing the Floristic Quality Assessment Index as an Indicator of Riparian Wetland Quality, Final Report to US Environmental Protection Agency. *Columbus, USA*.

FEPA (1991): National Environmental Protection (Effluent Limitation) Regulations of 1991. Federal Environmental Protection Agency, Lagos, Nigeria. Reference S.1-8.

Feuchtmayr, H., Moss, B., Harvey, I., Moran, R., Hatton, K., Connor, L. and Atkinson, D. (2010). Differential Effects of Warming and Nutrient Loading on the Timing and Size of the Spring Zooplankton Peak: An Experimental Approach with Hypertrophic Freshwater Mesocosms. *Journal of Plankton Resource*. **32**: 1715-1725. [**Crossref**]

Gafny, S. and Gasith, A. (1999). Spatially and Temporally Sporadic Appearance of Macrophytes in the Littoral Zone of Lake Kinneret, Israel: Taking Advantage of a Window of Opportunity. *Aquatic Botany*. **62**: 249-267. [**Crossref**]

Geest, G.J.V., Wolters, H., Roozen, F.C.J.M., Coops, H., Roijackers, R.M.M., Buijse, A.D., Scheffer, M. (2005). Water-Level Fluctuations Affect Macrophyte Richness in Floodplain Lakes. *Hydrobiologia*. **539**: 239-248. [**Crossref**]

Gijo, A.H. and Alagoa, K.J. (2022). A Survey of Aquatic Macrophytes in the Akassa Axis of the River Nun, Niger Delta, Nigeria. *Review of Environmental and Earth Sciences*. **9**(1): 1-7. [**Crossref**]

Heikkinen, R., Leikola, N., Fronzek, S., Lampinen, R. and Toivonen, H. (2009). Predicting Distribution Patterns and Recent Northward Range Shift of an Invasive Aquatic Plant: *Elodea canadensis* in Europe. *Bio-Risk*. **2**: 1-32. [**Crossref**]

Huang, J., Yin, H., Chapra, S.C. and Zhou, Q. (2017). Modelling Dissolved Oxygen Depression sin an Urban River in China. *Water*. **9**: 520. [**Crossref**]

Hutchinson, G.E. (1975). A treatise on Limnology: III. *Limnological Botany*.

Ibrahim, B.U., Auta, J. and Balogun, J.K. (2009). An Assessment of the Physico-Chemical Parameters of Kontagora Reservoir, Niger State, Nigeria. *Bayero Journal of Pure and Applied Sciences*. **2**(1): 64-69. [**Crossref**]

Inuwa, B. (2007): Studies on Aspects of Physicochemical Conditions and the Fish Biology in Jakara Dam, Kano, Nigeria. A M.Sc. Dissertation Submitted to the Biological Sciences Department, Bayero University, Kano.

Jeppesen, E., Jensen, J.P., Søndergaard, M., Lauridsen, T. and Landkildehus, F. (2000). Trophic Structure, Species Richness and Biodiversity in Danish Lakes: Changes along a Phosphorus Gradient. *Freshwater Biology*. **45**: 201-218. [**Crossref**]

Jeppesen, E., Lauridsen, T.L., Kairesalo, T., Perrow, M.R. (1998). Impact of Submerged Macrophytes on Fish-Zooplankton Interactions in Lakes. In: Jeppesen, E., Søndergaard, M., Søndergaard, M., Christoffersen, K. (eds) The Structuring Role of Submerged Macrophytes in Lakes. *Ecological Studies*. **131**. Springer, New York, NY. [**Crossref**]

Keddy, P.A. (2010). Wetland Ecology: Principles and Conservation (2nd Edition). *Cambridge University Press, Cambridge,* UK, p. 497. [**Crossref**]

Kio, P.R.O. and Ola-Adams, B.A. (1987). Economic Importance of Aquatic Macrophytes. In: lloba, C. (Ed.) *Ecological Implications in the Development of Water Bodies in Nigeria*.

Kirk, J.T.O. (1994). Light and Photosynthesis in Aquatic Ecosystems, *2nd edn. Cambridge, England: Cambridge University Press*. [**Crossref**]

Kolada, A., Hellsten, S., Kanninen, A., Søndergaard, M., Dudley, B., Nõges, P., Ott, I., Ecke, F., Mjelde, M., Penning, E., Bertrin, V., Davidson, T. and Duel, H. (2009). Overview and Comparison of

Macrophyte Survey Methods Used in European Countries and a Proposal of Harmonized Common Sampling Protocol to be Used for WISER Uncertainty Exercise Including a Relevant Common Species List. wiser.eu . Accessed 20 March 2014.

