E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2019; 7(6): 110-113

www.fisheriesjournal.com
Received: 16-09-2019
Accepted: 18-10-2019

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Physico-chemical, biological and bacteriological assessment of Nabao Lake in Cabiao, Nueva Ecija, Philippines

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Abstract
The study was conducted in order to provide preliminary information on the physico-chemical, biological and bacteriological status of Nabao Lake in Cabiao, Nueva Ecija Philippines. The lake was categorized as hypereutrophic based upon low Secchi disc visibility reading (< 100 cm), low level of DO (<5 ppm) and high level of phosphorus (>0.1 ppm). Identified algal genera in the lake such as *Ankistrodesmus, Chlorella, Closterium, Synedra, Euglena* and *Phacus* were considered to be indicators of organic pollution. The water and soil of the lake had a very high total bacterial count (TBB) and total coliform count (TCC).

Keywords: Water quality, bacterial count, coliform count, plankton

1. Introduction
Nabao Lake is located in the municipality of Cabiao, Nueva Ecija, Philippines [1]. The lake was once considered as part of the Pampanga River but sooner became and now known as the Nabao Lake [2]. It is a 39-hectare lake [1] that is surrounded by houses and is near commercial establishments. Thus, the lake is prone to water pollution and bacterial contamination brought by the wastes from the mentioned sources.
This little known lake through the great plains of Kapampangan corner of Nueva Ecija has once served as a site of attraction and an income-generating inland body of water [3]. It is used to be a fishing ground for the people in the community but has been neglected for long. It has been the source of livelihood for the townsfolk's forefathers [1]. These particular situations have convinced the provincial government of Nueva Ecija to promote Nabao Lake as one of the eco-tourism spots in the province [1].
Given its importance to the community, there were limited studies conducted about the lake. Scientific baseline information about primary productivity, water and soil quality, plankton inhabitants, and bacterial load of water, sediment and fish inhabitants are badly needed for the overall management of the lake.

2. Materials and Methods
2.1. Collection of water for physico-chemical analysis
A total of eight collection sites in the lake were considered. Each site was replicated thrice. Floating bamboo raft (0.25 m^2) was positioned in each sampling site as reference location. Exact coordinates of the sampling sites were determined using handheld GPS. The Secchi disc visibility reading in every station was multiplied by four to estimate the depth of photic zone. Water samples were collected using Kemmerer water sampler at 1/5 depth of the photic zone. The collected water samples per site (approximately 3 L) were stored in polyethylene (PE) bottles for chemical analysis in the laboratory.
Water quality parameters such as temperature, visibility, total dissolved solids (TDS), pH, dissolved oxygen (DO), salinity and conductivity were measured on site using YSI multi-parameter. Analysis of alkalinity, hardness, ammonia, nitrite and phosphorus was done in the laboratory using the stored water samples in PE bottles.

2.2. Collection of water for plankton identification
In each site, 5 L of water sample was collected using a basin and it was filtered using plankton net. The net-filtered water (50 mL) was stored in PE bottles and was immediately preserved using 0.15 mL Lugol's solution. The preserved water samples were placed in dark for three days for the settlement of the plankton. After three days, 1 mL from the stored sample was pipetted into a Sedgwick-Rafter counting chamber. The counting chamber was placed beneath the compound microscope and the plankton seen in every field was identified using the taxonomic keys of Edmondson [4], Pennak [5] and Segers [6].

2.3. Collection of water and soil for bacterial counting
The collected and stored water samples in PE bottles were also used for bacterial counting. Meanwhile, composite soil samples were collected from the same sites as described above. Improvised soil borer out of PVC material was used in the collection of soil samples. For bacterial counting, four sterilized test tubes were used in the dilution of the collected sample. Using pipette, each test tube was filled with 9 mL Normal Saline Salt Solution. One mL or 1 g of the sample was added in the first test tube (1/10 dilution). After vigorous mixing, from 1/10 dilution, 1 mL was transferred to the next test tube (1/100 dilution). The process was repeated to the remaining test tubes. From the fourth test tube (1/10,000 dilution), 0.1 mL was streaked in prepared Mueller Hinton Agar (MHA) (for the total bacterial count) and MacConkey Agar (for the total coliform count). The plates were incubated for 18-24 hours and the number of bacterial colonies was counted for the computation of bacterial count: Bacterial count = number of colonies/(volume plated x dilution factor).

