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Physico-chemical and Plankton Analysis of Ambuwaya Lake in Kiangan, Ifugao, Philippines

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Ambuwaya lake is a body of water sustained by groundwater. Dissolved oxygen (5.04±0.70 ppm), pH level (8.19±0.18) and total ammonia-nitrogen (0.11±0.09 ppm) of the lake were within the set standard of the Department of Environment and Natural Resources. However, lake temperature of 33.79±2.91°C was not within the set standard but still tolerable for tilapia and carp available in the lake. The secchi disk visibility reading of 34.58±3.60 cm suggested that the lake was hypereutrophic. The lake total dissolved solids were 45.56±1.04 ppm. Alkalinity level (29.60±3.32 ppm) of the lake was within the set standard by Australian and New Zealand Environment Conservation Council. Fifteen taxa of plankton from eight major groups were identified. Phylum Dinoflagellate had the highest abundance with the dominance of *Peridinium* sp. The diversity of phytoplankton and zooplankton was very low. Phytoplankton evenness was categorized as a stable community while zooplankton was categorized as an unstable community. The pollution index using

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the Palmer's index scored 16 indicating the high organic pollution of the lake. Further research study which includes the wet and dry seasons through monthly sampling was recommended to establish water quality in both seasons.

Keywords: Assessment; phytoplankton; water quality, zooplankton.

1. INTRODUCTION

Lake is a large area of water surrounded by land and not connected with the ocean except by rivers or streams. The proportion of freshwater on earth's surface is only 2.5% of which only 1% is accessible for use. In this context, lakes are one of the most important water resources and have been used as a source of water supply for human consumption and in general accounts for about 0.3% of the total surface water body sources [1]. The lakes all over the country are exposed to various forms of environmental degradation. The degradation is due to rapidly increasing population, rising standards of living, and exponential industrialization and urbanization. Water quality began to deteriorate due to various pollutant contributions in this process, thereby affecting the soundness of the aquatic ecosystem [2]. With water scarcity already an important environmental problem, the present focus is on improvement in the quality of existing water sources particularly lakes using characterization [1]. Water quality is usually determined by the general composition of water about its physical, biological and chemical properties [3]. The assessment of water quality is essential in developing a management strategy to control lake water pollution [4] and is used to determine whether the water is suitable for consumption or safe for the environment [5]. Water quality monitoring is given a high priority for the determination of current conditions and long-term trends for effective management [6]. The assessment of water quality, is usually carried out by determining its physico-chemical and biological properties or parameters against a set of standards [5]. The physico-chemical parameters play an important role in maintaining the restoration system and regulating the water quality [4].

Life in lakes is inevitably influenced by plankton. Plankton are free-floating microscopic organisms in the aquatic ecosystems [7]. They serve as bio-indicators and serve the purpose of monitoring environmental pollution. Changes in the plankton community structure about physico-chemical parameters may be the first sign of a deterioration in the water quality [8]. A strong relationship exists between the two main components of plankton communities, phytoplankton and zooplankton. Phytoplankton, which are the main producers of organic matter in the pelagic are also an essential source of food for zooplankton, directly for herbivorous animals and indirectly for detritus feeders [8]. As cited by Hastuti et al. [9], the abundance of phytoplankton in the waters is affected by several environmental parameters and physiological characteristics. The composition and abundance of phytoplankton will change at various levels in response to changing environmental conditions, whether physical, chemical and biological.

The primary goal of the study was to evaluate the present condition of the lake water by assessing its physico-chemical water quality and plankton. The physico-chemical parameters for analysis include temperature, secchi disk visibility depth, total dissolved solids, dissolved oxygen, pH, alkalinity, hardness, phosphorus, total ammonia-nitrogen and nitrite. Additionally, the study identified the abundance of phytoplankton and zooplankton. and biological indices such as diversity, evenness, dominance, richness, and Palmer's pollution index. Planktons were also identified to their genus level. Generated data were essential in creating policies for the management of the lake in general, and specifically, on the aquaculture activities. Available information from this study are useful in the implementation of various mitigation plans and strategies in improving and maintaining the good quality of water.

