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(Research Article)

Phytoplankton community of the Isaka-Bundu waterway in Rivers State, Nigeria; A polluted tidal mangrove wetland

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Abstract

This study aimed to investigate the composition, abundance, distribution, and diversity of the phytoplankton community of the Isaka-Bundu waterway in Rivers state, which is a polluted tidal mangrove wetland. Phytoplankton was collected bimonthly from July to December 2021 at high tide from four stations according to APHA methods. The species diversity was calculated using standard indices. The total composition of 334 individual phytoplankton was identified in the 3 stations and control. The total composition of 220 species from 5 Phylum was recorded. This observed decrease in the species diversity and richness could also be attributed to changes in environmental variables due to pollution resulting from industrial effluent discharge into the river which has adversely affected the aquatic biota. Based on these activities, there is an urgent need to carry out a regular study on the phytoplankton community that supports its fisheries in this aquatic environment. The results of this study indicate the characteristic species and compositions of phytoplankton in the Isaka-Bundu waterway in Rivers state. The species abundance and distribution are a confirmation while the composition, and diversity gave an insight into the adverse effect of these cumulative activities. The result showed that the Isaka-Bundu waterway had been extremely polluted.

Keywords: Artisanal refinery; Isaka-Bundu; Pollution; Mangrove wetland; Phytoplankton

1. Introduction

The aquatic environment is exposed to different kinds of effluent discharged from industries, sewage treatment plants, and drainages from urban and agricultural areas [1]. Discharges from municipal and industrial sources of sewage and the drainage of agricultural and urban areas are all disposed of in aquatic environments [2]. In addition to causing damage to aquatic life, these pollutants can also cause an imbalance in the composition of plankton [3]. Due to anthropogenic activities like those described above, there is a risk of an imbalance in the population and distribution of plankton, and consequently, damage to the resources that depend on them for their existence [4]. The composition of plankton has a direct impact on the trophic levels of plankton feeders, such as commercial fish [5].

However, phytoplankton and zooplankton communities are microorganisms that live at the first and second lower trophic levels, and the health of the aquatic ecosystem depends on the plankton colonies as plankton play an essential role as part of the food chain [6]; [7], Since phytoplankton are primary producers for the aquatic food web, they can use the sun's energy to transform air into sugars, and thus provide food for zooplankton and other aquatic creatures such as fishes that are also eaten by other animals and mammals [8]; [9]. Discharges such as these, particularly from industries, contain heavy inorganic metals [10].

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In recent times, it has become more challenging to maintain the quality of the aquatic ecosystem [11]. The introduction of a contaminant into an environment is called Pollution [12]. Water pollution is the introduction of contaminants by physical, chemical, disease-causing microbial agents or radioactive agents to the natural water body [13]. According to [14], some pollutants naturally enter the river system e.g., natural fires, volcanoes and oil and gas seeps, etc. The coastal and brackish water environment is usually known by large industrial settlements and urban areas by the impact of effluent discharge which causes the accumulation of heavy metals [15].

The brackish water environment is being endangered by discharges of untreated wastes and industrial effluents. This eventually causes harm to the sustainability of the living resources and public health. The waste transports a high level of toxicants, especially the metals which can accumulate in the basic food chain like the planktons and also move up to the higher trophic level. The Niger Delta region has a network of streams and tributaries connecting, of which the rivers are the major source of potable water for many towns and villages [16]. The area surrounding the creek has been urbanized and industrialized due to the quest for crude oil, gas, and other natural resources. The effluents discharged from human waste, pipeline leakage, accidental discharges, discharges from refineries, and sabotage (illegal bunkering) loading activities may be detrimental to the quality of the creek. This baseline information is crucial in identifying the special and seasonal pattern of the plankton, benthos, and benthic fauna, assemblage and the creation of an independent database for future research in this study area.

