

FISH DIVERSITY OF DIPANG LAKE IN THE MID-HILL OF KASKI DISTRICT, NEPAL



Submitted by

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in Zoology with special paper Fish and Fisheries

Submitted to

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Tribhuvan University

Kirtipur, Kathmandu

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May, 2018

DECLARATION

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

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RECOMMENDATION

This is to recommend that the thesis entitled “**Fish diversity of Dipang Lake in the mid-hill of Kaski District, Nepal**” has carried out by Bhuwan Thapa for the partial fulfillment of Master’s Degree of Science in Zoology with special paper **Fish and Fisheries**. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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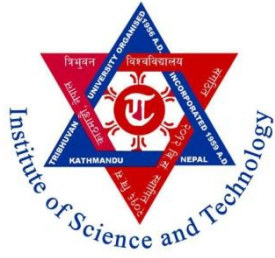
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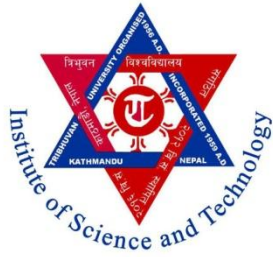
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LIST OF ABBREVIATIONS

Abbreviation form	Detail of Abbreviation
APHA	American Public Health Association
CaCO ₃	Calcium carbonate
DOFD	Directorate of Fisheries Development
DO	Dissolve Oxygen
EDTA	Ethylenediamine tetraacetic acid
EIA	Environmental Impact Assessment
Free CO ₂	Free carbon dioxide

ABSTRACT

Present study deals with the fish diversity of Dipang Lake located in the mid-hill of Kaski District, Nepal from May to November in 2017. It explored the fish diversity, species richness, evenness and physico-chemical parameter of Dipang Lake. Fish sampling were done by using cast net, gill net and local fishing gears. Fifteen different species (native and exotic) of fish belonging to 5 orders, 7 families, and 12 genera were recorded from this aquatic ecosystem. The order Cypriniformes (46%) was dominant in terms of both species composition as well as individuals captured. At family level, Cyprinidae contributed by 29.43% and Cichlidae 25% compare with family Channidae (4%) in total number of individual species sampled. *Puntius sophore* was the most dominant fish species (18.33%) of the total catch. The higher diversity index (2.10) and richness (2.16) was recorded in July and evenness index was recorded in May (0.883). Similarly, higher diversity index and richness were observed at station IV (2.08) and III (2.08) respectively. Higher evenness index recorded at station II (0.859). However, water quality parameters (water temperature; 23°C to 30°C, pH; 6.2 to 8 ppm, DO; 5.1 mg/l to 8.38mg/l, free CO₂; 0.8 mg/l to 3.2 mg/l, Hardness; 12 mg/l to 36 mg/l, Alkalinity; 50 mg/l to 100 mg/l) were observed within desirable range supporting freshwater fish. Due to pollution, illegal fishing, and excessive proliferation of aquatic weeds, human encroachments and introduction of exotic fishes the fish diversity and frequency were found decrease day by day.

Keywords: Dipang Lake, Fish diversity, Physico-chemical parameter

1. INTRODUCTION

1.1 Background

Fish diversity considers to variety of fish species depending on environment and scale (Burton *et al.*, 1992). Studies of ecological habitat and periodic pattern of distribution and species composition of freshwater fishes are useful to examine factors which are responsible for influencing the structure of the fish community (Galactos and Barriza-Salazar, 2004). The availability, distribution and composition of the fish species in each habitat were closely related with various factors such as food, breeding sites, water current, depth, topography and physico-chemical properties of water (Harris, 1995). In aquatic ecosystem, fish species are also an important indicator of ecological health. The abundance and health condition of fishes will show the quality of water bodies (Hamzah, 2007).

Lakes and rivers are very important part of our natural heritage. The maintenance of healthy aquatic ecosystem is dependent on the physico-chemical properties and biological diversity (Aazami *et al.*, 2015). The interaction of both the physical and chemical properties of water play a significant role in composition, distribution, abundance, movements and diversity of aquatic organisms (Deepak and Singh, 2014). In particular, fish populations are highly dependent upon the variations of physico-chemical characteristics of their aquatic habitat which supports their biological functions. Among the physico-chemical factors temperature, dissolved oxygen, pH, turbidity, water transparency and current are the key factor for diversification in biological functions. Their regular or irregular fluctuations of physico-chemical factors have been identified as determinants in riverine fish ecology (Mushahida-Al-Noor and Kamruzzaman, 2013).

Nepal is gifted with many forms of water resources scattered throughout the country. These water resources are in the form of rivers and streams, lakes, reservoirs, ponds, swamps and paddy fields. In Nepal, most river water originates in the Himalayan and flows towards the Terai. Water temperature varies greatly with altitude and it is also affected by change in seasons. Fish species diversity is comparatively high with diverse fish habitats that are isolated with physical barriers (Shrestha, 1995).

A lake is the most beautiful and expressive feature of a landscape. It is often described as the eye of the earth and rightly so. A pristine lake reflects the beauty and joy around it, but a polluted lake choked by callous dumping of waste is like a blind eye. Unfortunately, today many of our lakes have been dried and polluted on account of over-exploitation and reckless dumping of human and industrial waste which has become the major threats to fish biodiversity. Besides this flow modification, destruction of habitats, siltation, invasion by exotic species including the worldwide phenomena of eutrophication and sedimentation, all of which are interacting very pertinently has also played key role in diminishes of fish diversity (Helfman *et al.*, 2009).

1.2 Natural water resources of Nepal

Being a landlocked country, Nepal has only inland water resources including the river systems, lakes, reservoirs, village ponds, wetlands, and irrigated rice fields totaling 8,17,100 hectares of water surface area which cover about 5.5% of the total area of the country (DOFD, 2008). Natural water resources including rivers, lakes and reservoirs comprise approximately 54% of the total water (Pradhan and Pantha, 1995).

1.2.1 River system in Nepal

The river system of Nepal can be divided into three major groups from east to west, namely the Koshi, the Gandaki and the Karnali. According to their origin they can be categorized into three classes (I) Antecedent to Himalaya, (II) After the Mahabharat, and (III) After the Churiya range. The major river systems namely the Koshi, the Gandaki and the Karnali belong to the antecedent group. The second Group Rivers are originating from the Mahabharat range and cutting through Churia hills while the third group of rivers originates from the southern face of the Churia hills. These rivers have small catchment areas. In dry season, the discharge of these rivers becomes nominal while several rivers dry up. All these large and small rivers give rise to about 6,000 rivers totaling about 45,000 km in length. Approximately 1,000 of these rivers are more than 10 km long and about 100 of them are longer than 160 km (Sharma, 1977).

1.2.2 Lake system in Nepal

Lakes are distinctly noticeable physical features as the body of water on the surface of earth. They are found mostly in glaciated regions of the northern hemisphere. Lakes have multiple values. The moderate temperature and climate of the surrounding area helps to maintain biodiversity (Bhandari, 1994). For humans, lakes are valuable as the source of freshwater and sites for recreational activities, while several of them hold religious values. There are several lakes in Nepal which are scattered all over the country. The estimated area of the lake is 5000 ha (0.7%) of the total existing water areas of Nepal (DOFD, 2008). The lakes can be categorized into 3 types on the basis of their origin, viz., Glacial, Ox-bow and Tectonic lakes. There are 17 major glacial lakes in the northern Himalayan region which are located above 4000 meter altitude. In most cases, the tectonic lakes have drained out, and have been replaced by flat basins which occur in the hill region. Ox-bow lakes are mainly confined to the Southern part of the country. The presence of Ox-bow lakes indicates the shift of river course and there are more than two dozens of Ox-bow lakes in Nepal (Sharma, 1977).

1.2.3 Reservoirs in Nepal

Reservoir is an artificial lake constructed for the hydropower project and irrigation purposes. There are few reservoirs with a total of 1500 ha, comprising 0.2% of the total existing water area of Nepal (DOFD, 2008). Among the existing reservoirs Kulekhani, Mansarowar, Indrasarowar, Marsyandi, Kamalaha etc; are some examples.

1.3 Fish diversity and Status of fishes in Nepal

The fishes of Nepal have wide range of distribution according to the climatic condition and altitudinal variation. According to Shrestha (2008), 127 species are reported from Koshi, 157 species from Gandaki, 119 species from Karnali and 71 species from Mahakali River. Also, Shrestha (2011) 228 species of native fish diversity including endemic ones have reported. Furthermore, a total of 230 native species belonging to 104 genera, 34 families and 11 orders have reported (Rajbanshi, 2012).

Table1. Status accounts for fish species of Nepal

S.N	Categories	Status	Number of species
1.	Common	C	71
2.	Uncommon	UN	53
3.	Conservation dependent and rare	CDR	27
4.	Data Deficient Pristine Rare	PRO	32
5.	Data deficient, pristine, rare, ornamental	CE	0
6.	Endangered	EN	2
7.	Extinct	EX	0
8.	Vulnerable	VU	9
9.	Rare and near threatened	R	23
10.	Exotic	-	15
	Total		232

Source: Shrestha (2008)

1.4 Endemic species in Nepal

Freshwater fishes are a poorly studied group. There is no proper documentation and most of the information available is from studied locations only. In Nepal 6 endemic freshwater fish species are reported (Shrestha and Chaudhary, 2004). Additional endemic freshwater fish species were described by Ng (2006), Conway and Mayden (2010) and Conway *et al.*, (2011). Fifteen species are categorizes as endemic species, which are listed below.

