Plankton abundance and diversity in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines

Lorenz J. Fajardo, Ruth S. Lebeng, Mylene L. Morales, Alvin T. Reyes

College of Fisheries, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines. Corresponding author: A. T. Reyes, alvinreyes@clsu.edu.ph

Abstract. Four phyla of phytoplankton (Bacillariophyta, Chlorophyta, Cyanophyta and Dinophyta) and three taxa of zooplankton (Rotifers, Cladocerans and Copepods) were identified at five sampling stations in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines. Phylum Bacillariophyta had the highest mean abundance (3.28±0.90 inds mL^{-1}) especially in the residential site (Station 4) and open water zone (Station 2). The relative abundance of phylum Bacillariophyta in relation to other identified phyla was 48.97%. The genus *Aulacoseira* under the phylum Bacillariophyta was the most prevalent (39.59% to 57.62%). For the zooplankton group, rotifers had the highest mean abundance (541.20 inds mL^{-1}). Two taxa of zooplankton, the *Monostyla* and *Mesocyclops*, were the most common in the tourism site (Station 3), residential area (Station 4) and agriculture site (Station 5). In totality, 56.14% of zooplankton abundance was comprised of *Monostyla* (Rotifers) and 33.55% of *Mesocyclops* (Copepods). The overall computed Shannon-Wiener index (H') of the reservoir could be categorized as very low (<1.99) in terms of phytoplankton and zooplankton species diversity. The overall calculated evenness (J') and dominance (D) were below 1, indicating that there are no phytoplankton and zooplankton genera that dominate the community, because of uniformity in species distribution. A majority of the results of physico-chemical parameters were within the desirable range for the growth of plankton species. The influence of water quality parameters such as dissolved oxygen, temperature, pH and total dissolved solids was found significant among the five stations.
Key Words: abundance, diversity, phytoplankton, water quality, zooplankton.

Introduction. Lakes and reservoirs are major resources as these hold about 90% of the world's fresh surface water and are the key freshwater resources for agriculture, fisheries, domestic, industrial, recreational, landscape entertainment and energy production (Karmakar & Musthafa 2012). These bodies of water are very diverse both in terms of size and fisheries potential (Abdullahi et al 2017). An understanding of the natural and artificial influences common to the various uses of lakes and reservoirs helps in the interpretation or prediction of their physical, chemical and biological behavior (Thornton et al 1996). There are more than 1,000 impounding dams and reservoirs in the Philippines (Guerrero 1988). One of the country's largest reservoir, with a surface area of 8,900 ha and a maximum depth of 28.9 m, is the Pantabangan reservoir located in Pantabangan, Nueva Ecija, Philippines (Guerrero 1988). The Pantabangan reservoir was commissioned in 1974, aiming at hydropower generation, irrigation and flood control (Guerrero 1988). It is cleanest in the country and acclaimed as the second largest dam in Asia that can generate 112 megawatts of hydroelectric power and supplies the irrigation requirements of about 77,000 ha of agriculture lands in Central Luzon (Guerrero 1988).

The biological assessment of water quality is now largely developing because of the inclusion of biological indicators in water quality guidelines and in the assessment of environmental impact (Singh et al 2013). The term "bioindicator" is used as a collective term to refer to all terms relating to the detection of biotic responses to environmental stress (Holt & Miller 2011). The use of living organisms for monitoring water quality has originated in Europe and it is widely used throughout the world (Barman & Gupta 2015). Biological indicators provide information on the surrounding physical and/or chemical environment by their presence, absence, frequency and abundance at a particular site (Singh et al 2013). To monitor the integrity of aquatic ecosystems, plankton has been used recently as bioindicator (Ferdous & Muktadir 2009). The estimation of plankton analysis helps explaining the cause of color, turbidity, presence of odor, taste and visible particles in water (Vaidya 2017). Planktons react rapidly to ecological changes and are viewed as excellent indicators of water quality and trophic conditions due to their short time and rapid rate of reproduction (Ferdous & Muktadir 2009). They play an important role in food web by linking primary producers and higher trophic levels (Singh et al 2013). Planktons are assumed to indicate water quality, eutrophication and production of a freshwater body (Parmar et al 2016). The current study in Pantabangan Reservoir was conducted (1) to assess the plankton abundance and diversity indices, and (2) to measure physico-chemical water quality parameters.

Material and Method

Study area. One of the most important watersheds in the Philippines is the Pantabangan-Carranglan Watershed, which hosts the Pantabangan Dam. It is bounded by the Caraballo Mountains on the north, northwest and northeast and by the Sierra Madre ranges on the south, southeast and southwest. The Pantabangan reservoir (15°48′ 52′′ N, 121° 06′ 29′′ E) (Figure 1) has a surface area of 8,900 ha and a maximum depth of 28.9 m (Guerrero 1988). The catchment supplying water to the reservoir covers 853 km^2 and is located in the townships of Pantabangan and Carranglan (Nueva Ecija province), Alfonso Castañeda and Dupax del Sur (Nueva Vizcaya) and Maria Aurora (Aurora) (Lasco et al 2010). The major land cover types are natural forests (predominantly secondary forests), grasslands, reforestation areas and alienable and disposable lands, including barangay communities of residential sites and cultivated areas (Lasco et al 2010).

