

Journal of Coastal Life Medicine

journal homepage: www.jclmm.com



Original article

doi: 10.12980/jclm.3.2015j5-176

©2015 by the Journal of Coastal Life Medicine. All rights reserved.

Comparative study on composition and abundance of major planktons and physico-chemical characteristics among two ponds and Lake Tana, Ethiopia

Wondie Zelalem Amanu*

Bahir Dar Fishery and Other Aquatic Life Research Center, P. O. Box 794, Bahir Dar, Ethiopia

ARTICLE INFO

Article history:

Received 10 Sep 2015

Received in revised form 8 Oct 2015

Accepted 28 Oct 2015

Available online 4 Nov 2015

Keywords:

Aquaculture

Lake Tana

Pond water

Plankton

Abundance

Diversity

ABSTRACT

Objective: To evaluate the difference in physico-chemical characteristics, composition and abundance of plankton communities owing to the supplementary feed added in fish ponds as compared to Lake Tana.

Methods: Physico-chemical and biological data of plankton were collected from 3 studied sites from November 2008 to October 2009. Data were compared using One-way ANOVA to see the difference among sites. Diversity indices such as Margalef's index, Shannon-Wiener index, and evenness index were employed to describe the distribution of plankton community among the studied sites.

Results: The pH value was remarkably higher in ponds water. However, conductivity and total dissolved solids were the highest in lake water. Nitrate concentration was relatively high in ponds. Zooplankton species richness was higher in lake water than ponds. The lake also had the highest mean value of both Shannon-Wiener index and evenness index in phytoplankton.

Conclusions: The results revealed that the supplementary feed added to each pond had influence on nutrient content which enhanced algal biomass and productivity of the ponds. However, the pond water has to be regularly refreshed to control eutrophication.

1. Introduction

Aquaculture in fisheries sector is a recent and emerging phenomenon in Ethiopia, in order to contribute to food security and protein requirements of citizens. Bahir Dar Fishery and Other Aquatic Life Research Center is the only sector representing three regions for aquaculture and has been involved in this practice. The center started aquaculture practice since 2003 with the aim of utilization of the fisheries resource in the region, initiatives to strengthen environmentally sound and sustainable aquaculture development particularly in small-scale aquaculture and needs to ensure a maximum contribution to the region as well to the country food security.

The research center had constructed the fish hatchery and nursery ponds to provide seeds to individual farmers, who involved in fish farming, and even to the regional and zonal agricultural extension

agents in demand to enrich the natural and artificial water bodies. With the increased demands for the seeds through time, the center tried to increase the productivity of ponds so as to hold large fish fingerling densities by adding supplementary feed like Nuge cake, wheat bran, grinded fish bone and fish meal from manufacturer. The supplement of fish feed had dual purpose: it could be eaten by the fish and other zooplanktons directly, and the leftover would dissolve in the water and serve as nutrient source to fertilize water. The fertilized water in return enhances phytoplankton productivity that serves as the bases for the whole pond ecosystem.

The production of fish is directly dependent on the productivity of the entire pond water ecosystem, namely, the abundance of both phytoplankton and zooplanktons in a pond provides fish with ample natural feeds, by which fish can grow fast and increase the yield. The existence of large biomass of plankton is also favored by suitable physico-chemical factors, hence in fish cultures, water quality and the success in its management depend on a strong knowledge of the structure and functioning of the ponds, particularly with regard to the water's physical and chemical variables and to the biological communities[1]. In fish culture activities, plankton production is a factor of great importance since it constitutes the

*Corresponding author: Wondie Zelalem Amanu, Bahir Dar Fishery and Other Aquatic Life Research Center, P. O. Box 794, Bahir Dar, Ethiopia.

Tel: +251-0918-727506

E-mail: wondiehm@gmail.com

Foundation project: Supported by Amhara Regional Agricultural Research Institute, Host Institute of Bahir Dar Fishery and Other Aquatic Life Research Center (Grant No. 10/26/BD/2009).

most adequate food for the fish in their youngest phase, especially the rotifers and the cladocerans. The presence of these organisms in the environment may lead to better larval development of fish[2].

