FISH DIVERSITY OF TARUWA POND IN NAWALPARASI DISTRICT, NEPAL

Submitted By

Keshi Chaudhary

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T.U. Examination Roll No.: 424

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Submitted to

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Tribhuvan University

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Nepal

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DECLARATION

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

Date:- 2076/05/22

....

Keshi Chaudhary

TRIBHUVAN UNIVERSITY ☎ 01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

RECOMMENDATIONS

This is to recommend that the thesis entitled **"Fish Diversity of Taruwa Pond in Nawalparasi District, Nepal"** has been carried out by **Keshi Chaudhary** for the partial fulfillment of Master's Degree of Science in Zoology with special paper **Fish Biology and Aquaculture**. This is her 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.

Date:- 2076/05/22

....

Prof. Dr. Kumar Sapkota

Supervisor

Central Department of Zoology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

TRIBHUVAN UNIVERSITY ☎ 01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

Central Department of T.U., Kirtipur

LETTER OF APPROVAL

On the recommendation of supervisor **"Prof. Dr. Kumar Sapkota"** this thesis submitted by **Keshi Chaudhary** entitled **"Fish Diversity of Taruwa Pond in Nawalparasi district, Nepal"** is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of requirements for Master's Degree of Science in Zoology with special paper Fish Biology and Aquaculture.

Date:- 2076/05/22

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Prof. Dr. Tej Bahadur Thapa

Head of Department

Central Department of Zoology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

TRIBHUVAN UNIVERSITY ☎ 01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by **Keshi Chaudhary** entitled **"Fish Diversity of Taruwa Pond in Nawalparasi District, Nepal"** has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Fish Biology and Aquaculture.

EVALUATION COMMITTEE

....
Supervisor
Prof. Dr. Kumar Sapkota

....
Head of Department
Prof. Dr. Tej Bahadur Thapa

....
External Examiner

....
Internal Examiner

Date of Examination: 2076/06/05 (B.S) 22 sept. 2019 (A.D)

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LIST OF ABBREVIATIONS

Abbreviated form	Details of Abbreviations
APHA	American Public Health Association
CO2	Carbon-dioxide
DO	Dissolved Oxygen
FNU	Formazin Nephelometric Unit
pH	Hydrogen Ion Concentration
DCA	Detrended Correspondence Analysis
RDA	Redundancy Correspondence Analysis
FAO	Food and Agriculture Organization
SD	Standard deviation
Seaaut	autumn season
Seawint	winter season
Seasprg	spring season

ABSTRACT

In recent years, fishes have declined steeply due to shrinkage of water level, excess growth of aquatic weeds and macrophytes, excessive fishing pressure and human exploitation. The present study was conducted to explore the fish diversity and to investigate relation between the fish diversity and environmental variables in Taruwa Pond, Nawalparasi district. The fish sampling was done by using cast net in every three sampling months with the help of local fishermen. A total of 579 individual of fishes comprising 16 species and 8 families were recorded. Among them, the dominant order and family of fishes in Taruwa Pond were Cypriniformes (78.76%) and Cyprinidae (66.67%) respectively. The most dominant fish species was *Puntius ticto* followed by *Puntius terio*, *Lepidocephalus guntea, Danio devario*. Similarly, the lowest dominant order was found Beloniformes, Siluriformes (both with 6.25%) and lowest catch of species was *Mastacembelus artmatus* (0.17%). The species diversity indices were analyzed using the Shannon- Wiener's diversity index, Evenness index and Margalef species richness index. The highest diversity index was found during month of October (1.99) and the lowest diversity index was found during month of January (1.86). The highest species richness was found during month of October (13.82) while lowest species richness was found during month of April (11.79). Similarly, the highest evenness index was found during month of April (0.79) and the lowest evenness was found during both month of October and January (0.75). The relationship between the fish abundance and the environmental variables was performed by multivariate statistical analysis (RDA analysis). By RDA ordination plot, the DO value was found high degree of positive correlation with winter season and fish diversity. Similarly, the pH was found significant relation with spring season and highly associated with distribution of fish species *Colisa lalius* and *Colisa fasciatus*. The RDA ordination plot revealed that the environmental variables of Dissolved oxygen and pH are important two variables for the abundance of fish species in study area.

1. INTRODUCTION

1.1 General background

Biodiversity is the variety of life on Earth, it includes all organisms and plant species (Gaston 2000). Among ecosystems that support a higher biodiversity, wetlands occupy only about 1% of the earth's surface, but provide a habitat for about 20% of the world's species (Dugan 1993). Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. The water surface area of Nepal covers 0.1% of the total world water systems. Fish diversity accounts 0.21% of total global fish diversity (Shrestha 1995, Rai 2008, Gubhaju 2012).

Fish exhibit enormous biodiversity, inhabiting a variety of habitats and are important indicators of water quality (Hussain 2016). Fish assemblages are also an important element in aquatic ecosystems, which are used as one of four biological indicators for aquatic ecosystem assessment (Karr 1981, Oberdorff et al. 2002, Nogueira et al. 2010, Yan et al. 2011). Fish assemblages in river and lakes display spatial and temporal variation due to anthropogenic activities and environmental fluctuations. Empirical studies have been demonstrated the general importance of biotic, abiotic and spatial factors as determinants of fish community structure in natural ecosystems (Jackson et al. 2001, Tonn 1990). Stream fish live in habitats characterized by species-favorable abiotic and biotic conditions and in some cases a small number of environmental factors exercise a strong influence on assemblage or community structure while in others the number is considerably larger (Robinson and Tonn 1989, Edds 1993).

Several interrelated mechanisms operating over different spatial and temporal scales (Poff et al. 1997, Marchetti and Moyle 2001, Wu et al. 2003, Sa-Oliveira et al. 2015, Liu et al. 2017). Generally, during the low water season, lentic marginal environments such as lagoons, ponds and swamps experience the lowest degree of hydrological connectivity with the main river. In these temporarily isolated environments, local processes that depend on the topography, vegetation cover and water supply determine the physico-chemical characteristics of the water and regulate the composition and abundance of fish communities (Tejerina-Garro et al. 1998, Saint-Paul et al. 2000, Suarez et al. 2001).
Fish assemblage structure among oxbow lakes, species richness, diversity, and evenness were greatest in the connected oxbow lake (Winemiller et al. 2000). Similarly, more

species in oxbow lakes that are connected to the river, than in lakes permanently separated from the river (Galat et al. 1998, Petry et al. 2003, Miranda 2005, Miranda et al. 2014). Conditions in the lakes seem to be a major factor affecting diversity. It is widely accepted that environmental variation plays an important role in the organization of fish communities (Tejerina-Garro et al. 1998, Amarasinghe and Welcomme 2002). However, the most important factors in determining species composition differ between water bodies, ranging from physical habitat, like lake morphology, to water chemistry (Tejerina-Garro et al. 1998, Amarasinghe and Welcomme 2002, Petry et al. 2003, Zhao et al. 2006, Cheng et al. 2010).

In tropical lakes where fish biodiversity is richer than in temperate lakes, fish species richness can be predicted by a few variables such as lake area and altitude. Low fish species richness in most temperate lakes might be due to the effect of glaciation on colonization and speciation of fishes. In US, Canadian and northern European lakes, lake acidification is one of the important factors influencing fish species richness. Although, limnological characteristics influence fish species richness in temperate lakes, lake area and altitude have greater predictive power (Amarasinghe and Welcomme 2002).

The abiotic variables such as distance from the source, altitude and water discharge are key factors influencing species assemblages (Legendre and De Caceres 2013). According to Zakaria and Sabariah (1995), the low number of species might be due to the vicinity of tributaries which are considered to be montane with torrent flow, allowing only species specializing to live in a high elevation. Besides that, only a handful of species are able to live at such high elevation reflecting the low diversity in high altitude lake. The distribution and composition of species in each habitat is closely related to various factors such as food availability, breeding sites, depth, topography and water chemistry (Ali et al. 1988). Nutrient concentration, lake area and depth are the factors that determine the fish community structure. In lakes of large size or high trophic state, more fish species occur (Helminen et al. 2000, Jeppensen et al. 2000).

