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Hydrobiological Survey of the Bahir Dar Gulf of Lake Tana, Ethiopia *(Pp. 57-70)*

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Abstract

Fortnightly samples were collected from three points at the southern gulf of Lake Tana in the early wet season months of June and July 2007 to investigate physico-chemical condition, phytoplankton and zooplankton assemblages. Water temperature ranged from 22.2 to 25°C, depth, 0.96 to 4m; transparency 0.4 to 0.9m; conductivity 152 to 232µScm^{-1}; dissolved oxygen 1.66 to 7.7mgl^{-1}; pH 7.35 to 8.48; nitrate 0.92 to 4.18mgl^{-1} and phosphate 0.1 to 0.61mgl^{-1}. Of these parameters water column depth and pH were significantly different in the three sample stations and dissolved oxygen was positively correlated with depth and pH. Sixty one phytoplankton species classified into five divisions in the following order of percentage composition; Chlorophyta 39%, Bacillariophyta 38%, Cyanophyta 13%, Euglenophyta 8% and Dinophyta 2%. Forty four zooplankton species made up of 16 species of rotifers, 16 species of cladocerans and 12 species of copepods and their developing stages were recorded. There was a clear spatial pattern in the phytoplankton and zooplankton distribution in this study. Like the rest of the lake, the pelagic waters of the Bahir Dar gulf was oligotrophic while the inshore areas had greater plankton species diversity and prone to pollution from allochthonous nutrient input from adjacent wetlands and human encroachment.

Introduction

There has been concerted effort towards the study of various aspects of Lake Tana with greater emphasis on the lake's ichthyofauna especially barbs and

cyprinids (Nagelkerke, 1997; de Graaf, 2003 and Dejen, 2004). Records of plankton composition, assemblages and seasonal variations are quite few considering the size, peculiarity and importance of the lake and its biodiversity. Notable works include Wudneh (1998), Dejen *et al*., (2003) Wondie (2006), Wondie and Mengistou (2006) and Wondie *et al*., (2007). Changes in the physico-chemical characteristics of water bodies and the influence this has on the plankton assemblages have been well documented for several rivers and lakes (Chakrabarty *et a*l., 1959, Reynolds, 1998, Bucka and Zurek 1992, Chakrapani *et al*.,1996, Sukumaran and Das 2002,).
Dejen *et al*. (2003) reported the importance of microcrustaceans in the diet of two 'small barbs', *Barbus tanapelagius* and *B. humilis* which are the basis for the commercial fish production in the Lake, while Dejen *et al*. (2004) investigated the temporal and spatial distribution of microcrustacean zooplankton in relation to turbidity and other environmental factors in the lake, and Wondie and Mengistou (2006) investigated the duration of development, biomass and rate of production of the dominant copepods (calanoida and cyclopoida). Studies of the spatial and temporal variations in the physico-chemical properties of waters in relation to the periodicity of primary and secondary producers, and secondary consumers are essential for an evaluation of the trophic nature and community structure. These components are also important in determining the fisheries potential of the lake and for monitoring changes taking place as a consequence of human developmental activities and encroachment on the lake wetlands.

Lake Tana is the largest lake in Ethiopia, its geography and catchment area has been described in various publications (Wudneh, 1998; Dejen *et al.,* 2004; Wondie and Mengistou, 2006) and a repetition is not desirable. In the present study, samples were collected from three points in the Bahir Dar gulf area; two shoreline stations and one pelagic station.

Station 1 is on the open water about 10 km from the southernmost point of the lake at the 'Mango Park' in Bahir Dar City.
Station 2 is at the shoreline by Tana Hotel/Shum-Abo Resort. The shoreline vegetation comprise predominantly of the following macrophytes - *Ceratophyllum demersum* L. (Ceratophyllaceae), *Typha latifolia* L.(Typhaceae) *Nymphaea* sp. (Nymphaeaceae), *Potamogeton heterophyllus* Schreb. (Najadaceae) and *Lemna* sp.

Station 3 is at the shoreline by the Bahir Dar Resort area. The station is adjacent to one of the lake wetlands used extensively for livestock grazing and subsistent vegetable farming. *Typha latifolia* and *Nymphaea* sp. were observed as the dominant vegetation.