Table 2. Endemic freshwater fish species in Nepal

S.N	Scientific name	S.N	Scientific name
1.	<i>Schizothoraichthys macrophthalmus</i>	9.	<i>Erethistoides ascita</i>
2.	<i>Schizothoraichthys nepalensis</i>	10.	<i>Erethistoides cavatura</i>
3.	<i>Schizothoraichthys raraensis</i>	11.	<i>Psilorhynchus nepalensis</i>
4.	<i>Psilorhynchoides pseudecheneis</i>	12.	<i>Pseudecheneis crassicauda</i>
5.	<i>Myersglanis blythi</i>	13.	<i>Pseudecheneis eddsi</i>
6.	<i>Pseudeutropius murius</i>	14.	<i>Pseudecheneis serracula</i>
7.	<i>Batasio macronotus</i>	15.	<i>Turcinoemacheilus Himalaya</i>
8.	<i>Balitora eddsi</i>		

Source: Shrestha (2011)

1.5 Dipang lake

Pokhara Lekhnath metropolis is a remarkable place of natural beauty. It is the home to various lakes, caves and mountains. The city is also entitled as the garden city of seven lakes. The seven lakes are Begnas, Rupa, Dipang, Khaste, Maldi, Neureni, and Gude. Dipang Lake is the third largest lake of Lekhanth city with an area of 3.24 sq. km and 3 to 5 m depth. It is also called as Honeymoon Lake. The vegetation is almost similar with other parts of Pokhara valley. The aquatic and wetland floral diversity are made up of 60 species (Adhikari, 2008). The major species on the Northern part of the lake is *Shorea robusta* whereas the major species of the forest on the Southern aspect of the hill lying on the Southern part of lake is *Schima castonopsis*, *S. wallichii* etc. Twenty five species of such plant have been recorded in Dipang Lake out of them four species found to be invasive in nature (Oli, 1999). Notable aquatic weeds include *Hydrilla verticillata*, *Potamogeton crispus*, *Potamogeton pectinatus*, *Echiochloa* and *Panicum repens* (Shrestha, 1998). There is agricultural field on the Eastern and Western region of lake.

1.6 Objectives of the study

1.6.1 General objective

To investigate the fish diversity of Dipang Lake in the Mid-hill of Kaski District, Nepal.

1.6.2 Specific objectives

- To explore the diversity and distribution of fishes of Dipang Lake.
- To analyze the physico-chemical parameter of Dipang Lake.

1.7 Justification of the study

An important wetland around Pokhara valley with biodiversity richness has recently declared as a part of Ramasar site of Nepal. Main objectives to declared this site is to protect the naturality of the Pokhara valley and to fulfill the basic needs of people around the conservation area through the conservation and utilization of natural resources by proper management.

Dipang Lake is one of the watershed areas of lake clusters of Pokhara valley. It is rarely falls on the limelight in Pokhara, nevertheless its beauty is awesome. Although a small lake, Dipang is home to a number of fishes and aquatic plants but, having its own status in biodiversity it still remain unexplored about the fish diversity. Its size is gradually diminishing in recent year due to soil erosion and anthropogenic impact (Adhikari, 2008). This is the possibility of disappearance of fish species. Therefore, present study was based on the fish diversity of Dipang Lake. This study will be supportive background for conservation of fish diversity of Dipang Lake and further research in this lake.

1.8 Limitation of the study

- Due to limit time, transportation and financial resources the study could not cover the whole area of lake.

1.9 Research hypothesis

Null hypothesis: there is no significant difference between fish diversity and physico-chemical parameters.

Alternative hypothesis: there is significant difference between fish diversity and physico-chemical parameters.

2. LITERATURE REVIEW

Due to the good home place of several fish species different workers have contributed from time to time in exploring the ichthyo-fauna of Nepal. Hamilton (1822) had provided the first valuable authentic information concerned to the fishes of Nepal in his book entitled "An account of the fishes found on River Ganga and its tributaries". Gunther (1861) reported some cold-blooded vertebrates including fishes, collected by Hodgson in Nepal. Altogether 35 fish species were mentioned in his checklist. Beavan (1877) described two imperfectly known species of Cyprinid fishes from Panjab and had mentioned some of the fishes of Nepal.

Boulenger (1907) reported a collection of Nepalese fishes and western Himalayan fishes. Hora (1940) publishing many papers regarding his fish collection and reported as 158 specimens of which 22 species were from Nepal comprising 15 different genera. Also, he reported the Nepalese "Katle" (*Neolissocheilus hexagonolepis*). De Witt (1960) confined 102 species of fishes belonging to 21 families contributing ichthyology of Nepal. Shrivastava (1968) published a book entitled "Fishes of Eastern Uttar Pradesh" in which he mentioned a number of Nepalese fishes. Shrestha *et al.*, (1979) studied the aquatic ecology and fishing potential of Bagmati River and have reported 82 fish species from the River Bagmati. Edds (1993) studied the fishes of Kali Gandaki/ Narayani River and Chitwan National Park, reported 111 species and 107 species respectively. Swar (1994) studied the population ecology of Katle (*Neolissocheilus hexagonolepis*) in Nepalese reservoirs and reported population of Katle in Kulekhani reservoir underwent heavy mortality due to heavy monsoon floods, siltation from soil erosion and drawdown in the reservoir.

Karki (2000) studied on bio-diversity and fishery resources of lower Karnali, Nepal and registered 50 species belonging to 29 genera under 15 families and 8 orders. Bajracharya (2001) studied on the fish and fishery resources of Bhote Koshi River with partial references to impact of dam of fish distribution and recorded 16 species of fish under 3 families and 2 orders. Sharma and Shrestha (2001) reported 35 species belonging to 25 genera, 12 families and 5 orders from Tinau River. Dhital and Jha (2002) identified 69 species of fish belonging to 9 orders and 19 families from Narayani River. Malla (2004) studied diversity, distributional pattern and frequency occurrence of fish and invertebrates species in Dharam khola, Baglung.

Prajoo (2007) enumerated fish diversity of Harpan Khola and recorded 22 species of fishes belonging to 6 families, 16 genera under 5 orders. Rajbanshi (2005) worked on taxonomic review status of fish diversity and recorded a total number of 187 fish species representing 94 genera, 30 families and 10 orders. Shah (2005) studied on fish diversity of Budhigana River and reported 18 species of fish belonging to 2 orders, 4 families and 13 genera. Kafle (2007) identified 25 species from Ghodaghodi Lake. Saud and Shrestha (2007) reported only 2 indigenous fish species in the Kulekhani reservoir namely Katle (*Neolissocheilus hexagonolepis*) and Karange (*Nazirator chlynoides*) whereas other exotic fish species Bighead carp and Silver carp were recorded dominant group of fish

fauna. Tamrakar (2008) described 28 species of the fishes from the lake cluster of Pokhara valley. Shrestha (2008) in his book “Ichthyology of Nepal” sketched 75 species of fish from Karnali River, 108 species from Koshi River, 34 species from Trisuli River, 102 species from Narayani River, 69 species from Mahakali River, 82 species from Bagmati River, 69 species from Kaligandaki River and 29 species from Kulekhani reservoir.

Giri (2010) has recorded 21 species of fish related to 5 order, 6 families, and 16 genera from Phewa Lake in his study on distribution pattern of fishes and the socio-economic condition of fisher’s community. Thapa and Rai (2010) studied the fish diversity of Koshi Tappu Wildlife Reserve and reported altogether 92 species of fish belonging to 54 genera and 25 families. Gautam *et al.*, (2010) captured 2273 fishes by using gill nets from Jagadishpur reservoir, one of the Ramsar sites of Nepal. Among them 42 fish species were reported belonging to 6 orders, 18 families and 34 genera.

Pokharel (2011) studied on fish diversity of West Rapti River and recorded altogether 24 species belonging to 6 families, 16 genera under 4 orders with dominance of family Cyprinidae. Pokharel (2011) studied on the Spatio-Temporal variations in distribution and abundance of fishes of Seti Gandaki River along 30 km stretch and two major tributaries Mardi Khola and Vijaypur Khola in Pokhara valley. A total of 30 species of fishes belonging to 5 orders, 9 families and 22 genera were reported from river and its tributaries. He also reported predominant fishes of family Cyprinoids in his work. Pokharel (2011) studied in Pangre Jhalas wetland and its surrounding area by using cast net and reported 12 species of fish fauna. Saund *et al.*, (2012) mentioned a total of 24 fish species belonging to 3 orders, 4 families and 13 genera from Pancheshwar area of Mahakali on his research work for fish diversity in Autumn and Summer. Sharma and Edds (2012) studied the fishes of Nepal from main rivers of Nepal (Karnali, Gandaki and Koshi) and reported 141 species. Collection comprised 10 orders and 30 families, including 76 species from 5 families of Cypriniformes, 41 species from 9 families of Siluriformes, 15 species from 8 families of Perciformes, 3 species from 2 families of Synbranchiformes and 1 species each from Osteoglossiformes, Anguilliformes, Clupeiformes, Beloniformes, Cyprinodontiformes and Tetradontiformes.

Mandal and Jha (2013) studied on impact of damming on Ichthyofaunal diversity of Marshyangdi River in Lamjung District, Nepal and reported 26 species of fishes belonging to 5 orders, 6 families and 18 genera by using gill nets and cast net. Oli *et al.*, (2013) were collected 22 species belonging to 13 families and 5 orders from Rampur Ghol, a wetland in Chitwan, Central Nepal. Lamsal *et al.*, (2014) studied on fish diversity, uses and threats in the Ghodaghodi Lake and reported 19 fish species. Baro *et al.*, (2014) mentioned 49 ornamental fish species belonging to 34 genera, 18 families and 6 orders from Sunkoshi River. Jha and Bhujel (2014) studied the fish diversity of Narayani River and collected 108 fish species belonging to 9 orders, 27 families and 70 genera from different sampling point.

K.C (2015) described 15 species of fishes from Sharada River reporting 3 orders, 4 families and 10 genera. Rijal (2015) studied fish diversity of Tinau River and recorded 26 fish species, belonging to 4 orders, 9 families and 19 genera. Gautam *et al.*, (2016) studied on Rupa Lake about Fish faunal diversity and species richness by using local fishing gears and documented 23 fish species belong to 5 orders, 6 families and 18 genera. Lamichhane *et al.*, (2016) reported 37 species belonging to 6 orders and 15 families from Beeshazar Taal and its associated lakes of Chitwan. Shah (2016) studied on fresh water fish diversity of Koshi river of Nepal by using nets and gears and reported as 59 fish species. Mishra and Baniya (2016) studied on fish diversity of Melamchi River and found that 11 species with in 2 orders and 5 families. Raymajhi and Arunachalam (2016) described a new species, *Pseudolaguvia nepalensis* (Family Erethistidae) from Kasara Khola near to its confluence with Rapti River of Gandaki system, central Nepal. Shrestha (2016) mentioned 48 fish species under 35 genera belonging to 17 families and 6 orders from Triyuga River of Morang District.