The distribution, abundance and migration of aquatic organisms are also influenced by temperature and dissolved oxygen concentration (Alhassan 2013). Marshall and Elliot (1998) noted significant correlations between a number of individual fish species and water temperature, salinity, dissolved oxygen and depth. Blaber and Blaber (1980) reported that turbidity is associated with productive feeding areas and provides cover for fishes. The two key environmental variables such as the macrophyte complex and water depth plays significant role in spatial and seasonal variations of the fish community in shallow lakes (Ye 2007).

The most immediate threats to the lake's unique environment and biota are pollution from various sources and intensive fishing with illegal methods. These problems and their effects are increasing and immediate attention is required to assess and control these problems and conserve the biodiversity (Donohue 2003). Deforestation can cause deleterious impacts for the lake inhabitants especially for the fish fauna due to sedimentation, limiting food sources, changes in physicochemistry of water which will directly distorted the species richness, composition and species survival. Species richness, species diversity, and species survival in aquatic habitat are affected by several environmental factors, namely the physicochemistry of the water, topographic, hydrological characteristics and habitat destruction (Zakaria et al. 1999).

There has been an increase in human population and anthropogenic activities such as pollution and habitat alteration which have resulted in decrease fisheries resources availability and reduction in biodiversity (Braimah 1995, Ntow 2003).

1.2 Objectives

1.2.1 General objectives:

- To explore the diversity of fish of Taruwa Pond in Nawalparasi, Nepal.

1.2.2 Specific objectives:

- To evaluate the seasonal variation of fish species composition and abundance.
- To analyze the influence of environmental variables on fish diversity.

1.3 Rational of the study

Fishes in natural pond may be declined due to pollution, harmful fishing practices, habitat modification, environmental degradation and eutrophication and impact of other developmental activities. The physicochemical parameters of water are also changing in these recent years which are also the cause for the loss in fish diversity. Since, this natural pond contributes habitat for wide variety of aquatic species, the status of fish species is yet to be unknown. Therefore, this study will provided information about the variation in fish assemblage of the Taruwa Pond, which was first work in this study area.

2. LITERATURE REVIEW

It is well-known that the distribution of fish species in lake depends on several abiotic and biotic factors (Kadye et al. 2008). Among the abiotic factors such as water temperature and oxygen are two parameters that have influence on the fish distribution and population survival in the lake. High temperatures influence on high physiological demands apart from reducing the dissolved oxygen level from the water body. This process indicates the importance of the oxygen and its relationship with water temperature (Jackson et al. 2001).

The positive relationship between richness and lake area, depth or volume might reflect a greater environmental stability in large and deep lakes than in small and shallow lakes (Jeppesen et al. 2000, Irz et al. 2004, Volta et al. 2011). Natural factors and anthropogenic pressures may strongly interact in determining the local fish assemblage in lakes. In the face of the freshwater biodiversity crisis (Dudgeon et al. 2006, Vorosmarty et al. 2010), it is therefore important to estimate the relative contribution of natural and anthropogenic factors on the macroecological patterns of fish diversity in lakes. Fish species richness was unimodally or positively related to anthropogenically increased productivity in lakes (Jeppesen et al. 2000, Olin et al. 2002) and lake productivity was an important predictor of fish abundance and biomass in lakes (Mehner et al. 2005). Lake morphometry (area and depth) is considered the most important natural factor influencing local fish assemblage composition (Jeppesen et al. 2000, Olin et al. 2002, Mehner et al. 2005, Mehner et al. 2007). Fish community structures and diversity are co-affected by limnological characteristics (lake area, water depth), macrophyte coverage and some physico-chemical parameters (Cheng et al. 2010).

Altitude as well as slope gradient exert the primary influence on the abundance and distribution of fish species (Johal and Rawal 2005). Suvarnaraksha et al. (2012) also suggested that the geo-morphological parameters were more significant in predicting both species richness and Shannon diversity index than the physicochemical parameters, in which altitude was the most significant. Distinct patterns of fish assemblage along the longitudinal river gradient reflects the homogenous spatial units within the river basin (Welcomme 2006, Ferreira and Petrere 2009). Nautiyal (2001) suggested that the fish species abundance and distribution is highly influenced by altitudinal and longitudinal zonation. The effects of altitude on fish diversity can probably be attributed to its direct barrier effects on colonization and its indirect effects due to collinearity with temperature (Zhao et al. 2006). Larger and deeper lakes in warm areas tended to be the most species rich and diverse. Fish density was related mainly to anthropogenically driven productivity but also was sensitive to geographical/climatic factors. Thus, warmer and shallower lower-altitude European lakes, which are usually more eutrophic, had higher fish densities than cold and deeper higher-altitude lakes (Brucet et al. 2013).

Fish assemblages have widely been used as ecological indicators to assess and evaluate the level of degradation and health of water bodies at various spatial scales (Vijaylaxmi et al. 2010). Turbidity plays a significant role in the distribution of fish (Blaber and Blaber 1980). Several fish species have shown to actively choose turbid water over clear water during the early stages of life (Blaber and Blaber 1980, Emmet et al. 2004). The advantages of turbid water to juvenile fish were linked to reduced predation pressure where turbidity could act as a protective cover (Gregory 1993, Gregory and Levings 1998).

The aquatic habitat and water quality parameters affect the fish growth and development and ichthyofaunal diversity. Temperature is the important factor for the aquatic biota. According to FAO report (FAO 2010), the increase of temperature directly or indirectly impacts species distribution and the seasonality of production in fishes. Many studies have shown that the changes of environmental factors, such as dissolved oxygen and pH (Matthews and Hill 1979), water depth (Harvey and Stewart 1991), current velocity (Magoulick 2004) and turbidity (Aksnes et al. 2004) affects fish assemblages.

Moreover, air temperature, water temperature, dissolved oxygen, pH and free CO2 are positively correlated with fish assemblages and influenced the fish distribution (Negi and Mamgain 2013). Similar pattern was observed by Stalnaker (1979), Bovee (1982) and Baltz et al. (1987) who attributed the fish assemblage structure variation on various factors like river depth, velocity of water, water temperature, substrate and water quality. Paterson and Whitfield (2000) suggested that neither water salinity, nor temperature and turbidity influences fish distribution, instead fish distribution is more closely correlated to water depth.

Despite a number of studies related with aquatic diversity from different parts of Nepal, there is still no information has been available on the diversity of fish in Taruwa Pond, Therefore, this study is designed to investigate the diversity of fish in Taruwa Pond, Nawalparasi, Nepal.

3. MATERIALS AND METHODS

3.1 Study area

Taruwa Pond is located in Kawasoti Municipality-7, Nawalparasi district (Fig 1). It is about 1.5 km south of Kawasoti, Mahendra highway at geographical coordinates a 27º37’58.46”N and 84º07’55.35” E and occupies an area of 1.8975 hectares. The pond area is located at the altitude of 161.5 m (530 feet). Aquatic vegetation occur in middle part and the littoral region and a tropical forest occupies northern part and human settlement surrounded southern part of its borders. The Pond is divided into two portion (upper and lower) for the irrigation of agriculture land of approximately five villages.

