FISH, PHYTOPLANKTON AND ZOOPLANKTON DIVERSITY RELATIONSHIPS WITH WATER QUALITY PARAMETERS OF GHODAGHODI LAKE, SUDURPASCHIM PROVINCE, NEPAL

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Submitted to:

Central Department of Zoology

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Tribhuvan University

Kirtipur, Kathmandu

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the authors and institutions.

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CERTIFICATE OF ACCEPTANCE

The thesis work submitted by **Melina DC** entitled **"Fish, phytoplankton and zooplankton diversity relationships with water quality parameters of Ghodaghodi Lake, Sudurpaschim Province, Nepal"** has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Fish Biology and Aquaculture.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of Abbreviations
μS/cm	Micro Siemen Per Centimeter
APHA	American Public Health Association
MDS	Maximum Desirable Unit
NTU	Nephelometric Turbidity Unit
ppm	Parts per million
pH	Hydrogen Ion Concentration
TDS	Total Dissolved Solids

ABSTRACT

The present study aims to find fish, phytoplankton and zooplankton diversity relationships with water quality parameters of Ghodaghodi Lake, Sudurpaschim Province, Nepal. Fish and plankton samples were collected together with water quality parameters from six sampling sites of the Ghodaghodi Lake from June 2019 to December 2019. The fish sampling was done by using bamboo fish trap, net, helka and dhadiya. Collection of plankton samples were made by conical-shaped monofilament nylon plankton net, with the help of local fisherwomen. In total, 510 individuals of fishes representing six Orders, Ten Families, and 12 Genera were collected. Anabantiformes emerged as the most species-rich order, accounting for 57.84% of the total species. A total of 118 individuals of zooplankton belonging to copepods, cladocerans and rotifers were enumerated during the present investigation. Copepods were the most dominating group, followed by cladocerans and rotifers and unidentified organisms. A total of 138 individuals of phytoplankton belonging to Chlorophyceae, Bacillariophyceae, Cyanophyceae and Zygnematophyceae were enumerated during the present investigation. The most leading group was Chlorophyceae followed by Cyanophyceae, Bacillariophyceae and group Zygnematophyceae. To detect the feasible relationships between fish, phytoplankton and zooplankton diversity with environmental variables a Canonical Correspondence Analysis (CCA) was executed. Based on similarity percentage (SIMPER) analysis, the major contributing species are *Puntius sophore* (27.69 %), *Channa punctata* (22.56%), *Trichogaster faciatus* (17.6%), *Nandus nandus* (6.99%), *Macrognathus pancalus* (6.164%), *Esomus danricus* (4.653%), *Lepidocephalichthys guntea* (3.469%), *Xenentodon cancila* (3.288 %), *Amblypharyngodon microlepis* (2.82%), *Notopterus notopterus* (2.419)% , *Heteropneustes fossilis* (1.222%), *Channa marulius* (0.7551%), and *Monopterus cuchia* (0.3761%). The CCA results revealed that the pH, temperature, electrical conductivity, Dissolved oxygen, transparency, turbidity and total dissolved solids are the main drivers to shape the fish community structure of Ghodaghodi Lake. CCA further reveals a significant correlation between fish assemblage and phytoplankton and zooplankton diversity.

1. INTRODUCTION

1.1 General Background

The Sudurpaschim Province has the maximum number of wetland areas in Nepal, especially in the lowland Terai region, i.e., Kanchanpur and Kailali districts. Some of the potential lakes in these two districts are Ramaroshan Lake Complex (complex stands for a cluster of lakes), Ghodaghodi Lake Complex, Jhokar Lake, Jhilmila Lake, Betkot Lake etc. (Pant et al. 2019). Earth's landscape has valuable lakes which are potential habitats to plants and animals, moderate biochemical cycle, changes microclimate, add the aesthetic beauty of the landscape and flourish many recreational potentialities to humankind (Bharti and Niyogi 2015).

Fish exhibit enormous biodiversity, inhabiting various environments and are important indicators of water quality (Hussain 2016) due to different geological and geographical features of the surrounding (Shaikh et al. 2011, Joshi et al. 2017). Fish assemblages in water bodies are an important element, used as bio-indicators to monitor the aquatic ecosystem (Karr 1981, Oberdorff et al. 2002, Nogueira et al. 2010, Yan et al. 2011). Many researchers have documented that fish assemblages in lakes show spatial and temporal variation because of environmental fluctuations and anthropogenic interferences (Gaudrear and Boisclair 1998, TejerinaGarro et al. 1998, Jackson et al. 2001, Ru et al. 2008, Menezes et al. 2013, Ru and Liu 2013). Much research has shown that measures influencing fish diversity involve the physicochemical surroundings, which are spatially variable and temporally different and biological interactions that includes competition and predation (Gorman 1988, Harvey and Stewart 1991, Grossman et al. 1998, Dauwalter et al. 2008).

It is well-known that the heterogeneity of fish species in the lake depends on several nonliving and living factors (Kadye et al. 2008). Predation factor was the main factor affecting fish populations with direct and indirect movements. Besides, the literature related to resource fractionalization among fishes suggests that competition plays a crucial role in communities' local organization. On the other hand, both systems' abiotic components can be divided into chemical and physical factors (Ross 1986, Jackson et al. 2001). The study by Dowling and Wiley (1998) mentions that dissolved oxygen is a baring factor for aquatic fauna and fish distribution. High temperatures may exhibit high physiological demands apart from reducing the dissolved oxygen levels in a water body indicating the necessity of oxygen and its association with water temperature (Jackson et al. 2001). Blaber and Blaber (1980) reported that turbidity is linked with productive feeding areas and provides cover for three fishes. Massive researches established that habitat variables, including water temperature (Kadye et al. 2008), depth and distance to source (Vlach et al. 2005), stream width (Gerhard et al. 2004), substrate (Vlach et al. 2005, Kadye et al. 2008), altitude (Magalhaes et al. 2002), conductivity (Yu and Lee 2002) and climate (Menni et al. 2005) are also known to shape the fish community and structure. Besides, spatial and seasonal variations of the fish community can also be determined by macrophyte cover in shallow lakes (Ye 2007).

However, the fish community's diversity and distribution can also be determined by the abundance and diversity of plankton. Their abundance and diversity greatly affect the biological as well as aquaculture system through balancing oxygen level in the water, ensuring the maintenance between O_2 and CO_2, enhancing the decomposition of degradable matters produced in the lake, preventing the growth of demersal microalgae and pests, stabilizing water temperature in the lake, regulating pH value and the ecosystem of the lake and also reducing the fluctuation of physio-chemical parameters (Das and Bhuyan 1974). Apart from primary production, phytoplanktons are food for herbivorous organisms (Meshram and Dhande 2000).While Zooplanktons is essential food items of omnivorous and planktivorous fishes and shellfish that have a significant relationship with their survival and growth, these are the bottom of food chains in almost aquatic ecosystems. Their major role in recycling nutrients and cycling energy within their respective surroundings is considerable (Alam et al. 1987). Also, the number, type, and distribution of plankton present in any aquatic habitat serve to determine the quality of a water body (Jakhar 2013).

Lakes are nearly related to human activity and have been altered due to urban and industrial development throughout the world (Scheffer et al. 2001, Qin et al. 2006). Continuous anthropogenic threats, like increased harvesting and poaching, habitat destruction, population pressure, forest fragmentation, siltation, fertilizer and pesticide seepage, water pollution, overgrazing, and unmanaged irrigation system found endangered the existing environmental resources (Lamsal et al. 2014). Globally, the foremost causes of wetland loss are urbanization, land-use changes, reckless irrigation, unscientific infrastructure development, industrial effluent, agricultural runoff and climate change inconsistency (Dudgeon et al. 2015, Jha 2008, Weber 1995). Since lakes are dynamic ecotones of nature are open to influence from natural and human perturbations, global attention is needed to conserve their healthy status.

1.2 Objectives of the study

1.2.1 General objectives

The main objective of the present study finds out fish, phytoplankton and zooplankton diversity relationships with water quality parameters of Ghodaghodi Lake, Sudurpaschim Province, Nepal.

1.2.2 Specific objectives

To find out the diversity of fish, phytoplankton and zooplankton species.

To analyze the water quality parameters of the study area.

To assess the fish-water quality relations, fish-phytoplankton relations and fish-zooplankton relations.

1.3 Significance of the study

The research on fish, phytoplankton and zooplankton diversity relationships is lacking in Ghodaghodi Lake of the Sudurpaschim Province. Therefore, the present study was initiated with the main objective to examine fish, phytoplankton and zooplankton diversity in relation to water quality parameters. For the sustainable management of the fish resources in the lake, the water quality of the lake, information regarding phytoplankton and zooplankton diversity and the types of fishes should be known. The present investigation aims to address these issues.

1.4 Research question

1. What is status of fish, phytoplankton and zooplankton of the Ghodaghodi Lake?

2. How are fish, phytoplankton and zooplankton diversity related?

1.5 Limitation of the study

Due to the world’s Pandemic COVID-19, data was collected for only two seasons.

2. LITERATURE REVIEW

2.1 Fish diversity and water quality parameters

The distribution of fish species was affected by both living and nonliving factors (Kadye et al. 2008). Biotic factor such as predation and competition plays an important role in the local organization of communities. On the other hand, water temperature and oxygen are significant parameters that restrict survival, growth, and fish distribution (Akbulut 2009). There is a huge effect of water quality parameters on the fertility and development of aquatic organisms. Non-optimum water quality parameters can cause stress to fish and make them more susceptible to disease outbreaks (Boyd and Tucker 1998, Zamir-Saad 2014). An earlier study by Dowling and Wiley (1998) mentioned that dissolved oxygen is the most significant factor regulating the organism's metabolic processes. Extreme temperatures may exhibit high physiological demands apart from reducing the dissolved oxygen levels in a water body (Jackson et al. 2001). Blaber and Blaber (1980) reported that turbidity is linked with productive feeding areas and provides cover for fishes.

pH has a major role in water bodies to determine the speciation of inorganic chemicals and influence living system. Generally, a pH value of 6.5 to 8.5 is suitable for the growth and development of aquatic fauna. Due to changes in photosynthesis and other chemical reactions the pH may vary with depth in a lake (Panta et al. 2019). The decreasing of pH in monsoon may be due to higher runoff from the adjacent catchment area, which has slightly acidic soil (Biswas and Phukon 1989). Although the tolerance of individual species varies, pH values between 6.5 and 8.5 usually indicate good water quality and this range is typical of most major drainage basins of the world (Carr and Neary 2008).

In a freshwater ecosystem, dissolved solids are necessary components as they maintain the vitality of the organisms that rely on this ecosystem. The dissolved solids are, in fact, more diverse in nature, and apart from their natural sources of its input, sewage becomes the most important source (Sharma et al. 1978). The quantity, quality, intensity and duration of light influence the life of organisms in different ways (Devi et al. 2005). Transparency or light penetration was found to fluctuate according to season. An inverse relationship between transparency and suspended sediment load was observed. A similar observation was also made by (Timms and Midgley 1970). Baltz et al. (1987) studied fish community structures and diversity depends on certain variables like depth, velocity of water, water temperature, substrate and physiochemical parameters. Ichthyofaunal diversity is positively related to water depth than water salinity, temperature and turbidity in aquatic bodies (Paterson and Whitfield 2000).

Electrical conductivity is a measurement of ionic strength, and it depends on the presence of ions, their concentrations, mobility and temperature. The temperature in the lake waters has a significant proportional relation with the EC values as if the EC values of water increase by 2-3%, which resulted in an increase of 1℃ lake water temperature. Similarly, the TDS is also a good indicator of EC concentrations, as it increases with increasing TDS in the lakes (Panta et al. 2019).

