

Hydrobiological Assessment of Lake Lanao Subsequent to Its Unusual Greening in 2006

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Abstract

The biological, chemical, and physical parameters of Lake Lanao were investigated for two sampling periods in October and November 2006 at three stations namely, Kialdan, Lake Center, and Sugod. Findings revealed that the plankton composition was dominated by a filamentous diatom, *Melosira* sp.. The massive growth of this alga caused the shallow Secchi disc transparency of the lake and its apparent eutrophication. Such large phytoplankton biomass resulted in the presumed assimilation and consequent negligible quantities of NO₃-N, NH₃-N, and PO₄-P of the lake water. Coliform analysis showed that there is no site in the lake where one can get potable water.

Key words: eutrophication; plankton composition; tropical lake

Introduction

Lake Lanao is one of the ancient lakes in the world and has been known internationally for its endemic cyprinids. It is located in the province of Lanao del Sur, Autonomous Region of Muslim Mindanao (ARMM), Philippines. It is the second largest lake in the country with an area of 357 km². It is described as a low-altitude, oligotrophic and warm monomictic lake (Frey, 1969; Lewis, 1973) and classified as a first class lake since its morphometry permits maximal absorption of radiant energy (Birge, 1915, as cited by Frey, 1969).

Frey (1969) and Lewis (1973, 1974, 1977, 1978, & 1982) made extensive studies on the biological and physicochemical parameters

of Lake Lanao. Villaluz (1966) and Escudero (1990, 1995) conducted studies on its fisheries resources. In November 1998, the MSU Task Force observed a sudden occurrence of fish kill due to epizootic ulcerative syndrome (EUS) (Escudero *et al.*, 1998). However, these investigations were never reinforced by a hydrobiological monitoring of the lake until the recent occurrence of a 'blue-green algal bloom', which caused its unusual greening in September 2006.

The present paper reports on some aspects of the hydrobiological parameters of Lake Lanao for two sampling periods subsequent to this unusual greening.

The general objective of the study is to conduct a biological and physico-chemical assessment of Lake Lanao in relation to its reported unusual greening. The specific objectives are: 1) to assess the biological factors of the lake (plankton composition and coliform count); 2) to determine the chemical parameters related to possible eutrophication of the lake (nitrate nitrogen, ammonia nitrogen, soluble reactive phosphorous, dissolved oxygen and pH); 3) to determine possible pesticide contamination of the lake (organophosphates); and 4) to evaluate some physical characteristics of the lake (secchi disc visibility and temperature).

Significance/Impact of Project

Considering that Lake Lanao is the most important cultural and natural heritage of the Meranaos, this project will give an independent assessment of its hydrobiological condition in relation to its reported unusual greening. Results can be used to recommend local action agenda regarding the utilization of the lake and the conservation and management of its watershed.

Review of Related Literature

Lanao is believed to be tectonic-volcanic in origin and listed as one of the best examples of a lake formed by a lava dam (Hutchinson, 1957). It is one of the ancient lakes in the world. It is located on a plateau having an average elevation of 750 meters above sea level. It

has five major river tributaries and it flows to the sea through its only outlet, the Agus River.

Frey (1969) made the first limnological reconnaissance of Lake Lanao, which encompassed bathymetry, meteorology, hydrology, chemistry, and biota. Results of such study revealed that Lake Lanao is the deepest, with a maximum depth of 112 m, and the second largest lake in the Philippines with an area of 357 km². The extensive volume of the lake water and its great drop (700 m) on its way into the sea of Iligan Bay possibly made Lake Lanao the greatest hydroelectric power potential of any lake in the country. During Frey's sampling period, there was only little net phytoplankton in the lake and were mainly composed of *Botryococcus*, *Pediastrum*, *Melosira granulata*, and a filament of *Leptothrix*. Secchi disc visibility measurement was 6 m, indicative of an oligotrophic lake.

