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Assessment and Local Community Perception on the Water Quality of the Seven Crater Lakes of San Pablo City, Philippines

ABSTRACT

The Seven Lakes of San Pablo in the Philippines provide various ecosystem services including aquaculture and ecotourism which can degrade the lake's condition. The water quality of the lakes was assessed and the perception of the locals on this and on the impacts of aquaculture and ecotourism on water quality were determined. Water quality was assessed in August and November 2019 and May 2021 to determine the condition of the lakes. Aquaculture lakes had lower dissolved oxygen (DO) levels, higher biochemical oxygen demand (BOD) and chlorophyll-a indicating eutrophic condition. Participatory Rural Appraisal (PRA) was conducted to elicit the perception of locals on the historical water quality. Locals perceived that there is a relationship between degraded water quality and anthropogenic activities in the lake. The PRA result is a verification that water quality has been degrading since the establishment of fish cages and settlements around the lake. The condition of the Seven Lakes in terms of water quality is being threatened due to these factors. These results will be useful for the local government unit in crafting strategies for the protection and sustainable management of the Seven Lakes.

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INTRODUCTION

San Pablo City is a chartered city in the province of Laguna, Philippines which is approximately 70 km south of Manila. It is famous for its Seven Lakes, which are small scenic freshwater crater lakes. The Seven Lakes of San Pablo were formed by a unique process called phreatic eruption, where shallow lava from Mt. San Cristobal intersected the groundwater, which caused steam-heated eruption in the overlying rocks to form a crater-like depression that was eventually got filled up with rainwater (*LLDA 2008*). The lakes are considered a Class C water resource by the Department of Environment and Natural Resources (DENR), which is suitable for fishery propagation, non-contact recreational water (boating and fishing), agriculture, irrigation and livestock watering. These lakes are being administered and monitored by the Laguna Lake Development Authority (LLDA). These

lakes are important to local communities since they are utilized for fish cage aquaculture, communal fishing grounds and tourism (*Brillo 2016*). Lakes Pandin, Yambo, Sampaloc and Mohicap are popular as tourism sites while Lakes Bunot, Calibato, Sampaloc and Palakpakin serve as aquaculture and open water fishing sites (*Brillo 2015*). Aquaculture and inland capture fisheries have a growing importance in fish production for human consumption and poverty reduction especially in rural areas because they provide food and employment (*FAO 2014*).

The widespread aquaculture practices in the seven lakes began in 1975, with the challenges accumulating as the decades progressed such as mismanagement arising from unregulated aquaculture practices in some of the lakes (*Mendoza et al. 2019*). The financial benefits aquaculture brings may be outweighed by environmental costs such as water pollution and biodiversity loss, with implications for the deterioration of ecosystem functioning and services (*Legaspi et al. 2015*). With this trade-off, there is a need for well-developed and science-based management for lake ecosystems. Management must include integrated knowledge about the water quality (physical, chemical, biological) and socio-economic data to make careful decisions based on trade-offs among ecosystem services that are critical to humanity (*Levin et al. 2009*).

Participatory Rural Appraisal (PRA) is a methodology used for interactive processes for social development. It can assess, plan, monitor, and evaluate a community. PRA is a process of understanding people, their resources, and their socio-economic conditions and exploring their problems and aspirations (*Winnegge 2005*). PRA can be applied to fisheries and aquatic resources. However, PRA was rarely used for the management of lakes. A study on the application of PRA techniques in the verification of fisheries data and trends on Lake Kainji in Nigeria was conducted by *Okomoda and Alamu* (*2001*) to determine the entrepreneur dynamics, types of fishing gears and activities and preference in using twine and nylon gill nets on fishing. Based on their results, the use of PRA can assist in determining issues from the past and may be better discussed and offer possible solutions to it. Another study, *Singh et al.* (*2017*) on the use for watershed management in India, provided a comprehensive review of how it can be used to help the stakeholders work together to plan suitable programs for the watershed. Some studies revealed that participatory watershed management programs made a significant impact in terms of productivity gains in rainfed areas, which contribute to increased farm income and better livelihoods for the poor in high-risk environments (S*ingh et al. 2017*). Applying PRA in managing the resources of the seven lakes could be a useful strategy to determine the problems and provide short-term to long-term solutions to sustain the quality of the water resources.

In 2014, the Seven Lakes were proclaimed as 'threatened lakes' by the Global Nature Fund and were given the protected status by the Department of Environment and Natural Resources– Environmental Management Bureau (DENR-EMB) as candidate key biodiversity areas with moderate pollution, sedimentation and ecological stress (*DENR-EMB 2014*). Therefore, there is a need for assessing and monitoring the water quality of the Seven Lakes. This will provide empirical evidence to support decision making of the local government unit to manage the lake resources. Knowing the historical conditions of the Seven Lakes through the local community could help decision makers to create plans to sustainably managing the lakes.