3. Results and Discussion
The eight stations in the lake were pre-determined in order to cover holistically the lake and the contributing factors that might influence the results of the assessment. The description of each station is presented in Table 1.

Table 1: The exact location and description of the eight collection sites in Nabao Lake, Cabiao, Nueva Ecija, Philippines

Sampling Sites	Coordinates	Description
Station 1	N 15° 14.306' E 120° 50.815'	Located near the shore; point of entry of outside source of liquid waste
Station 2	N 15° 14.441' E 120° 50.894'	Located within water hyacinth
Station 3	N 15° 14.357' E 120° 50.804'	Located in the limnetic area and near the existing piggery
Station 4	N 15° 14.241' E 120° 50.691'	Located near the shore
Station 5	N 15° 14.119' E 120° 50.547'	Located in the limnetic area
Station 6	N 15° 14.032' E 120° 50.421'	Located near the shore and houses
Station 7	N 15° 14.062' E 120° 50.360'	Located near the shore; far from houses
Station 8	N 15° 14.008' E 120° 50.327'	Located within water hyacinth

3.1. Physico-chemical Analysis of Water
The results of physico-chemical analyses of water in Nabao Lake are provided in Table 2. The lake appeared to be shallow with a depth ranging from 0.91 to 3.90 m. The lake was considered to be hypereutrophic because the Secchi disc visibility readings were below 100 cm (31 to 72 cm) with an average reading of 54.13±15.20 cm. Hypereutrophic lake is commonly shallow and characterized by high biological productivity. The Secchi disc reading is affected by the clarity of the water due to algae or suspended matters [7]. Depth of light penetration ranged from 2.18 to 2.86 m (average of 2.41±0.23 m) and this might suggest that light could penetrate until and/or near the bottom. Water temperature was slightly low (24.40 to 26.63 ^{0}C; an average of 25.51±.87 ^{0}C) but still tolerable by the fish inhabitants of the lake. Temperature affects the solubility of gas and minerals, chemical and biological reactions and the toxicity of the water contaminants. Furthermore, temperature also affects the growth and respiration of aquatic organisms [8]. The lake water had near neutral pH (7.06-7.55; an average of 7.23±0.18) which was still ideal for fishes [9]. Optimal growth and survival of aquatic organisms are dependent on water pH [10]. Dissolved oxygen (DO) concentration was critically low in most sites (0.94 to 4.51 ppm; an average of 4.10±3.26 ppm. Sampling station near the entrance of liquid waste (Station 1), piggery (Station 3) and houses (Station 6) tends to have very low DO (0.63 to 2.33 ppm) due to the high rate of organic matter decomposition. Low DO is also a common characteristic of hypereutrophic lake. The oxygen present in the water is mainly produced by aquatic plants and algae as a by-product of their photosynthetic activity. The DO is mostly affected by salinity, temperature and altitude [11]. Phosphorus concentration was very high (0.38 to 0.51 ppm; average of 0.43±0.41) and this was strong evidence of hypereutrophication; phosphorus concentration should be $\leq$0.1 ppm. Phosphorus is an essential plant nutrient in the water that is often found in fertilizers, human and animal wastes. It can be further classified into two namely; the soluble reactive phosphorus (SRP) which is readily used by aquatic plants and algae and the other one is the total phosphorus which includes the dissolved and particulate forms of phosphorus [12]. Meanwhile, the concentration of salinity (0.23±0.00), total dissolved solids (TDS) (304.85 to 313.30 ppm; average of 310.60±2.75), total alkalinity (198.55 to 210.15 ppm; average of 204.17±3.24 ppm), total hardness (200.20 to 204.80 ppm; average of 203.46±1.53), total ammonia nitrogen (TAN) (0.11 to 0.59 ppm; average of 0.35±0.20 ppm), unionized ammonia (NH_3) (0.001 to 0.006; average of 0.004±0.002) ($\leq$0.05 mg/L), ionized ammonia (NH_4) (0.11 to 0.58 ppm; average of 0.35±0.20) and nitrite (NO_3) (0.003 to 0.007 ppm; average of 0.004±0.001 ppm) was still within tolerable limit for the growth of fishes [9].