The source of water for our on-station aquaculture ponds is Lake Tana that is pumped to the ponds through water pump. However the quality of water changes in terms of chemical and biological constituents due to the availability of nutrients for primary producers and the basic food source for the higher level communities in the food chain. This study was carried out to investigate the variation among the water bodies in ponds and Lake Tana in terms of physical and chemical characteristics and the composition and abundance of planktons owing to the supplementary feed added.

2. Materials and methods

2.1. Description of sampling sites

Samples were collected from two ponds in the territory of the research center and a lake shore area. Pond 1 is situated at 11°36'36.4" N and 37°22'38.4" E, which is the oldest pond paved with geo-membrane in the bottom to prevent water leakage. It has an area of 150 m² and mean depth of 0.95 m. The research center started it as hatchery and for fingerling rearing of *Oreochromis niloticus*. Pond 2 is made of concrete and introduced with fish species of experimental barbus; it is located on 11°36'39.7" N and 37°22'40.2" E. This pond has an area of 50 m² and mean depth of 1.10 m. The third site is the lake shore area near the research center, situated at 11°36'41.6" N and 37°22'42" E, which had a mean depth of 2.3 m.

2.2. Physico-chemical parameters

Water samples were collected from each study site from November 2008 to October 2009 and then immediately filtered through a Whatman GF/C glass microfiber filter paper in order to trim down effect of turbidity on photometric chemical analysis of nitrate, which was analyzed using portable water analysis kit (Wagtech International, Palintest transmittance display photometer 5000). Other parameters such as pH, conductivity, total dissolved solids (TDS) and temperature were measured using pocket meter digital instruments. Model WG pHScan 3⁺ (Wagtech International Ltd.) was used to measure pH. Conductivity, TDS and temperature were measured using WG conScan and TDS scan meter with temperature sensor (Wagtech International Ltd.). Dissolved oxygen and percentage of dissolved oxygen were measured using Multi 340i multi probe system instrument (Geotech WTW GmbH).

2.3. Biological parameters

Samples were collected from each site using a 10 L bucket. And 20 L of sample water were filtered using a 50 µm and 120 µm net for phytoplankton and zooplanktons respectively. Then the

phytoplankton sample was fixed with Lugol's iodine solution and the zooplankton sample was fixed with 4% formalin immediately. In the laboratory, phytoplankton samples were allowed to settle for a minimum of 24 h. The supernatant was removed carefully until 10 mL aliquot remained. Concentrated sample was properly shaken and 1 mL of sub-sample was collected from it and transferred into a Sedgwick-Rafter counting chamber using a stamped pipette. Identification and enumeration (standing crop estimation) were carried out under a Olympus CH2 binocular compound microscope with magnification 200×. Duplicates of the sub-samples were analyzed. Observation and identification of phytoplankton to taxa (genus) level was done and classification was performed with the aid of different phytoplankton manuals[3,4]. For each sample, each solitary cell or groups of cells were counted as one unit. Results were expressed in number of organisms per liter of sample. The calculation of plankton density was done according to Lind[5]. Similarly for zooplanktons, identification was based on standard keys[6,7]. The concentrated aliquot of 50 mL was poured to the girded glass counting chamber. Of the total grid (24 strips), 8 strips were counted and extrapolated to the total grid using the formula:

$$\text{Density of zooplankton (No. of organism per liter)} = \frac{\text{No. of organism in aliquot filtered} \times 1000}{\text{Volume filtered (mL)}}$$

2.4. Data analysis

Basic statistical measurement was done and results were expressed as mean ± SE. One-way ANOVA was used to study the difference among sites, where significant values ($P < 0.05$) were obtained and least significant difference test was subsequently applied to detect the specific point of difference among variables. Correlation among physico-chemical variables ($n = 45$) was conducted using SPSS version 16. To describe the distribution of plankton community, three indices of species diversity were used: Margalef's index, the Shannon-Wiener index, and evenness index which expressed the degree of uniformity in the distribution of individuals among the taxa in the collections. The zooplankton counts were analyzed for differences among sites.

3. Results

3.1. Physico-chemical characteristics

Some physico-chemical parameter records during this investigation were summarized in Tables 1 and 2. The temperature shown no significant mean variation in each site (Table 1). However, the lowest value was recorded in Pond 1 and the highest value was recorded in the lake. Conductivity and TDS showed significant difference among sites. Highly significant difference in conductivity were observed between lake and Pond 2 ($P < 0.01$) and Pond 1 and Pond 2 ($P < 0.01$). The lowest mean value was recorded in Pond 1 and the highest mean value was in Pond 2 (Table 1) for conductivity and TDS, respectively.

