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Long-Term Changes in The Composition, Abundance and Diversity of Phytoplankton Community of Oshika Rivers State

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was aimed at determining the long-term changes in composition, abundance, and diversity of the phytoplankton community of the Oshika freshwater biota. Phytoplankton samples at Oshika lake were collected from the same stations and similar months as in the year 1983 study of the 5000 barrels of oil spill. The samples were handled with optimum care and treated according to standard practices in order to preserve the plankton for further analysis and identification. The results of the analysis showed that the phytoplankton yielded a total of 40 species belonging to three groups in 1983 and 36 species belonging to four groups in 2019. Xanthophyceae was the group absent in 1983 but present in 2019, while Chlorophyceae, Cyanophyceae and Bacilariophyceae were common to both 1983 and 2019. Generally, the abundance of phytoplankton in each group in 1983 was significantly different from those of 2019. The Chlorophyceae was the most abundant in both 1983(12.31-186.5) and 2019 (1.27-6.58). The diversity indices result showed that the phytoplankton in 1983 (2.123- 2.563) had lower diversity compared to 2019 (2.381- 2.815). The cluster analysis revealed two groups in 1983 viz the

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generalist and the dry season specialist, while three groups viz the dry season specialist, wet season specialist and the generalist were observed in 2019. More so, greater data variations were observed in 1983 than 2019. Hence, we infer that there were changes in the phytoplankton community structure between 1983 and 2019. There were changes in the biological community structure between 1983 and 2019. These changes cannot be linked to the oil spill but seems more likely a result of natural variation since results of studies on the hydrocarbon values in water were very insignificant. Since the lake-riverine system is subject to flooding it can be concluded that new plankton from unaffected areas are transported into this area during the flood. The mixing of the water over the years leads to the high variable change. The high variable change brings about high species turnover given the unrestricted hydrodynamics of the River Niger flooding system and its influence on the floodplain Oshika lake.

Keywords: Oil spill; long-term; freshwater; 1983, 2019; oshika phytoplankton.

1. INTRODUCTION

Hydrocarbon contamination caused by the oil and gas sector is one of the greatest environmental challenges in today's world. Crude oil pollution and its refined derivatives have a substantial negative influence on the environment. Sabotage, human error, and equipment failure are the most typical causes of oil leaks. While oil pollution can impact both land and water, it is more likely to spread in water, causing more harm to aquatic ecosystems [1]. In exceptional circumstances, oil contamination can linger in the aquatic environment for years after an oil spill, and the effects can be measured for decades in mangrove and freshwater swamps. Most biotic habitats are either destroyed or transformed, rendering them unsuitable for habitation, as a result of oil pollution, which is primarily caused by oil spills [1]. Microorganisms, plants, and algae, as well as invertebrates and vertebrates, all live in the aquatic ecosystem. Plants, algae, and some plankton are primary producers in large food webs, as well as food for higher trophic level species [2]. The oil that lingers in the ocean has the greatest potential to cause long-term ecological impacts. Some species' biological traits can also take a long time to recover, but the most well-documented examples of such effects come from populations that have been exposed to long-term oil contamination [3] Biological communities evolve as a result of disturbances, climatic changes, and species invasions. The richness and function of biological communities may be jeopardized when anthropogenic disturbances increase. Repeated disruptions may weaken biological communities, resulting in the extinction of late-successional species [4]. In terms of composition and proportional turnover, biological communities are dynamic throughout time, and disturbance and invasive species have significant impacts on their composition. Individualistically, species are meant to adjust their distributional ranges in response to environmental change [5,6]. These range modifications will be perceived at the community level as emigration or local extinction of an existing species, or immigration and colonization of a new species [7]. The biodiversity loss leads to changes in the composition and structure of communities [7]. However, at the most general level, patterns in the composition and diversity of species are influenced by only four classes of the process: selection, drift, speciation, and dispersal. The selection represents deterministic fitness differences among species, drift represents stochastic changes in species abundance, speciation creates new species, and dispersal is the movement of organisms across space [8].

Kingston [9] noted in his review that most environmental resources recover quickly after an oil spill, particularly if the oil contamination has been cleared. But, Peterson, et al. [10] have cast doubt on the 'old paradigms' of rapid recovery, claiming that the considerable evidence collected from Exxon Valdez studies shows long-term ecosystem-level changes.

In times of pollution, environmental evaluation has generally consisted of three-year short-term studies, ranging from short-term studies to post-impact assessments. On the other hand, major oil spills can have a three-year impact. After three years, public attention begins to wane, and there is no longer any monitoring of the long-term consequences, which are known to endure for many years [3]. AURIS [11,12] found that out of over one hundred big spills with published literature there were only ten or eleven had documented consequences lasting longer than five years. Goyal [13] reported that most oil spills have occurred in marine ecosystems, there is a significant amount of research on the effects of oil on saltwater ecosystems. While some research has looked into the toxicity of oil on freshwater organisms, there is little information on how oil affects these ecosystems. The number of recorded long-term repercussions of oil spills in Nigeria, according to Akani, et.al [14], is quite small. It is vital to examine the Oshika freshwater ecosystem, where the oil spill has lasted 35 years, to contribute to the status of oil spill research. Therefore, the study is aimed at the determination of changes that have taken place in Oshika lake using the phytoplankton communities.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The oil spill location is in the outskirts of Oshika village an area typical of the Niger Delta flood plain, with geographical coordinates of Longitude 5^{o} 08' 14 E and latitude 6^{o} 55’ 74N. The point of the spill was about 100 meters north of its intersection with the Trans-Niger pipeline between Ahoada and Mbiama in Ahoada West Local Government area, at a distance of 75km from Port Harcourt along East-West Road (Port Harcourt-Warri Road) [15], Fig 1. The geology of the Oshika area resembles that of the Niger Delta in general. It belongs to the quaternary geological epoch. The geologic epochs stretch from the early Holocene through the Pleistocene. The area’s general geology is classed as part of the Sombreiro-Warri deltaic plain, which is characterized by freshwater swamp forest [16].

A tropical rain forest with Niger flood plains and seasonal swamp forest make up the landscape. It's a freshwater marsh with dryland farms and patches of bush fallow with oil palm, orange, pear, and coco-nut trees scattered about. Cassava, maize, yams, bananas, and plantains are the principal crops grown. Due to the abundance of palm trees in the area, some of which are placed along the lake's edge, local oil mills are a typical sight. The soil in the area is loam or clay loam, with clay and silts intermingled in some places. The area's primarily clay loam soil may be impervious to oil spills and pollutants [15]. The Oshika Lake stream passed through a large area of swamp forest on its way to Idu village and the Obulubulu creek, which flows into the Orashi River between Abesa and Egbema. The Lake runs and drains into a floodplain about 8 kilometres from Oshika hamlet during the rainy seasons. The lake is stagnant throughout the dry season, with dry terrain along its boundaries harbouring isolated sources of water, primarily in excavated ponds historically utilized for dry-season fish harvest. During the dry seasons of the year, when there is no surface water input, the water in the lake remains generally calm; as a result, the top surface temperature rises and the DO saturation values decline. In the case of Oshika, the flow is moderate throughout the dry season and heavier during the rainy season. The minimum ambient temperature in the research region is 23 degrees Celsius, the maximum ambient temperature is 33 degrees Celsius, and the average annual rainfall is 3800 millimeters. During the wet season, from May through October, expect a lot of rain.

2.2 Description of the Sampling Stations Occupied 35 Years Ago

The field studies' sampling stations were collected from locations directly affected by the spilled oil (Fig 1). The land area affected by the oil spill slopes southward from the spill location into the stream and lake system. The water level was 1.5 to 2.3 meters above the swampland during the flood.

2.3 Current Description of the Study Area

The research area is in Oshika village, which features a stream channel that flows during the wet season and develops into the Oshika lake during the dry season. During the rainy season, the lake flows and drains onto a floodplain about 8 kilometers from Oshika village, but during the dry season, the lake is stagnant and contains isolated bodies of water along its shores, primarily in excavated ponds historically utilized for dry season fish collection. During the dry season, a bush track leads to the lake. The Oshika Lake flows through a large area of swamp forest all the way to Idu village and the Obulubulu Creek, which flows into the Orashi River between Abesa and Egbema. The community of Oshika includes a number of other villages like Ulokobo, Ayanabe, Oyigba, Okogbe, and Upatabo as its neighbours. The research site is a freshwater marsh surrounded by farmland and patches of bush fallow with oil palm, orange, pear, and coco-nut trees scattered throughout. The main floating plant on the aquatic margins is Pistia and Ceratophyllum. The human presence on these farmlands has had a significant impact on the seasonal swamp forest. Another human aspect is the increased requirement for homes as the population grows.

The oil leak took place on the fringes of Oshika village, which is located in the Niger Delta flood plain. Along East-West Road between Ahoada and Mbiama in Ahoada West Local Government District, the spill occurred around 100 meters north of its intersection with the Trans-Niger pipeline (Port Harcourt-Warri Road) (Fig 1).

2.4 Description of Stations Reoccupied with GPS Coordinates

Five sampling stations were selected from the area that was directly impacted by the oil spill. These areas shown in Figs 1, in relation to the sampling stations of the previous study thirty-Five years ago. These sampling stations were selected for reoccupation based on the following criteria: Area originally covered by the oil spill, distance from the oil spill point, accessibility, and the ease of collecting samples.

2.5 Study Design

The study was designed to mimic the months, the phytoplankton communities in order to be able to compare the 1983 and 2019 environment.

2.6 Field Survey

Initial field reconnaissance was undertaken. During the visit, a study of the area was conducted on the sample stations along the stream stretch, both upstream and downstream. The old sampling sites were indicated for water study along the Oshika lake based on the visit and utilizing the Geographical Position System (GPS) of allocating sampling stations. The sampling for 2019 took place during the same months as the sampling for 1983. Some months were in the dry season, while others were in the wet season. Before the sampling date all the sampling materials such as containers, net, chemical etc were made available, checked and stored in good condition.