2. Material and methods

2.1. Description of the study area

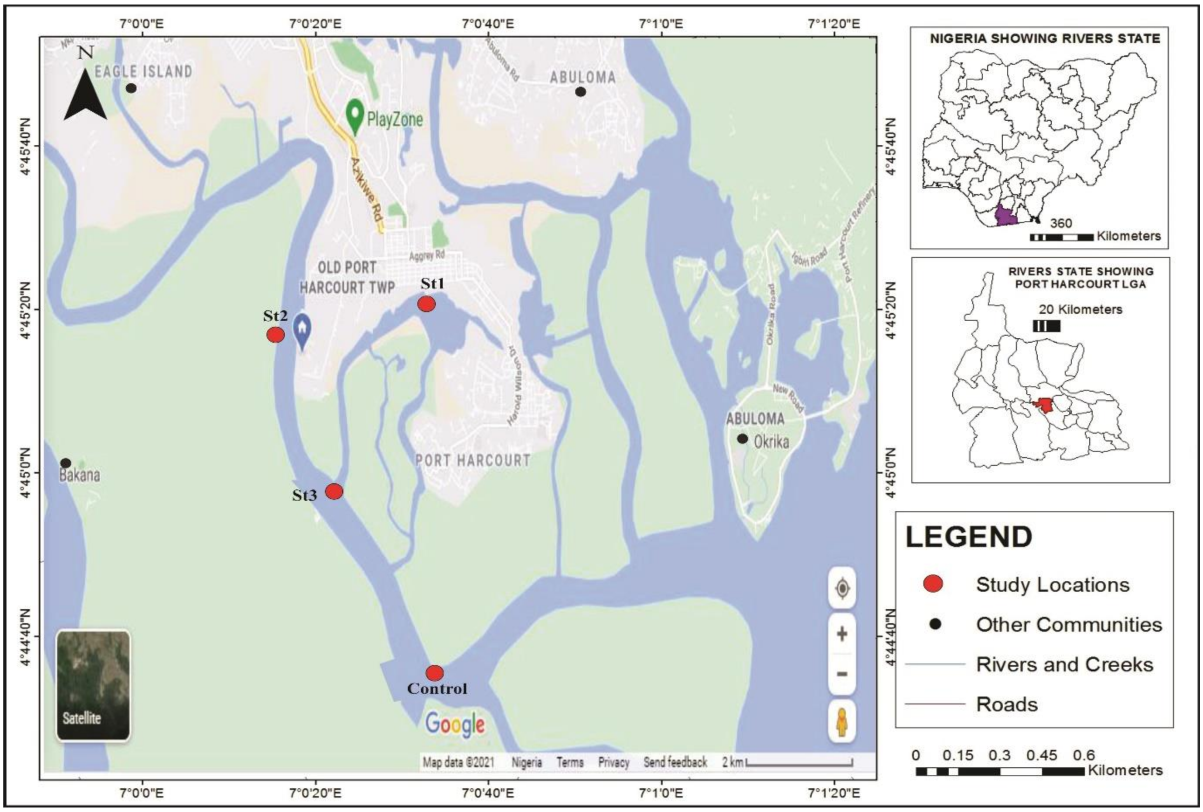

Figure 1 Map of study areas

The Isaka-Bundu ama waterfront in Rivers state is a polluted tidal mangrove wetland that is a tributary of the upper Bonny Estuary in the Niger Delta. It is a tidal soft-bottom ecosystem exposed to a wide range of mudflats. It is Nigeria. The sampling stations were at least 1,000 meters apart. The sampling stations were geo-referenced and selected specifically to cover study areas of the creek receiving effluents and wastes from different anthropogenic activities of the area; Station 1: 4°45'11.0"N 7°01'02.2"E (Bundu), Station 2: 4°45'06.3"N 7°00'12.3"E (Ibeto waterfront), Station 3: 4°44'13.9"N 7°00'14.8"E (Isaka waterfront), and Station 4: 4°45'23.8"N 7°00'10.5"E (Dockyard waterfront) as shown in (Figure 1). These creeks system consists of the main channel and associated feeder creeks linking different neighbouring communities. Effluence from Illegal refining sits, artisanal channelization, domestic dumps, bunkering activities, sand dredging, and runoffs are evident on the shorelines with residents for artisanal fishing ports with different water-related activities like commercial water transportation, industrial activities, and oil, and gas logistics operations are within the shores of the creeks. The vegetation such as the red mangrove (*Rhizophora mangles*) and white mangrove (*Laguncularia racemose*) are predominant in the area. Some of the dominant fish families such as Lutjanidae, Clupeidae, Cichlidae, and the Claroteidae, but the most abundant species are the Claroteidae (silver catfish) and Cichlidae (tilapias). Few other species such as gobies, mudskippers, periwinkles, and crabs, only to mention a few are also present.