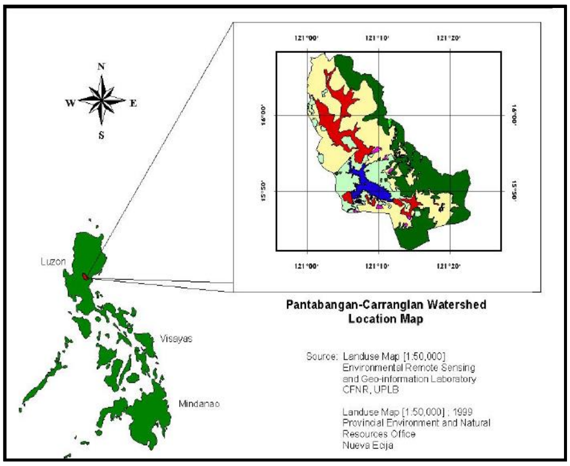

Figure 1. Location of the Pantabangan Reservoir and its watershed (Peras et al 2008).

Sampling stations. Five stations were selected in the southern basins of the reservoir (Figure 2, Table 1). Stations 1, 3, 4 and 5 had a buffer zone of 25 m diameter while Station 2 had a buffer zone of 50 m. There were three sites on every sampling station with a minimum distance of 5 m away from each point. The exact location (Table 1) of the sampling sites was recorded using a handheld Global Positioning System (GPS) unit.

Table 1
Location of the five sampling stations in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines

Station	*Location*
Station 1 Aquaculture site	N 15° 51' 26.10''; E 121° 08' 43.20"
Station 2 Open water zone	N 15° 50' 54.80"; E 121° 08' 50.10"
Station 3 Tourism site	N 15° 49' 40.50"; E 121° 08' 53.50"
Station 4 Residential area	N 15° 49' 08.10"; E 121° 09' 04.06"
Station 5 Agriculture site	N 15° 48' 58.45"; E 121° 09' 54.32"

Figure 2. Study area and sampling stations.

Collection of water samples. In each site, a plankton net with 48 µm mesh size was towed in the water column, at 10 m depth and the net-filtered water was stored in 50 mL polyethylene (PE) bottles and was immediately preserved using 4% buffered formalin. The preserved samples were used in plankton identification and counting. Additional water samples, 500 mL per site, were stored in PE bottles, in a box with ice for the chemical analyses.

Analysis of physico-chemical parameters. Water quality parameters such as temperature, pH, dissolved oxygen and total dissolved solids (TDS) were measured on site using HANNA HI9828 digital multi-parameter. The visibility depth of water was measured using a Secchi disk (SDVD). Analyses of alkalinity, total ammonia nitrogen (TAN) and phosphorus were done in the laboratory using the ice-preserved water samples in PE bottles. Absorbance of water samples for the analysis of TAN and phosphorus was determined using a UV-VIS spectrophotometer. The titration method was used in the analysis of alkalinity.

Plankton identification and enumeration. The preserved water samples were placed in a dark place for three days, for plankton settlement. 1 mL from 10 mL concentrate was pipetted into a Sedgwick Rafter counting chamber. Cover glass was carefully positioned in the counting chamber to avoid bubble formation. The planktons were allowed to settle for about 10 minutes before counting was done. The counting cell was placed beneath the microscope (50 mm long x 20 mm wide x 1 mm deep) (Olympus CKX31) and plankton seen in every field were counted. The identification was guided by available literature and identification keys (Bellinger & Sigee 2010; Fernando 2002). Phytoplankton and zooplankton abundance was computed using the formula of Boyd & Lichktoppler (1979).

$$\text{Abundance (ind mL}^{-1}\text{)} = \frac{\left(T \div \frac{1,000}{AN}\right)(\text{Vol of concentrate in mL})}{\text{Vol of sample in mL}} \; x \; 1,000$$

Where:
T - total number of zooplankton counted;
A - area of grid in mm^2;
N - number of grids employed;
1,000 - area of counting chamber in mm^2.

Statistical analyses. Paleontological Statistics Software and Statistical Package for the Social Sciences (SPSS) were used to analyze the results. Diversity indices such as Shannon-Wiener Index, evenness and dominance were computed using Paleontological Statistics version 3.21 software. Significant differences on diversity indices among collection sites were determined by analysis of variance using SPSS Version 16.0.

Results and Discussion

Abundance of phytoplankton. Four phyla of phytoplankton were identified in five sampling stations in Pantabangan Reservoir and these belong to phylum Bacillariophyta (diatoms), Chlorophyta (green algae), Cyanophyta (blue-green algae) and Dinophyta (golden brown algae). Table 2 shows the mean abundance of phytoplankton phyla identified in Pantabangan reservoir.

