Diversity of Phytoplankton Communities in a Tropical River Basin, Nigeria

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Abstract: Biological assessment is a useful alternative for understanding the ecological quality of aquatic ecosystems because biological communities integrate the environmental effects of water. This work investigates the diversity and abundance of phytoplankton in the Upper Jebba Basin of the Niger River in Nigeria. We sampled phytoplanktons by dragging plankton nets at three stations from March to May 2015 for qualitative and quantitative samples. Qualitative plankton samples were collected by towing 55µm mesh hydrobios plankton nets just below the water surface for five minutes at each sampling station. Quantitative samples, on the other hand, were collected by filtering 100 litres of water fetched with a bucket through a 55µm mesh hydrobios net. Both samples were preserved separately in a 4% buffered formalin solution. A total of 3160 cells/ml of phytoplanktons from taxa were identified in the study. High dominance of Oscillatoria sp., Microcystis sp., Chlorella sp., Pediastrum sp. and Synendra indicate that this lake has high amount of organic waste, polluted predominantly by upstream concerns (i.e., mining, agricultural, and domestic) and should be monitored strictly by relevant agencies in order to additional reduced health hazards caused by these pollutants.

Keywords: Diversity, ecosystem, organic waste, phytoplankton, population.

Introduction

Biological assessment is a useful alternative for assessing the ecological quality of aquatic ecosystems because biological communities integrate the environmental effects of river water and lakes (Stevenson and Pan, 1999). To assess water quality and the impact of environmental change, many groups of organisms have been studied, including algae, macrophytes, protozoa, fish and other animals (Spaak et al., 2010; Ogbuagu et al., 2011). Plankton are a mixed group of tiny, living plants and animals that float, drift freely or feebly swim in water column independent of the shore and bottom (Sommer, 1994) and occupy the base level of food chains (autotrophs) that lead up to commercially important fisheries. They are also reliable bio-indicators of water quality (Keller et al., 2008). Additionally, plankton communities play a major role in the biogeochemical cycles of many important processes such as the carbon cycle, nitrification, denitrification, remineralization, and methanogenesis. These cycles bring about such developments such as primary production and recycling. Plankton are ideal for theoretical and experimental population ecology due to their small size, short generation time, and relatively homogenous habits. These microscopic plants and animals are conveniently segregated into the terms "phytoplankton" and "zooplankton," respectively, though there are differences in opinion where the dividing line should be drawn (Cander-Lund and Lund, 1995).

Phytoplankton (microscopic algae) usually occurs in unicellular, colonial, or filamentous forms and is mostly photosynthetic. Plankton, particularly phytoplankton, have been widely used as indicators of water quality (Saha et al., 2000; Deng et al., 2007; Ogato, 2007; Sharma and Bhardwaj, 2011). Because of their short life span, plankton responds quickly to environmental changes. Some species have also been associated with noxious blooms that sometimes create offensive tasting water, odors, and/or toxic conditions.

Phytoplankton encountered in bodies of water reflects the average ecological conditions of that body, and therefore, they may be used as indicators of water quality (Bhatt et al., 1999; Saha et al., 2000). As well, phytoplankton are suitable organisms for the determining the impact of toxic substances on the aquatic environment because any effects on the lower levels of the food chain will also have consequences for the higher level (Joubert, 1980).

The study of species composition, their numerical density and the relative dominance of plankton are important features with respect to analyzing the water quality in a body of freshwater. The pattern of interactions amongst the different water parameters with the plankton is important for fish production. Phytoplankton converts light energy to chemical energy through primary production which makes them very important in the food web. The present study is aimed at evaluating the phytoplankton index of the study area as water quality criteria with reference to freshwater bodies polluted by various anthropogenic activities.

Materials and Method

Study Area

The Upper Jebba basin was dammed to create Jebba Lake in August 1983 as part of a hydroelectric scheme. The basin extends from the dam site at Jebba to southern tip of the Kainji dam at Kainji. The lake is therefore unique as the first and the only man-made lake in Nigeria that has a direct flow from another man-made lake located upstream to it. It is located in the northern hemisphere between latitudes 9°0′N and 9°55′N and longitudes 4°30′N and 5°00′E. Its tributaries include the Awun, Eku, Moshi and Oli rivers. It falls within the savanna zone, but specifically Guinea savanna (KLRI, 1983).