2.2. Samples and Sampling Techniques

2.2.1. Plankton Composite

Phytoplankton composite samples were collected quantitatively by filtering 50litres of water through a 55µm mesh size Hydrobios plankton net. All samples (concentrated to 100ml) collected for phytoplankton analysis were preserved in Lugol's iodine, while samples collected for Zooplankton were preserved in 4% buffered formaldehyde in a sample bottle. In the laboratory, the Zooplankton and Phytoplankton samples were thoroughly examined and counted using an Olympus® binocular microscope with a calibrated eyepiece at different magnifications (5 X, 10 X, and 40 X). Direct plankton counts were done using the drop count method. Taxonomic identification was carried out as far as possible, to identify organisms to the highest practicable level.

2.2.2. Determination of species abundance/dominance Index (SIMPSON)

The species abundance/Density was determined using Simpson's dominance index using the following equation:

$$C = \sum \left(\frac{n_i}{N}\right)^2$$

Were

n_i = the no. of individuals in the species

N = the total no. of individuals.

Determination of Species Diversity Indices (d), and Productivity

This is also known as the species diversity/richness index. The species richness was given by the equation.

$$d = \frac{S - 1}{\text{In N}}$$

Where d = Margalef richness index of species diversity index

S = Number of species in the population

N = Total number of individuals in species.

The results of the species diversity, species richness, species dominance, and species evenness index are presented in Table 2 for all sampled stations. During the study, the diversity was low across the station with the diversity index of 3.137, 3.059, 2.481, and 2.885 for the control, stations 1, 2, and 3. However, 5.936, 4.979, 3.938, and 5.166 for the species richness index for the control, stations 1, 2, and 3 were observed. The species evenness index value of 0.974, 0.975, 0.916 and 0.948 for the control, Stations 1, 2 and 3 respectively while the species dominance were 0.046, 0.05, 0.1 and 0.068 for all stations. There were no significant differences ($P<0.05$) for the diversity Indices between stations 1 and 2; stations 3 and 4 as well.

The variation observed could probably be attributed to the uniformity and stability of the physicochemical conditions of the environment [17; 18; 19]. However, the diversity indices were higher in the control with station 2 showing the least. This was similar to the situation in the Cross River where the diversity and species richness also shows significant variations [20]. The high diversity in the control and station 1 could be attributed to increased stability of the environmental factors during the study, especially sunlight, which may have led to a more stable increase [21]. [22] Reported that species diversity indices often reflect the impact of pollution on aquatic communities. The higher species diversity in this study revealed by the Shannon-Wiener and Margalef's richness indices could be a reflection of the increased number of the individual phytoplankton species. The lower values recorded in stations 2 and 3 of the biotic indices reflect the occurrence of reduced species diversity during the study season.

