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Phytoplankton species diversity and biomass and its impact on the sustainable management of Lake Bosomtwe in the Ashanti Region of Ghana

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Lake Bosomtwe is a closed, stratified, natural freshwater body located in the Ashanti Region of Ghana. Recently residents along the Lake shore complain of foul smells emanating from the Lake and also there have been occasional fish deaths there. This led to the study of the composition of phytoplankton community dominating the lake. Sampling was done during the rainy and dry seasons. Samples were collected from twelve towns along the lakeshore. Phytoplankton samples were collected using clean 100-ml bottles and fixed with Lugol's solution. In the laboratory, phytoplankton was identified using a Carl Zeiss inverted microscope. The results obtained during the dry season (August) showed the dominance of blue-green algae in all the twelve stations, comprising more than 90% of the biomass as was also found in the rainy season. This implied that the presence of the blue-green algae in Lake Bosomtwe was not seasonal but all year round, and is also nutrient-dependent as shown by the chemical data collected during the studies. However, the green algae population reduced from 6.2 to 3.7%, in August while the diatoms increased from 0.9 to 3.5%. Notable among the blue-green algae were *Cylindrospermopsis*, *Planktothrix* and *Spirulina* for both the dry and rainy seasons. A positive correlation was obtained between temperature, phytoplankton and dissolved oxygen. This was expected as the blue-green algae which form over 90% of the phytoplankton counts are favoured by elevated water temperatures, a phenomenon which is notable of tropical Lakes. A mean temperature of 27°C was recorded in Lake Bosomtwe. High mean temperature (27°C) and high nutrient of the lake, coupled with its stagnant nature had led to its eutrophic state and the proliferation of blue-green algae. Some blue-green algae contain toxins that are toxic to both man and animals. These could be the cause of the occasional fish deaths and foul smells emanating from the Lake.

Key words: Lake Bosomtwe, fish deaths, phytoplankton, sustainability, blue-green algae, eutrophic state, Ghana.

INTRODUCTION

The importance of phytoplankton in nature, especially in aquatic ecosystem dynamics is beyond question.

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Planktons' primary production provides the base upon which the aquatic food webs are founded. This results in the natural fish populations being exploited by man (Reynolds, 1993). Phytoplankton also generates about 75% of atmospheric oxygen supply through the process of photosynthesis (Selorm, 2014). This is possible due to the large surface area of water bodies that house the organisms, as well as the relatively larger specific surface area of the plankton. Photosynthesis is also responsible for the transformation of carbon dioxide from the atmosphere into food and energy. Worldwide, this "biological carbon pump" transfers about 10 Gigatonnes of carbon from the atmosphere each year into food chains (Birdsey et al., 2009). Cyanobacteria have the ability to fix atmospheric nitrogen within their cells. In some cases nitrogen fixation by cyanobacteria contributes as much as 50% of the annual nitrogen input into lakes (McCarthy, 1980). Phytoplanktonic organisms are sensitive indicators, as their structure and metabolism changes quickly in response to environmental changes (Reynolds et al., 1987) and are therefore used as a basis for preparing and monitoring the strategies for management of lakes. Growth rate of phytoplankton is subject to cyclic changes; fluctuation and succession play a vital role in all aquatic ecosystems (Arhonditsis et al., 2004). However, unnatural or excessive growth of algae especially the cyanobacteria (Harmful blooms) may interfere with the enjoyment of aquatic resources and may even be harmful (Odum, 1971 Oberemm, 2001). The pressure from human activities along Lake Bosomtwe has led to decreasing water quality as evident by the response of respondents in a survey (Amu-Mensah et al., 2014). These people testify that certain species of fishes which they used to catch during their fishing activities were no longer there, as well as the occasional death of fishes, skin irritation and foul odour emanating from the water. It is for these reasons reported by Amu-Mensah et al. (2014), that the study of the phytoplankton interplay in Lake Bosomtwe was initiated.

