1. INTRODUCTION

1.1 Background

Nepal is a small country with diverse geographical regions, viz., lowland, midland and highland with snow cover. It is roughly rectangular and elongated in shape obtaining about 885 km in length (east-west) and 193 km in width (north-south). The altitude ranges from 70 m above sea level in the Terai region (south) to 8,848 m at the highest peak of the world, the Mount Everest (Sagarmatha) in the north. It is situated on the northern hemisphere in between 26°22 to 30°27 north latitude and 80°4 to 88°12 east longitude with the total area of 1,47,181 sq. km (Amatya and Shrestha 1967).

Topographically, Nepal has been divided into three distinct geographical regions according to the altitudinal variation i.e. The Himalayan region, which occupies 15 percent (22,077 sq. km.) of the total area of Nepal and it lies above the altitudinal range of 16000 ft (4800 m) from the sea level. The Sub-Himalayan region are found between the south of the Himalayas and the north of the Terai region with a chain of massive mountains running from west to east which constitutes about 60 percent of the total area of Nepal, lying in between 2000 ft (600 m) to 16000 ft (4800 m). This part consists of many Basins, Valleys, Rivers, Streams, Lakes etc. And lower plain of Terai region which occupies about 25 percent of the total area of Nepal. which is a narrow belt of low land situated at an altitude above 70 m from sea level to sub-Himalayan region (Amatya and Shrestha 1967).

"Biological Diversity" or Biodiversity is the term given to the variety of life on earth. It is the variety within and between all species of plants, animals, and micro-organisms and the ecosystems with which they live and interact. Nepal is a less explored country regarding fish diversity (Shrestha 2008). Moreover, fish diversity of Nepal has been poorly studied or understood relative to other fauna (Shrestha et al. 2009). 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).

1.2 Water Resources

The inland water resources of Nepal totaling 8,17,100 ha consisting of river systems, lakes, reservoirs, village ponds, wet lands and irrigated rice fields covering the surface area of about 5.5 % of the total are of the country (DOFD 2008). These resources can be categorized as i) open inland waters of rivers, lakes and reservoirs, ii) closed water bodies, ponds and wet lands and iii) seasonal irrigated rice fields. The natural water resources of Nepal consist of rivers, lakes and reservoirs, comprising of approximately 54 % of the total existing water of Nepal (Pradhan and Pantha 1995). 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 to 3 types on the basis of their origin, i.e. I) Glacial, ii) Tectonic and iii) Ox-bow. A glacial lake is a body of water which is created by the direct action of glaciers and continental ice sheets. There are 17 major glacial lakes in the northern Himalayan region which are located above 4000-meter altitude. Tectonic lakes are those water body which is formed by the deformation and resulting lateral and vertical movements of the Earth's crust which occur in the Hill region. Ox-bow lakes are mainly those water body which is formed by the collection of surrounding water sources such as rivers, lakes and precipitation. The presence of Ox-bow lakes indicates the shift of river course and form a separate stagnant water body and there are more than two dozen of ox-bow lakes in Nepal (Sharma 1977).

1.3 Fish diversity in Nepal

Nepal occupies a large part of the central Himalayas which supports the varying array of water bodies supporting biologically diverse fish fauna. According to Shrestha (2019), there are 252 fish species included in 104 genera belonging to 35 families and 15 orders. Among 15 orders, Cypriniformes is the most dominating order with 135 species. On this account, mostly we can say that Nepal is a habitat for Order Cypriniformes. The fish of Nepal usually not mentioned under the category of IUCN and CITES list. However, realizing the present status of fish of Nepal, some fishes are found under threatened condition. Total 36 threatened fish species (vulnerable, endangered and rare species) are recorded from Nepal consisting of 14 percent of total number species. 71 species (28 % of total number of species) have the status of rarely/occasionally recorded. 42 species (16 %) have the status of insufficiently known.

The maintenance of healthy aquatic ecosystem is dependent on the physico-chemical properties of water and biological diversity (Aazami et al. 2015). The interaction of both the physical and chemical properties of water that effect the environmental variables play a significant role in composition, distribution, abundance, movements and diversity of aquatic organisms (Deepak and Singh 2014). Among the factors that affect environmental condition, temperature, dissolved oxygen, pH, turbidity, water transparency and free carbon-dioxide are the key one for diversification in biological functions (Aazami et al. 2015). Regarding the spatial and temporal distribution of fish assemblages of Nepal, very few research works has been carried out. Some aspects of the fisheries and fish ecological studies such as their diversity, spatial and temporal distribution and abundances are needed (Mishra and Baniya 2016).

1.4 Endemic fish 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). Later Conway and Mayden (2010) and Conway et al. (2011) enlisted Fifteen species of freshwater fish under endemic species, which are listed below.

Table 1: Endemic freshwater fishes of Nepal

S.N.	Scientific name	S.N.	Scientific name
1.	*Schizothoraichthys macrophthalmus*	9.	*Erethistoides ascita*
2.	*Schizothoraichlhys nepalensis*	10.	*Erethistoides cavatura*
3.	*Schizothoraichthys raraensis*	11.	*Psilorhynchus nepalensis*
4.	*Psilorhynchoides pseuclecheneis*	12.	*Pseudechenesis crassicauda*
5.	*Myersglanis blylhi*	13.	*Pseudechenesis eddsi*
6.	*Pseudeutropius murius*	14.	*Pseudechenesis serracula*
7.	*Batasio macronotus*	15.	*Turcinooemacheilus Himalaya*
8.	*Balitora eddsi*		

Source: Shrestha (2011)

1.5 Objectives of the study

General objective

The general objective of this study was to assess conservation importance of Jakhor Taal with special emphasis on fish diversity and fishing communities in Dhangadi, Kailali, Nepal.

Specific objectives

a) To identify the fish diversity of Jakhor Taal
b) To assess the factors determining fish diversity of Jakhor Taal
c) To assess the socio-economic status of local fishing community
d) To identify conservation challenges of fish fauna of Jakhor Taal.

1.6 Justification of study

The Jakhor Taal is one of the large (13.49 ha) perennial and highly diversified lake which lies in the Far Western Development Region of Nepal. The main sources of water for this lake is usually through rain fall and small streams which runoff from nearby surrounding forest. The water level during the winter and summer falls to considerable amount but doesn't dry up. Hence it is important from bio-diversity point of view. Since there is a lack of research on this place before, there was a nice opportunity to understand the factors and condition about the current state about of Jakhor Taal. Therefore, the present study has been undertaken to gather the basic information about fish diversity, fishing communities, environmental factors and conservation implication of the Jakhor Taal. It is believed that this study will helps in obtaining the basic knowledge to meet the government's target to further helps in improvement in planning, management, conservation of the fresh water fishes of Jakhor Taal and its surrounding habitat.

1.6 Limitation of the Study

a) Absence of secondary data about the Jokhar Taal, since no one has done research or thesis in this place before.

b) Large number of induced fishes have been cultivated in the same lake, hence to catch or collect local fishes become difficult.

c) Dense vegetation cover of Water hyacinth (*Eichhornia cassipes*) that negatively affect the fish catch per effort.

2. LITERATURE REVIEW

Fish diversity

The first authenticated information about the fishes of Nepal was given by Hamilton (1822) in the work "Fishes of the Ganges" where he gave an account of fish fauna of the Ganges and its tributaries. Hora (1937) obtained a collection of fishes from Nepal through Colonel Bailey which included 158 specimens of 22 species. Taft (1955) submitted a report of his survey of fishes of Nepal and collected 94 species of fishes from Kathmandu and adjoining areas. Bhatta and Shrestha (1973) studied the fish fauna of Suklaphanta and listed 27 species of fishes. A milestone work in the field of taxonomic study of fish fauna in Nepal has been done by (Shrestha 1970-1986) who published her findings in various journals. She has published a very popular book entitled *"Fishes of Nepal"* in 1981, describing scientific details of 120 species. Shrestha (2001) recorded 183 species of fishes in their work "Taxonomic Revision of Cold-Water Fishes of Nepal". Rajbanshi (2005) prepared a checklist from the published literature and reported 187 species. Tamrakar (2008) described 28 species of the fishes from the lake cluster of Pokhara valley. Shrestha (2008) in their 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.

Gautam et al. (2010) recorded 42 species of fishes belonging to 6 order, 18 families and 34 genera in their work "Fish Diversity of Jagadishpur Reservior, Kapilbastu District, Nepal – a Ramsar Site". Giri (2010) 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. Lamsal et al. (2014) studied on fish diversity, uses and threats in the Ghodaghodi Lake and reported 19 fish species. 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. 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. Thapa (2018) studied fish diversity of Dipang Lake and reported 15 species belonging to 5 orders, 7 family and 12 genera.

Factors determining fish diversity

Ferro and Swar (1978) The water temperature influence on water chemistry and high-water temperature cause the fluctuation in DO and pH of water. The factor which determine the fish assemblages' structure in riverine of both temperate and tropical regions are altitude, temperature, water velocity, depth, habitat complexity (Tejerina et al. 2005). The temperature is one of the most important factors limiting the fish diversity in the tropical and great altitude (Jacobsen, 2008). All aquatic organisms like fish, insects, zooplankton, and phytoplankton have different temperature ranges. The water temperature influence on aquatic life cycle, metabolism and behavior of fish and high-water temperature leads to the thermal stratification in the river and lake which may lead reduction in diversity and unequal distribution of fish (Jain et al. 2013). In Seti Gandaki River, the fish assemblages' structure is positively correlate with conductivity, carbon dioxide, phosphate and nitrogen compounds while the negatively correlated with pH and DO (Pokhrel et al. 2018).

Socio-economic status of local fishing community

A number of researchers in the country have studied on the socioeconomic status and ethnobiological knowledge of some fishing communities. Thapaliya (1998) has studied the both ethnic group and their involvement in local fishing in many rivers and wetlands. Swar (1980) estimated that there were about 80,000 fishing populations in the country. Guvaju et al. (2002) have studied on the contribution of cold-water fishes in the livelihood of mountain people of Nepal which reported that indigenous cold-water fishes have significant contribution as nutritional protein supplement and as a means of income source for the livelihood of local ethnic fisher communities. According to Bhudhathoki (2003), women too have been playing major roles in fisheries and agriculture since the very ancient time of human civilization. Mostly women from lower ethnic groups such as Mushar, Dhangar, Dom, Paswar, Malah, Danuwar, Majhi and Tharu are involved in fishing. Out of 103 ethnic groups, 20 of these groups largely live on the bank of water resources and are heavily dependent on the wet land products and services (IUCN 2014). The prominent groups are Pode or Jalari; Suneha, Mallah, Bote or Majhi, Mushahar, Mukhiya, Danuwars, Darai, Kumal and Tharu.

Conservation threats and challenges of fish

The fish assemblages have used as ecological indicators to evaluate health of water as well as level of degradation (Basavaraja et al. 2014).In context to conservation, Hill et al. (2018) propose practical steps for the effective incorporation or enhancement of ponds within five policy areas: through open water sustainable urban drainage systems in urban planning, increased incentives in Agri-environment schemes, curriculum inclusion in education, emphasis on ecological scale in mitigation measures following anthropogenic developments, and the inclusion of pondscapes in conservation policy. Strayer and Dudgeon (2010) made survey on freshwater biodiversity conservation which briefly discuss four important challenges for freshwater conservation. First, climate change that will imperil both freshwater species and human uses of fresh water. Second, because freshwater extinctions are already well underway, freshwater conservationists must be prepared to act now to prevent further losses. Third, we need to bridge the gap between freshwater ecology and conservation biology. Fourth, we suggest that scientific societies and scholarly journals concerned with limnology or freshwater sciences need to improve their historically poor record in publishing important papers and influencing practice in conservation ecology. Jha (2008) studied on status and conservation of lowland Terai Wetlands in Nepal that deals with current status and conservation challenges of Tarai wetland. Siwakoti and Karki (2009) studied on conservation status of Ramsar sites of lowland Nepal which highlight the status, threats, conservation issues and management practices of these Ramsar sites lying in Nepal Tarai. Wang and Yan (2017) studied on impact of water hyacinth on aquatic environment which stated that water hyacinth has negatively affect the physico-chemical parameters mainly DO, pH, Transparency and Free CO_2.