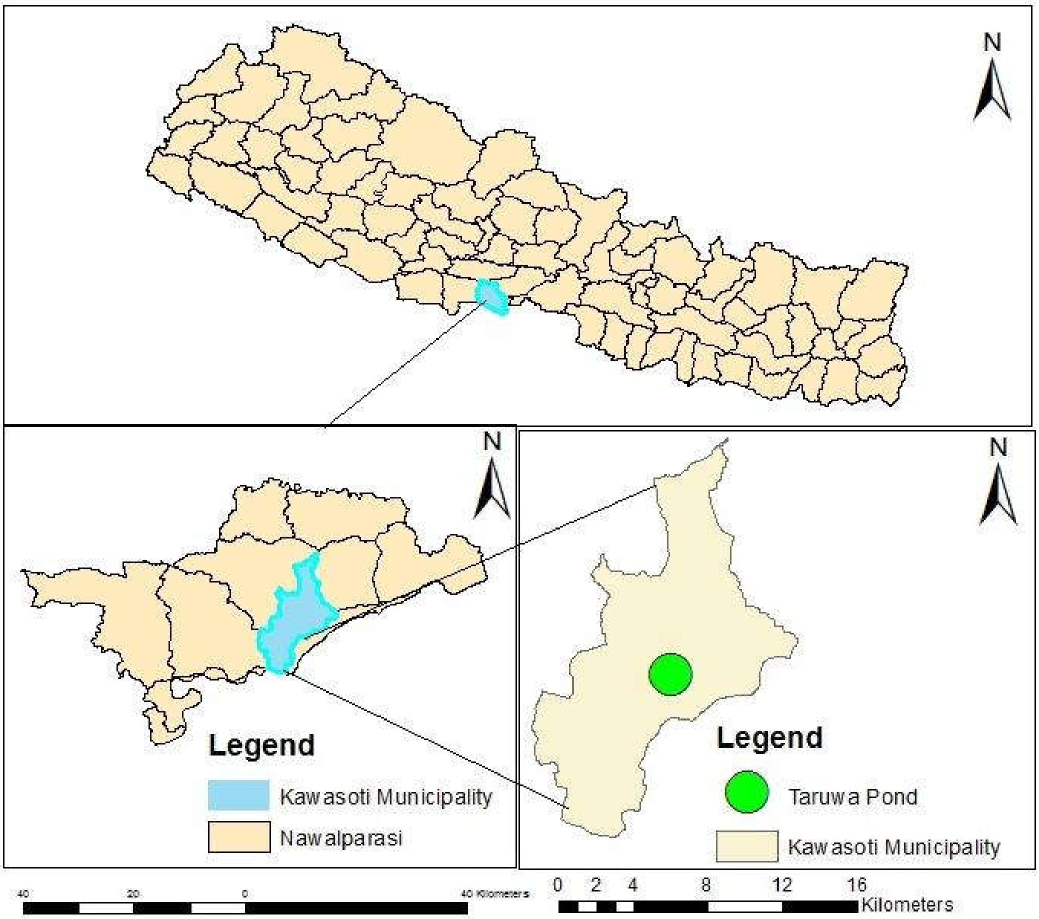

Fig 1: Location map of study area (Taruwa Pond and its adjoining area)

3.2 Materials

- GPS
- Fishing gears
- Camera
- pH meter
- Thermometer
- Measuring tape, nylon rope.
- Chemicals – Formalin(10%) and
- Chemicals for water parameter test (KI, $MnSO_4$, $Na_2S_2O_3$, H_2SO_4 for DO analysis and Phenolphthalein for free carbon dioxide)

3.3 Fish Sampling and preservation techniques

Fishes were collected from different sampling sites of Taruwa Pond in the morning (9:00 am to 11:00 am) once every three months for seven months covering three seasons starting from October 2018 to April 2019. Local fishermen were hired for fish sampling. From sampling site, fish samples were collected by using cast net. The cast net used for fish captured was 4 kg in weight and having 3.80 m in length and 22.5 m breadth with 12 mm mesh size. The cast net was operated for 2 hours at sites (catch effort 15 times installation of cast net in pond for fishing in every three sampling months) in the morning. The number of fish species in the samples and the number of individuals in each species were counted and the local name of fish species was taken from local fishermen. The collected fish samples were photographed and were preserved in 10% formalin solution in plastic jars and brought to CDZ lab for further identification.

3.4 Identification of specimens and deposition

The collected fish samples were identified by using standard method of Talwar and Jhingran (1991), Shrestha (1981, 1994), Shrestha (2008) and Jayaram (2010) and collected specimens at the field survey was deposited in laboratory of Central Department of Zoology, T.U. Kirtipur, Kathmandu, Nepal.

3.5 Analysis of Environmental variables

Physico-chemical parameters of water were determined following standard methods of APHA (1976), Adoni (1985), and Trivedy and Goel (1989). Water samples of Taruwa

Pond were collected during morning time (9:00 am to 10:00 am) and analyzed once every three months during field visit.

3.5.1 Water Temperature:

The temperature of water was recorded by using a standard mercury thermometer by dipping directly on the surface water.

3.5.2 Depth:

The depth was measured by using nylon rope with weight and a measuring tape was used to record the depth in centimeter (cm).

3.5.3 Turbidity:

To measure the turbidity, water samples were collected in bottle and measured directly with turbidity meter (Turb Delagua).

3.5.4 Hydrogen ion concentration (pH):

A pH meter was used to measure the hydrogen ion concentration of water during the study period.

3.5.5 Dissolved Oxygen (DO):

The dissolved oxygen of water was calculated by using Winkler's method. The sample of water from every station was collected in BOD bottle without bubbling. 2 ml of manganese Sulphate and 2 ml of alkaline-iodine-azide solution were added and shaken. Brown precipitation was obtained which was again dissolved by adding 2 ml of concentrate Sulphuric acid. Then this solution was titrated against standard sodium thiosulphate solution (0.025N) and the calculation was carried out by using following formula.

$$\text{Dissolved Oxygen (mg/l)} = \frac{(ml \times N) \text{ of } Na_2S_2O_3 \text{ used during titration} \times 8 \times 1000}{V_2\{(V_1 - V)/V_2\}}$$

Where,

ml = Amount of $Na_2S_2O_3$ used during the titration

N= Normality of $Na_2S_2O_3$

V= Volume of $MnSO_4$ +KI used

V_1= Volume of BOD bottle

V_2= Volume of the part of the content titrated.

3.5.6 Free carbon dioxide (CO_2)

Free carbon dioxide present in the water was analyzed by titrating water sample against a strong alkali (NaoH). Phenolphthalein indicator was used in titration and calculation was done by using following formula of Trivedy and Goel (1989).

$$\text{Free } CO_2 = \frac{(ml \times N) \text{ of NaoH} \times 1000 \times 44}{V}$$

Where,

ml = Amount of NaoH used during the titration

N= Normality of NaoH

V= Volume of water sample taken (ml)

3.6 Diversity Status

3.6.1 Species diversity index

The diversity of species was calculated by using Shannon-Weiner diversity index (Shannon and Weaver 1949). Shannon Weiner diversity index is designated as H', which is calculated as:

$$H' = -\Sigma (Pi) \log (Pi)$$

Where,

$Pi = ni/N$

Ni = Number of all individuals in the species

N = Total number of all individuals in the sample

Log = Logarithm of base e

3.6.2 Species richness index

The species richness was calculated by using Margalef Species richness (Margalef's 1968). Margalef richness index is designated as d, which is calculated as:

Margalef species richness (d) = S-1/ log N

Where,

S = Total number of species

N = Total number of individuals in the sample

3.6.3 Evenness index

To calculate whether species are distributed evenly across seasons and across landscapes elements, evenness index was determined by the following equation (Pieleu 1966).

$$E = H' / \log S$$

Where,

H' = Shannon- Weiner's diversity index.

S = Total number of species in the sample.

3.7 Data analysis

To establish the relationship between the fish abundance and the environmental variables, multivariate statistical analysis (RDA) was performed. The relation between species diversity and environmental variables (water temperature, depth, turbidity, DO, pH and Free CO_2 of water) were analyzed by redundancy analysis (RDA) method (ter Braak 1988a, ter Braak and Prentice 1988) by using vegan library in 'R' (Oksanen et al. 2015).

4. RESULTS

4.1 Environmental variables

4.1.1 Water temperature

As shown in Fig 2, the water temperature ranged from 20.3 ºC to 27.8 ºC. During the study period, the lowest temperature (20.3 ºC) was recorded in month of January and highest (27.8 ºC) in the month of April.