Study area

Lake Bosomtwe is located in the Ashanti Region of Ghana within latitudes 6° 28' 15.11"N and 6° 32' 28.53"N and longitudes 1° 24' 24.06"W and 1° 26' 46.30"W (Figure 1). It lies within the semi-deciduous forested zone of West Africa (Hall and Swaine, 1981). It is the only natural closed lake in Ghana and Africa, and the third largest closed lake in the world. The lake is enclosed within two administrative districts namely, Bosomtwe District and the newly created Bosome-Freho District. The catchment is semi-forested and semi-cultivated. The steep-sided catchment has no outflows. Over 80% of its water input is from direct rainfall and loses most of it through evaporation (Amu-Mensah et al., 2014, 2017).

For the most part of the year, Lake Bosomtwe is stratified (Puchniak et al., 2009).

The main livelihood activities of the people are fishing and agriculture. Recently, tourism has developed in Abono, Ankaase and Abrodwom with its negative effects on the Lake's environment. Rainfall is high ranging from 1,419.8 to 1,454.3 mm indicating significant humid periods within each year. Temperatures are moderate to high for the most part of the year ranging from 20°C in August to 32°C in March. This allows for high yields of agricultural cash crops such as cocoa, plantain, cassava, cocoyam, maize and vegetables including pepper, tomatoes, okra and garden eggs.

METHODOLOGY

The catchment of Lake Bosomtwe was divided into four zones, namely North, South, East and West to reflect the human and economic activities within the watershed. Some of these activities were tourism, agriculture, irrigation, fishing, hunting, animal watering, recreation, building and water cooling for small breweries. Sampling was done between April and August 2015, which represents the end of the dry season and the start of the raining season. A total of twelve phytoplankton samples were collected each during the raining and dry seasons. These were from Pipie, Nkawie and Amakom from the East, Esaase, Adwafo and Apewu in the West, Duase, Dompa, Agyamanmu and Ankaase in the South and Obo Nsebi and Abono in the North. Samples were collected using the Van Dorn water sampler. This is an integrated water sampler. Samples were fixed in Lugol's solution immediately after collection and transported to the laboratory of the CSIR-Water Research Institute for identification and counts. Activities around the surroundings of the sampling locations were noted.

In the laboratory, water samples were well shaken and aliquots of 25 ml were transferred into counting chambers for microscopic study. Identification and enumeration of algae were done using a Carl Zeiss inverted microscope with a counting chamber as described by Lund et al. (1958). Sedimentation was carried out in counting chambers with a settling time of four hours for every 1 cm of the water column of the sample (Wetzel and Likens, 1991). All colonies and filaments were counted as individuals, and the average number of cells was determined for 20 individuals and cell concentration calculated at 20% error. In order not to contaminate the samples, counting chambers were cleaned with detergent after each sample analysis and the cover slides were also changed. Identification was carried out using a combination of identification books (Cronberg and Annadotter, 2006).

RESULTS AND DISCUSSION

A total of 16 taxa were identified in the Bosomtwe Lake (Table 1). This was made up of five taxa of green algae, eight of blue-green algae and three of Diatoms. The blue-green algae dominated all the twelve stations sampled (Figure 2).

The dominance of blue-green algae is typical of most stratified lakes such as Lake Bosomtwe which is noted to have high water retention time, high surface irradiance and high surface temperature (Puchniak et al., 2009). Nutrients, especially nitrate and phosphorous mostly locked up in the bottom during stratification would not be available to other phytoplankton forms such as green algae. This gives the blue-green algae an advantage to