However, [23] stated that hydrologic and climatic factors were the most important factors structuring the zooplankton community. The hydrogeomorphic differences between the stations probably may have accounted for the differences observed, and that differing hydrogeomorphic patches generate divergent ecological processes and patterns, that influence plankton dominance patterns, and induce differences in plankton community structure and dynamics between creeks and rivers. This agrees with [24] who stated that most rivers around the world are progressively more eutrophic from point and non-point pollution sources, due to urbanization, agricultural and industrial activities, and improper disposal of domestic organic wastes, the higher abundance of species in the control can be associated with stability in the environmental parameters and nutrient availability [25]

3. Results and discussion

3.1. Phytoplankton Species Composition, Relative Abundance Distribution, and Diversity

The study revealed the total composition of 334 individual phytoplankton identified in the 3 stations and control (Table 1). The total composition of 220 species from 5 Phylum was recorded. The dominant and most prevalent phylum was the Baccilariophyta has a high number of individuals (125) and comprises 80 species in the control, 73 in station 1, 45 species in station 2, and 55 species in station 3. The Cyanophyta has a low number of individuals (33) which comprises 13 species in the control, 17 in station 1, 1 specie in station 2, and 3 species in sstation3. Chrysophyta recorded a significantly low number of individuals (7) which comprises 2 species in the control, 0 specie in station 1, 0 specie in station 2, and 5 species in the station. Chlorophyta has a total composition of 20 species which comprises 3 species in the control, 6 species in station 1, 2 species in station 2, and 9 species in station 3. Pyrrophyta was composed of a total number of individuals (16) which comprises 6 species in the control, 1 specie in station 1, 2 species in station 2, and 8 species in station 3. Other Phyla such as Chlorophyta, Cyanophyta, Chrysophyta, and Pyrrophyta recorded very low occurrence with Chrysophyta as the least with 0 specie in stations 1 and 2. The phytoplankton composition in the study area was contrary to that in Elechi Creek, where only 5 phytoplankton taxa namely: Bacillariophyceae (diatoms), Cyanophyceae (blue-green algae), Euglenophyceae (euglenin), Chlorophyceae (green algae) and Dinophyceae (dinoflagellates) were recorded.

This total composition of 334 individual Phytoplankton identified in the 3 stations and control was high and in agreement with the findings of [26] in Owena River of Ondo State, and [27] in Okpokwu River of Benue State. It was however incomparable to that of [25] and [28]. This result was also higher than the recorded 42 species from 4 families of phytoplankton, consisting of the Bacillariophyceae, Chlorophyceae, Chrysophyceae, and Xanthophyceae only reported by [29], in the Sombrero River. The phytoplankton composition in the study area was contrary to that in Elechi Creek, where only 5 phytoplankton taxa namely: Bacillariophyceae (diatoms), Cyanophyceae (blue-green algae), Euglenophyceae (euglenin), Chlorophyceae (green algae) and Dinophyceae (dinoflagellates) were recorded. [25], reported that environmental influences like high temperature, low pH, transparency, and dissolved oxygen were directly responsible for increased species availability. The high temperature during the dry months enhances photosynthesis. Also, low pH makes nutrients (such as phosphate and nitrate) available to the primary producers, and high nutrient status (phosphate, nitrate, and sulphate) stimulates phytoplankton growth.

[30], attributed this trend to increased water transparency, high temperature, chemical nature of the creek, decrease in water level, and nature of input into the river which could lead to an increase in the biomass of planktons except for station 2 which reported the least. [31] Attributed the higher number of individuals recorded across the different stations to turbulence in the movement of the water bodies, which could enhance an increase in population. Furthermore, the composition shows that in all stations during the study, Bacillariophyta was the dominant phylum. This agrees with the findings from some studies in the Niger Delta basin such as, in the Elechi Creek [25], and the Sombrero River [32]. According to [33], phytoplankton in lotic environments is directly regulated by hydrophysical factors. Also, the phytoplankton species occurrence and dynamics in rivers are mainly shaped by hydrophysical conditions and nutrient availability [34].