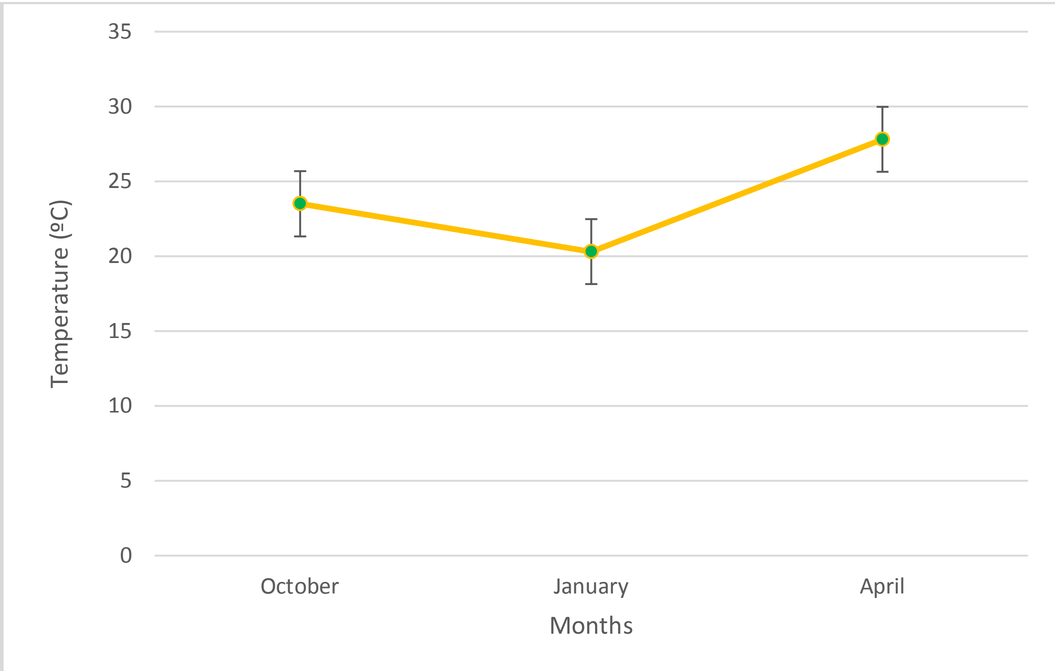

Fig 2: Variations of temperature in different months of Taruwa Pond

4.1.2 Depth

The depth of Taruwa Pond varied during study period and ranged from 83.8 cm to 108.8 cm (Fig 3). The depth was found to be highest (108.8 cm) in the month of October (autumn) and the lowest (83.8 cm) was recorded in month of January (winter).

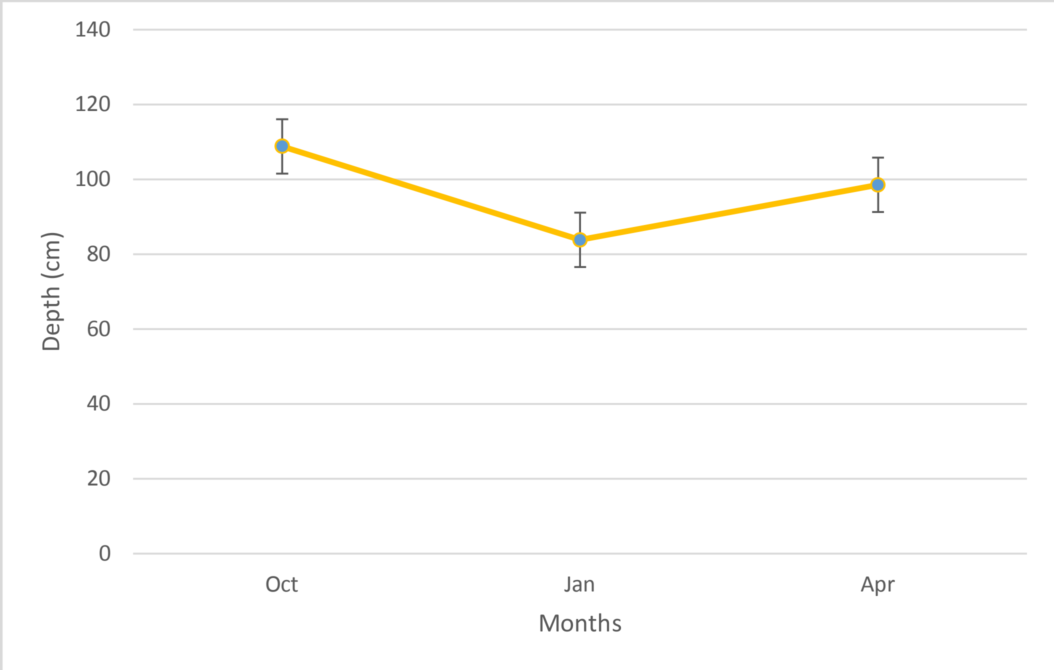

Fig 3: Depth in different months of Taruwa Pond.

4.1.3 Turbidity

The turbidity of water was ranged from 0.3 to 0.5 FNU (Fig 4). The turbidity was found to be highest (0.5 FNU) in the month of April (spring) and the lowest (0.3 FNU) was recorded in the month of January (winter).

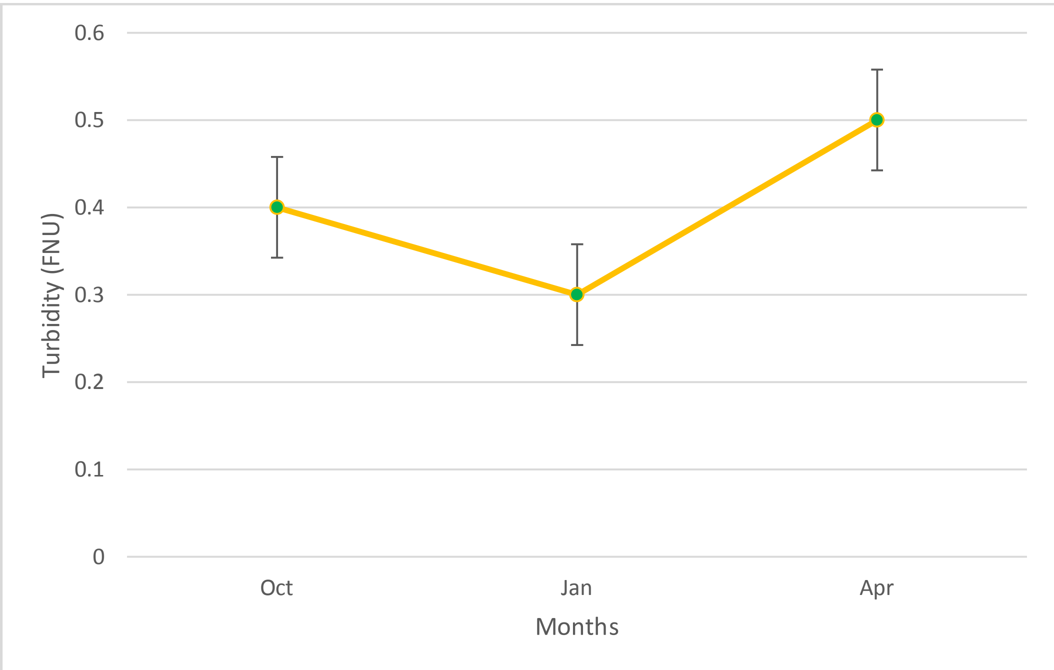

Fig 4: Variations of turbidity in different months of Taruwa Pond

4.1.4 Hydrogen ion concentration (pH)

The pH value of water ranged from 6.7 to 7.85 (Fig 5). The highest value of pH (7.85) was recorded on April (spring) and lowest (6.7) was recorded on October (autumn).