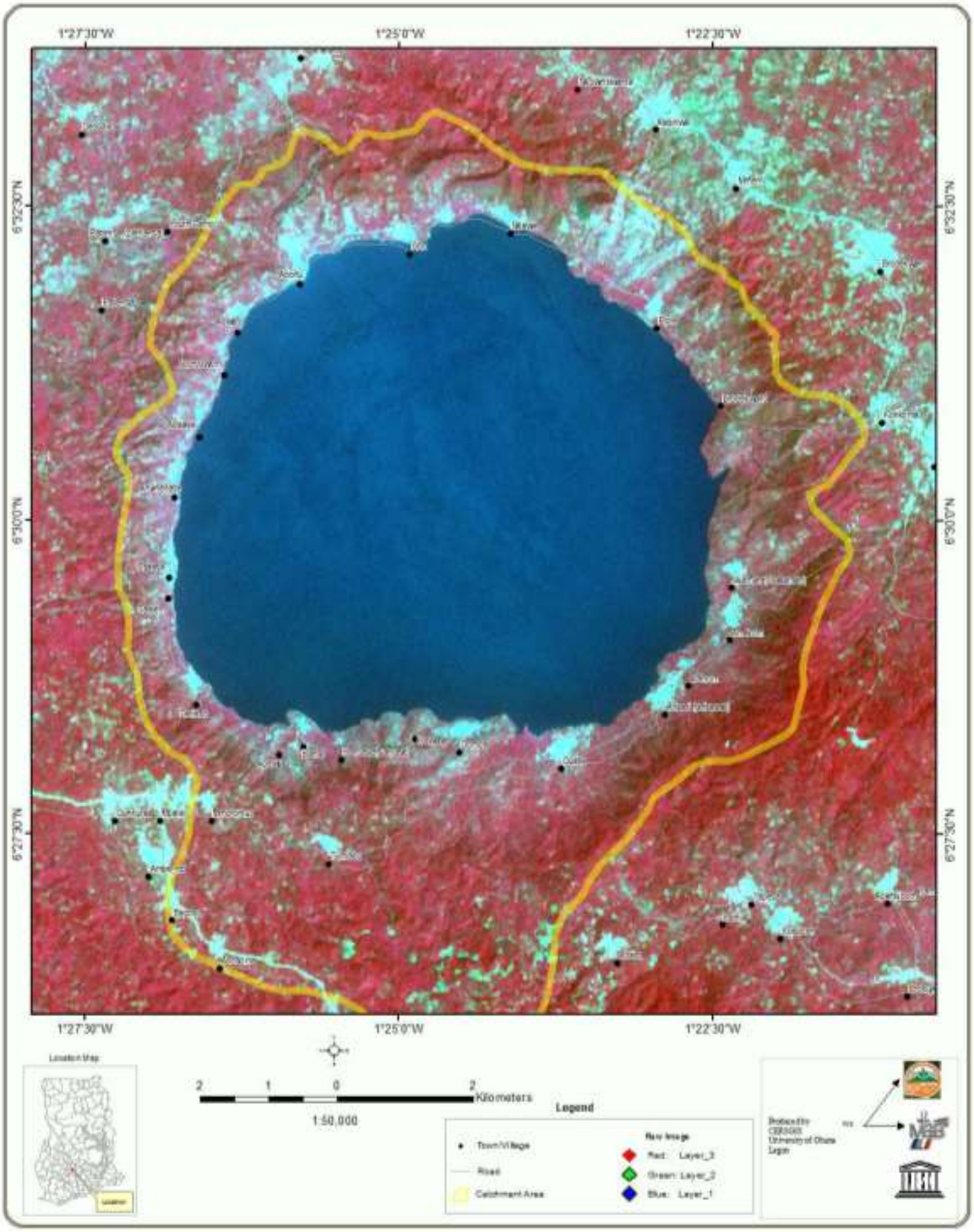

Figure 1. Raw satellite image of Catchment of Lake Bosomtwe showing watershed boundary. Source, MAB Ghana (2012).

grow and proliferate to such nuisance levels. Blue-green algae have been described as strategist (Cronberg and Annadotter, 2006). Cronberg and Annadotter (2006) gave eight reasons for blue-green algal dominance. These were total nitrogen to total phosphorous ratio, low light hypothesis, elevated water temperatures, zooplankton grazing hypothesis, trace metal hypothesis, storage strategy hypothesis and inorganic hypothesis. Lake

Table 1. Phytoplankton species distribution within the twelve stations sampled in Lake Bosomtwe in the Ashanti Region.