2.2 Fish and phytoplankton diversity relationships

The relationship between species richness and productivity is pivotal to understanding biodiversity in lakes. Phytoplankton plays a vital role in fish production since it is a primary producer of the freshwater ecosystem. Species composition and density of phytoplankton determine the density and diversity of zooplankton and finally affect fish production (Schroeder 1987). Komarkova (1998) detected a direct pattern where phytoplankton is mainly consumed directly by herbivorous or omnivorous fish; and another indirect pattern where phytoplankton is consumed by zooplankton, which is regulated by the fish stock. The release of nutrients from fecal pellets due to the feeding activity of fish in shallow waters provides further feedbacks to the enhancement of phytoplankton growth. Eutrophication of the pond water creates blooms of phytoplankton. The decomposition of this overgrown phytoplankton leads to the depletion of DO hike in BOD, thereby resulting in negative impacts on fish biomass (Hosetti and Kumar 2002). However, the richness–productivity relationship for phytoplankton and fish was strongly dependent on the lake area (Dodson et al. 2020).

2.3 Fish and zooplankton diversity relationships

Zooplankton feeds on phytoplankton and is directly related to the growth of fish. Zooplanktons are an essential food item of omnivorous and planktivorous fishes

(Alam et al. 1987) in a freshwater ecosystem. The zooplankton contributes about 32% of the food item of *Notopterus notopterus* (Mustafa and Ahmed 1979), 47% of the *Catla catla*, 6.37% of the *Labeo rohita* (Menon et al. 1981), and 23% of the food item of shrimp (Alam et al. 1987). The juveniles of some of these fishes are obligate zooplanktivores (Mwebaza-Ndawula 1994) and depend solely on zooplankton for their survival. Zooplankton, especially copepods, served as a major food for the fish than other zooplankton and animal larvae.

The fish production can be increased by plankton growth and they also act as a biomarker for water quality assessment for fish production (Pradhan 2008). Zooplankton plays an important role in the trophodynamics of aquatic ecosystems as the primary mediator of energy that transfers from primary producer to higher trophic levels, including fishes (Jin et al. 2010, Vinas et al. 2013). Zooplankton abundance is also affected by the transport of organisms from source areas to the lake and the reproduction and growth of organisms (Hynes 1970, Kapoor 2015).

A considerable amount of research works was conducted in Lake Ghodaghodi, such as by Kafle (2007), Diwakar (2009), Lamsal et al. (2014), Joshi and K.C. (2017), and Bhatta et al. (2018). However, literature on fish diversity concerning phytoplankton and zooplankton diversity is lacking. Therefore, this study is aimed to study the diversity of fish in relation to water quality parameters and fish, phytoplankton and zooplankton diversity relationship.

3. MATERIALS AND METHODS

3.1 Study area and sampling locations

The study was conducted in Ghodaghodi Lake, a Ramsar Site, in the Kailali District of western Nepal. It is the largest inter-connected natural shallow lake system, with finger-like projections, with associated marshes and meadows surrounded by tropical deciduous forest on the Siwalik range's lower slopes. It covers 2,563 ha (6,330 acres) at an altitude of 205 m (673 ft) with 28°41'03" latitude and 80°56'43" longitude on the lower slopes of the Siwalik Hills. It is characterized by various wetlands, including several rivers and their floodplains, ox-bow lakes, swamps, marshes, reservoirs, ponds, water storage areas and paddy fields. The lake is fed by direct precipitation during the monsoon season and by surface flows from the watershed area, ground water springs and small streams.

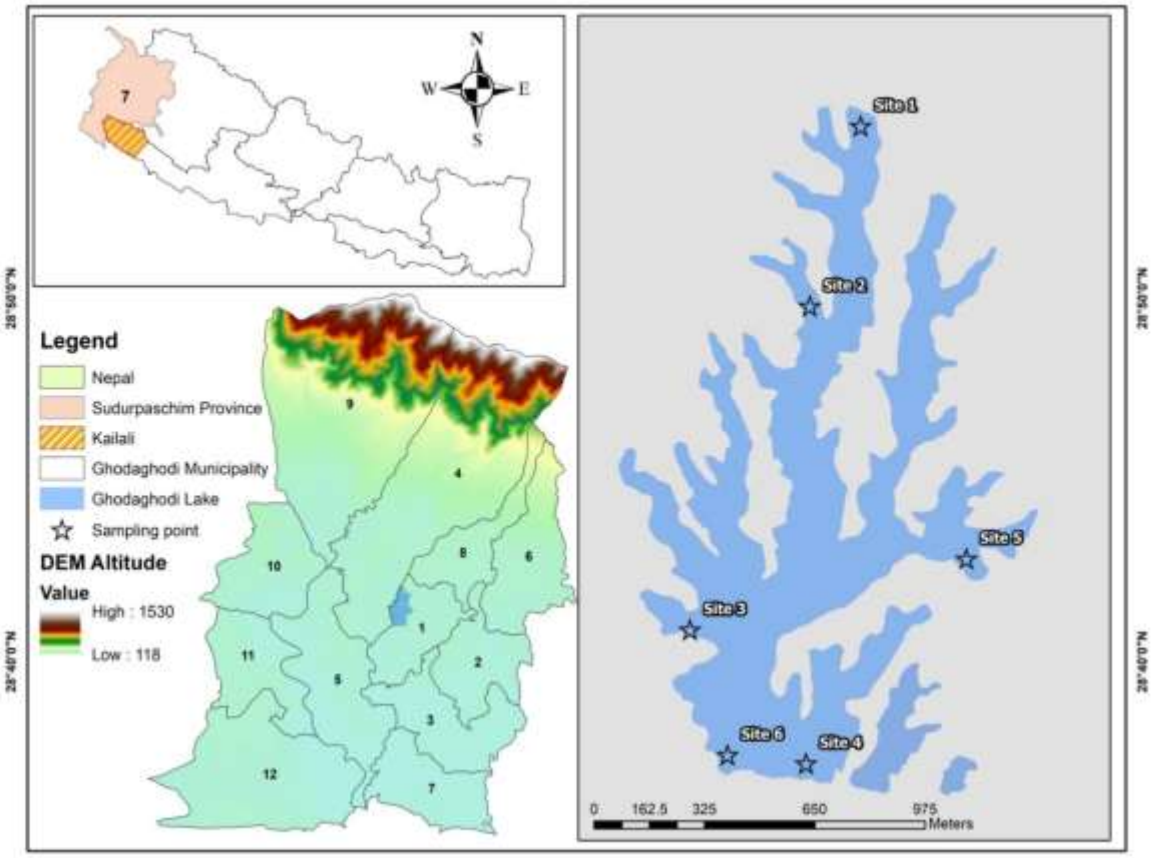

Figure 1: Map of the study area (Ghodaghodi Lake)

The study area was divided into six sampling sites based on different features such as human intervention, cattle grazing, settlement area, religious spot, disturbed and undisturbed area, etc.

Site I: 28 º41´19.9´´N 080º56´50.5´´E It is near the old view tower that is dense forest area.

Site II: 28 º41´29.6´´N 80º56´36.9´´ E It is a portion of the lake consisting of shallow water.

Site III: 28 º41´13.1 ´´N 80º56´45.7´´E It is below Temple where Indigenous Tharu people celebrate a traditional festival Agan Panchami during December worshipping, offering animals and taking holy bath in the lake.

Site IV: 28 º41´01.0´´N 080º56´47.4 ´´E It is an outlet human influence area along the Mahendra high way.

Site V: 28 º41´06.4´´N 80º56´53.7´´E It is just opposite of crocodile breeding area.

Site VI: 28 º41´81.6´´N 80º56´02.5´´E It is the outlet between two statues of horses from where water is passed for irrigation to nearby villages.

3.2 Analysis of water quality parameters

Water quality parameters were measured by using digital probes such as:

3.2.1 Water pH:

calibrated pH meter (HI 98107, HANNA Instrument).

3.2.2 Temperature:

Temperature was measured in (temperature, ^{o}C).

3.2.3 Dissolve oxygen:

DO meter (DO, mg/L). DO meter was put on, the reading zeroed and then the electrode dipped into the water sample and the reading taken.

3.2.4 Transparency:

Transparency of the water was measured with Secchi Disc and recorded in centimeters. For taking the transparency of water in different places of lake, the secchi disc was dipped in water and the depth was noted at which it just disappeared.

3.2.5 Electrical conductivity:

Conductivity was recorded by a conductivity meter (EC, µS/cm), adjusting the reading portion and dipping the meter into the water sample and approximate reading taken.

3.2.6 Total dissolved solids:

Total dissolved solid (ppm) was measured by TDS meter.

3.2.7 Turbidity:

Turbidity (NTU) was recorded by a Turbidity meter.

3. 3 Fish sampling

Fishes were collected from Ghodaghodi Lake in the morning (8:00 am to 11:00 am) from June to December 2019. Local fishermen were hired for fish sampling. From sampling site, fish samples were collected by using bamboo fish trap, net, helka and dhadiya (Plate VIII). The net used for fish captured was 2kg in weight and having 3m in length and 20m breadth with 10mm mesh size. The collection was done for 3 hours. Fishes were kept in transparent plastic and the length and weight of the fishes were measured in cm and grams, respectively. After taking all measurements, some specimens were preserved in 10% formalin and deposited to the Central Department of Zoology laboratory for further study. The colour, size of fish and morphometric characters were also noted in the field. Fishes were photographed by using Redmi Y1 of MDI6S model. In the laboratory, samples were sorted and identified to species level by using pertinent literature such as Talwar and Jhingram (1991), Jayaram (2010), Shrestha (2019). Some of the information was also taken from the websites dedicated to fish information (e.g., fishbase.org).

3.4 Plankton sampling

Collection of plankton samples were made by conical-shaped monofilament nylon plankton net of 90 µm mesh net size from approximately 10 - 12 cm depth, and the collected samples from six different sites were transferred to one litre capacity plastic bottles and immediately preserved in 5 % formaldehyde-labeled and then transferred to the Central Department of Zoology laboratory at Tribhuvan University for further analysis (Plate VIII). The abundance of plankton was estimated by counting their presence per focus of the microscopic field under 10 and 40. Each sample was stirred smoothly just before microscopic examination for qualitative analysis. 10 ml of water from each site was observed under a microscope in the laboratory, making five slides for each one ml. Plankton was identified by using the standard keys following APHA (1998).

3.5 Data analysis

To visualize the major contributing species to space and time, similarity percentage (SIMPER) (Clarke, 1993) analysis was performed. Samples by species, sites, seasons and environmental variables were analyzed through a multivariate analysis tool. I then performed a detrended correspondence analysis (DCA) (Hill & Gauch, 1980) to determine whether redundancy analysis (RDA) or canonical correspondence analysis (CCA) would be the most appropriate model to describe the association between species abundance, sites, months, years and environmental variables. The axis length (≥ 2.5) and eigenvalue (≥ 0.5) acquired from DCA suggested that the linear model of Canonical Correspondence Analysis (CCA) was more applicable. Therefore, a direct multivariate ordination method based on a linear response of species to environmental gradients (Ter Break, 1986) was applied by using the vegan library in “R” (Oksanen et al. 2019).

4. RESULTS

4.1 Water quality parameters of the study area

Water quality parameters like temperature, pH, electrical conductivity, dissolved oxygen, transparency, total dissolve solids and turbidity of the study area were measured (Appendix 1, Table 1).

4.1.1 Water temperature

The highest value was observed in site V during June 2019 (35.4°C) and lowest in site I during December 2019 (17.9°C) (Figure 2). The mean water temperature was highest in June (31.7°C ± 2.28°C) than in winter (19.75 ± 1.60°C).

