Physical variables, nutrient status and primary productivity of Kyoga basin lakes of Lemwa, Omunuo, Gawa, Adois and Owapet

By

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1. Introduction

The review report on Kyoga basin lakes (NAFIRRI 2007) described Kyoga basin lakes as important natural resource for the communities within the basin and the surrounding areas. Fisheries of the basin provide a source of protein, income, and employment to generally poor communities in the area. The lakes also generate revenue to the local Governments within the catchment. This indicates that the fisheries of Kyoga basin lakes are a key instrument in poverty eradication and food security. The lakes also act as a source of water for domestic, agricultural and transport purposes. Some of the Kyoga small lakes harbour fish species, which have disappeared from the main lakes Victoria and Kyoga and are therefore important for biodiversity conservation.

However, there is concern that the fish stocks of these basin lakes are declining and may not be enough to meet the increasing demand. Stock enhancement of some of the Kyoga basin lakes was therefore proposed as one of the solutions to ensure sustainability of the fisheries resources of these lakes. Therefore, an assessment of the prevailing environmental quality is important for the exercise. The review was based on lakes Kyoga main, Kwania, Nawampasa, Kimira, Gigati, Bisina, Nyaguo, Agu, Opeta and Nabisojjo. On environmental quality of the lakes, it was noted that most data for the lakes were inconsistent and did not reflect the seasonality. The little information available was for a few lakes e.g. Lemwa, Kawi and Gigati. Also the information is “grey literature”, i.e. not published. It was therefore necessary for NAFIRRI to establish the environmental quality status of the selected lakes in order to guide in restocking of fish in some of the small lakes.

A field survey was conducted in early June 2007, on lakes Lemwa, Omunuo and Gawa/Gawe in Pallisa, Adois/Alos in Kumi, and Owapet/Aibapet in Katakwi, being some of the candidates that have been proposed for restocking. This report covers the findings specifically on physical, chemical, nutrient status, and phytoplankton composition and primary production of the lakes.

1.1 Major objective of the study

To determine the environmental quality of Kyoga basin lakes

1.1.1 Specific objectives of the study

1) To determine physical and chemical characteristics of the waters of the selected small lakes,
2) To determine the nutrient characteristics of the waters and their relation to phytoplankton biomass as an indicator of the water productivity,
3) To make some assessment of which nutrients might become deficient during phytoplankton growth as possible limiting factor for production,
4) To assess the composition of phytoplankton community in relation to environmental quality.

1.2 Study area

The study was conducted on lakes Lemwa, Omunuo and Gawa/Gawe in Pallisa, Adois/Alos in Kumi and Owapet in Katakwi as shown (Figure 1). Lakes Lemwa, and Omunuo are relatively open with minimal macrophyte cover mainly at the inshore areas. Gawa, Adois and Owapet are generally covered by macrophytes e.g. Nymphaea and *Ceratophyllum* spp.,