This paper aims to provide a preliminary report on the physico-chemical conditions, phytoplankton and zooplankton assemblages in the Bahir Dar gulf of Lake Tana with a view to document their species composition spatial distribution and community structure. There is need to document these features of the Lake Tana at large and specifically, the Bahir Dar gulf with its peculiar biodiversity and the increasing threats of expanding urban habitation and attendant effect on the wetlands.

Materials and Methods

Samples were collected from three stations at fortnightly intervals using a 3.5liter capacity Van Dorn water sampler between June and July 2007. Triplicate samples were collected with the water sampler at different depth intervals and homogenized before being sub sampled for physico-chemical analyses and plankton composition. Temperature, depth and secchi disc transparency were recorded *in-situ*. Conductivity, dissolved oxygen and pH were also recorded *in-situ* using a WTW water sampler probe. Nitrate and phosphate were determined colometrically using Palintest analytical kit.

Phytoplankton samples were collected by filtering lake water with 55µm plankton net and immediately fixed in Lugol's iodine. Observation and identification of phytoplankton up to species level was done with an Olympus model microscope and classification was with the aid of various literature, publications and phytoplankton manuals. The species were cross checked with herbarium samples in the Phytoplankton Laboratory of the Botany Department of University of Benin, Nigeria.

Vertical plankton hauls were made at each of the sample stations using a 55µm net and immediately fixed in 4% formaldehyde solution for zooplankton. Observation and identification of phytoplankton and zooplankton to species level was done with an Olympus model microscope and classification was with the aid of relevant literatures (Korinek, 1999; Flössner, 2000; Smirnov, 1996; Defaye, 1988; Van de Velde, 1984), at the Bahir Dar Fisheries and other Aquatic life Research, Department of Biology, Bahir Dar University and cross checked with herbarium samples at the zooplankton Laboratory of the Department of Animal and Environmental Biology, University of Benin, Benin Nigeria.

Statistical analyses of the result were carried out to obtain mean and standard error values for each of the physico-chemical parameters. Single factor ANOVA was used to test significant difference between the stations while correlation analysis was performed to assess the relationship between the parameters.

Results

Physico-chemical Parameters

The spatial variation of physico-chemical parameters investigated during the sampling period is shown in Table 1. Water temperature ranged between 22.2 and 25 ^{o}C throughout the study period with the highest mean temperature value (24.13±0.59 ^{o}C) recorded in station 2. Depth ranged between 0.96 and 4 m across the sampling stations, the pelagic zone of station 1 was significantly ($P<0.001$) deeper than other sections of the lake in the study area. Secchi transparency ranged from a minimum of 0.4 m (station 3) to a maximum of 0.9 m (recorded in station 2). Generally, the lake water was relatively turbid at all the stations.

Conductivity values ranged from 152 to 232µScm^{-1} with a progressive increase from station 1 to station 3. Lowest ionic content of the lake water was recorded in station 1 (156.3±1.93 µScm^{-1}), while the highest record was for station 3 (185.5±15.2). A weak alkaline pH range of 7.3 – 8.5 was observed across the stations. Dissolved oxygen concentration values (1.667mgl^{-1} - 7.7mgl^{-1}) recorded in the Bahir Dar gulf of Lake Tana were significantly lower ($P>0.05$) in station 3 than other stations (Table 2). The essential primary productivity nutrient, nitrate was comparatively higher (0.92 - 4.18mgl^{-1}) than phosphate (0.1 to 0.61mgl^{-1}). (See table 1)

Phytoplankton Composition

A total of sixty-one phytoplankton species belonging to five divisions were recorded and the percentage composition is shown in Figure 1. The Bacillariophyta were highest with 39% and closely followed by the Chlorophyta with 38%. Cyanophyta and Euglenophyta made up 13% and 8%

respectively of the total phytoplankton in the gulf while the Dinophyta was least with 2% as shown in figure 1.