Table 2

Abundance of phytoplankton phyla in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines

	Abundance (inds mL^{-1})					
Phylum	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*	*Mean*
Bacillariophyta	3.79±1.67	1.77±0.76	3.12±1.36	3.86±1.70	3.85±1.70	3.28±0.90
Chlorophyta	3.06±0.49	1.13±0.10	1.92±0.16	5.20±0.54	3.01±0.29	2.86±1.54
Cyanophyta	0.78±0.05	0.20±0.04	0.34±0.09	0.65±0.19	0.78±0.17	0.50±0.23
Dinophyta	0.11±0.12	0.03±0.02	0.03±0.03	0.04±0.02	0.03±0.01	0.05±0.04

Station 1- aquaculture site; Station 2-open water zone; Station 3-tourism site; Station 4-residential area; Station 5-agriculture site.

Phylum Bacillariophyta had the highest mean abundance of 3.28±0.90 inds mL^{-1} followed by phylum Chlorophyta (2.86±1.54 inds mL^{-1}), phylum Cyanophyta (0.50±0.23 inds mL^{-1}) and phylum Dinophyta (0.05±0.04 inds mL^{-1}). Phylum Bacillariophyta was more abundant in Station 4 (residential site) and less in Station 2 (open water zone). According to Celekli & Kulkoyluoglu (2006), the dominance of Bacillariophyta could be a result of their high tolerance to chemicals and nutrients, nitrates, phosphates and other metals. Variations in the abundance of phytoplankton in different sampling stations could be influenced by the activities conducted in the site.

According to Fonge et al (2015), human activities in residential areas can affect the abundance of phytoplankton through the waste discharge into the water and fertilizer applied on the crops nearby, which could be a source of nitrogen and phosphorus. In this study, nutrients from commercial feeds given to cultured tilapia in cages, waste discharges from household activities and agricultural inputs like fertilizer could have contributed to the growth of Bacillariophyta in aquaculture (Station 1), residential (Station 4) and agriculture (Station 5) sites. The highest mean abundance of phylum Chlorophyta was recorded at Station 4 (5.20±0.54 inds mL^{-1}) and the lowest at Station 2 (1.13±0.10 inds mL^{-1}). The mean abundance of phylum Cyanophyta and Dinophyta across stations was below 1 inds mL^{-1}, with the highest levels measured in the aquaculture site. The study of Mercurio et al (2006) also found that Cyanophyta had the highest density in the aquaculture site. Cyanophyta or blue-green algae are nuisance algae which become abundant when the nutrients in waters are in excess. Based on the study of Kadam et al (2015), the blue-green algae were found to be abundant during summer months. Their study showed that temperature, due to light intensity, stimulated the growth of blue-green algae. Cyanophyta can tolerate low oxygen conditions and concentrations of sulfuric acid, and they prefer alkaline conditions (Mercurio et al 2006). Generally, it is found that high temperature, organic matter and low dissolved oxygen are favorable to the growth of blue-green algae (Munawar 1970).

The relative percent abundance of different phytoplankton groups during the sampling in Pantabangan Reservoir is shown in Table 3.

Table 3
Relative abundance of phytoplankton genera in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines

	Relative abundance (%)				
Taxa	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*
			Bacillariophyta		
Aulacoseira	48.19	54.80	56.47	39.16	51.33
Stauroneis	0.28	0.83	0.63	0.33	0.35
Navicula	0.08	0.26	0.18	0.04	0.08
Synedra	0.34	0.58	0.30	0.02	0.08
Pinnularia	0.03	0.06	0.04	0.04	0.03
Sub-total	48.92	56.52	57.62	39.59	51.87
			Chlorophyta		
Closterium	0.05	0.06	0.07	0.06	0.11
Microspora	22.23	8.95	9.13	19.50	13.31
Monoraphidium	1.83	1.28	0.92	1.85	2.80
Oedogonium	1.68	5.24	3.33	5.66	7.38
Pediastrum	0.70	1.28	1.59	1.27	0.97
Scenedesmus	5.39	8.44	7.69	8.92	4.50
Selenastrum	1.65	4.03	3.14	5.45	6.04
Staurastrum	0.75	0.58	1.00	1.21	0.89
Tetraedron	1.47	1.15	1.29	0.98	0.81
Cosmarium	1.37	1.02	4.25	4.82	1.02
Arthrodesmus	2.37	3.96	3.00	3.57	2.78
Sub-total	39.49	36.00	35.43	53.29	40.61
			Cyanophyta		
Spirulina	10.12	6.52	6.36	6.66	7.11
Sub-total	10.12	6.52	6.36	6.66	7.11
			Dinophyta		
Ceratium	1.47	0.00	0.59	0.45	0.40
Sub-total	1.47	0.96	0.59	0.45	0.40
Total	100.00	100.00	100.00	100.00	100.00

Station 1- aquaculture site; Station 2-open water zone; Station 3-tourism site; Station 4-residential area; Station 5-agriculture site.

Phylum Bacillariophyta was the most abundant in all sampling stations, with an average relative abundance of 48.97%. According to the study of Effendi (2016), Bacillariophyta is the most diverse and abundant algae species, because it adapts to a wide range of environmental variables.