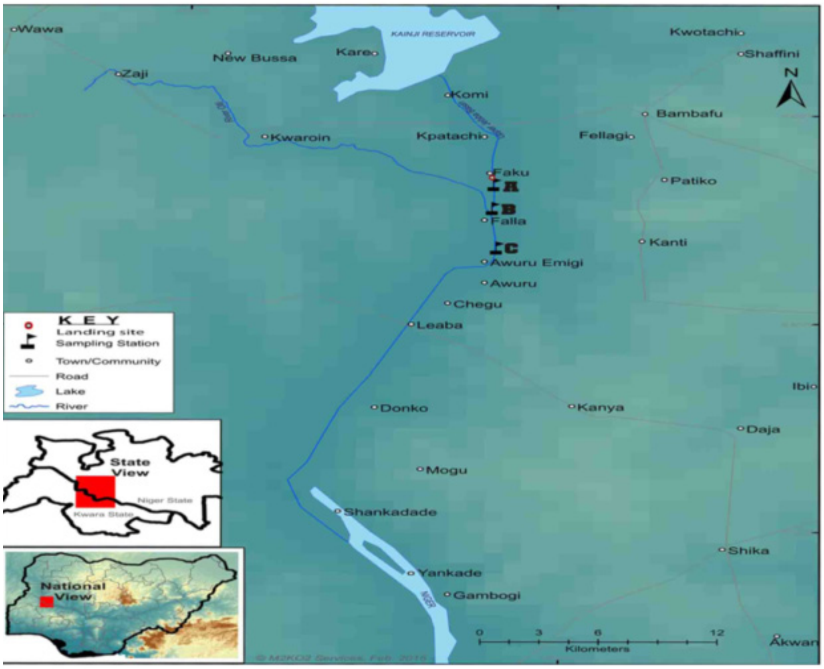

Figure 1: Map of the study areas on Jebba Upper Basin. The sampling stations 1, 2, and 3 are marked A, B and C, respectively.

In the laboratory, specimens were sorted and dissected where necessary under a binocular dissecting microscope. Identification of specimens was carried out in the Limnology Laboratory at the National Institute of Freshwater Fisheries Research (NIFFR), New Bussa, Nigeria, using relevant literature (Smirnov, 1974; Van de Velde, 1984; Imoobe, 1997; Korinek, 1999).

The percentage relative abundance of specimens was estimated by direct count. Each quantitative sample was concentrated to 10 ml and from this 1 ml samples were taken and all individual phytoplankton counted. Relative abundance was calculated as the number of individuals per litre of water filtered through the net. Species diversity indices were constructed to analyze the phytoplankton community structure.

Sampling Station

Three sampling stations were selected: an upstream, a midstream, and a downstream station. Station 1 is located upstream approximately eight kilometers from a hydroelectric power plant. The substratum is clay, mud, and decaying plant matter. A major portion of the substratum is covered with stones, but the bank area is sandy. Sampling station 1 is surrounded by trees of Vitellaria paradoxa, Anacardium spp., and has very turbid water with fewer decaying plant matter at the bottom. Human activities near station 1 include farming, fishing, washing, and bathing.

Station 2 is about two kilometers downstream of Station 1, at the basin confluence with the Oli River. Apart from deposited major anthropogenic wastes, including animal feces and urine, mining effluent, agriculture runoff, domestic waste, the major human activity at this station is fishing.

Station 3 is further downstream two kilometers from Station 2. The vegetation is mainly seaweed and guinea grass in this area. There is no human activity near Station 3 except for animal grazing.

Methodology

We collected samples between 0800 and 1100 hours between March and May 2015. We began collecting the samples at Station 1 and progressed downstream to Station 3.

Qualitative plankton samples were collected by towing a 55µm mesh hydrobios plankton net just below the water surface for five minutes at each sampling station. Quantitative samples were collected by filtering 100 litres of water a 55µm mesh hydrobios net. Both samples were preserved separately in 4% buffered formalin solution.

Result

Diversity and Abundance of Phytoplankton in Upper Jebba Basin

When you look at a drop of water, it seems to be clear; however, when you put a drop of water under microscope you will see that the water is teeming with life. Nearly every creature in a body of water spends either part or all of its life drifting in the current.

A total of 3,160 cells/ml of phytoplanktons from three taxa identified in the study. Looking at the three sampling stations, Station 1 had the highest density of phytoplankton (1,330 cells/ml) followed by station 3 (990 cells/ml) and station 2 (840 cells/ml). At all three stations, Oscillatoria sp. was the most common phytoplankton family present. Hence, the most abundant species in the overall study area were Oscillatoria splendid (620 cells/ml) and Oscillatoria rubens (610 cells/ml), both of which belong to the cyanophyceae class. Based on sampling by class, cyanophyceae has the highest population (1,950 cells/ml) followed by chlorophyceae (950 cells/ml). Bacillariophyceae (260 cells/ml) were the least abundant of all the classes of phytoplankton.