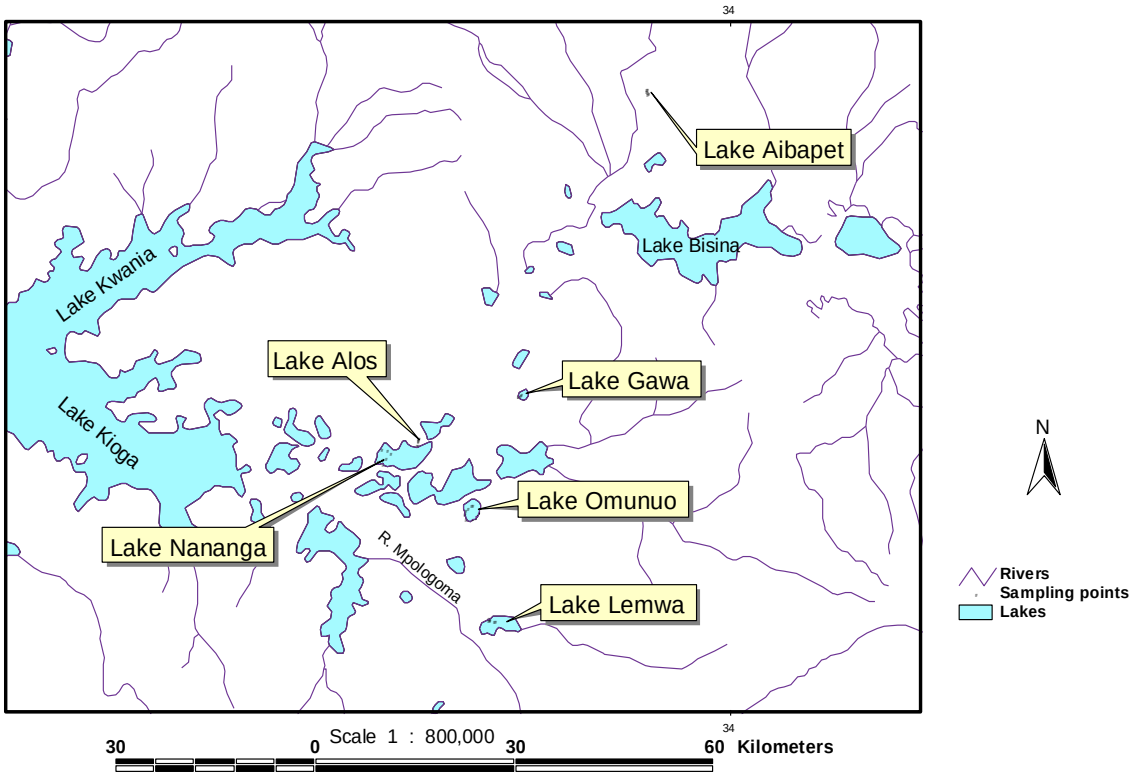

Figure 1: A map showing the Kyoga basin lakes sampled

2.0 Materials and methods

2.1 Sampling procedures

Sampling was conducted during the month of June 2007, which was a wet season in the area. Sampling was done at least in three stations (2 in inshore, 1 mid lake) across each lake. Physical variables namely dissolved oxygen (mg/L), temperature (^{o}C), pH and water conductivity (µs/cm) at the stations were measured *in situ*, using standard portable meters, at two points of every station (n=6). They were measured at equidistance of the water column, following the shallow depths (< 3m) of these lakes.

Water transparency and depth (m) of all the sites were measured using standard secchi disc and echo sounder, respectively.

Water samples for nutrient analyses (e.g. TN and TP) and phytoplankton biomass (chl a) and composition were collected using a Van Dorn sampler, from each of the three stations across the lake (n=3). Water samples were also collected from equidistance of the water column of the lakes, due to the shallow depths. Water was transferred from Van Dorn sampler to clean plastic sample bottles, which were placed in cool boxes containing ice blocks, to prevent their deterioration. 20ml of unfiltered water, to cater for phytoplankton composition and biomass determination, was transferred to clean scintillation vials and preserved with Lugol's solution. Some of the water samples were filtered using Whatman GFC filter papers (47 mm, pore size 0.7µm). Filter papers were gently folded using fine forceps and covered in petri dishes containing silica gel. The dishes were wrapped with aluminium foils to keep the filter papers in dark. Papers and other water samples (filtered and unfiltered) were taken for extraction of chlorophyll-a and nutrient analyses, respectively, at NAFIRRI laboratory, Jinja. Primary production was assessed by determining the amount of dissolved oxygen produced per given area within a given time. It was determined following dark-light standard method, at only lakes Lemwa, Omunuo and Adois/Alos, as representative lakes in the area.

2.2 Sample analyses

Analyses for the nutrients (total nitrogen (TN), ammonium (NH_4-N), nitrates (NO_3-N), Nitrites (NO_2-N), total phosphorus (TP), soluble reactive phosphorus (SRP), soluble reactive silica (SRSi) and chlorophyll-a (Chl a) were conducted following the methods of freshwaters (Stainton *et al*., 1977). An inverted microscope was used for identification and biomass determination of phytoplankton.