Among the sampling stations, *Aulacoseira* under phylum Bacillariophyta was the most dominant (39.59 to 57.62%) identified genus. *Aulacoseira* is the oldest, most successful and widely distributed non-marine diatoms (Ambwani et al 2003). Some *Aulacoseira* taxa (mainly high-mantle ones) are characteristic for eutrophic and human-impacted waters, while others (many low-mantle forms) are restricted to less disturbed, pristine habitats. The second most abundant genus was *Microspora* under phylum Chlorophyta. This phylum is primarily freshwater (90%) algae and only about 10% is marine. The abundance of phylum Chlorophyta at comparatively high temperature is found in tropical water (Venkateswarlu et al 1990). High temperature and bright sunlight have been reported as favorable factors for their development. Water temperature also plays an important role in the periodicity of green algae (Munawar 1970). The third most abundant phylum was Cyanophyta with one genus identified (*Spirulina*). The presence of blue-green algae was one of the most important factors in controlling the fluctuation in green algae population (Munawar 1970).

Diversity indices of phytoplankton. The computed diversity indices such as Shannon-Wiener index (H'), evenness (J') and dominance (D) are shown in Table 4. The H' value was the highest (1.95) at Station 4, located near a residential area, followed by Stations 5 (1.74), 2, (1.72), 3 (1.69) and 1 (1.68). The H′ of the reservoir could be categorized as very low in terms of species diversity. According to Cam-ani (2016), values <1.99 were considered very low, as low from 2.00 to 2.49, as moderate from 2.50 to 2.99, as high from 3.00 to 3.49 and as very high when >3.50. If the value of D is approaching to 1, it indicates that a species tend to dominate. In this study, the highest value of D was found at Station 3 (0.46), where *Aulacoseira* was the most abundant. *Aulacoseira* is the most common and successful freshwater diatom that could be abundantly found in lakes and large rivers. On the other hand, Station 1 has attained the lowest D value (0.41). Evenness was the highest at Station 1 (0.69) and the lowest at Station 3 (0.61). The overall calculated values of J′ and D of Pantabangan Reservoir were 0.64 and 0.43, respectively. This indicates that there are no phytoplankton genera that dominate the community, because of uniformity of the species distribution.

Table 4

Overall diversity index of phytoplankton in five stations in Pantabangan Reservoir, Panatabangan, Nueva Ecija, Philippines

	Diversity index		
Station	*H′*	*J′*	*D*
1	1.68	0.69	0.41
2	1.72	0.62	0.45
3	1.69	0.61	0.47
4	1.95	0.62	0.45
5	1.74	0.63	0.44
Overall	1.81	0.64	0.43

Station 1- aquaculture site; Station 2-open water zone; Station 3-tourism site; Station 4-residential area; Station 5-agriculture site.

Abundance of zooplankton. The mean abundance of zooplankton groups at the five stations is presented in Table 5. Zooplankton was represented by three different groups namely, rotifers, cladocerans and copepods. Rotifers had the highest mean abundance (541.20 inds mL^{-1}) followed by copepods (341.20 inds mL^{-1}) and cladocerans (76.00 inds mL^{-1}).

Table 5

Abundance of zooplankton taxa in Pantabangan Reservoir, Panatabangan, Nueva Ecija, Philippines

	Abundance (inds mL^{-1})					
Taxa	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*	*Mean*
Rotifers	8.00	12.00	62.00	1,780.00	844.00	541.20
Cladocerans	184.00	76.00	30.00	54.00	36.00	76.00
Copepods	1,016.00	254.00	238.00	90.00	108.00	341.00

Station 1-aquaculture site; Station 2-open water zone; Station 3-tourism site; Station 4-residential area; Station 5-agriculture site.

The result of this study was in agreement with the studies of Ismail & Adnan (2016), in two small man-made lakes in Malaysia, of Barrabin (2000), in a Spanish reservoir and of Saler (2004), in Keban Dam Lake, stating that rotifers are the most abundant group in freshwater ecosystems. Rotifers have a parthenogenetic reproductive pattern and short development rates under favorable conditions. They have the shortest life cycle with peak reproductive period of 5 to 12 days (Ekpo 2013). Rotifers are more sensitive to alterations in the quality of water (Gannon & Stremberger 1978) and they exhibit a very wide range of pH and turbidity tolerance (Yildiz et al 2007). They preferentially prey on phytoplankton species under phylum Chlorophyta such as *Chlorella* and *Scenedesmus* (Wallace et al 2006), which are common in oligo- and mesotrophic environments.

Rotifers are also able to grow and reproduce when they feed on cyanobacteria, which are frequent in eutrophic ecosystems (Claps et al 2011). Zooplankton abundance is usually closely related to the phytoplankton concentration and species composition and it increases with elevating nutrient concentrations (Jeppesen et al 2000). In freshwater systems, total zooplankton abundance may increase with increasing eutrophication and its diversity may vary according to the limnological features and trophic state (Jeppesen et al 2000).

Copepods were the most abundant at Station 1 (1,016 inds mL^{-1}) wherein Nile tilapia (*Oreochromis niloticus*) was cultured in fish cages. Feed input for *O. niloticus* could be a source of nutrient for the zooplankton in the station. However, aquaculture operations in Pantabangan Reservoir only started few years ago. Copepods are generally abundant in any freshwater ecosystem. Copepods build up their population during a longer period than rotifers and other zooplanktons. However, once they become dominant, they continue to dominate the habitat until the hydrobiological conditions favor their existence (Wasudha 2014). The abundance of rotifers was the highest at the Station 4 (1,780 inds mL^{-1}) which is near the residential area, wherein different activities such as bathing, laundry and washing were observed. There was also a presence of animals, such as carabao, and few crops nearby this station. These could contribute to the nutrient load of water through the animal waste and fertilizers being used. Zooplankton composition was found to be affected by eutrophication, shifting the dominance from large species (copepods) to smaller species (rotifers) (Emam 2006).