3. MATERIALS AND METHODS

3.1 Study area

The present study was carried out in Jakhor Taal which is a large perennial Ox-bow lake lies in Dewariya-7, Dhangadhi, Kailali, Nepal. It is one of the largest and richest lake in biodiversity (especially for fishes) and also listed as one of the finest wetland resources of Nepal which plays an important role in biodiversity. It covers a total area of 13.49 ha which consists large number of local and induced fishes. Near this lake there are another two lakes at the distance 200 m and 440 m, named Murfutta and Murfutti whose area are about 2.52 ha and 1.32 ha respectively. This lake is surrounded by the dense forest in the North-western part circulating 2/3 of the whole lake boundary and attached to the Dewariya Botanical Garden towards its south which contain total area of 149.50 ha which play an important role in In-situ and Ex-situ conservation. The main sources of water for this lake is usually through rain fall and small streams which runoff from nearby surrounding forest and collected in this place. This lake is situated at 165m high from the sea level. The water level during the winter and the summer falls to considerable amount but doesn't dry up. But during rainy season water level extend to high and get overflowed. Hence it is important from bio-diversity point of view.

Altitude: 150 m above sea level

Latitude: 28.70641ºN

Longitude: 80.6225 ºE

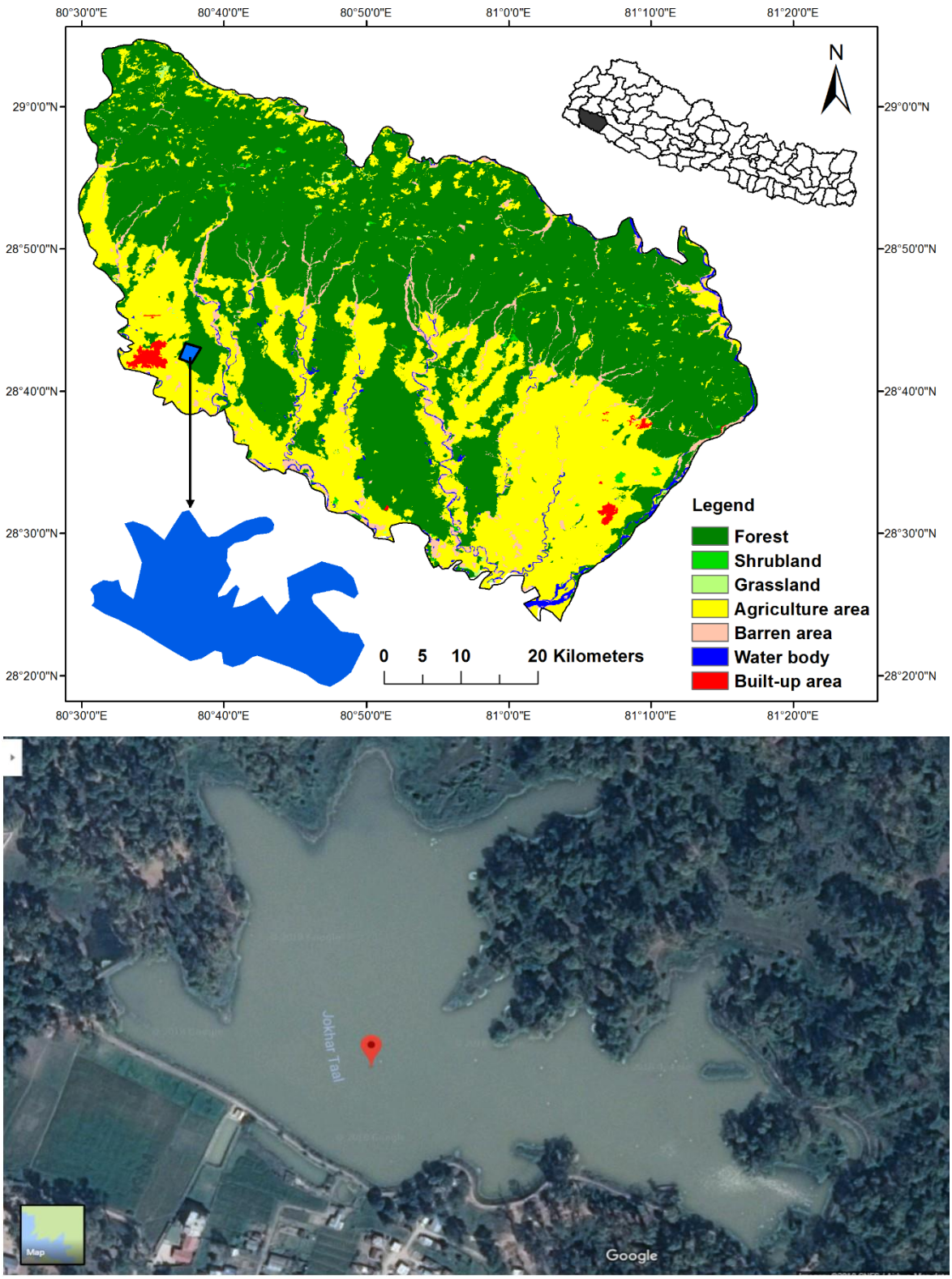


Figure 1: Map of study area of Jakhor Taal

3.2 Selection of sampling stations

A preliminary survey was done prior to the selection of sampling stations. Four sampling stations were selected on the basis of human disturbance, habitat and outlet. The selection of these different station was done considering its slightly different habitats such as edges of the lake having shallow water was taken as station-1, dense vegetated places was taken as station-2, middle and deep area of the lake was taken as station-3 and outlet area was taken as station-4.

3.3 Data collection and identification of fishes

The primary or basic source of data was taken on the basis of direct field observation and questionnaires survey. Questionnaires were also done to collect the information regarding changing pattern of the lakes with fish diversity, socio-economic status of the local fishing community, general environment of the lakes like the lowering of lake water level, severe land erosion, siltation, eutrophication etc. During the study period, a total of 109 peoples were questionnaires from the local respondents and the socio-economic status of local fishing communities was studied on the basis of information collected from those respondents and direct observation.

Field visits was carried out twice during the study period. First visit was carried out during the month of February 2019 and second visit at July 2019. Various kinds of locally available fishing gears such as cast net (mesh size 0.5cm, 1cm and 2cm) and Gill nets (mesh size 3cm, 5cm and 6 cm) of length 15m, 18, and 25m were used for fish catching. Cast net fishing was done randomly in 3 sites except station 3 twice a day (morning 7-9 am and evening 4-6pm) using CPUE method (Catch Per Unit Method). However, Gill net was placed in all the four sites and left installed overnight and observed next morning and evening all along the study period. Scoops nets were also used for capturing larvae, fingerlings, and small fishes. The fishes which were collected from all the study sites by employing local fishermen. The morphometric characteristics and measurement of all the collected fishes were noted in the field itself. All the collected fishes were carefully preserved in 10% formalin solution and the specimens were taken to the laboratory of the Central Department of Zoology (CDZ) for identification. The identification was carried out with the help of taxonomic references Jayaram (2010), and Shrestha (2008, 2019).

3.4 Factors determining fish diversity

Water samples were collected from four sampling sites of the lake and the following parameters such as pH, Temperature and Depth that effect the fish diversity were analyzed at the spot and others parameters like Dissolve oxygen and free carbon dioxide was analyzed in the laboratory of Drinking Water Supply Corporation, Dhangadhi, using standard procedures of (Trivedy and Goel 1989).

3.4.1 Hydrogen ion Concentration (pH)

A battery-operated electrical pH meter (HI 98107) was used to record the pH of water during the study period at different places of Jakhor Taal.

3.4.2 Temperature

The water temperature was measured by using a standard mercury thermometer graduated up to 50^{o}C with a precision of 0.1^{o}C by dipping the bulb of thermometer inside the water below 1 feet surface for 1 minute and obtained value is noted.

3.4.3 Depth

The depth of the lake was measured using nylon rope with heavy weight at its ends and a measuring tape was used to record the depth in centimeters (cm).

3.4.4 Dissolved Oxygen

Modified Winklers method was used to determine the dissolved oxygen which was originally developed by Winkler in 1888 (Shriwastav et al. 2010). In this method water samples were collected in a BOD (300 ml) without bubbling. Then 2 ml of manganous sulphate and 2 ml of alkaline sodide-azide solution were added and shaken well. Thus, obtained brown ppt was dissolved by adding 2 ml of concentrated sulphuric acid. Then this sample solution was titrated against standard sodium thiosulphate solution (0.025 N) and the calculation was done by using the following formula.

$$\textbf{Dissolved oxygen (DO)} = \frac{\boldsymbol{ml * N\ of\ titrant * 8 * 1000}}{\boldsymbol{v2}\left(\frac{\boldsymbol{v1 - v}}{\boldsymbol{v1}}\right)}$$

Where,

- V = Volume of $MnSO_4$ and KI added,
- V1 = Volume of BOD bottle, and
- V2 = Volume of the part of the content titrated.

3.4.5 Free carbon dioxide

For the determination of Free Carbon dioxide, 50 ml of sample water was taken in conical flask and 2 drops of phenolphthalein indicator was added to it. The colorless solution indicated the presence of Free Carbon dioxide. This solution was titrated against standard alkali titrant (NaOH 0.02272N) to the slight pink end point. Calculation of Free Carbon dioxide was done by using the following formula,

$$\textbf{Free } (CO_2) = \frac{(ml * Normality\ of\ NaOH * 1000 * 44}{V}$$

Where, V = Volume of water sample taken

3.5 Statistical analysis

Statistical analysis was performed using two major statistical analytical tools i.e. MS-Excel and R-Studio.

The corresponding Figures and Bar diagrams were made with the help of MS-Excel. The relation between environmental variables (pH, Temperature, Depth, Dissolved Oxygen and Free Carbon-dioxide), site (I, II, III, IV), Season (winter and summer) and fish species were analyzed through multivariate analysis tool using 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, season, and environmental variables.

The values of Axis length, Decorana value and eigenvalues obtained from DCA suggest that whether CCA or RDA was more applicable in our data. Therefore, a direct multivariate ordination method based on a linear response of species to environmental variables (Gauch, 1982; Ter Break 1986) was applied by using vegan library in "R" (Oksanen et al. 2019).

Fish species were analyzed into different assemblage clusters based upon abundances of each fish species by utilizing *pvclust* package in R (Suzuki & Shimoddaira, 2019).

3.5.1 Fish diversity

Seasonal and site-wise Shannon-Weiner diversity index, Simpson dominance index (D) and Pielou Evenness index (J) was performed using library “vegan” in R (Oksanen et al., 2019).

3.5.1.1 Shannon-Weiner diversity index (H')

Shannon-Wiener Index (H') - is an information index and is the most commonly used diversity index in ecology. Technically, the Shannon-Wiener Index (when applied to ecology) quantifies the uncertainty associated with predicting the identity of a new taxa given number of taxa and evenness in abundances of individuals within each taxa.

$$H' = -\sum (ni\ N \times \ln ni\ N)$$

where ni is the number of individuals of amount (biomass) of each of the i species and N is the total number of individuals (or biomass) for the site. Values of H′ can range from 0 to 5, although they typically range from 1.5 to 3.5

3.5.1.2 Simpson dominance index (D)

Simpson's Index (λ) is actually a measure of dominance and as such weights towards the abundance of the most common taxa. It is the probability that two individuals drawn at random from an infinitely large community will be different species. Simpson's Index is usually expressed as the reciprocal ($DS=1-\lambda$) so that as a measure of diversity, higher values represent higher diversity. It is less sensitive to rare species than the Shannon-Wiener Index which is sometimes a positive and sometimes a negative. The Simpson's index ranges from 0 to 1.

$$\lambda DS = \sum ni(ni-1N(N-1) = 1-\sum ni(ni-1N(N-1)$$

3.5.1.3 Pielou evenness index

Pilou evenness (J) compares the actual diversity value (such as the Shannon-Wiener Index, H′) to the maximum possible diversity value (when all species are equally common, Hmax=ln S where S is the total number of species). For the Shannon-Wiener Index,

$$\text{Pielou evenness (J): } = H'Hmax = H'\ln S$$

Pielou evenness (J) is constrained between 0 and 1.0 and the more variation in abundances between different taxa within the community, the lower J. Unfortunately, Pilou's J is highly dependent on sample size (since S - the estimated number of species is dependent on sampling effort) and is also highly sensitive to rare taxa.