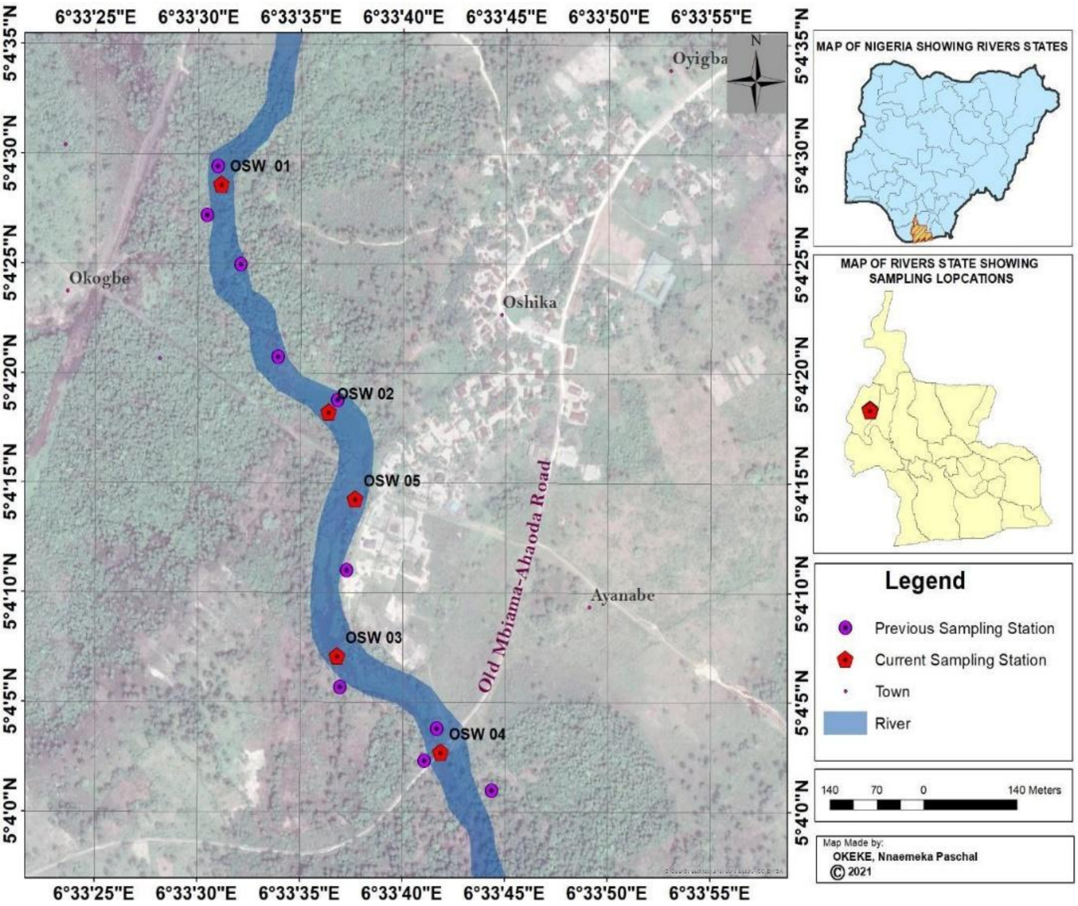


Fig. 1. Map of Oshika showing old and new sampling stations

2.7 Sample Collection

The phytoplankton sample collection was carried out in dry and wet seasons, these samples were stored and handled, and sent to the laboratory for analysis. The samples were collected with a standard plankton net filtration method. For the filtered samples, subsurface water was collected in 10litre plastic buckets and poured through a 65µ mesh size plankton net fifty times. The net samples (representing 500litres of water) were washed into sample collecting bottles and immediately fixed in formalin (final concentration 10%). Samples were diluted to 200ml in the laboratory using distilled water. After 48hours, the supernatant was pipetted off to the 50ml level. Following thorough agitation, 1ml sub-samples were taken using a stempel pipette and transferred to a graded 1ml counting chamber (Sedgwick-Ralter type) for observation under a binocular microscope with magnification of 40-400 X. The organisms were simultaneously identified and enumerated, and results recorded. The results of these counts were made by multiplying by appropriate dilution factors and expressed as organisms/litre. Separate sub-samples were evaluated for zooplankton and phytoplankton and replicates were analyzed for each.

2.8 Data Analysis

Diversity index analysis was calculated using all the identified phytoplankton groups. The number of the individuals of each of the identified groups in the replicates during each sampling was summed up by species to obtain the total number of each species at each station. Biodiversity indices such as species richness, diversity, and evenness were calculated following standard formula [17,18,19].

Shannon-Weaver Diversity Index. This measurement considers species richness and the proportion of each species within the local aquatic community. This measures the proportion (p) of individuals in the species [17] and is defined as: -

$$H^1 \text{ or } H(s) = \sum_{r=1}^{n} P_i \log P_i$$

S = Total number of species observed
N = Total number of individuals (sample size)
P_i = Proportion of individuals of each species in the station

Note: if we take N to be the sample size (total number of individuals) and f to be the number of individuals of i^{-th} species in a station.
$P_i = P_i/N$

Then

$$H(s) = \frac{n\log_n - \Sigma P_i \log P_i}{n}$$

The Shannon Wiener information measures the importance of each species in the community.

1. Equitability Index (J) also called Evenness Index, measures the distribution of individuals and is defined as: -

$$J = H_s/H_{max}$$

H_s = Shannon-Wiener Diversity Index
H_{max} = Log_2S
S = Total number of species

The Species Richness Index [17] is defined as the ratio of the number of species to the number of individuals. It does not consider the proportion and distribution of each species within the local aquatic community.

$$M = \frac{S-1}{\log_e N}$$

Where:

S = the number of species in the sample
N = the total number of individuals (sample size)
M = species richness index.

Data collected were subjected to statistical analysis using descriptive statistics such as mean, standard deviation; while a t-test was used to determine the differences between seasons and stations. Where t-test result shows a significant difference, the Tukey test was performed for mean separation.

$$t = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{(s^2(\frac{1}{n_1} + \frac{1}{n_2}))}}$$

t = the

x_1 and x_2 = the means of the two groups being compared,
s^2 = the pooled standard error of the two groups,

n_1 and n_2 = the number of observations in each of the groups.

$$T = q \cdot \sqrt{\frac{MSE}{n}}$$

n = the size of each of the group samples,
q = the distribution range,
MSE = Mean Square Error from t-test output,
T = Tukey test.

3. RESULTS

3.1 Dry and Wet Season Mean Variation of Phytoplankton Population

The relative abundance and distribution of the phytoplankton community within the Oshika lake are shown in Fig 2. A total of four (4) classes of phytoplankton namely Chlorophyceae; Bacillariophyceae; Cyanophyceae and Xanthophyceae were identified for both dry and wet seasons. In the dry season, the four classes yielded twenty-two (22) species and fourteen (14) species in the wet season respectively (Table 1). The results indicate that the Chlorophyceae (green microalgae) had the highest abundance (77%), for both dry and wet seasons as shown in Figure 2. All the other classes were below 12% for both dry and wet season {(Dry season Bacillariophyceae (10.5%); Cyanophyceae (8.3%); and Xanthophyceae (4.2%)). (Wet season Bacillariophyceae (9.1%); Cyanophyceae (7.8%) and Xanthophyceae (5.9%)}.

The Chlorophyceae which was both dominant as a class is also dominant for the number of species. The Chlorophyceae which were represented by nineteen species, had the pattern of occurrence vary between species. Eleven (11) species were found in dry and eight (8) in the wet season. (Fig 3). The count of *Volvox globistor*, and *Volvox* aureus were the highest in terms of numbers for the dry season, while *Chlorogonium elegans* was highest for the wet season. These species occurred with 100% abundance and in terms of distribution the most widely distributed were *Volvox globistor*, *Volvox aureus*, (Figs 4 and 5), *Chlorogonium elegans*, (Fig 6).