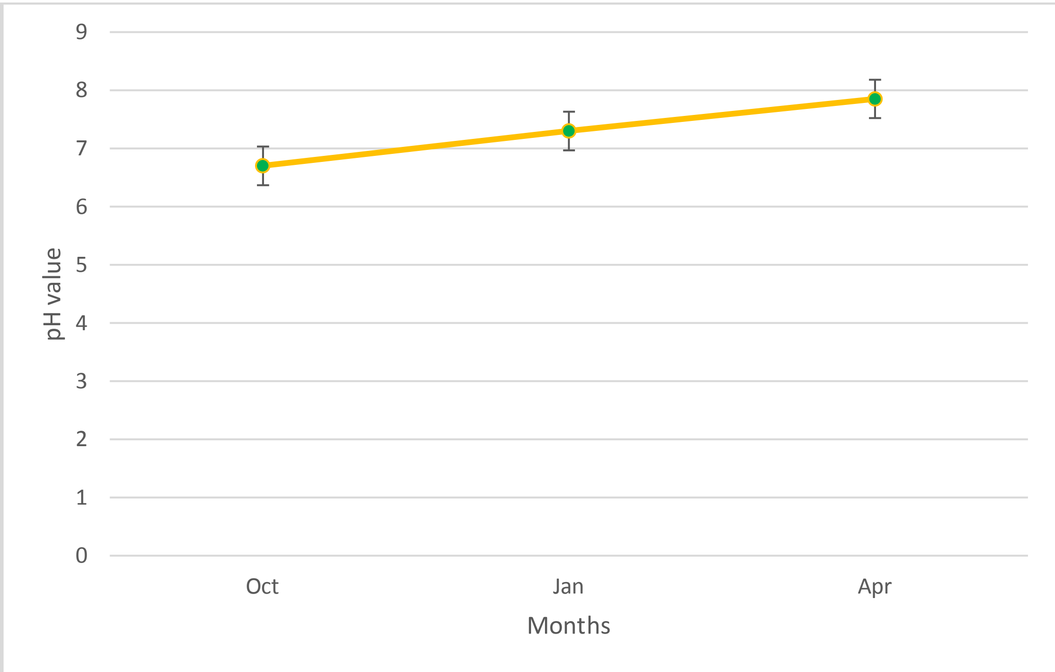

Fig 5: pH values in different months of Taruwa Pond

4.1.5 Dissolved Oxygen (DO)

The dissolved oxygen was ranged from 5.33 to 7.2 mg/l (Fig 6). The maximum DO (7.2 mg/l) was recorded in the month of January (winter) and minimum (5.33 mg/l) in the month of April (spring).

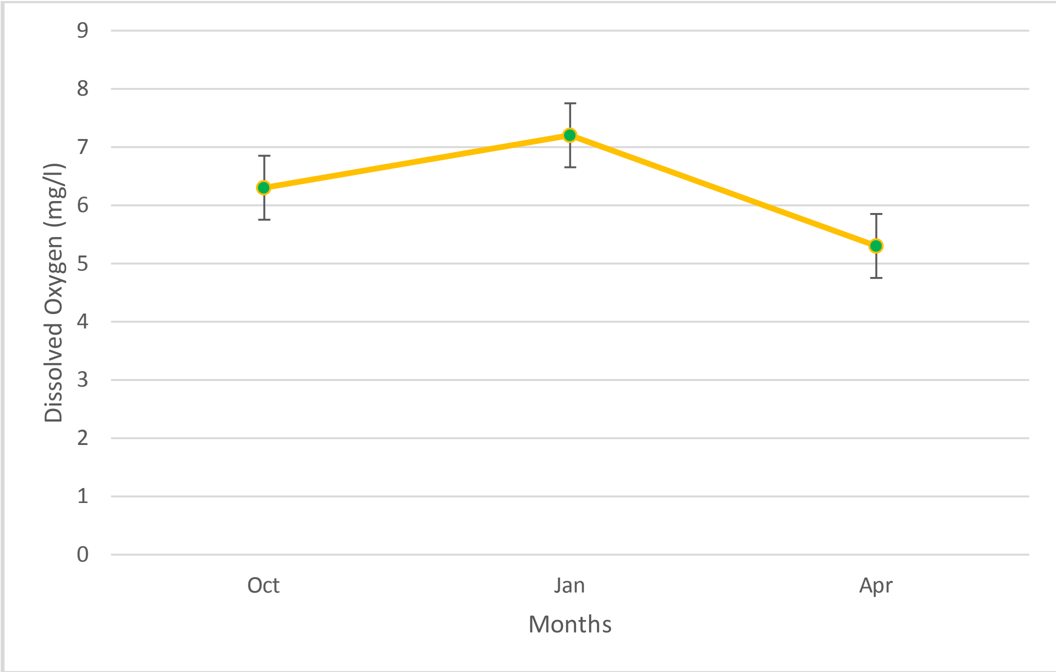

Fig 6: Variations of DO in different months of Taruwa Pond

4.1.6 Free Carbon dioxide (CO_2)

Free CO_2 of water was recorded highest (10.53 mg/l) in month of April and lowest (7.75 mg/l) was in month of January (Fig 7).

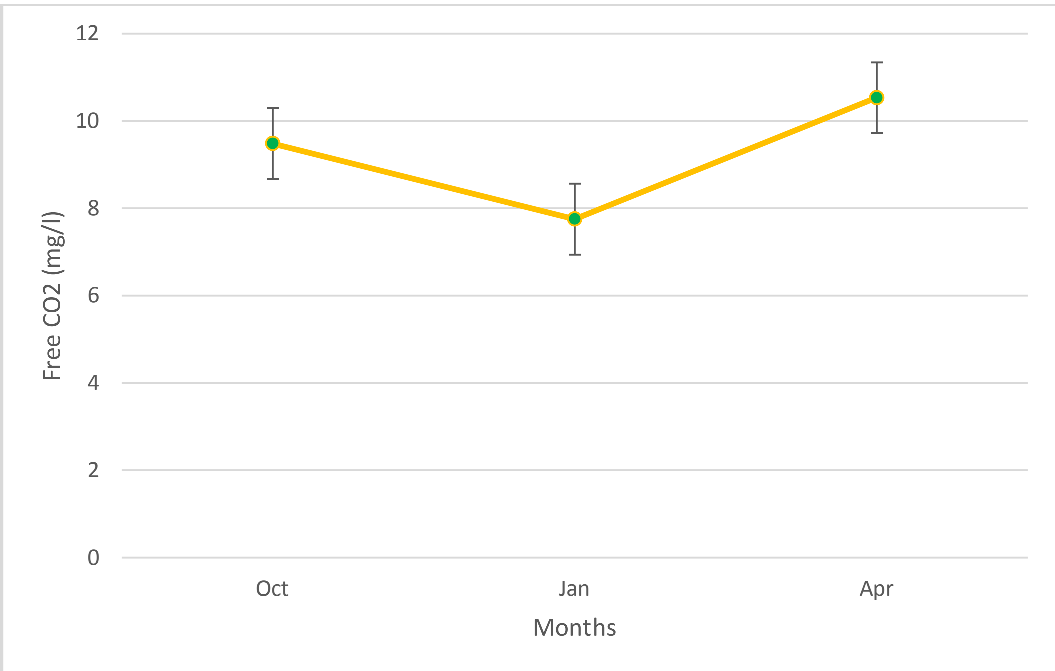

Fig 7: Free CO_2 in different months of Taruwa Pond

4.2 Fish diversity

The Taruwa Pond furnishes a habitat for fresh water fishes of various types. A total of 16 different fish species were collected during study period which included 5 orders, 4 suborders, 8 families, 6 sub families and 13 genera. The seven fish species belongs to order Cypriniformes was found as dominant with frequency 43.75 % followed by order Perciformes comprises five fish species with frequency 31.25 %, while order Beloniformes and Siluriformes belonged to single fish species (6.25%). Order Synbranchiformes contained 2 species (12.5%). Out of 579 fish catch, 456 specimens belonged to order Cypriniformes with about 78.76% of total fish catch which was most abundant order among fish catch during study period. The lowest number of fish catch was only 5 fishes (0.86%) of total catch belonged to Order Synbranchiformes.