Kotta, J., Moller, T., Orav-Kotta, H. and Parnoja, M. (2014). Realized Niche Width of a Brackish Water Submerged Aquatic Vegetation under Current Environmental Conditions and Projected Influences of Climate Change. *Marine Environment Resource*. **102**: 88-101. [Crossref]

Lacoul, P. and Freedman, B. (2006). Environmental Influences on Aquatic Plants in Freshwater Ecosystems. *Environ. Rev.* **14**: 89-136. [Crossref]

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M. and Bazzaz, F.A. (2000). Biotic Invasions: Causes, Epidemiology, Global Consequences, and Control. *Ecological Applications*. **10(3):** 689-710. [Crossref]

Madsen, J.D. (1999). Point Intercept and Line Intercept Methods for Aquatic Plant Management. *Aquatic Plant Control Technical Note MI-02*. [Crossref]

Mamman, A.B., Oyebanji, J.O. and Peters, S.W. (2000). Nigeria: A People United. A Future Assured (Survey of States). *Gabumo Publishing Co. Ltd., Calabar, Nigeria,* **2.**

Marba, N., Arias Ortiz, A., Masque, P., Kendrick, G.A. and Mazarrasa, I. (2015). Impact of Seagrass Loss and Subsequent Revegetation on Carbon Sequestration and Stocks. *Journal of Ecology*. **103**: 296-302. [Crossref]

Munyai, L.F. and Dalu, T. (2023). Aquatic Macrophytes Metal and Nutrient Concentration Variations, with Implication for Phytoremediation Potential in a Subtropical River System. *Sustainability*. **15**: 14933. [Crossref]

Mustapha, A. (2008a). Environmental Pollution in Kano: The Contribution of Wastewater Discharge from Kano Old City and Bompai Industrial Estate to Jakara River Basin. *Journal of Technology and Science*. **2**(1): 83-88.

Mustapha, A. (2008b). An Assessment of the Suitability of Water in Jakara-Getsi River System, For Fadama Production at the Kano Region, Kano State. *Journal of Technology and Science*. **1**(1): 118-124.

Niemi, G.J., DeVore, P., Detenbeck, N. *et al.* (1990). Overview of Case Studies on Recovery of Aquatic Systems from Disturbance. *Environmental Management.* **14**: 571-587. [Crossref]

O'Farrell, I., Izaguirre, I., Chaparro, G., Unrein, F., Sinistro, R., Pizarro, H., Rodriguez, P., Pinto, P.D.T., Lombardo, R., Tell, G. (2011). Water Level as the Main Driver of the Alternation between a Free-Floating Plant and a Phytoplankton Dominated State: A Long-Term Study in a Floodplain Lake. *Aquatic Science*. **73**: 275–287. [Crossref]

Obot, E.A. and Mbagwu, I.G. (1988). Successional Pattern of Aquatic Macrophytes in Jebba Lake, Nigeria. *African Journal of Ecology*. **26**(4): 295-299. [Crossref]

Ondiviela, B., Losada, I.J., Lara, J.L., Maza, M., Galvan, C., Bouma, T.J. and van Belzen, J. (2014). The Role of Seagrasses in Coastal Protection in a Changing Climate. *Coastal Engineering*. **87**: 158-168. [Crossref]

Oyedeji, A.A. and Abowei, J.F.N. (2012). The Classification, Distribution, Control and Economic Importance of Aquatic Plants. *International Journal of Fisheries and Aquatic Sciences*. **1**(2): 118-128.

Pandey, G.N. (1997). *Environmental Management*. Published on May 01, 1997. Publisher: Vikas Publishers. ISBN 10: 8125902929 / ISBN: 13: 9788125902928. [Crossref]

Pedersen, O., Colmer, T.D. and Sand-Jensen, K. (2013). Underwater Photosynthesis of Submerged Plants – Recent Advances and Methods. *Frontiers in Plant Science*. **4**: 140. [Crossref]

Pennisi, E. (2018). This Salt Water Trout Evolved to Live in Freshwater—In Just 100 Years. *Science*. [Crossref]

Quist, M.C., Bruce, L., Bogenschutz, K. and Morris, J.E. (2007). Sample Size Requirements for Estimating Species Richness of Aquatic Vegetation in Iowa Lakes. *Journal of Freshwater Ecology*. **22**(3): 477-491. [Crossref]

Ragnar, R. (2004). Environmental Load, Charnet-Aquafarmer. www.holar.is/aquafarmer. Accessed 05.08.2009.

Raulings, E.J., Morris, K., Roache, M.C., Boon, P.I. (2010). The Importance of Water Regimes Operating at Small Spatial Scales for the Diversity and Structure of Wetland Vegetation. *Freshwater Biology*. **55**: 701–715. [Crossref]

Riis, T., Olesen, B., Clayton, J.S., Lambertini, C., Brix, H. and Sorrell, B.K. (2012). Growth and Morphology in Relation to Temperature and Light Availability during the Establishment of Three Invasive Aquatic Plant Species. *Aquatic Botany*. **102**: 56-64. [Crossref]

Rothausler, E., Gomez, I., Karsten, U., Tala F. and Thiel, M. (2011). Physiological Acclimation of Floating *Macrocystis pyrifera* to Temperature and Irradiance Ensures Long-Term Persistence at the Sea

Surface at Mid-Latitudes. *Journal of Experimental Marine Biology and Ecology*. **405**: 33-41. **[Crossref]**

Sculthorpe, C.D. (1985). *The Biology of Aquatic Vascular Plants. Königstein-West Germany*. Koeltz Scientific Books. p. 597.