Yadav (2017) studied on Fish diversity and Need for their conservation of Singhiya River, Morang District, Nepal by using local gears and reported 26 species of fishes comprising 7 orders, and 20 genera. Bhusal and Chitrakar (2017) reported hill stream fishes of Roshi Khola, Panuti, Nepal by using various fishing gears such as home made net, thumche, etc. and reported altogether 5 genera, 3 families and 2 orders from an altitude of 2000m. Raymajhi (2017) studied the fish assemblage structure of Chitwan National Park and its adjacent zones by using cast net with varying mesh sizes and dip nets. In her study, 55 fish species belonging to 38 genera, 20 families and 7 orders were recorded. Husen and Sherpa (2017) reported 5 order, 6 family and 21 native fish species of Begnas and Rupa Lake of Pokhara with 6 exotic fish species. Joshi and K.C (2017) studied fish diversity of Ghodaghodi Lake and mentioned 13 species including 5 orders, 8 families from this lake.

3. MATERIALS AND METHODS

3.1 Study area

The present study was carried out in Dipang Lake. It is located at Pokhara Lekhanath metropolis in Kaski District, Nepal. Its naturalism found in the mid-hill area just 10 Km away from Pokhara city towards its east with altitudinal range 694 to 1,266 m from sea level. It coordinates 84°03'44.8" to 84°04'48.0" E, and 28°12'42.0" to 28°12'9.1"N. It covers an area of 3.24 sq. km with water bodies occupying an area of 0.06 sq. km. It has small inlet stream and Kali Khola functioning as the outlet. It falls in the lap of green hill and extends like a shape of boat. It is one of the major water resources of that location and one of the wetland areas out of Lake Cluster of the Pokhara valley. It has got recently international importance since inclusion in Ramsar site along with the lake clusters of this region. The lake clusters of Pokhara valley was declared in the 10th Ramsar site of Nepal on 2 February 2016 (Ramsar Convention Secretariat, 2016).

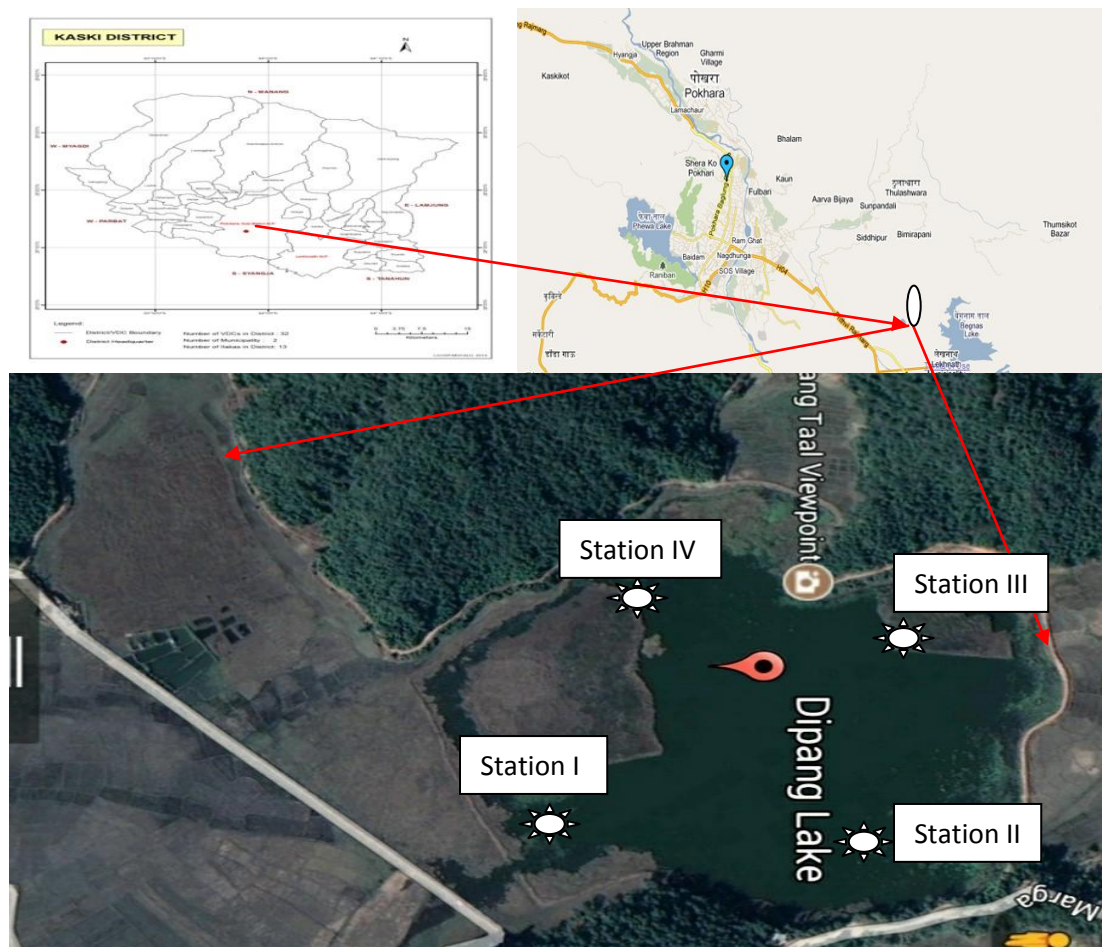


Fig 1. Map of study area

Source: www.googlemap.com

3.2 Selection of sampling station

Station I

The sampling station I was selected on East, which consists of outlet. Water passes out from here. This area was disturbed by human being and domestic animals.

Station II

The sampling station II was selected on North, near hotel area. This area was highly disturbed by visitors. In this area one fishing boat also kept for fishing. The main features of this area also manifested by tall trees and small herbs.

Station III

The sampling station III was selected on Western part of lake. This site was surrounded by agricultural land and also with small inlets point called as Ashare khola. Especially this area was covered by Lotus plants.

Station IV

The sampling station IV was selected on Southern part of lake. This site was covered by forest area and small herbs. The special character of this site was presence of large floating mass of water grass called as wild rice and high soil erosion area.

3.3 Collection and identification of fishes

Field visits were carried out for four months May, July, September and November in 2017. Four sites selected for sampling fish diversity, station I: outlet area of the lake; station II: hotel area of the lake; station III: western and agricultural area of the lake; station IV: southern and grassy area of the lake. In sampling sites four continuous days in each month visited during the study period with local fishermen. Various kinds of locally available fishing gears such as cast net (mesh size 1cm x 1cm x 1 cm) and Gill nets (mesh size 6 cm x 6 cm x 6 cm / 1 cm x 1 cm x 1 cm) were used for fish catching. Cast nets was placed during morning whereas gill net was left installed overnight and observed next morning and total number of individuals in each sampling station was recorded. The fixed time frame was maintained to collect water sample from 8 am to 10 am. The collected fishes was preserved in 10% formalin solution and identify to species level using taxonomic references of Jayaram (1981), Shrestha (1994) and Shrestha (2008) and Fish base. The threat status of collecting fishes was mentioned according to Shrestha (2011).

3.4 Analysis of physico-chemical parameters

Water samples were collected from four sampling sites of the lake. Water depth, water temperature, transparency, pH were determined on the spot itself and other parameters were analyzed at laboratory of Bhadrakali higher Secondary school using standard procedures of Trivedy and Goel (1984).

3.4.1 Analysis of physical parameters

3.4.1.1 Water color: Simple method was used to determine the color of water. A little amount of water was collected from the lake and placed on a white disc/paper and color was recorded.

3.4.1.2 Temperature: Standard mercury thermometer was used.

3.4.1.3 Water depth: A Nylon rope with heavy metal and measuring tape used to determine the depth of water.

3.4.1.4 Transparency: Transparency of the water was measured with the help of a Sacchi Disc. The transparency was calculated by applying the following equation.

$$\text{Transparency (D)} = A+B/2$$

Where, A = depth at which Sacchi Disc disappears

B = depth at which Sacchi Disc reappears

3.4.2 Analysis of chemical parameters

3.4.2.1 Dissolve Oxygen: It was measured by titration method using following formula

$$\text{DO mg/l} = \frac{(\text{ml} \times N) \text{ of titration} \times 8 \times 1000}{V_2(V_1 - V)/V_1}$$

Where, V_1 = volume of sample bottle after placing the stopper, V = volume of MnSO_4 and KI added and V_2 = volume of part of the contents titrated

3.4.2.2 Free carbon dioxide: CO_2 was measured by the help of titration method using following formula

$$\text{Free CO}_2 \text{ (ml/l)} = \frac{(\text{ml} \times N) \text{ of NaOH} \times 1000 \times 44}{\text{Volume of sample used (ml)}}$$

3.4.2.3 Hydrogen-Ion concentration (pH): pH of the water was measured by the help of digital pH meter.

3.4.2.4 Water hardness: It is the total amount of salts present in the water (i.e. Chlorides and sulfates of calcium and magnesium). The total hardness of water was measured by EDTA titration method.

$$\text{Amount of calcium} = \frac{\text{Volume of EDTA consumed of EDTA (0.01)} \times 40 \times 1000}{\text{Total volume of ample taken}}$$

3.4.2.5 Total Alkalinity: The total alkalinity of water (carbonate) was measured by the help of titration using different chemicals.

$$\text{Total alkalinity CaCO}_3 = \frac{\text{Normality of H}_2\text{SO}_4 \times 50 \times 50 \times 1000}{\text{Volume of sample in ml}}$$

3.5 Statistical analysis

Species diversity was assessed using four different indices viz., Shannon- Wiener diversity, species richness and evenness.

Shannon-Weiner diversity index (Shannon and Weaver, 1949)

Mathematically, $H = \sum_{i=1}^S P_i \times \log P_i$

Margalef's richness Index (D) (Margalef, 1968)

Mathematically, $D = (s-1) / \ln N$

Pielou's evenness (Pielou, 1966)

Mathematically, $E = H / \ln S$

Where,

H= diversity index, S= total number species, ln= natural logarithm, Pi= relative abundance of ith species, ni= total no. of individuals of particular species, s= the number of individual of each species, N= total no. of individuals

Karl Pearson's Correlation co-efficient (Singh, 2011)

Correlation co-efficient (r) =
$$\frac{N.\Sigma XY - \Sigma X.\Sigma Y}{\sqrt{(N.\Sigma X^2) - (\Sigma X^2)(N.\Sigma Y^2) - (\Sigma Y^2)}}$$

Probability error (P.E.) =
$$\frac{1 - r^2}{\sqrt{N}} \times 0.6745$$

4. RESULTS

4.1 Fish diversity of Dipang Lake

A total of 15 species belonging to 5 orders, 7 families and 12 genera were recorded during study period (Plate I, II and III). Among them 11 species were indigenous and other 4 species were exotic. The exotic species were *Cyprinus carpio*, *Ctenopharyngodon idella*, *Clarias gaeripinus* and *Oreochromis nilotica*. Among indigenous fishes, 10 species were found under Common (C) list of threat status and *Chagunius chagunio* reported as Fairly common (FC).