4. RESULTS

4.1 Fish diversity of Jakhor Taal

A total of 24 species of fishes were reported from the Jakhor Taal during the present study from all the four station of the study sites. It consists of 7 orders, 14 families, 22 genera and 24 species. Among the total species, 16 species are local fishes (L) which are the natural inhabitant of this lake and 8 species were Induced (I) or Exotic fishes which are imported from outside.

Table 2: Fish diversity of Jakhor Taal.

S.N.	Order	Family	Scientific Name	Local Name
1	Cypriniformes	Cyprinidae	*Catla catla*	Vakur (I)
			Labeo rohita	Rohu (I)
			Cirrhinus mrigala	Mrigal/Naini (I)
			Ctenopharygodon idellus	Grass carp (I)
			Puntius sophore	Sidhra/pothi (L)
			Cyprinus carpie	Common carp (I)
			Hypothalmichthys molitrix	Silver carp (I)
			Amblypharyngodon mola	Mada/Mahila (L)
			Rasbora daniconius	Dedhan (L)
		Corbitidae	*Lepidocephalus guntea*	Guitna (L)
2	Siliriformes	Bagridae	*Mystus vittatus*	Tegna (L)
		Siluridae	*Wallago attu*	Lachea (L)
		Clariidae	*Clarias gariepinus*	Mangur (I)
			Clarias batrachus	Mangur (L)
		Heteropneustidae	*Heteropneustes fossilis*	Singi (L)
3	Perciformes	Ambassidae	*Chanda nama*	Cahnerbijuwa (L)
		Gobiidae	*Glossogobius giuris*	Vulvule (L)
		Channidae	*Channa punctatus*	Charanga (L)
			Channa orientalis	Bhoti (L)
4	Synbanchiformes	Mastacembelidae	*Macrognathus pancalus*	Bam (L)
		Synbranchidae	*Monopterus cuchia*	Andho Bam (L)
5	Cichliformes	Cichlidae	*Oreochromis niloticus*	Tilapia (I)
6	Osteoglosiformes	Notopteridae	*Notopterus notopterus*	Kauwa (L)
7	Anabantiformes	Osphronemidae	*Trichogaster lalius*	Theski (L)

Plate I

Systematic Positions of fish from Jakhor Taal.

ORDER - CYPRINIFORMES

Family - Cyprinidae

Genus - *Catla* Valenciennes

1. *Catla catla* (Hamilton, 1822)

Genus - *Cirrhinus* (Oken) Cuiver

2. *Cirrhinus mrigala mrigala* (Hamilton, 1795)

Plate II

Genus - *Ctenopharyngodon* Steindachner

3. *Ctenopharyngodon idellus* (Valenciennes, 1844)

Genus – *Cyprinus* Heckel

4. *Cyprinus carpie* (Linnaeus, 1758)

Plate III

Genus – *labeo* Cuvier

5. *Labro rohita* (Hamilton, 1822)

Genus – *Puntius* Hamilton

6. *Puntius sophore* (Hamilton, 1822)

Plate IV

Genus – *hypophthalmichthys* Bleeker

7. *Hypophthalmichthys molitrix* (Valenciennes, 1844)

Genus – *Amblyphryngodon* Bleeker

8. *Amblyphryngodon mola* (Hamilton, 1822)

Plate V

Genus – *Parluciosoma* Rasbora

9. *Rasbora daniconius* (Hamilton, 1822)

Family - Cobitidae

Genus – *Lepidocephalus* Bleeker

10. *Lepidocephalus guntea* (Hamilton, 1822)

Plate VI

ORDER – SILIRIFORMES

Family – Bagridae

Genus – *Mystus* Scopoli

11. *Mystus vittatus* (Bloch, 1794)

Family – siluridae

Genus – *Wallago* Bleeker

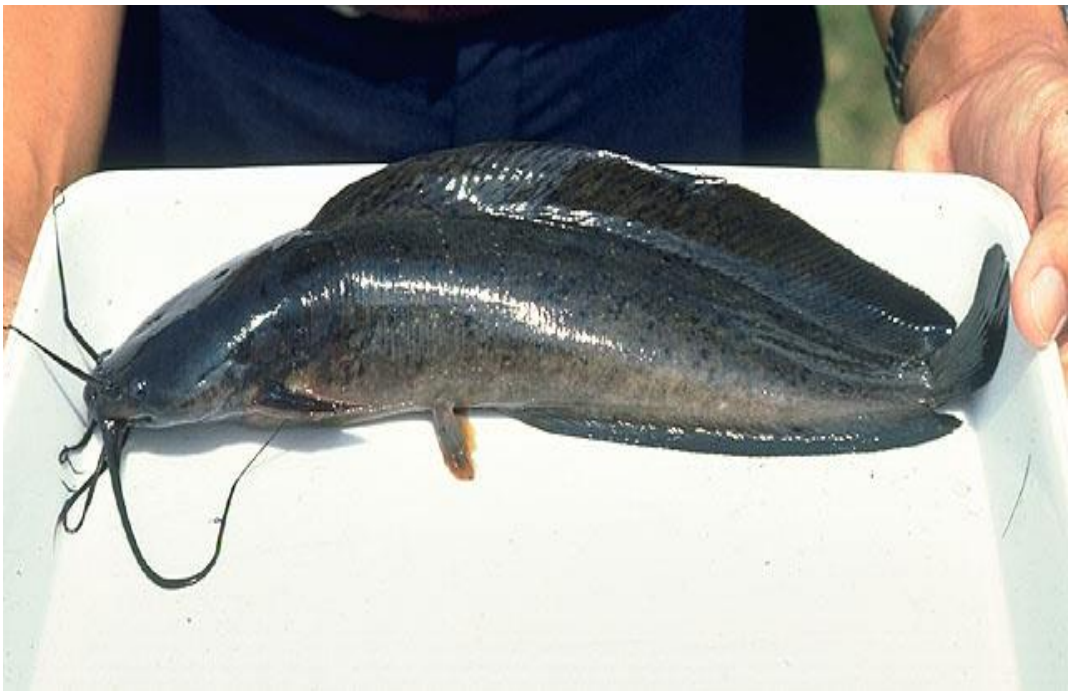
12. *Wallago attu* (Bloch and Schneider, 1801)

Plate VII

Family – Clariidae

Genus – *Clarias* Scolopi

13. *Clarias gariepinus* (Burehell, 1822)



14. *Clarias batrachus* (Linnaeus, 1758)

Plate VIII

Family – heteropneustidae

Genus – *heteropneustes* Muller

15. *Heteropneustes fossilis* (Bloch, 1794)

ORDER – PERCIFORMES

Family – Ambassidae

Genus – *Chanda* Hamilton

16. *Chanda nama* (Hamilton, 1822)

Plate IX

Family – Gobiidae

Genus – *Glossogobius* Gill

17. *Glossogobius giuris* (Hamilton, 1822)

Family – channidae

Genus – *Channa* Gronovius

18. *Channa punctatus* (Bloch, 1793)

Plate X

19. *Channa orientalis* (Bloch and Schneider, 1801)

ORDER – ANABANTIFORMES

Family – Osphronemidae

Genus – *Trichogaster* (Bloch and Schneider)

20. *Trichogaster lalius* (Hamilton, 1822)

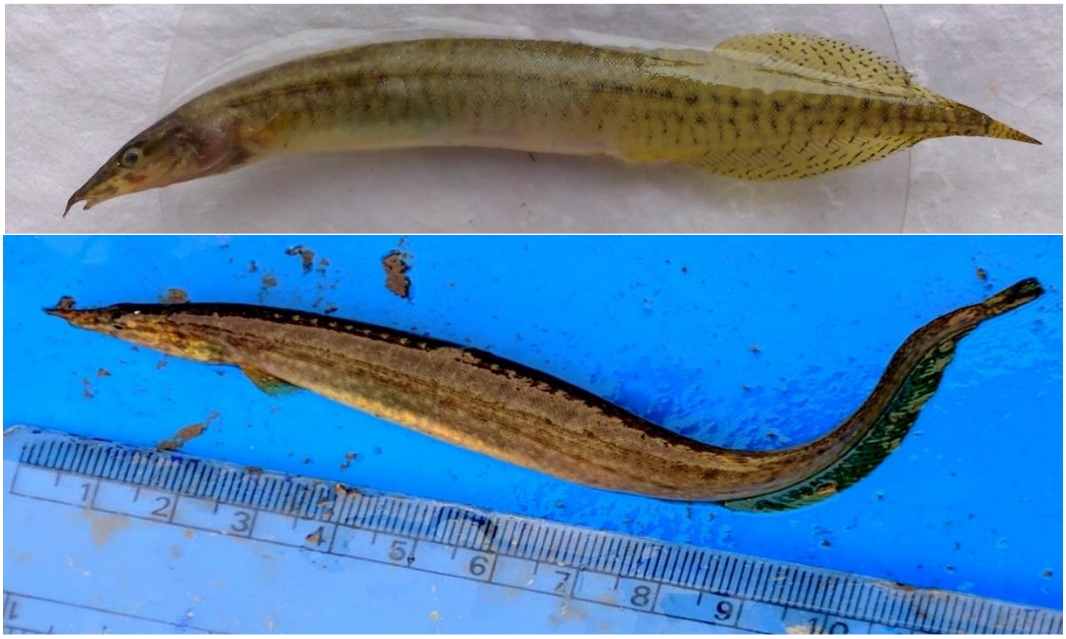
Plate XI

ORDER – SYNBRANCHIFORMES

Family – mastacembelidae

Genus – *Macrognathus* Lacepede

21. *Macrognathus pancalus* (Hamilton, 1822)



Family – Synbranchidae

Genus – *Monopterus* Lacepede

22. *Monopterus cuchia* (Hamilton, 1822)

Plate XII

ORDER – CICHLIFORMES

Family - Cichlidae

Genus – *Oreochromis* Gunther

23. Oreochromis niloticus (Linnaeus, 1758)

ORDER – OSTEOGLOSSIFORMES

Family – notopteridae

Genus – *Notopterus* Lacepede

24. *Notopterus notopterus* (pallas, 1769)

4.2 Distribution and frequency occurrence of fishes in Jakhor Taal

Among 24 species caught during the study periods, *Clarias gariepinus, Cyprinus carpie, Trichogaster lalius, Amblyphangodon mola, Puntius sophore and Rasbora daniconius* were reported from all four stations in which *Rasbora daniconius* shows the highest number of fish catch of frequency 16.61 followed by *Puntius sophore* (9.91), *Labeo rohita* (6.55), *Hypophthalmichthys molitrix* (6.25), and *Amblyphangodon mola* 6.15). The lowest number of fish catch was shown by *Monopterus cuchia* (0.05) which was recorded only from station II followed by *Heteropneustes fossilis* (0.15) as shown in Table 3.