Shtein, I., Popper, Z.A. and Harpaz-Saad, S. (2017). Permanently Open Stomata of Aquatic Angiosperms Display Modified Cellulose Crystallinity Patterns. *Plant Signaling and Behavior*. **12**(7). **[Crossref]**

Sleigh, M. (1991): Protozoa and Other Protists. *1st Edition, Cambridge University Press, UK*. P. 50-288.

SMEWW (1999). *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, American Water Works Association, Water Environment Federation.

Sousa, W.T.Z., Thomaz, S.M., Murphy, K.J. (2010). Response of Native *Egeria najas* Planch. and Invasive *Hydrilla verticillata* (L.f.) Royle to Altered Hydroecological Regime in a Subtropical River. *Aquatic Botany*. **92**(1): 40-48. **[Crossref]**

Strand, J.A. and Weisner, S.E.B. (2001). Morphological Plastic Responses to Water Depth and Wave Exposure in an Aquatic Plant (*Myriophyllum spicatum*). *Journal of Ecology*. **89**: 166–175. **[Crossref]**

Thomaz, S.M., Dibble, E.D., Evangelista, L.R., Higuti, J. and Bini, L.M. (2007). Influence of Aquatic Macrophyte Habitat Complexity on Invertebrate Abundance and Richness in Tropical Lagoons. *Freshwater Biology*. **53**(2): 358-367. **[Crossref]**

Thomaz, S.M., Esteves, F.A., Murphy, K.J., Dos-Santas, A.M., Caliman, A. and Guariento, R.D. (2008). Aquatic Macrophytes in the Tropics: Ecology of Population and Communities, Impact of Invasion and Use by Man. *Tropical Biology and Conservation Management*. **4**: 33-37.

Tosin, O. (2009). "A Dam of Controversy".

Uka, U.N. (2006). Impact of Water Hyacinth Infestation on Water Quality and Plankton Diversity in Awba Reservoir, Ibadan-Nigeria. *Unpublished M.Sc. Project of the University of Ibadan, Ibadan*. p. 87.

Umar, K.A. and Ipinjolu, J.K. (2001). The Efficiency of Baited Malian and Ndurutu Trap in Three Freshwater Bodies in North-West Nigeria. *Journal of Agriculture and Environment*. **2**(1): 101-111.

van der Valk, A. (2006). The Biology of Freshwater Wetlands. New York: *Oxford University Press*. **[Crossref]**

Verma, P.S. and Agarwal, V.K. (2007). Principles of Ecology. 11th Reprinted Edition. S. Chand and Co. Ltd. *Environmental Biology*. pp. 3-500.

Vymazal, J. (2013). Emergent Plants Used in Free Water Surface Constructed Wetlands: A Review. *Ecological Engineering*. **61**: 582–592. **[Crossref]**

Wakawa, J.R. (2008). Impact Assessment of Effluent Discharge on Physicochemical Parameters and Some Heavy Metal Concentrations in Surface Water of River Challawa, Kano, Nigeria. *African Journal of Pure and Applied Chemistry*. **2**(10): 100-106.

Wantzen, K.M., Rothhaupt, K.O., Mörtl, M., Cantonati, M., Tóth, L.G. and Fischer, P. (2008). Ecological Effects of Water-Level Fluctuations in Lakes: An Urgent Issue. *Hydrologia*. **613**(1): 1-4. **[Crossref]**

Westlake, D.F., Kvet, J. and Szczepanski, A. (1998). The Production Ecology of Wetlands. *Cambridge University Press, Cambridge, UK*. p. 568. **[Crossref]**

Wetzel, R.G. (2001). Limnology: Lake and River Ecosystems. (3rd ed.). Philadelphia: *Academic Press*. p. 1006. **[Crossref]**

WHO (1999). Limits for Effluents Discharge into Surface Waters. *World Health Organization, Geneva, CH.*

Wrona, F.J., Prowse, T.D., Reist, J.D., Hobbie, J.E., Lévesque, L.M.J. and Vincent, W.F. (2006). Climate Change Effects on Aquatic Biota, Ecosystem Structure and Function. *AMBIO: Journal of Human Environment*. **35**(7): 359-369. **[Crossref]**

Zhang, X., Liu, X., Wang, H. (2014). Developing Water Level Regulation Strategies for Macrophytes Restoration of a Large River-Disconnected Lake, China. *Ecological Engineering*. **68**: 25–31. **[Crossref]**

Zhu, G., Li, W., Zhang, M., Ni, L. and Wang, S. (2012). Adaptation of Submerged Macrophytes to Both Water Depth and Flood Intensity as Revealed by Their Mechanical Resistance. *Hydro Biological*. **696**: 77–93. **[Crossref]**

Zhu, M., Zhu, G., Nurminen, L., Wu, T., Deng, J., Zhang, Y., Qin, B. and Ventelä, A. (2015). The Influence of Macrophytes on Sediment Resuspension and the Effect of Associated Nutrients in a Shallow and Large Lake (Lake Taihu, China). *PLOS ONE*. **10**(6): e0127915. **[Crossref]**