The relative abundance of zooplankton taxa at the five sampling stations is shown in Table 6. At Station 1 (aquaculture site), *Mesocyclops* comprised 79.80% of the total zooplankton and they were followed by *Bosmina* with 14.40%. Similarly, at Station 2 (open water zone), *Mesocyclops* had the highest relative abundance (69.59%), followed by *Bosmina* (22.22%). At Station 3 (tourism site), *Mesocyclops* still had the highest relative abundance (72.12%) and *Monostyla* (17.58%) was the second. Meanwhile, *Monostyla* had the highest relative abundance at Station 4 (residential area) and 5 (agricultural site) with 91.99% and 85.22%, respectively, followed by *Mesocyclops* (Station 4=4.26%; Station 5=8.7%). Overall, 56.14% of the zooplankton abundance was comprised of *Monostyla* and 33.55% of *Mesocyclops*. In the study of Sunkad et al (2013), *Mesocyclops* have the ability to adapt to both clean and contaminated waters. Cyclopoid copepods are preferentially carnivorous, and their diet is mainly composed by microcrustaceans (Neves et al 2013).

Table 6

Relative abundance of zooplankton genera in Pantabangan Reservoir, Panatabangan, Nueva Ecija, Philippines

	Relative abundance (%)				
Taxa	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*
		Rotifers			
Monostyla	0.67	3.51	17.58	91.99	85.22
Trichocerca	0.00	0.00	1.21	0.52	0.21
Sub-total	0.67	3.51	18.79	92.51	85.43
		Cladocerans			
Bosmina	14.40	22.22	9.09	2.81	3.64
Ceriodaphnia	0.83	0.00	0.00	0.00	0.00
Sub-total	15.23	22.22	9.09	2.81	3.64
		Copepods			
Mesocyclops	79.80	69.59	72.12	4.26	8.70
Unidentified	4.30	4.68	0.00	0.42	2.23
Sub-total	84.10	74.27	72.12	4.68	10.93
Total	100.00	100.00	100.00	100.00	100.00

Station 1-aquaculture site; Station 2-open water zone; Station 3-tourism site; Station 4-residential area; Station 5-agriculture site.

Diversity indices of zooplankton. The computed H', J' and D of zooplankton are shown in Table 7. The H' was the highest at Station 1(0.33), near an aquaculture site, followed by Stations 2 (0.31), 5, (0.26), 4 (0.24) and 3 (0.13). In general, the computed H' at all stations was very low, <1.99 (Cam-ani 2016). The values of D (0.85 to 0.63) across stations were less than 1, thus, no species tend to dominate. The evenness was the highest at Station 4 (0.83) and the lowest at Station 1 (0.67). The overall calculated J' and D of zooplankton, in Pantabangan Reservoir, was 0.69 and 0.71, respectively. This indicates that there are no zooplankton genera that dominate the community because of the uniformity of the species distribution.

Table 7

Overall diversity index of zooplankton in five stations in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines

	Diversity index		
Station	*H'*	*J'*	*D*
1	0.33	0.63	0.67
2	0.31	0.63	0.67
3	0.13	0.63	0.64
4	0.24	0.85	0.83
5	0.26	0.71	0.73
Overall	0.25	0.69	0.71

Station 1-aquaculture site; Station 2-open water zone; Station 3-tourism site; Station 4-residential area; Station 5-agriculture site.

Physico-chemical water parameters. Mean readings of the physico-chemical parameters of water at each station are presented in Table 8. There were significant differences observed in DO, temperature, pH and TDS across the five stations and no significant difference was observed in the values of TAN, alkalinity and phosphorus, among stations. DO was generally low at all sampling stations. DO levels were significantly higher at Station 3 (tourism site) and 4 (residential area) which could be attributed to the different recreational and anthropogenic activities such as boating and jet skiing. The DO can enter water through the air, the oxygen can slowly diffuse across the water's surface from the surrounding atmosphere or be quickly mixed in through aeration. pH was the highest at Station 3 (tourism site). The oxygen content of water decreases when there is an increase in nutrients and organic materials from industrial wastewater, sewage discharges and runoff from the land. DO and pH are directly proportional; an increase in DO also results into an increase in pH. The highest TDS reading was obtained at Station 4 (residential area), since many households are located near this station, where domestic waters directly leak to the water system of the reservoir, which might be the source of the high value of TDS in the area. SDVD (transparency) was the highest at Station 4 (residential area).