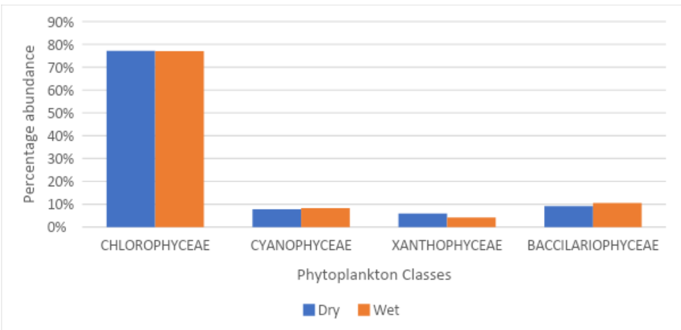


Fig. 2. Dry and Wet Season Percentage Abundance of Phytoplankton Classes

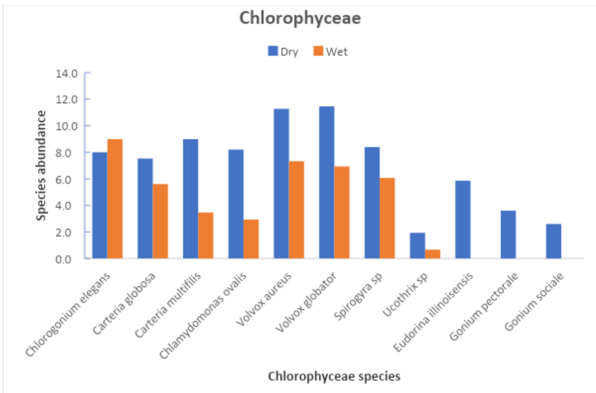


Fig. 3. Relative Abundance of Phytoplankton (Chlorophyceae*)* species

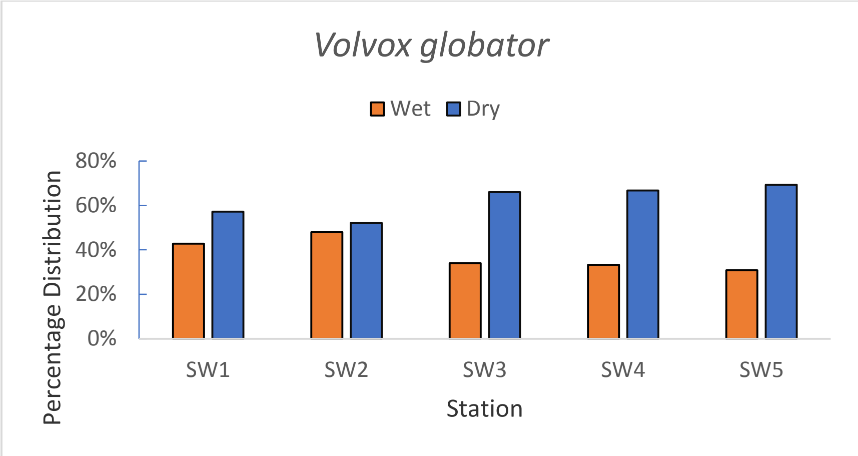


Fig. 4. Seasonal Percentage (%) Distribution and Abundance of *Volvox globator*

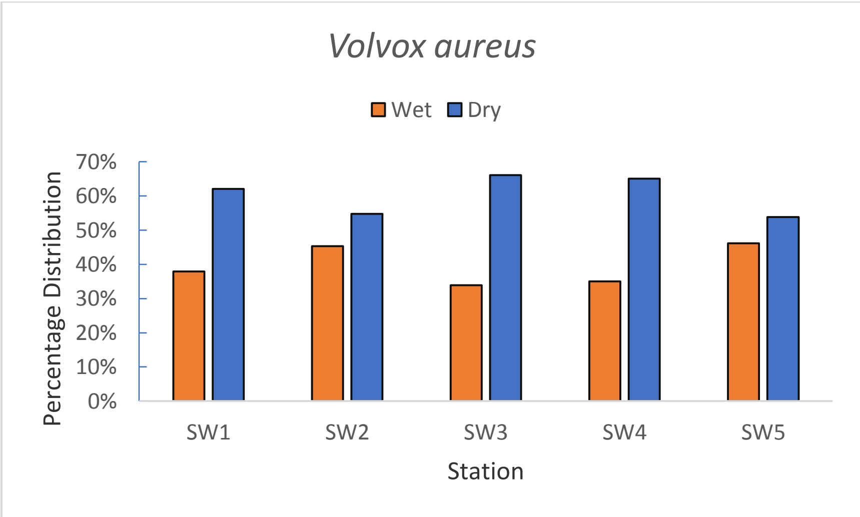


Fig. 5. Seasonal Percentage (%) Distribution and Abundance of *Volvox aureus*

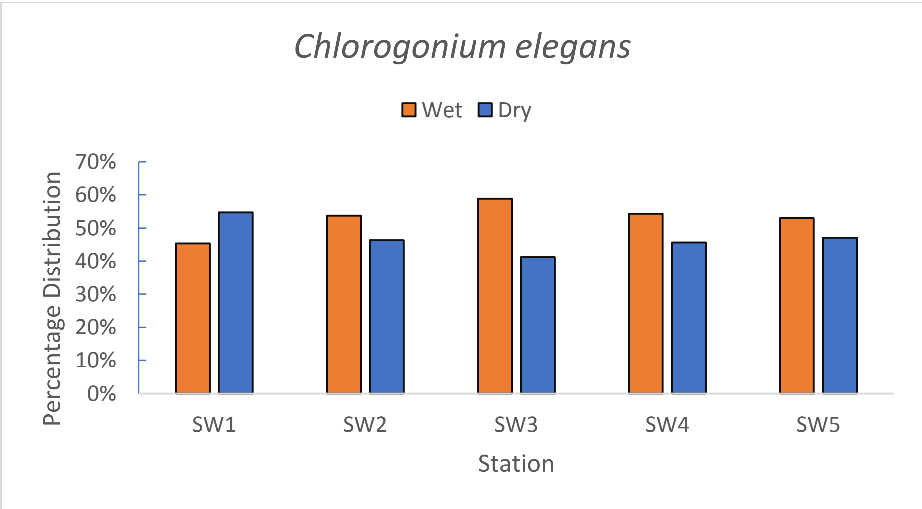


Fig. 6. Seasonal Percentage (%) Distribution and Abundance of *Chlorogonium elegans*

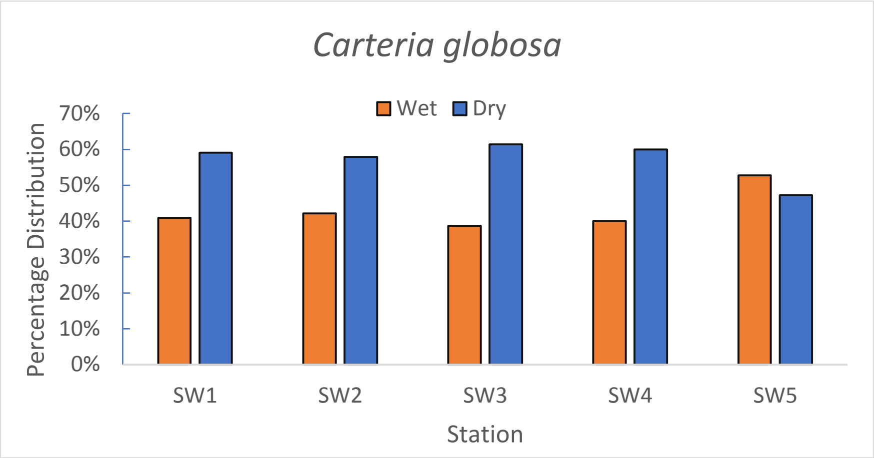


Fig. 7. Seasonal Percentage (%) Distribution and Abundance of *Cateria globosa*

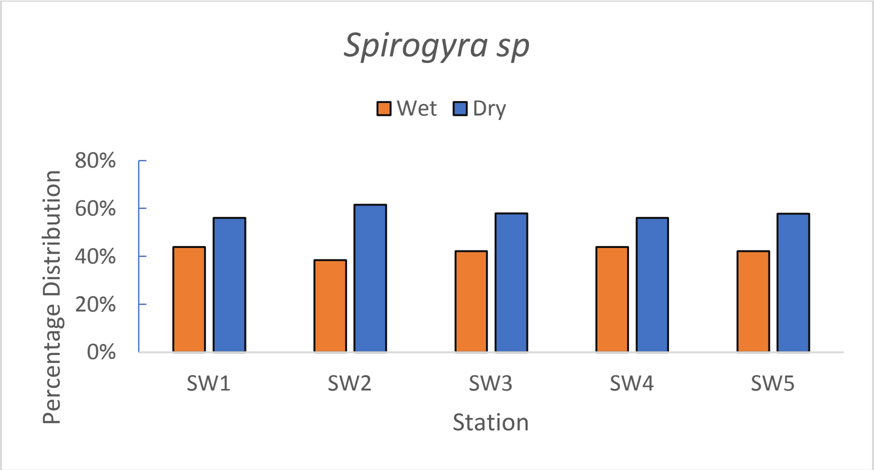


Fig. 8. Seasonal Percentage (%) Distribution and Abundance of *Spirogyra sp*

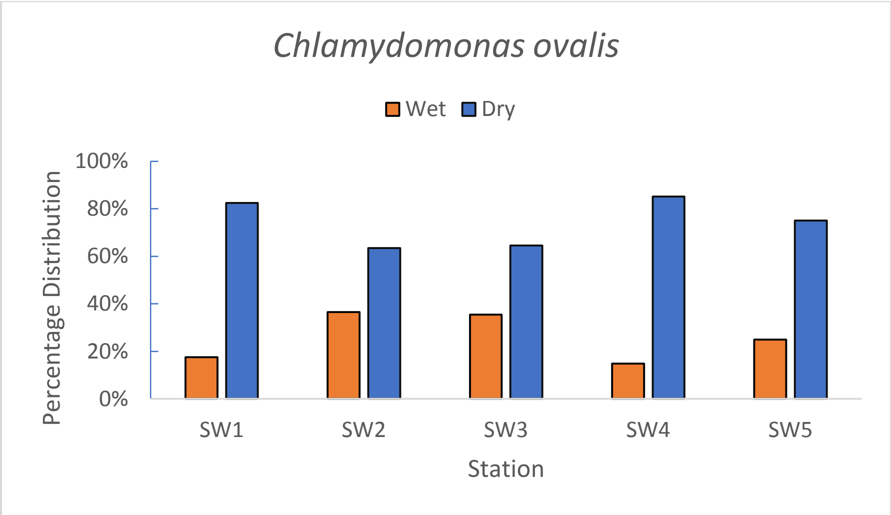


Fig. 9. Seasonal Percentage (%) Distribution and Abundance of *Chlamydomonas ovalis*

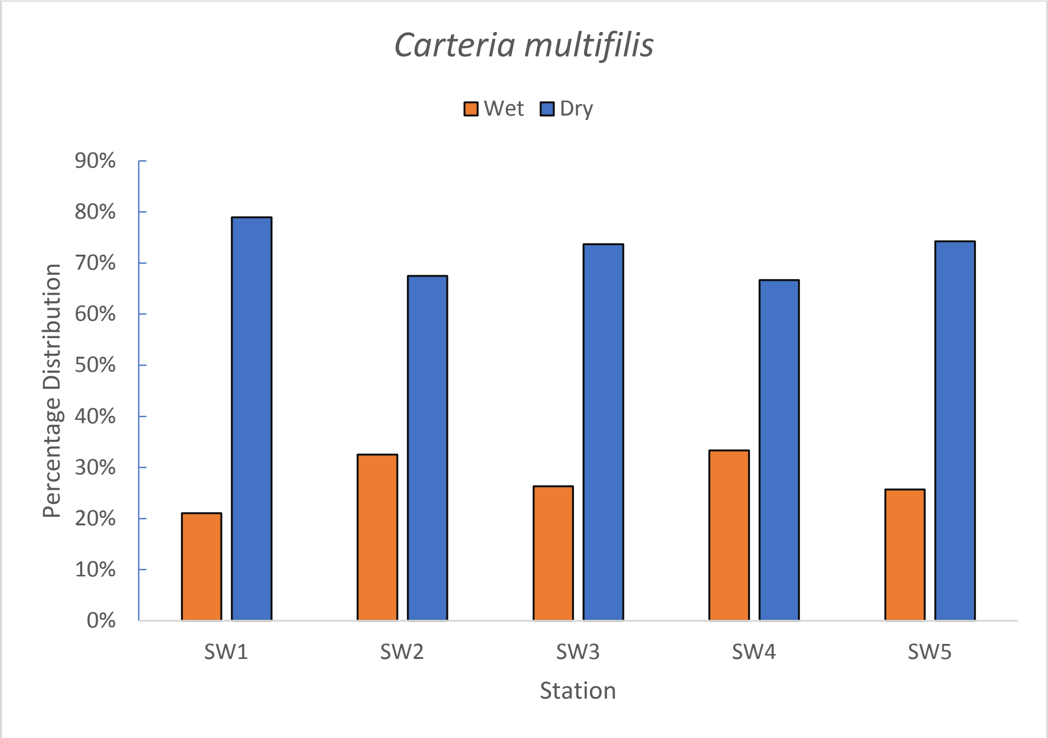


Fig. 10. Seasonal Percentage (%) Distribution and Abundance of *Cateria multifilis*