MATERIALS AND METHODS

Study site

The Seven Lakes is found in San Pablo City, Laguna, Philippines (**Figure 1**). It is approximately 70 km south of Manila. It is bounded by six municipalities and one city namely, Calauan, Laguna in the northwest; Nagcarlan in the northeast; Alaminos, Laguna in the west; Rizal, Laguna in the east; Lipa, City Batangas in the southwestern tip; and the municipalities of Tiaong and Dolores Quezon in the south (CLUP of San Pablo). The sampling sites in the seven lakes were identified purposively to determine the impacts of aquaculture, human settlements, and natural vegetation on water quality. Four to five sampling sites were considered in each lake. Four of the Seven Lakes– Bunot, Calibato, Sampaloc and Palakpakin were considered as aquaculture lakes since these are primarily for aquaculture. On the other hand, Mohicap, Pandin and Yambo were ecotourism lakes.

The study was conducted to assess the water quality condition of the Seven Lakes compared to DENR standards for class C water resources. The study also conducted Participatory Rural Appraisal to elicit local ecological knowledge and perception of local communities on the historical water quality changes in relation to fish cage operation on the Seven Lakes of San Pablo.

Water Sampling and Water Quality Determination. Water quality sampling was done during August 2019, November 2019 and May 2021. The collection was

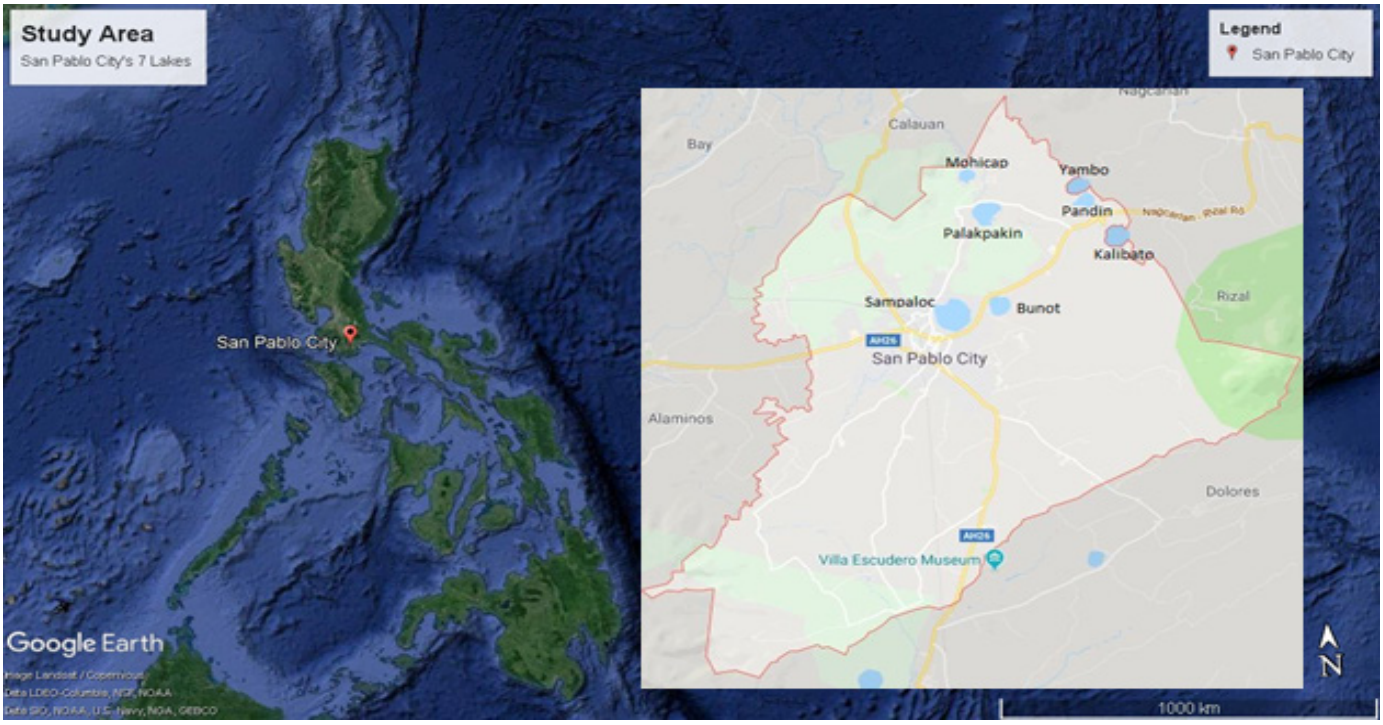

Figure 1. Location map of the Seven Lakes of San Pablo, Philippines (Google Earth and Google Maps, 2019).

limited to these three sampling months because of the restrictions due to the COVID-19 pandemic. In-situ and ex-situ determination were done to assess the water quality at the surface and at 5 m or less (around 2 m) below the surface. Some stations of the lakes would have less than 5.0-meter depth. Sampling locations include pelagic, littoral near vegetation, littoral near settlements, inside the fish cage and outlet. Three replicate samples were collected at each sampling station. The following 52 parameters were collected: Dissolved oxygen (DO), temperature, pH, conductivity, total dissolved solids (TDS) were collected using YSI Professional Plus Multiparameter, chlorophyll using YSI Multiparameter Sonde 6600 V2, transparency using Secchi disk (SDT) while 6 L of water sample was collected and submitted to Department of Science and Technology-Regional Standard and Testing Laboratories laboratory for the 5-day BOD analysis. The BOD-5 analysis was done twice during the August 2019 and May 2021 samplings.