Table 1

Physico-chemical characteristics of the three study sites (n = 45).

| Parameters | Pond 1 | | Pond 2 | | Lake | |
|-------------------------|--------------|--------------------------------|---------------|---------------------------------|---------------|--------------------------------|
| | Range | Mean ± SE | Range | Mean ± SE | Range | Mean ± SE |
| Temperature (°C) | 18.50–26.10 | 22.5600 ± 0.5992 | 20.10–26.60 | 23.8200 ± 0.4928 | 21.70–28.30 | 23.9800 ± 0.4448 |
| pH | 6.87–9.72 | 8.3800 ± 0.2637 ^a | 7.78–10.20 | 8.7800 ± 0.1958 ^b | 7.01–8.39 | 7.6000 ± 0.0910 ^{ab} |
| Dissolved oxygen (mg/L) | 1.31–11.90 | 5.0067 ± 0.6577 | 1.20–8.57 | 4.9690 ± 0.5756 | 1.05–8.60 | 4.3767 ± 0.5568 |
| % Saturation of oxygen | 12.70–105.70 | 56.6770 ± 6.9160 | 12.40–103.40 | 61.4300 ± 7.9370 | 11.60–103.10 | 54.2667 ± 7.7836 |
| Conductivity (µS/cm) | 90.00–150.00 | 121.8000 ± 0.0046 ^a | 130.00–190.00 | 147.0000 ± 0.0045 ^{ab} | 120.00–140.00 | 129.6000 ± 0.0021 ^b |
| TDS (mg/L) | 40.00–70.00 | 58.3000 ± 0.0027 ^a | 60.00–90.00 | 70.3000 ± 0.0023 ^{ab} | 60.00–70.00 | 62.7000 ± 0.0012 ^b |

^{a, b, ab}: Means followed by the same superscript on the same row indicate that there is significant difference at *P* < 0.05.

Table 2

Two-tailed Pearson correlation coefficient and half matrix values were used for physico-chemical parameters of the three studied sites (n = 45).

| | Water temperature | pH | Conductivity | Dissolved oxygen | % Saturation of oxygen | TDS | Nitrate |
|------------------------|----------------------|--------|---------------------|---------------------|------------------------|-------|---------|
| Water temperature | × | | | | | | |
| pH of the water | 0.397 ^{**} | × | | | | | |
| Conductivity | -0.062 | -0.207 | × | | | | |
| Dissolved oxygen | -0.555 ^{**} | 0.033 | -0.005 | × | | | |
| % Saturation of oxygen | -0.680 ^{**} | -0.146 | 0.122 | 0.928 ^{**} | × | | |
| TDS | -0.052 | -0.192 | 0.951 ^{**} | -0.003 | 0.095 | × | |
| Nitrate | -0.029 | -0.228 | 0.159 | -0.154 | -0.112 | 0.104 | × |

^{**}: Correlation is significant at the 0.01 level (2-tailed).

pH varied from slightly acidic to moderate alkaline. The highest value of pH was recorded in Pond 2 and the lowest was in Pond 1 (Figure 1). There was a highly significant difference in mean value of pH among Pond 1 and lake water (*P* < 0.01) and Pond 2 and lake water (*P* < 0.001). Relatively, the highest value (11.9 mg/L) of dissolved oxygen and percentage saturation of oxygen (105.7%) were recorded in Pond 1 and the lowest was in the lake. However, there was no significant difference in mean value of dissolved oxygen and percentage saturation of oxygen among the three sites (*P* > 0.05).

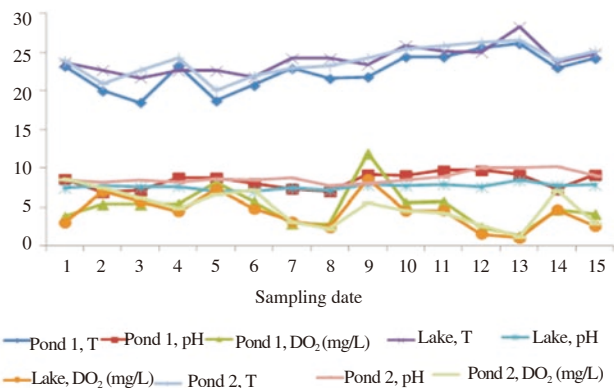


Figure 1. Trends of some physico-chemical characteristics in the three studied sites.