2. MATERIALS AND METHODS

2.1 Sampling Stations at Ambuwaya Lake Kiangan, Ifugao

Five sampling stations were considered at Ambuwaya lake, Kiangan, Ifugao. Station 1 at coordinates N 16°47.234' and E 121°05.967', represents the frontmost section of the lake. Station 2 (N 16°47.213'; E 121°05.985') is the second deepest portion of the lake. Station 3 (N 16°47.225'; E 121°05.966') is the center most part of the lake and the deepest. Station 4 situated at coordinates N 16°47.202' and E

121°05.981' is the entrance point of the lake where most rocks are observed. Station 5 (N 16°47.197'; E 121°05.977') is the shallowest of all stations and mostly disturbed.

2.2 Collection of Water Samples for Physico-chemical Analysis

Water samples for laboratory analyses were collected at the surface level in every sampling station [10]. Garmin Ff250 depth sounder was used to measure the total depth of each sampling station. The 1.0 L polyethylene (PE) bottles were rinsed three times with lake water prior to the collection of water sample in every site. Each sampling stations were replicated thrice. The water samples in PE bottles were placed in an ice chest for immediate transport in the laboratory after collection. The temperature inside the ice chest was maintained at around 4 °C until it reached the laboratory.

2.3 Analysis of Water Samples

The water temperature, dissolved oxygen, total dissolved solids and pH were directly determined on-site. The visibility of water was assessed using secchi disk. The analysis for total ammonia-nitrogen, alkalinity, phosphorus and nitrite was preceded at the Soil and Water Quality Laboratory, Central Luzon State University (CLSU), Science City of Muñoz, Nueva Ecija.

2.4 Collection and Preservation of Water Samples for Plankton Analysis

Water samples for plankton identification and quantification were collected in the same sampling stations with a maximum depth of 0.5 m. For the phytoplankton, 10 L of water sample was collected in a basin for filtration using a 20 µm plankton net [11]. Each station was replicated three times [12]. The net-filtered water samples (50 mL) were stored in concave PE bottles for immediate preservation using 0.15 mL Lugol's solution [12]. Water samples for zooplankton were collected using the same procedure but were preserved using 1 mL of 4% formalin [13].

2.5 Identification and Quantification of Plankton

The preserved phytoplankton samples in PE bottles were placed in a dark place for plankton settlement. After three days, 1 mL from the stored sample was pipetted into a Sedgwick-Rafter counting chamber [12]. Taxonomic keys of Suther and Rissik [14] were used for plankton identification. Plankton were identified to their genus level. Abundance, diversity, dominance, evenness, richness and Palmer pollution index were computed. The abundance of plankton was computed using the formula:

$$Abundance\ (cells/mL) = \frac{(T)\,1000}{AN}\ x\ \frac{Volume\ of\ concentrate\ (mL)}{Volume\ of\ sample\ (mL)}$$

Where:

T = total number of planktons counted
A = area of grid mm²
N = numbers of grid counted
1000 = area of counting chamber mm²

Plankton diversity and evenness was computed using the following formula adapted from Shannon-Weiner index;

$$Diversity\ (H) = -\Sigma pilnpi$$

Where:

Σ = the summation of total number of species
pi = proportion of species in the *i*th species
ln = natural logarithm

The diversity status was categorized according to Boyd and Lichktoppler [15] as: very low (<1.99), low (2.0 to 2.49), moderate (2.5 to 2.99), high (3.0 to 3.49) and very high (>3.5).

Plankton species evenness was computed using the formula adapted from Boyd and Lichktoppler [15]:

$$Eveness\ (E) = \frac{H}{ln\ (no.of\ species)}$$

Where:

H = species diversity
ln= natural logarithm

The evenness index ranges from 0 to 1. The evenness status was categorized as: depressed community (0<E≤0.5), unstable community (0<E≤0.75) and stable community (0.75<E≤1) [16].

Plankton species richness was computed using the formula adapted from Margalaef [17] as cited by Hossain et al. [18]:

$$Richness\ (R) = \frac{(S-1)}{Log\ N}$$

Where:

S = number of species

N = total number of individuals in the sample

The dominance index was calculated using the dominance index from Simpson [19] as cited by Rahayu et al. [20]:

$$Dominance\ (D) = \Sigma(\frac{ni}{N})^2$$

Where:

ni = number of individuals per species
N = number of individuals of all species

The dominance status was categorized as low (0<D<0.5), moderate (0.5<D≤0.75) and high (0.75<D≤1.00) [16]. The study included the computation of Palmer pollution index using the plankton genera proposed by Palmer [21] as pollution indicators. The pollution status of the water was determined through computing the relative number of points per alga: 0 to 10 indicates lacks organic pollution; 10 to 15 indicates moderate pollution; 15 to 20 indicates probable high organic pollution and ≥20 confirms high organic pollution. The reference values that were proposed by Palmer [21] is shown in Table 1.