Species	Sampling Station (Counts/ml)											
	Esaase	Pipie	Duase	Nkawie	Obo Nsebi	Dompa	Amakom	Adwafo	Abono	Agyamanmem	Ankaase	Apewu
Green Algae												
Ankistrodesmus	79	63	93	77	106	57	46	61	93	102	69	0
Scenedesmus	66	92	4	54	69	84	84	12	28	84	67	61
Staurastrum	39	27	23	18	21	17	0	0	0	16	0	23
Ulothrix	0	28	48	64	34	24	0	0	0	28	0	0
Blue-green Algae												
Dolichospermum	0	129	56	0	0	0	75	58	0	29	0	0
Aphanocapsa	0	131	21	46	24	12	13	0	0	21	8	0
Cylindrospermopsis	48	632	398	252	481	310	96	48	28	34	32	21
Merismopedia	54	16	8	26	17	14	0	14	0	20	0	16
Oscillatoria	15	6	9	12	7	8	9	0	13	3	0	0
Planktothrix	1493	1548	1603	1583	1308	1408	1207	1314	1105	1403	1523	928
Spirulina	1320	1191	1302	1386	1423	1538	501	667	432	531	613	1223
Pseudanabaena	71	56	93	83	59	74	0	46	93	44	102	22
Diatoms												
Navicula	0	36	14	31	3	24	0	0	12	16	4	56
Pleurosigma	0	0	0	2	0	3	0	0	5	0	0	0
Synedra	13	27	8	11	18	22	0	0	0	25	3	0

Bosomtwe which is a tropical lake with high water temperatures (average of 26°C) throughout the year will benefit the blue-green algae to out - compete the other forms of phytoplankton. Blue-green algae, which have the ability to alter their position in the water column can migrate vertically down the stratified layer to assimilate stored phosphorous and nitrogen in the water for growth; this is what the green algae and diatoms are not able to do thereby out-competing them. Kromkamp (1987) reported that unlike green algae, blue-green algae has the capacity to store large amounts of nitrogen in the cytoplasmic inclusion phycocyanin and cyanophycin functioning as reserve products.

These together with other factors such as the buoyancy strategy which allow them to accumulate on the water surface and intercept necessary sunlight needed for photosynthesis, and their ability to fix their own nitrogen, have given them the unique advantage to over populate the other phytoplankton forms (Cronberg and Annadotter, 2006) (Figure 2).

Horne and Commins (1987) concluded that to induce nitrogenous activity in the blue-green algae total inorganic nitrogen must be lower than 0.050 – 0.100 µg/l. Amu-Mensah et al. (2014) reported mean values for total nitrogen as 0.272, 0.245 and 0.202 mg/l for Abono, Nana Abrewa (Apewu) and Atafram streams respectively during the study (Table 2). These three rivers are the tributaries of Lake Bosomtwe which influence the chemistry of the lake. These values are all higher than the needed total nitrogen stress to induce nitrogenase activity in the lake as reported by Horne and Commins (1987). This may imply that there is enough natural nitrogen supply in the Bosomtwe Lake to support the growth and proliferation of the blue-green algal dominance as shown in Figure 3.

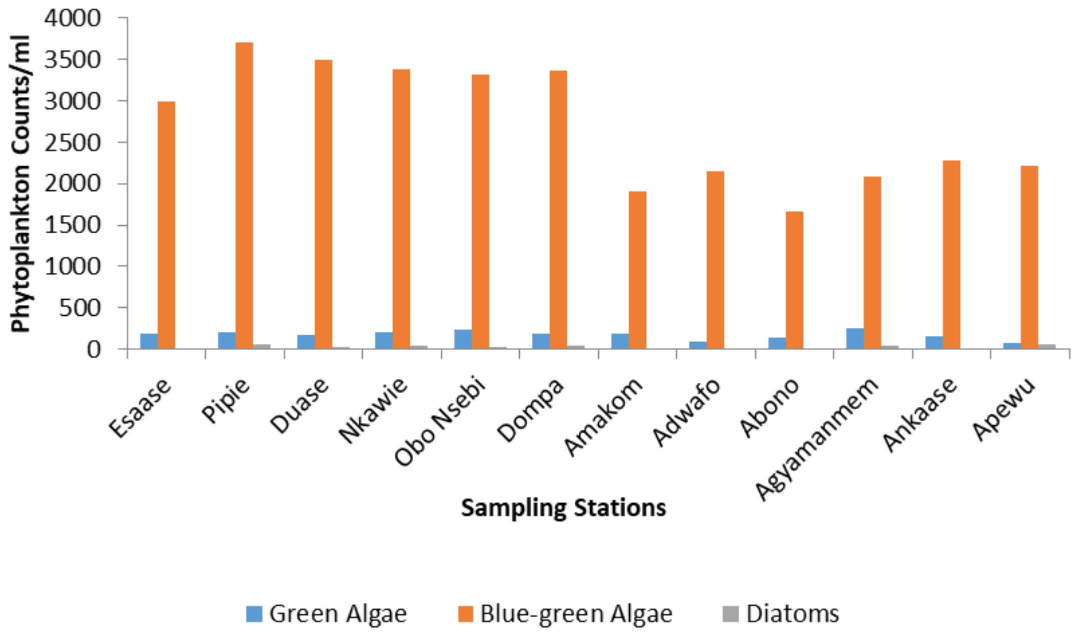

Figure 2. Composition of the various phytoplankton taxa identified in Lake Bosomtwe.