Timeline activity was conducted through Participatory Rural Appraisal (PRA) by asking the participants questions regarding the historical status of the lakes (1940s to present) in terms of water quality, fish cages and settlements around the lakes. PRA was implemented to elicit local ecological knowledge regarding water quality changes.

Data Analysis. The water quality data collected were compared to the water quality standards of the DENR for Class C water. Data analysis includes descriptive statistics and comparison of means. One-way ANOVA and Tukey's HSD post hoc test were performed if the dataset are normally distributed to compare the different sampling months and lakes. Otherwise, Kruskal-Wallis test was employed if the dataset are not normally distributed. The Mann- Whitney U test was utilized to compare the surface and subsurface waters.

RESULTS AND DISCUSSION

Water Quality Assessment of the Seven Lakes

Dissolved oxygen is one of the most critical and limiting factors in aquaculture. It is necessary for many aquatic life forms including fish, invertebrates, bacteria, and plants as they use oxygen for metabolic processes. The distinct diurnal pattern of dissolved oxygen is low at night and high during the day with maximum level in the late afternoon due to daytime photosynthetic production of oxygen. A DO level of 5.0 ppm is the standard for class C water based on the Department of Environment and Natural Resources AO 2016-08- Water Quality Guidelines and General Effluent Standards of 2016.

The surface waters of the Seven Lakes in San Pablo in Laguna, Philippines passed the 5.0 ppm level during the months of August 2019 and May 2021 (**Figure 2**). However, Lakes Bunot, Calibato and Sampaloc failed to reach the 5.0 ppm mark during the November 2019

Figure 2. Dissolved oxygen levels of the surface and subsurface of the Seven Lakes of San Pablo, Philippines during the three sampling months.

sampling. For the subsurface waters, lakes Pandin and Yambo were above the limit for all the sampling months. It indicates that the DO levels on these lakes are much better than the other lakes. Some lakes (Mohicap, Sampaloc and Bunot) have higher subsurface DO level during the month of May. Statistical analysis showed that there is a significant difference in the DO level of surface waters between months. Tukey's HSD test determined that May 2021 sampling was significantly different August and November 2019. On the other hand, no significant differences were observed when comparing the lakes. In addition, no significant differences were reported on the subsurface water for months and lakes. Mann-Whitney U test revealed a significant difference in the surface and subsurface waters of the Seven Lakes of San Pablo. A DO level below 5.0 ppm is stressful for fish and other aquatic life as they start to gasp for air on the surface. Mortality or fish kill usually occurs at concentrations less than 2.0 ppm DO. Usually, large fish are affected immediately by very low DO before the smaller fish. One cause of oxygen depletion in aquaculture lakes is due to the biodegradation of organic waste, such as fish excreta and excess feeds, by microoganisms (*Floyd 2003*).

Water temperature is a critical environmental factor for freshwater fish as it influences their physiology, reproduction and distribution. In terms of temperature, the surface water has higher temperature than the subsurface due to direct exposure to sunlight. The recommended temperature for class C water is from 25-31˚C. The temperature levels for the Seven Lakes during the three sampling months were within the recommended levels except for lakes Bunot (31.83˚C) and Sampaloc (32.61˚C), which exceeded slightly in August 2019. The Mann-Whitney U test showed a significant difference in the surface and subsurface temperature levels. The observed difference in the temperature might be due to factors such as direct solar heat, wherein surface waters receive direct sunlight, which warms them up. The intensity of solar radiation is higher at the surface, causing higher temperatures compared to the subsurface.

The pH levels of the Seven Lakes were within the standard range of 6.5-9.0 for class C water. The Seven Lakes had slightly basic to basic pH levels ranging from 7.8 to 9.62. Lakes Mohicap and Sampaloc exceeded the limit of 9.0 on May 2021. Mann-Whitney U test showed no significant difference between surface and subsurface for the Seven Lakes. Freshwater lakes, ponds and streams usually have a pH of 6-8, depending on the soil and bedrock (*Lenntech 2013*). In deeper lakes, when stratification (layering) occurs, the pH of water is generally higher (7.5-8.5) on the surface and lower (6.5-7.5) at greater depths (*Washington State Department 1991*). In the case of the Seven Lakes, stratification is observed causing the pH level to vary. An increase or decrease in the pH level of water could either be due to natural or anthropogenic activities. Agricultural runoff produce acid runoff that may have caused the decrease in pH level of water. Wastewater discharge that contains detergents and soap-based products can increase water pH (*Fondriest Environmental Inc. 2013*).