Table 3. Fish diversity of Dipang Lake with its local and threat status in Nepal

Order	Family	Scientific name	Local name	Threat Status
Beloniformes	Belontiidae	<i>Xenentodon cancila</i> (Hamilton-Buchanan) 1822	Chhuchebam	C
Cypriniformes	Cyprinidae	<i>Barilius barna</i> (Hamilton-Buchanan) 1822	Baghfageta	C
		<i>Chagunius chagunio</i> (Hamilton) 1822	Rewa	FC
		<i>Esomus dandricus</i> (Hamilton-Buchanan) 1822	Dheduwa	C
		<i>Puntius sophore</i> (Hamilton-Buchanan) 1822	Bhitte	C
		<i>Puntius ticto</i> (Hamilton-Buchanan) 1822	Bhitte	C
		<i>Cyprinus carpio</i> * (Linnaeus) 1758	Common carp	–
		<i>Ctenopharyngodon idella</i> * (Valenciennes) 1844	Grasscarp	–
Perciformes	Channidae	<i>Channa punctatus</i> (Bloch) 1793	Bhoti	C
		<i>Channa gachua</i> (Bloch) 1793	Bhoti	C
	Chichlidae	<i>Oreochromis nilotica</i> * (Linnaeus) 1758	Tilpia	–
Siluriformes	Bagridae	<i>Mystus bleekeri</i> (Day) 1878	Junge	C
	Clariidae	<i>Clarias batrachus</i> (Linnaeus) 1758	Chilly	C
		<i>Clarias gariepinus</i> * (Burchell) 1822	Magur	–
Synbranchiformes	Mastacembelidae	<i>Mastacembelus armatus</i> (Lecepede) 1800	Bam	C

Note: Threat status based in the data available at Shrestha (2011); FC= fairly common, C= common and *= exotic fish.

4.2 Distribution and frequency occurrence of fishes in Dipang Lake

Among 11 indigenous species higher number of total catch occurred as *Puntius sophore* (147). Similarly, *Mystus bleekeri* (110) and *Clarias batrachus* (108) found to be position second and third. Out of four exotic fishes high catch number observed as *Oreochromis nilotica* (203) and other species contributed its minimum number during study period. On the basis of frequency distribution, the most dominant indigenous species was *Puntius sophore* that contributed by 18.33% of total number of catch. Other two major fishes with high catch frequency were *Mystus bleekeri* (13.92%) and *Clarias batrachus* (13.47%). Furthermore, Tilapia (*Oreochromis nilotica*) was the dominant species on both exotic and indigenous species contributing by 25.31%. The lowest frequency distribution of *Cyprinus carpio* and *Ctenopharyngodon idella* were recorded (Table 4). Distribution pattern almost similar in 10 species while some species were recorded only specific points such as *Esomus dandricus* only observed at station I. Similarly, *Channa punctatus* and *Cyprinus carpio* recorded only at station IV while Grass carp (*Ctenopharyngodon idella*) reported at station III.

Table 4. Distribution and frequency occurrence of fishes in Dipang Lake

S.N	Name of fish	Stations				Total no of individuals	Frequency
		I	II	III	IV		
1.	<i>Xenentodon cancila</i>	+	+	+	+	65	8.11
2.	<i>Barilius barna</i>	+	+	+	+	38	4.74
3.	<i>Chagunius chagunio</i>	+	+	+	+	5	0.62
4.	<i>Esomus dandricus</i>	+	-	-	-	8	1.00
5.	<i>Puntius sophore</i>	+	+	+	+	147	18.33
6.	<i>Puntius ticto</i>	+	+	+	+	36	4.49
7.	<i>Channa punctatus</i>	-	-	-	+	1	0.13
8.	<i>Channa guachua</i>	+	-	+	+	28	3.49
9.	<i>Mystus bleekeri</i>	+	+	+	+	110	13.92
10.	<i>Clarias batrachus</i>	+	+	+	+	108	13.47
11.	<i>Mastacembelus armatus</i>	+	+	+	+	48	5.99
	Exotic species						
12.	<i>Clarias gariepinus</i>	+	-	+	-	3	0.37
13.	<i>Ctenopharyngodon idella</i>	-	-	+	-	1	0.13
14.	<i>Cyprinus carpio</i>	-	-	-	+	1	0.13
15.	<i>Oreochromis nilotica</i>	+	+	+	+	203	25.31
	Total					802	

4.3 Community structure of fishes in Dipang Lake

4.3.1 Order wise fish diversity of Dipang Lake

All total of 802 numbers of fishes were captured during study period. About 46% of fish species belonging to order Cypriniformes and 20% of fish species contributed by order Siluriformes and Perciformes separately. Similarly, Beloniformes and Synbranchiformes were contributed by 6.70%.

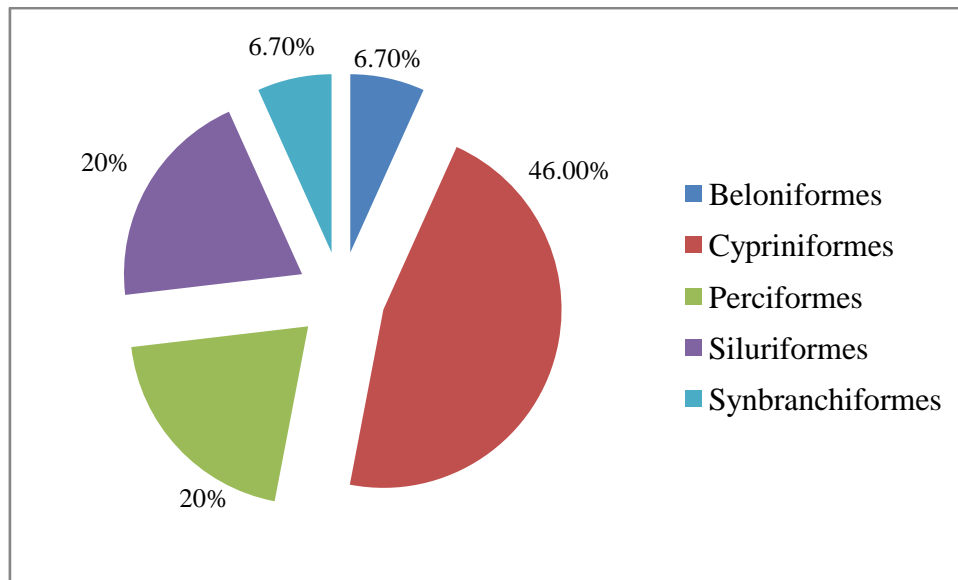


Fig 2. Total fish species diversity based on total catch % at order level.

4.3.2 Family wise fish diversity of Dipang Lake

During study period all together 7 families were recorded. The highest number of catch belongs to family Cyprinidae (29.43%) and lowest for Channidae (3.62%) in this lake community. Two families Bagridae and Claridae were contributing nearly equal number of fishes by 13.84% and 13.72% of the total catch percentage (Fig 3). Similarly, Belonidae and Mastacembelidae were recorded its total catch percentage value 8.10% and 5.98% respectively. Family Cichlidae contributed by 25.31% based on total catch percentage.

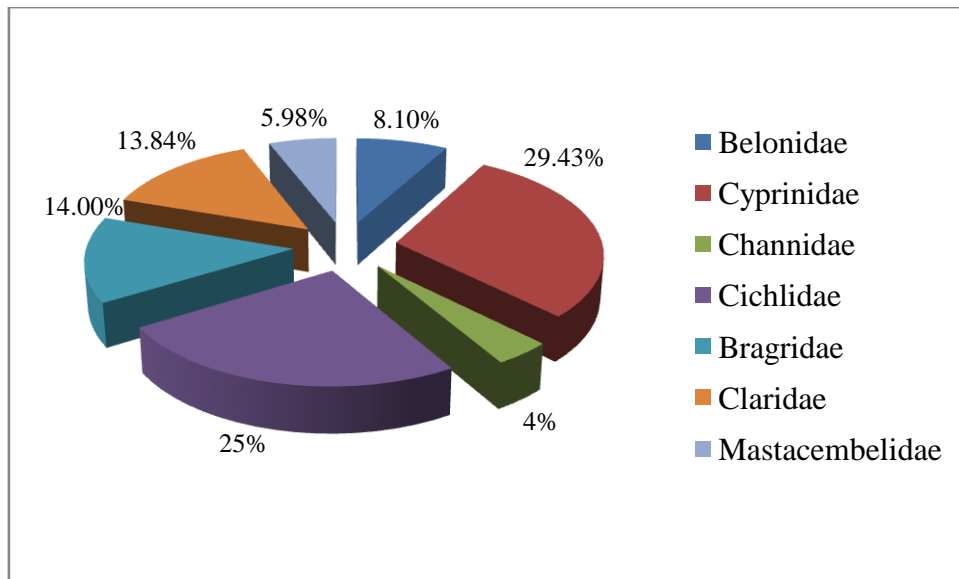


Fig 3. Total Fish species diversity based on total catch % at family level.

4.3.3 Monthly wise fish diversity, richness and evenness of Dipang Lake

The highest catch of 11 species was recorded in July, September and November whereas the lowest catch was recorded in May only 10 species. Monthly values of Shannon-Weaver diversity (H), Margaf's richness (D) and Pielou' evenness indices (e) were presented in Fig 4. The average values of H, D and e were recorded as 1.90, 1.73 and 0.844 respectively. Also, diversity index, richness index and evenness index ranged from 1.68 to 2.10, 1.53 to 2.16 and 0.808 to 0.883 respectively.