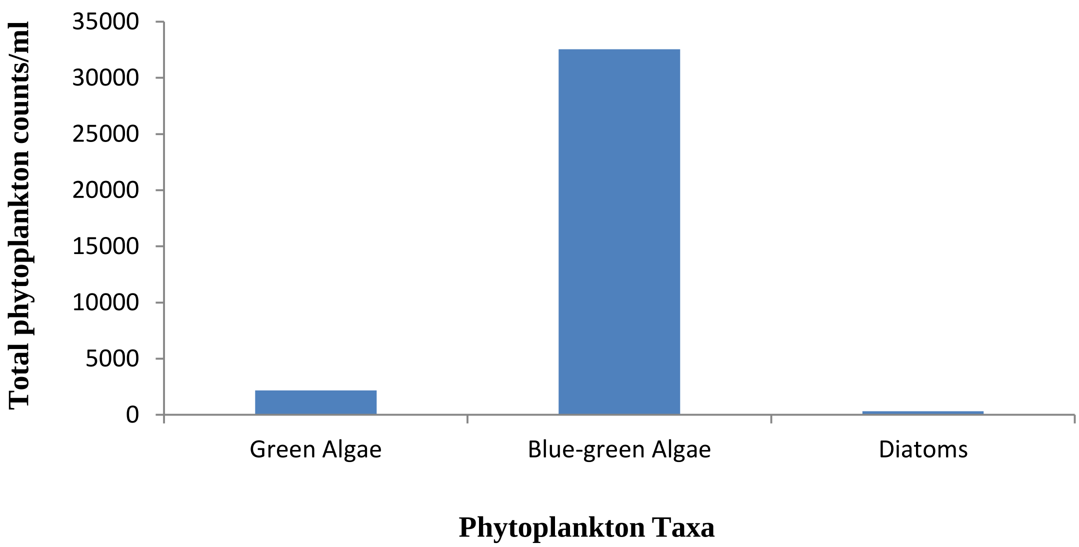

Figure 3. Dominance of blue-green algae in Lake Bosomtwe.

These unnatural nitrogen supply sources come from domestic, sewage and agricultural wastes discharged into the Lake. Calculating the nitrogen/phosphorous ratio which is a good indicator for explaining the dominance of blue-green algae dominance, as reported by Smith (1983), a low N/P ratio of 0.316, 0.308 and 0.474 was obtained for Abono, Nana Abrewa (Apewu) and Atafram streams respectively. This indicates that phosphorous which is usually the limiting factor to blue-green algae was abundant to support their growth (Chapman, 1996).

Karikari and Bosque-Hamilton (2004) reported that Lake Bosomtwe has high nutrient concentration especially nitrate-nitrogen and phosphate to support phytoplankton growth. Amu-Mensah et al. (2014) also reported very high phosphorous concentrations in the lake's water, which is above the Water Resources Commission recommended guideline of 0.1 mg/L (WRC 2003e). The high concentration of phosphorus in the lake may be due to inputs from human activities such as domestic waste-water, fertilizer leachates, and livestock