T: Temperature; DO₂: Dissolved oxygen; 1: Nov 19, 2008; 2: Dec 03, 2008; 3: Dec 17, 2008; 4: Dec 31, 2008; 5: Jan 13, 2009; 6: Jan 28, 2009; 7: Feb 11, 2009; 8: Feb 25, 2009; 9: Jul 22, 2009; 10: Aug 6, 2009; 11: Aug 22, 2009; 12: Sep 6, 2009; 13: Sep 23, 2009; 14: Oct 8, 2009; 15: Oct 29, 2009.

The concentrations of nitrate ranged between 0.040 to 1.628 mg/L, with mean value of (0.631 ± 0.114) mg/L in the lake, 0.207 to 2.860 mg/L, with mean value of (1.01 ± 0.19) mg/L in Pond 1 and 0.092 to 3.30 mg/L, with mean value of (0.850 ± 0.207) mg/L in Pond 2. There were temporal and spatial variations in concentration of nitrate in all the three sites with a slight increment in the ponds (Figure 2). But the variation was not significant among sites (*P* > 0.05, n = 45).

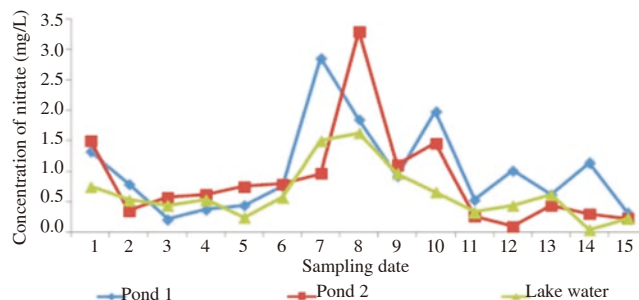


Figure 2. Concentration of nitrate (mg/L) in the three study sites.

1: Nov 19, 2008; 2: Dec 03, 2008; 3: Dec 17, 2008; 4: Dec 31, 2008; 5: Jan 13, 2009; 6: Jan 28, 2009; 7: Feb 11, 2009; 8: Feb 25, 2009; 9: Jul 22, 2009; 10: Aug 6, 2009; 11: Aug 22, 2009; 12: Sep 6, 2009; 13: Sep 23, 2009; 14: Oct 8, 2009; 15: Oct 29, 2009.

3.2. Biological characteristics

3.2.1. Phytoplankton

Phytoplankton community in this study consisted of seven classes. Chlorophyceae, Bacillariophyceae, Cyanophyceae, Euglenophyceae, Conjugatophyceae, Dinophyceae and Cryptophyceae. The first three classes were dominant, comprising 17, 9 and 5 genera, respectively. The rest was represented by a single genus each. The result showed that there were differences in abundance and composition of phytoplankton among studied sites (Figures 3 and 4).

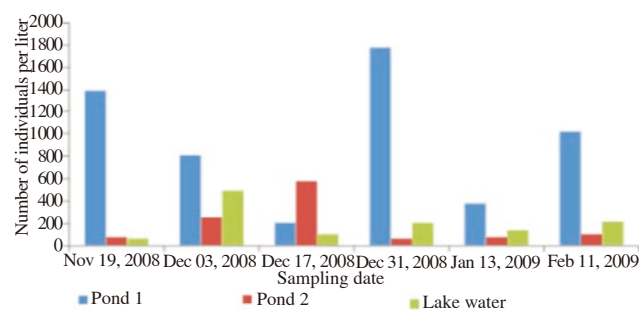


Figure 3. Abundance of phytoplankton taxa in the three studied sites.