3. RESULTS

3.1 Physico-chemical Analysis

The results of the water quality analysis of Ambuwaya lake in Kiangan, Ifugao are presented in Table 2. The lake appeared to be shallow with the deepest and lowest depth of 9 m and 3 m, respectively. The lake temperature ranged from 30.35±2.87 to 36.45±2.82 °C with an average of 33.79±2.91 °C. The lowest temperature was recorded in Station 4 and was significantly lower compared to Stations 1, 2 and 3.The secchi disk visibility depth reading ranged between 33.33±3.76 to 36.25±4.40 cm with an average of 34.58±3.60 cm. Total dissolved solids (TDS) of the lake ranged from 45.17±0.75 to 46.17±0.41 ppm with an average reading of 45.56±1.04 ppm. The dissolved oxygen (DO) of Ambuwaya lake ranged from 3.84±0.53 to 5.38±0.39 ppm. The pH range of the lake was from 7.93±0.05 to 8.43±0.05 with an average reading of 8.19±0.18. The lake alkalinity varied between 26.83±4.40 to 32.50±4.08 ppm, averaging to 29.60±3.32 ppm. The phosphorus level of the lake ranged between 20.30±0.92 and 21.16±69 ppm, with an average of 20.69±0.83 ppm. The total ammonia-nitrogen (TAN) of the lake ranged between 0.9±0.05 and 0.11±0.8 ppm with an average reading of 0.11±0.09 ppm. Phosphorus, hardness, TAN, TDS and nitrite in all stations were comparable with no significant differences.

3.2 Biological Analysis

Results in Tables 3 and 4 show that 15 taxa of plankton from eight major groups were identified in Ambuwaya lake. The plankton and zooplankton community were dominated by Phylum Chlorophyta and Phylum Rotifera, respectively. As presented in Table 5, Phylum Dinoflagellate had the highest abundance due to the dominance of *Peridinium* sp. while Phylum Charophyta had the least abundance.

The recorded total phytoplankton and zooplankton abundance were 79.14±13.64 plankton/mL and 11.69±2.76 plankton/mL, respectively. An average phytoplankton diversity of 1.99±0.05 and average zooplankton diversity of 1.74±0.01 suggested that the computed diversities were very low (Tables 6 and 7). Phytoplankton evenness ranged between 0.78 to 0.83 with an average of 0.81±0.10 was categorized as a stable community. However, the zooplankton evenness that ranged from 0.70 to 0.71 suggested that the community was unstable. The dominance value of phytoplankton that ranged between 0.21 to 0.26 and zooplankton of 0.18 to 0.19 was categorized as low.

Table 1. Algal genus and their corresponding pollution index score

Algal Genus	Pollution Index	Algal Genus	Pollution Index
Anacystis	1	*Micractinum*	1
Ankistrodesmus	2	*Navicula*	3
Chlamydomonas	4	*Nitzschia*	3
Chlorella	3	*Oscillatoria*	5
Clostrium	1	*Pandorina*	1
Cylotella	1	*Phacus*	2
Euglena	5	*Phormiduim*	1

Table 2. Results of physico-chemical analysis of the five sampling stations in Ambuwaya lake, Kiangan, Ifugao