Table 3: Distributional and frequency occurrence of fishes in Jakhor Taal

S.N.	Name of fish	Code	Stations				Total no. of individuals	Frequency (%)
			I	II	III	IV		
1	*Labeo rohita*	C1	2	72	330	0	404	6.55
2	*Catla catla*	C2	0	38	176	0	214	3.47
3	*Oreochromis niloticus*	C3	0	88	254	0	342	5.55
4	*Clasias gariepinus*	C4	53	14	6	41	114	1.85
5	*Cyprinus carpie*	C5	3	90	207	2	302	4.90
6	*Hypophthalmichthys molitrix*	C6	1	116	268	0	385	6.25
7	*Ctenopharyngodon idellus*	C7	0	32	69	0	101	1.64
8	*Cirrhinus mrigala mrigala*	C8	21	107	223	0	351	5.69
9	*Wallago attu*	C9	109	0	17	8	134	2.17
10	*Clasias batrachus*	C10	18	72	0	12	102	1.65
11	*Heteropneustes fossilis*	C11	1	6	0	2	9	0.15
12	*Macrognathus pancalus*	C12	67	4	0	13	84	1.36
13	*Mystus vittatus*	C13	32	11	0	16	59	0.96
14	*Trichogaster lalius*	C14	113	60	13	80	266	4.23
15	*Notopterus notopterus*	C15	12	203	19	0	234	3.80
16	*Amblyphryngodon mola*	C16	200	75	4	100	379	6.15
17	*Puntius sophore*	C17	300	100	11	200	611	9.91
18	*Lepidocephalichthys guntea*	C18	14	12	0	232	259	4.20
19	*Chanda nama*	C19	239	2	0	18	259	4.20
20	*Rasbora daniconius*	C20	500	200	24	300	1024	16.61
21	*Glossogobius giuris*	C21	209	9	0	38	256	4.15
22	*Channa orientalis*	C22	35	50	0	7	92	1.49
23	*Channa punctatus*	C23	62	100	0	18	180	2.92
24	*Monopterus cuchia*	C24	0	3	0	0	3	0.05
	Total	**I**	**1,991**	**1,464**	**1,621**	**1,087**	**6,164**	

4.3 Taxonomic order-wise fish species of Jakhor Taal.

According to the population of the ichthyofauna caught during this study period, three orders of ichthyofauna, i.e. “Cypriniformes”, “Siluriformes”, and “Perciformes” were found abundant that include 10, 5 and 4 species respectively, making them well existing in that habitats and other four orders of ichthyofauna, i.e. “Synbranchiformes” “Cichliformes” “Anabantiformes” and “Osteoglossiformes” were found very less obtaining 2, 1, 1 and 1 species respectively. Usually the fish’s diversity under the order “Cypriniformes” were found predominated throughout the study period and alone constituted 41.66 % of the total collected fish fauna, followed by the fish of order “Siluriformes” and “Perciformes” which were also found nearly equal constituting about 20.33% and 16.67% respectively. While other species of fish of order “Synbranchiformes”, “Cichliformes” “Anabantiformes” and “Osteoglossiformes” were also caught less during present investigation period constituting 8.33%, 4.16 %, 4.16 and 4.16% respectively. However, the frequency of fish catch is slightly different to that of the species composition where the order “Perciformes” shows high numbers of fish catch then order “Siluriformes” in spite of being less in fish diversity shown in the Figure 2.

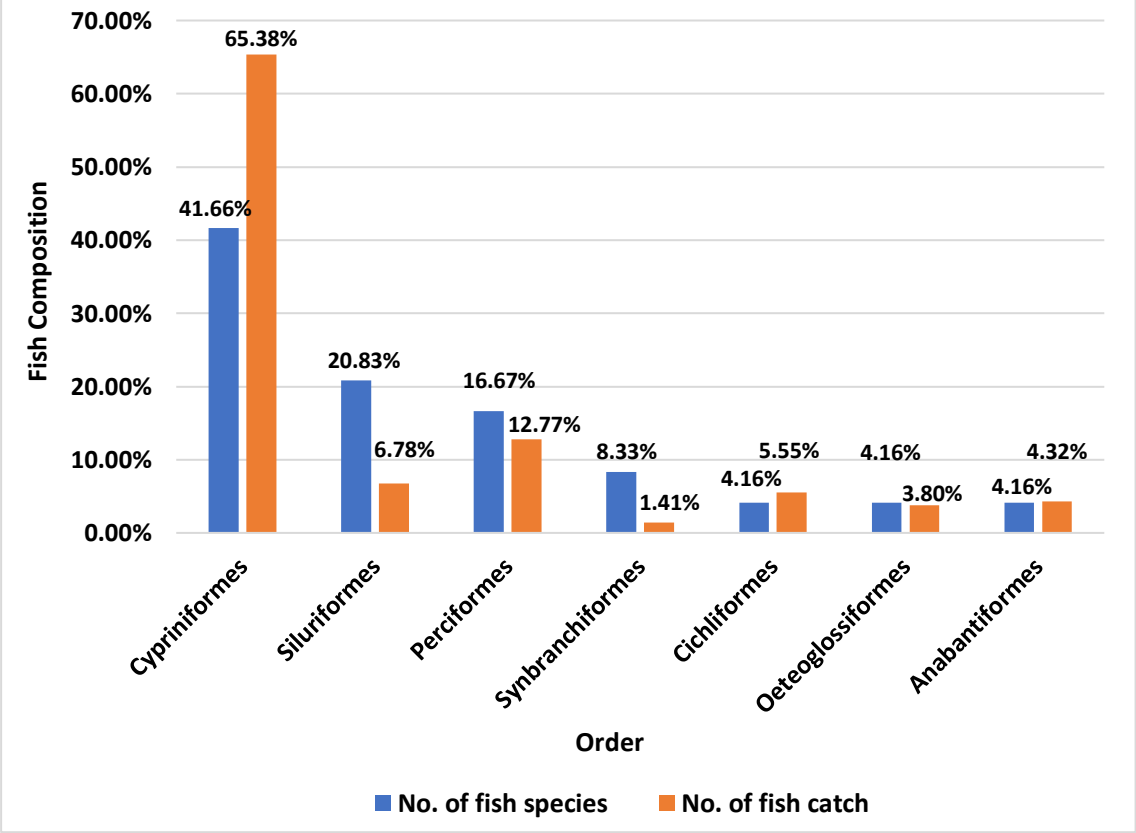


Figure 2: Order-wise fish species composition in Jakhor Taal

4.4 Taxonomic family-wise fish species of Jakhor Taal

According to the population of the ichthyofauna caught during our present study all together 14 families were recorded in which "Cyprinidae" shows the highest number of fish diversity obtaining nearly 64.27% of total fish species followed by "Clariidae" and "Channidae" Obtaining 14.286% each. Similarly, the frequency of fish catch of family Cyprinidae shows the highest obtaining 61.18 % which is more than half of the total fish caught during the study periods. However, the frequency of fish catch of others family is slightly different to that of the species composition where the family than order "Cichlidae" shows 2nd highest number of fish caught in spite of being single species than family "Channidae" and "Clariidae" which constitute two of fish species. The lowest number of fish catch is shown by the family "Synbranchidae" and "Hateropneustidae" which contain only 0.05 and 0.15% respectively as shown in Figure 3.

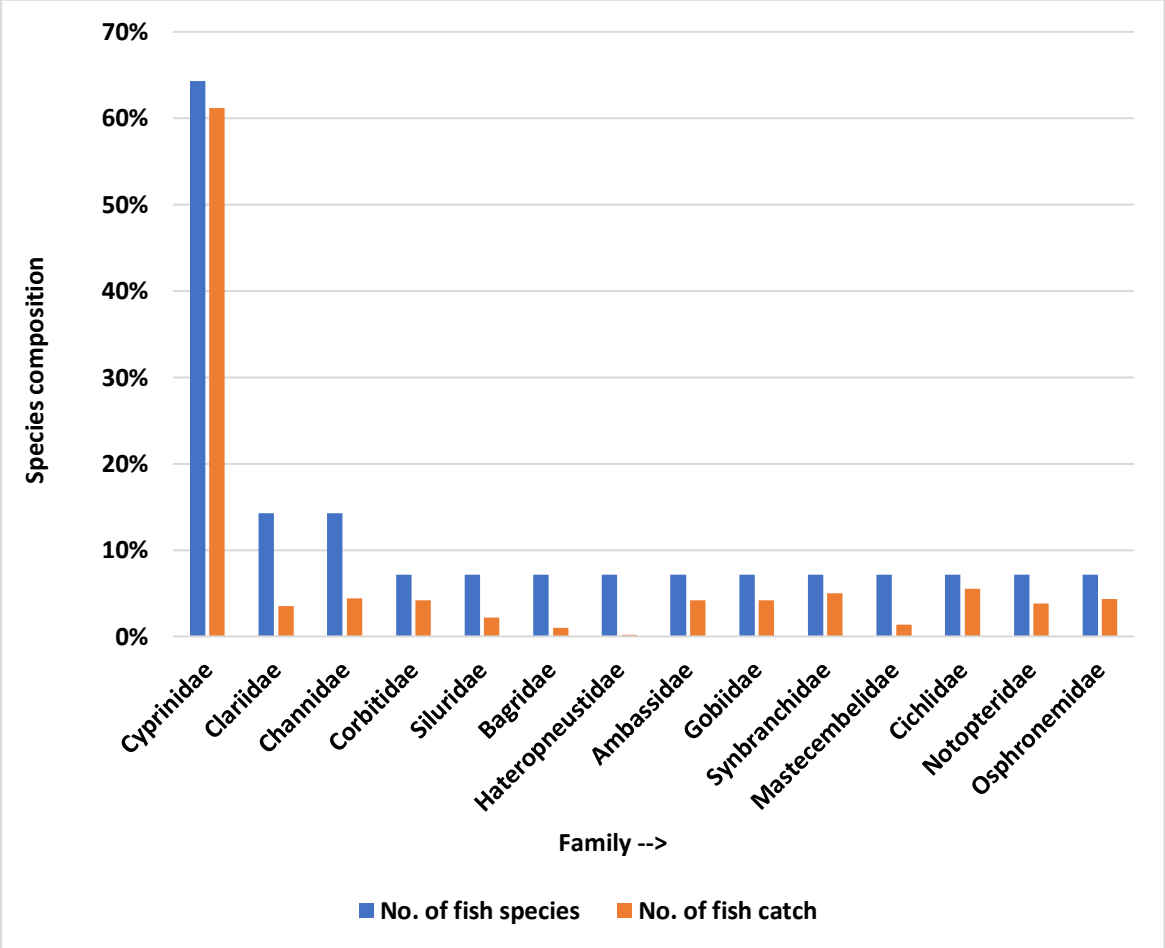


Figure 3: Family-wise fish species composition in Jakhor Taal

4.5 Seasonal and station wise variation in fish diversity

The value of Shannon Weiner diversity index (H'), Simpson index (D), and Pielou's evenness index (J) were calculated according to season and site. In case of season, the Shannon diversity index was found high (2.93) in the month of February and low (2.76) in the month of July. Similarly, Simpson and Evenness value was also found slightly high in the month of February in comparison to the month of July as shown in the figure 4.

In case of Station, the Shannon diversity index was found high (2.73) at the Station II in compare to the Station I, Station III and Station IV which is 2.31, 2.09 and 2.04 respectively. Similarly, Simpson and Evenness value was also found slightly high at the site II in comparison to the Station I, Station III and Station IV as shown in the figure 5.