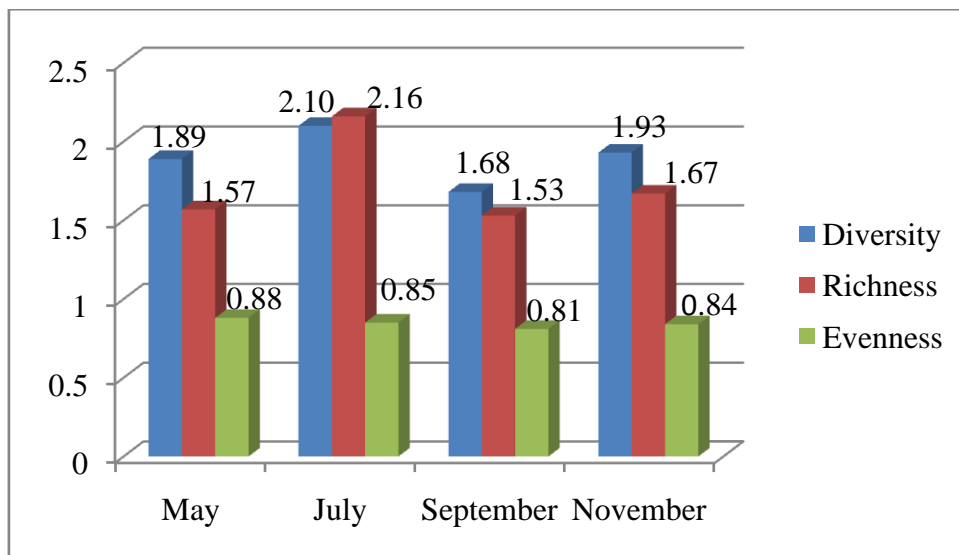


Fig 4. Month wise fish diversity, richness and evenness indices of Dipang Lake

4.3.4 Station wise fish diversity, richness, evenness of Dipang lake

The highest number fish species were recorded at station III whereas the lowest number recorded at station II. Statistical values of Shannon-Weaver diversity, Margalef's richness and Pielou's evenness indices collectively for all study sites were presented in Fig 5. The value of diversity indices, richness indices and evenness indices were ranged from 1.83 to 2.08, 1.56 to 2.08, and 0.738 to 0.859 respectively. The highest rank of diversity recorded at station IV (2.08) and lowest at station II (1.83). Similarly, it was recorded that highest richness at station IV (2.08) and lowest at station II (1.56). Pielou's evenness indices was lowest at station I (0.738) and highest at station II (0.859).

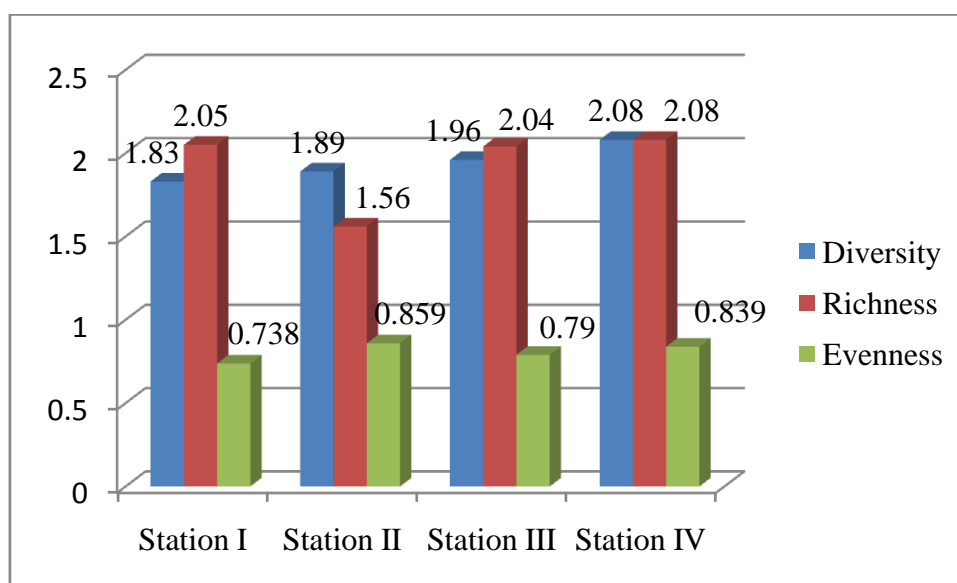


Fig 5. Station wise fish diversity, richness and evenness indices of Dipang Lake

4.4 Systematic position of fishes

The collected fishes were identified and given proper systematic position based on the identification method of Jayram (1981), Shrestha (2008) and Shrestha (2011).

I. Order: Synbranchiformes

Family: Mastacembelidae

Genus: *Mastacembelus* (Scopoli) 1777

Species: *M. armatus* (Lecepede) 1800

II. Order: Beloniformes

Family: Belonidae

Genus: *Xenentodon* (Regan) 1911

Species: *X. cancila* (Hamilton-Buchanan) 1822

III. Order: Cypriniformes

Family: Cyprinidae

Sub-family: Cyprininae

Genus: *Chagunius* (Smith) 1945

Species: *C. chagunio* (Hamilton) 1822

Genus: *Puntius* (Hamilton-Buchanan) 1822

Species: *P. ticto* (Hamilton-Buchanan) 1822

Species: *P. sophore* (Hamilton-Buchanan) 1822

Genus: *Ctenopharyngodon* (Steindachner) 1866

Species: *C. idella* (Valenciennes) 1844

Genus: *Cyprinus* (Linnaeus) 1758

Species: *C. carpio* (Linnaeus) 1758

Sub- family: Rasborinae

Genus: *Barillius* (Hamilton-Buchanan) 1822

Species: *B. barna* (Hamilton-Buchanan) 1822

Genus: *Esomus* (Swalnsn) 1839

Species: *E. dandricus* (Hamilton-Buchanan) 1822

IV. Order: Perciformes

Family: Channidae

Genus: *Channa* (Scopali) 1777

Species: *C. punctatus* (Bloch) 1793

Species: *C. gauchua* (Bloch) 1793

Family: Cichlidae

Genus: *Oreochromis* (Gunther) 1889

Species: *O. nilotica* (Linnaeus) 1758

V. Order: Siluriformes

Family: Bagridae

Sub-family: Braginae

Genus: *Mystus* (Scopali) 1777

Species: *M. bleekeri* (Day) 1878

Family: Clariidae

Genus: *Clarias* (Scopali) 1777

Species: *C. batrachus* (Linnaeus) 1758

Species: *C. gariepinus* (Burchell) 1822

4.5 Physical parameters

4.5.1 Water color

Water color of Dipang Lake was grayish muddy during May and it remained greenish during rainy period (July to November).

4.5.2 Water temperature

Water temperature ranged from 23°C to 30°C with an average temperature of 26.5°C. The highest temperature was recorded 30°C in July and September at station I, III and IV and lowest temperature in November at station III (23°C).

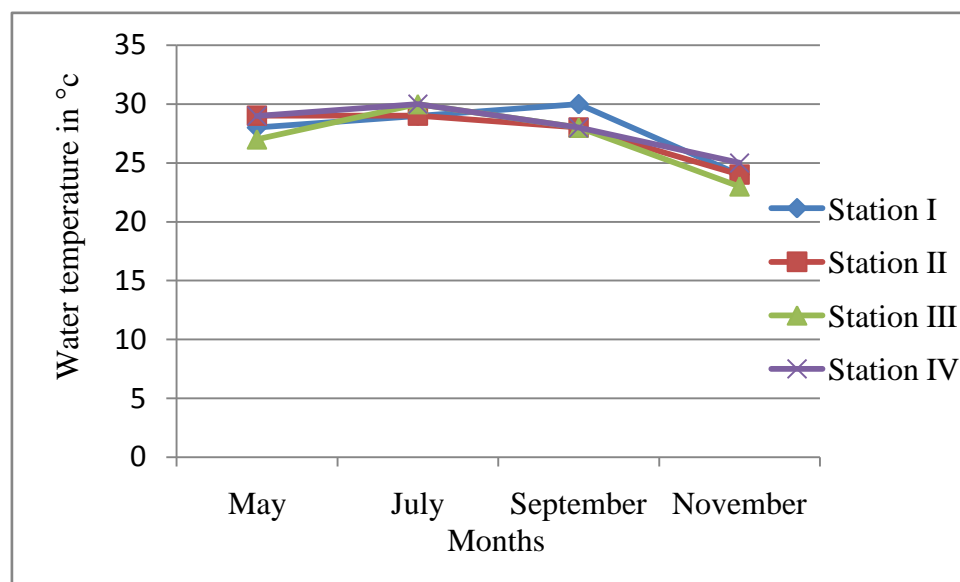


Fig 6. Variation in temperature at four sampling stations

4.5.3 Water depth

The highest depth was recorded in July (235 cm) and the lowest depth was recorded in May (90 cm). Similarly, highest depth found to be at station IV (235 cm) and lowest at station I (90 cm).

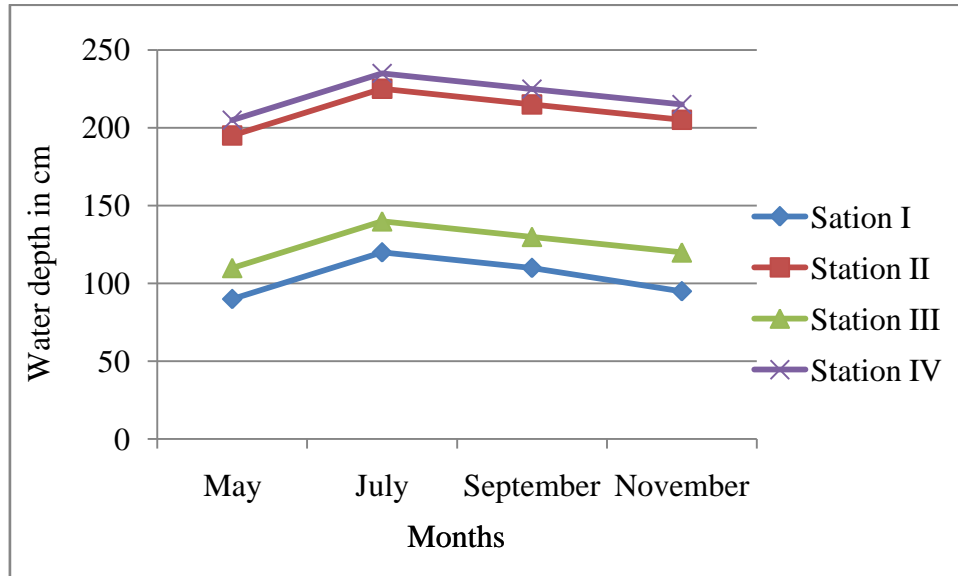


Fig 7. Variation in depth at four sampling stations

4.5.4 Water transparency

Water transparency was found comparatively higher in July at station IV (107.5 cm) and lower in May at station II (69 cm).