3.0 Results

3.1 Physical variables

Physical variables at the sampling sites of each lake are shown (Figure 2). Average water depth ranged from 1.0 at Owapet/Aibapet to 2.8m in Adois/Alos, among the lakes. Sechhi (water transparency) was lowest (< 1m) at Lakes Lemwa and Omunuo as compared to other lakes (Figure 2a). The water column of other lakes (Owapet and Adois) was transparent down to bottom, as shown by the values of water and sechhi depths of these lakes (Figure 2a). Temperature values were generally above 25°C, with the highest value (28.4 ^{o}C) in Lemwa. The lowest values of about 25°C were found in Gawa and Adois (Figure 2b). Dissolved oxygen levels were almost at saturation (8.4-11.2 mg/L) in lakes Lemwa and Omunuo, except in Gawa, Adois and Owapet, which had low values of 0.8, 1.0 and 3.4 mg/L, respectively (Figure 2c). The pH values were between 7.0 and 7.8 for the lakes except Gawa and Adois which had values of 6.6 and 6.5, respectively (Figure 2c). Water conductivity values were generally between 300-380 µs/cm for all the lakes except Owapet which had 287 µs/cm (Figure 2d).

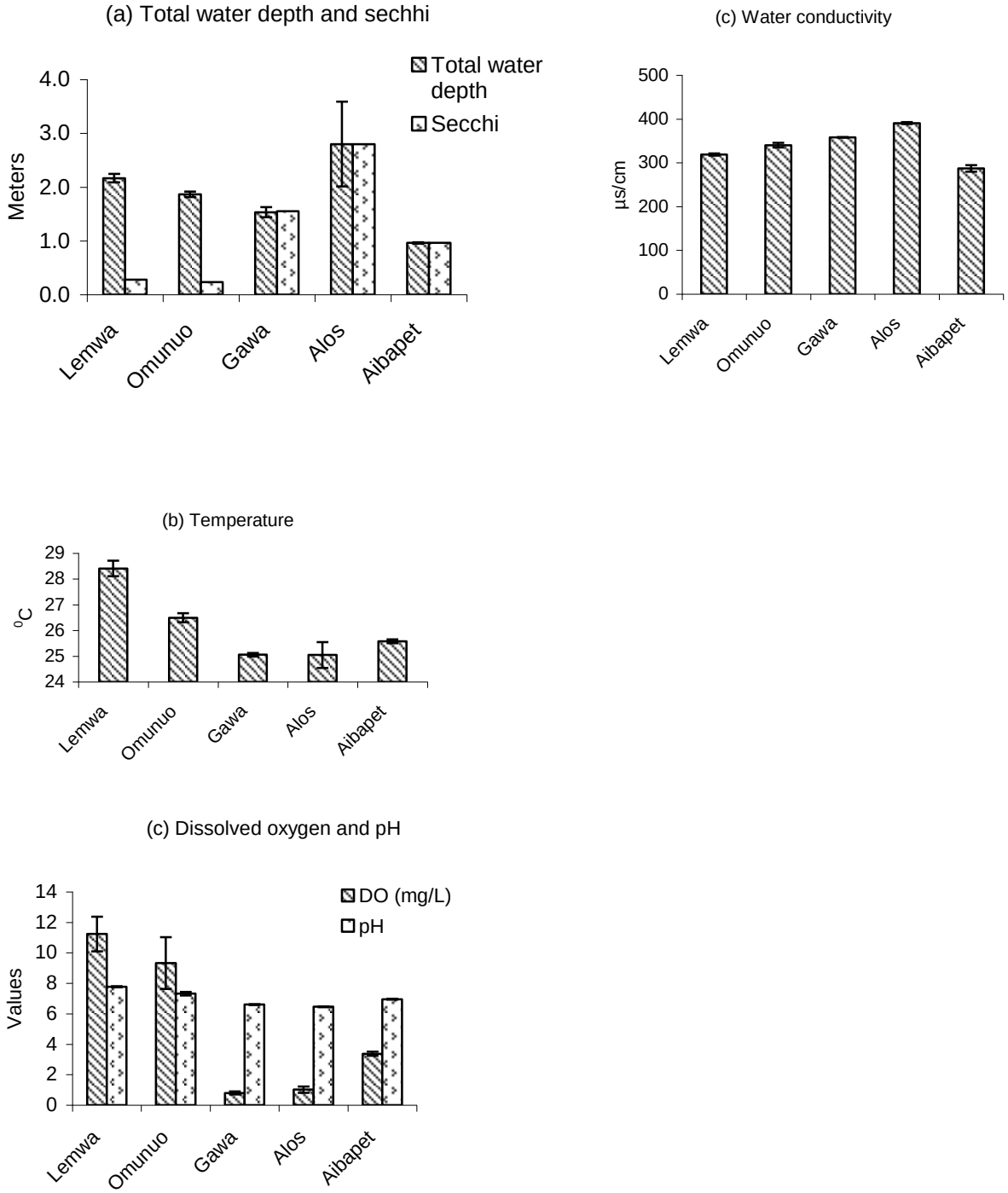