Water Parameter	Station 1	Station 2	Station 3	Station 4	Station 5	Mean
Temperature (°C)	36.45±2.82[b]	34.72±0.84[b]	34.20±2.15[b]	30.35±2.87[a]	33.23±1.78[ab]	33.79±2.91
Secchi disk visibility depth (cm)	34.17±3.77[a]	36.25±4.40[a]	33.75±3.79[a]	33.33±3.76[a]	35.42±2.45[a]	34.58±3.60
Total dissolved solids (ppm)	45.17±0.75[a]	45.33±0.52[a]	45.83±1.9[a]	45.33±0.82[a]	46.17±0.41[a]	45.56±1.04
Dissolved oxygen (ppm)	5.38±0.39[b]	5.36±0.27[b]	5.29±0.21[b]	3.84±0.53[a]	5.33±0.38[b]	5.04±0.70
pH	8.23±0.05[c]	8.43±0.05[d]	8.30±0.00[c]	8.07±0.05[b]	7.93±0.05[a]	8.19±0.18
Alkalinity (ppm)	32.50±4.08[b]	30.67±1.63[ab]	29.00±1.79[ab]	29.00±0.89[ab]	26.83±4.40[a]	29.60±3.32
Hardness (ppm)	29.20±3.77[a]	27.86±3.76[a]	25.52±6.26[a]	28.03±7.02[a]	25.35±4.55[a]	27.19±5.10
Phosphorus (ppm)	20.80±0.87[a]	20.76±0.97[a]	21.16±69[a]	20.42±0.66[a]	20.30±0.92[a]	20.69±0.83
Total ammonia-nitrogen (ppm)	0.9±0.05[a]	0.20±0.15[a]	0.7±0.03[a]	0.09±0.05[a]	0.11±0.8[a]	0.11±0.09
Nitrite (ppm)	0.05±0.02[a]	0.04±0.02[a]	0.04±0.02[a]	0.04±0.02[a]	0.04±0.03[a]	0.04±0.02

Note: Different superscript is statistically significant at P <0.05

Table 3. Listing of phytoplankton identified in Ambuwaya lake, Kiangan, Ifugao

Phylum	Class	Family	Genus
Bacillariophytes	Coscinodiscophyceae	Aulacoseiraceae	*Aulacusiera*
	Bacillariophycea	Fragilariaceae	*Synedra*
	Bacillariophycea	Cocconeidaceae	*Cocconeis*
	Bacillariophycea	Naviculaceae	*Navicula*
Chlorophytes	Chlorophyceae	Selenastraceae	*Ankistrodemus*
	Ulvophyceae	Ulotrichaceae	*Ulothrix*
	Chlorophyceae	Oedogoniaceae	*Oedogonium*
Charophytes	Zygnematophyceae	Closteriaceae	*Closteruim*
Cyanophytes	Cyanophyceae	Aphanizomenonaceae	*Anabaena*
	Cyanophyceae	Oscillatoriaceae	*Oscillatoria*
Euglenophytes	Euglenophyceae	Euglenaceae	*Euglena*
	Euglenophyceae	Euglenaceae	*Trachelomonas*
Dinoflagelate	Dinophyceae	Peridiniaceae	*Peridinium*

Table 4. Listing of zooplankton identified in Ambuwaya lake, Kiangan, Ifugao

Phylum	Class	Family	Genus
Arthropod	Copepoda	Cyclopidae	*Mesocyclops*
	Branchiopoda	Bosminidae	*Bosmina*
Rotifer	Monogononta	Brachionidae	*Branchionus*
	Monogononta	Synchaetidae	*Polyathra*
	Monogononta	Epiphanidae	*Epiphanes*
	Monogononta	Trichocercidae	*Trichocerca*

Table 5. The abundance of phytoplankton and zooplankton in Ambuwaya lake, Kiangan, Ifugao

Phylum	Abundance (Plankton/mL)	Phylum	Abundance (Plankton/mL)
Bacillariophytes	13.93	Rotifer	6.44
Chlorophytes	9.76	Arthropod	5.19
Cyanophytes	8.94		
Euglenophytes	5.04		
Dinoflagellate	36.19		
Charophytes	5.26		

Table 6. The biological indices of phytoplankton in Ambuwaya lake, Kiangan, Ifugao

Sampling Site	Station 1	Station 2	Station 3	Station 4	Station 5	Mean
Diversity	2.05	2.00	2.02	2.00	1.90	1.99±0.05
Evenness	0.83	0.81	0.81	0.80	0.78	0.81±0.10
Richness	3.74	3.69	3.65	3.85	3.83	3.75±0.08
Dominance	0.21	0.24	0.23	0.23	0.26	0.23±0.20

Table 7. The biological indices of zooplankton in Ambuwaya lake, Kiangan, Ifugao

Sampling Site	Station 1	Station 2	Station 3	Station 4	Station 5	Mean
Diversity	2.05	2.00	2.02	2.00	1.9	1.74±0.01
Evenness	0.71	0.70	0.70	0.70	0.70	0.70±0.00
Richness	2.07	2.07	2.02	2.24	2.21	2.12±0.09
Dominance	0.18	0.19	0.18	0.18	0.19	0.18±0.00

Table 8. Correlation of water quality variables and plankton abundance in Ambuwaya lake, Kiangan, Ifugao

	Temp	SDVD	TDS	DO	pH	Alkalinity	Hardness	Phosphorus	TAN	Nitrite
Bacillariophytes	0.562	-0.081	-0.261	0.452	0.856	0.538	-0.056	0.989**	-0.087	0.025
Chlorophytes	0.591	0.087	-0.097	0.592	0.837	0.420	-0.045	0.961**	0.058	0.018
Cyanophytes	0.460	-0.030	-0.263	0.398	0.894*	0.493	0.041	0.968**	0.074	-0.074
Euglenophytes	0.643	0.219	-0.279	0.611	0.928*	0.585	0.113	0.900*	0.243	0.178
Dinoflagellate	0.495	0.281	0.117	0.659	0.771	0.199	-0.302	0.859	0.186	-0.092
Charophytes	0.603	0.003	-0.299	0.499	0.892*	0.586	0.112	0.969*	0.057	0.096
Rotifers	0.596	-0.080	-0.127	0.522	0.786	0.447	-0.060	0.993**	-0.101	0.016
Arthropods	0.665	0.254	-0.088	0.705	0.848	0.442	-0.070	0.901*	0.180	0.137

Note: statistically significant at P <0.05 (*) and P <0.01 (**)

The pollution status of Ambuwaya lake through the Palmer pollution index scored 16 which indicated probable high organic pollution. Plankton genera identified in Ambuwaya lake include *Ankistrodesmus, Euglena*, *Navicula*, *Oscillatoria*, *Closterium*.

The correlation analysis of physico-chemical water parameters with plankton abundance in the Ambuwaya lake is presented in Table 8. The correlation analysis showed that Baccillariophyta, Chlorophyta, Cyanophyta, Euglenophyta, Charophyta, Rotifers and Arthropods had very strong linear relationship with phosphorus.

4. DISCUSSION

4.1 Physico-chemical Analysis

The recorded temperature of Ambuwaya lake was not within the set standard but still within the 40°C tolerable by tilapia [22]. The lowest temperature was also recorded in Station 4 and was significantly lower compared to Stations 1, 2 and 3. The lower temperature at Station 4 was a result of the presence of aquatic vegetations. According to Senyshen and Chen [23], their research findings strongly demonstrated that vegetation significantly contributed to the decrease in surface water temperature. The lake was suggested as hypereutrophic based on secchi disk visibility depth. Human activities have changed the contents of nitrogen and phosphorus in aquatic ecosystems leading to water eutrophication. Hypereutrophic was common in shallow lakes. Secchi disk reading was affected by plankton and suspended particles. The DENR-DAO has yet to set an acceptable level for TDS, hence according to WWF – Water Quality Guidelines for Pakistan, the lake TDS level was within the set standards. TDS contain minerals and organic molecules that provide benefits such as nutrients or contaminants in the form of toxic metals and organic pollutants. With an average DO of 5.04±0.70 ppm, the lake was within the set standard by the Department of Environment and Natural Resources - DAO 2016. The DO in Station 4 was significantly lower compared to other stations. As observed, Station 4 was the part of the lake where household activities such as washing of clothes and dishes, and taking a bath takes place. According to Bindulekha [24], there is a decreased DO content with a higher concentration of detergent. The reduced DO level in Station 4 could be attributed to detergents present in household effluents. As per findings by Giri et al. [25], the decline in DO occurs in response to increased organic load. The pH readings of the lake were within the accepted level set by Brazilian Environmental Legislation and Canadian Water Quality Guidelines. However, with the set water quality standard on pH by Australian and New Zealand Environment and Conservation Council (ANZECC) of 6.0 to 8.0, the pH level of the Ambuwaya lake was slightly beyond the limit. pH level was significantly different from each station. Aquatic vegetation varies among stations in the lake, as evident from the observation. According to Araoye [26], photosynthesis by aquatic plants removes carbon dioxide hence pH would increase. As of now, the DENR-DAO standard lacks a defined acceptable alkalinity level. Nevertheless, the alkalinity in Ambuwaya lake falls within the ANZECC [27] standard. The alkalinity of Ambuwaya lake was within the acceptable range. Station 5 had the lowest alkalinity which was significantly lower compared to Station 1. The rest of the stations had almost the same level of alkalinity. The lake's phosphorus concentration surpasses the recommended level for Class B. Large phosphorus concentrations were generally associated with runoff events, which carry a substantial proportion of suspended sediments to which phosphorus was attached [28]. With the standard set by DENR-DAO [29], the TAN level was higher than accepted.