Lewis (1977, 1978) conducted a series of investigations on the same lake. They included the composition, dynamics, and succession of phytoplankton for 16 months. Findings showed 70 euplanktonic autotroph species belonging to the Cyanophyta, Euglenophyta, Chlorophyta, Chrysophyta, Bacillariophyceae, Dinophyceae and Cryptophyceae. The Chlorophytes comprised the dominant group. Analysis of the growth rates and correlations in these major classes of phytoplankton provided evidences that the niche space is divided temporarily on the basis of nutrient and light availability. Growth maxima of diatoms and cryptomonads occur during periods of relatively low light availability and high nutrient availability. Pulses of green algae, blue-green algae and dinoflagellates occurred successively towards the high light and low nutrient end of the spectrum. Phytoplankton succession can be regarded as a series of episodes initiated by abrupt changes in abiotic factors, and such episodes appear to be numerous over a year in tropical lake Lanao than in most temperate lakes.

In a later study, Lewis (1979) reports that the distribution of total autotroph biomass seems to be related in a very straightforward manner to light penetration and turbulence. Under calm weather conditions, the biomass curve reflects the productive curve, which is in turn under the control of light penetration. Individual species

segregate under these conditions, with the motile species above the non-motile species. Deep turbulence generated by wind or thermal inversion masks the effects of light penetration, and smoothes the vertical distribution of total biomass. Motile species cannot segregate from non-motile species under these conditions although *Melosira* may accumulate toward the bottom of the water column because of its high sinking rate.

The preceding studies did not mention any algal bloom in Lake Lanao. Recently, however, BFAR (2006) reported the occurrence of a massive growth of blue-green algae. One of the most important factors triggering an algal bloom appears to be the mixing of the previously stratified surface and deeper water layers in lakes, rivers, or reservoirs (Wetzel, 1983). The release of nutrients from the deeper waters into the surface can cause blue-green algae to grow to large numbers and form thick accumulations on the surface of the water. Such accumulations are commonly known as scum. Scum individuals float to the water surface using vesicles within their cells that they inflate with gas. Coming close to the surface enables them to gain maximum sunlight. Wind pushes the floating algae across the water, concentrating scums toward leeward shores. Blooms are often green or blue-green, but can also be white, brown, blue, yellow-brown or red. Swirling patterns of a mixture of these colors in scums can be caused by wind movement, bleaching by sunlight, and other blooming algae (www.naturalsciences.nsw.gov.au, 2000).

Algal blooms can cause degradation of water quality, an event that calls for protective regulations of lakes. Tropical lakes are more sensitive than temperate lakes to increases in nutrient supply and show higher proportionate changes in water quality and biotic communities in response to eutrophication. Consequently, where lakes have been most profoundly altered and have lost much of their value, scientific understanding of lakes is being used in prescribing restoration methods. The future of applied limnology involves even more extensive efforts to protect and restore lakes (Lewis, 2000).

Methodology

The biological, chemical, and physical factors that might be correlated to the greening of Lake Lanao were assessed on October 19, 2006 and November 2, 2006.