Figure 2: Physical variables (mean ± SE, n = 6) of the lakes

3.2 Nutrient concentrations

A summary of the nutrient concentrations in the sampled lakes is shown (Figure 3). Total nitrogen (TN) mean values were high (above 3000 µg/L) in most of the lakes except in Adois where a relatively low value (2792 µg/L) was observed. The concentrations of ammonium (NH_4-N), as a nitrogen compound, was generally high in most of the lakes as compared to other forms of nitrogen compounds like nitrates (NO_3-N) and Nitrites (NO_2-N). Lake Lemwa had the highest concentration (360 µg/L) of NH_4-N and Omunuo had the lowest (30.8 µg/L). Total phosphorus values were about 40 µg/L in most of the lakes except at Lemwa which had a value of 122 µg/L. Soluble reactive phosphorus (SRP) values were generally more than half of the TP values for every lake except in Lake Lemwa where it was about a quarter of the TP value. Soluble reactive Silica was twice more abundant in lakes Gawa, Adois and Owapet than in Lemwa and Omunuo.

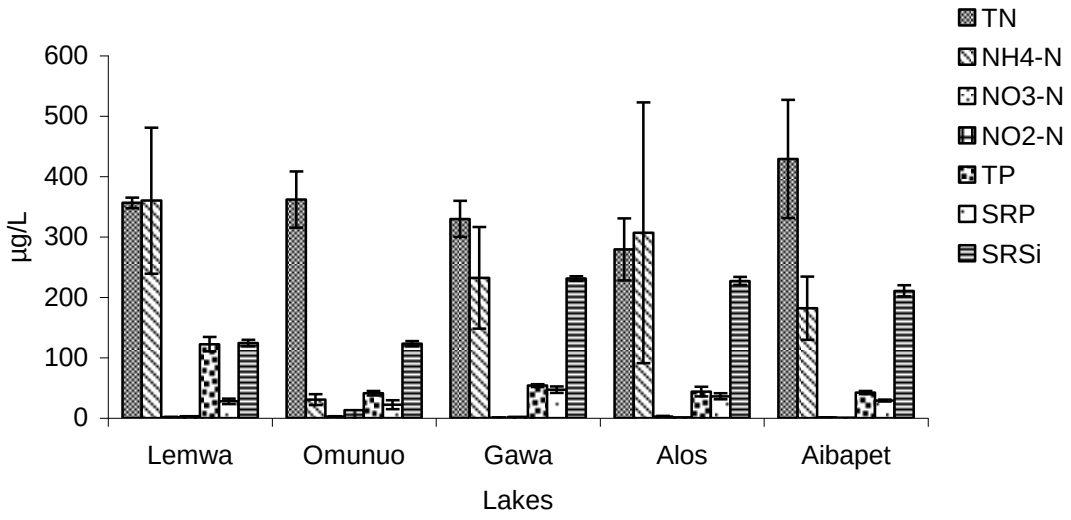

Figure 3: Nutrient concentrations (mean ± SE, n = 3) of the lakes (TN & SRSi concentrations multiplied by 10^{-1})