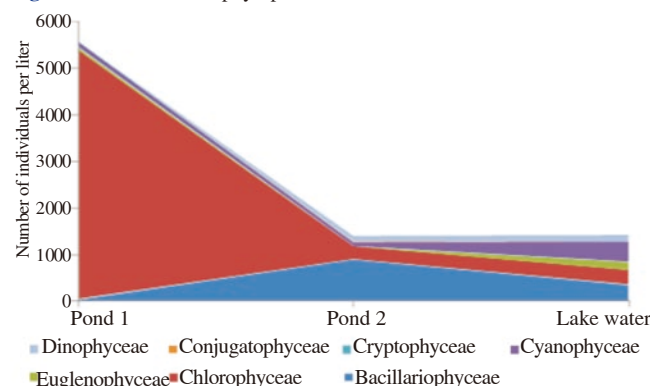


Figure 4. Composition of phytoplankton classes in the three studied sites.

Phytoplankton were more highly abundant in Pond 1 than the other two sites in the whole study period except on December 17, 2008, when Pond 2 showed the greatest abundance of phytoplankton among the three sites. Of the total phytoplankton taxa Chlorophyceae [with the highest composition of *Pediastrum* spp. (75.6%)], Bacillariophyceae [with the highest composition of *Nitzschia* spp. (62%)] and Cryptophyceae [with the highest composition of *Microcystis* spp. (96.4%)] were dominant in Pond 1, Pond 2 and the lake, respectively. The lake water had the highest mean value in both Shannon-Weiner diversity index and evenness index followed by Pond 2 (Figure 5).

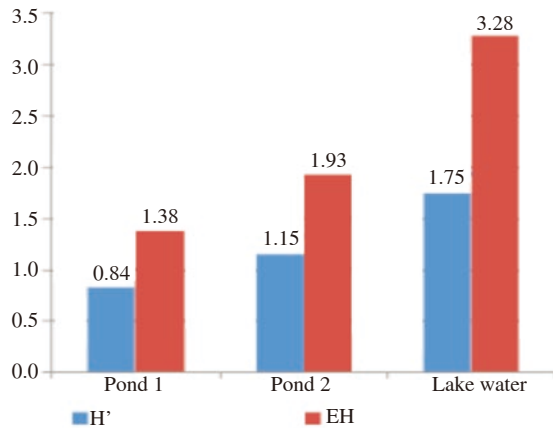


Figure 5. Mean value of Shannon-Wiener diversity index (H') and evenness index (EH) of phytoplankton in the three studied sites.

3.2.2. Zooplankton

The zooplankton community consisted of 25 taxa: 11 cladocerans, 2 copepods and 12 rotifers (Table 3 and Figure 6).

Table 3

Zooplankton composition and their abundance per liter of water in the three studied sites.

| Zooplankton taxa | Pond 1 | | Pond 2 | | Lake | |
|-------------------------------|-----------|-------------|-----------|-------------|-----------|-------------|
| | Abundance | % Abundance | Abundance | % Abundance | Abundance | % Abundance |
| Cladocera | | 23.3 | | 91.6 | | 12.7 |
| <i>Alona quadrangularia</i> | 0.90 | | 14.80 | | 0.25 | |
| <i>Alona guttata</i> | | | | | | |
| <i>Alona</i> sp. | | | | | | |
| <i>Moina dubia</i> | | | | | | |
| <i>Moina</i> sp. | 77.50 | | 33.70 | | 4.20 | |
| <i>Chydorus</i> sp. | 1.20 | | 19.75 | | 0.20 | |
| <i>Diaphanosoma</i> sp. | | | | | | |
| <i>Diaphanosoma orghidani</i> | 29.70 | | 16.15 | | 2.60 | |
| <i>B. longirostris</i> | 7.20 | | 1491.75 | | 5.70 | |
| <i>Ceriodaphnia cornuta</i> | 0.15 | | 144.75 | | 4.80 | |
| <i>Ceriodaphnia</i> sp. | | | | | | |
| Copepod | | 71.1 | | 8.0 | | 64.5 |
| Calanoid | 10.50 | | 14.05 | | 11.95 | |
| Cyclopoid | 343.05 | | 136.80 | | 78.41 | |
| Rotifer | | 5.6 | | 0.4 | | 22.8 |
| <i>Keratella cochleari</i> | | | | | | |
| <i>Keratella tropica</i> | 4.65 | | 1.70 | | 0.60 | |
| <i>Filinia</i> spp. | 0.05 | | 0.15 | | 1.00 | |
| <i>Trichocerca elongate</i> | 17.30 | | 3.85 | | 4.35 | |
| <i>Trichocerca</i> sp. | | | | | | |
| <i>Brachionus falcatus</i> | | | | | | |
| <i>Brachionus</i> sp. | 1.90 | | 0.20 | | 20.35 | |
| <i>Cephalodella</i> sp. | 2.40 | | - | | - | |
| <i>Mytilina ventralis</i> | - | | 0.30 | | - | |
| <i>Asplanchna</i> spp. | 1.50 | | 0.15 | | 5.40 | |
| <i>Monostyla</i> sp. | - | | 0.15 | | - | |
| <i>Euchlanis</i> sp. | 0.15 | | - | | 0.35 | |
| Total | 498.15 | 100.0 | 1878.25 | 100.0 | 140.16 | 100.0 |