Similarly, family Cyprinidae was found as dominant with five fish species and lowest number of fish species belongs to families Belonidae, Bagaridae and Channidae with single fish species, while each of the other 4 families (Cobitidae, Mastacembelidae, Nandidae and Belontiidae) were represented by a two species. Out of total fish catch, 386 fishes belongs to family Cyprinidae with highest frequency (66.67%). The fish species belonges to families Belonidae, Bagaridae and Channidae were represented with different fish catch frequency 2.94%, 2.59% and 4.32% respectively. During study period, family Mastacembelidae comprised least number of fish catch (5 individuals).

The dominant fish species of Taruwa Pond were *Puntius terio, Puntius ticto, Puntius sophore, Danio devario, Esomus danricus, Lepidocephalus guntea, Acanthocobotis botia, Channa punctatus* and *Badis badis* (Table 1). The most abundant fish species of Taruwa pond was *Puntius ticto* with highest fish catch and lowest fish catch was of *Mastacembelus armatus* with single individual which was recorded.

Table 1: Fish species occurrence and diversity in Taruwa Pond

S.N.	ORDER	SUB-ORDER	FAMILY	SUB-FAMILY	SCIENTIFIC NAME	LOCAL NAME
1	Cypriniformes	-	Cyprinidae	Cyprininae	*Puntius terio*	Sidra
2		-			*Puntius ticto*	Tikuli sidra
3		-			*Puntius sophore*	Sidra
4		-		Danioninae	*Danio devario*	Chuna
5		-			*Esomus danricus*	Donahi
6		-	Cobitidae	Cobitinae	*Lepidocephalus guntea*	Chikti goira
7		-		Nemacheilinae	*Acanthocobotis botia*	Nekta goira
8	Beloniformes	-	Belonidae	-	*Xenentodon cancila*	Dhona
9	Siluriformes	-	Bagaridae	-	*Mystus tengara*	Tengana
10	Synbranchiformes	Mastacembeloidei	Mastacembelidae	-	*Macrognathus pancalus*	Gachi
11				-	*Mastacembelus armatus*	Ghorochha
12	Perciformes	Channoidei	Channidae	-	*Channa punctatus*	Khasro bhoti
13		Percoidei	Nandidae	-	*Nandus nandus*	Dhenari
14				Badinae	*Badis badis*	Kalo sidra
15		Anabantoidei	Belontiidae	Trichogasterinae	*Colisa lalius*	-
16					*Colisa fasciatus*	-

4.3 Distribution, abundance and frequency occurrence of fishes in Taruwa Pond

Altogether 579 fish specimens were caught during sampling period. Out of 579 fishes, the most abundant species with high frequency of occurrence was *Puntius ticto* comprises 253 individuals with frequency 43.70% and followed by *Puntiusterio*, *Lepidocephalus guntea*, *Badis badis*, *Danio devario* having frequency 10.36%, 7.60%, 6.90% and 6.74% respectively. The lowest fish catch was single individual fish species includes *Mastacembelus armatus* with lowest frequency (0.17%) is shown in Table 2. The maximum fish species belonged to family Cyprinidae (7 species) and minimum to families Belonidae, Bagaridae and Channidae (with single species). The cyprinids showed higher relative abundance (78.76% of total catch) compared to other fish families during the whole study period. The relative abundance (%) of fish species was more in autumn month compared to winter and spring months.

Table 2: Distribution, abundance and frequency occurrence of fish species in Taruwa Pond according to months

S.N.	**Name of fish**	**Code**	**Months**			**Total**	**Frequency (%)**
			Oct	**Jan**	**Apr**		
1	*Puntius terio*	Punt_ter	34	12	14	60	10.36
2	*Puntius ticto*	Punt_tic	128	70	55	253	43.70
3	*Puntius sophore*	Punt_sop	15	2	5	22	3.80
4	*Danio devario*	Dan_dev	30	9	-	39	6.74
5	*Esomus danricus*	Eso_dan	7	-	5	12	2.07
6	*Lepidocephalus guntea*	Lepi_gun	23	11	10	44	7.60
7	*Acanthocobotis botia*	Acan_bot	11	12	3	26	4.49
8	*Xenentodon cancila*	Xen_can	11	5	1	17	2.94
9	*Mystus tengara*	Myst_ten	9	3	3	15	2.59
10	*Macrognathus pancalus*	Mac_pan	3	1	-	4	0.69
11	*Mastacembelus armatus*	Mast_arm	1	-	-	1	0.17
12	*Channa punctatus*	Chan_pun	9	8	8	25	4.32
13	*Nandus nandus*	Nan_nan	4	2	-	6	1.04
14	*Badis badis*	Badi_bad	12	20	8	40	6.90
15	*Colisa lalius*	Coli_lal	-	-	7	7	1.21
16	*Colisa fasciatus*	Coli_fas	-	-	8	8	1.38
	Total		297	155	127	579	100

4.4 Diversity status of fish fauna of Taruwa Pond

The diversity status of fish fauna of Taruwa Pond was obtained from the value of Shannon Weiner diversity index (H'), Margalef species richness index (d) and Evenness index (E) which were calculated according to months. The highest Shannon diversity index values (1.99) was found in October (autumn season) whereas lowest value (1.86) during in January (winter season). No significant difference was found in the mean Shannon diversity index among months. The maximum Margalef richness value was found 13.82 during October (autumn) whereas lowest value was found 11.79 during April (spring). It is similar to Shannon diversity index. Similarly, highest evenness value (0.79) was found during April (spring) and lowest (0.75) value was found on both month of October (autumn) and January (winter). No significant difference was found in evenness value among the months. The value of Shannon-Weiner diversity, Margalef richness and the evenness in the different months are shown in the Fig 8.

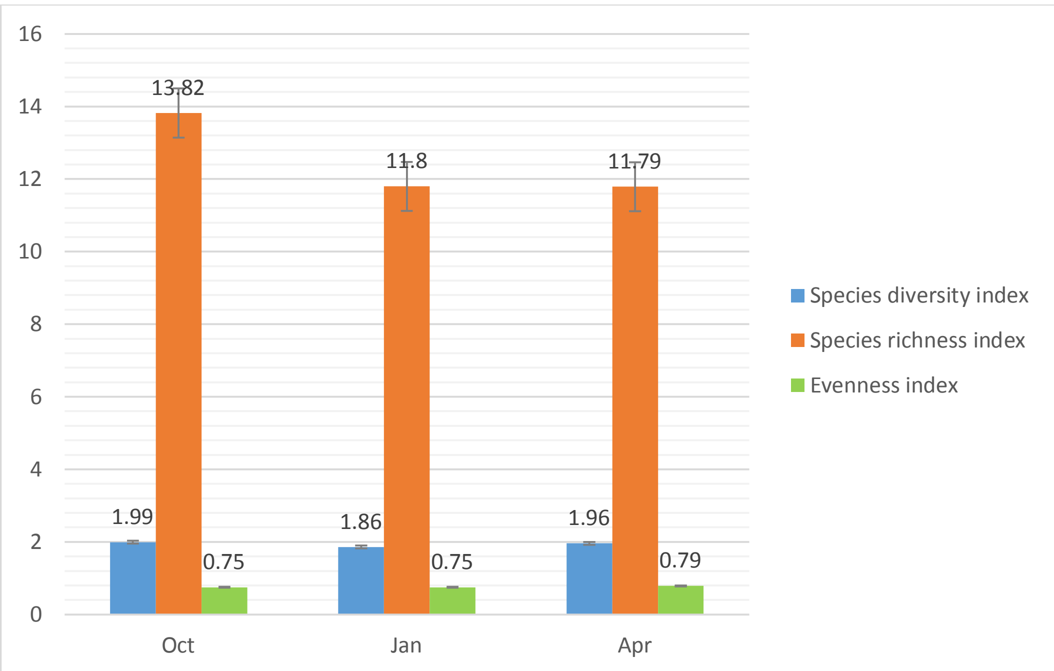

Fig 8: Month wise species diversity index, species richness index and evenness index

4.5 Ordination

The axis length of the first axis of Detrended Correspondence Analysis (DCA) was obtained 0.74 standard deviation unit (SD unit) that followed by 0.48 by the second DCA axis (Table 5). The overall variance explained by the data matrix was 9 %. Thus, application of RDA was justified.