Electrical conductivity (EC) is an indicator of the amount of salts and carbonates in water. It is affected by the presence of inorganic dissolved solids such as

chlorides, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron, and aluminum ions. The more ions present in water, the higher the conductivity level. A sudden increase or decrease in the conductivity level in water can indicate pollution. Lake water conductivity may be controlled by various factors such as watershed geology, watershed's size in relation to lake size, wastewater from point sources, runoff from non-point sources, atmospheric inputs, evaporation rates, and bacterial metabolism (*Pal et al. 2015*). Agricultural runoff and sewage leak can increase conductivity due to chloride, phosphate, and nitrate ions (*Wetzel 2001*). The highest recorded conductivity was in Lake Mohicap during the August 2019 sampling with a mean of 0.42 mS cm^{-1}, while Lake Yambo had the lowest level during the month of November with a mean of 0.18 mS cm^{-1}. There are no recommended standards for conductivity in the Philippines, but according to US EPA, a water that can support fisheries should have a range of 0.15 to 0.50 mS cm^{-1}. Based on the collected data, the conductivity for the seven lakes is suitable for aquaculture.

The level of conductivity is directly related to the level of TDS. Sources of TDS include agricultural runoff, leaching of soil contamination and point source water pollution from industrial and domestic wastes (*DENR-EMB 2005*). The concentration of TDS can affect the water balance in the cells of aquatic organisms. Based on the obtained results, the TDS did not exceed the 500 ppm level. Same as conductivity, Lake Mohicap had the highest level while Lake Yambo had the lowest. There are no standards for TDS in the Philippines, but according to US EPA, TDS should not exceed 500 ppm for aquaculture. According to the study of *Pal et al.* (*2015*) on Rudrasagar Lake in India, spatial and temporal monitoring of water quality including electrical conductivity and total dissolved solids is a good indicator of water quality.

Another important water quality parameter is the Biological Oxygen Demand (BOD). BOD is the measurement of total dissolved oxygen consumed by microorganisms for biodegradation of organic matter such as food particles or sewage (Bhatnagar and Devi 2013). In terms of BOD, two sampling months were assessed, August 2019 and May 2021 that represented wet and dry seasons, respectively. Based on DAO16-08, the limit of BOD for class C water is 7.0 ppm. The highest recorded BOD level during the August 2019 sampling was from Lake Palakpakin (5.60 ppm) while Lake Calibato had the highest (10.48 ppm) during the May 2021 sampling. Sampaloc had the lowest recorded BOD (0.83 ppm) during August 2019 and Pandin (1.26 ppm) during May 2021 (**Figure 3**). There was no significant difference in BOD levels during the two sampling months. In addition, no significant difference was also reflected when comparing the lakes. In general, all the fish cage stations had the highest BOD levels for all the seven lakes. This might be due to the microorganisms that degrade the organic matter from fish excreta, excess fish feeds and dead fish. Further degradation and misuse of lake water could increase the BOD levels and exceed the recommended level. BOD levels between 3.0 and 6.0 ppm are optimum for normal activities of fishes while BOD level of 6.0-12.0 ppm is sublethal and > 12.0 ppm can usually cause fish kill due to suffocation (*Bhatnagar et al. 2004*). In relation to dissolved oxygen, the higher the BOD, the more rapidly oxygen is depleted in water. Hence, less oxygen is available to aquatic organism (*Pleto et al. 2020*). High BOD levels resulted in higher intake of oxygen in order to break down organic materials. The process of breaking down organic materials can decrease dissolved oxygen concentration in water which can cause anoxic state (*Wisnu et al. 2019*).

The Secchi Disk Transparency (SDT) measures the clarity of the water. It is influenced by the dissolved inorganic and organic substances, total suspended solids, algae and other microscopic organisms found on the water. The higher the SDT, the clearer the water. Based on the obtained data, lakes Pandin and Yambo consistently had the highest SDT compared to the five other lakes. It just indicated that the water on these two lakes was clearer. The aquaculture lakes- Bunot, Calibato, Palakpakin and Sampaloc had lower SDT levels. The Kruskal-Wallis test revealed no significant difference between the sampling periods and lakes. The SDT could also indicate the trophic status of lakes. An oligotrophic state indicated that the level of nutrients is low, mesotrophic has medium nutrients and eutrophic

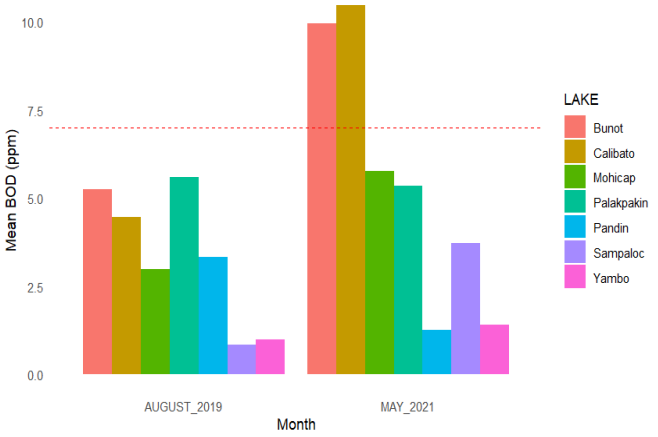

Figure 3. Biological Oxygen Demand (BOD) levels of the Seven Lakes of San Pablo, Philippines during August 2019 and May 2021.