Table 8

Mean physico-chemical water parameters in five sampling stations in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines

Parameter	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*
DO (mg L^{-1})	2.11 ± 0.22^{b}	2.48 ± 0.32^{b}	4.53 ± 0.58^{a}	4.21 ± 0.47^{a}	2.68 ± 0.50^{b}
Temperature (°C)	25.93 ± 0.09^{a}	26.26 ± 0.05^{a}	26.13 ± 0.17^{a}	26.66 ± 0.26^{a}	26.56 ± 0.31^{a}
pH	8.06 ± 0.17^{a}	7.90 ± 0.07^{ab}	8.02 ± 0.05^{a}	7.84 ± 0.06^{b}	7.90 ± 0.07^{ab}
TDS (mg L^{-1})	65.60 ± 0.55^{b}	66.00 ± 0.55^{ab}	67.60 ± 0.89^{a}	68.40 ± 1.67^{a}	67.00 ± 0.71^{ab}
TAN (mg L^{-1})	0.38 ± 0.06^{a}	0.78 ± 0.06^{a}	0.37 ± 0.06^{a}	0.34 ± 0.07^{a}	0.39 ± 0.02^{a}
Alkalinity (mg L^{-1})	40.40 ± 5.13^{a}	40.00 ± 5.15^{a}	42.00 ± 1.22^{a}	42.00 ± 2.00^{a}	44.20 ± 2.49^{a}
Phosphorus (μg L^{-1})	0.12 ± 0.01^{a}	0.11 ± 0.01^{a}	0.12 ± 0.01^{a}	0.11 ± 0.01^{a}	0.11 ± 0.01^{a}
SDVD (cm)	36.83 ± 0.27^{b}	37.25 ± 0.25^{ab}	37.81 ± 0.44^{a}	38.12 ± 0.82^{a}	37.45 ± 0.36^{ab}

Means ±SD with the same superscripts are not significantly different ($p \geq 0.05$). Columns are the one compared.
Station 1-aquaculture site; Station 2-open water zone; Station 3-tourism site; Station 4-residential area; Station 5-agriculture site.

Physico-chemical parameters of water quality for lakes, in the Pantabangan reservoir, are shown in Table 9. The recorded mean reading for DO was 3.20 mg L^{-1}, below the recommended level of 5 mg L^{-1} (DENR Administrative Order 2016). Levels of oxygen are affected by different factors such as temperature, altitude and salinity. Temperature of the water had the mean reading of 26.31°C, which was within the required range of 25 to 31°C (DAO 2016). The recorded mean pH was 7.94 which was within the required range of 6.5 to 9.0, based on DAO (2016). The most favorable range of pH for fish and for biological productivity ranges between 7 and 8.5 (Bhatnagar & Devi 2013). At lower pH, the organism's ability to maintain its salt balance is affected and the reproduction ceases.

The TDS of the reservoir had a mean value of 67.04 mg L^{-1}, under the maximum acceptable threshold of <600 mg L^{-1} (Pandey 1997). The recorded TAN mean was 0.37 mg L^{-1}, within the desirable range of 0 to 2 mg L^{-1} (Bhatnagar & Devi 2019). This water quality parameter is dependent on the temperature and pH, whose increase may result in toxic levels of ammonia in the water (Ebeling et al 2004). The recorded mean reading for alkalinity was 40.44 mg L^{-1}, which was under the standard maximum threshold for the protection of aquatic life of 20 mg L^{-1} (Panchagnula & Charan 2016). The desired range of total alkalinity level for plankton species is between 50 to 150 mg L^{-1} (Boyd 2004). The recorded level of phosphorus was 0.114 µg L^{-1}. Phosphorus is often a limiting factor for the growth of algae in surface waters (Mulla 1998). A lake with a concentration of below 10 µg L^{-1} is considered as oligotrophic, while concentrations between 10 and 20 µg L^{-1} are indicative of mesotrophy and concentrations exceeding 20 µg L^{-1} are already considered eutrophic (Muller & Helsel 1999). The recorded mean SDVD (transparency) was 37.49 cm.

Table 9

Physico-chemical parameters of water in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines relative to water quality standards for lakes

Parameter	*Pantabangan reservoir*	*Water quality standards for lakes*	
		*PHILMINAQ**	*DAO 2016-08***
DO (mg L^{-1})	3.20	5.0	5.0
Temperature (°C)	26.31	No standard set	25 to 31
pH	7.94	6.5 to 8.5	6.5 to 9.0
TDS (mg L^{-1})	67.04	No standard set	No standard set
TAN (mg L^{-1})	0.37	No standard set	No standard set
Alkalinity ($CaCO_3$) (mg L^{-1})	40.44	No standard set	No standard set
Phosphorus (µg L^{-1})	0.11	0.05 to 0.20	No standard set
SDVD (cm)	37.49	No standard set	No standard set

*PHILMINAQ-water quality standards/criteria relevant to freshwater aquaculture; **DAO 2016-08 – Class C (Fishery Water and Recreational Water Class II).

Pantabangan Reservoir is of Class C, according to its intended usage, such as: fishery water (propagation and growth of fish and other aquatic resources), recreational water (boating, fishing or similar activities) agriculture irrigation and livestock watering (DAO 2016). A majority of the physico-chemical parameters were within the desirable range for the growth of plankton species.