Based upon the classification of the Department of Environment and Natural Resources (DENR), Nabao Lake belongs to Class C which is intended for propagation and growth of fish and other aquatic resources and for boating. Inland body of water classified as Class C should have biological oxygen demand (BOD) of $\leq$7 ppm, DO of at least 5 ppm, pH range of 6.50 to 9.00, phosphate of $\leq$0.5 ppm, temperature range of 25 to 31 ^{0}C and total suspended solid of $\leq$80 ppm [13].

Table 2: Physico-chemical assessment of the eight sampling sites in Nabao Lake, Cabiao, Nueva Ecija, Philippines

Sampling Sites	Secchi Disc Visibility (cm)	Photic Depth (m)	Temperature (^{0}C)	pH	DO (ppm)	Salinity (ppm)	TDS (ppm)
Station 1	31	2.24	24.40±0.20	7.43±0.07	1.93±0.32	0.23±0.01	304.85±2.83
Station 2	31	2.24	24.90±0.20	7.06±0.03	0.63±0.16	0.23±0.00	313.08±1.99
Station 3	63	2.52	24.57±0.15	7.09±0.03	0.96±0.21	0.23±0.00	310.18±1.03
Station 4	65	2.58	25.23±0.32	7.16±0.04	3.32±0.07	0.23±0.01	311.87±4.39
Station 5	58	2.32	26.20±1.56	7.28±0.10	6.99±0.14	0.23±0.00	311.35±1.13
Station 6	55	2.18	25.70±0.00	7.08±0.06	2.33±0.07	0.23±0.00	308.75±1.72
Station 7	58	2.32	26.63±0.06	7.55±0.01	8.53±0.31	0.23±0.00	311.43±1.06
Station 8	72	2.86	26.47±0.23	7.16±0.05	8.13±0.28	0.23±0.00	313.30±0.65
Mean	54.13±15.20	2.41±0.23	25.51±0.87	7.23±0.18	4.10±3.26	0.23±0.00	310.60±2.75

Table 3: Physico-chemical assessment of the eight sampling sites in Nabao Lake, Cabiao, Nueva Ecija, Philippines

Sampling Sites	Tot. Alkalinity (ppm)	Tot. Hardness (ppm)	TAN (ppm)	NH_3 (ppm)	NH_4 (ppm)	Nitrite (ppm)	Phosphorus (ppm)
Station 1	210.15±10.04	203.65±3.04	0.41±0.09	0.006±0.002	0.41±0.09	0.007±0.001	0.43±0.01
Station 2	202.90±6.64	204.04±3.70	0.58±0.02	0.004±0.000	0.58±0.02	0.005±0.000	0.51±0.00
Station 3	204.35±0.00	202.50±20.16	0.57±0.14	0.004±0.001	0.57±0.14	0.005±0.000	0.44±0.01
Station 4	198.55±2.51	200.20±1.99	0.53±0.12	0.005±0.001	0.53±0.12	0.004±0.001	0.44±0.02
Station 5	205.80±2.51	204.80±1.15	0.21±0.01	0.002±0.001	0.21±0.01	0.004±0.000	0.43±0.00
Station 6	204.35±0.00	203.27±0.66	0.11±0.04	0.001±0.000	0.11±0.04	0.004±0.000	0.39±0.03
Station 7	202.90±2.51	204.42±0.66	0.16±0.02	0.004±0.000	0.16±0.02	0.003±0.000	0.38±0.03
Station 8	204.35±4.35	204.80±1.15	0.20±0.13	0.002±0.001	0.19±0.13	0.003±0.000	0.40±0.02
Mean	204.17±3.24	203.46±1.53	0.35±0.20	0.004±0.002	0.35±0.20	0.004±0.001	0.43±0.41

3.2. Biological Analysis of Water

Results in Table 3 show that around 25 taxa of plankton from nine major groups were identified in Nabao Lake. This result has provided the impression that the plankton population in the lake was highly variable. The plankton community in the lake was dominated by dinoflagellates (Phylum Phyrrophyta) and green algae (Phylum Chlorophyta) but the latter group was the most preferred food of fishes. Algal genera such as *Ankistrodesmus*, *Chlorella*, *Closterium*, *Synedra*, *Euglena* and *Phacus* were considered to be indicators of organic pollution. According to Baker [14], biomonitoring or biological monitoring is the use of living organisms to determine the presence, amounts, changes in and effects of physical, chemical and biotic factors in the environment. Plankton population observation may be used as a reliable tool for biomonitoring studies to assess the pollution status of aquatic bodies [15]. The different types of invertebrates have different tolerances to pollution and are also affected by the quality of their habitat. This only indicates that we can tell how good the water and habitat quality depending on the types and numbers of invertebrates living on it [16].