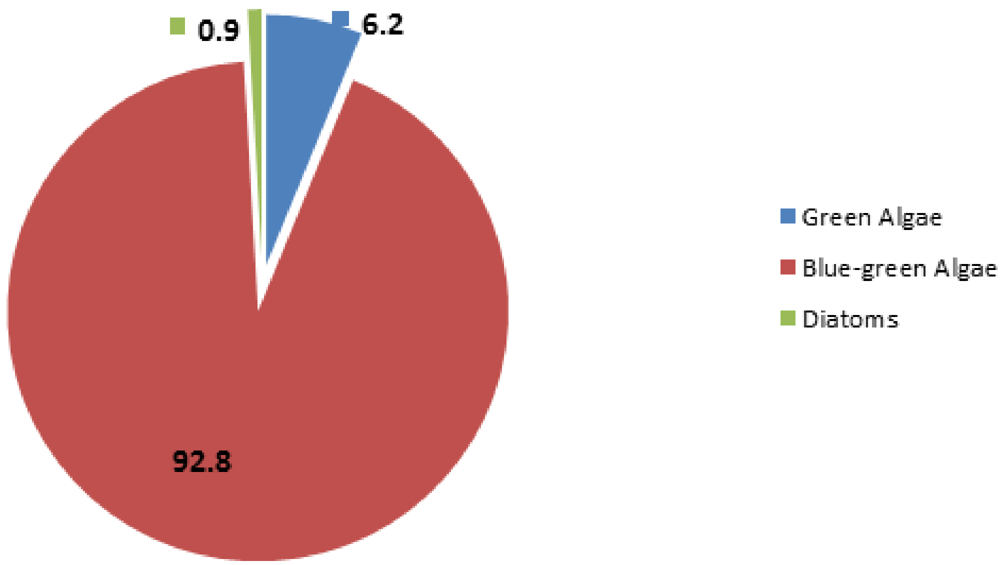

Figure 4. Phytoplankton density (%) of the three major genera recorded in Lake Bosomtwe.

Table 2. Physico-chemical data used to calculate N/P ratio.

Location	pH	Turbidity	Colour	Conductivity	TSS	TDS	NO_2-N	NO_3-N	PO_4-P	Fe	Mn	Na
Abono (Lake)	8.72	10	12.5	1161	4	639	0.132	0.104	0.748	0.052	0.007	325
Apewu	8.76	19.4	37.5	1210	2	666	0.08	0.076	0.506	<0.010	<0.005	242
Atafram	7.77	4.5	1	415	1	252	0.05	0.132	0.311	0.04	0.02	23.1

droppings from the surrounding communities (Prakash et al., 2005).

The major human activities within the catchment of Lake Bosomtwe are farming, fishing and animal rearing for domestic consumption. Recently tourism activities have increased within the catchment with some hotel facilities equipped with rudimentary sanitary facilities. Puchniak et al. (2009) also reported the dominance of blue-green algae in Lake Bosomtwe for all seasons. The blue-green dominance in Lake Bosomtwe was over 90% of the phytoplankton biomass (Figure 4). Three species of the blue green algae contributed to their high biomass.

Planktothrix is a highly toxic alga and is noted to produce a neurotoxin, a secondary amine alkaloid with toxic effect on the nervous system, and hepatotoxins, a major cyanotoxin causing illness and occasional death in both man and animal (Sivonen et al., 1990). It is possible that their high numbers recorded at all the twelve stations sampled (Table 1) may be responsible for the death of fishes in the lake and poisoning of animals along the banks of the lake as several variants of microcystins have been measured in other lakes in Ghana (Addico et al., 2006, 2009, 2017) . Fish deaths can occur directly as a result of intoxication by cyanotoxin during oral intake of contaminated water or by absorption through surface tissues (Tencalla et al., 1994). Indirectly, fish kills can occur through the process of asphyxiation when dissolved oxygen is depleted by the sudden lysis and decomposition of algal blooms during the early hours of the day (Pillay, 1992). The low density of green algae (6.2%) and diatoms (0.9%) may also be due to overgrazing by zooplankton and herbivorous fishes as blue-green algae are not palatable to them and are also not easily digested. The lake is used as a source of drinking water and other domestic activities such as cooking, washing and bathing. The high blue-green algae in the Lake can affect human health through these uses and has the potential to increase downtime, reduce productivity and the economy of the area if not controlled.

Conclusion

It is evident by the phytoplankton data supported by the chemistry of the water that Lake Bosomtwe is organically polluted by waste materials generated from within the catchment, domestic, sewage and agricultural sources. This has been compounded by the lentic (static) nature of the aquatic system. This has had direct influence on the chemistry and the type and biomass of phytoplankton in the lake and its resources.

RECOMMENDATION

There were no data collected on spatial and temporal water temperature and dissolved oxygen during this study. This would have given a better insight into the most probable if not actual cause of the occasional fish mortality in the lake. It is recommended that future studies should include these two important parameters.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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