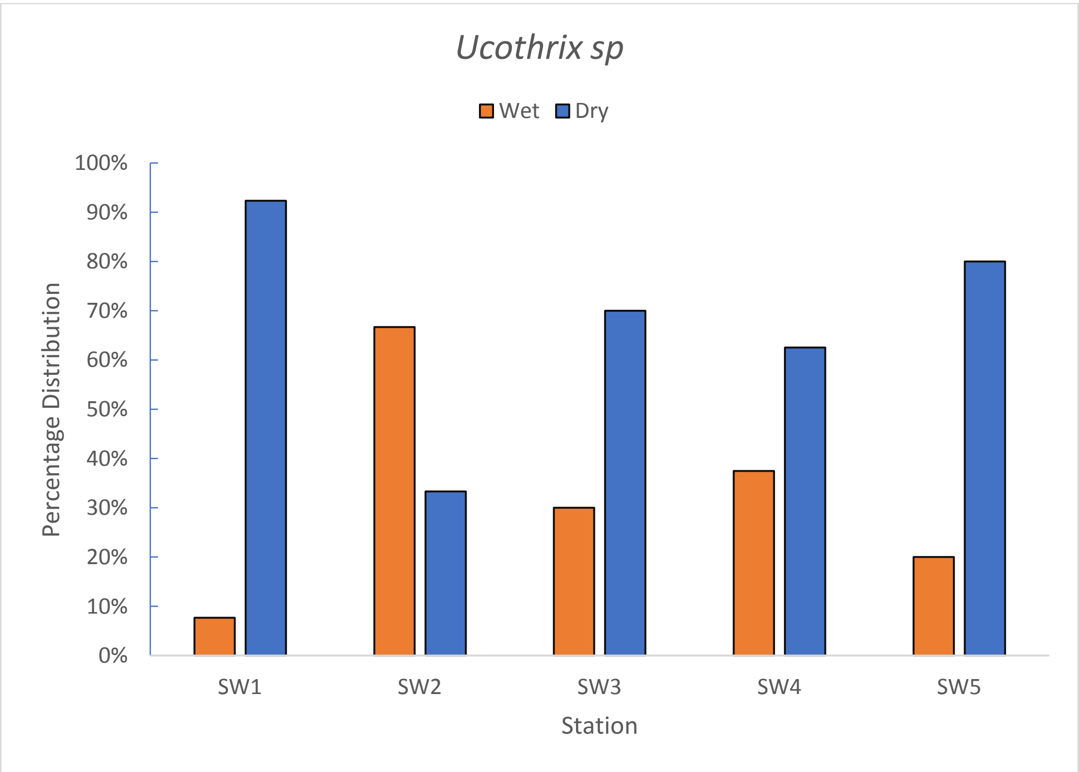


Fig. 11. Seasonal Percentage (%) Distribution and Abundance of *Ucothrix sp*

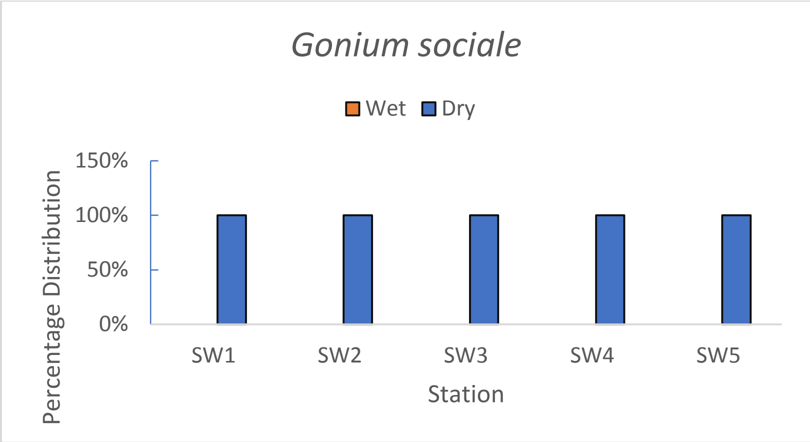


Fig. 12. Seasonal Percentage (%) Distribution and Abundance of *Gonium sociale*

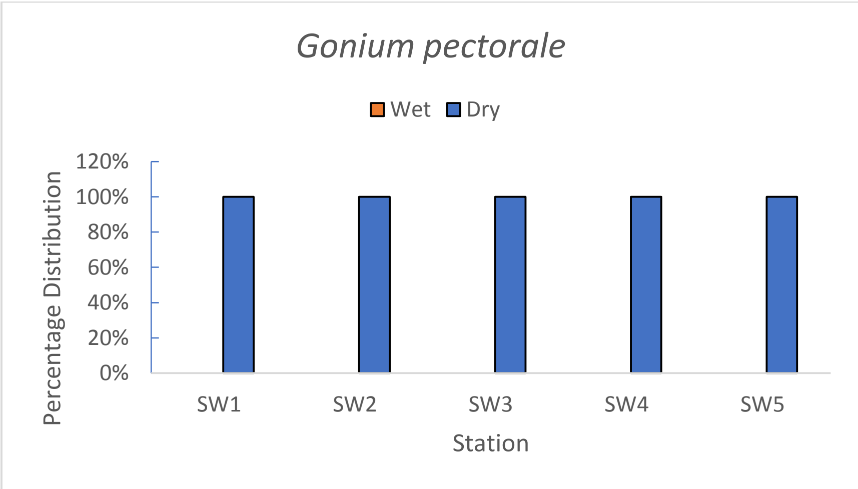


Fig. 13. Seasonal Percentage (%) Distribution and Abundance of *Gonium pectoral*

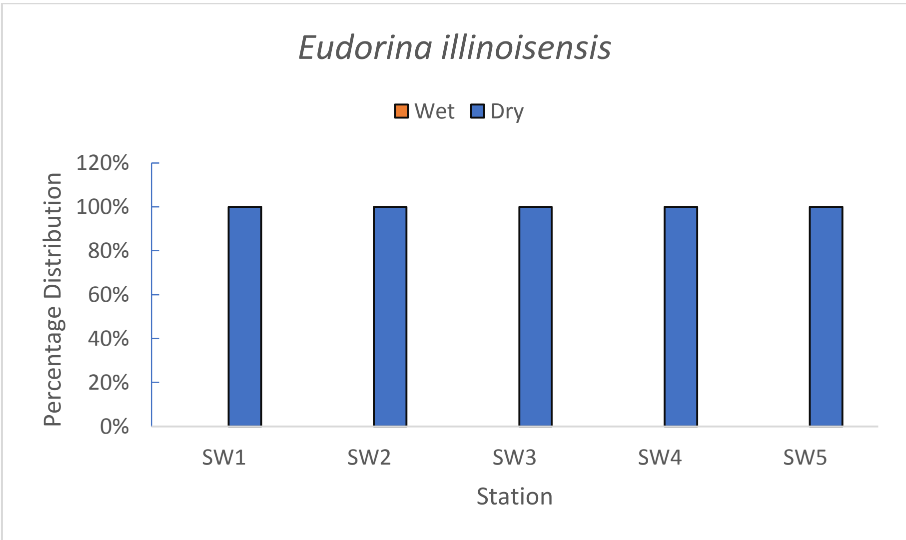


Fig. 14. Seasonal Percentage (%) Distribution and Abundance of *Eudorina illinosensis*

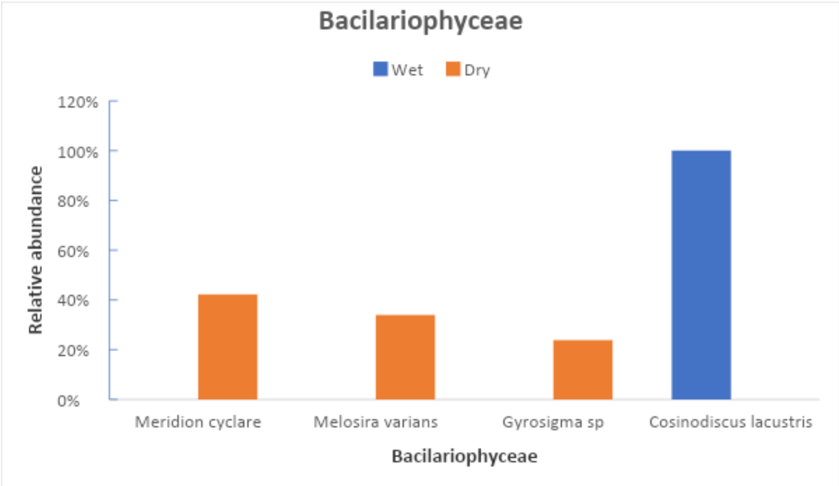


Fig. 15. Relative Abundance of Phytoplankton (Bacillariophyceae) Species

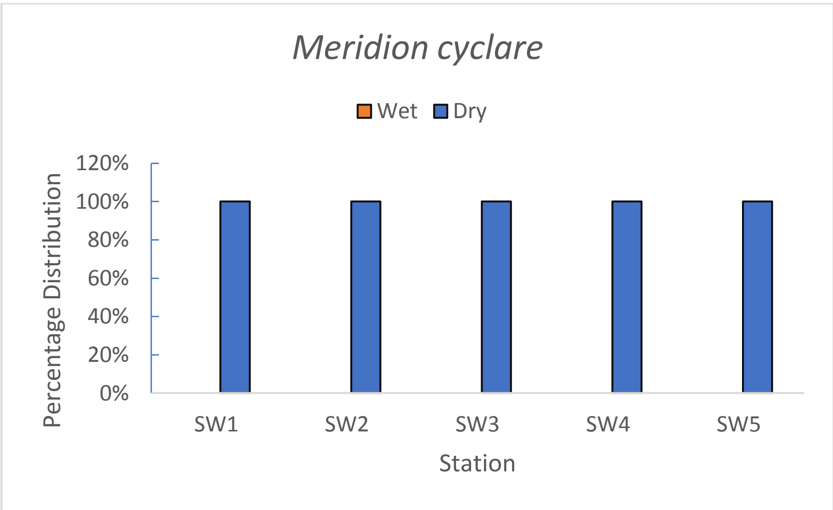


Fig. 16. Seasonal Percentage (%) Distribution and Abundance of *Meridion cyclare*

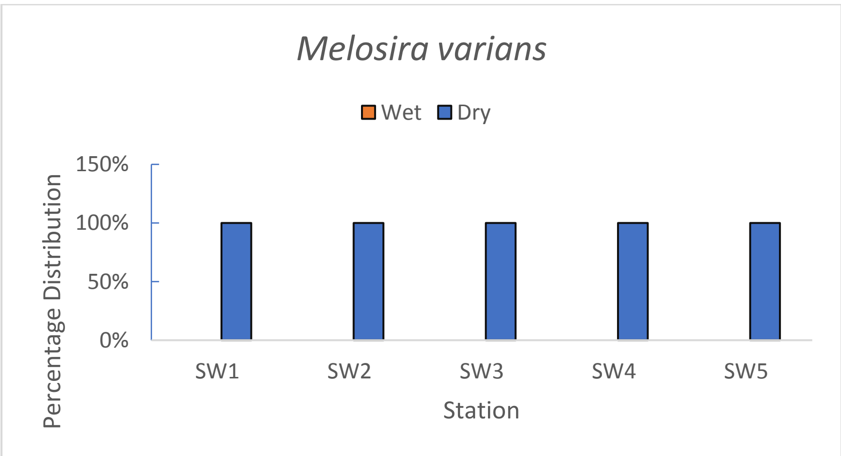


Fig. 17. Seasonal Percentage (%) Distribution and Abundance of *Melosira varians*

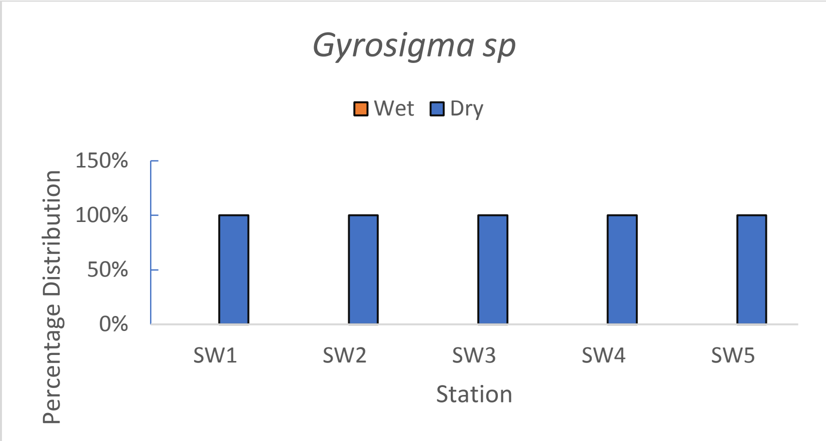


Fig. 18. Seasonal Percentage (%) Distribution and Abundance of *Gyrosigma sp*

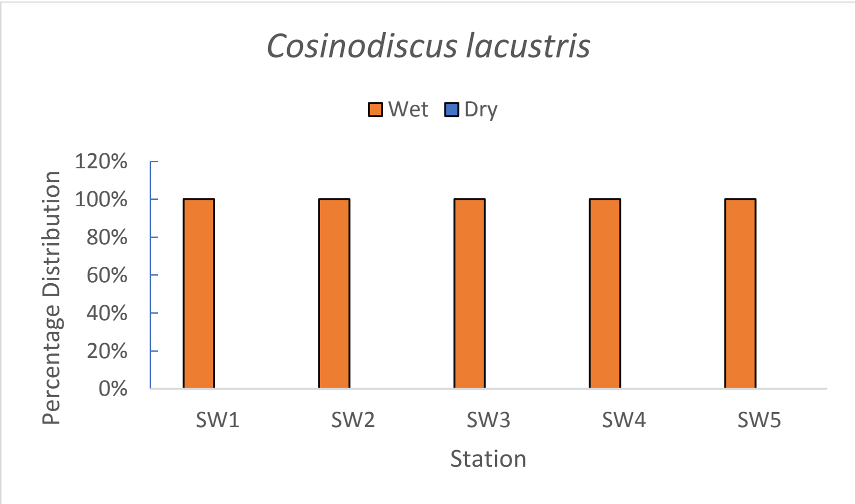


Fig. 19. Seasonal Percentage (%) Distribution and Abundance of *Cosinodiscus lacustris*

Carteria globistor, and *Spirogyra sp.* occurred in all the five stations sampled for the dry and wet seasons at a relative percentage, as shown in Fig. 7 and Fig. 8.