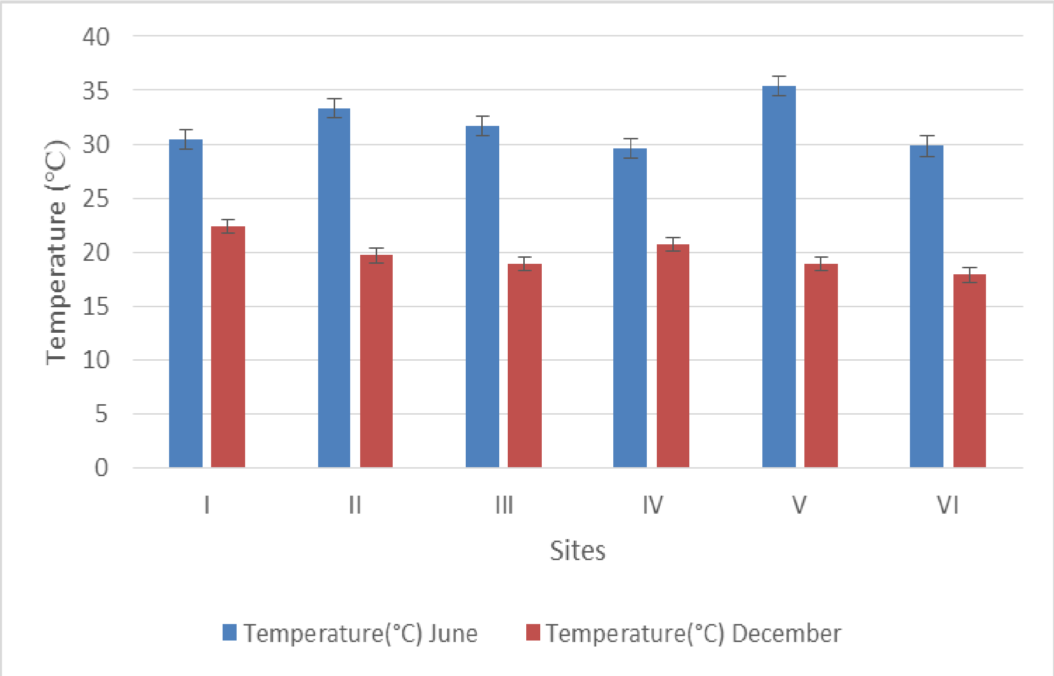

Figure 2: Temperature value (°C) in lake water for June and December

4.1.2 Hydrogen ion concentration (pH)

The highest value was observed in site III during June 2019 (9.48), and the lowest was in site I during December 2019 (7.21) (Figure 3). The mean pH value was highest in June (8.56 ± 0.55) than in December (7.65 ± 0.71).

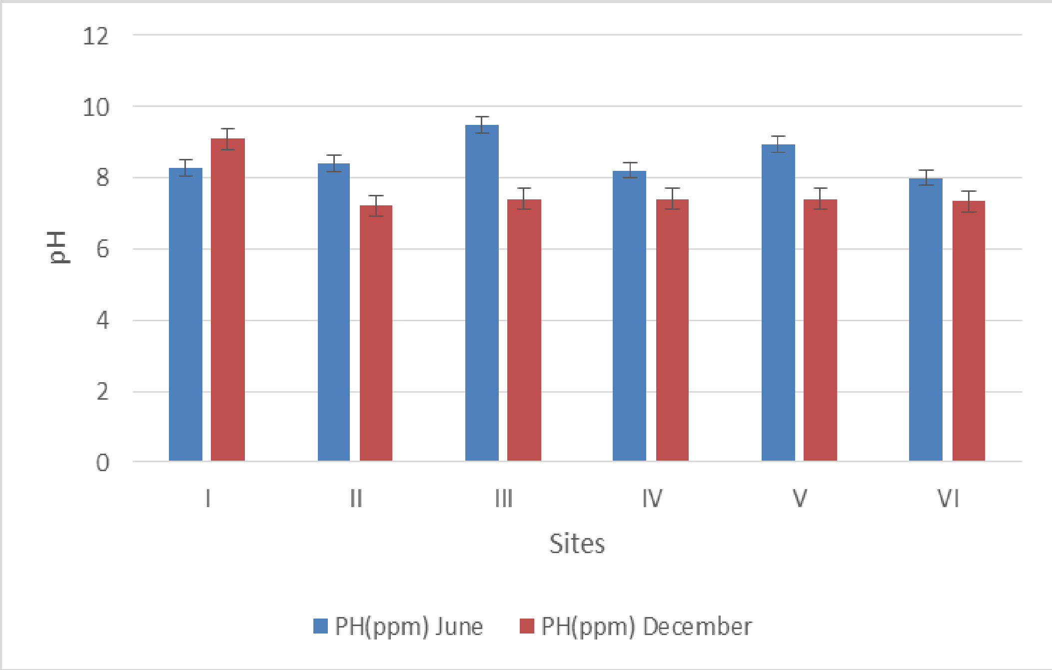

Figure 3: pH value in lake water for June and December

4.1.3 Electrical conductivity (EC)

The highest value was obtained in site II in the June (164 µS/cm) and the lowest in the December in the same site (122 µS/cm) (Figure 4). The average value of electrical conductivity (EC) was higher in June (151.17 ± 12.77 µS/cm) than in December (134.15± 7.01 µS/cm).

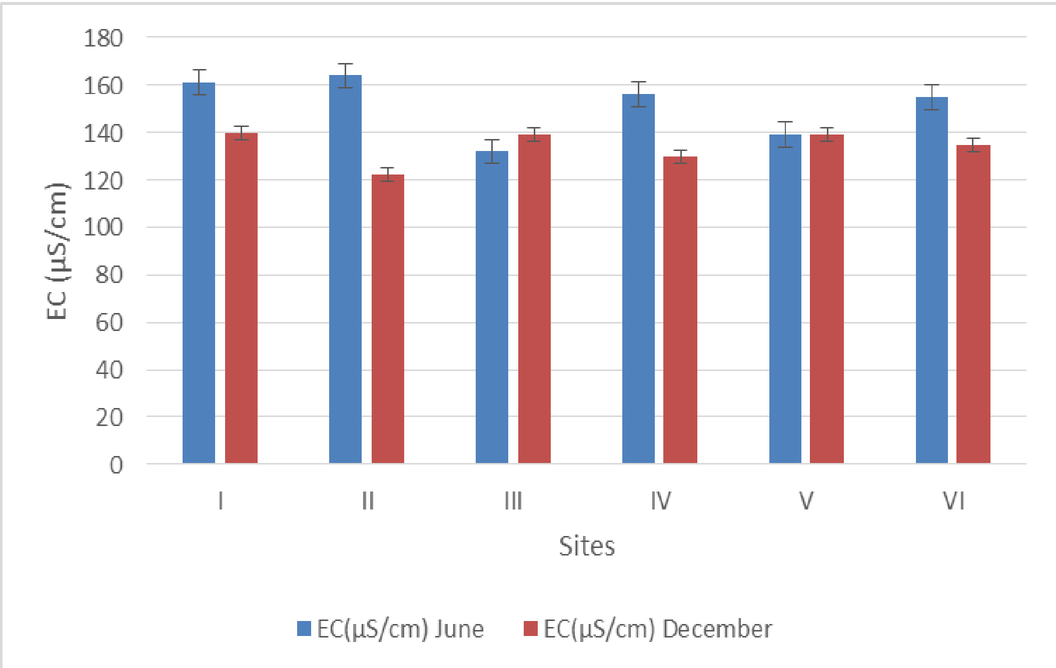

Figure 4: EC value (µS/cm) in lake water in June and December

4.1.4 Dissolved oxygen (DO)

The highest DO value was obtained in site I in December (9.4 mg/L) and lowest in VI (4 mg/L) in the June (Figure 5). The Dissolved oxygen value was higher in the December (7.17 ± 1.76 mg/L) than June (5.27 ± 1.55 mg/L).

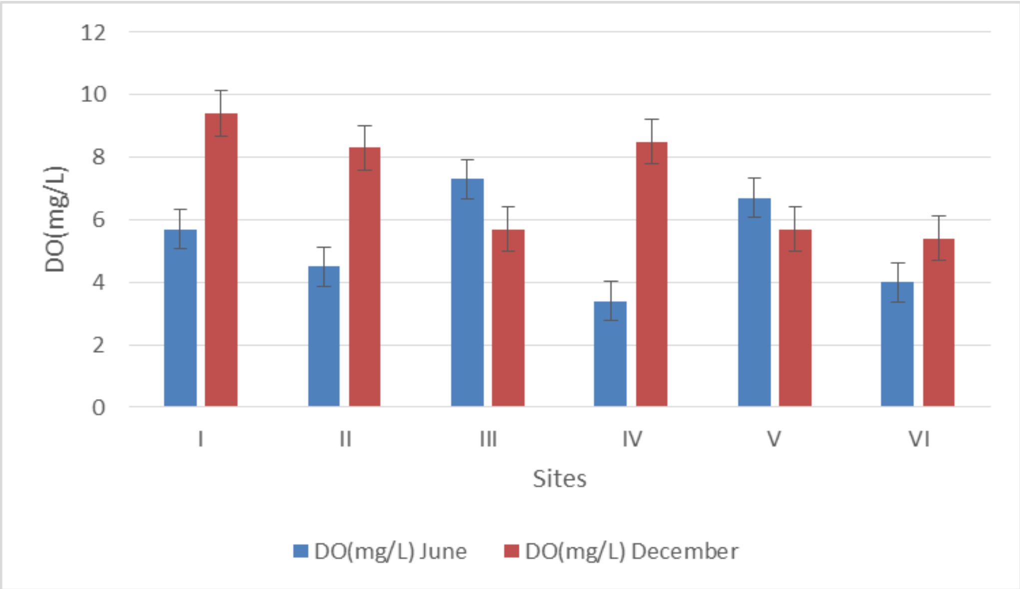

Figure 5: DO value (mg/L)) in lake water in June and December

4.1.5 Secchi Disc transparency (SD)

The highest value was obtained in site III in June (69 cm) and lowest in Sites II and VI (13 cm) in the same season (Figure 6). The mean Secchi disc transparency value was higher in June 2019 (32.4 ± 20.53cm) than in December 2019 (27 ± 8.52cm).

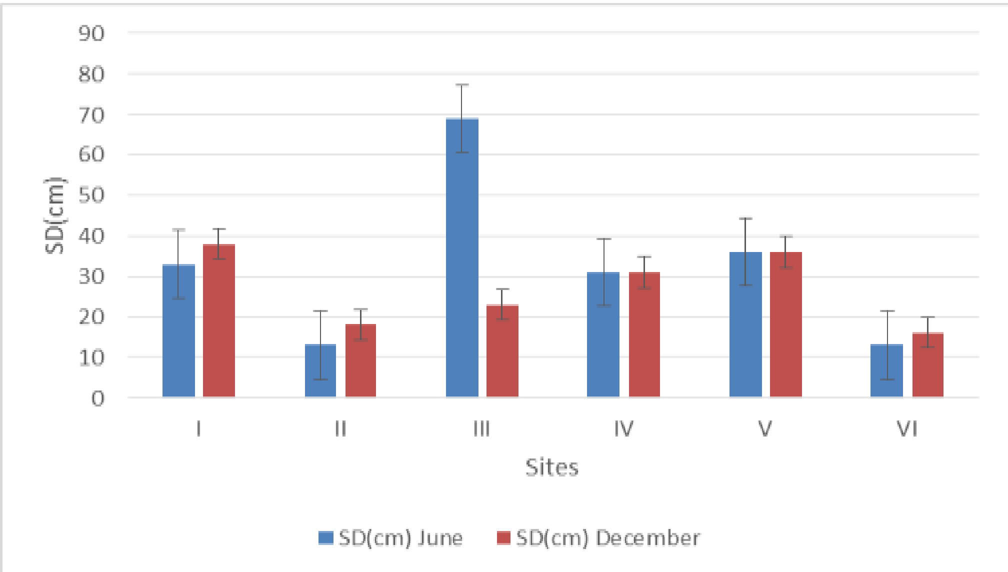

Figure 6: Sechi Disc transparency value (cm) in lake water in June and December

4.1.6 Total dissolved solids (TDS)

The highest TDS value was recorded in site II in June (80 ppm) and lowest in same site (60 ppm) in December (Figure 7). The Total dissolve solids value was higher in June (72.33 ± 5.54 ppm) than December (69.1 ± 6.55 ppm).