Among the Bacillariophyta the pennales were most abundant and represented by species of *Cymbella*, *Eunotia*, *Fragillaria*, *Frustulia*, *Gomphonema*, *Navicula*, *Nitzschia*, *Pinnularia*, *Rhopalodia*, *Surirella* and *Synedra*. Of the Chlorophyta the desmids were dominant and represented by species of *Closterium*, *Cosmarium*, *Euastrum* and *Staurastrum*. Other green algae present include species of the genera *Ankistrodesmus*, *Chlorella*, *Eudorina*, *Kirchneriella*, *Pedisatrum* and *Scenedesmus.* Filamentous forms include *Oedogonium* and *Spirogyra* spp.

Members of division Cyanophyta recorded during the survey include; *Anabaena*, *Aphanotheca*, *Merismopedia*, *Microcystis*, *Oscillatoria* and *Spirulina*. Euglenophyta species were *Euglena acus*, *E. oxyuris*, *Phacus acuminatus*, *P. longicauda* and *P. tortus.*

The shoreline stations exhibited greater number of individuals of different species than the pelagic station with a preponderance of the green algae; while *Cymbella affinis*, *Eunotia flexuosa*, *E. monodon* (Diatoms), *Oscillatoria princeps* (Cyanophyta) and *Euglena* spp were totally absent from the lake open waters. Ubiquitous species were *Aulacoseira agassizi*, *A. granulata*, *A. granulata* var. *muzzanensis*, *Cymbella laceolata*, *Eunotia gracialis*, *Fragillaria brevistraita*, *Frustulia rhomboids*, *Navicula tenelle*, *Nitzschia acicularis*, *Rhopalodia gibba*, *Surirella elegans*, *S. robusta* and *Synedra* spp. Others include *Closterium aciculare*, *Eudorina elegans*, *Pediastrum duplex*, *P. simplex*, *Staurastrum leptocladium*, *Anabaena solitaris*, *Aphanotheca* sp., *Merismopedia elegans*, *Oscillatoria proboscidea*, *Sprirulina* sp. and *Peridinium* sp.

In terms of biovolume estimated by number of cells per ml, diatom species were most represented as shown in figure 2 below. Eleven out of the twenty three diatoms species accounted for almost 50% of the total phytoplankton composition by biovolume. They include;
Aulacoseira, Cymbella,Eunotia, Fragillaria, Frustulia, Gomphonema, Navicula, Nitzschia, Pinnularia, Surirella and *Synedra. Aulacoseira* and *Navicular* were most abundant in the shore line stations than in the open water.

Discussion

Physico-chemical conditions and phytoplankton

The present study was carried out in the early months of the Ethiopian summer (June and July), characterized by heavy rainfall and flood, which resulted in the relatively low Secchi transparency observed across the stations. The obvious difference between the water depth at station 1 and the other two stations is expected because stations 2 and 3 were located along the shoreline while station 1 was at the pelagic zone of the lake.

Water temperature was within the range of variation observed in most tropical water bodies (John, 1986). Conductivity values were low an indication of the low ionic concentration of the lake and that of the inflowing rivers. There was observed trend of higher conductivity values at the shoreline than in the open water, though this was not significant, it is attributable to influx of dissolved solutes from the marshland and wetland especially in station 3. Although anoxia was not observed at any station during the study, the continued invasion of the adjacent wetland by grazing cattle and early wet season farming could drastically impact on the quality of the lake water at the inshore areas. The possible entry of organic matter during runoff from the surrounding urban areas and agricultural fields and their decomposition contributed to the low levels of dissolved oxygen in the shoreline station 2 and 3. Ionic composition and concentration of exchangeable bases are quite low in the lake as could be attested to by the conductivity and pH results. There was an observed positive correlation between dissolved oxygen and depth and pH. (Table 2).

Plankton Composition and Community Structure

Phytoplankton species composition reported in the present study is comparable to 85 species reported in previous study of the entire lake by Wondie (2006) with similar order of dominance of (Bacillariophta > Chlorophyta > Cyanophyta > other minor groups was also observed. However, by biovolume (number of cells per ml), *Microcystis* sp., *Aulacoseira* spp., *Synedra* sp., *Peridinum* sp., *Pediastrum* spp., *Staurastrum triangularis* and *Nitzschia acicularis* accounted for over 70% of the phytoplankton assemblage in the gulf (figure 2) This is attributable to the ability of these species to optimize nutrient input in the early main rainy season. Due to the low average depth (<4m) of the study area, the productive layer (trophogenic layer) is in direct contact with the layer in which the decomposers are most active (tropholitic layer), thus accelerating recycling of nutrients between the sediments and water column. Generally, because of the large drainage basin of the lake, nutrient loading tend to be greater and originates from external allochthonous sources (Dejen, 2004).