with high level of nutrients. A transparency level of greater than 4.0 m indicates an oligotrophic state. A range of 2.0-4.0 m indicates that the water is in a mesotrophic state and less than 2.0 m indicates that the lake is in a eutrophic state (*OECD 1982*). The ecotourism lakes Yambo and Pandin were observed oligotrophic. The aquaculture lakes are considered eutrophic (**Figure 4**). Comparing the stations, generally, it showed that the fish cages and near household sampling stations had the highest SDT, meaning there was water turbidity in these sites. High turbidity in water can significantly reduce the aesthetic quality and productivity of lakes, which can have a harmful impact on recreation and tourism (*MPCA 2008*).

Chlorophyll is another parameter that can indicate the trophic status of lakes. The concentration of chlorophyll in water is directly related to the abundance of phytoplankton found in the water. Phytoplankton is important in lakes because it provides oxygen to the water as a by-product of photosynthesis. However, excessive algae or high chlorophyll in the water can cause detrimental effects to fishes. Trophic state classification would vary on different freshwater bodies based on trophic state index calculation. But according to *Wetzel* (*2001*), a chlorophyll mean value greater than 14.3 µg/L is already considered eutrophic state. A eutrophic state has greater concentrations of nutrients and chl. Algal blooms would occur during warmer seasons. In relation to this, water transparency is significantly reduced. Other trophic classifications are oligotrophic and mesotrophic. In oligotrophic state, the level of nutrients is low, and it supports limited biological production therefore low algal biomass and chlorphyll. In terms of clarity, water tends to be clear. Mesotrophic lakes have moderate levels of nutrients, biological production and chl. Based on the water quality assessment, the chl level of the seven lakes was generally higher on the sub-surface than the surface. It means that much of the phytoplankton settles at about 5 m below the surface. Based on the guidelines, Lakes Pandin and Yambo have low levels of chl indicating an oligotrophic state while Mohicap is considered mesotrophic. Lake Sampaloc is sometimes mesotrophic and eutrophic. Aquaculture lakes Bunot, Calibato and Palakpakin were considered eutrophic (**Figure 5**). Based on the study of *Mendoza et al.* (*2019*), lakes Palakpakin, Bunot, and Calibato were categorized as eutrophic while lakes Sampaloc, Mohicap, Yambo and Pandin were classified as mesotrophic. Lakes Pandin and Yambo were also previously reported as oligotrophic, which was also observed in this study (*Zapanta et al. 2008*). Kruskal Wallis test revealed that there is significant difference among the lakes on the level of chlorphyll on the surface and subsurface waters. There were no significant differences in comparing the three sampling periods as well as the sampling depths.

Perception of people on the historical water quality of the Seven Lakes through Participatory Rural Appraisal

The respondents were asked about their perception on the water quality of the Seven Lakes from 1940s to present. Their perception was merely based on their observations such as the color of water and unusual odor coming from the lake water. According to them,

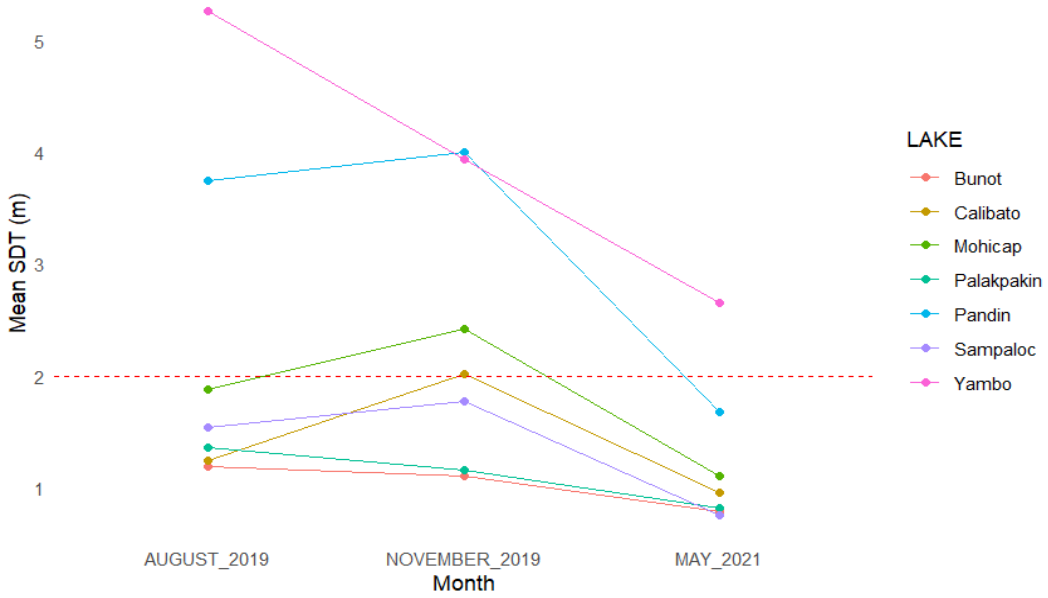

Figure 4. Secchi disk transparency (m) of the Seven Lakes of San Pablo, Philippines during the three sampling months.