Visual inspections

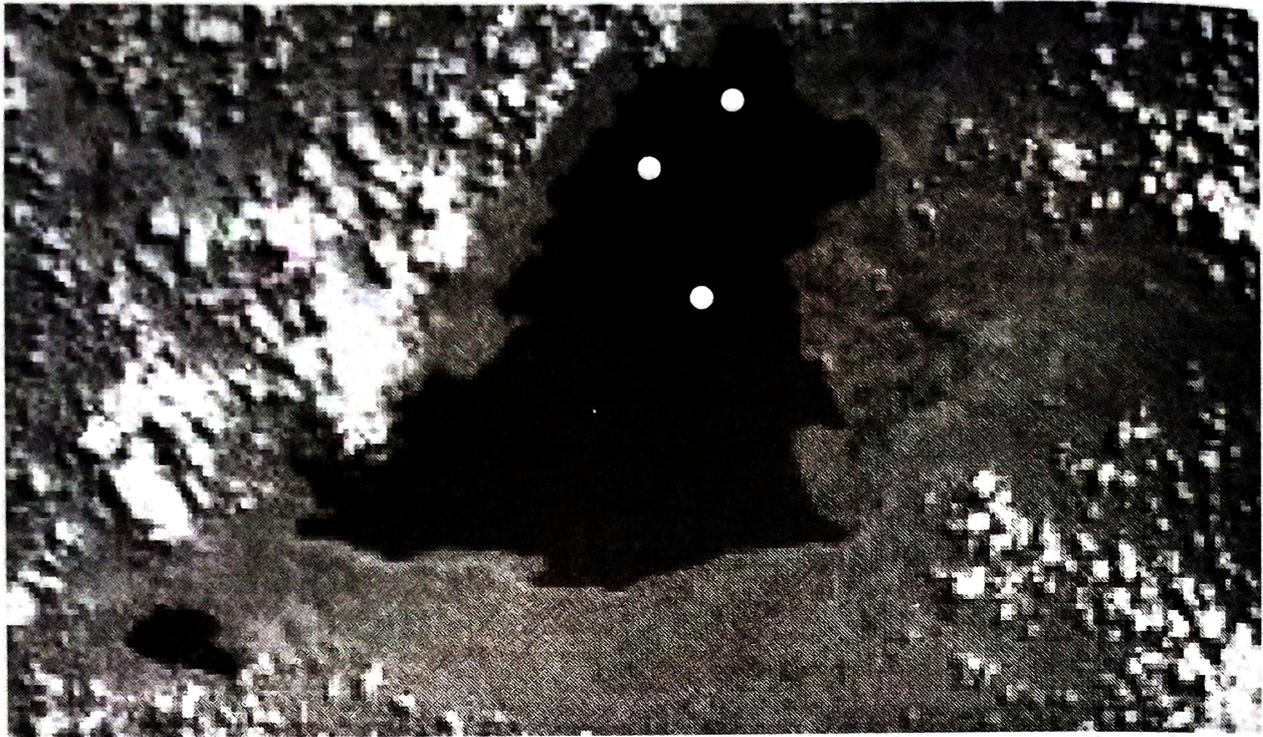
Visual inspections for the greening of Lake Lanao were made. The presence of algae in the samples was assessed, as distinct from general turbidity, by their characteristic color and possible particulate appearance.

Sampling and analyses

Water samples were collected from three sampling stations, namely: Kialdan, Lake Center and Sugod. Simultaneously, temperature and dissolved oxygen and pH were determined *in situ* using a DO meter and pH meter, respectively, while water transparency was measured by means of a Secchi disc (Lind, 1985).

Water samples for the assessment of the presence of coliform and plankton composition were placed in ice buckets and were brought to the research room of the Biology Department. Thereafter, these were subjected to coliform analysis using the multiple tube fermentation technique (Standard Methods, 1975). Microscopic examination was done to determine the appearance and concentration of plankton. The plankton composition was identified using reference materials and its density was measured using a Sedgewick Rafter counting cell.

Water samples intended for the analyses of nitrate nitrogen, ammonia nitrogen, soluble reactive phosphorous and organophosphates were brought to MSU-IFRD at Naawan, Misamis Oriental and results were taken from said laboratory after three days.



Lake Lanao (large dark area, from satellite photo, Google Earth)

Legend:

○ Water Sampling Sites

Municipality	Coordinates		Description	Station No
	Latitude N	Longitude E		
Marawi City Sugod				N 1
Marantao				NW
Lake Lanao Center				NSEW

Parameters:

Biological	Algae (Plankton)	
	Coliform	
Chemical	pH	
	soluble reactive	
	Phosphorous (PO_4^{3-})	
	Nitrogen: NH_3	
	NO_3	
	Dissolved oxygen	
Physical	Temperature	
	Secchi Disc Visibility	

Results

Table 1. Bacteriological analysis of Lake Lanao water samples for two sampling periods

Station	October 19, 2006		November 2, 2006		
	Presumptive test No. of positive tubes out of 5 inoculated w/ 10ml, 1ml, 0.1ml	MPN, most probable number of total coliforms per 100 ml of water	Presumptive test No. of positive tubes out of 5 inoculated w/ 10ml, 1ml, 0.1ml	MPN, most probable number of total coliforms per 100 ml of water	Confirmed test (EMB agar), positive/negative for fecal coliform
Stn. 1 Marantao Surface	3-2-0	14	3-0-0	8	negative
5 m	4-1-0	17			
Stn. 2 Lake Center Surface	1-0-0	2	1-0-1	4	positive
Stn. 3 Sugod Surface	4-5-3	920	4-4-0	34	positive
5 m	3-2-0	14	34		
Near Nusa Is. Surface			5-2-0	49	negative

Table 2. Plankton analysis of water samples collected at the Lake Center for two sampling periods