There was significant difference between the inshore and open water phytoplankton assemblages in the gulf. In the open water, members of the division cyanophyta (represented by species of *Microcystis*, *Aphanothece*, *Merismopedia, Oscillatoria* and *Spirulina*); diatoms predominantly species of *Aulacoseira*, *Eunitia*, *Navicula* and *Synedra* and the dinofalgallate *Peridinium* were dominant. Conversely the Chlorophyta were dominant at the inshore area of the gulf.

Wondie *et. al.*, (2007) observed that main rainy season primary production was probably limited by reduced duration and intensity of sunlight and high concentration of silt reducing water transparency. But conditions improve in the post rainy season with relatively high nutrient availability leading to higher productivity mostly in favor of *Microcystis*, They observed that as the rainy season progressed and nutrient concentration reach seasonal peak, all taxa are favored, but the Cyanophyta are dominant in the lake open water as a result of other phytoplankton groups suffering disproportionate higher losses (Agusti *et.al.* 1990). In the present study it was observed that the inshore stations with swallow depth, low photic zone coupled with low mixing depth and the fact that more nutrients enter the lake from the adjacent wetland, especially in station 3 presented quite distinct conditions different from the lake open water and this was responsible for the different phytoplankton assemblages.

The forty four zooplankton species reported in this study is a mixture of tropical and temperate species, most of which have earlier been reported from the lake (Wudneh, 1998**;** Dejen *et al.,* 2004). The presence of temperate species is most probably due to the generally low water temperature of the lake as a result of its high altitude location. The number of zooplankton species reported here can be described as high when compared with previous reports from the area. Wudneh (1998) listed a total of 17 species, which include 3 Copepoda, 7 Cladocera, and 7 Rotifera with the predominant species in the community being *Thermodiaptomus galebi*, *Thermocyclops sp. Mesocyclops sp*, *Bosmina longirostris, Diaphanosoma excisum*, *Keratella* *quadrata*, *K. crassa* and *Brachionus falcatus*. Dejen *et al.* (2004) reported a total of 13 species, four copepods and nine cladocerans, the calanoid copepod *Thermodiaptomus galebi lacustris*, dominated the zooplankton community, while *Thermocyclops ethiopiensis* was the most abundant cyclopoid. *Bosmina longirostris*, *Daphnia hyalina, Daphnia lumholtzi* and *Diaphanosoma sarsi* were the most abundant cladoceran species.

In the present study *Bosmina longirostris*, *Daphnia lumholtzi, Thermodiaptomus galebi*, *Thermocyclops ethiopiensis, Diaphanosoma excisum, Keratella sp*. and *Brachionus sp. Filinia sp. and Trichocerca longiseta,* have been found to still be important among the zooplankton in Bahir Dar Gulf of Lake Tana. The rotifer family Brachionidae which constituted 29% of the zooplankton population is dominant and this conforms to generally known fact as the most dominant in terms of species in freshwater ecosystems in other parts of the world (Fernando, 1980a; Arcifa, 1984; Sendacz, 1984). Diversity of the limnetic cladocerans is relatively high because of the co-occurence of both tropical and temperate species particularly the daphniids as compared with other African Lakes and reservoirs (Dumont, 1994; Marshall, 1997).