3.3 Phytoplankton biomass, primary production and composition

3.3.1 Phytoplankton biomass

The phytoplankton biomass which was estimated as chlorophyll-a concentrations in a liter of water (ug/L) was highest in Lemwa (131.2), followed by Omunuo (66.9), Owapet (38.2) and the lowest values (< 12) were found in Gawa and Adois (Figure 4).

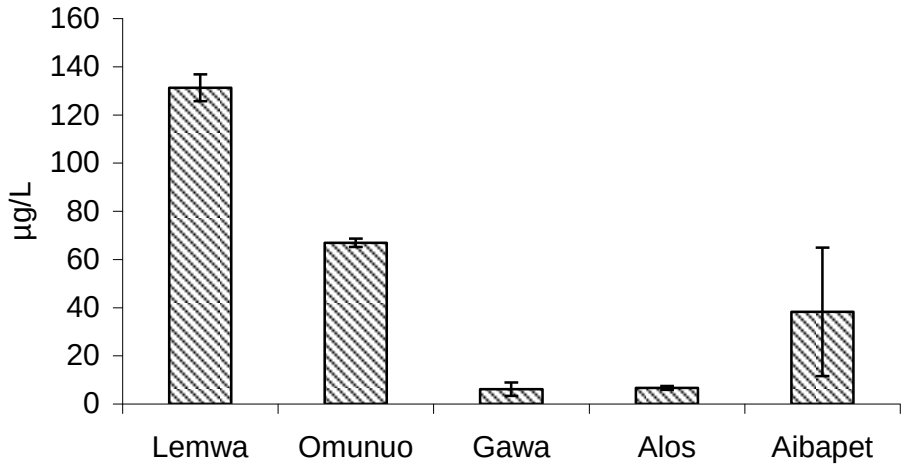

Figure 4: Phytoplankton biomass (chlorophyll-a) of the lakes

3.3.2 Primary production

The primary productivity levels ($mgO_2\ m^{-2}\ h^{-1}$) were found to be relatively higher (801-1434) in Lemwa and Omunuo, and lowest (35-77) in Adois (Figure 5).

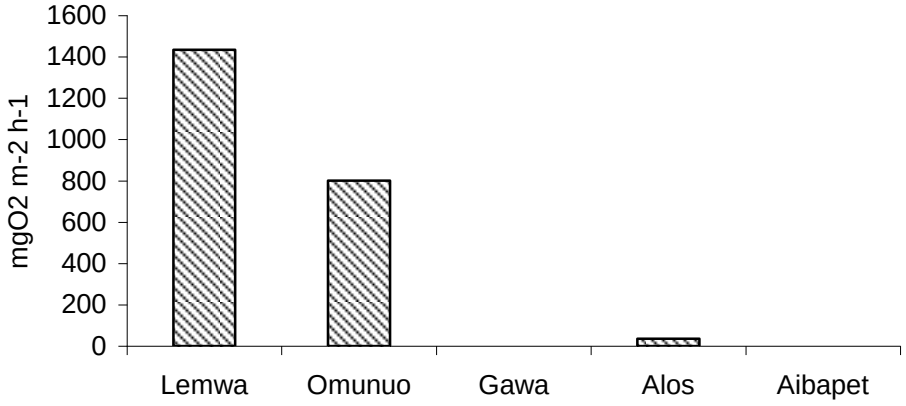

Figure 5: Areal phytoplankton productivity in the lakes (Gap = No data, not done)

3.3.3 Phytoplankton composition

The composition of phytoplankton communities in the Kyoga small lakes, are shown (Figure 6). Three prominent classes Blue green, Green and Diatoms were found in all the lakes. Lake Lemwa had blue green phytoplankton as the most dominant (over 95%) and other groups contributing low abundances (Figure 6). Omunuo and Adois also had Blue greens as the most dominant groups, with the values of 66 and 47%, respectively.