Chlamydomonas ovalis and *Carteria multifilis* were also present in the dry season and wet season but in different proportions, as shown in Fig. 9 and Fig. 10.

Ucothrix sp distribution varied between seasons in the different stations both dry and wet season as shown fig 11 Other species found in the dry season include *Gonium Sociale, Gonium pectorale, and Eudorina illinoisis* (Figs.12-14). Dry and Wet Season Phytoplankton Species Percentage (%) Distribution chart.

The other groups of phytoplankton were the Bacillariophyceae, they were represented by four species: three (3) for the dry season and (1) for the wet season as shown in Fig 15. In terms of distribution *Meridion cyclare, Melosira varians, and Gyrosigma sp* species were absent in the wet season. *Cosinodiscus lacustris* was present in the wet season in all the stations. These are shown in figs 16 - 19.

The Cyanophyceae has a total of eight species for both dry and wet season (Fig. 20). The *Oscillatoria tenuis* and *Spirulina major* had the highest count for the dry and wet season as shown in figs 21 and 22, but in terms of distribution, all the other species were either found in the dry (*Oscillatoria limosa*, *Spirulina princeps* and *Phormidium mucicola)* as shown in figs 23-25 or wet seasons *(Rivularia planctenica)* Fig. 26.

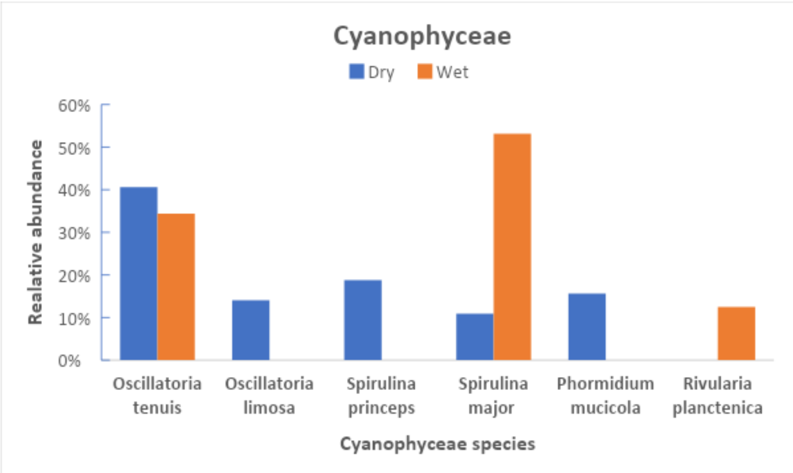


Fig. 20. Relative Abundance of Phytoplankton (Cyanophyceae) species

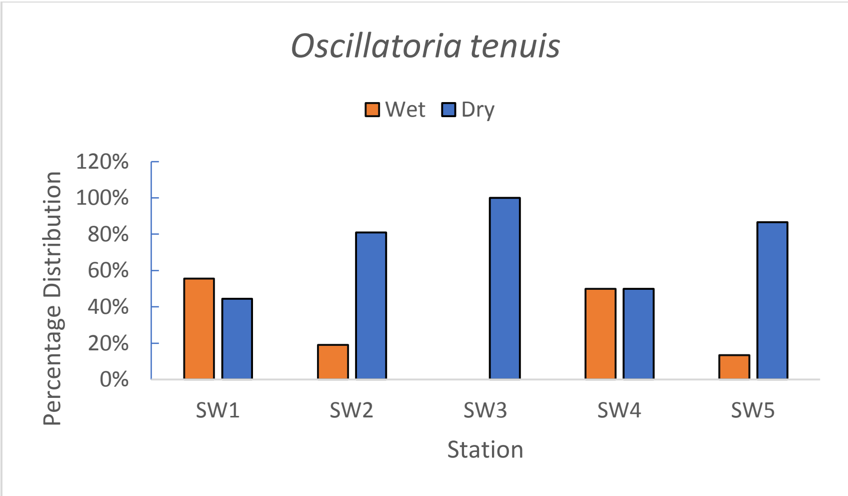


Fig. 21. Seasonal Percentage (%) Distribution and Abundance of *Oscillatoria tenuis*

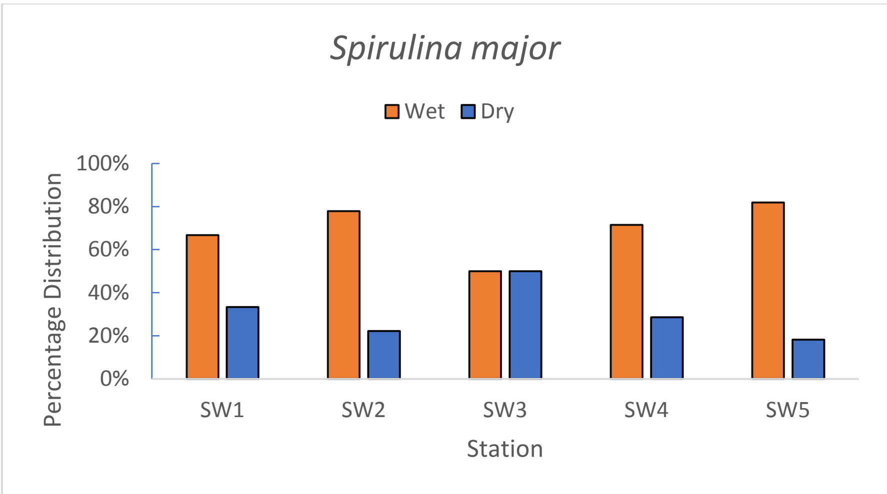


Fig. 22. Seasonal Percentage (%) Distribution and Abundance of *Spirulina major*

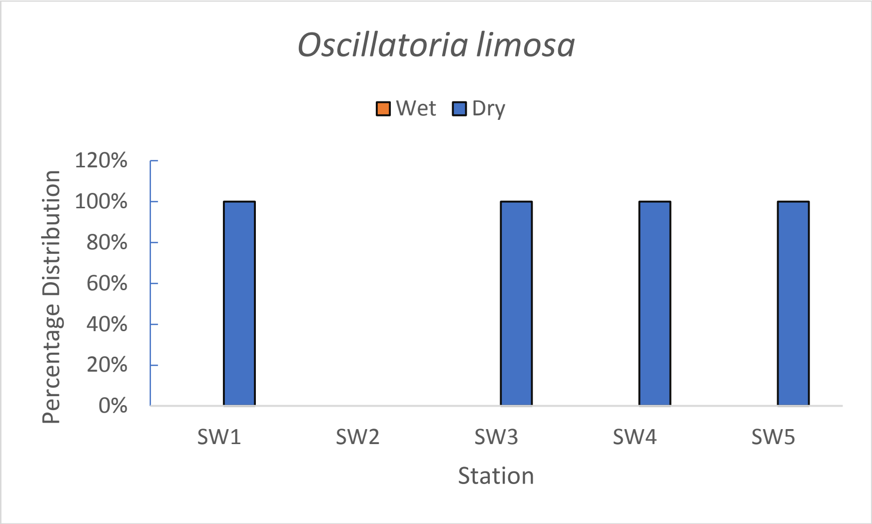


Fig. 23. Seasonal Percentage (%) Distribution and Abundance of *Oscillatoria limosa*

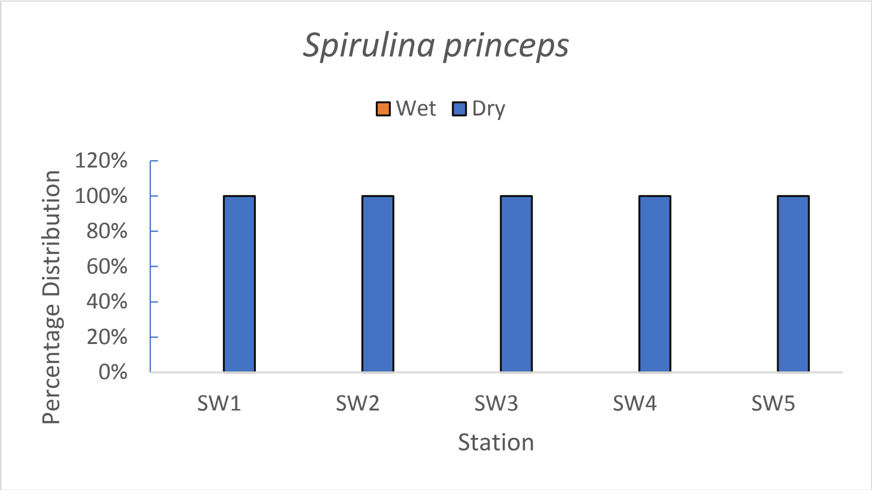


Fig. 24. Seasonal Percentage (%) Distribution and Abundance of *Spirulina princeps*

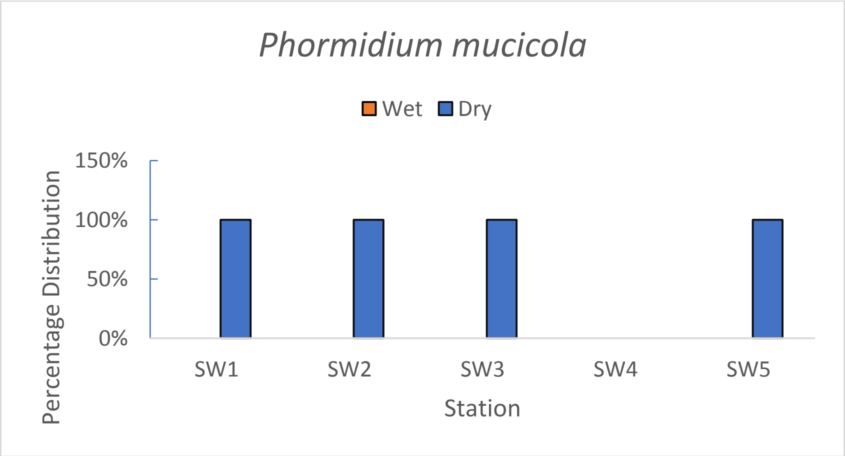


Fig. 25. Seasonal Percentage (%) Distribution and Abundance of *Phormidium mucicola*