Conclusions. The sampling locations in Patabangan Reservoir had an influence on the abundance of phytoplankton and zooplankton. Bacillariophyta phylum was more abundant in the aquaculture, residential and agriculture areas, phylum Chlorophyta in the residential area and phylum Cyanophyta and phylum Dinophyta at the aquaculture site. In the zooplankton group, rotifers were more abundant in the residential and agricultural areas, copepods at the agricultural site and cladocerans in the open water zone. The overall diversity of the phytoplankton and zooplankton based on the computed Shannon-Wiener index (H') was very low. The overall calculated evenness (J') and dominance (D) was below 1, indicating that there are no phytoplankton and zooplankton genera that dominate the community. A majority of the physico-chemical parameters were within the desirable range for the growth of plankton species. Water quality parameters such as dissolved oxygen, temperature, pH and total dissolved solids were found significantly different among the five stations. The Pantabangan Reservoir is of Class C, according to its intended usage, such as for fishery water (propagation and growth of fish and other aquatic resources), recreational water (boating, fishing or similar activities) and for agriculture, irrigation and livestock watering.

Conflict of interest. The authors declare no conflict of interest.

References

Abdullahi Y., Mustapha Y., Indabawa I. I., Sindama A., 2017 The relative abundance, distribution and species diversity of phytoplanktons in Kanye Dam in Kano, North western- Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology 11(4-1):20-31.

Barman B., Gupta S., 2015 Aquatic insects as bio-indicator of water quality- A study on Bakuamari stream, Chakras hila Wildlife Sanctuary, Assam, North East India. Journal of Entomology and Zoology Studies 3(3):178-186.

Barrabin J. M., 2000 The rotifers of Spanish reservoirs: Ecological, systematical and zoogeographical remarks. Limnetica 19:91–144.

Bellinger E. G., Sigee D. C., 2010 Freshwater algae: Identification and use as bioindicators. JohnWiley and Sons, pp. 138-254.

Bhatnagar A., Devi P., 2019 Water quality guidelines for the management of pond fish culture. International Journal of Environmental Sciences 5(2):1-30.

Boyd C. E., Lichktoppler F., 1979 Water quality management in pond fish culture. International Centre for Aquaculture. Alabama Agriculture Experiment Station. Auburn University Research Development Series No. 22, 32 p.

Boyd P., 2004 Ironing out algal issues in the Southern Ocean. Science 304:396–397.

Cam-ani D., 2016 Plankton population of Nabao Lake in Cabiao, Nueva Ecija. BSc thesis, Central Luzon State University-College of Fisheries. Science City of Muñoz, Nueva Ecija, Philippines, 67 p.

Celekli K. O., Kulkoyluoglu O., 2007 On the relationship between ecology and phytoplankton composition in a karstic spring (Cepni, Bolu). Ecological Indicators 7(2):497-503.

Claps M., Ferrando N., Benitez H., Gabellone N., 2011 Influence of temperature and conductivity on the life-history characteristics of a pampean strain of Brachionus plicatilis. Scientific Electronic Library Online 90(2):1431-1444.

Ebeling J., Ogden S., Sibrell P., Rishel K., 2004 Application of chemical coagulation aids for the removal of suspended solids (TSS) and phosphorus from the microscreen effluent discharge of an intensive recirculating aquaculture system. North American Journal of Aquaculture 66:198-207.

Effendi H., Kawaroe M., Lestari D. F., Permadi T., 2016 Distribution of phytoplankton diversity and abundance in Mahakam Delta, East Kalimantan. Procedia Environmental Sciences 33:496-504.

Ekpo I., 2013 Effect of physico-chemical parameters on zooplankton species and density of a tropical rainforest river in Niger Delta, Nigeria using canonical cluster analysis. The International Journal of Engineering and Science (IJES) 2(4):13-21.

Emam W., 2006 Preliminary study on the impact of water pollution in El-Rahawy drain dumping in Rosetta Nile branch on zooplankton and benthic invertebrates. MSc thesis, Zoology Department, Faculty of Science, Ain Shams University, 358 p.

Ferdous Z., Muktadir A. K. M., 2009 A review: Potentiality of zooplankton as bioindicator. American Journal of Applied Sciences 6(10):1815-1819.

Fernando C. H., 2002 A guide to tropical freshwater zooplankton: Identification ecology and impact on fisheries. African Journal of Aquatic Science 28(1):87-88.

Fonge B. A., Tabot P. T., Mange C. A., Mumbang C., 2015 Phytoplankton community structure and physicochemical characteristics of streams flowing through an agro-