Table 3: DCA summary

	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.09828	0.04930	0	0
Decorana values	0.13146	0.01645	0	0
Axis lengths	0.73778	0.47768	0	0

4.6 Relationship between fish diversity and environmental variables

The relationship between distribution, abundance of fish species and environmental variables in months was established by using multivariate analysis investigated with Redundancy analysis (RDA). RDA is direct gradient multivariate analysis, which can reveal the relationships among community structure, sites and environmental variables by a stepwise multiple regression (Ter Braak, 1986), was applied by using vegan library in 'R' (Oksanen et al. 2015).In the biplot, the importance of each environment characteristic was indicated by the length and angle of the vectors.

The analysis of environmental factors such as water temperature, water depth, turbidity, DO, pH and free carbon dioxide plotted in RDA ordination plots. Although all recorded environmental variables shows significant relation with fish diversity but in this RDA ordination plot, only two environmental variables, Dissolved Oxygen (DO) and pH showed positive correlation with occurrence of fish species in this study. Biplots were generated using RDA after extracting and integrating data from the fish community indices with the environmental variables (water temperature, water depth, turbidity, DO, pH and free carbon dioxide).

The vector length of a given variable indicates the importance of that variable in RDA analysis and the longest vector length of Dissolved Oxygen (DO) at first axis describes significant relation with *Badis badis* and occurrence of *Badis badis* may show positive correlation in winter season. Vector length of Dissolved Oxygen shows positively associated with the occurrence of *Badis badis, Acanthocobotis botia, Xenentodon cancila, Nandus nandus* and *Macrognathus pancalus* and these fish species also showed positive correlation with winter season (Fig 10).Occurrence of *Puntius ticto, Danio devario,* and *Channa punctatus* are positively correlated with the dissolved oxygen and also showed positive correlation with autumn season. Similarly, the occurrence of *Colisa lalius* and *Colisa fasciatus* were found significant relation with the pH during spring season but the occurrence of *Danio devario* and *Xenentodon cancila* showed insignificant relation with all three seasons during study period. In contrast, the vector length of dissolved oxygen and pH revealed negative correlation with the occurrence of *Puntius terio, Puntius sophore, Lepidocephalus guntea, Esomus danricus* and *Mystus tengara*. The higher occurrence of *Puntius ticto* during autumn season, showed positive correlation with dissolved oxygen and negative correlation with the pH. In this RDA plot (Fig 9) showed lesser significant role of remaining four environmental variables (water temperature, depth, turbidity and free carbon dioxide) with the occurrence of fish species during study period. The ordination plot revealed the perfect negative relation of dissolved oxygen (DO) with pH (Fig 9). The biplot was done to show the relation between seasons, environmental variables and fish abundance. The RDA biplot showed that the autumn season is the important seasons for the occurrence of fish species during study period (Fig 10). The ordination plot (Fig 9) revealed that the environmental variables of dissolved oxygen and pH are the two important variables for the presence of fish species during seasons.

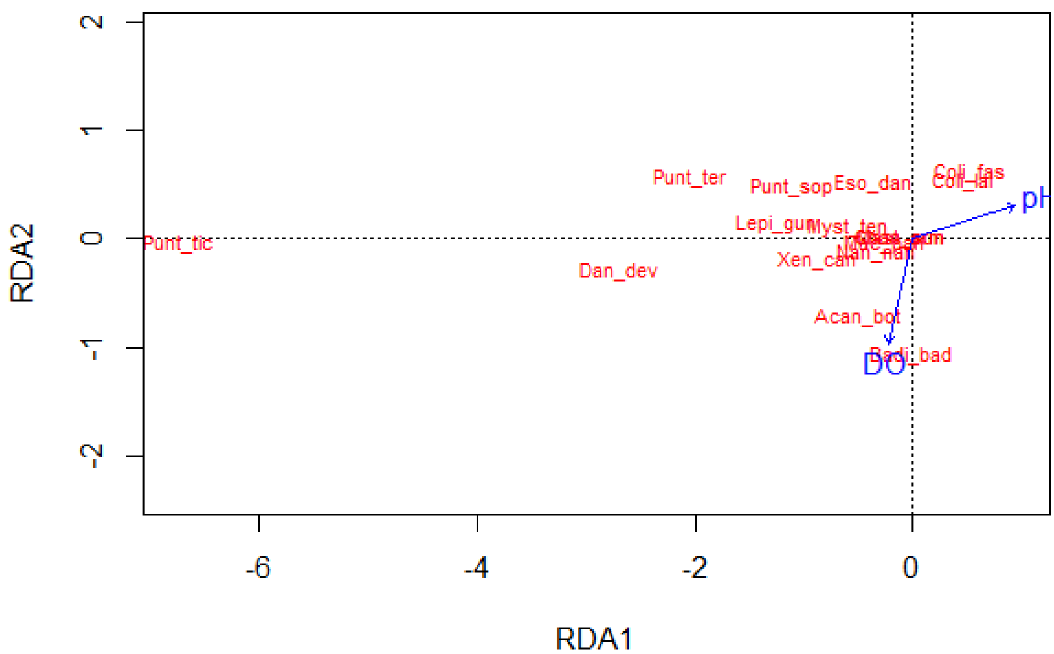

Fig 9. Ordination biplot of fish species abundance and environmental variables obtained by RDA.

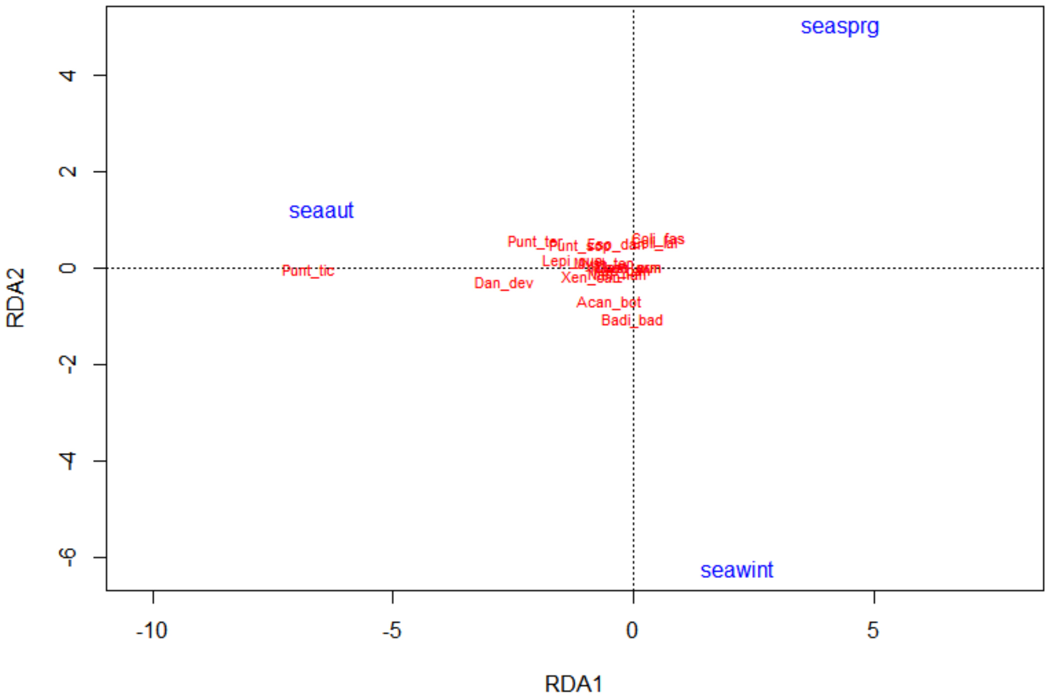

Fig 10. Ordination biplot of fish species abundance obtained by RDA across sampling periods (seasons).