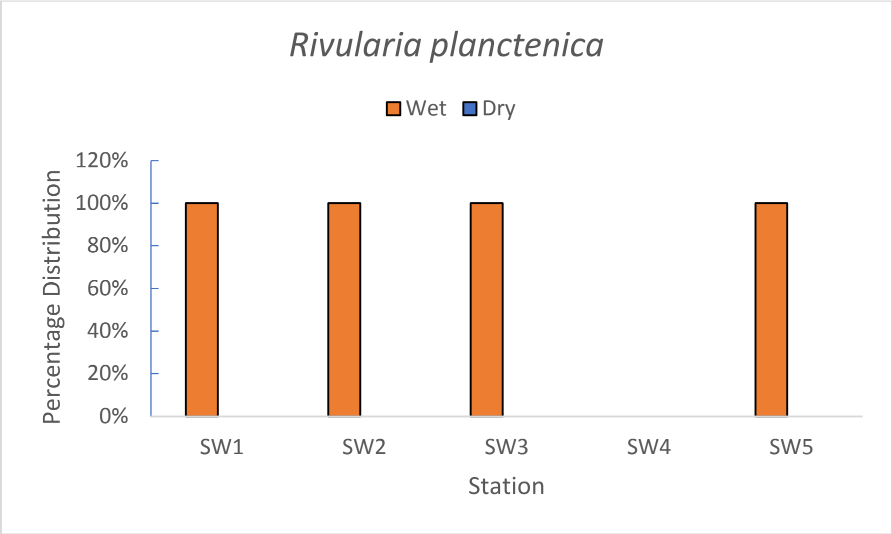


Fig. 26. Seasonal Percentage (%) Distribution and Abundance of *Rivularia planctenica*

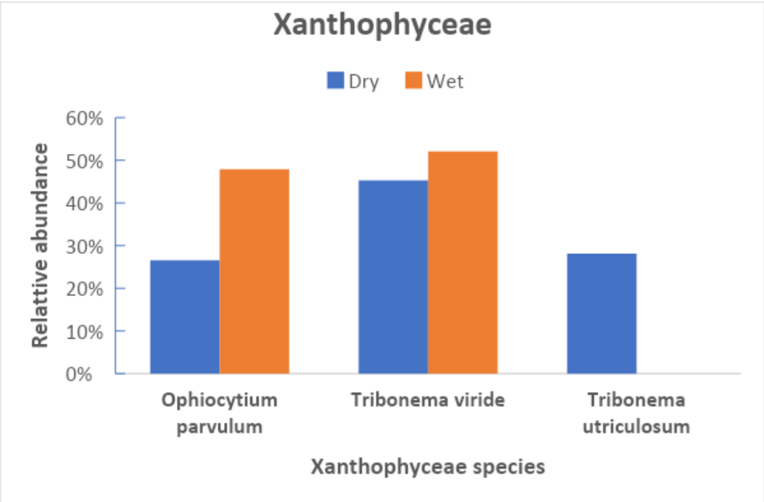


Fig. 27. Relative Abundance of Phytoplankton (Xanthophyceae) species

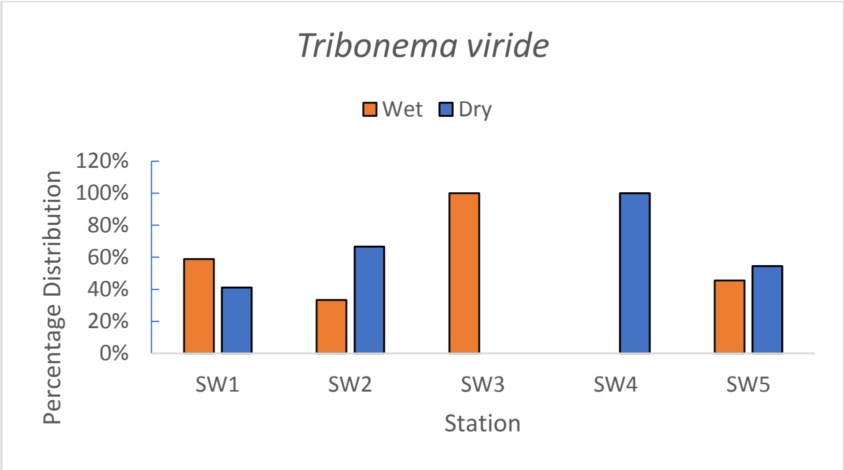


Fig. 28. Seasonal Percentage (%) Distribution and Abundance of *Tribonema viride*

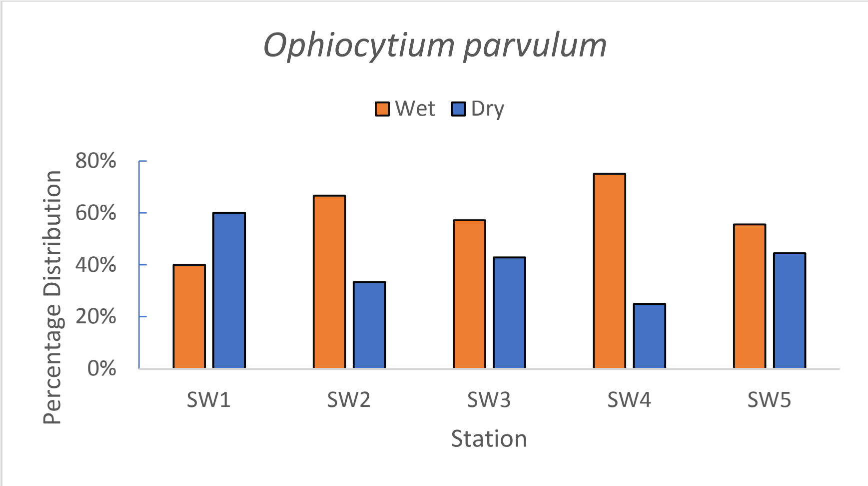


Fig. 29. Seasonal Percentage (%) Distribution and Abundance of *Ophiocytium parvulum*.

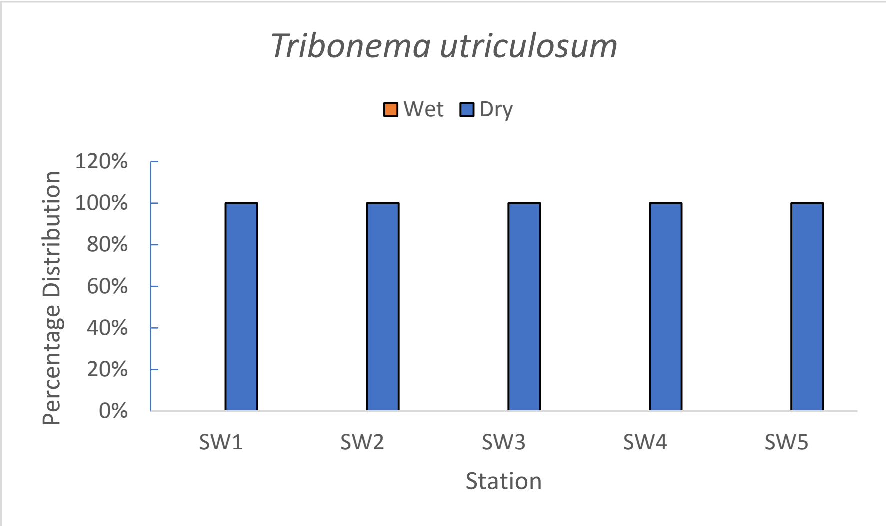


Fig. 30. Seasonal Percentage (%) Distribution and Abundance of *Tribonema utriculosum*.

The least in terms of dominance is the Xanthophyceae, members of the family include *Tribonema species, Ophiocytium parvulum* (Fig 27)

There was no significant difference in the seasonal variation of the different species of phytoplankton except for *Volvox aureus* which showed a significant decrease in the dry season. The wet season experienced a significant difference in the variation of *Carteria multifilis* and *volvox aureus* species of phytoplankton. Overall, the dominant pattern of the various classes of phytoplankton in the aquatic systems around oshika lake is in the order of chlorophyceae > bacillariophyceae > cyanophyceae > xanthophyceae. Phytoplanktonspecies composition and diversity areknown to change with environmental conditions such as nutrient levels, temperature, light, predator pressure, etc. The relative importance of these factors varies considerably among the different taxa and ecosystems [20]. Under conditions of nutrient enrichment or eutrophication, the bacillariophyceae are known to proliferate [21,22].

3.2 Cluster analysis for 1983 and 2019 Phytoplankton Species

Figure 31 and 32 shows the seasonal cluster of phytoplankton in the study area for 2019 and 1983. Three groups of clusters were identified in 2019 as follows: the dry season specialist (x), the wet season specialist (*), and the generalist

(#) – those that occurred in the wet and dry season. Two group of clusters were identified in 1983 the generalist (x) and the dry season specialist(Y). The 2019 dry season specialist had 10 species such as *Eudorina illinoisensis, Gonium pectoral, Gonium sociale, Oscillatoria limosa, Spirulina princeps, Phormidium mucicola, Tribonema utriculosum, Meridion cyclare, Melosira varians,* and *Gyrosigma sp;* the wet season specialist had two species such as *Rivularia planctenica* and *Cosinodiscus lacustris;* while the generalist had 12 species such as *Chlorogonium elegans, Carteria globose, Carteria multifilis, Chlamydomonas ovalis, Volvox aureus, Volvox globator, Spirogyra sp., Ucothrix sp, Oscillatoria tenuis, Spirulina major, Tribonema viride* and *Ophiocytium parvulum.*

While the 1983 dry season specialist yielded 4 species namely: *Cyclotella, Diatom, Dinobryon and scenedesmus*; the generalist yielded 13 species out of which 3 were common to both the 2019 and 1983, they are *Ucothrix sp, Oscillatoria tenuis, Volvox (aureus, and globator).* The remaining species are *Cosinodiscus, Melosira, Navicula, Nitzchia, Synedra, Ankistrodesmus, Closterium, Cosmarium, Nicrasteria, and Phacus.* The *Cosinodiscus,* and *Melosira* species that occurred in 1983 as generalist was identified as wet season specialist and dry season specialist in 2019 respectively.

3.3 Community Structure

The community Structure was determined using diversity indices namely the Shannon–Wiener diversity (*H′*), Specie Eveness, Margalef Index (d) of richness, and Similarity index. These diversity indices for phytoplankton, zooplankton and benthos were calculated for the 2019 and 1983 dry and wet seasons for study, and the seasonal variation of the diversity indices for phytoplankton, zooplankton, and benthos are shown in Table 2.