plantation complex in Tiko, Cameroon. Journal of Ecology and the Natural Environment 7(5):170-179.
Gannon J., Stemberger R., 1978 Zooplankton (especially crustaceans and rotifers) as indicators of water quality. American Microscopical Society 97(1):16-35.
Guerrero R. D., 1988 The conservation and management of our freshwater ecosystems. Transactions of the National Academy of Science and Technology, pp. 154-155.
Holt E. A., Miller S. W., 2011 Bioindicators: Using organisms to measure environmental impacts. Nature Education Knowledge 2(2):1-8.
Ismail A. H., Adnan A. A. M., 2016 Zooplankton composition and abundance as indicators of eutrophication in two small man-made lakes. Tropical Life Sciences Research 27(1):31–38.
Kadam A. A., Lade H. S., Lee D. S., Govindwar S. P., 2015 Zinc chloride as a coagulant for textile dyes and treatment of generated dye sludge under the solid state fermentation: Hybrid treatment strategy. Bioresource Technology 176:38-46.
Karmakar S., Musthafa O. M., 2012 Lakes and reservoirs: Pollution. Encyclopedia of environmental management. CRC Press, pp. 1576-1587.
Lasco R. D., Cruz R. O., Pulhin J. M., Pulhin F. B., 2010 The case of Pantabangan-Carranglan watershed. Assessing climate change impacts, vulnerability and adaptation. Journal of Environmental Science and Management 11(2):14-31.
Mercurio A. L., Querijero B. L., Ching J. A., 2006 Phytoplankton community in aquaculture and non-aquaculture sites of Taal Lake, Batangas. Philippines. Journal of Experimental Biology and Agricultural Sciences 4(1):67-72.
Mulla D. J., 1998 Phosphorus in surface waters: The Minnesota River case study. Better Crops 82(8):1-11.
Muller D. K., Helsel D. R., 1999 Nutrients in the nation’s water. Too much of good thing? Circular 1136, U.S. Geological Survey, Denver, 24 p.
Munawar M., 1970 Limnological studies of freshwater ponds of Hyderabad. India I The Biotope Hydrobiologia 35(1):127-162.
Neves G. P., Fileto C., Portinho J. L., Troguer A., Júnior M. S., 2013 Relations among planktonic rotifers, cyclopoid copepods, and water quality in two Brazilian reservoirs. Latin American Journal of Aquatic Research 41(1):138-149.
Panchagnula S., Charan S. T., 2016 A study of alkalinity in water samples - titrimetry. International Journal of Trend in Research and Development (IJTRD) 3(6):2394-9333.
Pandey G. N., 1997 Environmental management. Vikas Publishing House, New Delhi, India, pp. 33-37.
Parmar T. K., Rawtani D., Agrawal Y. K., 2016 Bioindicators: The natural indicator of environmental pollution. Frontiers in Life Science 9(2):110-118.
Saler S., 2004 Observation on the seasonal variation of rotifer fauna of Keban Dam Lake (Cemisgezek Region). Science and Engineering Journal of Firat University 16(4):695–701.
Singh U. B., Ahluwalia A. S., Sharma C., Jindal R., Thakur R. K., 2013 Planktonic indicators: A promising tool for monitoring water quality (early-warning signals). Ecology, Environment and Conservation 19(3):793-800.
Thornton J., Steel A., Rast W., 1996 Water quality assessments - A guide to use of biota, sediments and water in environmental monitoring. 2nd edition. Chapter 8-Reservoirs, UNESCO/WHO/UNEP, 651 p.
Vaidya S. R., 2017 Biomonitoring of zooplankton to assess the quality of water in the nagpokhari of Kathmandu valley. International Journal of Zoology Studies 2(1):61-65.
Venkateswarlu V., SampathKumar P. T., Nirmala Kumari J., 1990 Ecology of algae in the river Moosi, Hyderabad a comprehensive study. Journal of Environmental Biology 11(1):79-91.
Wallace R. L., Snell T. W., Ricci C., Nogrady T., 2006 Rotifera Part 1: Biology, ecology and systematics. Guides to the identification of the microinvertebrates of the continental waters of the world. Kenobi Productions, Gent, Belgium/Backhuys Publishers, 291 p.

Wasudha M. J., 2014 Seasonal diversity of copepods in relation with physico-chemical status of Devtaki Pond, Distt. Gondia, Gondia (M.S.), India. International Journal of Life Sciences A2:147-149.

Yildiz F., Altinda A., Ergonul M. B., 2007 Seasonal fluctuations in the zooplankton composition of a eutrophic lake: Lake Marmara (Manisa, Turkey). Turkish Journal of Zoology 31:121-126.

*** DAO, Department of Environment and Natural Resources (DENR) Administrative Order, 2016 Water quality guidelines and general effluent standards of 2016-08.

Received: 30 January 2022. Accepted: 11 June 2021. Published online: 26 June 2022.

Authors:
Lorenz Javier Fajardo, Central Luzon State University, College of Fisheries, Department of Aquatic Resources, Ecology and Management, Science City of Muñoz, Nueva Ecija, Philippines, e-mail: lorenzfajardo@clsu.edu.ph
Ruth Sayap Lebeng, Central Luzon State University, College of Fisheries, Department of Aquatic Resources, Ecology and Management, Science City of Muñoz, Nueva Ecija, Philippines, e-mail: ruthslebeng98@gmail.com
Mylene Lina Morales, Central Luzon State University, College of Fisheries, Department of Aquatic Resources, Ecology and Management, Science City of Muñoz, Nueva Ecija, Philippines, e-mail: mylenemorales09@gmail.com
Alvin Toledo Reyes, Central Luzon State University, College of Fisheries, Department of Aquatic Post-Harvest, Science City of Muñoz, Nueva Ecija, Philippines, e-mail: alvinreyes@clsu.edu.ph

How to cite this article:
Fajardo L. J., Lebeng R. S., Morales M. L., Reyes A. T., 2022 Plankton abundance and diversity in Pantabangan Reservoir, Pantabangan, Nueva Ecija, Philippines. AACL Bioflux 15(3): 1541-1552.