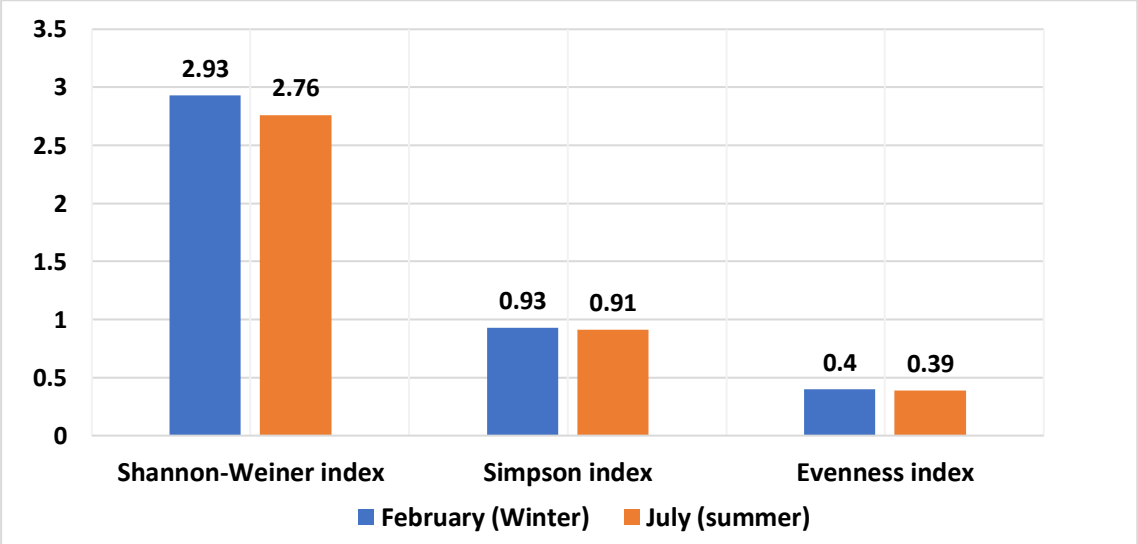


Figure 4: Seasonal variation of Shannon, Simpson and Evenness index of two season

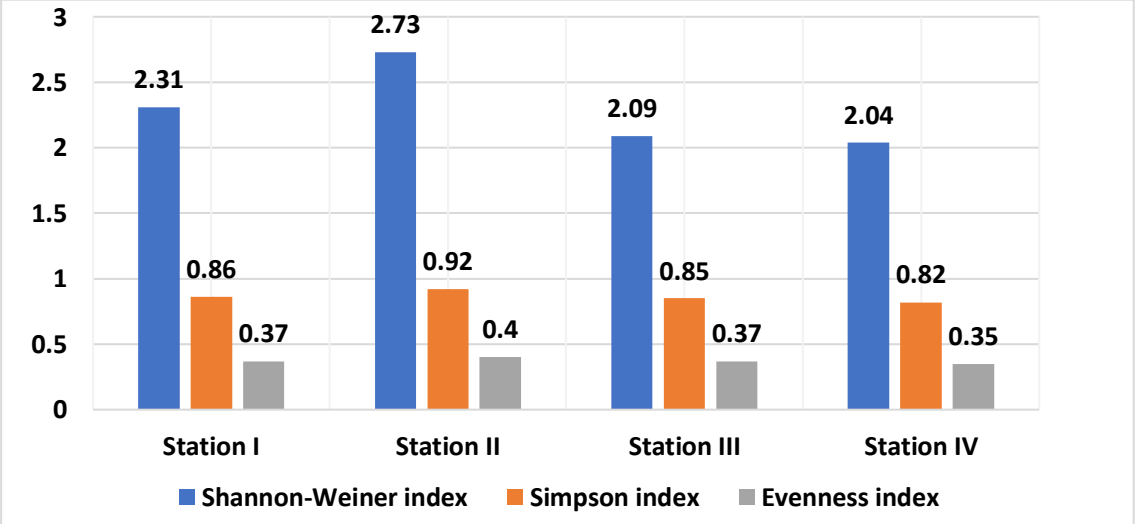


Figure 5: Station wise variation of Shannon, Simpson and Evenness index of two season

4.6 Factors determining fish diversity

4.6.1 Hydrogen Ion Concentration (pH)

The pH of water has shown slight changes along the different station during the study period. The average pH of water during the study period was found nearly acidic to slightly alkaline with the value ranges from 6.2 to 8.2 pH. The highest value of pH was recorded 8.2 at station-4 on July. The lowest pH value was recorded 6.2 at station-2 on February.

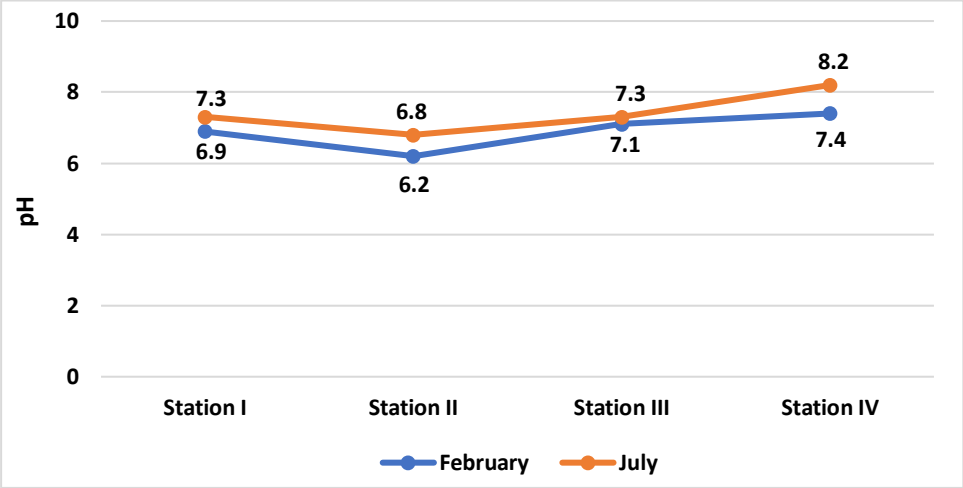


Figure 6: pH values of water of Jakhor Taal at different stations in different months

4.7.2 Water temperature

The water of lake ranges from 12° C – 25° C according to the seasonal variation. The water temperature was recorded to be the lowest at 12° C in the month of February at station-2 and highest at 25° C in the month of June at station-1.

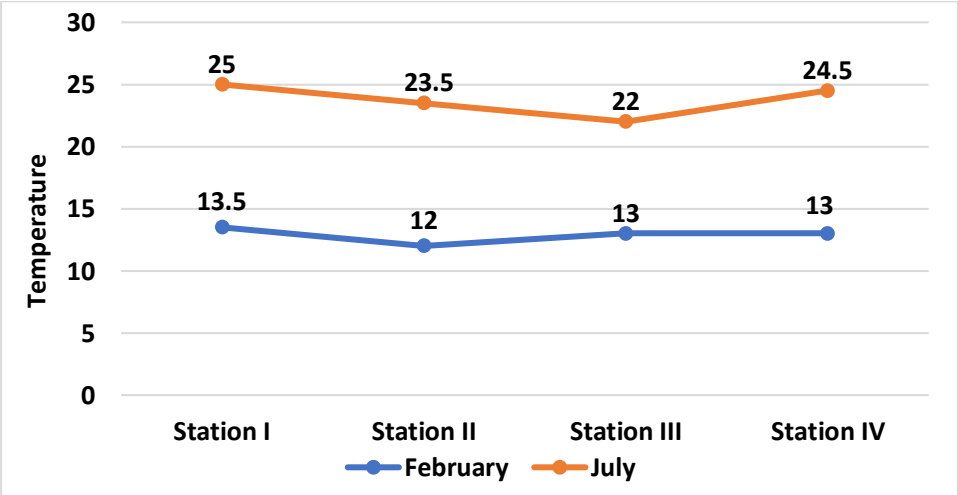


Figure 7: Water Temperature at different stations of Jakhor Taal in different months

4.6.3 Water Depth

The depth of the lake varies all along the different stations during the study periods in between different months. It usually ranges from 28 to 457 cm in different stations along the study period. The highest depth was recorded was 457 cm during the month of July at station-3 and lowest depth was recorded was 28 cm at the month of February at station-4.

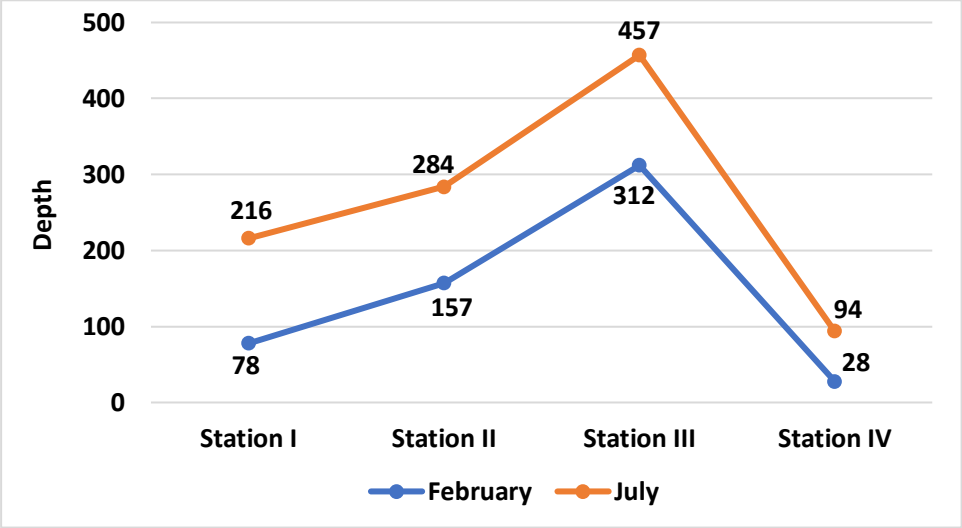


Figure 8: Depth (cm) at different stations of Jakhor Taal in different months

4.7.4 Dissolved oxygen (DO)

Dissolved oxygen was seen slightly different in different stations. The dissolved oxygen was observed ranging from 4.7 mg/l to 7.7 mg/l in the study period. The highest dissolved oxygen value recorded was 7.7 mg/l at station-4 in the month of July and the lowest dissolved oxygen value recorded was 4.7 mg/l at station-2 in the month of February.

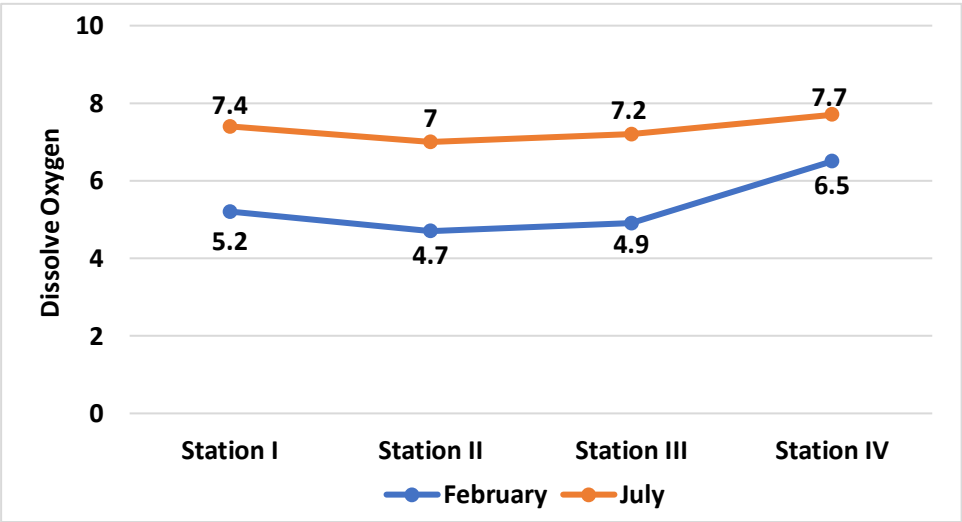


Figure 9: Dissolved Oxygen (mg/l) of different station of Jakhor Taal in different months

4.7.5 Free Carbon dioxide (CO_2)

The free carbondioxide of all the samples water collected from different stations was seen slightly different during the study periods, which ranges from 1.74 to 6.51 mg/l. The highest value of free carbon dioxide observed was 6.51 mg/l during the month of February at station-3 and lowest value was 1.74 mg/l during the month of July at station-4.