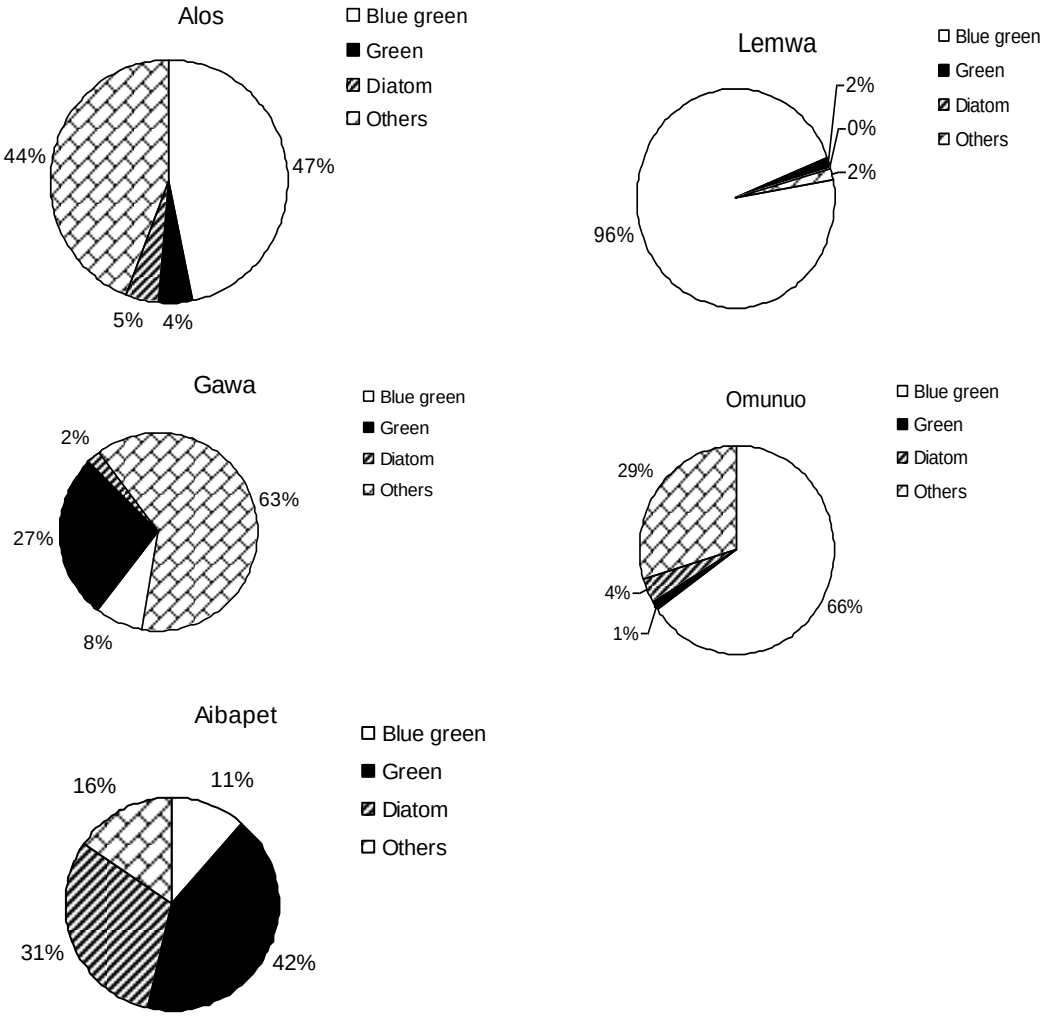

Figure 6: Phytoplankton composition in the lakes (Others =Cryptophytes, Euglenophytes and Dinoflagellates)