There was a clear spatial pattern in the zooplankton distribution in this study, densities per litre being high in the littoral zone and reduced toward the deeper open water areas. This supports the findings of Sladecek (1983) and Wudneh (1998) that the bulk of the zooplankton often occured at the littoral zones. This is however, in contrast with Dejen *et al.* (2004), who reported that in Lake Tana the cladocerans were most abundant in the sublittoral zone and least abundant in the littoral zone because the littoral zones sampled were devoid of aquatic macrophytes. Large lakes have been reported to have greatest abundance at the littoral zones, and Lake Tana is a large lake. However, a possible factor explaining the low abundance of zooplankton in the deeper part of the lake could be the high predation pressure in the open water. According to Dejen *et al*. (2004) adult *Clarias gariepinus*, *Barbus brevicephalus* and *Barbus trispilopleura*, are important predators on zooplankton, and are more abundant in the open water. The impact of predation on zooplankton abundance is also an important factor with significantly lower plankton density associated with the presence of the planktivore fishes.

The relative percentage compositions of the various groups of zooplankton show that the small sized zooplankton dominated the community. These high values were mostly due to small-bodied nauplii stages, high densities of small rotifers and cladocerans which are characteristic of lakes with planktivorous fishes. Densities of large bodied Cladocera and Calanoida were low during the period probably as a result of predation pressure. The size range in this study was similar to that found in other tropical freshwater bodies in Africa, South-East Asia and Latin America (Burgis *et al.* 1973).

Conclusions

According to the UN-World Water Development Report (2003), a healthy and unpolluted natural environment is essential to human well-being and sustainable development, stressing that the aquatic ecosystems and their dependent species are an integral part of our lives and provide resource base that help us to meet a multitude of human and ecosystem needs. The lake had been previously characterized as oligotrophic by levels of algal biomass expressed in chlorophyll *a* and physico-chemical conditions (Dejen, 2003 and Wondie, 2006) and the present study corroborates the fact conditions in the gulf area is same as the rest of the lake.

The plankton community structure of Bahir Dar Gulf of Lake Tana is a mixture of tropical and temperate species, thus resulting in the relatively high biodiversity of limnectic phytoplankton and zooplankton in this lake. Majority of these zooplankton are small-bodied nauplii stages, high densities of small rotifers and cladocerans found in larger number in the littoral zone than the pelagic zone an indication of the presence of abundance of planktivorous fishes in the open water.

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Table 1: Spatial Distribution of Physico-chemical Parameters from the Bahir Dar gulf of Lake Tana

PARAMETERS	STATION 1 Range	X±SE	STATION 2 Range	X±SE	STATION 3 Range	X±SE	P-VALUE *
Temperature °C	22.2-24	23.03±0.37	23.5-24.9	24.13±0.59	23-25	23.7±0.44	P>0.05
Depth m	3.5- 4.00	3.73± 0.10	1.58-2.25	1.91±0.15	0.96-1.8	1.27±0.19	P<0.001
Transparency m	0.4-0.57	0.49 ± 0.03	0.4-0.9	0.58±0.11	0.4-0.56	0.51±0.04	P>0.05
Conductivity μScm^{-1}	152-160	156.3±1.93	153-165	160.5±2.72	169-232	186.5±15.2	P>0.05
pH	8.3-8.4	8.45± 0.02	8.2-8.5	8.31±0.07	7.3-8.2	7.78±0.18	P<0.01
Nitrate mgl^{-1}	0.92-3.3	1.92 ± 0.50	0.97-3.5	2.31±0.56	0.97-4.18	2.61±0.80	P>0.05
D.O mgl^{-1}	5.9 -7.7	6.66 ± 0.53	3.5-7.2	5.50±1.06	1.66-5.06	2.84±1.11	P>0.05
Phosphate mgl^{-1}	0.14-0.16	0.15± 0.03	0.22-0.61	0.43±0.11	0.1-0.18	0.15±0.03	P<0.05

*P<0.001, P<0.01 =highly significant, P<0.05 = significant and P>0.05 = not significant

Figure 1: Species Composition of Phytoplankton groups in Bahir Dar gulf of Lake Tana