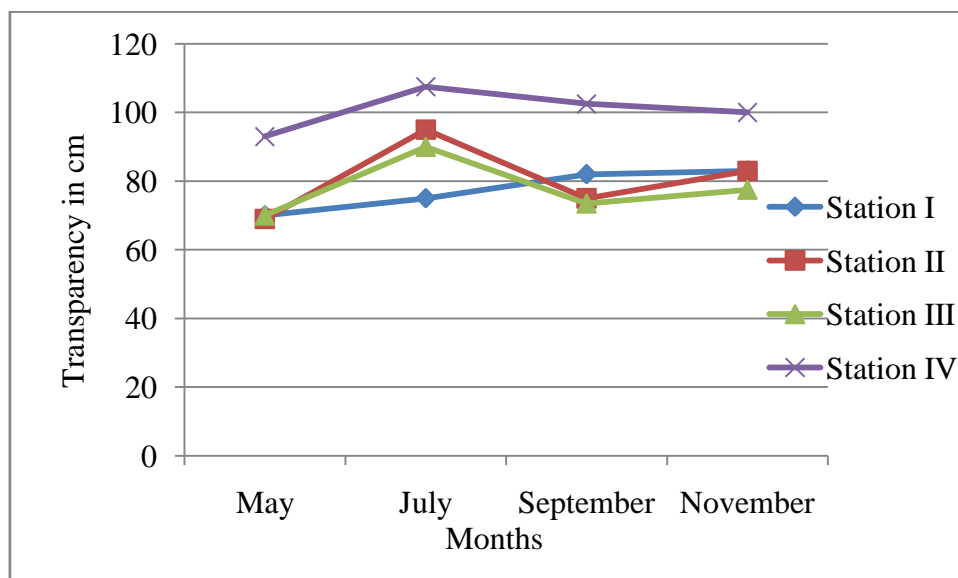


Fig 8. Variation in water transparency at four sampling stations

4.6 Chemical parameters

4.6.1 Dissolve oxygen

The concentration of dissolved oxygen was found lowest 5.1mg/l in May at station II and the highest value 8.38mg/l in September at station I.

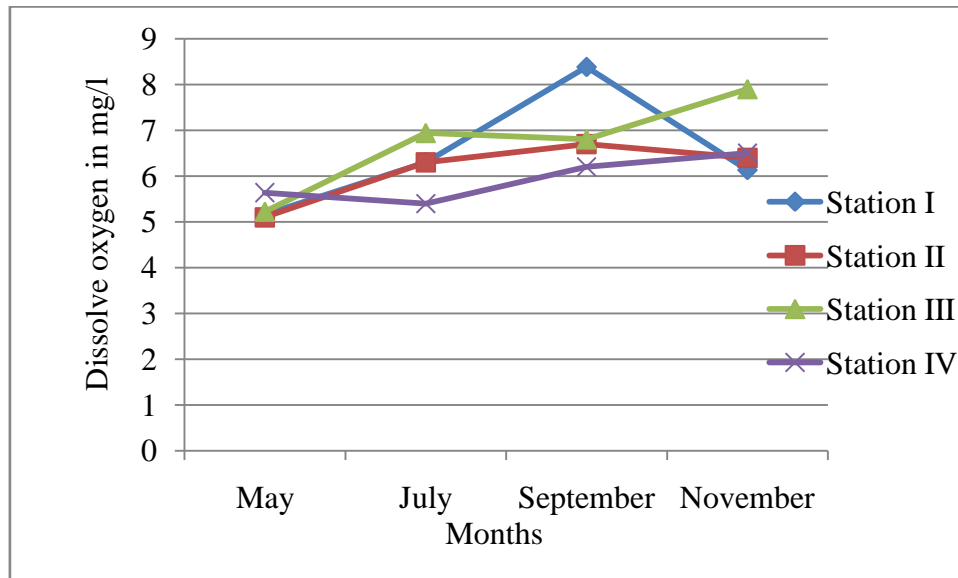


Fig 9. Variation in dissolve oxygen at four sampling stations

4.6.2 Free carbon dioxide

The free carbon dioxide of the Lake ranged from 0.8 to 3.2 mg/l. The highest value of CO₂ was recorded in September and November almost in all stations (3.2 mg/l) while lowest value recorded in May at station III (0.8mg/l).

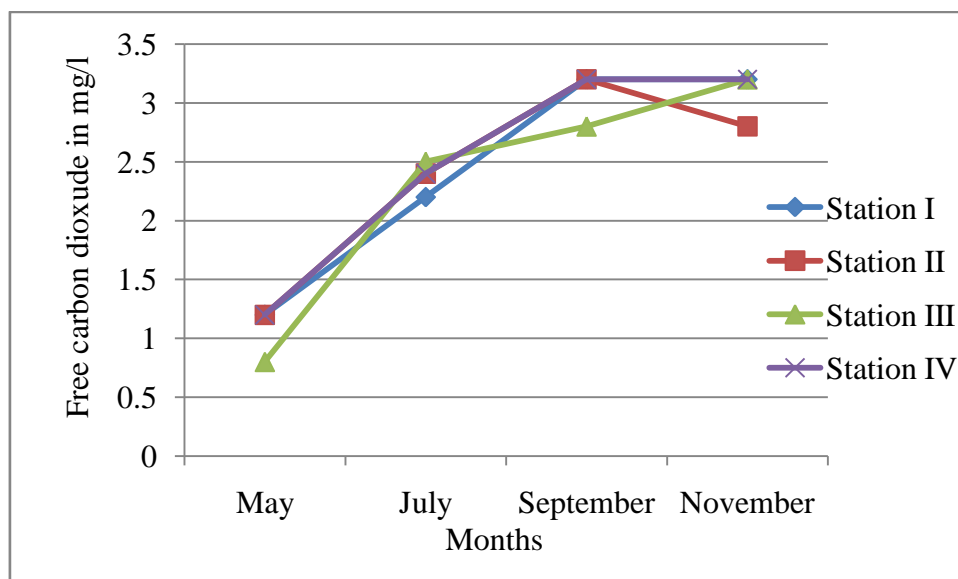


Fig 10. Variation in free carbon dioxide at four sampling stations

4.6.3 Hydrogen ion concentration

The water pH was found to be slightly changeable during study period. The pH ranged from 6.2 to 8 ppm during the study period. The highest value of pH recorded at station III (8 ppm) in September and lowest value at station I in May (6.2 ppm).

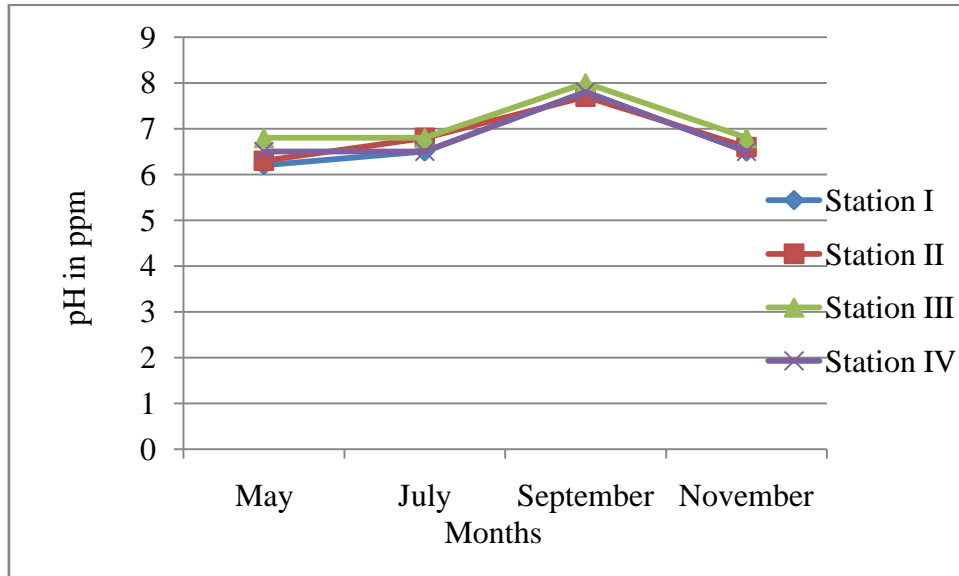


Fig 11. Variation in pH at four sampling stations

4.6.4 Water hardness

The hardness of water ranged from 12 mg/l to 36 mg/l. Hardness was found to be highest at station I (36 mg/l) and the lowest was recorded at station III (12 mg/l).

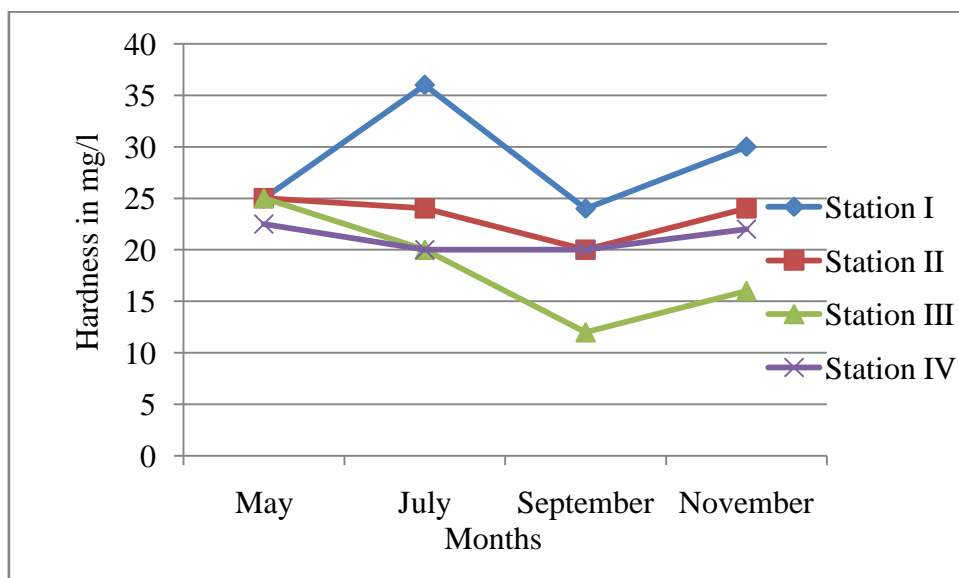


Fig 12. Variation in hardness at four sampling stations

4.6.5 Total alkalinity

The total alkalinity of the water ranged from 50mg/l to 100mg/l. It was found to be highest range in May and lowest range during November. The highest value recorded at station III (100mg/l) and lowest at station II (50mg/l).