4.2 Biological Analysis

Phylum Dinoflagellate had the highest abundance due to the dominance of *Peridinium* sp. The proliferation of dinoflagellate could be due to an increase in runoff of organic substances from the catchment area induced by climate change [30]. Dinoflagellates are pelagic microalgae that have the ability to survive under stressful conditions and physical environmental disturbances [31]. The main influential agents for the distribution of dinoflagellates include light, temperature, salinity, and nutrition [32]. *Peridinium* sp*.* has been also observed in many reservoirs or lakes [33,40]. The bloom forming *Peridinium* was also observed at Lake Kinneret, Israel [41]. The blooms of *Peridnium* was initiated by high precipitation, low wind speed and high temperature of greater than 31 °C. The conduct of study falls within the rainy season of Kiangan, Ifugao. With the data provided by CENRO Ifugao, the months of April and May are the start of the rainy season with an average precipitation of 305.6 mm and 696.06 mm, respectively. Basing from the collected temperature which was higher than 31°C (33.79±2.91°C) and low wind speed of the area (<1.0 miles/hr) which implies calmness; the environmental characteristics of the lake provided a conducive habitat for the mass growth of *Peridinium* sp*.* According to Golubkov et al. [30], temperature also affected dinoflagellates, most species preferred relatively low temperature, only *Peridinium* sp. showed high biomass at the temperature above 20 °C.

According to Shen et al. [42], urbanization reduces species diversity and the diversity of urban pollution has seriously affected the zooplankton community structure. Changes in zooplankton abundance, species diversity and community composition could indicate a change or disturbance of the environment [43]. In recent years, the road to Ambuwaya lake had been paved which also includes the construction of a tourist cemented pathway along the lake. This year maintenance activities including riprapping had been implemented as part of the lake's development plan. The low number of species might be attributed to frequent eutrophication phenomena [44]. Effects of eutrophication have been widely documented in lakes [45]. The most pronounced effects were increased phytoplankton biomass and associated degradation of water quality, as well as a decreased in lake plankton and changes in plankton diversity [46]. The presence of certain zooplankton species, such as *Brachionus* sp., *Bosmina* sp., and *Mesocyclops* sp. indicates a high amount of suspended material in the water body, which may lead to eutrophication of the water body. The instability may result from factors such as changes in nutrient level, water temperature and other environmental conditions that could influence the growth and survival of phytoplankton. The low dominance category of the plankton indicated that there were no dominant species in the plankton community.

Due to their short life span, plankton rapidly adapts to alterations in the environment. They thrive in extremely eutrophic waters, while some are highly responsive to organic and chemical pollutants. According to the Food and Agriculture Organization global review, agrochemicals, drug residue, sediments, organic matter and water discharges from agricultural farms play a significant role in water pollution [47].

The phosphorus in lake water had very strong linear correlation with Baccillariophyta, Chlorophyta, Cyanophyta, Euglenophyta, Charophyta, Rotifers and Arthropods. Phosphorus enter lakes through several routes which include runoff, air deposition and rainfall. Phosphorus is usually present in very small amounts in a lake and is considered the limiting nutrient in aquatic ecosystem. The effects of nutrients on the phytoplankton community composition varied with taxa groups, especially true for Cyanophyta, Chlorophyta, and Bacillariophyta [48]. Bacillariophyta were the most abundant group of phytoplankton, and their success lies in their significant adaptation ability to stressful conditions, such as nutrient limitation. A study on the effect of phosphorus on growth of Bacillariophyta showed that growth rate increases when phosphorus increases. According to Bai et al. [48], phosphorus promotes the development of Cyanophyta. As mentioned by Gu et al. [49], phosphorus was an essential element for the growth of Cyanophyta. Chlorophyta were photosynthetic algae characterized by having chlorophyll which was the primary pigment of photosynthesis. Phosphorus plays a key role in photosynthesis, the metabolism of sugars, energy storage and transfer and cell division. According to Solorzano [50], *Trachelomonas* which belong to Euglenophyta were found highest in high concentration of phosphorus. Thus, the availability of phosphorus in the lake must have promoted the growth of plankton and eventually the zooplankton. According to Brock [51], observations on a wide variety of acidic environments, both natural and man-made, revealed that blue-green algae (Cyanophyta) were completely absent from habitats in which pH was less than 4 or 5. These was also noted in one study that Cyanophyta were exceptional among microorganisms in their inability to grow at low pH. The lake pH in Ambuwaya lake was at an optimal level to support the growth of Cyanophyta. A study conducted by Predojevic et al. [52] showed that at water pH 7.6 to 8.82 they were able to identify 89 taxa from Euglenophyta division. Similar to Cyanophyta, the pH conditions in Ambuwaya lake were conducive to the flourishing of Euglenophytes.