The relative abundance as shown in Table 4, revealed that the Phylum Bacillariophyta recorded the highest numerical abundance with a total of 334 Phytoplankton individuals, and a relative abundance of 77%, followed by Cyanophyta with 33 individuals and a relative abundance of 10%, Chlorophyta with 20 phytoplanktons and relative abundance of 6%, Pyrrophyta with 16 individuals and a relative abundance of 5% while Chrysophyta was the least abundant with individuals 7 and a relative abundance of 2% from an abundance of a total 334 individuals (100%), of Phytoplanktons in the various Phylum (figure 2). The analysis of variance between the stations and the control as shown in Table 4, revealed a significant difference in the relative abundance of the phytoplankton community across the stations with the control far higher numerically than the other three stations.

Firstly, the total numerical abundance of the Phytoplankton Community in the sample stations exceeded that of the Phytoplankton community numerical abundance in others reported by [35]. This higher numerical abundance in the control was comparable to the findings of [36] and [37]. The study showed spatial variations in phytoplankton abundance, where the relative abundance of the phytoplankton families recorded varied greatly, with more species in the control. This agrees with studies by [38] who reported a similar trend. While the low abundance of species in stations 1, 2, and 3 as compared to the control could be likened to the collapse of the phytoplankton community [34];[39]. [40] Attributed it to the significant dilution of essential growth nutrients for biotic communities during annual episodic flooding periods, at the peak of rainfall, between August and November. [41] Reported it to be a result of the high-water discharge, turbidity, and suspended solids, decrease in water temperature, deteriorating physiological status of diatoms due to prolonged poor light conditions resulting from low transparency, and wash-out enhanced algal loss during turbulent periods. Such conditions retard phytoplankton development, and species loss in situations like these overwhelms recruitment [34].

Low pH makes nutrients such as phosphate and nitrate available to the primary producers, and high nutrient status (phosphate, nitrate, and sulphate) stimulates phytoplankton growth at the control. This composition was high and in agreement with the findings of [42] in Ondo State and [43] in Orashi River of Rivers State. It was however incomparable to that of [41] and [44] in the Nasarawa reservoir. This was higher than the recorded 42 species from 4 families of phytoplankton, consisting of the Bacillariophyceae, Chlorophyceae, Chrysophyceae, and Xanthophyceae only reported by [36], in the Sombrero River. The phytoplankton composition in this study area was compared to that in Elechi Creek, where only 5 phytoplankton taxa namely: Bacillariophyceae (diatoms), Cyanophyceae (blue-green algae), Euglenophyceae (euglenin), Chlorophyceae (green algae) and Dinophyceae (dinoflagellates) were recorded. This conforms to several studies in the Niger Delta Area such as those of [39] and [30].

The results of the Shannon-Wiener diversity index, Margalef's species richness index, and Pieolu Evenness index are presented in Table 4 for the sampled stations. During the study, the diversity was low with the values for the Shannon-Wiener diversity index being; 3.687, 3.322, 3.002, and 3.625 for the control, station 1, 2, and 3 However, 10.099, 7.351, 6.613, and 9.467 for Margalef's species richness index for Station 1, 2 and 3 were observed and finally Pieolu's Evenness index value of 00.953, 0.934, 0.911 and 0.90.97 for the control, Stations 1, 2 and 3 respectively. These indices were slightly similar for all stations 1, 2, and 3.

There were significant differences ($P<0.05$) for the diversity Indices across the station. This minimal variation is probably due to the uniformity and stability of chemical and physical conditions of the environment [33]; [36]. However, the diversity indices were higher in the control than those of the other sample stations. This was similar to the situation in the Cross River where Shannon-Weiner diversity and species richness exhibit significant spatial variability, though values were higher during the dry compared to the rainy season [35]. The increased diversity could be attributed to the increased stability of the environmental factors during this season, especially sunlight, which leads to a more stable/increased temperature [36]. Also, species diversity indices often reflect the impact of pollution on aquatic communities. The higher species diversity in this study revealed by the Shannon-Wiener and Margalef's richness indices also is a reflection of the increased diversity of phytoplankton species. The lower values of biotic indices, therefore, reflect the occurrence of reduced species diversity during the wet season. [45], reported higher Margalef's diversities for phytoplankton biotypes in Some Ponds within Wilberforce Island, Rivers State.