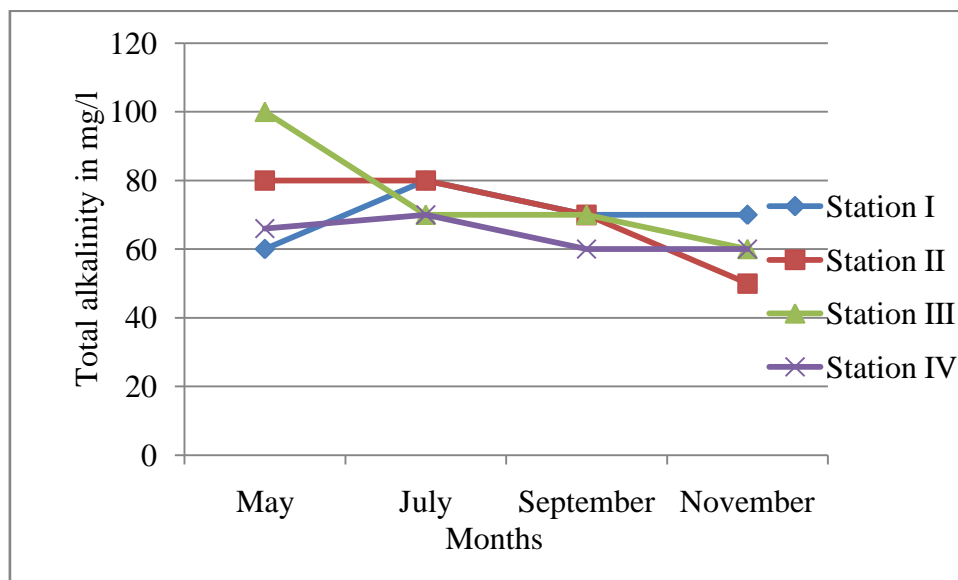


Fig 13. Variation in total alkalinity at four sampling stations

4.7 Correlation between fish diversity and water parameter of Dipang Lake

The coefficient of correlation between different physico-chemical parameters and fish diversity was calculated by Karl Pearson method (Singh, 2011) and significance of correlation was tested. DO and fish diversity were found to be positively correlated at all stations (0.190, 0.104, 0.138 and 0.150). The water temperature and fish diversity were also found positively correlated at all stations (0.959, 0.927, 0.324 and 0.671). Similarly, alkalinity and fish diversity were also positively correlated at all the stations with higher correlation at station I (0.852) and lower correlation at station II (0.246). Free carbon dioxide and fish diversity observed positively correlated at station II (0.645) and III (0.183) while it was found negatively correlated at station I (0.091) and IV (0.519). Fish diversity and transparency were negatively correlated at station IV (-0.045) while it was positively correlated at stations I (0.062), II (0.108) and III (0.299). Further, pH and fish diversity showed positive correlation at stations I (0.217), II (0.853) and III (0.773) while it showed negative correlation at station IV (-0.543). Water depth and fish diversity showed positive correlation at three stations with higher value at station I (0.979) and lowest at station II (0.674) and negatively correlated at station IV (-0.948). Water hardness and fish diversity showed negative correlation at stations II (-0.902) and III (-0.954) and positive correlation at stations I (0.298) and IV (0.775).

Table 5. Correlation coefficient between physico-chemical parameter and fish diversity

S. N.	Variables	Station I		Station II		Station III		Station IV	
		r	PE(r)	r	PE(r)	r	PE(r)	R	PE(r)
1.	Temperature and fish diversity	0.959	0.027	0.972	0.048	0.324	0.302	0.671	0.186
2.	Water depth and fish diversity	0.979	0.014	0.674	0.184	0.775	0.135	-0.948	0.034
3.	Transparency and fish diversity	0.062	0.336	0.108	0.334	0.299	0.307	-0.980	0.014
4.	Water DO and fish diversity	0.190	0.325	0.104	0.334	0.138	0.331	0.190	0.330
5.	CO ₂ and fish diversity	-0.091	0.339	0.645	0.197	0.183	0.326	-0.519	0.247
6.	pH value and fish diversity	0.217	0.322	0.853	0.092	0.773	0.136	-0.543	0.238
7.	Alkalinity and fish diversity	0.852	0.093	0.246	0.312	0.502	0.252	0.331	0.300
8.	Water hardness and fish diversity	0.298	0.308	-0.902	0.063	-0.954	0.031	0.775	0.135

5. DISCUSSION

The present study was conducted for four different months from May 2017 to November 2017 to cover the maximum species occurrence. This study revealed that a total of 15 species of fish fauna belonging to 5 orders and 7 families. Out of 15 species, 11 species were mentioned as indigenous species and 4 were exotic species. Existence of one invasive species of catfish *Clarias gariepinus* and hardy species like *Oreochromis nilotica* were found in this lake. According to local people and fishermen, this genus might have been introduced along with carp fingerlings during the practice of open water polyculture from 2000 to 2005 in this lake.

The result found that Cypriniformes was the most dominant order comprising 46% of all the number of species recorded. Similar result was reported from Begnas Lake and Rupa Lake by Husen and Sherpa (2017) and Gautam *et al.*, (2016). Pokharel (1999) mentioned the order Cypriniformes was dominant in terms of both species composition as well as individuals captured in the lakes of Pokhara valley. Similarly, Perciformes and Siluriformes were reported as second and third dominant order in Dipang Lake. According to fishermen these orders were reported throughout the year in this lake. The important indigenous species *Puntius sophore*, *Mastacembelus armatus*, *C. batrachus*, *Mystus bleekeri* and *Xenentodon cancila* were also found to be dominant forms at most of the present study sites.

In total fish species diversity based on total catch percentage at family level, family Cyprinidae contributed by 29.43%. It was probably due to their inhabitant in fresh water and ample food resources viability. Pokharel (2011) and Gautam *et al.*, (2016) have also reported family Cyprinidae was dominant family from Seti River and Rupa Lake of Pokhara. According to Gautam *et al.*, (2016) family Mastacembelidae was recorded as lowest in Rupa Lake but in this lake family Channidae found to be lowest in number and catch during study period due to muddy living nature of Channidae. Also, it might be due to inefficient implementation of fishing gears.

This study revealed that higher frequency distribution of hardy species of *O. niloticus* (25.31%). It is due to high tolerates capacity of this fish in adverse water quality conditions (Rao, 2017). Also, indigenous species such as *P. sophore* (18.33%) found to be higher distribution in comparison to other species. According to fishermen, *Tor putitora*, *Tor tor*, *Puntius sarana* and *Labeo dero* were also reported in this lake but it was not observed during my study period.

The maximum numbers of species were found in July, September and November while only 10 species were recorded in May. Higher number of fish species were recorded in these months due to favorable conditions such as sufficient water and ample food resources but lowest species in May which might be due to shrinkage of water coverage of lake. Result also showed that maximum number of fish was caught in November due to the low water depth, profoundly development of phytoplanktons and minimal rainfall which allows fishermen to employ their fishing gears more efficiently. Similar result was

reported by Gautam *et al.*, (2016) in Rupa Lake and Nath and Deka (2012) in Chandibi Lake, India. Probably due to good area for fishing and having input stream with lotus plants for their habitat maintenance the total catch number found to be high at station III compared to station II. Some species like *E. dandricus* was only recorded during July in shallow water surface nearer to rice field it was probably due to its shallow water inhabitant. Similarly, *C. punactatus* was reported in station IV in July due to their spawning season and muddy habitat. *C. idella* and *C. carpio* were recorded from stations III and IV during this study period. Especially Grass carp was recorded in that area where water plants such as water lotus and water weeds were highly present. Common carp is one of the bottom feeder fish they can feed their food from bottom of the lake. According to local fishermen, these fishes are caught occasionally anywhere of this lake.

Indices for both diversity (Shannon-Weaver diversity) and richness (Margalef's richness index) of fish species were calculated higher during July i.e. 2.10 and 2.16. Similarly, station wise diversity index and richness enumerated higher at stations IV (2.08) and (2.08) respectively. The Shannon-Weaver biodiversity index values obtained from present study was not very high. The reason for showing lower species biodiversity is that fishing gears used have high selectivity effect (Keskin and Unsal, 1998). Evenness indices standardize abundance and range from near zero when most individuals belong to a few species, to close to one, when species are at nearly abundant (Smith and Wilson, 1996). The Evenness Index was found to be highest at station II (0.862) in May (0.883) whereas the lowest was found to be at station I (0.740) during September. In this lake, evenness index considered as nearly abundant.

Water color of this lake was recorded as grayish muddy in May but in remaining three months it was greenish in color. The color of water may be determined by suspending clay particles and presence of phytoplankton. Decline (1992) stated that the abundance of phytoplanktons and zooplanktons are responsible for color of an aquatic body and green bluish green color of water indicates good plankton population.

The water temperature largely influences the physical, chemical and biological factors of an aquatic ecosystem. The oxygen retaining capacity of water diminishes and biological oxygen demand increases with the rise in water temperature (Holden and Armstrong, 1980). According to Hutchinson (1957) the metrological conditions are responsible for seasonal water temperature change. The water temperature almost remained similar in three months and it was found slightly changed during November (Fig 6). Bastola (2013) recorded water temperature 17.2°C to 25°C from this lake during August to January and considered that water temperature of the lake seems to be related with the atmospheric temperature. Santosh and Singh (2007) mentioned suitable water temperature for fish is between 24°C to 30°C. The correlation between temperature and fish diversity found to be positive at all stations. It showed the higher correlation at station I (0.959) and lower at station III (0.324).

The depth of water is important physical parameters which directly or indirectly affects fish species diversity. It was observed that small species like *Barilius spp.*, *Puntius spp.*,

etc. were found to be distributed in shallow habitat and large sized species such as *Clarias spp.*, *Cyprinus spp.*, were recorded in deeper region. According to Shaikh *et al.*, (2011) it is due to high level of trophic flexibility which makes them to occupy the some ecological niche. Water depth was found to be positively correlated in three stations while it was negative correlation at station IV (0.948).

Probably due to more settlement of suspended particles and higher production of phytoplankton highest value of transparency was recorded during July (107.5 cm) (Fig 8). The Minimum value of transparency was found during May (69 cm) possibly due to less production of phytoplankton and degradation of organic and inorganic materials. It is also suggested that the rain-fed turbidity, reflection of light and restriction of light penetration in an aquatic environment are responsible for transparency status (Stepanek, 1959; Gregory *et al.*, 1991). Transparency value of this lake also recorded from 1.4 m to 2 m by Bastola (2013) and mentioned the higher value due to growth of phytoplanktons. The correlation found to be positively correlated at stations I (0.062), II (0.108) and III (0.299) whereas it was recorded negative correlated at station IV (-0.980).