4.3 Lake Management

Dumping waste materials into aquatic ecosystem leads to pollution [53]. Solid wastes have been observed within and at the banks of the lake which include plastic bottles, snack and detergents plastic. The introduction of MRF (material recycling facility), a facility that receives, separates and prepares recyclable waste materials was recommended. This strategy supports waste segregation. Recycle bins should also be distributed around the lake to provide a designated area for waste disposal.

Suspended sediments can also increase heat absorption contributing to water temperature [54]. As the current depth of the lake compared to the established depth suggest that the lake has a high sedimentation. This could be due to the decade of organic decompositions. Minimizing possible sources of organic decomposition can stop further sedimentation. The disposal of dead animals, terrestrial plants and tree trimmings must carried-out properly. Dumping of solid waste, particularly construction debris from current developments in the lake and other materials could also introduce further sedimentation. The restriction of burning of waste along the lake must be fully implemented as not incinerated waste can settle at the bottom of the lake contributing to sedimentation. The east side most of Ambuwaya lake is surrounded by large trees, its preservation helps prevent soil erosion to the lake as during insufficient vegetation rainwater can carry more sediment during runoff.

Water hyacinth and water spinach are common aquatic vegetations in Ambuwaya lake. Water hyacinth can completely cover lakes and wetlands, outcompeting native aquatic species, reducing oxygen levels for fish, and creating ideal habitat for disease-carrying mosquitos [55]. Proliferation of water spinach results in a dense impenetrable canopy hindering the process of photosynthesis, hence, affecting the DO content of the lake. Therefore, the constant clearing or control of water hyacinth and water spinach should be a regular activity to avoid colonization of these aquatic vegetations.

Agricultural contaminants can impair the quality of surface water and groundwater. Fertilizers and pesticides do not remain stationary on the landscape where they are applied; runoff and infiltration transport these contaminants into local streams, rivers and groundwater [56]. Ambuwaya lake is surrounded by fruit farms and rice farms. Effluents from these farms flow directly into the lake. These factors could contribute to the elevated phosphorus level of the lake. High phosphorus can cause increased growth of algae which could result in decreased levels of DO. The evident hypereutrophication of the Ambuwaya lake could be attributed to the high level of phosphorus. Hence it is essential to effectively manage agricultural effluents to reduce the contamination of the lake. Agricultural effluents may also carry insecticides that could impact the biological species within the lake. The agricultural waterways need appropriate redirection to prevent the flow of water from agriculture into the lake. It is important to carefully apply fertilizers and insecticides to avoid excessive amounts.

The impacts of climatic variation and human activities are considered as the most important factors for the recent lake changes. Ambuwaya lake is also used as washing area of clothes and dish washing of neighboring constituents. According to Chen et al. [57], detergents contain phosphorus and surfactants [58] which are considered water pollutants that could alter the good water quality. Therefore, the limitation of such lake activities is crucial to halt further lake pollution.

5. CONCLUSION

The present study aimed to assess the current state of Ambuwaya lake in terms of physico-chemical analysis of water which include temperature, secchi disk visibility depth, TDS, DO, pH, alkalinity, hardness, phosphorus, TAN and nitrite. The lake complies with DENR standards for DO, pH, and TAN. However, the SDV depth indicated that the lake was hypereutrophic. The alkalinity aligned to the set standard of ANZECC (2000). Plankton was considered of low and unstable community. Based on the findings, the lake was categorized as class B under the classification of DENR intended for primary contact recreation. Therefore, the cultivation of tilapia and carp could flourish, given that water quality parameters meet the standards for aquaculture. However, it was advisable to opt for a semi-intensive or intensive propagation method, as plankton availability may be insufficient.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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