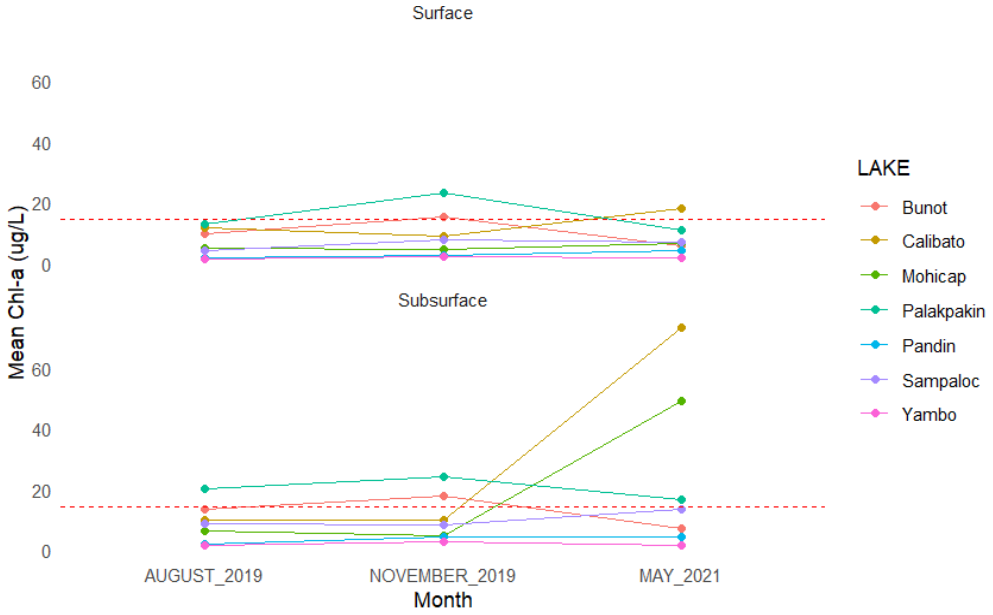

Figure 5. Chlorophyll-a levels (ug L^{-1}) Seven Lakes of San Pablo, Philippines during the three sampling months.

quality was good until the 1980s. During the 1960s a decrease in the water quality was observed for Lakes Palakpakin and Sampaloc. According to the people, this is due to the establishment of fish pens and fish cages. The quality of water in Lakes Bunot and Calibato decreased during the 1970s due to the rapid increase in fish cages in the lake. For the ecotourism lakes, the decrease in water quality is due to the establishment of fish cages in the lakes. According to the respondents, influx of tourist might have contributed to the degrading water quality. Household activities such as laundry and dishwashing were also observed in on the lake.

According to the knowledge of people living near the lake, it was during the 1960s that fish pens were established for the seven lakes. It was a source of their income and livelihood. According to them, during the lake water from 1940 to 1960 was pristine and clean and was a source of drinking water (**Figure 6**). In the three lakes of Mohicap, Pandin and Yambo, water 1940s when fish cages were not yet present on the seven lakes, they would just practice open fishing on the lakes (**Figure 7**). The number of fish pens in Lakes Palakpakin and Sampaloc drastically increased from 1990s to 2000s. *Mendoza et al.* (*2019*) stated that the fish cage surface area percentage from 2017 to 2018 increased in Lakes Bunot (13.08% to 18.70 %), Calibato and Palakpakin (11.78% to 17.25%). The twin lakes, Pandin and Yambo had only few fish pens during this period. In 2018, Lake Pandin had only 1.80% surface area for fish cages and Yambo had 2.07% surface area of fish cages occupying the lake (*Mendoza et al. 2019*). Accordingly, tilapia raised in the fish pens in these lakes are utilized for the food for tourists visiting the lake. In 2000, the LLDA regulated

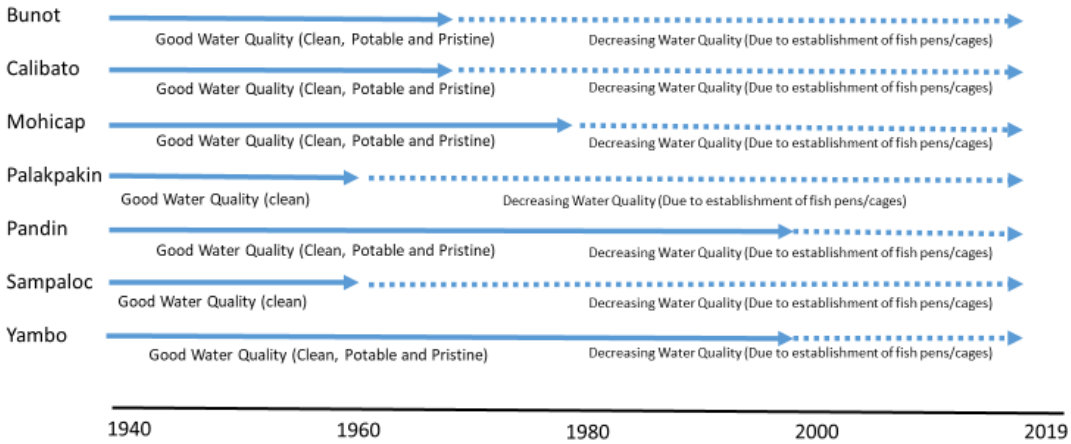

Figure 6. Perception on the water quality of the Seven Lakes of San Pablo, Philippines from 1940s to 2019.