Aphanocapsa, Cylindrospermopsis Planktolyngbya and *Anabaena* constituted the blue greens in Omunuo and Adois. There was a poor diatom composition in all the lakes except Owapet (Figure 6). *Aulacoseira* which used to be the main food item in the native tilapines (*Oreochromis esculentus*) in Lake Victoria, was found in the waters of Lakes Omunuo and Owapet. Owapet had well distributed communities with diatoms and greens almost in equal proportion. The green community dominated and was more diversified (*Scenedesmus, Ankistrodesmus* ,*Monoraphidium, stuarastrum, Oosytis, Closterium,Selenustrum* and *Ankistrodesmus*) as compared to Blue green algae which was poorly represented by only *Planktolyngmbia*. However the diatom community was mainly composed of *Nitzschia* and *Aulacoseira*. Gawa also had some good percentage (27%) of Greens while the rest of the lakes had insignificant proportions of the Greens.

4.0 Discussion

The shallow depths (< 3m) were some of the characteristics observed on the small Kyoga basin lakes. They were more of permanent water bodies that are sufficiently shallow to allow penetration of light to the bottom sediments and the light being adequate enough to support photosynthesis of higher aquatic plants within them (the lakes). These characteristics have been described for most of the world shallow lakes (Wetzel 2001). The low secchi (water transparency) values in Gawa, Alos and Aibapet relative to other lakes are inline with low abundance of phytoplankton in these lakes. The relatively low temperatures at Gawa and Adois, could be attributed to the expanse cover and shading by the macrophytes e.g. Nympheae and *Ceratophyllum* spp in the two lakes as compared to other lakes. High values of dissolved oxygen in lakes Lemwa and Omunuo was due to abundance of phytoplankton biomass relative to lakes Gawa, Adois and Owapet. Low values of dissolved oxygen (< 3.5mg/L) in lakes Gawa, Adois and Owapet are indications that conditions are becoming anoxic and may not be supportive to organisms e.g. fish. Low dissolved oxygen conditions (< 5.0 mg/L) have been reported in other study (Chapman and Kimstach 1992) to adversely affect the functioning and survival of biological communities.

Although low abundance of phytoplankton is a factor causing low dissolved oxygen in Gawa, Adois and Owapet, decomposition of plant organic materials from the invasive submerged and floating leaved macrophytes dominating in the lakes, is another cause for this. However, the shallow depths of the lakes could probably allow access of oxygen by some organisms. Higher values of pH in Lemwa and Omunuo relative to Gawa, Adois and Owapet were the result of high photosynthetic activities in the former than the latter. Humic acid as well, could be emerging from the decomposing macrophyte materials and leading to low pH values in Gawa, Adois and Owapet. High conductivity values of above 3000 µs/cm, which were observed in all the lakes except Owapet, are related to the geological background of the basin, which may be contributing to high concentrations of mineral ions in the water. The value at Owapet showed that it was in area probably with different geological background that contributes to relatively low concentrations of ions to the lake waters.

High concentrations of TN in almost all the lakes could be attributed to presence of nitrogen fixing Blue-green phytoplankton (Cyanobacteria). However, even in an area with low abundance of Blue-greens e.g. Lake Owapet, the TN was high. This is because even heterotrophic bacteria like the *Azobacter* and *Clostridium* that live free in water, epiphytically on submerged plants and in the sediments also contribute to *in situ* nitrogen fixing. The number of such heterotrophic bacteria is high in lakes with humic organic matter (Wetzel 2001). These may have been the contributors to high TN concentrations in areas with less Cyanobacteria e.g. Owapet with shallow depth and a lot of submerged and floating leaved macrophyte cover. The values of NH_4-N in the lakes were generally within the ranges that have been reported for surface waters (Chapman and Kimstach 1992). However, accumulation of the same compound, is likely to occur in lakes like Gawa and Adois, where low photosynthetic activities coupled by decomposing of organic matter, has led to very low levels of dissolved oxygen. Low

levels of dissolved oxygen block bacterial conversion of NH_4-N to NO2-N and NO3-N, and finally nitrogen. Accumulation of such compounds, especially the un dissociated NH_4-OH causes detrimental effects to many organisms, especially fish. This is a likely problem in lakes like Gawa, Adois and Owapet.