Also, in the Cross River, [34] attained the lowest species richness, Shannon-Weiner diversity for all the stations during peak rainfall. This situation could be attributed to less stable to lowered environmental parameters such as lower salinity and temperature [46]. Also, this observed decrease in the species diversity indices in the other stations could be attributed to changes in the nutrient composition of the environment, due to pollution [20];[34] resulting from industrial effluent discharge into the river [47].

The phytoplankton biomass, species richness, and diversity observed during the study from the control could be attributed to favourable climatic and hydrologic conditions resulting from elevated temperature. Such conditions tend to encourage plankton development in rivers [48]. The reasons for such elevation in biomass are more solar irradiation and increased water retention time [33] and more directly, efficient utilization of light and nutrients, and reduced algal wash-out [35]. The higher species diversity and richness in the control as revealed by the Shannon-Wiener and Margalef's indices respectively were due to higher species composition observed in the station during the period of study while the lower Shannon-Wiener diversity and Margalef's indices in the other stations could be associated with lower salinity and temperature as reported by [38]. This observed decrease in the species diversity and richness could also be attributed to changes in environmental variables due to pollution resulting from industrial effluent discharge into the river.

Table 1 Variation and distribution of phytoplankton species at the various stations

Phylum	**Phytoplankton species**	**Control**	**Station 1**	**Station 2**	**Station 3**	**Total number of species**
Baccilariophyta						
	Bacillinia paradoxa	1	0	1	2	4
	Naviala amphibola	4	6	1	0	11
	Navicula amrupta	4	3	0	2	9
	Nitzschia paradoxa	1	2	1	2	6
	Thalassiosira eccentrica	2	1	8	1	12
	Coscinodus wailisii	3	2	0	3	8
	Coscinodus granii	6	5	7	1	19
	Coscinodus centralis	4	6	0	0	10
	Coscinodus asteromphalus	0	1	0	1	2
	Cyclotella stylorum	2	2	0	1	5
	Cyclotella striata	1	2	1	0	4
	Melosira nummuloides	3	0	4	0	7
	Melosira varian	1	1	0	0	2
	Diploneis litoralis	1	0	0	1	2
	Diploneis elliptica	3	5	2	1	11
	Paralia sulcata	2	1	2	1	6
	Fragilaria paradora	0	1	0	1	2
	Pleurosigma elongatum	0	0	1	0	1
	Pleurosigma strigosum	3	4	0	2	9
	Thalassiosira oestrupii	5	4	1	0	10
	Tabellaria floculisa	2	2	0	0	4
	Tabellaria fenestrate	1	0	0	1	2
	Cyclotella meneghiniana	1	0	1	0	2
	Pinnularia heniiptera	2	3	0	2	7
	Pinnularia braunii	1	0	0	2	3
	Pinnularia mesolepth	2	0	3	2	7
	Suirrella sulcata	2	0	0	2	4
	Suirrella fastuasa	1	2	2	1	6
	Gyrosigma attenuatum	1	2	1	1	5
	Cocconeis diminuta	0	1	0	1	2
	Achnauthes prominula	2	1	2	0	5