5. DISCUSSION

The most abundant fishes recorded from Taruwa Pond were *Puntius ticto*, *Puntius terio* and *Lepidocephalus gentea*. Gautam et al. (2010) reported 42 fish species from Jagadispur Reservoir, Kapilbastu District. Among them *Puntius sophore, Acanthocobotis botia, Lepidocephalus guntea, Mystus tengara, Mastacembelus armatus, Nandus nandus, Colisa fasciatus, Channa punctatus* were common fishes in the studies. Some species such as *Notopterus notopterus, Anabas testudineus, Clupisoma garua, Ompak bimaculatus, Monopterus cuchia, Channa striatus* etc were not found in present study. It may be due to altitude variation and other environmental variations.

In Taruwa Pond, Fishes belonged to order Cypriniformes and Perciformes were dominant. Out of total fish species 43.75% belongs to order Cypriniformes which is consistent with the findings of Negi et al. (2007), Joshi (2015), K.C. (2015) and Guo et al. (2018).

In this study, the water temperature was found to be varied from 20.3 – 27.8 °C. Maximum water temperature (27.8 °C) was recorded during spring and minimum (20.3 °C), in winter which is nearly same value as supported by previous studies (Alam (1993), Kamal (1992), Hossain et al. (2012) and Limbu et al. (2018)).Water temperature plays important role in fish species composition in natural ponds, lakes, reservoirs etc. During this study, temperature was found to be significantly related with fish diversity.

In the study, dissolved oxygen of Taruwa Pond was varied from 5.33- 7.2 mg/l. Studies have shown that dissolved oxygen decreases during the summer season and steadily increases in autumn till maximum in winter due to seasonal variation. The maximum value of dissolved oxygen (7.2 mg/l) was found in winter and the minimum value (5.33 mg/l) was recorded in spring. These results are quite similar to the findings of Kaul and Handoo (1980), Dowling and Wiley (1998), Kar et al. (2006), Kamaruddin (2010), Tian et al. (2012), Khan et al. (2017).

In this study, the pH values were found slightly acidic to alkaline and ranged from 6.7 (autumn) to 7.85 (spring) during study period. The acidic pH may be influenced by the presence of humic acids from the decomposition of organic matters from other macrophytes grown within pond which is nearly similar with the values of pH reported by Boyd and Lichkoppler (1979) and Bastola (2013).

The depth of water is important physical parameter that also affects the fish distribution. During study period, the depth of pond was found be ranged from 83.8 cm to 108.8 cm which is also consistent with the finding of Zhao et al. (2015). It was also observed that water depth played the significant role in distribution and abundance of fish species in Taruwa Pond.

During the study period, turbidity value was ranged from 0.3 to 0.5 FNU. The minimum turbidity values was 0.3 FNU recorded in winter season and maximum values was 0.5 FNU recorded in spring season. Similar studies made by Kadye and Moyo (2007) and Mensah et al. (2018) reported that turbidity recorded in the wet season was higher than that in the dry season and may have contributed to the supposed inability of fishes to detect nets in turbid waters. This contradicts a study made by Ayanwale et al. (2013).

Free carbon dioxide is highly soluble in water and the main sources of CO_2 in water are from atmosphere and respiration of aquatic animals. In the present study, the highest value ofCO_2 was observed in spring while the lowest in winter seasons, which is in consistent with the finding of Chakraborty et al. (1959), Osmundson et al. (2002) and Surana et al. (2010).

From the present investigation, the analysis of RDA showed that Dissolved Oxygen and pH, acts as important physicochemical variables that significantly affected fish distributions and assemblage composition in different seasons. Similar observations had also been made by Zhao et al. (2015) and Guo et al. (2018). Many studies have also found that the changes of environmental factors, such as dissolved oxygen and pH affected fish assemblages (Matthews and Hill 1979).

The relative abundance (%) of fish was higher in autumn season compared to winter and spring season (Table 2). It is interesting to note that the relative abundance and the value of diversity indices were found lowest during month of January. This could be due to the weather and feed effect. The fish may hide itself under natural shelters in ponds in the month of January because of extreme drop of temperature in winter season and hence chances of fish capture by cast/drag net are poor.

Species richness varied in months but there was no specific seasonal trend. The variations in species richness and diversity in relation to different sampling periods and months have been observed in several studies (Ornellas and Coutinho 1998, Pires et al. 1999, Reichard et al. 2002).

6. CONCLUSION

A total of 579 individual fish comprising 16 species, 13 genera and 8 families were caught in Taruwa Pond during the sampling period. Five genera, namely *Puntius*, *Lepidocephalus*, *Badis* and *Danio*, dominated the catches. They contributed 57.86%, 7.60%, 6.90% and 6.74% by number respectively, of the total catch. The total catch was dominated by *Puntius ticto* (43.70% by number, respectively) followed by the *Puntius terio* (10.36%), *Lepidocephalus guntea* (7.60%) and *Badis badis* (6.90%). The frequency of occurrence of the species in the catch revealed that, *Puntius*, *Esomus*, *Lepidocephalus*, *Acanthocobotis*, *Channa* and *Badis* appeared in all the samples as compared to the other species.

Taruwa Pond is a natural pond which provide habitat for diverse indigenous fish species like *Puntius terio*, *Puntius ticto*, *Puntius sophore*, *Danio devario*, *Esomus danricus*, *Lepidocephalus guntea*, *Acanthocobotis botia*, *Xenentodon cancila*, *Mystus tengara* etc. The relative abundance (%) of cyprinids was found more in autumn months compared to winter and spring months. The highest value of Shannon-Weiner diversity index was found in autumn season and lowest value was found in winter season. Similarly, highest value of Margalef species richness index was observed in autumn season and lowest in spring season. Also, highest value of evenness index was found in spring season while lowest in both autumn and winter season. There was no significant effect of season on fish abundance and diversity indices values.

Fluctuations in the environmental variables between the seasons were minimal. Dissolved oxygen and pH appeared to be a major environmental gradient determining the structure of the fish species community. Most of fish species showed strong associations with high levels of dissolved oxygen and pH. During the study period, water temperature, depth, turbidity and free- carbon dioxide were of lesser significant importance. Fish abundance and diversity in Taruwa pond are probably related to the habitat structure, season and several environmental variables. Variation in characteristics of the pond is likely to be caused by natural variability of the ecosystems and harmful human activities.

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APPENDIX-1

REPRESENTATIVE PHOTOPLATES

Photo 1: *Puntius terio* Hamilton-Buchanan, 1822.

Photo 2: *Puntius ticto* Hamilton-Buchanan, 1822.

Photo 3: *Puntius sophore* Hamilton-Buchanan, 1822.

Photo 4: *Danio devario* Hamilton-Buchanan, 1822.

Photo 5: *Esomus danricus* Hamilton-Buchanan, 1822.

Photo 6: *Lepidocephalus guntea* Hamilton-Buchanan, 1822.

Photo 7: *Acanthocobotis botia* Hamilton-Buchanan, 1822.

Photo 8: *Xenentodon cancila* Hamilton-Buchanan, 1822.

Photo 9: *Mystus tengara* Hamilton-Buchanan, 1822.

Photo 10: *Macrognathus pancalus* Hamilton-Buchanan, 1822.

Photo 11: *Mastacembelus armatus* Day, 1876.

Photo 12: *Channa punctatus* Bloch, 1793.

Photo 13: *Nandus nandus* Hamilton-Buchanan, 1822.

Photo 14: *Badis badis* Hamilton-Buchanan, 1822.

Photo 15: *Colisa lalius* Hamilton-Buchanan, 1822.

Photo 16: *Colisa fasciatus* Bloch and Schneider, 1831.

Photo 17: Fish sampling with the help of local fishermen

Photo 18: Analysis of environmental variables at site and laboratory

Photo 19: Identification of fish species in CDZ Fishery lab