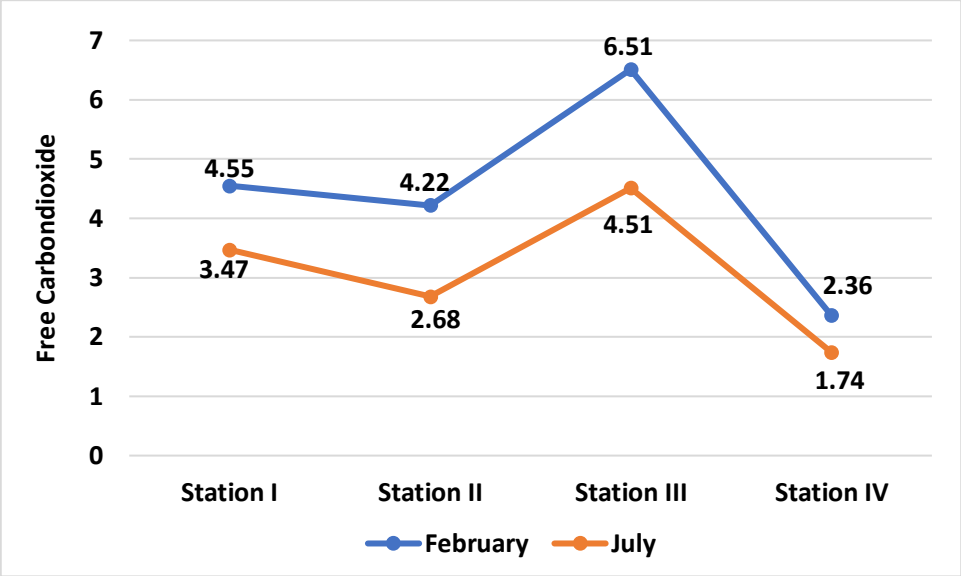


Figure 10: Free Carbondioxide (mg/l) of different stations of Jakhor Taal in different months

4.7. Species environmental variable relation

The ordination is a statistical technique in which data from a large number of sites or population are represented as a point in a multidimensional space. The axis length of the first axis of Detrended Correspondence Analysis (DCA) was found 2.9 standard deviation unit (SD unit) that followed by 1.2 by the second DCA axis (Table 4). The overall variance explained by the data matrix was 67 %. Thus, the application of RDA was justified.

Table 4: DCA summary

	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.6706	0.1398	0.1007	0.044474
Decorana values	0.7183	0.1611	0.0321	0.003047
Axis lengths	2.9515	1.2206	1.1273	0.650901

4.7.1 Fish species, sites, season and environmental variables relationship

The result obtained after running the redundancy analysis (RDA) was plotted in Figure 11. This result shows that Dissolved oxygen (DO) and Temperature (Temp) were found positively correlated with the Station I and the species such as *Rasbora daniconius, Puntius sophore, Chanda nama, Glossogobius giuris, Amblyphryngodon mola, Trichogaster lalius, Wallago attu, Macrognathus pancalus* and *Mystus vittatus* were also positively correlated with Station I along with Dissolved oxygen and Temperature. Similarly, Depth was found positively correlated with Station III and the species such as *Labeo rohita, Hypophthalmichthys molitrix, Oreochromis niloticus, Cirrhinus mrigala mrigala, Catla catla* and *Ctenopharyngodon Idella* were also found positively correlated with Station III with water depth. The only species *Lepidocephalichthys guntea* was found highly correlated with Station IV which is negatively correlated with depth of the water. In case of Station II, *Notopterus notopterus* was the only species which shows positively correlation which is a dense vegetation habitat where dissolve oxygen and Temperature shows negative correlation. In case of environmental parameters Dissolved Oxygen is seen highly significance as well as shows positive correlation with Station I and IV which is usually a peripheral area of the lake where there is a slightly movement of water due to wind and other phenomena. Similarly, Temperature was also is seen highly significance as well as shows positive correlation with Station 1 and III which is usually a shallow clean water body where many of the fish inhabitant and caught during the study period.

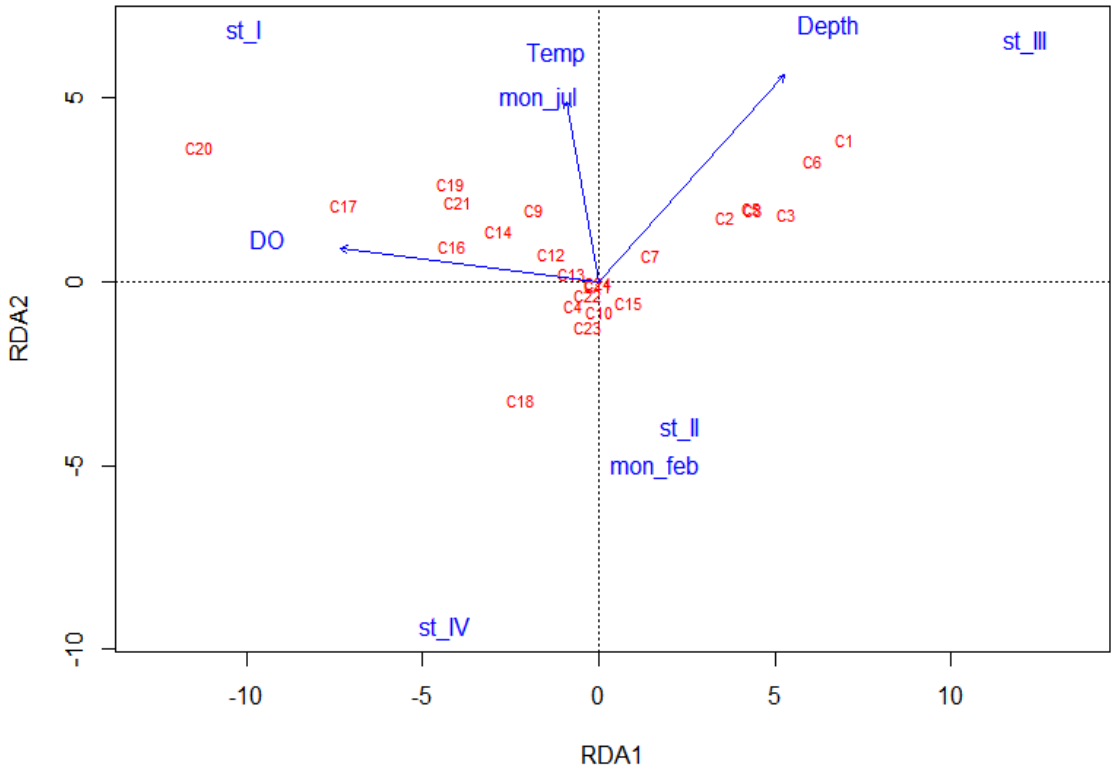


Figure 11: Redundancy analysis of fish species, sites, season and environmental variables relationship

4.7.2 Cluster analysis of fish species of Jakhor Taal

There are altogether 22 clusters were formed in Jakhor Taal which lives in mutual coordination with each other and with another group. In the right side, the cluster number 2, 3, 8, 9, 10 and 15 formed the highly significant cluster group which inhabitant in similar type of habitat. Similarly, cluster group in the left and center also form significant clustering according to their habitat preference. Normally the exotic fishes such as *Labeo rohita* (C1), *Catla catla* (C2), *Oreochromis niloticus* (C3), *Cyprinus carpie* (C5), *Hypophthalmichthys molitrix* (C6), *Ctenopharyngodon idella* (C7) and *Cirrhinus mrigala mrigala* (C8) forms the separate highly significant cluster group, whereas in the right the cluster number 1 (i.e.) *Chanda nama* (C19) and *Glossogobius giuris* (C21) didn't formed the significant cluster group within themself but together they form significant cluster with *Macrognathus pancalus* (C12) which is cluster number 5. The species of *Lepidocephalichthys guntea (C18)* and with cluster number 21 formed significant cluster group with all the groups in the center and left which is the Indigenous species who are natural inhabitant of Jakhor Taal.

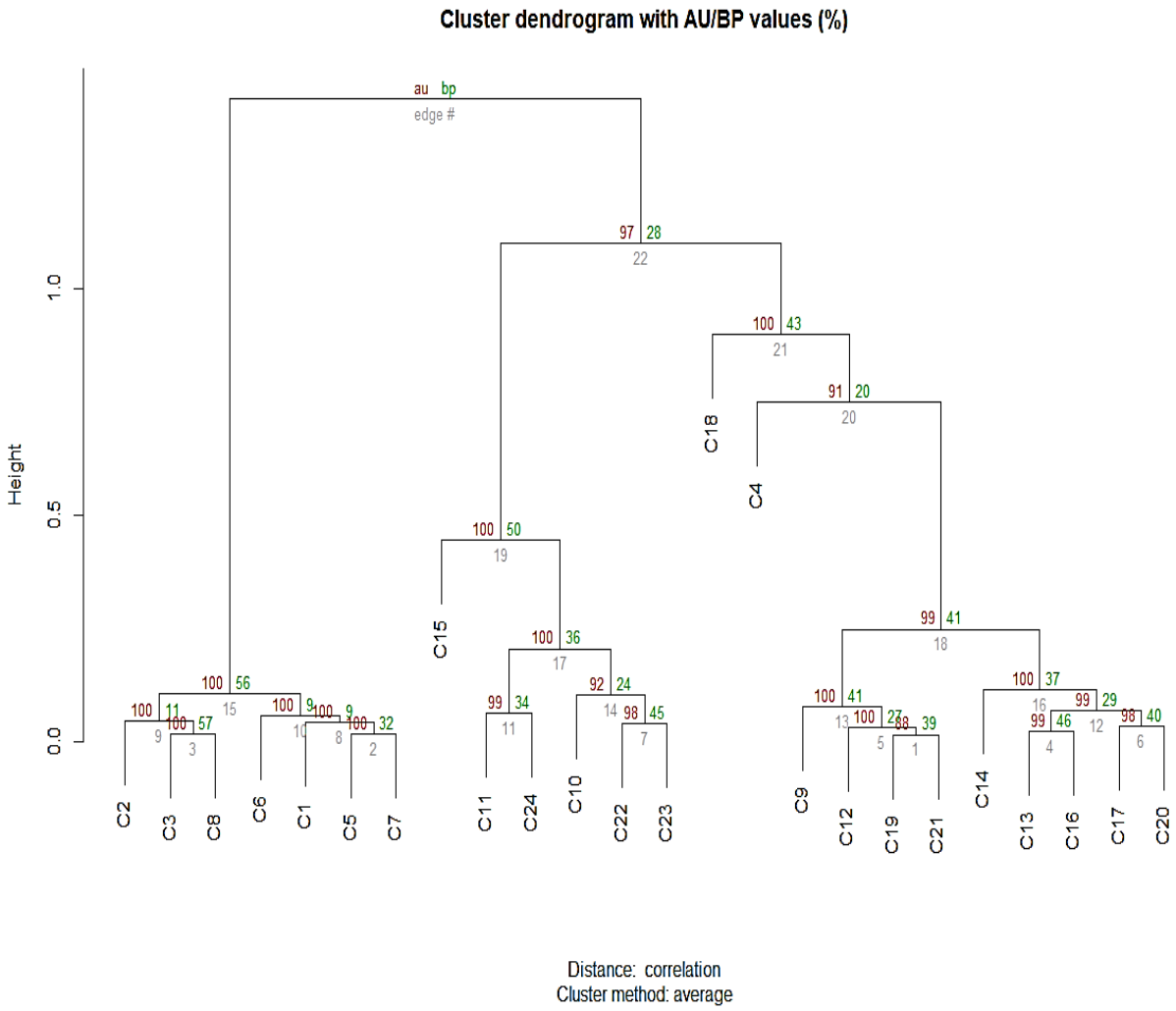


Figure 12: Dendrogram of cluster analysis comparing fish species on the basis of fish assemblage.

- Hierarchical clustered dendrogram of fish species from the Jakhor Taal,
- Black and dark colored code name represents the fish species.
- Black and soft colored number represents the cluster number.
- Red number represents probability of Automatic Unbiased (AU) value.
- Green colored number represents Bootstrap Probability (BP) value.
- AU value > or = 95 represents significant cluster.