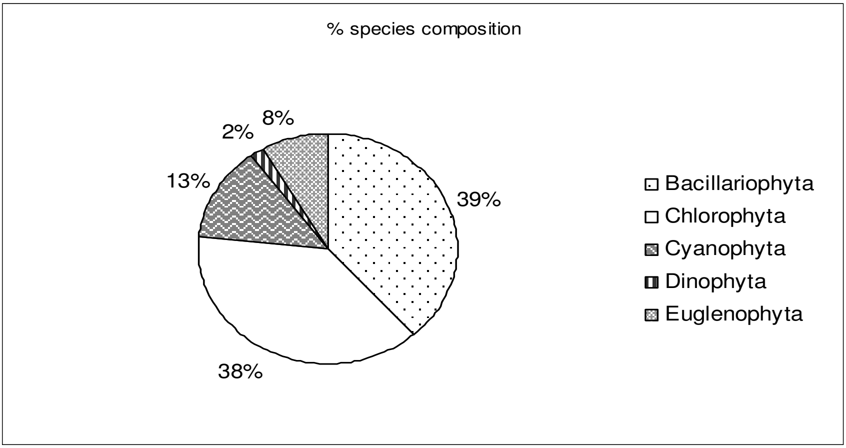

Figure 2: Spatial variations of diatoms

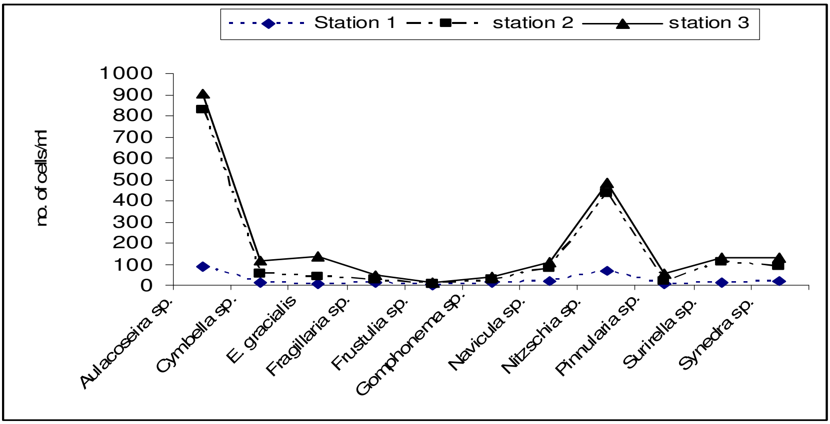

Figure 3: Spatial variations of other phytoplankton groups

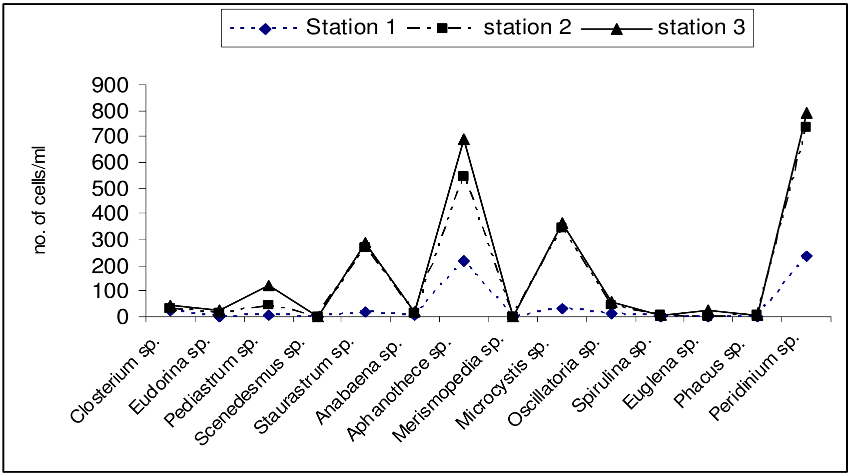

Table 2: Correlation Coefficients of Physico-Chemical Parameters

	Temp	Depth	Tran	Cond	pH	NO_3	D.O	PO_4
Temperature	1							
Depth	-0.543	1.000						
Transparency	-0.192	-0.096	1.000					
Conductivity	-0.081	-0.523	-0.041	1.000				
pH	0.119	0.670*	-0.077	-0.627*	1.000			
Nitrate	-0.569	-0.064	0.432	0.352	-0.281	1.000		
Dissolved oxygen	-0.516	0.789*	-0.389	-0.355	0.638*	-0.092	1.000	
Phosphate	0.495	-0.437	-0.404	0.496	-0.023	-0.389	0.050	1.000

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