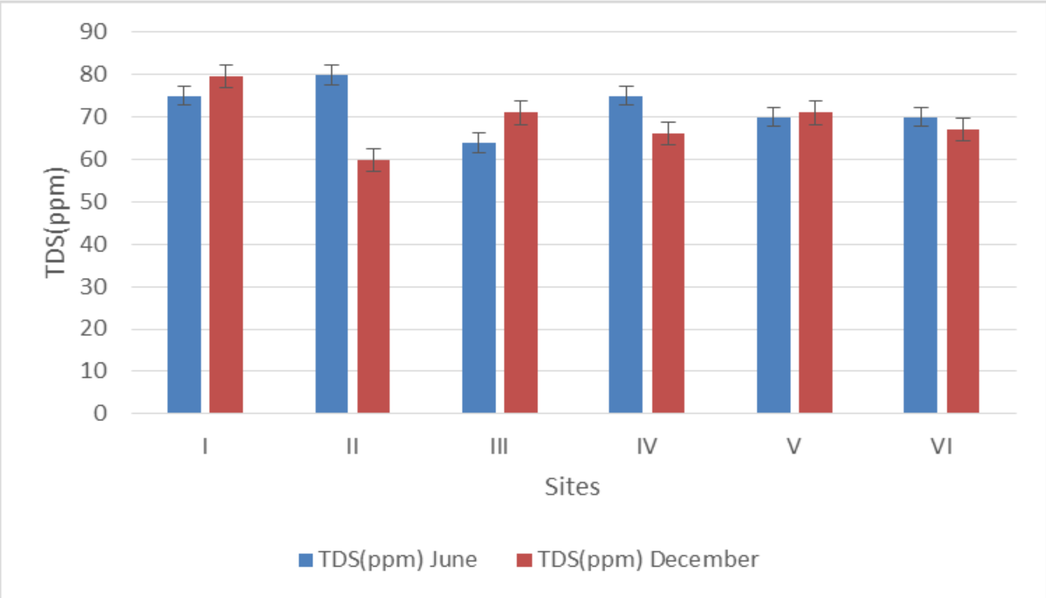

Figure 7: TDS value (ppm) in lake water in June and December

4.1.7 Turbidity

The highest turbidity value was recorded in site III in the June (4.17 NTU) and lowest in the site V (1.21 NTU) in the December (Figure 8). The turbidity value was higher in June (2.95 ± 0.99 NTU) than in December (2.29 ± 0.74 NTU).

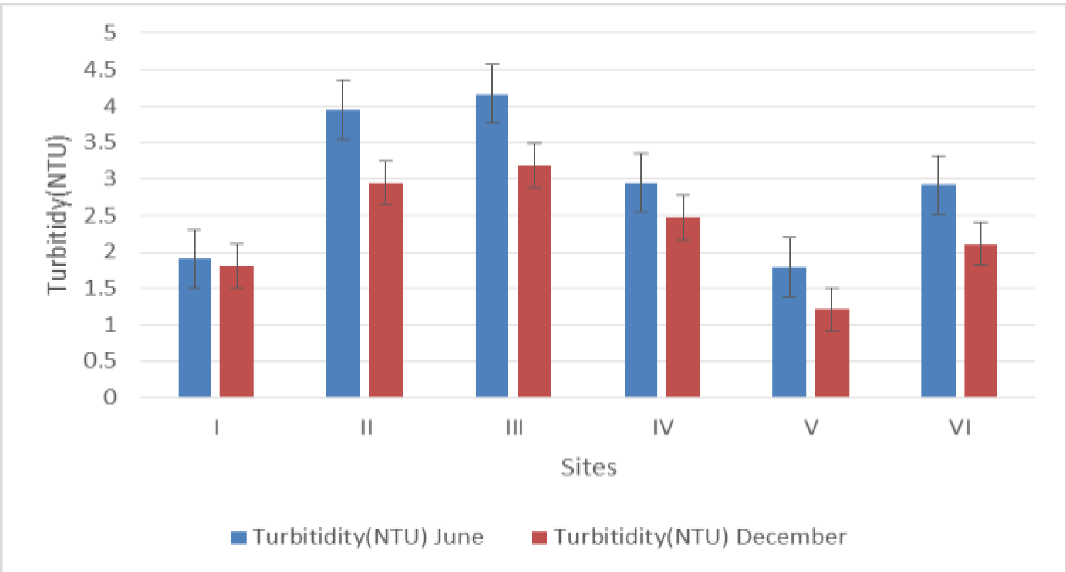

Figure 8: Turbidity (NTU) value in lake water in June and December

4.2 Fish diversity

A total of 510 individuals were enumerated which comprises 13 species of fishes belonging to six orders (i.e., Anabantiformes, Cypriniformes, Osteoglossiformes, Beloniformes, Synbranchiformes, Siluriformes (Plate I, Plate II) , ten families (i.e., Channidae, Osphronemidae, Nandidae, Cyprinidae, Cobitidae, Notopteridae, Belonidae, Mastacembelidae, Synbranchidae, Heteropneustidae), and twelve genera (i.e., *Channa*, *Trichogaster*, *Nandus*, *Esomus*, *Puntius*, *Amblypharyngodon*, *Lepidocephalichthys*, *Notopterus*, *Xenentodon*, *Macrognathus*, *Monopterus*, and *Heteropneustes* (Table 1).The maximum number was counted for *Puntius sophore* (146 individuals) and the minimum for *Monopterus cuchia*, which are 28.63% and 0.20% catch composition of total individuals, respectively. The maximum number (136 individuals) was counted in site II with 8 species throughout the study period. The lowest number (34 individuals) was found in site I with six species. A marked difference was evident between fish assemblages at the different sampling points during the study. A higher number of individuals were recorded in December.

Table 1: Fish species abundance and distribution.

Species	**Code**	**Total**	**%**	**I**	**II**	**III**	**IV**	**V**	**VI**	**Jun**	**Dec**
Channa punctata (Bloch, 1793)	chan_pun	127	24.90	6	48	17	23	22	11	81	46
Channa marulius (Hamilton-Buchanan, 1822)	chan_mar	2	0.39	0	0	1	1	0	0	0	2
Trichogaster faciatus **(**Bloch and Schneider, 1801**)**	tric_fac	144	28.24	13	40	31	25	21	14	61	83
Nandus nandus (Hamilton-Buchanan, 1822)	nand_nan	22	4.31	2	0	3	12	5	0	13	9
Esomus danricus (Hamilton-Buchanan, 1822)	esom_dan	14	2.75	5	1	2	0	0	6	8	6
Puntius sophore (Hamilton-Buchanan, 1822)	punt_sop	146	28.63	6	38	25	19	13	45	49	97

Amblypharyngodon microlepis (Bleeker, 1853)	ambl_mic	11	2.16	2	2	3	0	4	0	11	0
Lepidocephalichthys guntea (Hamilton-Buchanan, 1822)	lepi_gun	7	1.37	0	0	0	0	7	0	7	0
Notopterus notopterus (Pallas, 1769)	noto_not	6	1.18	0	0	0	4	2	0	1	5
Xenentodon cancila (Hamilton-Buchanan, 1822)	xene_can	8	1.57	0	0	2	6	0	0	2	6
Macrognathus pancalus (Hamilton-Buchanan, 1822)	macr_pan	19	3.73	0	5	1	10	3	0	9	10
Monopterus cuchia (Hamilton-Buchanan, 1822)	mono_cuc	1	0.20	0	1	0	0	0	0	0	1
Heteropneustes fossilis (Bloch,1794)	hete_fos	3	0.59	0	1	0	0	2	0	0	3
TOTAL		**510**	**100**	**34**	**136**	**85**	**100**	**79**	**76**	**242**	**268**

4.2.1 Order wise fish diversity

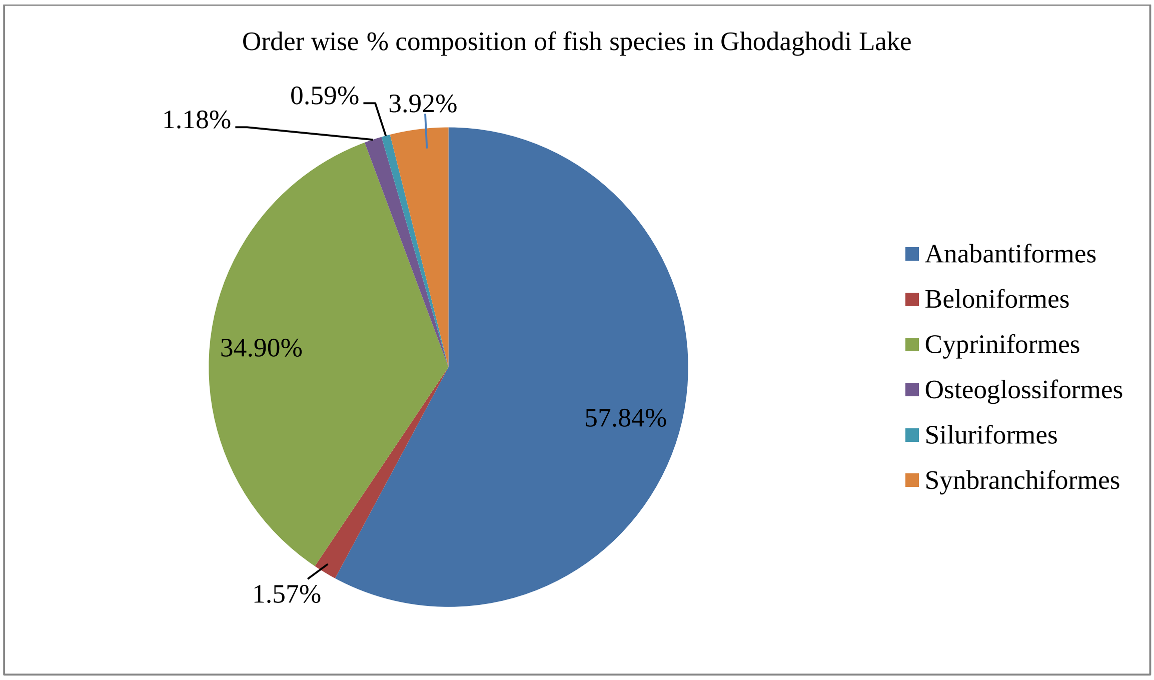

Figure 9: Order wise percentage composition of fish species in Ghodaghodi Lake

4.2.2 Family wise fish diversity

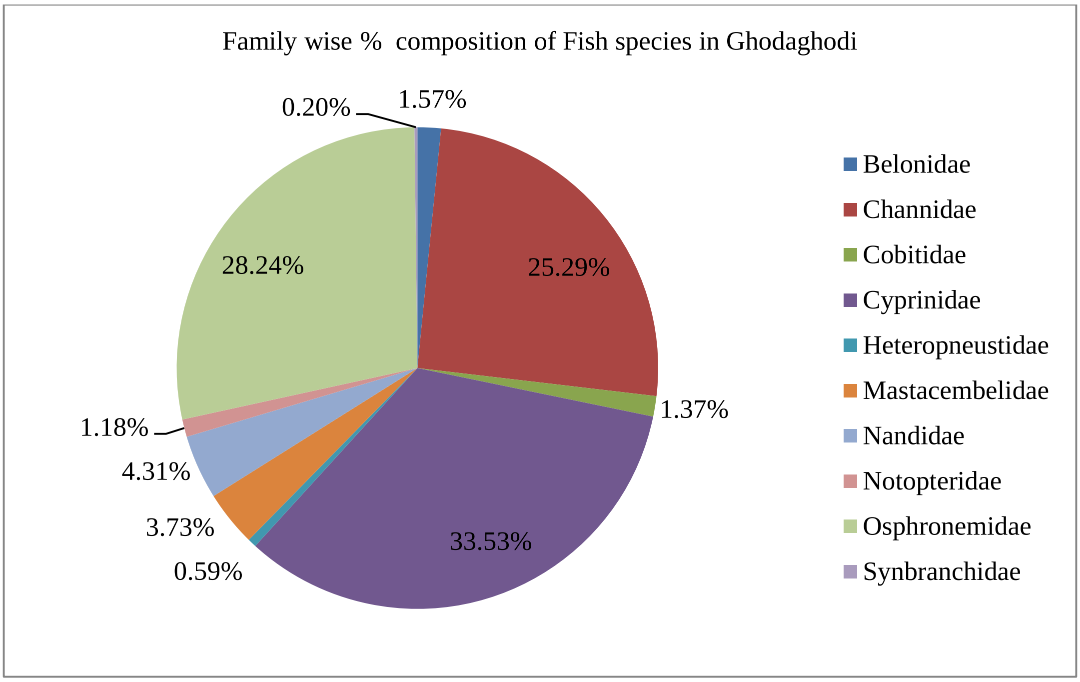

Figure 10: Family wise percentage composition of fish species in Ghodaghodi Lake

4.2.3 Correlation between the water quality parameters and fish species diversity

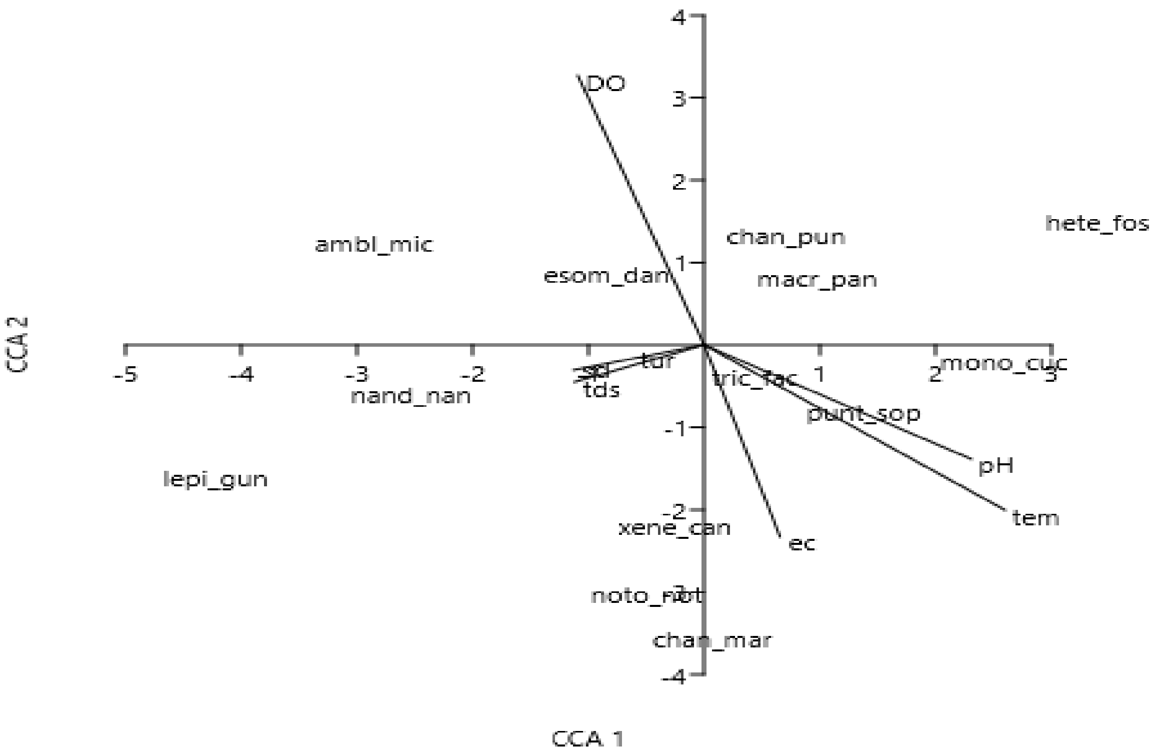

Figure 11: CCA of fish assemblages with water quality parameters.

The result obtained from canonical correspondence analysis (CCA) was plotted in Figure 14. Electrical conductivity (ec), Temperature (tem) and pH were significantly correlated and strongly negatively correlated with DO. *Trichogaster faciatus, Puntius sophore,* and *Monopterus cuchia* show a positive correlation with pH, Temperature (tem), and electrical conductivity (ec) at the first axis CCA1.The physicochemical parameters like transparency (sd), turbidity (tur) and total dissolved solids (tds) at the first axis describe significant relation with *Channa marulius, Notopterus notopterus, Xenentodon cancila, Lepidocephalichthys guntea,* and *Nandus nandus.* The fish species of *Amblypharyngodon microlepis and Esomus danricus* preferred positively correlated values of dissolved oxygen. Although all recorded fish species show significant relation with water quality parameters, in this CCA ordination plot, only three fish species *Channa punctata, Macrognathus pancalus* and *Heteropneustes fossilis,* do not show correlation with water quality parameters in this study.

4.2.4 Similarity percentage analysis (SIMPER)

Table 2: Similarity percentage analysis (SIMPER)

Taxon	**Av. dissim**	**Contrib. %**	**Cumulative %**	**Mean Site I**	**Mean Site II**	**Mean Site III**	**Mean Site IV**	**Mean Site V**	**Mean Site VI**
punt_sop	11.78	27.69	27.69	6	38	25	19	13	45
chan_pun	9.6	22.56	50.24	6	48	17	23	22	11
tric_fac	7.492	17.6	67.85	13	40	31	25	21	14
nand_nan	2.975	6.99	74.84	2	0	3	12	5	0
macr_pan	2.623	6.164	81	0	5	1	10	3	0

esom_dan	1.98	4.653	85.65	5	1	2	0	0	6
lepi_gun	1.476	3.469	89.12	0	0	0	0	7	0
xene_can	1.399	3.288	92.41	0	0	2	6	0	0
ambl_mic	1.2	2.82	95.23	2	2	3	0	4	0
noto_not	1.029	2.419	97.65	0	0	0	4	2	0
hete_fos	0.5199	1.222	98.87	0	1	0	0	2	0
chan_mar	0.3214	0.7551	99.62	0	0	1	1	0	0
mono_cuc	0.1601	0.3761	100	0	1	0	0	0	0

According to Similarity percentage (SIMPER) analysis (Table 2), major contributing species are *Puntius sophore* (27.69 %), Channa *puntata* (22.56%), *Trichogaster faciatus* (17.6%), *Nandus nandus* (6.99%), *Macrognathus pancalus* (6.164%), *Esomus dancrius* (4.653%), *Lepidocephalichthys guneta* (3.469%), *Xenentodon cancila* (3.288 %), *Amblypharyngodon* microlepis (2.82%), *Notopterus notopterus* (2.419)% , *Heteropneustes fossilis* (1.222%), *Channa marulius* (0.7551%), and *Monopterus cuchia* (0.3761%).

4.3 Plankton diversity

4.3.1 Phytoplankton abundance and distribution

A total of 138 individuals were enumerated, comprising 12 Genera of phytoplankton belonging to four groups (i.e., Chlorophyceae, Bacillariophyceae, Cyanophyceae and Zygnematophyceae (Plate III, Plate IV). The maximum number was counted for *Spirogyra* sp (50 individuals) and minimum for *Lamanea* sp (1 individual), 36.23% and 0.7% percentage composition of total individuals, respectively. The maximum number (25 individuals) were counted in site II, and the lowest number, 22 individuals, were found in site III, V and VI. Maximum individuals were recorded in December (Table 3).

Table 3: Phytoplankton abundance and distribution in Ghodaghodi Lake

S. N	Group	Genus	Total	%	I	II	III	IV	V	VI	Jun	Dec
1	Chlorophyceae	*Spirogyra* sp	50	36.23	10	9	5	9	7	10	20	30
2		*Selenastrum* sp	4	2.9	3		1				1	3
3		*Ankistrodesmus* sp	12	8.8	2		5	2		3	5	7
4		*Closterium* sp	8	5.7	1	3	2			2		8
5		*Elakatothrix* sp	3	2.2				1	1	1		3
6		*Lamanea* sp	1	0.7				1				1
7		*Schizomeris* sp	18	13.1	2	3	3	3	4	3	11	7
8	Bacillariophyceae	*Melosira* sp	7	5.1				4	3			7
9	Cyanophyceae	*Microcystis* sp	7	5.1		5	2				2	5
10		*Oscillatoria* sp	11	8.1	2	5		2	2		8	3
11		*Gloeotrichia* sp	7	5.1	2		1		2	2	2	5
12	Zygnematophyceae	*Zygnema* sp	10	7.3	1		3	2	3	1	4	6
	Total		**138**	**100**	**23**	**25**	**22**	**24**	**22**	**22**	**53**	**85**

4.3.2 Group-wise phytoplankton abundance and distribution

The most dominating group was Chlorophyceae (96 individuals), consists of *Spirogyra* sp, *Selenastrum* sp, *Ankistrodesmus* sp, *Closterium* sp, *Elakatothrix* sp, *Lamanea* sp, and *Schizomeris* sp followed by Cyanophyceae (25 individuals) comprises of *Microcystis* sp, *Oscillatoria* sp, *Gloeotrichia* sp, Zygnematophyceae (10 individuals) consist of *Zygnema* sp, and group Bacillariophyceae (7 individuals) consists of *Melosira* sp (Figure 15).

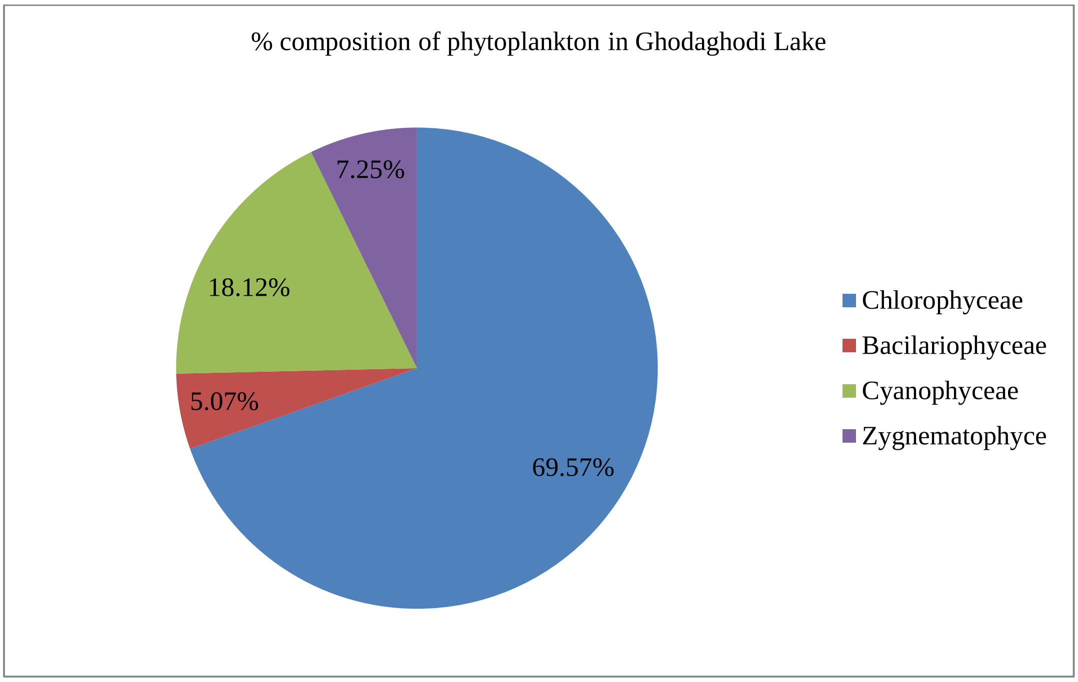

Figure 12: Percentage composition of phytoplankton in Ghodaghodi Lake

4.3.3 Zooplankton abundance and distribution

A total of 118 individuals were enumerated during the present investigation, which comprises 15 Genera of zooplankton belonging to Cladocera (i.e., *Daphnia* sp, *Bosmina* sp, *Alona* sp, and crustacean larvae), copepods (i.e., *Mesocyclops* sp, *Trichocera* sp, *Diaptomus* sp) and rotifers (i.e., *Synchaeta* sp, and *Brachinus* sp) and others unidentified (Un-a, Un-b, Un-c, Un-d, Un-e, Un-f (Plate V, Plate VI). The maximum number was counted for *Mesocyclops* sp (40 individuals) and minimum for six different unidentified organisms, which are 33.90% and 0.85% percentage composition of total individuals, respectively (Table 4). The maximum numbers (28 individuals) were counted in site I and the lowest number (13 individuals) were found in site II. Maximum individuals were recorded in December.

Table 4: Zooplankton abundance and distribution in Ghodaghodi Lake

S.N.	Group	Genus	Total	%	I	II	III	IV	V	VI	Jun	Dec
1	Cladocera	*Daphnia* sp	29	24.58	4	5	6	6	4	4	14	15
2		*Bosmina* sp	8	6.78	2		3		3			8
3		*Alona* sp	2	1.69						2		2
4		*Crustacean larvae*	10	8.47	4	1	3	2			4	6
5	Copepods	*Mesocyclops* sp	40	33.90	9	5	5	7	5	9	22	18
6		*Trichocera* sp	5	4.24	2			2		1		5
7		*Diaptomus* sp	7	5.93	5		1		1		6	1
8	Rotifera	*Brachinus* sp	4	3.39				2	1	1	4	
9		*Synchaeta* sp	7	5.93		1		1	4	1	4	3
10	Unidentified	Un-a	1	0.85	1						1	
11		Un-b	1	0.85		1						1
12		Un-c	1	0.85				1				1
13		Un-d	1	0.85				1				1
14		Un-e	1	0.85					1			1
15		Un-f	1	0.85	1							1
		Total	**118**	**100**	**28**	**13**	**18**	**22**	**19**	**18**	**55**	**63**

Un- unidentified species

4.3.4 Group-wise zooplankton abundance and distribution

In the present study, Copepods population (44.07%) was most abundant, followed by Cladocera (41.53%), Rotifers (9.32%) and unidentified (5.08%) (Figure 16) .

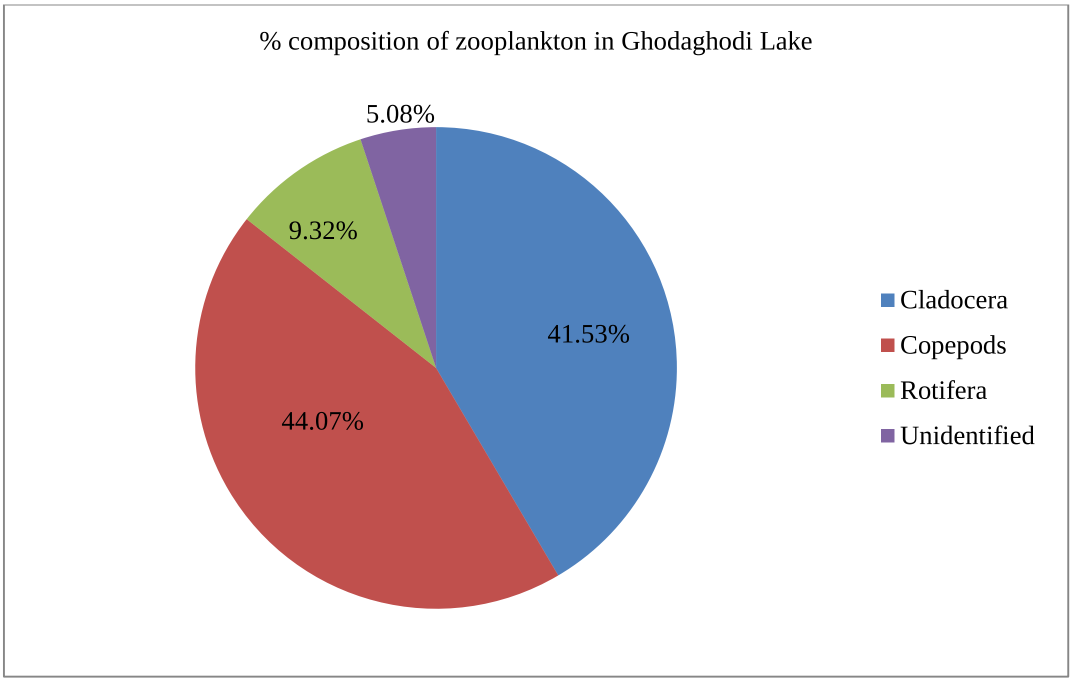

Figure 13: Percentage composition of zooplankton in Ghodaghodi Lake

4.4 CCA of fish community structure with phytoplankton

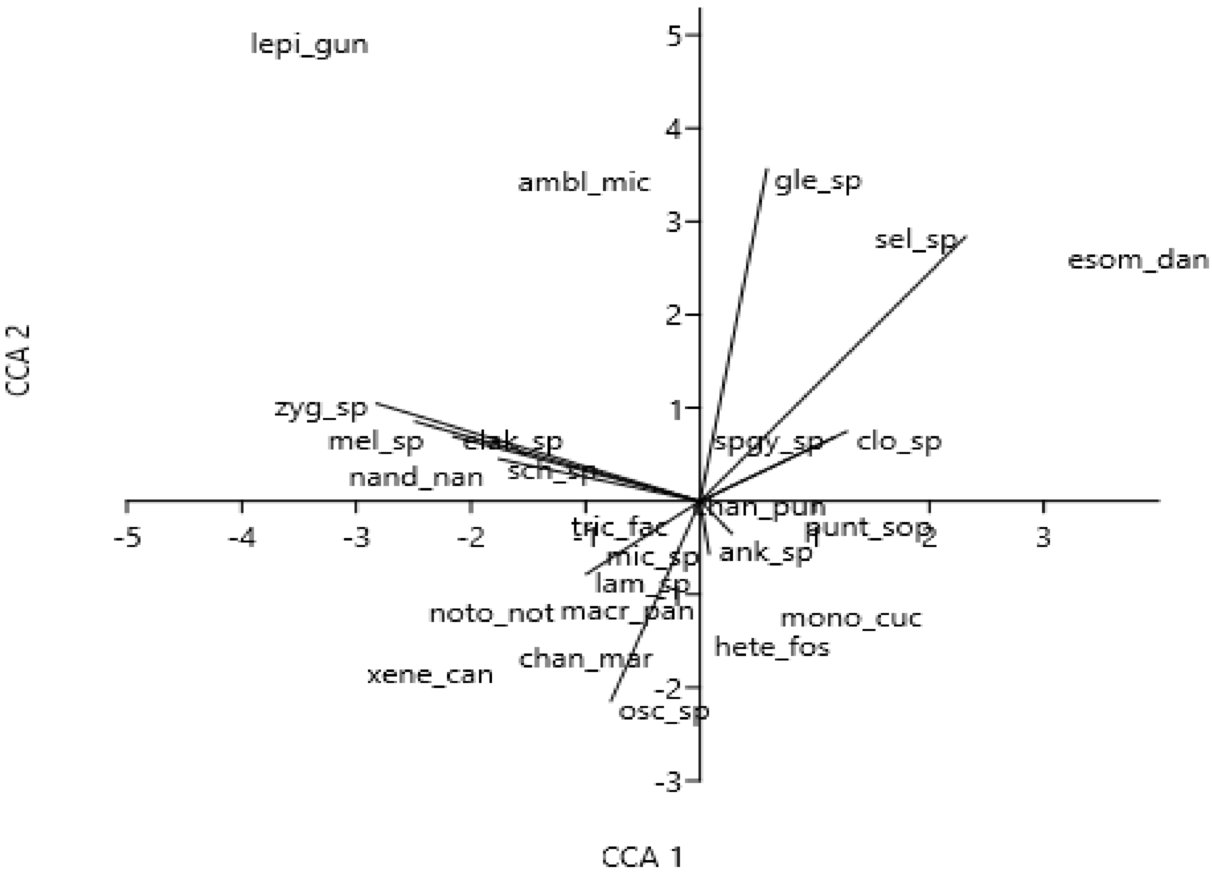

Figure 14: CCA of fish community structure with phytoplankton

CCA ordinate figure 14 showed that fish species of *Puntius sophore* (punt_sop), *Monopterus cuchia* (mono_cuc), *Heteropneustes fossilis* (hete_fos) *and Channa punctata* (chan_pun) has a high degree positive correlation with *Ankistrodesmus sp.* The fish species of *Trichogaster faciatus* (tric_fac), *Macrognathus pancalus* (macr_pan), *Channa marulius* (chan_mar) and *Xenentodon cancila* (xene_can) shows a positive association with the occurrence of *Oscillatoria* sp, *Lamanea* sp and *Microcystis* sp. At axis CCA2, the occurrence of *Nandus nandus* (nand_nan), *Amblypharyngodon microlepis* (ambl_mic), and *Lepidocephalichthys guntea* (lepi_gun) were found to have significant relation with *Zygnema* sp, *Melosira sp, Schizomeris* sp and *Elakatothrix* sp. Vector length of *Esomus danricus* (esom_dan) shows positively associated with the occurrence of *Gloeotrichia* sp, *Spirogyra* sp, *Selenastrum* sp and *Closterium* sp at axis CCA2.

4.5 CCA of fish community structure with zooplankton

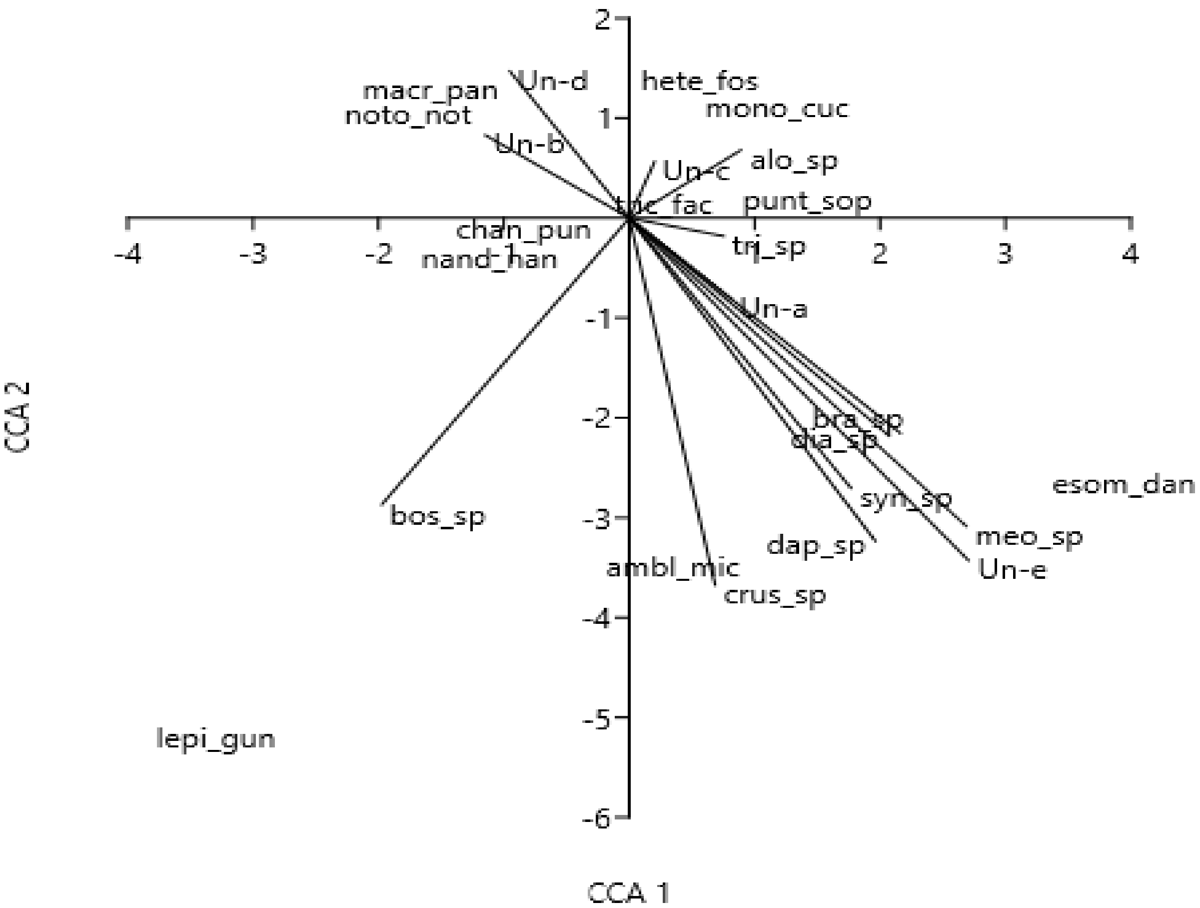

Figure 15: CCA of fish community structure with zooplankton

The CCA of fish community structure in relation to zooplankton is shown in Figure 15. The fish species of *Amblypharyngodon microlepis* and *Esomus danricus* preferred positively correlated values of *Crustacean larvae*, *Daphnia* sp, *Synchaeta*, *Mesocyclops* sp, *Diaptomus*, *Brachinus*, *Trichocera* sp. *Lepidocephalichthys guntea* and *Nandus nandus* at axis CCA2 show a positive association with the presence of *Bosmina* sp.

5. DISCUSSION

5.1 Water quality parameters

Water quality is considered the main factor influencing health and disease in all aspects of a biotic system. Higher water temperature in monsoon might be due to higher air temperature as the water temperature is influenced by air temperature and solar radiation intensity (Oli et al. 2013). Natural water bodies may exhibit a seasonal and diurnal variation and are closely related to the change in atmospheric temperature (Kundanagar et al. 1996). Maximum water temperature (35.4 °C, June) was reported at site V, and minimum (17.9 °C, December) at site VI due to seasonal variation .The highest pH value was observed in site III in June (9.48), and the lowest was in site II in December (7.21), indicating the alkaline conditions during the study period. This is due to extreme human interferences with a waste passage, different debris and chemicals from the temple area. Higher pH in June might be due to higher water temperature. Higher temperature causes increased pH levels due to the conversion of CO_2 to organic carbon by photosynthesis (King 1970). The seasonal variation in temperature and pH values observed in the study agrees with the results of Niroula et al. (2010) and Hazarika (2013) carried out in other lakes. The electrical conductivity value was higher during June than December because evaporation increases the concentration of inorganic solid matter in water, as reported by Sancer & Tekin-Özan (2016). Studies have shown that dissolved oxygen decreases during the summer season and steadily increases in autumn till maximum in winter due to seasonal variation. The highest DO value was obtained in site I in the December (9.4 mg/L). Maximum DO in the winter may be due to low temperature. Similar trends were found by previous studies (Niroula et al. 2010, Chaurasia & Tiwari 2011) in different wetlands. During previous studies in Ghodaghodi Lake, DO range between 5.27-6.56 mg/L (Diwakar 2009) and 6.42 -8.09 mg/L (Bhatta et al. 2018) around winter seasons, which is consistent with the present study (DO = 7.17mg/L). The depth of water is an important physical parameter that also affects fish distribution. The highest value was obtained in site III in June (69 cm) and lowest in site II (13 cm) in the same season, which is inconsistent with the finding of Zhao et al. (2015). The Total dissolved solids value was higher in pre-monsoon (72.33 ± 5.54 ppm) than in winter (69.1 ± 6.55 ppm). TDS values in lakes and streams are typically found to be in the range of 50 to

250 mg/L (Bhateria & Jain 2016), and TDS values of this study fall within the typical values. The highest turbidity value was recorded in site III in June (4.17 NTU) and lowest in site V in December (1.21 NTU). Similar studies made by Mensah et al. (2019) reported that turbidity recorded in the wet season was higher than that in the dry season.

5.2 Fish species abundance and distribution

A total of 510 individuals were enumerated, which comprises 13 species of fishes belonging to six Orders, 10 Families and 12 Genera. Lamsal et al. (2014) recorded 18 fish species from the Ghodaghodi Lake complex. Recently, Joshi and K. C. (2017) reported 13 fish species from the different sections of Lake Ghodaghodi in 2014. Among them, *Puntius sophore*, and *Xenentodon cancila* were common fish species in all studies. Some species such as *Labeo gonius*, *Amblypharyngodon mola*, *Mystus tengara*, *Pseudambassis baculis*, *Badis badis*, *Channa striatus*, *Labeo boga*, *Mystus vittatus*, *Clarias batrachus*, *Channa striatus*, *Channa gachua*, *Puntius gelius*, *Puntius conchonius*, *Puntius chola*, *Rasbora daniconius*, *Mastacembelus pancalus*, *Mastacembelus armatus* etc. were not recorded in the present study. Fish species such as *Channa marulius, Trichogaster faciatus, Lepidocephalichthys guntea, Notopterus notopterus, Heteropneustes fossilis* were available during the present study, which was absent in Lake during the research work of Joshi and K. C. (2017). However, this study recorded *Monopterus cuchia* as one additional species not reported in the previous phase of research in Ghodaghodi Lake. The possible reason may be that this species might have been introduced and survived due to suitable environmental conditions at this lake. In Ghodaghodi Lake, Anabantiformes were most leading Order constituting 57.48 % of total fish species, followed by Cypriniformes (34.90%), Synbranchiformes (3.93%), Beloniformes (1.57%), Osteoglossiformes (1.18%), and Siluriformes (0.59%). This is contrary to the most dominant species was from order Cypriniformes as documented by Joshi and K.C. (2017) from the study area.

Similarly, *Puntius sophore* was the most dominant species in the Ghodaghodi Lake. This species was recorded during both seasons. The percentage composition of this species was 28.63% compared to *Monopterus cuchia*, which was only 0.20%. However, *Puntius sophore* was rare species recorded by Joshi and K. C. (2017) during 2014.

Lepidocephalichthys guntea, Notopterus notopterus, Xenentodon cancila, Macrognathus pancalus, Monopterus cuchia and *Heteropneustes fossilis* were not found at the site I. It might be due to unfavorable environmental conditions. *Lepidocephalichthys guntea* was found only from site V and comprised 1.37% of the total catch composition. *Channa puntata*, *Trichogaster faciatus* and *Puntius sophore* were found in all sampling sites. The possible reason might be favorable environmental conditions and availability of food. A maximum number (136 individuals) were counted in site II with eight species throughout the study period and were the most common species of the present study. This might be due to relatively low human interference and optimum water quality condition. On the other hand, the lowest number of individuals observed at site I might be due to unfavorable environmental conditions.

The maximum number of individuals and diversity were recorded in December (winter season). According to Oli et al. (2013), the higher number and diversity of fish species in winter seasons might be due to sufficient water, ample food resources, and high dissolved oxygen (above 5 mg/l in all sampling sites in the present study) and less human interferences. Contrary to it, less water flow and high anthropogenic activities could be the cause of the smaller number of fish species and their abundance and diversity in monsoon. Most fishes were recorded during both seasons except for *Channa marulius*, *Monopterus cuchia* and *Heteropneustes fossilis.*

5.3 Phytoplankton abundance and distribution

In the present study Chlorophyceae population (69.41%) was most abundant, followed by Cyanophyceae (18.11%), Zygnematophyceae (7.3%) and Bacillariophyceae (5.07%). This is in accordance with the findings of Bharati et al. (2015) and Tyagi and Malik (2017). Similar findings were also reported by (Mishra et al. 2010) from Dhaura and Baigul reservoirs. Malik and Bharti (2012) also reported that Chlorophyceae was dominant in the Sahastradhara at Uttarakhand.

5.4 Zooplankton abundance and distribution

Maximum zooplanktons were observed in winter, probably due to low temperature, high DO content and low velocity (Khanna et al. 2000, Khanna and Bhutiani 2003, Purushothama et al. 2011). The most dominating group was Copepods (52 organisms) followed by Cladocera (49 organisms), Rotifers (11 organisms), and unidentified (6 organisms) which contributes 44.07%, 41.53%, 9.32%, and 5.08%, respectively. However, Rotifers dominated over the other zooplankton in Turkaulia Lake, Motijheel Lake, Kararia Lake, Suraha Lake and Rupa Lake (Prasad 2009, Gautam et al. 2016).

5.5 Fish diversity and water quality parameters

In the present study, the result obtained from canonical correspondence analysis (CCA) shows the occurrence of fish community composition of the Ghodaghodi Lake positively correlated to pH, Temperature, electrical conductivity, Dissolved oxygen, transparency, turbidity, and total dissolved solids. Likewise, Edds (1993) and Dubey et al. (2012) observed that the habitat variables such as conductivity, DO, pH, alkalinity, and salinity were most strongly correlated with the fish community composition of the Kali Gandaki River Basin, Nepal, and the Ganga River Basin, India.

5.6 Fish, phytoplankton and zooplankton diversity relationships

The phytoplankton is the base of lake food webs, and fish production is related to phytoplankton diversity. In the present study, the result obtained from canonical correspondence analysis (CCA) ordinate (Figure 14) shows the occurrence of fish community composition of the Ghodaghodi Lake positively correlated with phytoplankton composition. They play an important role as primary producers and can affect higher trophic levels by providing nutritional bases for zooplankton and subsequently to other invertebrates, shellfish and finfish (Emmanuel and Onyema 2007). Phytoplanktons are consumed directly by herbivorous or omnivorous fish, which is regulated by the fish stock. The feeding activity of fish, which releases fecal pellets, provides further nutrients to enhance phytoplankton growth, as stated by Komarkova (1998).

Zooplankton plays an important food item for omnivorous and carnivorous fishes (Alam et al. 1987). In the present study, the result obtained from canonical correspondence analysis (CCA) ordinate (Figure 15) shows the occurrence of fish community composition of the Ghodaghodi Lake is positively correlated with zooplankton composition. According to Bardach et al. (1972) zooplankton provides the necessary amount of protein required for the rapid growth and development of different organs, e.g., gonads of fishes. About 32% of the food item of the *Notopterus notopterus* (Mustafa and Ahmed 1978) is found on zooplankton. Rotifers are basic food fishes at conditions such as dissolved oxygen, temperature and early stages of their external feeding; hence it forms salinity etc., as stated by Nikolsky (1963).

6. CONCLUSION

A total of 510 individual fish comprising of 13 species were collected during the sampling period. Three Genera, namely *Puntius*, *Trichogaster* and *Channa*, dominated the catches. They contributed 28.63%, 28.24%, and 24.90% by the number of the total catch, respectively. Ghodaghodi Lake is a natural Lake that provides habitat for diverse indigenous fish species like *Lepidocephalichthys guntea*, *Notopterus notopterus*, *Macrognathus pancalus*, *Monopterus cuchia*, *Heteropneustes fossilis*, *Esomus danricus*, *Xenentodon cancila*, etc.

A total of 138 and 118 individuals of phytoplankton and zooplankton were enumerated during the present investigation. Chlorophyceae and Copepods were the dominating groups of phytoplankton and zooplankton, respectively. The maximum individual of phytoplankton and zooplankton was higher in site II and site I. In the present study, phytoplanktons were dominant over zooplankton. Therefore, we can conclude that these resources are also favorable for flourishing fish diversity in a lake ecosystem.

The Canonical Correspondence Analysis (CCA) showed that pH, temperature, electrical conductivity, dissolved oxygen, transparency, turbidity and total dissolved solids are the main drivers to shape the fish community structure of the Ghodaghodi Lake. CCA further reveals a significant correlation between fish assemblage and phytoplankton and zooplankton diversity. Thus, the phytoplankton and zooplankton abundance and distribution in lake food webs are linked to fish production. However, intense human interferences and illegal fishing pressure became a great menace to fisheries diversity in the Ghodaghodi Lake. Thus, to sustain fish and fishery resources, knowledge of phytoplankton and zooplankton composition diversity and reducing human activities around the Lake ecosystem must be pursued vigorously.

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APPENDICES

Appendix 1: Table containing data of water quality parameters for June and December

Table 1: Mean value of water quality parameters of Ghodaghodi Lake during study period

		Temp		PH		EC		DO		SD		TDS		Turbidity
Sites	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec
I	30.4	22.4	8.29	9.1	161	139.9	5.7	9.4	33	38	75	79.6	1.91	1.81
II	33.3	19.7	8.41	7.21	164	122	4.5	8.3	13	18	80	60	3.95	2.95
III	31.7	18.9	9.48	7.41	132	139	7.3	5.7	69	23	64	71	4.17	3.19
IV	29.6	20.7	8.21	7.41	156	130	3.4	8.5	31	31	75	66	2.95	2.47
V	35.4	18.9	8.96	7.41	139	139	6.7	5.7	36	36	70	71	1.79	1.21
VI	29.8	17.9	8	7.34	155	135	4	5.4	13	16	70	67	2.92	2.11
Total	190.2	118.5	51.35	45.9	907	804.9	31.6	43	195	162	434	414.6	17.7	13.7
Mean	31.70	19.75	8.56	7.65	151.2	134.2	5.27	7.17	37.25	27	72.3	69.1	2.95	2.29
SD	2.28	1.60	0.55	0.72	12.77	7.01	1.55	19.18	20.53	8.52	5.54	6.55	0.99	0.74

PLATE- I

Fishes belonging to order Anabantiformes and Cypriniformes

Photo 1: *Channa punctata*

Photo 2: *Channa marulius*

Photo 3: *Trichogaster faciatus*

Photo 4: *Nandus nandus*

Photo 5: *Esomus danricus*

Photo 6: *Puntius sophore*

PLATE- II

Fishes belonging to order Cypriniformes, Osteoglossiformes, Beloniformes, Synbranchiformes and Siluriformes

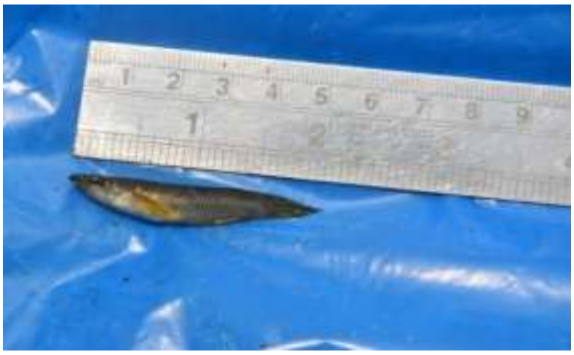

Photo 7: *Amblypharyngodon microlepis*

Photo 8: *Lepidocephalichthys guntea*

Photo 9: *Notopterus notopterus*

Photo 10: *Xenentodon cancila*

Photo 11: *Macrognathus pancalus*

Photo 12: *Monopterus cuchia*

Photo 13: *Heteropeustes fossilis*

PLATE- III

Phytoplankton belonging to group Chlorophyceae

Photo 14: *Spirogyra* sp

Photo 15: *Selenastrum* sp

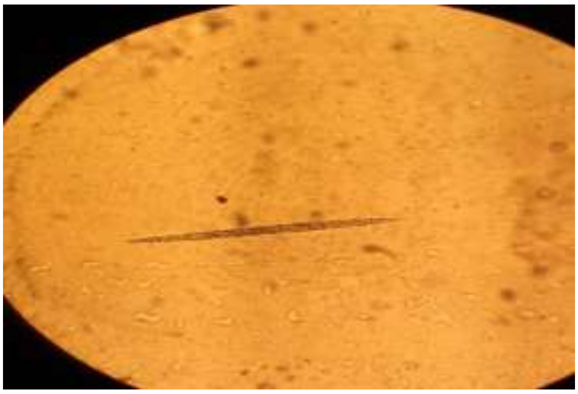

Photo 16: *Ankistrodesmus* sp

Photo 17: *Closterium* sp

Photo 18: *Elakatothrix* sp

Photo 19: *Lamanea* sp

PLATE- IV

Phytoplankton belonging to group Chlorophyceae, Bacillariophyceae, Cyanophyceae and Zygnematophyceae

Photo 20: *Schizomeris* sp

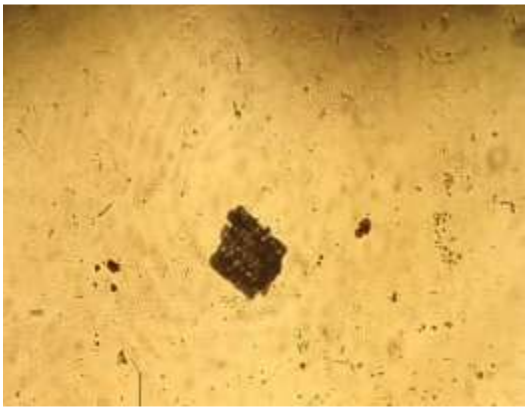

Photo 21: *Melosira* sp

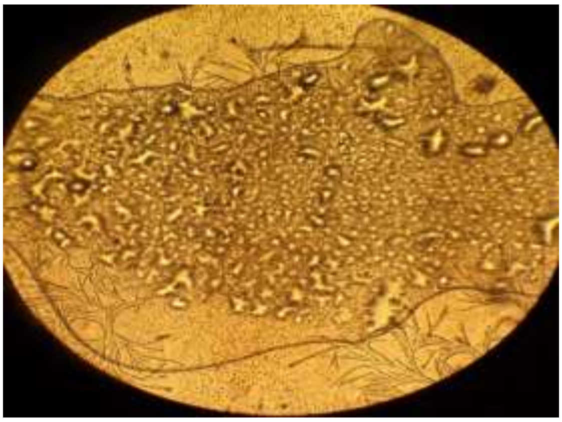

Photo 22: *Microcystis*

Photo 23: *Oscillatoria* sp

Photo 24: *Gloetrichia* sp

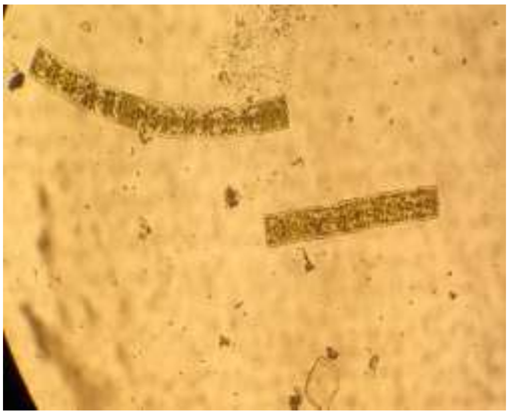

Photo 25: *Zygnema* sp

PLATE- V

Zooplankton belonging to group Cladocera, Copepods



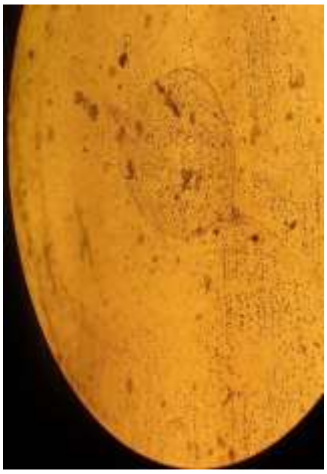

Photo 26: *Daphnia* sp Photo 27: *Bosmina* sp Photo 28: *Alona* sp


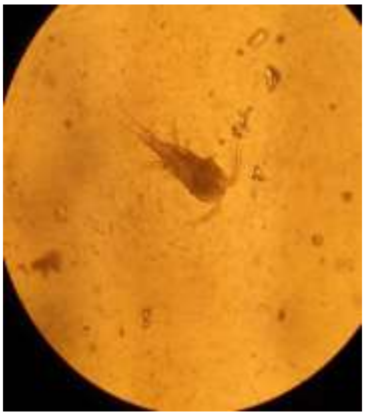


Photo 29: *Crustacean larvae* Photo 30: *Mesocyclops* sp Photo 31: *Trichocera* sp



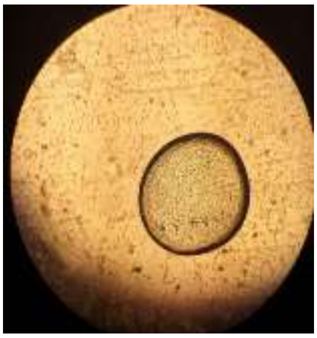

Photo 32: *Diaptomus* sp Photo 33: *Brachinus* sp Photo 34: *Synchaeta* sp

PLATE- VI

Unidentified Zooplankton

Photo 35: Unidentified-a

Photo 36: Unidentified-b

Photo 37: Unidentified-c

Photo 38: Unidentified-d

Photo 39: Unidentified-e

Photo 40: Unidentified-f

PLATE- VII

The study site

Photo 41: Ghodaghodi Lake during June   Photo 42: Ghodaghodi lake during December

Photo 43: Fish sampling   Photo 44: Analysis of water quality parameters

PLATE- VIII

The study site

Photo 45: Plankton collection

Photo 46: Helka and Dhadiya

Photo 47: Net used to capture fish

Photo 48: Bamboo fish trap

Photo 49: Fish identification at Lake

Photo 50: Plankton identification at Central Department of Zoology Laboratory