In the cyanophyceae class, the most common species were Oscillatoria splendida followed by Oscillatoria rubens, Athrospira sp., Anacytis sp., Microcytis sp. and Anabaena spirodes, respectively.

The second most common class of phytoplankton was chlorophyceae, which was dominated by the species Chlorella ellipsoidea, Starorastrum rotula, Pediastrum simplex, Hormiclium sp., Spirogyra sp., Volvox sp., Closterium simplex, Tetraspora sp. and Micrateria radiate while class bacillariophyceae was dominated by Diatomella sp., Synedra sp., Melosira granulata, Fragillaria sp. and Tabellaria sp. in decreasing order.

Species composition	Station 1	Station 2	Station 3	Total per specie	Frequency of occurrence along the sampling stations
Chlorophyceae					
Chlorella ellipsoidea	50	80	150	280	+++
Pediastrum simplex	40	30	30	100	+++
Spirogyra sp.	30	20	20	70	+++
Starorastrum rotula	70	70	130	270	+++
Volvox sp.	20	20	30	70	+++
Closterium simplex	-	20	10	30	++
Hormiclium sp.	60	20	20	100	+++
Micrateria radiate	-	10	-	10	+
Tetraspora sp.	-	-	20	20	+
Total				**950**	
Cyanophyceae					
Oscillatoria rubens	330	170	110	610	+++
Oscillatoria splen-did	310	160	150	620	+++
Athrospira sp.	220	70	50	340	+++
Microcytis sp.	20	10	80	110	+++
Anacytis sp.	70	60	130	260	+++
Anabaena spirodes	-	-	10	10	+
Total				**1950**	
Bacillariophyceae					
Diatomella sp.	20	40	40	100	+++
Synedra sp.	60	10	-	70	++
Fragillaria sp.	-	20	-	20	+
Melosira granulate	30	10	10	50	+++
Tabellaria sp.	-	20	-	20	+
Total				**260**	

Table 1: Phytoplankton diversity and abundance of Upper Jebba Basin (March-May, 2015)

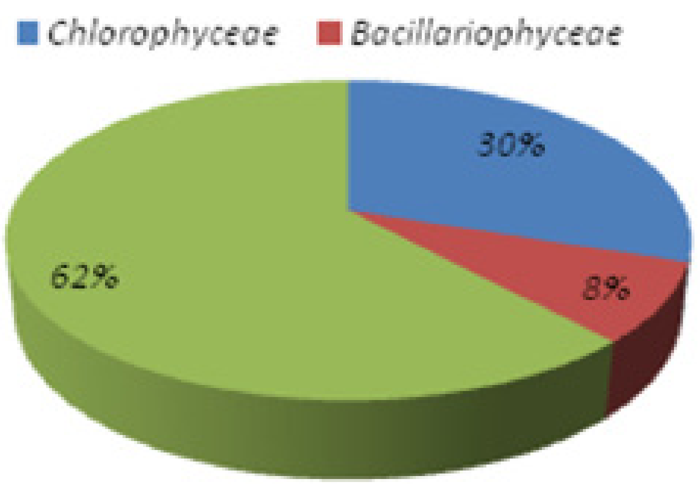

Figure 2: Percentage Composition of Phytoplanktons in Upper Jebba Basin during the study

Variation in Phytoplankton Abundance in the Sampling Stations during Sampling Period

Phytoplankton were present throughout the sampling period and show spatial variation. The maximum density of phytoplankton of 580 cells/ml was recorded at Station 3 in May while Station 2 recorded the lowest density (150 cells/ml) in March. Except for Station 1, which recorded its peak of 470 cells/ml in March and May, minimum phytoplankton loads in the sampling period was recorded in March for all stations. In April, station 1 had the highest phytoplankton loads with 390 cells/ml, while Stations 2 and 3 recorded 360 cells/ml and 260 cells/ml, respectively.

Discussion

Planktonic organisms are not evenly distributed in water. They exhibit what is called patchiness, which is a characteristic that reduces predator pressure. Plankton show monthly variation in abundance, which likely depends on changes in water currents, water level transparency, and the amount of nutrient available (Ndebele-Murisa, et al 2010; Ojo, 2011; Sharma and Bhardwaj, 2011). Plankton has very high surface area to volume ratio because they are small (microscopic) in size. As well, plankton's surface area to volume ratio is related to the fact that movement is easier near the surface due to diminished frictional force between the organism and the water.