	Chactoceros	2	4	1	0	7
	Chactoceros compressus	0	0	1	0	1
	Nitzschia sigmisidea	2	0	1	2	5
	Odontella aurita	1	0	0	2	3
	Actinocyclus octonarius	2	2	0	1	5
	Coscinodiscus janischii	1	0	0	5	6
	Gyrosigma acuminatum	2	5	1	0	8
	Amphiphora	1	0	0	2	3
	Entonioneis sulcata	2	1	1	2	6
	Rhizosoleuia longiseta	3	3	0	2	8
	Triceratium broeckii	2	1	2	2	7
	Bacteriastrum hyalinum	1	0	0	3	4
	Fragilaria foma	0	0	0	1	1
	Total	80	73	45	53	251
Cyanophyta						
	Oscillatoria tenius	8	11	0	0	19
	Gloeotrichia echimicha	1	0	0	2	3
	Oscillatoria priceps	4	6	1	0	11
	Total	13	17	1	2	33
Chrysophyta						
	Dinoloryin divergen	1	0	0	2	3
	Dinoloryin cylindrueum	1	0	0	3	4
	Total	2	0	0	5	7
Chlorophyta						
	Pediastrum simplex	0	1	0	2	3
	Microthmnion	3	4	0	3	10
	Errerella bornhemlensis	0	1	0	1	2
	Planklosphaeria gelatinosa	0	0	2	1	3
	Chlamydominas	1	0	0	2	2
	Total	3	6	2	9	20
Pyrrophyta						
	Procentrum rhathymum	3	0	0	3	6
	Cryptomonas reflexa	1	1	1	0	3
	Procentrum gracile	0	0	0	1	
	Procentrum lima	2	0	1	4	7
	Total	6	1	2	8	16

Table 2 Diversity Indices of phytoplankton species at the various stations

Diversity Indices	Control	Station 1	Station 2	Station 3
Number of Taxa	39	35	27	42
Number of Individuals	105	102	51	76
Species richness (d) (Margalef's Index)	10.099	7.351	6.613	9.467
Species diversity (H) (Shannon-Wiener Index)	3.687	3.322	3.002	3.625
Species evenness (Pielou Evenness Index)	0.953	0.934	0.911	0.97
Species dominance (Simpson's Index)	0.03	0.044	0.069	0.03

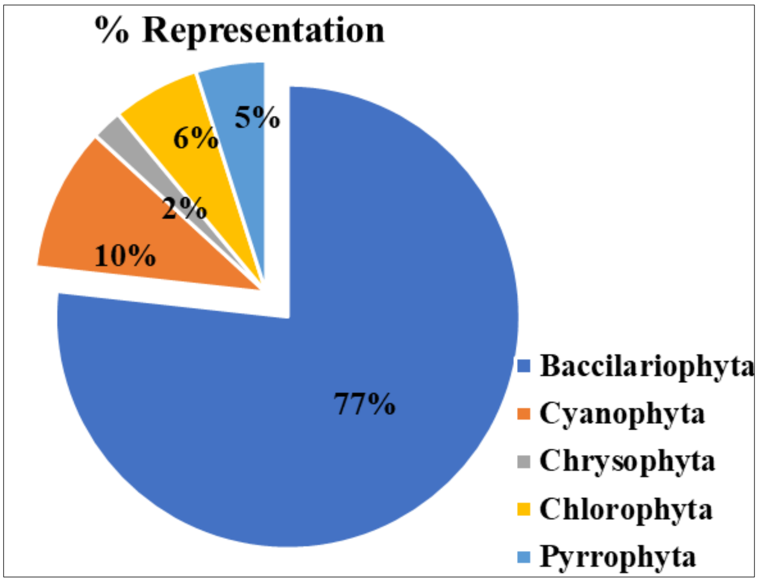

Figure 2 Percentage representation of the Phytoplankton fauna

4. Conclusion

The community structure of the phytoplankton species, in this study, revealed a spatial variation in abundance, composition, and diversity of the species with the control exhibiting a more stable environment while the other stations showed a gradually decreased population status. The species diversity indices reflect impacted and polluted aquatic communities which may have accounted for the low number of individuals recorded in some of the sample stations. However, the effluents from observed artisanal refinery discharges and illegal bunkering activities may have affected the Phytoplankton community structure and dynamics of the Isaka-Bundu waterway. It is therefore recommended that long-term research be undertaken to appreciate the assemblage over time and to advise appropriate agencies on the state of the creeks.

Compliance with ethical standards

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Disclosure of conflict of interest

All of the authors declare that they have both participated in the design, execution, and analysis of the paper and that they have approved the final version. Additionally, there are no conflicts of interest in connection with this paper, and the material described is not under publication or consideration for publication elsewhere.

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