3.4 Phytoplankton Diversity

The Shannon–Wiener diversity (H′) for the phytoplankton was highest in the dry season for both the 1983 and 2019 studies 2.563 and 2.851 lowest in the wet season, 2.381 (Fig 33). Phytoplankton species richness was highest in the wet seasons for 1983 and 2019 (0.2010 and 0.179) and lowest in the dry season (0.162) (Fig 34). The species evenness for the phytoplankton was highest in dry season 0.452 for 2019 and in 1983 it was higher in the wet season (0.428) (Fig 35).

3.5 Similarity Index

The similarity index results showed that the Phytoplankton had an index of 0.1. This shows the sites still have the same composition of organisms.

3.6 Phytoplankton Similarity

The 2019 study results of phytoplankton abundance for dry and wet seasons were used to compare past Oshika lake EIA study results from similar dry and wet seasons in the year 1983 (Table 3). From the study, 3 classes of Phytoplankton were common: Chlorophyceae, Bacillariophyceae, and Cyanophyceae to both the 1983 and 2019 study, Xanthophyceae a class that was absent in the 1983 study was identified in the 2019 study. A higher number of phytoplankton were observed in the dry season than in the wet season in both the 1983 and 2019 studies (Figs 36 and Fig. 37). This is consistent with the previous studies [23,24]. The 1983 study results for the Cyanophyceae, Chlorophyceae, and Bacillariophyceae were higher than the results obtained in the 2019 study. The order of occurrence for the Phytoplankton in the 2019 study is Chlorophyceae>Bacillariophyceae>Cyanophyceae> Xanthophyceae, while the 1983 study occurred in this order Chlorophyceae>Cyanophyceae>Bacillariophyceae. The Chlorophyceae was the dominant class in the 2019 study, this observation was consistent with the Oshika Lake environment before the oil spill. [25]. In the 1983 study, the Cyanophyceae was the dominant class. The increase in Chlorophyceae in the 2019 study is in fact due to the relative decrease in Cyanophyceae, which in turn could be due to the decrease in predators [25]. Chlorophyceae has been reported to be the most abundant group in Nigeria freshwater [26,27,28].

The following species Ulothrix, Volvox, and Spyrogira were identified in both studies. Some new species identified in the 2019 study that was not present in 1983 include Chlorogonium, Carteria globosa, Chlamydomonas ovalis. Also, some species identified in 1983 were not seen in the 2019 study they include *Closterium, phacus, cladophoera*. The Oscillatoria is the common species that were identified in both studies for the Cyanophyceae class. A total of 13 species of Bacillariophyceae was identified in 1983, whereas in the 2019 study 3 species were identified. *Melorisa* is the specie common in both studies.

In all, there was a significant difference in the abundance of Chlorophyceae and Cyanophyceae between the 1983 and 2019 studies in the dry season. Whereas, for the wet season no significant difference was observed in the abundance of Chlorophyceae, Bacillariophyceae, and Cyanophyceae between the 1983 and 2019 study.

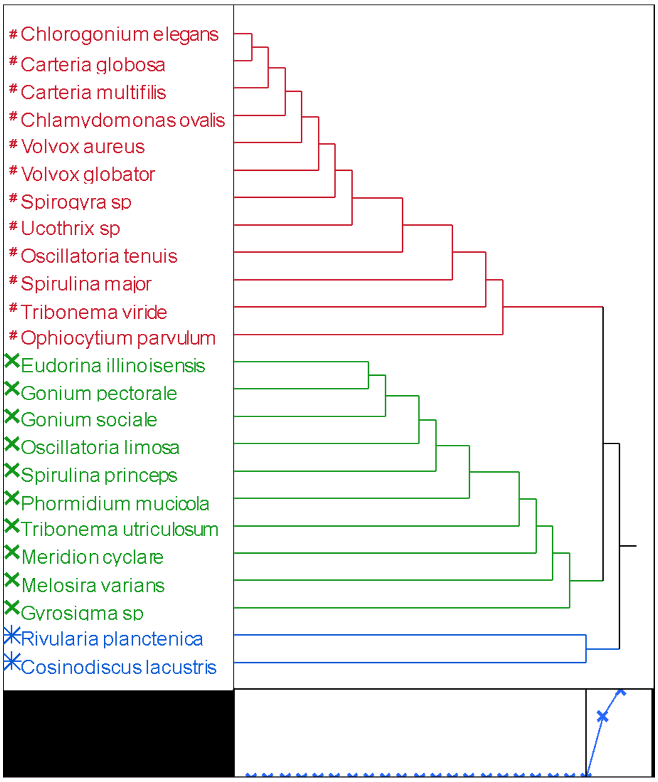
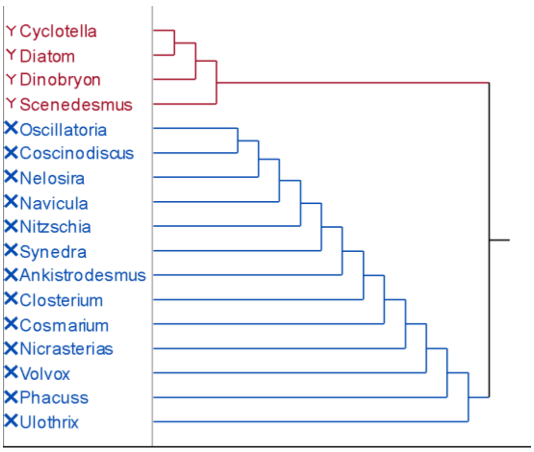


Fig. 31. **2019 Hierarchical clustering analysis showing the association of Phytoplankton Species in dry and WET SEASONS**



x-generalist, y-dry season specialist

Fig. 32. **1983 Hierarchical clustering analysis showing the association of the Phytoplankton Species in dry and wet seasons**

Table 2. Diversity Indices for 1983 and 2019

Diversity Indices	1983		2019	
	Dry	Wet	Dry	Wet
Phytoplankton				
Shannon Diversity Index	2.563	2.123	2.815	2.381
Species Richness	0.119	0.201	0.16	0.178
Species Evenness	0.306	0.428	0.452	0.425
		Zooplankto n		
Shannon Diversity Index	1.839	1.425	2.907	2.445
Species Richness	0.147	0.118	0.167	0.186
Species Evenness	0.209	0.217	0.454	0.483
		Benthos		
Shannon Diversity Index	-	2.699	2.658	2.027
Species Richness	-0.223		0.232	0.325
Species Evenness	-0.603		0.616	0.659

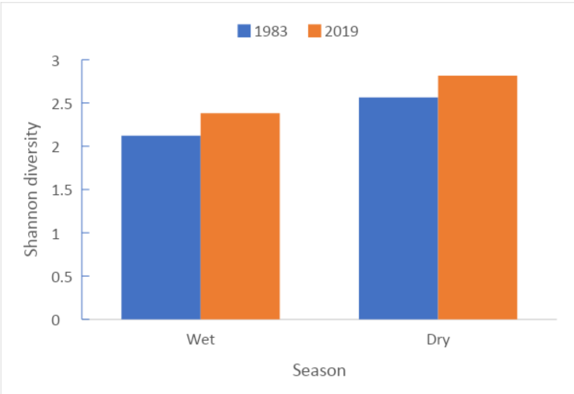


Fig. 33. The Phytoplankton Diversity for 1983 and 2019

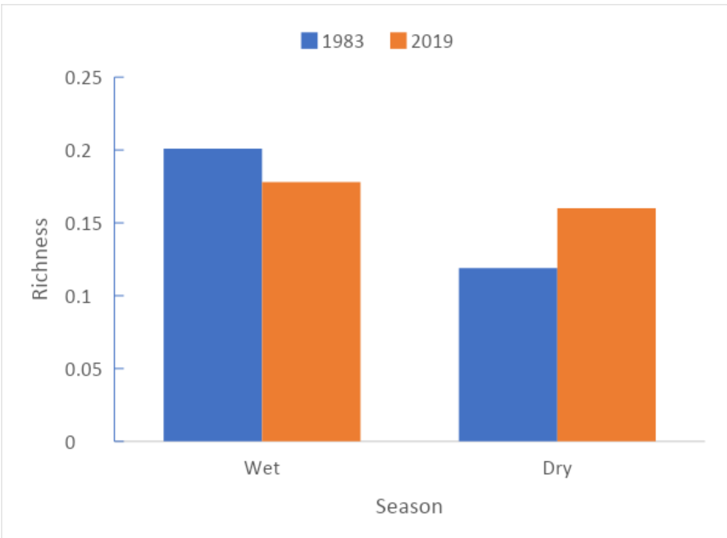


Fig. 34. The Phytoplankton Richness for 1983 and 2019

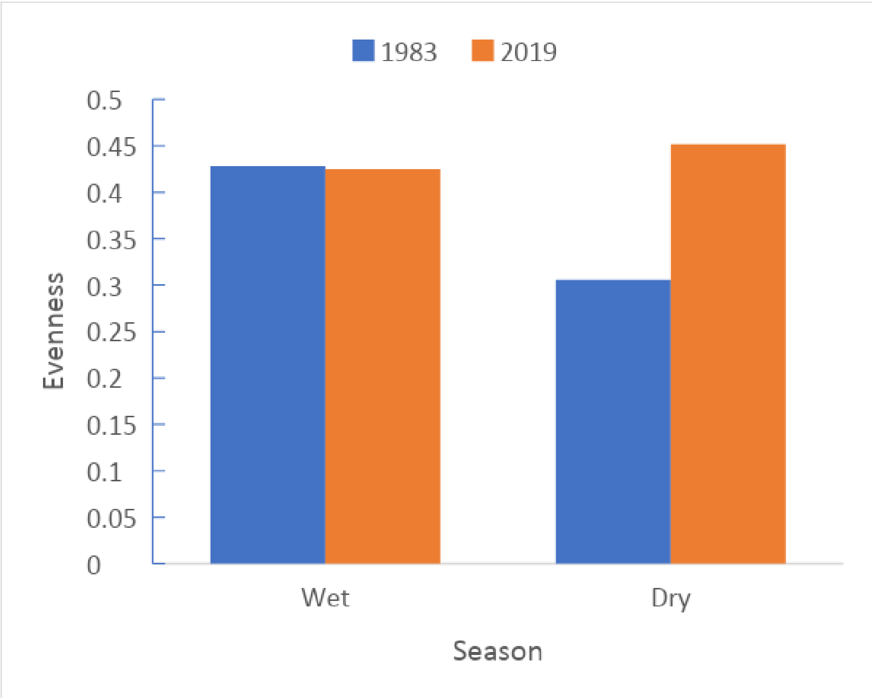


Fig. 35. The Phytoplankton Evenness for 1983 and 2019

Table 3. Mean Values of Phytoplankton in 1983 and 2019 Oshika Studies

Groups	Dry Season 1983	2019	Wet Season 1983	2019
Chlorophyceae	186.5±119.23 [b]	6.58±1.05[a]	12.31±25.88 [a]	1.27±0.57 [a]
Cyanophyceae	176±269.84[b]	1.53±0.58 [a]	3.96±2.04 [a]	3.76±0.41 [a]
Xanthophyceae	-	1.73±1.02	-	1.5±0.84
Bacilariophyceae	175.88±118.96 [a]	2.60±1.55 [a]	3.34±2.48 [a]	5.2±2.04 [a]