4.8 Socio-economic status of local fishing community

4.8.1 Social status

Fishermen of Jakhor Taal are locally known as "Majhi" and are generally inhabiting near or around the Jakhor Taal belonging to different castes viz. Tharu, Rana, Sunar, Magar, Gurung, and Chhetri. In this study Tharu, Rana and Sunar community are the majority of inhabitants living around the Jakhor Taal from pre-historical time and they were in this occupation from very long period of time. The average family size of the fishermen is 5-6 persons. Nearly 70 percent males and 30 percent females are engaged in fishing during the raining season but during off seasons male work as labor or drive local rikshaw and electric auto. The females are engaged in their household affairs such as cooking, preparing bamboo basket implements, collection of fire-wood, making dung-cake etc. Approximately 88% of the population living within the Jakhor Taal region consider themselves to be Hindu and 7% were fall under Christian and remaining 5% were fall under Buddhism. About 30 percent of the fishermen know about the family planning idea but only 15% have taken benefits from it. Many of them think that there is no need of family planning system because children are the bless of god for them.

Fishing village can be recognized by the presence of bamboo fishing traps, cast nets, gill nets hung on the doors or windows of their houses. Normally, fishermen house is generally a small hut made up of bamboo (*Dandrocalmus strictus*) and khar (*Imperata cylindrica*). The bamboo wall is lapped with alluvial soil. But nowadays their started to made their houses made up of brick wall and have roofs of tiles and some are made with stone walls and have roofs of Khar and Zinc plates (Karkatpata). The cattle sheds are constructed very near to the house. Local fishermen themselves make different types of fishing implements especially during leisure periods with the help of locally available plant fibers (bamboo) and nylon strings. The meticulously prepared gears are kept directly over a smoke. It is said that fumes make the gear water proof and durable and avoid rooting. Mostly locally prepared implements such as Cast net, Gill net, Helka, Dragnet and Hook lines are used for the fishing purposes. Fishing activities continue throughout the year except the monsoon (July) when they are engaged in agriculture work.

4.8.1 Economic Status

Fishermen are one of the poorest groups of the urban population along the far-west region of Nepal. According to the investigation of present study, there are 142 family of fisherman living around Jakhor Taal. The economic condition of fishermen is very poor. The standard of living of fishermen appears to be low both in absolute terms and by comparison to the living standards of other rural inhabitants. They usually fall below poverty line; therefore, the levels of education are low and awareness towards living, personal hygiene, general health is also low, leading to incidences of various health hazards. They also own some agricultural lands which are not sufficient for their economic development. Mostly they don't have pet animals but few of them rear goat, buffalo, ox, chicken and cows etc. The literacy rate of the fishermen is very low. About 80 % of the total fishermen falls under illiterate (below SLC) and only 20 percent have been education up to higher class (above SLC). Normally the local fishermen are often unaware of their children's right to education or unfamiliar with the structure of the local public education system. Among the local Tharu family only few has passed board exam of class 10. Nowadays they are very much interested to give education to their children. Sixty percent are sending their children to school regularly.

4.9 Conservation challenges of Jakhor Taal

There are various challenges in Jakhor Taal regarding fish conservation and management. Some of the major factors are

4.9.1 Destruction of wetland habitat

Habitat destruction is the process in which natural habitat is disturbed so intensely that it unable to support the species presence that has been inhabiting from past long time. Improper land use and heavy deforestation and over grazing in the surrounding forest area for commercial and individual purposes causing soil degradation or soil erosion during rainy season destroying natural habitat in the Jakhor Taal, which drastically effect the ichthyofauna living there in their natural condition. In this process, the organisms that previously found in that site are displaced or destroyed, reducing biodiversity.

4.9.2 Illegal fishing

As per few sources from the villagers, the fishes in the Jakhor Taal are being illegally catch or killed by destructive methods like poisoning and electric fishing. Such fishing methods not only kill the fries, fingerlings and brood fishes but also destroy the breeding habitats of the fish themselves. Hence these methods of catching fishes not only kill the fishes in larger amount but also effect the natural habits of the local fishes which further get extinct from those places.

4.9.3 Lack of conservation awareness

Lack of conservation awareness about the importance of lakes and its diversity in the local inhabitants is the major problem for the destruction of fishes and their natural habitats. Uneducated fishermen's do not understand the destructive nature of the use of poison or electric fishing that negatively affect the whole habitat of those fishes as well as the importance of natural habitat of fish and they continue to use those methods for catching fishes.

4.9.4 Urbanization and encroachment in wetland

Nowadays urbanization becomes the major factor which play a vital role in changing the natural habitat of the surrounding environment that effect the diversity either positively or negatively. Due to increase in population in recent decades the lands around the lake is being legalized by the government for personal and commercial purposes which causing the major threats to lake.

4.9.5 Invasive plants

In Jakhor Taal, Water hyacinth (*Eichhornia Crassipes*) and Water cabbage (*Pistia stratiotes)* are the major invasive plants that cause severe negative impacts to the whole lake almost destroying its natural habitat. The main problems caused by water hyacinth is eutrophication which is caused by the obstruction of sunlight reaching the water body that alters the photosynthetic process that changes the chemical parameters of water that negatively affect the fish diversity and its natural habitat (Jha 2008). The thick surface cover of the weed restricted diffusion of atmospheric oxygen into the water and the decay processes of dead weed debris depleted most of the oxygen accumulated hence cause negative impact on the economic status of the fishing community in regard to fish kills caused by oxygen depletion (Wang et al. 2012)

5. Discussion

The present study deals with fish diversity of Jakhor Taal in accordance with environmental variables and fishing community. This study was conducted for the period of seven month from February 2019 to August 2019 covering two major seasons i.e. Winter and Summer. Total 24 species of fish were coughed during the study period which belongs to 7 orders, 14 families and 22 genera. In past, IUCN (1998) also reported similar kind of findings by recording 27 species of fish fauna from Ghodaghodi Lake Complex. Similarly, DNPWC and WWF Nepal (2003) also reported 29 fish species from Ghodaghodi Lake Complex. Recently. Kafle (2007) identified 25 species from same area almost recording similar kinds of fish species such as *Clarias batrachus, Channa striatus, Puntius sophore, Amblyphryngodon mola, Trichogaster lalius, Chanda nama, Rasbora daniconius etc* which shows, the fish diversity of lowland ponds and lakes are similar kinds constituting similar fish species diversity. Among the total recorded fish, *Rasbora daniconius, Puntius sophore,* were the most abundant species which contribute about 16.61% and 9.91% respectively followed by *Labeo rohita, Hypophthalichthys molitrix¸ Amblyphryngodon mola, and Cirrhinus mrigala mrigala obtaining 6.55%, 6.25%, 6.15%,* and *5.69%* respectively. This shows that Order Cypriniformes is the most dominant order comprising 41.66% among the total fish species recorded and 65.38% of total fish caught during the study periods which is more than half of the total number of fish caught. Similar findings are reported from Begnas and Rupa Lake by (Husen and Sherpa 2017) and (Gautam et al. 2016). Pokharel (1999) also mentioned the order Cypriniformes was dominant in terms of both species composition as well as individuals captured in the lakes of Pokhara valley. The is because, Cypriniformes is the largest order of fresh water fishes, which includes 2,422 species (Nelson 1984). Similarly, Siluriformes and Perciformes was recorded second and third dominant order constituting 20.33% and 16.67% respectively, which is similar to the findings of Ghodaghodi Lake (Joshi 2015). In case of family, Cyprinidae shows the highest number of fish diversity obtaining 64.27% of total fish species occupying more than half of total fish caught during the whole study period. Similarly, the frequency of fish catch of family Cyprinidae shows the highest obtaining 61.18 % which is more than half of the total fish caught during the study period. Pokharel (2011) and Gautam et al. (2016) have also reported similar kind of result supporting my study where family Cyprinidae was dominant family from Seti River and Rupa Lake of Pokhara.

In case of environmental variables, there are five major factors i.e. Hydrogen ion concentration, Temperature, Depth, Dissolved oxygen and Free carbon dioxide that plays a vital role in fish diversity and its surrounding habitats of Jakhor Taal. First one is the Hydrogen ion concentration which was found around 6.2 to 8.2 ppm which was nearly acidic to slightly alkaline in nature (Figure 4). The highest pH value 8.2 ppm was recorded at the station IV which is the outlet region of the lake where water current is seen during the month of July and lowest 6.2 ppm was recorded at the station II on February which is occupied of dense vegetation of Water hyacinth, Lotus, Water lily and water cabbage. 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 the 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.

In most cases, water temperature plays a major role influencing environmental variables. Water temperature of the Jakhor Taal was seen ranging from 12º C – 25º C throughout the study periods (Figure 5). The lowest recorded value is 12º C in the month of February at station-2 and highest 25º C in the month of June at station-1. According to Hutchinson (1957) the metrological conditions are responsible for seasonal water temperature change. Bastola (2013) also recorded water temperature 17ºc to 25 ºc from lake and considered that water temperature of the lake seems to be related with the atmospheric temperature. Depth of the also seems to play a very important role in lentic bodies which directly or indirectly affects fish species diversity and their habitat. The depth of the lake varies all along the different stations during the study periods in between winter to summer providing diverse habitat for fish species to thrive well (Figure 6). The highest depth was recorded 457 cm during the month of July at station-3 due to high rainfall and also the center portion of the lake which support inhabitant for various large indigenous and exotic fish such as *L. rohita, C. catla, O. niloticus, C. carpie, H. molitrix, C. idellus, C. mrigala mrigala* and some large mature *Wallag attu* and lowest depth was recorded 28 cm at February due to lack of rainfall and slightly high elevated land which is also the only outlet portion of the entire lake. This station support habitat for some small indigenous fish species such as *T. lalius, A. mola, P. sophore, L. guntea, C. nama* and *R. daniconius*. According to (Shaikh et al. 2011) it is due to high level of trophic flexibility which makes them to occupy the same ecological niche.

Dissolve Oxygen is one of the essential limnological factors in Lentic water bodies (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). In Jakhor Taal, the dissolved oxygen was observed ranging from 4.7 mg/l to 7.7 mg/l in the study period (Figure 7). The highest value recorded was 7.7 mg/l at station-4 in the month of July due to high rain fall and moderate temperature. Similar result was also recorded by (Vass et al. 1977; Rather et al. 2001), as during rainy season growth of plankton and rain also helps to aerate the surface water. And the lowest dissolved oxygen value recorded was 4.7 mg/l at station-2 in the month of February due to less water level and low temperature. However high diversity is also recorded from the same site which is quite unexpected. This might be due to suitable habitat formation due to vegetation growth which gives shelter and protection for major of the local species. Dutta and Patra (2013) also reported similar value where due to low oxygen dissolution at low temperature and most of it is used by decomposers in water body. Bastola (2013) recorded 6.7 mg/l to 8.7 mg/l from this lake which was slightly higher than present study.

In case of free carbondioxide, the lentic water bodies always contain more amount of CO_2 in compare to lotic water bodies due to the higher decomposition of organic matter and respiration of organism (Ekulo and Abowei 2011). In our study, the CO_2 level of water seen different in different stations which ranges from 1.74 to 6.51 mg/l. The highest value recorded was 6.51 mg/l during the month of February at station-3 which is deepest site of the lake and lowest was 1.74 mg/l during the month of July at station-4 near the outlet. According to Ekulo and Abowei (2011) tropical fishes can tolerate CO_2 level over 100 mg/l but the ideal level of CO_2 in fish ponds is less than 10 mg/l. The highest Free CO_2 value during winter may be due to the absence of long-term photosynthetic process due to the absence of sun energy (Thapa and Pal 2011) and decomposition of organic matter (John and Martin 1996). The minimum values of Free CO_2 during summer probably due to its utilization in Photosynthesis activities (Sreenivasan 1971). Bastola (2013) recorded CO_2 value from 1.8 mg/l to 5.6mg/l in this lake and considered photosynthetic activities of planktons is an important factor for CO_2 fluctuation

Diversity status of the fish's species in Jakhor Taal shows variations in both spatial and seasonal condition. A biodiversity index seeks to characterize the diversity of fishes or community by a single number (Magurran 1988). The concept of the species diversity involves two components: the number of species or richness and the distribution of

individuals among species (Williamson 1973). In this study, seasonal variation in fish species shows very less differences i.e. Shannon diversity index was found slightly high (2.93) in the month of February and low (2.76) in the month of July (Figure 9). This might be due to low level of water during winter season which helps to match more species of fishes. Similarly, Simpson and Evenness value was also found slightly high (0.93 and 0.4) in the month of February in comparison to the month of July (0.91 and 0.39). This value shows that this lake has very less effect on diversity in terms of seasonal variation which might be due to its placement near the large community forest which provide sufficient nutrient during water runoff and also due to human settlement's which look after this lake for their commercial purpose.