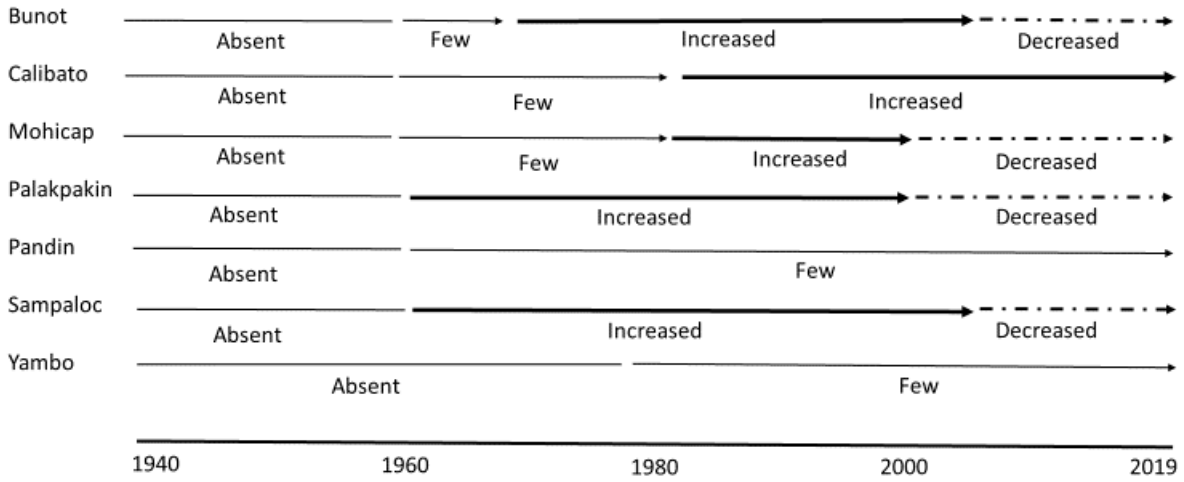

Figure 7. Knowledge on the number of fish pens/cages in the Seven Lakes of San Pablo, Philippines from 1940s to 2019.

the number of fish pens in these lakes, and the decrease in the number of fish pens and cages has continued up to the present time. The surface area covered by fish cages in Lake Sampaloc decreased from 9.56% (2017) to 7.68% (2018). Fish pens require low capital outlay and uses only simple technology popular with fish farmers. However, the concern with intensive fish pen culture in a water body is pollution and the subsequent decrease in water quality and eutrophication (*Beveridge 1984*). Water pollution is usually due to excessive fish feeds in the fish cages. The unconsumed feeds, fecal matter and excretory products by the fishes tend to accumulate at the bottom of the lake thus enriching the water with organic matter, phosphorus, nitrite, ammonia, and other toxic substances. Water enriched with nutrients causes eutrophication that could affect the primary productivity causing algal blooms that in turn, deplete dissolved oxygen during algal die-off. Increased Biological Oxygen Demand (BOD) level can cause a fish-kill event. Fish stocking beyond the carrying capacity of the cages would decrease the quality of water (*Araullo 2001*). Another impact is the spread of diseases and parasites when farmed fish escape and interact with other fish species in the open water (*Kashindye et al. 2015*).

In the early decades of 1940-1960, residential households around the Seven Lakes of San Pablo City, Philippines were very few (**Figure 7**). From 1960s, settlements around five of the Seven Lakes started to increase including Lakes Bunot, Palakpakin, Pandin, Sampaloc and Yambo. In Lake Mohicap, settlements around the lake slowly increased from the 1980s until the present. There was a rapid increase in the number of households around Lakes Sampaloc and Palakpakin during the period of 1980-2000. This rapid increase resulted to degradation of these lakes; thus, the local government unit regulated the number of households starting in year 2000. On the other hand, great increase in settlements occurred in Lakes Bunot and Calibato during the recent decades from 2000. It was around Lake