B. longirostris: *Bosmina longirostris*.

The abundance of these three taxa varied among sites. Pond 2 was dominated by Cladocera due to the high population of *B. longirostris*, followed by copepod. In the other two sites, copepod was the dominant

taxa followed by Cladocera and rotifer in Pond 1, and rotifer and Cladocera in the lake (Figure 6). There is also variation in diversity of species among the three sites. The Shannon-Wiener index ranged from 0.62 to 1.67, 0.23 to 1.78 and 0.75 to 1.64 in Pond 1, Pond 2 and lake water respectively; and evenness index ranged from 0.24 to 0.63, 0.09 to 0.66 and 0.33 to 0.57 in Pond 1, Pond 2 and lake water, respectively. Similarly, Margalef richness index ranged between 1.29 to 4.26, 1.73 to 15.9 and 2.71 to 7.04 in Pond 1, Pond 2 and lake water, respectively. The mean values of these indices are showed in Figure 7.

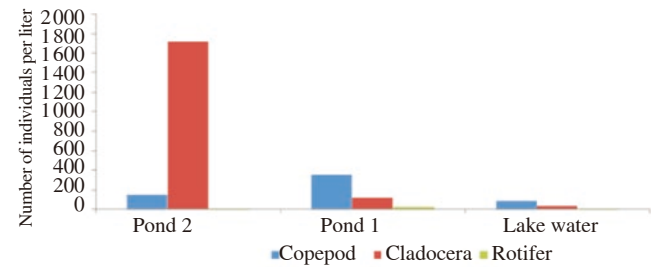


Figure 6. Abundance of the three zooplankton taxa in the three studied sites.

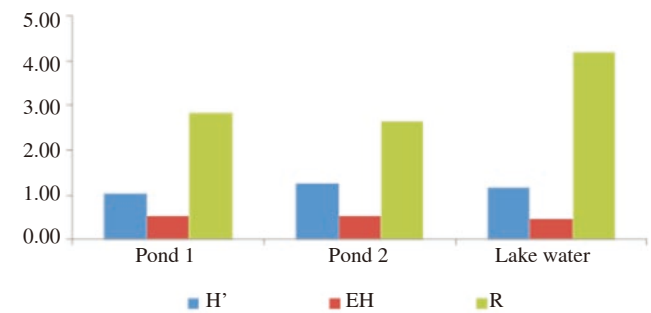


Figure 7. Mean value of Shannon-Wiener diversity index (H'), evenness index (EH) and Margalef richness (R) index of zooplankton species in the three studied sites.

4. Discussion

The physico-chemical parameters in water bodies vary in composition and concentration on a seasonal, diurnal or even hourly basis. These variations may be related to the patterns of water use and rainfall[8]. pH is an important parameter in water quality assessment because it influences on many biological and chemical processes in the water body and all processes associated with water supply and treatment[9]. In this study the difference among sites was highly significant. The slightly acidic pH was recorded in Pond 1 and moderate alkalinity peaks was recorded in Ponds 1 and 2. In contrast the lake had shown a normal range from 7.01–8.39. pH is positively correlated with dissolved oxygen. The variations in pH may be due to the fluctuations of carbon dioxide amount as a result of respiration, and moderate pH in ponds may be resulted from the presence of dense phytoplankton in pond water. The magnitude of variation in pH is determined by the buffering capacity of water or its ability to absorb acids and/or bases. Photosynthetic activity in a poorly buffered pond can cause pH to increase, possibly from as low as six in the morning to nine or more by late afternoon[10].