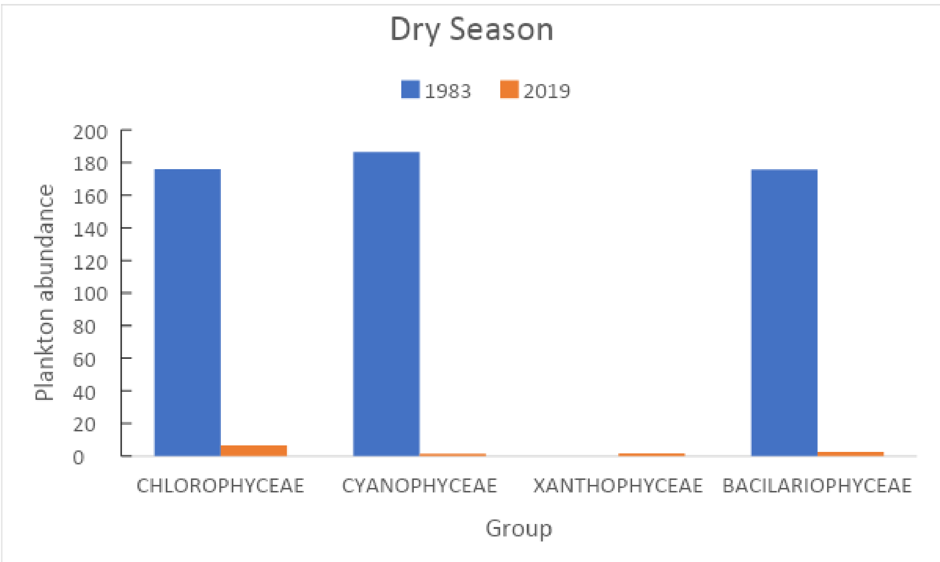


Fig. 36. Long Term Changes of Phytoplankton abundance (Dry Season)

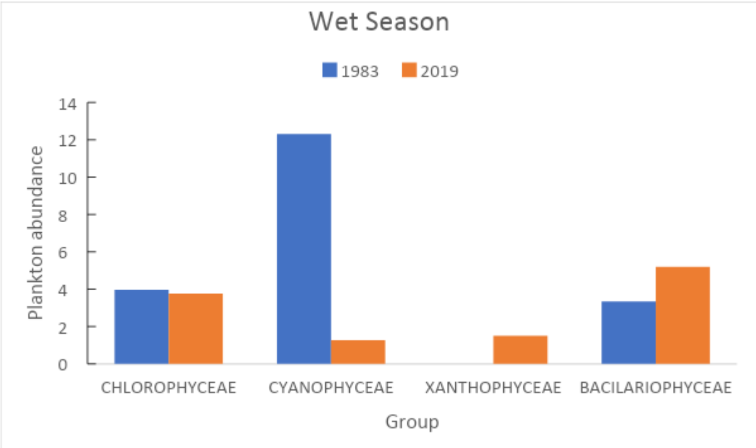


Fig. 37. Long Term Changes of Phytoplankton abundance (Wet Season) Chi Square Test

Table 4. Coefficient of Variation between 1983 and 2019 Phytoplankton Classes

Class	1983 (%)	2019 (%)
Chlorophyceae	247.7	32.4
Cyanophyceae	132.1	36.9
Xanthophyceae		43.8
BAcillariophyceae	144.7	59.8

Results of the test between the observed (1983) and the expected (2019) levels of Chlorophyceae, (2.38356E-37). Cyanophyceae (5.89319E-44), and Bacillariophyceae (1.01105E-39) were significantly different ($p<0.05$).

3.7 Coefficient of Variation

The results of the coefficient of variation for the Phytoplankton between the 1983 and the 2019, showed that there was a higher variation in the data set from the 1983 study (Table 4). Chlorophyceae recorded variations of 247.7% and 32.4% for the 1983 and 2019 studies respectively; Cyanophyceae recorded variations of 132.1% and 36.9% for the 1983 and 2019 studies respectively and Bacillariophyceae recorded variations of 144.7% and 59.8% for the 1983 and 2019 studies respectively.

4. DISCUSSION

The study showed that in the phytoplankton community there were a higher number of species in 1983 compared to 2019. In terms of species turnover, the similarities between assemblages show three major classes of phytoplankton namely Chlorophyceae, Bacillariophyceae, Cyanophycae to be common in both shortterm (1983) and longterm (2019) studies. The similarity was also observed in the dominance of Chlorophyceae in both studies. The dissimilarity was observed in the occurrence of Xanthophyceae in the 2019 study. In addition, the dissimilarity in the abundance of the different classes was evident wherein 1983 the order of abundance was Chlorophyceae>Cyanophyceae>Bacillariophyceae, while in this study the order was Chlorophyceae>Bacillariophyceae>Cyanophyceae> Xanthophyceae. tropical lakes [23, 29] where Cyanophyceae is known to be more abundant than the other classes of algae. This study however agrees with Ogamba et al [30] who sampled Taylor creek from Polaku to Agbia and observed Chlorophyceae and Bacillariophyceae as the most abundant phytoplankton groups. Similar trends in the abundance of Chlorophyceae and Bacillariophyceae groups were also reported by Abowei et al. [26] and Ogbuagu et al. [31] in Koluama River, Bayelsa State, and Imo River, respectively. Still, yet other deviations were reported by Ibiebele *et al*. [25] for this study site which showed that the Bacillariophyceae was the most abundant phytoplankton in both seasons.

In the analyses of the dominant Chlorophyceae class the species turnover was high (78%) where out of a total of eighteen species in both studies only four species namely *Ucothrix* sp, *Oscillatoria* *tenuis*, *Volvox aureus*, and *Volvox globator* were co-occurred consistently. The species turnover for Baccilarophycae was also as high as 78% with only two species namely *Cosinodiscus lacustris* and *Melosira varians* co-occuring consistently in the two studies out of nine species. In this study, the class Xanthophycae which occurred with three species only in the 2019 study also represents an element of species turnover. The interpretation of the high species turnover cannot be easily correlated to the event of the oil spill since this area also experiences extreme events of annual water-level fluctuations. Flooding is known to be wide from the River Niger and lasts for periods ranging from 30 days to 90 days per year [32]. Flooding is known to be high because of the connections through a maze of braided systems. Even so understanding of how extreme flooding variation influences plankton mechanisms remains limited.

In contrast to the likely influence of annual water variation on species turnover through time, the diversity measures were weakly related to the response to floods. This is because the Shannon–Wiener diversity (H′) for the phytoplankton was consistently highest in the dry season for both the 1983 and 2019 studies and lowest in the wet season. This observation corresponds with reports of other ecologists in the freshwaters of Nigeria, Onyema [33]; Onyema *et al.* [34]; Onyema and Nwankwo [35] in Iyagbe Lagoon Lagos State, as well as the 1983 Oshika oil spill study [25]. Onyema in [34] proposed that the reduced phytoplankton diversity in the wet season could be a result of the flushing of the phytoplankton algal during the rains by floodwater towards the river. The species evenness for the phytoplankton was highest in the dry season for 2019 and in 1983 it was higher in the wet season.

Seasonal variation of the population composition and abundance of phytoplankton is commonly understood to be influenced by the dynamics of water circulation, nutrient concentrations, rainfall patterns, location, and the nature of the physical environment which differ mostly with the dry and wet seasons in tropical waters [36,37]. The Chlorophyceae was the most abundant class in both 1983 and 2019. Xanthophyceae. a class that was present in 2019 was absent in 1983, and this composition conforms with observations made in other studies [38.39].

The variation for the Phytoplankton between 1983 and 2019, showed that there was a higher variation in the 1983 organisms from the study compared to the 2019 study. The order of occurrence for the Phytoplankton in the 1983 study is in this order Chlorophyceae>Cyanophyceae>Bacillariophycea e, while the 2019 study occurred in is the order of Chlorophyceae>Bacillariophyceae> Cyanophyceae> Xanthophyceae, The abundance of phytoplankton in Oshika lake showed seasonal variations. Cyanophyceae is known to be more abundant than the other classes of algae in most shallow, tropical lakes [23],30] This was not the case, for the 1983 and 2019 Oshika Lake results, Chlorophyceae was the most abundant phytoplankton class. This agrees with the studies of Ogamba et al 2019, who sampled Taylor creek from Polaku to Agbia and observed Chlorophyceae and Bacillariophyceae as the most abundant phytoplankton groups. Similar trends in the abundance of phytoplankton groups were also reported by Abowei et al. [26] and Ogbuagu et al. [32] in Koluama River, Bayelsa State, and Imo River, Etche Local Government Area, Rivers State, Nigeria respectively. The decrease in Cyanophyceae is in fact due to a relative increase in Chlorophyceae, which could, in turn, be due to a decrease in predators [15]).

This observation is in contrast to the findings in the Oshika lake 1987 which showed that the Bacillariophyceae was the most abundant phytoplankton [25]. The abundance of the Bacillariophyceae during the wet season according to the Oshika report is consistent with general ecological observations that Bacillariophyceae are increased in fast-flowing water and decrease in sluggish water [25].

The most abundant species of phytoplankton for both the 1983 and 2019 studies belong to the Chlorophyceae class. Three keystone species were identified to be common in 1983 and 2019, they are Ucothrix sp, Oscillatoria tenuis, Volvox (aureus, and globator). The Cosinodiscus, and Melosira species that occurred in 1983 as generalist was identified as wet season specialist and dry season specialist in 2019 respectively.

In the current study species observed during the dry season to be most abundant were *Volvox aureus, Volvox globator*, and *Carteria multifilis,* and for the wet season Chlorogonium elegans. The least abundant species observed during the wet season was *Rivularia planctenica* which belongs to the Cyanophyceae class. This implies that the green algae are mostly freshwater forms that may not tolerate the eutrophic or polluted conditions.

It follows then that in this study given the longterm between 1983 and 2019 the planktonic community observed are the result of natural variation since the hydrocarbon values in water were very insignificant. Since the lake-riverine system is subject to flooding it can be concluded that new plankton from unaffected areas is transported into this area during the flood. The mixing of the water over the years leads to the high variable change and high species turnover given the unrestricted hydrodynamics of the River Niger flooding system and its influence on the floodplain Oshika lake.

5. CONCLUSION

The study revealed that there were changes in the phytoplankton community structure between 1983 and 2019. These changes cannot be linked to the oil spill but seems more likely a result of natural variation since results of studies on the hydrocarbon values in water were very insignificant [40]. Since the lake-riverine system is subject to flooding it can be concluded that new plankton from unaffected areas are transported into this area during the flood. The mixing of the water over the years leads to the high variable change. The high variable change brings about high species turnover given the unrestricted hydrodynamics of the River Niger flooding system and its influence on the floodplain Oshika lake.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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