The values of TP were generally low in the lakes and may have been one of the factors affecting phytoplankton growth. When compared with values obtained from other lake in the basin e.g. Nakuwa that had minimal anthropogenic disturbance (NAFIRRI 2006), TP in the present study was generally low. However, at Lemwa, the level of TP may have been associated with some contribution from the local drainage, especially from the eastern part of the country. Invasion of most of the Kyoga basin lakes e.g. Gawa, Adois and Owapet by macrophytes, is an evidence that a nutrient especially P, may have become limiting in the waters thus macrophytes with ability to derive such nutrients direct from the sediments are now out competing the phytoplankton. This shows that nutrient like P could have gone low in some of these lakes especially during the long dry spell, with poor input from the local drainage, then the macrophyte with alternative source in bottom sediments started growing rapidly and now eliminating the phytoplankton through shading effect on the lakes e.g. Gawa and Adois. The TN:TP (molar) ratios for the lakes were generally > 60, indicating that P was a limiting nutrient in these lakes, as it has been determined across a broad range of other lakes (Guilford and Hecky 200). However, it has been stressed in other findings that it is light other than nutrient (e.g. N and P) availability in such shallow lakes (Wetzel 2001) that may limit phytoplankton growth. The low SRP values in the lakes like Lemwa and Omunuo, is due to consumption by the biota especially the phytoplankton. High concentrations of SRSi in most of the lakes are indications that the bottom types and local drainage are composed of such nutrients and also as result of very minimal consumption by the biota, especially the diatoms that are generally low in biomass and numbers in most of the lakes, except Owapet (Figure 6).

Phytoplankton biomass (Chl-a) that form base of the food chain was generally low in the lakes except in Lemwa, Omunuo and to some extent in Owapet. When compared to an average value (~ 50 µg/L) of northern Lake Victoria, only Lemwa and Omunuo were above this average. The relatively high values Chl-a concentrations and others like dissolved oxygen and primary productivity in Lemwa and Omunuo, make the two lakes potential water bodies for fish production. However, this would go hand in hand with further improvement of their environmentally status, if the best yield are to be attained. Dominance by Blue-greens (Cyanobacteria), in most of the lakes indicates general deteriorating conditions within such water bodies. For example, nutrient encrichment from sources like land runoffs containing nutrients from gardens and possibly from atmospheric deposition, could be occurring during specific seasons. Cyanobacteria are not palatable to fish as compared to other groups like diatoms and Greens that had significant proportions in Owapet and to some extent in Gawa. This would make Owapet and Gawa potential lakes for fish production but due to poor physical conditions e.g. low dissolved oxygen in both of them and the seasonal occurrence of the former; they deviate from such potential.

5.0 Summary

The physical, nutrient and phytoplankton status in Lakes Lemwa and Omunuo were found to be fairly good and supportive to fish relative to Gawa, Adois and Aibabet. Most of the environmental problems in Gawa, Adois and Aibabet seem to be related to the massive macrophyte invasion, hence need to have in-depth understanding of the cause of such problem and bring in actual management procedures. Lakes Lemwa and Omunuo could be potential lakes for the proposed fish stock enhancement. Some of them like Lake Lemwa may require only further improvement on the environmental conditions and management of the fishing effort, then fish yield and sustainability would improve. The data that has been used for this report may not representative of the actual conditions prevailing in the mentioned lakes since it was collected within one season (wet) and short period. However, as an initial approach, it has given a clue on the environmental status of the selected lakes, to guide in the restocking exercise. More work on the environmental quality of the selected Kyoga lakes would still be of relevance in order to have a firm base for managing and monitoring of such resources for increased and sustainable production.

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