In the Upper Jebba basin, based on the sampling stations; station one had the highest diversity of phytoplankton (1330 cells/ml) followed by site three (990 cells/ml) while site two had 840 cells/ml with all the stations dominated by Oscillatoria sp. Hence, the most abundant species in the study area were Oscillatoria splendid (620 cells/ml) and Oscillatoria rubens (610 cells/ml) both belonging to the class cyanophyceae. Based on sampling by class, Cyanophyceae has the highest population of (1950 cells/ml), followed by Chlorophyceae (950 cells/ml) while Bacillariophyceae (260 cells/ml) recorded the least abundance. Another major class of phytoplankton in the study area was Chlorophyceae, which was dominated by Chlorella ellipsoidea, followed by Starorastrum rotula, Pediastrum simplex, Hormiclium sp., Spirogyra sp., Volvox sp., Closterium simplex, Tetraspora sp. and Micrateria radiate while class Bacillariophyceae was dominated by Diatomella sp., Synedra sp., Melosira granulata, Fragillaria sp. and Tabellaria sp. in increasing order.

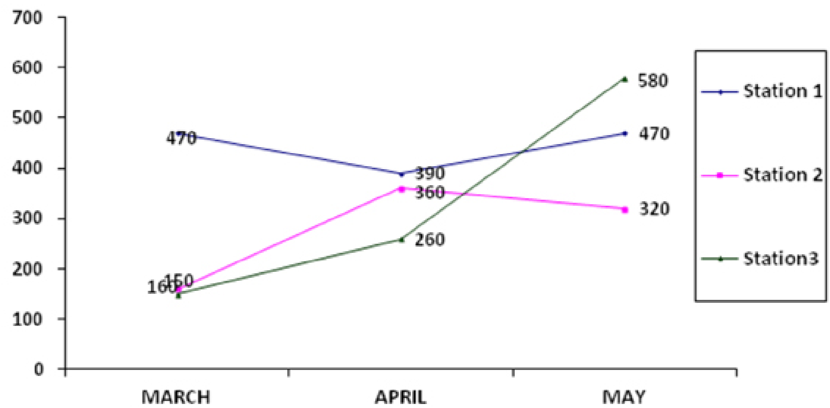

Figure 3: Monthly variation in phytoplankton diversity along the sampling stations during the sampling period.

Overall, it's found that blue green algal (cyanophyceae) growth dominates over chlorophyceae and bacillariophyceae. The dominance of cyanophyta in this river correspond with findings by Sekadende et al. 2004, Ogato 2007, Deng et al. 2007, and Shakila and Natarajan 2012. Paramsivam and Sreenivasan (1981) who reported that the polluted water zones had a heavy blue green algal growth and dominated over chlorophyceae and bacillariophyceae . Sarles 1961 stated that water bodies with large drainage areas or that receive domestic sewage effluents are the most conducive to the luxuriant growth of phytoplankton. However, the presence of cyanophyceae, and others that prefer similar ecological conditions in areas where they are not expected to normally occur might be a sign of the enrichment of waters, a term referred to as eutrophication. One particular risk of the cyanophytes group is the fact that most of the species (including Anabaena sp.) contain toxic substances that can lead to fish kills wherever their blooms occurs, especially in hyper-eutrophic ecosystems.

The major interest in plankton is to understand environmental factors that influence their diversity since they serve as indicator organisms of water types, fish yield and total biological production. From the results of this study, it appears that the growth of phytoplanktons is an important factor for the fish production. The planktons not only enhance fish production but also facilitate bioremediation of heavy metals and other toxic material.

At a primary level, fish make use of available flora and fauna for their food based on the quantity of the various food items consumed and the frequency with which they are consumed.

Food majorly consumed by a particular fish is usually the main part of the stomach content and such food defined the feeding habit of the particular fish species. Phytoplankton feeding fish are called phytophagus; an inland water fishes usually dominated by Tilapia species. Another group of fish feed mainly on zooplankton such fish are mud catfish and silver catfish. The great diversity of food items encounter in different species is an indicative of fact that fish species differ in feeding habit, hence occupying different habitat.

Conclusion

Information about phytoplankton is essential in understanding the functioning and trophic dynamic of different water bodies; they are valuable indicators of trophic status of various aquatic biotopes.

Presences of diverse phytoplanktonic forms indicate good ecological condition of the river. Planktons are ubiquitous. The most characteristic feature is their variability over space and time in aquatic ecosystem. High dominance of Oscillatoria sp., Microcystis sp., Chlorella sp., Pediastrum sp. and Synendra indicate that this lake has high amount of organic waste and therefore the water of the lake is organically polluted.

Based on these findings, all effluents (mining, Mainstream Energy Solution Company, agricultural and domestic) from upstream should be monitored strictly by relevant agencies in order to prevent environmental pollution and to reduce health hazards caused by activities of these wastewaters. Since phytoplankton is a foundational part of the food chain, it is important to monitor natural as well as human caused changes in plankton populations.

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