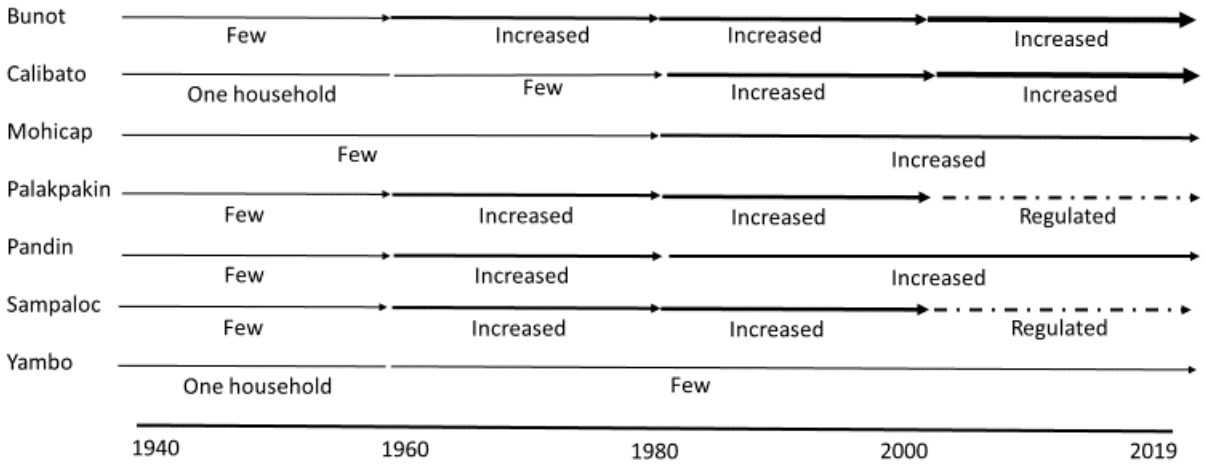

Figure 8. Knowledge on the number of settlements around the Seven Lakes of San Pablo, Phillipines from 1940s to 2019.

Yambo where settlements were very few and it has the most pristine lake water.

Based on the knowledge and perception of local people gathered, there was a relationship between water quality with aquaculture and settlements around the lake. An increase in the number of fish cages and settlements caused degradation of the water quality. A better water quality was observed in ecotourism lakes (Mohicap, Pandin and Yambo) compared to the aquaculture lakes (Bunot, Calibato, Palakpakin and Sampaloc).

The PRA result was a verification that water quality has been degrading since the establishment of fish pens and fishcages and increase in settlements around the lake. It showed that water quality is being affected due to anthropogenic activities such as aquaculture and domestic practices. Excessive feeding and stocking beyond the carrying capacity resulted to water pollution in the lake. This is the common aquaculture practice of fish pen operators to maximize profit. An increase in settlements around the lake was another factor that will make the lakes vulnerable to other sources of pollution such as domestic and kitchen wastes. These wastes could enrich the water with organic matter, nitrogen and phosphorus as well as fecal coliforms. The change in water quality could alter the succession of primary productivity. An algal bloom could occur which could deplete dissolved oxygen in the water due to die-off. This was already observed in lakes Bunot and Palakpakin, where there is a high chlorophyll concentration, representing primary productivity. On the other hand, ecotourism lakes such as Pandin and Yambo still had better water quality than aquaculture lakes. However, these lakes were also vulnerable to water quality degradation due to the influx of tourists and increasing settlements around the lakes. Various recreational water activities such as boating and other shoreline activities, may directly impact the lake ecosystem (*Dokulil 2014*). Nutrient accumulation will lead to algal growth, bloom and die-off, may decrease dissolved oxygen level. Algal blooms will also create aesthetic problems such as greening of the water and foul smell due to algal decay (*Dokulil 2014*).

CONCLUSION AND RECOMMENDATION

Water quality assessment is one of the important aspects of water resource management. This can provide empirical evidence on the status of water resources such as lake ecosystems. The study was conducted to assess the water quality condition of the Seven Lakes. The Seven Lakes of San Pablo are small freshwater lakes that provide essential ecosystem services to its stakeholders. Water quality was compared to the Department of Environment and Natural Resources standards for class C water resources. The study also conducted Participatory Rural Appraisal (PRA) to elicit local ecological knowledge and perception of local communities on the historical water quality changes in relation to fish cage operation in the Seven Lakes of San Pablo.

There were water quality parameters that exceeded the recommend level based on DENR16-08. The DO levels of Lakes Bunot, Calibato and Sampaloc were below the 5.0 ppm limit during the November 2019 sampling. A high level of pH was observed on lakes Mohicap and Sampaloc that exceeded the limit of 9.0 during the month of May 2021. For the BOD, lakes Bunot and Calibato exceeded the 7.0 ppm limit in May 2021. Based on the perception of stakeholders, water quality is degraded due to the different anthropogenic activities specifically aquaculture operation. The PRA result was a verification that water quality has been degrading since the establishment of fish pens and fish cages and due to the increase in settlements around the lake. The current condition of the Seven Lakes of San Pablo in terms of water quality is being threatened due to different anthropogenic activities. Immediate intervention should be made such as reducing the fish pens and settlements around the lakes. Lakes Pandin, Yambo and Mohicap which were being developed as ecotourism sites should maintain the trophic status which is still relatively clean. However, the continuous influx of tourists and domestic activities around these lakes will cause degradation on the water quality. The stakeholders should be more aware of the status of the lakes and be educated on ways how to preserve the good water quality. The results of this study will be useful for the local government unit of San Pablo City in crafting strategies for the protection and sustainable management of the Seven Lakes.

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