October 19, 2006	No. of cells/filaments per liter of lake water	November 2, 2006	No. of cells/filaments per liter of lake water
Species		Species	
<i>Melosira</i> sp.	13,441	<i>Melosira</i>	1271
<i>Protococcus</i> sp.	36	Diatom 1 (very fine filament)	937
<i>Crucigenia</i> sp.	20	<i>Rhizosolenia</i>	602
<i>Anabaena</i> sp.	19	Diatom 2 (<i>Fragillaria</i>)	515
<i>Staurastrum</i> sp.	15	<i>Peridinium</i>	226

Colonial globular	13	Diatom 3 (<i>Nitzschia</i>)	84
Colonial with sheath	13	<i>Staurastrum</i>	82
		<i>Closterium</i>	51
		<i>Protococcus</i>	45
		<i>Chaetoceros</i>	26
		<i>Anabaena</i>	14
		Nauplius	8
		Colony	8
		<i>Gloecapsa</i>	8
		<i>Calanus</i>	3
TOTAL	13,557		3880



Figure 1. Confirmed test of fecal coliform on EMB agar plate



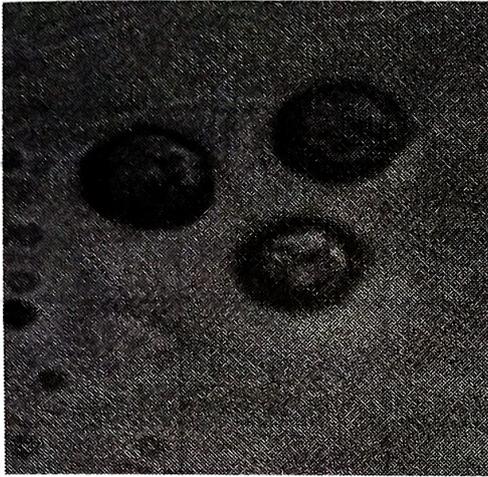
Figure 2. *Melosira* sp., a filamentous diatom



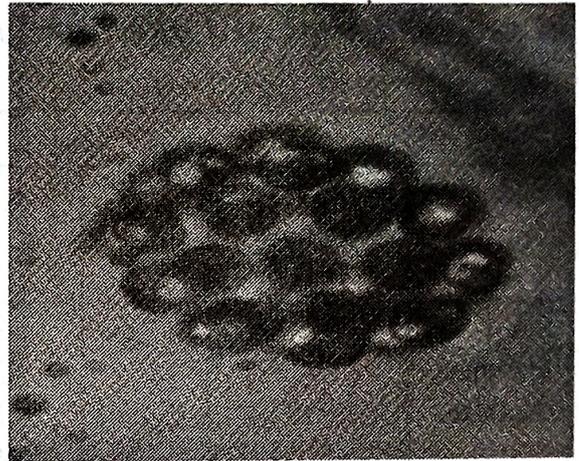
Figure 3. A microscope field of *Melosira*



Figure 4. *Staurastrum* sp.



**Figure 5. *Protococcus* sp.
(single cell)**



**Figure 6. *Protococcus* sp.
(colony)**

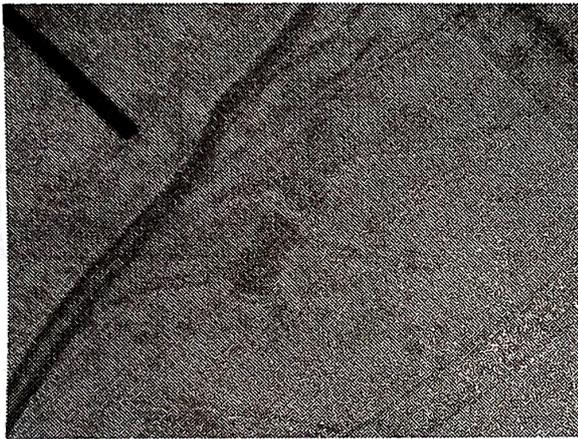


Figure 7. *Chaetoceros* sp.



Figure 8. *Coelastrum* sp.

Discussion

The test for the potability of water was made through the coliform test, which determines the presence of fecal pollution. Based on the National Standards for Drinking Water, which states that there should be 0 total coliform per 100 ml of water (DENR, 1990), there is no site among the sampled stations in the lake that one can get water which is safe for drinking. These can be supported by the findings obtained from two sampling periods with all stations positive for total coliform and two stations (Lake Center and Sugod) confirmed positive for fecal coliform (Table 1 and Fig. 1).

Fecal coliform bacteria can come from direct discharge of untreated human sewage, and from mammals and agricultural wastes through water runoff. Their presence indicates possible contamination of the water with pathogenic organisms. This may be cause for concern because diseases can be spread through fecal transmission. (<http://switzerland.k12.in.us/watershed/fecal.html>).

Table 2 shows the different plankton organisms. Phytoplankton analysis for the first and second sampling periods revealed the presence of an algal bloom dominated by the filamentous diatom *Melosira* sp. (Figs. 2 & 3), which is an indicator alga of eutrophic lakes (www.google.com, 2006). The decrease in the density of said alga in the first sampling favored the growth of more algal species during the second sampling (Table 2; Figs. 4-8).

However, earlier investigation conducted during the occurrence of an unusual green coloration of the lake reported the bloom of a blue-green alga, *Anabaena* sp. (BFAR-Central Office, September 20, 2006). Such algal proliferation is a natural phenomenon and happens when growth conditions such as light and nutrient availability are favorable (www.naturalciences.nsw.gov.au, 2000; Lewis, 1978). Lathrop *et. al.* (1998) cited that high nutrient load from excess human sources of nutrients, such as fertilizers and sewage, result in blue-green algal blooms.

The difference in the data of the present study from the one reported by BFAR can be correlated with the findings of Lewis (1977) in that the abundance of species vary markedly in their amplitudes of variation through time and some species fluctuate wildly, while others maintain a remarkably constant population size. In addition, Lewis (1978) discovered a succession of seventy species of phytoplankton in Lake Lanao. During the BFAR second sampling, BFAR-Central Office (September 27, 2006) noted that the density of *Anabaena* sp. diminished in the water sample that was collected after one week of its massive growth.

Table 3 reveals the Secchi disc transparency of the three stations for the two sampling periods. Apparently, there was a shallower transparency depth (mean 2.62 m) on October 19, 2006 than on November 2, 2006 (mean 4.22 m). This can be correlated with the denser population of the phytoplankton during the first sampling compared with that of the second sampling. It will be noted that the first sampling was conducted right after the BFAR report of a massive growth of a blue-green alga (*Anabaena* sp.).

Frey (1969) got a Secchi depth reading of 6 m and noted that Lake Lanao was the most transparent among the Philippine lakes during that time of investigation. Wetzel (1983) reported that the annual variations in the Secchi depth of an unproductive hardwater lake almost always went below 4 m, whereas that of a highly productive lake almost never went deeper than 3 m. Consequently, the initial findings of this study show that Lake Lanao has become a eutrophic lake.

Chemical measurements ($\text{NO}_3\text{-N}$, $\text{NH}_3\text{-N}$ and $\text{PO}_4\text{-P}$) as shown in Table 4 are low. This is expected inasmuch as the large phytoplankton biomass had assimilated these nutrients. Natural concentrations of these nutrients are frequently less than 1 mg N per liter and often less than 0.01 mg P per liter, especially during periods of high primary production (Lind, 1985).

The lake water was found to be free from pesticide contamination and its pH values fall within the natural range.

Because of the current state of eutrophication of Lake Lanao, it is evident that there must have been nutrient inputs to the lake. Three hypotheses are proposed as possible sources of these nutrients. First, these could be carried by floodwater from the fertilized rice fields. Second, organic and sewage inputs from the increased lakeside population have now overshoot the natural purification capacity of the lake (Odum, 1971). Third, the nutrients that have been sequestered in the deep layer (hypolimnion) of the lake (most of which might have come from the wastes of the lakeside population) was released due to overturn. Hence, these hypotheses would show that the preservation of the lake is largely dependent on the people of the lake themselves.

Recommendations

To substantiate the initial results of the present study, Mindanao State University in Marawi City through the Lake Lanao Fact Finding Technical Committee should conduct a long-term hydrobiological monitoring of the lake with sampling stations that would represent the whole lake.

To prevent further eutrophication of the lake, the Local Government Units (LGUs) of Lanao del Sur should construct sanitary toilets for the communities living along the lakeshores. Likewise, the lakeside residents should properly dispose of their domestic wastes.

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