Table 4: Listing of phytoplankton and zooplankton identified in Nabao Lake, Cabiao, Nueva Ecija, Philippines

Phyla/Taxa	Identified Genera	Phyla/Taxa	Identified Genera
Chlorophyta	*Ankistrodesmus*	Phyrrophyta	*Alexandrium*
	Chlorella		*Gambierdiscus*
	Chlorococcum		*Prorocentrum*
	Closterium		*Dinophysis*
	Haematococcus		*Fragilidium*
	Eremosphaera		*Mesoporus*
Chrysophyta	*Synedra*		*Rhinodinium*
Xanthophyta	Unknown genus		Unknown dinoflagellate
Cyanophyta	*Anacystis*	Ciliophora	*Amphileptus*
	Glaucocystis		*Dileptus*
Euglenophyta	*Euglena*	Actinopoda	Unknown heliozoan
	Strombomonas	Cladocera	*Daphnia*
	Phacus		

3.3. Bacteriological Analysis of Water and Soil

Provided in Table 4 is the result of the bacteriological assessment done in the water and soil of Nabao Lake. Generally, total bacterial count (TBC) and total coliform count (TCC) in water (TBC = 4.14 x 10^8; TCC = 3.73 x 10^7) and soil (TBC = 1.90 x 10^9; TCC = 6.25 x 10^4) was very high. The presence of coliform bacteria into the environment is generally not a cause of alarm for fishes. But, other disease causing bacteria, which can include some pathogenic strains, may also be present in the environment and might pose a health threat to humans [17]. According to Geldreich *et al.* [17], coliform bacteria could be used as an indicator of suitable water quality for human consumption. TBC in water and soil should be <1 x 10^5 and <5 x 10^7, respectively [18].

Table 5: Total bacterial count and total coliform count of water and soil in Nabao Lake, Cabiao, Nueva Ecija

Sampling Sites	TBC Water (CFU/mL)	TBC Soil (CFU/g)	TCC Water (CFU/mL)	TCC Soil (CFU/g)
Station 1	5.80×10^8	1.00×10^9	3.20×10^7	3.33×10^4
Station 2	3.97×10^8	5.40×10^8	3.58×10^7	0.00×10^0
Station 3	3.40×10^8	4.85×10^9	3.60×10^7	3.33×10^4
Station 4	3.43×10^8	2.86×10^9	5.15×10^7	3.33×10^4
Station 5	9.33×10^8	1.10×10^9	4.24×10^7	3.33×10^4
Station 6	2.52×10^9	2.88×10^9	4.22×10^7	6.67×10^4
Station 7	2.22×10^9	7.47×10^8	5.23×10^7	1.00×10^5
Station 8	2.47×10^9	1.19×10^9	3.55×10^7	2.00×10^5
Mean	4.14×10^8	1.90×10^9	3.73×10^7	6.25×10^4

4. Conclusion
The lake was categorized as hypereutrophic based upon low Secchi disc visibility reading (< 100 cm), low level of DO (<5 ppm) and high level of phosphorus (>0.1 ppm). Identified algal genera in the lake such as *Ankistrodesmus*, *Chlorella*, *Closterium*, *Synedra*, *Euglena* and *Phacus* were considered to be indicators of organic pollution. The water and soil of the lake had very high TBC and TCC. The fishes in the lake are not safe for consumption if cooked improperly. Aquaculture activities in the lake were not recommended even though the lake supported a wide-array of plankton that could serve as food for the fishes.

5. Acknowledgment
The authors wish to extend their profound gratitude to the Department of Environment and Natural Resources-Nueva Ecija for the extended support to make this study possible.

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