Photosynthesis, respiration, exchanges at the air-water interface and supply of water to the ponds are the four factors that influence the oxygen concentration in the water. Consequently, oxygen concentrations in the pond water often have a daily cycle. Oxygen concentration is low in the early morning due to respiration, and high in the afternoon due to photosynthesis[11]. And also it is highly negatively correlated with temperature. Small variation was seen among sites but it is hard to made definitive conclusion about the dissolved oxygen results because measurements were taken only once on each sampling date at about 9:30–12:00 a.m. Dissolved oxygen concentrations in productive ponds are known to fluctuate widely during the day[12].

The electrical conductivity of water is the capacity to transport an electrical current. The transport of electricity is ensured by the presence of ions. The measure gives an indication of the total amount of ionizable salts in solution. Similarly TDS by definition are the inorganic salts, organic matter, and other dissolved materials in water[13]. In this study Pond 2 had the highest values in both conductivity and TDS. This is probably due to the added feed, more of fish meal, to the pond.

Higher species diversity and species equitability of phytoplankton population were recorded in the lake water. Conversely, Pond 2 had higher species diversity in zooplanktons population. In the richness index, lake water had higher species composition both in phytoplankton and zooplankton species. Water bodies with higher diversity generally indicate the good quality of water. Also the phytoplankton community in the ponds was affected by the grazers. The presence or the feeding behavior of the fish may result in the size selection of the phytoplankton in ponds[14]. Eutrophic water body can be easily explained by the low biodiversity and the presence of few dominant species, since sensitive organisms are incapable of surviving in extreme environment[15]. In Ponds 1 and 2 in this investigation, the dominance of *Pediastrum* spp. and *Nitzschia* spp. respectively and the high amount of nitrate concentration had shown the symptom of eutrophication.

Similarly, the succession of zooplankton communities in the tropics has been attributed to a number of factors such as the environmental characteristics of the water, predation, quality and quantity of edible algae and competition[16]. The density of Cladocera in Pond 2 was 91.6% of the population which much exceeded the rest copepod and rotifer. This is due to the abundance of small sized *B. longirostris*, which is reported as an indicator of eutrophic water body[17].

The lowest zooplankton abundance was recorded in lake water as compared to the ponds. This is due to the availability of edible phytoplankton species in ponds, and the predation pressure of planktivorous *Barbus* species, *Barbus trispilopleura* and juveniles of *Labeobarbus* species, *Labeobarbus brevicephalus* and *Labeobarbus intermedius* in the lake water[18]. In Pond 1 relatively high density of copepods was recorded, which was 71.1% of the total zooplankton population in the pond. Instar stages of copepods contributed more for their density. A large sized cladoceran like *Moina* and *Diaphanosoma* species were reared in lake and Pond 2 as compared to Pond 1, a hatchery site for *Oreochromis niloticus* fish species. The juveniles of *Oreochromis* spp. and *Clarias* spp. are obligate zooplanktivores[19]. Shannon-Wiener diversity index of zooplanktons in the lake water varied from 0.75–1.64, which did not vary significantly in the study period, showing relatively stable physico-chemical characteristics as compared to the ponds.

From this study we can conclude that in the two aquaculture ponds the abundance of both phytoplankton and zooplanktons was higher than lake. This revealed that the supplement feed added to each pond had influence on nutrient content of pond water and enhanced the productivity of ponds. It is recommended that the pond water should be refreshed with lake water with regular interval of time to control the eutrophication hazard and there should be a continuous follow up of water quality characteristics.

Conflict of interest statement

I declare that I have no conflict of interest.

Acknowledgments

This work was done as a partial study under the title “Assessment of the physical, chemical and biological limnology of major water bodies in Amhara region”, which was registered in a code number 10/26/BD/2009 under a regular budget of Amhara Regional Agricultural Research Institute, Host Institute of Bahir Dar Fishery and Other Aquatic Life Research Center. I thank the officials and the research

center for the facilities and support to the work. I am also grateful to Mr. Goraw Goshu for his encouragement and guidance during the study and to Berhan Mohamed, Getenet Temesgen and Beniam Hailu for their enthusiastic help in data collection. Adane Melaku and Bezash Berbo are also acknowledged for helping in the identification of planktons in the laboratory.