In case of spatial condition (Figure 10), the Shannon diversity index was found high (2.73) at the station II in compare to the station I, station III and station IV which is 2.31, 2.09 and 2.04 respectively. This is due to the factor that station II is occupied by dense vegetation which provide suitable habitat such as shelter, food and breeding ground for large no of species. Similar kind of statements are also given by (Decker et al. 2016) where they also recorded high fish richness in those area which is occupied by vegetation. Similarly, Simpson and Evenness value was also found slightly high (0.92 and 0.4) at the station II in comparison to the station I (0.86 and 0.37) station III (0.85 and 0.37) and station IV (0.82 and 0.35) respectively. There is no significant difference was found in the mean Shannon diversity index among the two seasons which might be due to the slight change in living habitat in pond due to the stagnant properties of water.

In Ordination plot (Figure 11), the total species diversity, the spatial and seasonal value and all the environmental variables are interpreted all together in a single plot to give the brief detail about the present status and condition of all species diversity in according to the its environment. However, Fishes were not found uniformly distributed in the lake, it might be due various factors such as different habitat and environmental parameters. The result shows that Dissolved oxygen (DO) and Temperature (Temp) were found positively correlated with the site I during the month of July and the species such as *R. daniconius, P. sophore, C. nama, G. giuris, A. mola, T. lalius, W. attu, M. pancalus* and *M. vittatus* were also seen positively correlated with station I along with Dissolved oxygen and Temperaure. Similarly, Depth was found positively correlated with station III which is the center most and deepest part of the lake and some large exotic species such as *L. rohita, H. molitrix, O. niloticus, C. mrigala mrigala, C. catla* and *C. Idella* were also found positively correlated

with station III with water on both seasons. The only species *L. guntea* was found highly correlated with station IV which is the outlet region of the lake from where excessive water was driven out of the lake. Therefore, it is negatively correlated with depth of the water. In case of station II, *Notopterus notopterus* was the only species which shows positively correlation which is a dense vegetation habitat where dissolve oxygen and Temperature shows negative correlation.

The socio-economic status of the fisherman or local community people inhabiting around Jakhor Taal are seems to be below poverty line, where the levels of education are inadequate and awareness towards living, personal hygiene, general health is also low. This might be due to the lacking of necessary information for the formulation of government assistance program which gives awareness about the need of educations, illness/decease, agriculture etc. Giri (2010) and Devkota (2011) also summed up similar type of result in this thesis dissertation giving similar type of explanation. In ethnic group, people belonging to different castes i.e., Tharu, Rana, sunar, Magar, Gurung, and Chhetri where found in which Tharu, Rana and sunar community constitute the majority (85%) of inhabitants living around the Jakhor Taal from pre-historical time and they were in this occupation from very long period of time. Approximately 88% were Hindu, 7% under Christian and remaining 5% under Buddhism. The literacy rate of the fishermen is very low. About 80 percent of the total fishermen is illiterate and only 20 percent have been education up to higher class. Normally, house is generally a small hut made up of bamboo (*Dandrocalmus strictus*) and khar (*Imperata cylindrica*) lapped with alluvial soil. But nowadays their started to made their houses made up of brick wall and have roofs of tiles.

Local fishermen also make different types of fishing implements especially during leisure periods with the help of locally available plant fibers (bamboo) and nylon strings. The mostly used fishing implements are Cast net, Gill net, Drag net, Helka and Eel trap and the best timing for fishing is from mid-August to October after the completion of breeding season of most of the indigenous and exotic fishes. Hence, there is an urgent need to educate, support and provide fishermen health insurance to assure the access to health care facilities. Nowadays UNDP has launched SCDP (sustainable Community Development Programme) in the study area all around the Jakhor Taal. This program provides loan specially to the local fishing community living near the Jakhor Taal especially Tharus, Ranas, Raji family in order to raise their over-all level of social and economic condition. However, the necessary information for the formulation of government assistance

programs is lacking. The purpose of this research is to provide such information through the surveys of fishermen and fish farmers, whose numbers have been decreasing rapidly in recent years.

When it comes to Conservation challenges and implications there was always been the diplomatic state all over the world despite the existence of well-established international environmental and nature conservation policies (e.g., the Ramsar Convention and Convention on Biological Diversity) where ponds are largely missing from national and international legislation and policy frameworks (Hill et al. 2017). In Asia, international legislation specifically targeted for conservation of pond habitats is largely lacking (Hassall et al. 2016). Human demands on freshwater ecosystems have risen steeply over the past century leading to large and growing threats to biodiversity around the world (Dudgeon et al. 2006). In case of Jakhor Taal, there are also various challenges regarding fish conservation and management of wetland in which habitat destruction, illegal poaching and fishing, Urbanization, Climate change, Invasive plants and Lack of Awareness are the major threats. Habitat destruction by human activity is mainly for the purpose of harvesting natural resources for individual use, industry purposes and urbanization (Siwakoti and Karki 2009). Clearing habitats for agriculture is the principal cause of habitat destruction which is drastically increasing day by day to meet the food supplements (Dudgeon et al. 2006).

Due to increase in population in recent decades the lands around the lake is being legalized by the government for personal and commercial purposes which further cause agriculture runoff (nitrogenous fertilizers) and other various chemicals, and pollution caused by the anthropogenic activities causing the major threats to lake (Decker et al. 2016). This may cause natural habitat change in their environment where they usually found in large amount and start to disappear from those places due to their habitat loss and slowly get extinct if those method are being continuously use (Strayer and Dudgenon 2010). It is mostly nitrogen and phosphorus that are responsible for eutrophication in the aquatic environments (Smith 2003, Xu et al. 2010). Water hyacinth (*Eichhornia Crassipes*) is the only invasive plants that cause severe negative impacts to the whole lake almost destroying its natural habitat (Babourina and Rengel 2011). The present condition of lake is manifesting by annual siltation, eutrophication, human encroachment, seasonal micro phytic coverage and intervention of exotic as well as invasive species which are the most important factor for decline and extinction of indigenous fish (Dudgeon et al. 2006).

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The total of 24 fish species were recorded form different stations of Jakhor Taal belonging to 7 orders, 14 families and 22 genera. The dominant order and family in this lake were Cypriniformes and Cyprinidae respectively.

Fish diversity is significantly correlated with environmental parameters of Jakhor Taal. RDA revealed that the environmental variables of water such as temperature, depth and dissolved oxygen were found highly significant to most species with respect to different sites and month however, pH and free CO_2 has not shown any relation or significance.

The socio-economic status of the local fishing communities seems to be below the poverty line and the lake and its resources play a very important role in their diet and income source.

Conservation challenges and implications of this lake is highly neglected from both governmental and local communities which negatively affect the natural habitats. Some of the major factors effecting the study area are lack of awareness, habitat destruction, illegal fishing, urbanization and invasive species.

6.2 Recommendation

The initiation towards conservation and management of fishery resources in Jakhor Taal has not been taken seriously. Although a work on soil conservation and watershed management has been continuing in large number of districts by a project of "HMG" in combination with Germany and Switzerland, no work has been done for the conservation strategy of fish fauna in the Jakhor Taal by any sector so far. Due to the absence of any official administration or priority on the conservation and management of Jakhor Taal in the past, there is a degradation of natural habitat and fish's resources. Therefore, for successful conservation and management of indigenous fish species in the Jakhor Taal, following recommendation are suggested.

- Ban of Harmful Fishing Implements.
- Introduction of exotic/invasive fish should be controlled.
- Pollution caused due to human activities is suggested to be minimized.
- Aquatic weeds are suggested to be cleaned without disturbing the habitat of fish.
- Community and school-based awareness program should be conducted, regarding the conservation of lake.
- The Aquatic Animals Protection Act (AAPA) is recommended to be implemented effectively through the concerned governmental agencies.

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APPENDICES

Appendix I: Questionnaires

A list of questionnaires used in interview with fishermen of Jokher Taal to study Socio-economic condition and their demography.

Zone: VDC: District:

Ward No.: Village:

1. Name of Fishermen

   Caste: Age: Sex: Religion:

2. Number of Member of the family.

   Total: Male: Female:

3. Are you literate?
4. Are you giving school education to your children?
5. If no then why?
6. Do you know about family planning?
7. How many members are included in fishing from your family?
8. How many fishermen come to fishing at this site?
9. Is fishing your main profession?

   Yes No

10. If Yes in which category do you falls?

    Full-time fishermen part-time fishermen Occasional

11. If Full-time, is your income sufficient for your current expenditure?

    Yes No

12. How many species of fish are available in the lake?
13. Which fish species are most common in the lake?
14. How much fish does your family consume per day/month?
15. In which month do you capture more fishes?
16. In which season do you go to fishing?
17. What type of fishing gears do you use during different time of year?
18. What do you say about fish species has increased or decreased?
19. Do you know any flood impact on lake in the rainy season?
20. Is it good to being carried out agriculture near by the lake?
21. What are the main causes for pollution in the lake?

22. Do you have outstanding Loan?

    Yes No

23. If yes how much loan you have at present?

24. Which fish species are abundant/ common/ uncommon in this lake?

Name of the Fish	Abundant	Common	Uncommon	Remarks

25. What do you do with captured fish?

    Consume Sell Both

26. If you sell fish where do you sell it?

Place	Market/Village	Distance from house	Frequency

27. How much fish do you captured per Month/ year?

28. What type of fishing gears do you used during different time of the year?

29. Do you observed or heard about fish spawning/ breeding?

30. In which month do you observe more fry's and fingerlings in the pond in your catch?

31. Where do you catch the most number of species?

River Zonation			
Running	Shallow	Sand bed	Large boulders

32. What do you think fish population has increased or decreased in this recent year?

33. If increased /decreased please give the reason?

34. What are the aquatic predators of this lake?

35. Do you receive any facilities from public or private institutions at present?

36. Any organizations are come to release fish fries here?

37. What are our responsibilities to conserve the Lake Dipang?

Any suggestion would you like to give for the improvement of fishery of the Jakhor Taal?

Appendix II: Tables of Recorded Value of Environmental Factors

S.N.	Months (2019)	Temperature (º C)			
		Station-1	Station-2	Station-3	Station-4
1	February	13.5	12	13	13
2	July	25	23.5	22	24.5

S.N.	Months (2019)	pH			
		Station-1	Station-2	Station-3	Station-4
1	February	6.9	6.2	7.1	7.4
2	July	7.3	6.8	7.3	8.2

S.N.	Months (2019)	Depth (cm)			
		Station-1	Station-2	Station-3	Station-4
1	February	78	157	312	28
2	July	216	284	457	94

S.N.	Months (2019)	Free Carbon dioxide (mg/l)			
		Station-1	Station-2	Station-3	Station-4
1	February	4.55	4.22	6.51	2.36
2	July	3.47	2.68	4.51	1.74

S.N.	Months (2019)	Dissolved O_2 (mg/l)			
		Station-1	Station-2	Station-3	Station-4
1	February	5.2	4.7	4.9	6.5
2	July	7.4	7.0	7.2	7.7

Appendix III: Location of four selected station during the study period

Station 1

Station II

Station III

Station IV

Appendix IV: Photographs during field work