Dissolve Oxygen is one of the essential limnological factors in lake water reaction (Edmondson, 1966). In any aquatic ecosystem, DO concentration is the most important factors and DO above 5 mg/l is suitable to support diverse biota (APHA, 1976). DO of Dipang Lake ranged from 5.1 to 8.38 mg/l with an average of 6.74 mg/l (Fig 9). Due to low oxygen dissolution at high temperature (Dutta and Patra, 2013) and use by decomposers in water body, low value was measured in May. During rainy season growth of plankton and rain also helps to aerate the surface water (Vass *et al.*, 1977; Rather *et al.*, 2001). Kafle (2000) also reported similar result in Rupa Lake. Bastola (2013) recorded 6.7 mg/l to 8.7 mg/l from this lake which was slightly higher than present study. DO show the positively correlated at all stations with higher correlation at station I (0.190) and lower at station II (0.104).

Most of the CO₂ in the water is formed by the decomposition of organic matter and from respiration of organism. According to Ekulo and Abowei (2011) tropical fishes can tolerate CO₂ level over 100 mg/l but the ideal level of CO₂ in fish ponds is less than 10 mg/l. In the present study Free CO₂ was found to be increasing from May to September while similar values were recorded during September and November (Fig 10). The highest value of Free CO₂ in September and November may be due to presence of maximum Free CO₂ in rainy season (Thapa and Pal, 2011) and decomposition of organic matter (John and Martin, 1996). Chawdhari (2011) also suggested that longer photoperiod and high decomposition rate at high temperature made Free CO₂ higher in summer. The minimum values of Free CO₂ during May probably due to CO₂ utilization in photosynthesis activities (Sreenivasan, 1971). Bastola (2013) recorded CO₂ value from 1.8 mg/l to 5.6mg/l in this lake and considered photosynthetic activities of planktons is an important factor for CO₂ fluctuation. The correlation of Free CO₂ and fish diversity was found to be positively correlated at station II (0.645) and III (0.183) and it was recorded negative correlation in two stations.

Due to sewage and solid waste chemicals discharge from agricultural fields, the highest pH value was recorded at station III in September (Fig 11). Lowest pH value in May at station I might be due to decreasing level of water and high evaporation effect (Dutta and Patra, 2013). Bastola (2013) also observed the pH value range 6.5 to 7.5 ppm from this Lake and suggested that pH value depends upon the precipitation of calcium carbonate by planktons. Wetzel (1973) considered that the majority of open lakes have pH range 6 to 9 ppm and most of these lakes are bicarbonate type and favorable for the aquatic inhabitation. The correlation coefficient with fish diversity found to be positive at stations I (0.217), II (0.853) and III (0.773) while it was negative value at station IV (-0.543).

The desirable range of water hardness is 50 to 150 mg/l and acceptable range is above 10 mg/l as CaCO₃ (Stone and Thomforde, 2004). In present study the higher value of hardness recorded at station I (36 mg/l) and lowest value at station III (12 mg/l) (Fig 12). Higher total hardness during July at station I might be due to maximum photosynthetic activity, free carbon dioxide utilization and formation of carbonates and precipitation as calcium salts. Such type of result was recorded by Reid and Wood (1976) from inland water and eustaries. Similarly, it was higher in May possibly due to low volume of water and slow current of water. But, due to dilution affect its value lower in rainy period (Patralekh, 1994; Usha *et al.*, 2006). The correlation co-efficient found to be negative at stations II (-0.902) and III (-0.610).

According to Wurts and Durbow (1992), alkalinity between 75 to 100 mg/l but not less than 20 mg/l is ideal in aquaculture pond. In water, the carbonate alkalinity occurs only in the absence of carbon dioxide and pH greater the 8.3 mg/l (Rutter, 1953). The total alkalinity was recorded higher level at station I in May possibly due to low depth, high organic matter accumulation and decomposition. Similarly, it was recorded lower in September and November probably due to dilution effect. Similar trends were also reported by Shristi and Pandse (2001) from Daikuta reservoir and Rai (2000) from Fewa, Begnas and Rupa Lake. Bastola (2013) recorded the total alkalinity from 105 mg/l to 114 mg/l in this lake and considered that alkalinity was mainly due to carbonate and bicarbonate ions. The correlation of total alkalinity and fish diversity of lake showed positive relation at all stations (Table 5).

The ichthyo-faunal study indicates that this water body is rich in fish diversity. It consists of indigenous species, economically cultivatable and ornamental fishes. But, due to the introduction of exotic fishes like Tilapia (*O. niloticus*) and Magur (*C. gariepinus*) showed negative impact on indigenous fish species. Local fishermen of this area found to be using both traditional and modern gears to catch fishes (Plate V and VI). The traditionally prepared gears were Thakai, Bamboo basket, Hook in bamboo stick and modern gears were Cast net, Gill net and Rod and line. The selectivity of the fishing gear was varied with the fishes to be caught. During study period, it was observed that the most common period for fishing on June to October. Basically, unemployment male, school age children and house hold female were found to be interested in fishing. They consume fish by smoking or frying and use only for their food items.

Dipang Lake has innumerable value in Lake Clusters of Pokhara valley. Infrastructure development around the lake and management of water plants and weed are necessary to facilitate the tourist destination. Some water weeds and plants are beauty of lake, they not only makeup the beauties of lake also maintain the ecosystem of lake by providing shelter for aquatic species. Similarly, without taking EIA measurement it increases anthropogenic inputs, pressure on the life of biodiversity and aquatic ecosystem and makes the lake unsightliness. To balance such environment, EIA implementation and water-hyacinth from these open use areas need to be removed regularly and eater hyacinth in the protected areas of the lakes should be kept untouched in natural condition for the healthy and natural aquatic bio-diversity purpose (Kafle *et al.*, 2008).

Future priority of lake is incomparable. It has greater value in ground water recharged, flood control, sediment trapping and irrigation. Although having its innumerable value in human life, its condition going on problem due to shoreline encroachment, water pollution, sedimentation, illegal fishing and catching brooder fishes. It is necessary to stop such activities for extends its life span, maintain its cleanliness, conservation of fish diversity and promote it as an attractive tourists destination. The management of lake and wetland can be done by making future priorities such as wetland restoration focusing on sedimentation control, sustainable land use practices, water quality improvement and pollution control. Therefore, management priority of lake is common objective in now. A sustainable strategies needs to explore more fish species, utilization and save fish community of this lake. The study will prove future strategies for development and fish conservation in this lake.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The total numbers of 15 fish species were recorded from the different stations of Dipang Lake belonging to 5 orders, 7 families and 12 genera. Fishes were not found uniformly distributed in the lake it might be due to variation of physico-chemical conditions. Dipang Lake is the good habitat for different species of fish such as *Puntius* spp., *Channa* spp., *Clarias* spp., *Mastacembelus* spp. etc. The dominant order, family and species of lake were Cypriniformes, Cyprinidae and *Oreochromis nilotica* respectively. However, dominancy of indigenous species was represented by *Puntius sophore* and *Chagunius chagunio* was reported as fairly common species. In diversity index, richness index and evenness index, there was no significant different observed in the present study.

Water qualities of Dipang Lake not show significant variations except for carbon dioxide and hydrogen ion concentration. The result indicates the anthropogenic activities (agricultural activities) and rainfall regime as major factors affecting water parameters. However most of the physico-chemical parameters of this lake meet suitable range for aquatic habitat and it was also found that fish diversity is significantly correlated with physico-chemical parameters of lake. The present condition of lake is manifesting by annual siltation, eutrophication, human encroachment, seasonal microphytic coverage and intervention of exotic as well as invasive species which are the most important factor for decline and extinction of indigenous fish. To address this situation, concerned authorities like Pokhara Wetland Conservation Committee, Dipang Sahakari Sasthan (Co-operative Organization) and other related organizations need to take immediate action for their conservation.

6.2 Recommendations

- Maintenance of minimum water depth during dry season by water extraction.
- Introduction of exotic/invasive fish *Clarias gariepinus* should be totally band.
- Suitable cultivation practices should be encouraged in the sub-watershed areas to check sedimentation to the stream and Lake.
- The Aquatic Animals protection Act 2017 should be implemented effectively through the concerned governmental agencies.

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PLATE I

Fishes of Dipang Lake



Clarias batrachus (Linnaeus) 1758



Barilius barna (Linnaeus) 1758



Mystus bleekeri (Day) 1878



Esomus dandricus (Hamilton-Buchanan)
1822



Puntius sophore (Hamilton- Buchanan)
1822



Puntius ticto (Hamilton- Buchanan) 1822

PLATE II

Fishes of Dipang Lake



Chagunius chagunio (Hamilton- Buchanan)
1822



Channa punctatus (Bloch) 1793



Channa gauchua (Bloch) 1793



Mastacembelus armatus (Lecepede) 1800



Xenentodon cancila (Hamilton-Buchanan)
1822



Cyprinus carpio (Linnaeus) 1758

PLATE III

Fishes of Dipang Lake



Clarias gariepinus (Burchell) 1822



Oreochromis niloticus (Linnaeus) 1758



Ctenopharyngodon idella (Valenciennes) 1844

PLATE IV

Short view of Dipang Lake area



Scenario of Dipang Lake



Fish collection and sampling



Fishermen fishing at Kali khola of Dipang Lake

PLATE V

Fishing implements and methods



Thakai and fish collecting bamboo basket



Fishing disc and using mosquito net for fishing



Women fishermen and chemical analysis

PLATE VI

Fishing implements and methods



Describing fishing gear by local fishermen



Present condition of lake and water measuring Range

APPENDIX I
Questionnaires for fishermen

Name of respondent: Gender:
Age: Occupation: Date:
Place: Month:

- 1) How many species of fish are available in the lake?
.....
- 2) Which fish species are most common in the lake?
.....
- 3) What do you do with captured fishes?
.....
- 4) If you sell fish, where do you sell it?
.....
- 5) How much fish does your family consume per year?
.....
- 6) In which month do you captured more fishes?
.....
- 7) Do you smoke fish?
.....
- 8) In which season do you go to fishing?
.....
- 9) What type of fishing gears do you use during different time of year?
.....
- 10) What do you say about fish species has increased or decreased?
.....
- 11) How can you identify the fishes?
.....
- 12) Do you know any flood impact on lake in the rainy season?
.....
- 13) Is it good to being carried out agriculture near by the lake?
.....
- 14) What are the main causes for pollution in the lake?
.....
- 15) Any organizations are come to release fish fries here?
.....
- 16) What are our responsibilities to conserve the Lake Dipang?
.....

Name of interviewer: