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Water Quality Assessment of the South-Eastern Part of Lake Lanao, Philippines

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Abstract. This paper aimed at underlying some physico-chemical characteristics of the water of Lake Lanao at Poona-bayabao, Lanao Del Sur during the first quarter of 2015, by evaluating a total of eight (8) water quality parameters. Physical parameters were temperature, depth, transparency, and total suspended solids. On the other hand, the chemical parameters were pH, dissolved oxygen, phosphate and nitrate. Three sampling stations were considered in the study. Community's knowledge, perceptions, and attitudes towards the utilization and condition of the lake were also evaluated through interview. Results showed that all assessed physico-chemical parameters still conformed to the Philippines standards set by Department of Environment and Natural Resources (DENR) for fresh surface water as Class A as for the year 2015. One-way Anova showed no significant difference in the overall average of the physico-chemical characteristics in the three sampling stations of Lake Lanao ($p > 0.05$). With the results obtained, the Lake can still be a source of water supply that require complete treatment in order to meet National Standards for Drinking Water (NSDW) of the Philippines, within the year of the conduct of the study. For the assessment of community's knowledge, perceptions, and attitudes, Kruskal-Wallis test showed that the knowledge, perceptions, and attitudes are not significantly different in terms of stations. A more comprehensive and wider range monitoring is recommended for future study about the lake.

1. Introduction

Freshwater ecosystems can be divided into two categories: those in which the water is relatively stationary, such as lakes, ponds, and reservoirs, and those in which the water is running downhill, such as streams and rivers [1]. Lakes are inland bodies of water that lack any direct exchange with an ocean. Lake ecosystems are made up of the physical, chemical and biological properties contained within these water bodies [2]. Freshwater bodies are important source of water for human activities. They serve as sources of drinking water, water for agricultural use, domestic use (including cooking, washing etc.), transportation, electricity generation, recreation and sometimes, the disposal of waste materials [3].

Lake Lanao is the largest lake in Mindanao with a total area of 347 sq km and is one of 17 ancient lakes on earth [4]. Noted as a pre-historic and socio-culturally significant lake known the world over, Lake Lanao still exudes its majestic and tranquil waters flourishing with great bio-diversity of aquatic life forms. Through the years however, the lake has not been spared from various anthropogenic activities associated with the growing demand of the lake's resources- the water for domestic and agricultural use as well as for hydro-power generation, contact recreation, boating, laundry and bathing, ritual use, water sports, fishes for domestic consumption and livelihood, and host of numerous lake's related uses [5]. People of Poona-Bayabao depend on Lake Lanao for such purposes. It is also on the lake where they catch fishes which will then be sold to nearby barangays and municipalities. Fishing is one of their livelihoods.

On 2014, studies showed that Lake Lanao can now be categorized as **"Class A"** or whose waters require complete treatment to meet national standards of drinking water [6,7]. This classification is similar with the Lake Danao in Ormoc City, the upper reaches of Paypayan and Langaran River in Misamis Occidental.

Two similar studies have been reviewed. One is about monitoring and evaluation of the water quality of Taal Lake at Talisay, Batangas, Philippines, where a total of nine (9) water quality parameters were assessed [8]. The other is about the assessment of the water quality of Mamba River of Mts. Palaypalay/Mataasnagulod, Southern Luzon, Philippines [9]. For Taal Lake, the assessed parameters conform to the standards set by DENR except for phosphate, chlorine, and 5-Day 20°C BOD which are below the standards. Its lake water can still be classified as Class B, Recreational Water Class I. For Mamba River, its Phosphate concentration is also found to be below the standards set by DENR including its color. The river can be best used for primary contact recreation such as bathing, swimming, and skin diving. The river can also be developed for aquaculture purposes, and it is suitable for fish propagation and growth.

There is a need to perform water quality analysis in the Lake Lanao in order for the residents to gain awareness on the present condition of the lake. Consequently, this can also provide knowledge to the residents as to how human activities, industrial activities, and agricultural activities can affect the water quality of the lake. Some physico-chemical parameters were assessed by which contributed in providing information to the residents for the potential use of the lake and to the Local Government Unit for future policy implementation. The study sought to know the present state of south-eastern part of Lake Lanao at Poona-bayabao using physico-chemical parameters such as surface water temperature, pH, depth, dissolved oxygen (DO), transparency, and total suspended solid and its phosphate and nitrate content. The immediate community's knowledge, perceptions, and attitudes towards the utilization and condition of the lake were also assessed.

2. Materials and Methods

Study site

The study area was the south-eastern part of Lake Lanao at Poona-bayabao, Lanao Del Sur, Philippines (Figure 1). Lake Lanao is one of the most important inland body of water in the Philippines. It is considered the second largest inland aquatic resource and the biggest and deepest freshwater lake in the Philippines [10]. The Lake can be roughly fitted to a right triangle with the Basak Area, or lowland plains, to the right of the upright leg, the Masiu-Ganassi line forming the base, and the Marawi-Ganassi line the hypotenuse. A line joining Balindong and Tamparan will divide the Lake into a shallow north (maximum depth of 55 meters) and a deep south (55 meters deep and greater) [6]. Fronting the lake are rice fields and right before these rice fields is a community. Water hyacinths were seen on the shore of the lake.

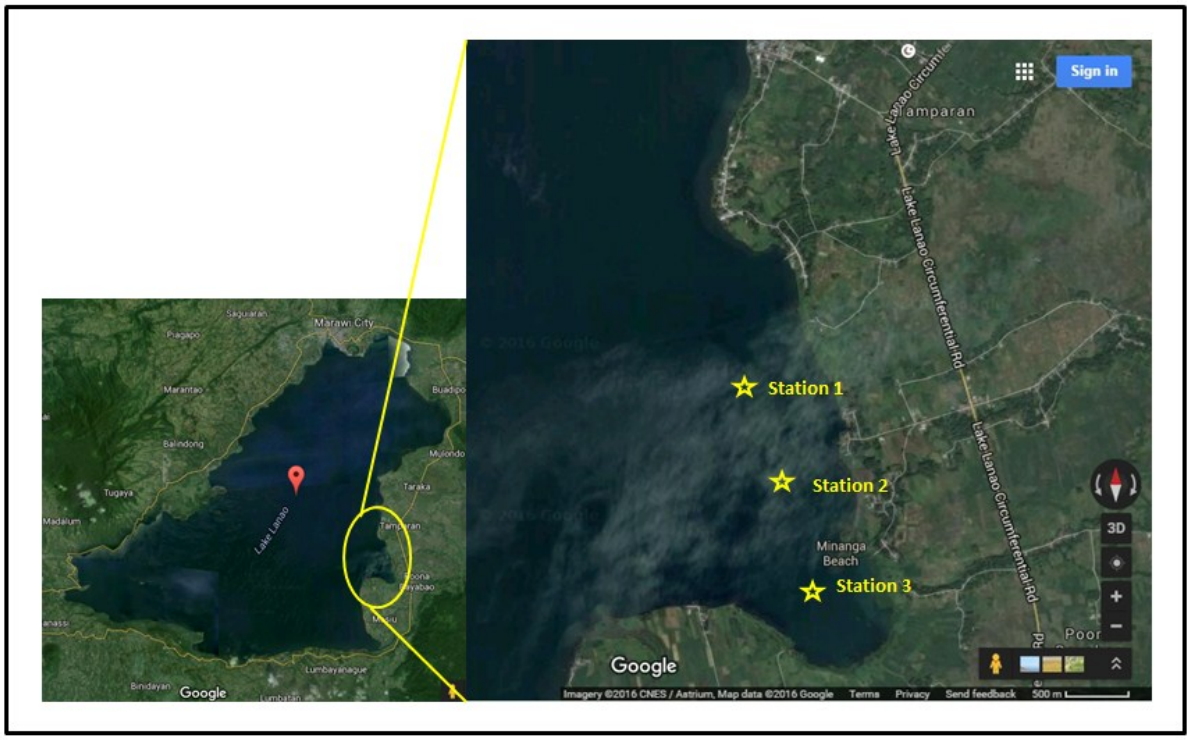

Figure 1. Map of Lake Lanao at Poona-bayabao, Lanao Del Sur showing the sampling stations.

Water Sampling

Using Geographical Coordinates, three sampling stations were established along the south-eastern part of Lake Lanao and sampling was done on March 16, 2015 (Table 1). Station 1 was situated at Barangay Kadayonan, Station 2 was at Barangay Rogan, and Station 3 was at Barangay Punud. Surface water temperature, depth, and transparency, were directly determined on site. Water samples for DO, phosphate, nitrate, pH, and TSS analyses were collected at three stations and were placed in three empty plastic bottles (labeled with station number, sample name, and replicate number) with three replicate samples per station. The samples were placed in a stryrofoam box with ice and were brought to Mindanao State University at Naawan – Institute of Fisheries Research and Development (MSUN-IFRD) Chemistry Laboratory for analyses.

Table 1. Geographical coordinates, sampling time and weather condition of Lake Lanao, Poona-bayabao, Lanao Del Sur during water sampling on March 16, 2015.

Stations	Geographical Coordinates		Time of sampling	Weather Condition
1	N7°50’53.1189	E124^{0}19’39.6550	10:22 AM	Mild Sunny
2	N7°50’21.1239	E124^{0}19’43.8200	11:30 AM	Mild Sunny
3	N7°50’3.3119	E124^{0}19’47.2558	11:52 AM	Sunny

Physico-chemical Analysis

Surface water temperature, depth, and transparency, were directly determined on site using thermometer for temperature, rope for depth, and secchi disk, respectively. DO was fixed on site by putting 1.5 ml Manganous sulfate solution and 1.5 ml Alkaline KI solution in the water samples placed in DO bottles. The value of water sample’s pH, total suspended solid (TSS), dissolved oxygen (DO), phosphate and nitrate were analyzed at MSUN-IFRD Chemistry Laboratory.

The pH of the sample was determined using a pH meter. In determining the total suspended solids (TSS) of the water sample, filtration method was used.The nutrients (PO_4 and NO_3) were analyzed using a UV-Vis spectrometer.

Community component

Using Slovin formula, 100 respondents were chosen randomly within the three barangays. A semi-structured questionnaire was used and translated to Maranao (the area's local language) to obtain the demographic profile of the respondents and to assess their knowledge, perceptions, and attitudes towards the utilization and condition of the lake through Likert scale responses to statements.

3. Results and Discussion

The water samples in all sampling areas appeared colorless and odorless. The weather condition during the sampling was generally mild sunny. Result showed that the pH level of water ranged from 7.5 to 7.6 which appeared to be slightly basic. Station 1 and 2 had the same pH reading which is 7.6. The average pH value was 7.6. This value conforms to the standard pH range 6.5-8.5 which is set by DENR. The pH is an important factor in determining productivity of an ecosystem. The indirect effects of pH are more important than the direct effects. Most of the biochemical parameters of aquatic bodies are influenced by pH [10].

The recorded water temperatures from the three sampling stations ranging from 23 to 24 ºC were within the permissible limit set by DENR since there was no recorded increase of more than 3°C compared with the ambient temperature. Direct exposure to sunlight can significantly raise the temperature of a water body. Other factors that contributed to the temperature variation included water depth, air temperature, amount of shade, and thermal pollution from human activities [11].

In the southern part of Lake Lanao, depth has an average value of 12.3 meters. Station 1 was recorded to be the deepest that has a value 14.4 meters while Station 2 has a depth which is 10.8 meters. Lake Lanao has a mean depth 60.00 meters and its maximum depth is 112.00 meters (Naga, 2010). In this study, the recorded depth is not great since the measuring of depth took place near the shoreline and not at the center. Compared to Lake Lanao, Lake Mainit in CARAGA is much deeper with a mean depth 129 meters and a maximum depth 219 meters [12].

The clarity of lake water is reduced by the presence of suspended sediment and Marl ($CaCO_3$), bits of organic matter, free-floating algae, and zooplankton. Algae are often the dominant influence on transparency of lake water [13]. The transparency of the three sampling stations has an average value of 7.4 meters. Station 1 was the most transparent with a value 7.9 meters while Station 3 was recorded to have a transparency of 6.7 meters. During the sampling, no visible algae growth was observed and there were no observed runoffs since the study was conducted during dry season. During the dry season, secchi-disc transparency mean value was higher compared to that of the rainy season which could be due to absence of floodwater, surface runoffs and settling effect of suspended materials that followed the cessation of rainfall [14].

Table 2 shows the mean values of each physico-chemical parameters for each station compared to the standard set by DENR for surface waters [15].

Table 2. Results for physical and chemical characteristics of the south-eastern part of Lake Lanao, Poona-bayabao, Lanao Del Sur on March 16, 2015 compared to National Standard.

Parameters	Station 1 (Brgy. Kadayonan)	Station 2 (Brgy. Rogan)	Station 3 (Brgy. Punud)	Mean Values	Standard Set by DENR-EMB (for Class A)	Interpretation of Data
Water temperature (°C)	23.00	23.00	24.00	23.33	3*	Within the standard
Depth (m)	14.4	10.8	11.6	12.3	_____	_____
Transparency (m)	7.9	7.5	6.7	7.4	_____	_____
Total Suspended Solids (TSS) (mg/L)	0.002	0.001	0.002	0.002	50 mg/L	Within the standard
pH	7.60	7.60	7.50	7.57	6.5-8.5	Within the standard
Dissolved Oxygen (D.O.) (mg/L)	6.846	7.118	6.846	6.937	≥ 5 mg/L	Within the standard
Phosphate PO_4-P (mg/L)	0.028	0.030	0.035	0.031	0.05 or 0.1 mg/L	Within the standard
Nitrate NO_3-N (mg/L)	0.011	0.011	0.012	0.011	10 mg/L	Within the standard

*allowable temperature increase over the ambient temperature is 3°C

Total suspended solids (TSS) of samples ranged from 0.001 to 0.002 mg/L. Stations 1 and 2 have the same TSS value which is 0.002 mg/L. The higher the TSS value, the lower is the ability of the water to support aquatic life due to reduced light penetration affecting plant photosynthesis [4]. Since the obtained TSS is within the standard set by DENR-EMB, aquatic life within the lake is in good condition. The low TSS value also coincides to the high transparency values in all stations.

Dissolved oxygen (DO) is necessary for the survival of aquatic organisms. It is the amount of oxygen dissolved in the bodies of water. Low DO readings show high oxygen requirement of aquatic organisms. This is maybe due to severe pollution [8]. The results for the DO of water ranged from 6.846 to 7.118 mg/L and the calculated mean value is 6.937 mg/L. This value conforms to the standard set by DENR which ≥ 5.0 mg/L. This is a good indication that DO concentration of the lake water in Lake Lanao can sustain the oxygen demands of the aquatic organisms within it.

The phosphate content of the lake water samples was recorded in the range of 0.028 to 0.035 mg/L. The average phosphate concentration from the three sampling stations is 0.031 mg/L. This value is within the permissible limit (maximum 0f 0.05 or 0.01 mg/L) set by DENR. Large total phosphorus concentrations generally are associated with runoff events, which carry a substantial proportion of suspended sediment to which phosphorus is attached [16]. Low phosphate levels were observed since the conduct of the study was done in summer and not on rainy days were there could be an observed runoff events.

Nitrate as nutrient favor growth of aquatic plants (algae) which are food for fish, but if their concentration reaches beyond the allowable limit (maximum 10 mg/L) this could lead to excessive growth of algae referred to as “algal bloom”. Die-off of algae which occurred normally at nighttime, require oxygen thus resulting to depletion of oxygen and eventually affecting aquatic life especially fishes [17]. In Lake Lanao, nitrate concentration from the three sampling stations has a mean value of 0.011 mg/L. It is within the standard set by DENR.

Table 3 shows the result of the One-way ANOVA test for significant difference among the three sampling stations for each parameter. The obtained p-value for DO was 0.7833, 0.1449 for PO_4, 0.1715 for NO_3 and 0.5787 for TSS. In the three sampling stations, all parameters showed no significant variations ($p > 0.05$). Similar observations have been made by Ibrahim *et al* [14] on their study on the assessment of the physico-chemical parameters of Kontagora Reservoir, Niger State, Nigeria, which showed that physico-chemical characteristics of the five sampling stations considered had significant differences. Likewise, the study of Martinez and Galera [8] on Taal Lake at Batangas that showed no significant difference in the overall average of the two sites they considered in their study.

Table 3. One-way ANOVA for Dissolved Oxygen, Phosphate, Nitrate and Total Suspended Solids at different sampling stations.

Parameters	Stations	Mean	p-value	Remarks
Dissolved	Station 1	6.846		
Oxygen (DO)	Station 2	7.118	0.7833	Not significant
mg/L	Station 3	6.846		
Phosphate	Station 1	0.028		
(PO_4)-P	Station 2	0.030	0.1449	Not significant
mg/L	Station 3	0.035		
Nitrate	Station 1	0.011		
(NO_3)-N	Station 2	0.011	0.1715	Not significant
mg/L	Station 3	0.012		
Total Suspended	Station 1	0.002		
Solids (TSS)	Station 2	0.001	0.5787	Not significant
mg/L	Station 3	0.002		

*With 0.05 Level of significance

Overall, the assessed water quality parameters were within the standard set by DENR-EMB. The study of Martinez *et al* [9] on Mamba River in Southern Luzon also showed that the assessed water quality parameters (temperature, pH, TSS, and DO) conformed to the standard set by DENR-EMB. Phosphate concentration on that said river was below the standard since the obtained result was significantly higher. It was due to heavy rains that had caused the increased downpour of top soils containing naturally occurring phosphorus from the surrounding uplands.

Community component

Respondents were found to be knowledgeable and showed positive perceptions and attitudes regarding the importance, utilization and condition of Lake Lanao in the Poona-bayabao area. The Kruskal-Wallis test of significant difference showed the p-value of 0.3964 for knowledge, 0.1375 for perceptions, and 0.8407 for attitudes, which indicated that there is no significant difference in community's knowledge, perceptions and attitudes towards the lake among the three barangays (Table 4). Gender also showed no significant difference to their responses.

Table 4. Kruskal-Wallis test for community's knowledge, perceptions and attitudes between the three barangays.

Category	Stations	n	p-value	Remarks
	Station 1	41		
Knowledge	Station 2	25	0. 3964	Not significant
	Station 3	34		
	Station 1	41		
Perceptions	Station 2	25	0. 1375	Not significant
	Station 3	34		
	Station 1	41		
Attitudes	Station 2	25	0. 8407	Not significant
	Station 3	34		

*With 0.05 Level of significance

Generally, community's knowledge, perceptions and attitudes towards the utilization and condition of Lake Lanao showed no significant difference according to stations which means that residents from the three stations perceived the value, treat, and utilization of the lake similarly. These findings are similar to the study of Hao [18] on Nansihu Lake in China which also showed no significant difference on the knowledge, perceptions and attitudes of the urban and suburban residents on the lake.

Culture can shape our view of the world. Many studies have shown that people from different cultures see and perceive things differently and that is probably due to how their culture shaped the way they view the world. Culture does seem to affect individuals' thoughts and/or perception [19]. Perceptions are affected by all the events in your life. People's thinking depends on those experiences as well. So perception is always experiential. Perception is the process of making sense out of an experience as well as the imputing of meaning to experience. Our past experiences play a vital role in perception [20]. People's attitudes are favorable or unfavorable opinions toward other people, things, or situations. Many things affect their attitudes, including the environment where people were brought up in and their individual experiences [21].

The similarity of respondent's knowledge, perceptions and attitudes towards the utilization and condition of the lake is mainly due to the similarity of the experiences they have with regards to the lake. They utilize the lake similarly and they also treat the lake in a similar way. Although they came from different barangays, they share common culture and ethnic background (Maranao), and that could also be the reason why their perceptions and attitudes are not significantly different.

Conclusions

On the overall results, water from South-eastern part of Lake Lanao can still be classified as Class A (under Public Water Supply Class II) at the time of conduct of this research (2015). In general, the Lake's water is usable as a source of drinking water upon complete treatment (coagulation, sedimentation, filtration and disinfection) in order to meet the National Standards for Drinking Water (NSDW) of the Philippines. However the findings of this study do not give the over-all representation of the present state of Lake Lanao considering other factors not given into account. Respondents were found knowledgeable and showed positive perceptions and attitudes regarding the lake. Thus, future comprehensive assessment and monitoring of the water condition of the lake should be taken into consideration.

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