References

- [1] Bhatnagar A, Devi P. Water quality guidelines for the management of pond fish culture. *Int J Environ Sci* 2013; **3**: 1980-2009.
- [2] Das P, Mandal SC, Bhagabati S, Akhtar MS, Singh SK. Important live food organisms and their role in aquaculture. In: Munilkumar S, editor. *Frontiers in aquaculture*. New Delhi: Narendra Publishing House; 2013, p. 69-86.
- [3] Gasse F. *East African diatoms: taxonomy, ecological distribution*. Oslo: Lubrecht & Cramer Ltd; 1986, p. 1-201.
- [4] Prescott GW. *How to know the freshwater algae*. Dubuque: C. Brown Publishers; 1975, p 1-211.
- [5] Lind TO. *Handbook of common methods in limnology*. 2nd ed. United States: Mosby; 1979, p. 199.
- [6] Fernando CH. *A guide to tropical freshwater zooplankton: identification, ecology and impact on fisheries*. Leiden: Backhuys Publishers; 2002, p. 1-291.
- [7] Korinek V. *A guide to limnetic species of Cladocera of African inland waters (Crustacea, Branchiopoda): using the morphology of parthenogenetic females*. Tuscaloosa: University of Alabama; 1999, p. 1-130.
- [8] Meme FK, Arimoro FO, Nwadukwe FO. Analyses of physical and chemical parameters in surface waters nearby a cement factory in North Central, Nigeria. *J Environ Prot* 2014; **5**: 826-34.
- [9] George B, Kumar JIN, Kumar RN. Study on the influence of hydro-chemical parameters on phytoplankton distribution along Tapi estuarine area of Gulf of Khambhat, India. *Egypt J Aquat Res* 2012; **38**: 157-70.
- [10] Buttner JK, Soderberg RW, Terlizzi DE. An introduction to water chemistry in freshwater aquaculture. Massachusetts: Northeastern Regional Aquacultural Center; 1993. [Online] Available from: http://www.extension.org/mediawiki/files/7773/Introduction_to_Water_Chemistry_for_Freshwater_Aquaculture.pdf [Accessed on 26th August, 2015]
- [11] Delincé G. The ecology of the fishpond and ecosystem. In: Dumont HJ, editor. *Development in hydrobiology*. London: Kluwer Academic Publishers; 2000, p. 20-52.
- [12] Baumann H, Wallace RB, Tagliaferri T, Gobler CJ. Large natural pH, CO₂ and O₂ fluctuations in a temperate tidal salt marsh on diel, seasonal, and interannual time scales. *Estuar Coasts* 2015; **38**: 220-13.
- [13] Muthulakshmi L, Arasu PT, Ilavarasi R, Selvanayagam S. Hydrochemical trend of ground water-Rajapalayam town, Tamil Nadu, India. *J Mater Environ Sci* 2015; **6**(4): 1004-8.
- [14] Hashim F, Narejo NT, Jalbani S, Jalbani YM. Studies on the feeding behavior of a carp, *Labeo gonius* (Hamilton) from Keenjhar Lake, District Thatta, Sindh, Pakistan. *Standard Sci Res Essays* 2014; **2**(9): 418-20.
- [15] Xiong J, Mei X, Liu J. Comparative studies on community structure, biodiversity of plankton and zoobenthos in four lakes of different trophic states in China. *Asian Fish Sci* 2003; **16**: 361-72.
- [16] Boit A, Gaedke U. Benchmarking successional progress in a quantitative food web. *PLoS One* 2014; doi: 10.1371/journal.pone.0090404.
- [17] Valerievna SM, Nikolaevich ZD, Georgievich KI. Using zooplankton indicators to assess the ecological condition of a lake. *Adv Mater Res* 2014; **955-9**: 1429-32.
- [18] Dejen E, Rutjes HA, de Graaf M, Nagelkerke LAJ, Osse JWM, Sibbing FA. The ‘small barbs’ *Barbus humilis* and *B. trispilopleura* of Lake Tana (Ethiopia): are they ecotypes of the same species? *Environ Biol Fish* 2002; **65**: 373-86.
- [19] Okogwu OI. Seasonal variations of species composition and abundance of zooplankton in Ehoma Lake, a floodplain lake in Nigeria. *Rev Biol Trop* 2010; **58**(1): 171-82.