1. INTRODUCTION

1.1 General Background

Nepal is a landlocked country in South Asia, situated between latitudes $26^0$12'N and $30^0$27'N and longitudes $80^0$04'E and $88^0$12'E, and bordered by China in the north and by India in the south, east and west. Nepal has a land area of 1, 47,181 km^2.Within the limited area, there exists a remarkable altitudinal variation ranging from the plain in the south with hot subtropical climate to the mountain region in the north with temperate climate and very cold alpine climate in Himalayan Region (Rao and Gupta, 1998). Thus, topographically Nepal has three distinct regions i.e. High Himalayan, Sub-Himalayan and Terai region.

1.2 Water Resources of Nepal

The natural water resources of Nepal consist of rivers, lakes and reservoirs comprising of approximately 49.14 percent of the total existing water area of Nepal (Table 1).

There are more than 6000 rivers and rivulets in Nepal. The topography changes sharply from mountainous region in North to Terai Region in the South. The rivers mostly flow from North to the South direction passing through different regions. Along with the rivers, Nepal is provided with several types of wetlands.

Table:1 Estimated Water Resources of Nepal

Resources Details	Estimated Area (Ha)		Percentage Coverage	Potential Area (Ha)
Natural Water	Rivers	3,95,000	48.34	
	Lakes	5,000	0.61	
Reservoirs		1,500	0.18	78,000
Village Ponds		6,500	0.80	14,000
Seasonal Water	Marginal Swamps	11,100	1.36	
	Irrigated Rice Fields	3,98,000	48.71	
Total		8,17,100	100	92,000

Source: Directorate of Fisheries Development, 2014

1.3 Fish Resources of Nepal

The published literature on fish and fisheries of Nepal reveals a total of 238 fish species identified till now (Fish Base, 2013). These fish species are found in various water bodies at different altitude ranging from few hundred meter from sea level to as high as 4,000 meters. The total number of species belongs to 98 genera under 35 families and 11 orders. In the upper Himalayan Region, fishes like Snow Trout (*Schizothorax* spp.) and

Schizothoraichthys spp.), Suker headed (*Garra* spp.), Stone loaches (*Nemacheilus* spp.) are found in the lower hilly region (900-2000) fishes like Sahar (*Tor* spp.), Bhakur (*Catla catla*), Rohu (*Labeo* spp.), Faketa (*Barilius* spp.), Kabre (*Pseudecheneis sulcatus*) are found. The lower plain of Terai consists of some fish species such as Rohu (*Labeo* spp.), Sidre (*Puntius* spp.), Catfishes like *Heteropneustes fossilis, Wallago attu, Clarias batrachus, etc.*

In the last few years, inland water has been subjectedto a range of stress caused by direct and indirect human activities such as irrigation, hydro-electric projects, urbanization, industrialization, modernization of agriculture etc. has adverse effects on the aquatic biodiversity specially the native fish fauna (Swar and Shrestha, 1997). Many problems have been identified such as siltation, chemical pollution, introduction of exotic fish species, over exploitation like irrational use of fishing gears (small mesh gillnets, use of explosive, electro-fishing and poisoning) and hydraulic engineering (dam and improvement, canalization etc.). All these activities posed a danger to many of the indigenous species inhabiting water bodies (Shrestha, 1990/1998).

Several exotic fish species have been introduced in to the country. Brown trout (*Salmo trutta*) and Rainbow trout (*Oncorhynchus mykiss*) are exotic cold water species. The other warm water speciesare *Cyprinus carpio, Ctenopharyngodon idella, Hypopthalmichthys molitrix, Aristichthys nobilis, Carassius carassius, Carassius auratus, Cyclocheilichthys apogon, Puntius gonionotus, Clarius gariepinus, Oreochromis mossambica, Pangasius sutchi.* Several indigenous fish species are declining which are recommended for legal protection. The recommended fish species are *Neolissocheilus hexagonolepis*as vulnerable(V), *Chagunius Chagunio* (V), *Tor putitora* (V), *Tor tor endangered*(E), *Schizothorax richardsonii* (V), *Anguilla bengalensis* (V), *Myersglanis blythi* (V) *and Schizothorax progastus* (V) (Shrestha, 2001).

1.4 River System of Nepal

There are more than 6,000 rivers and rivulets in Nepal. The topography of Nepal changes sharply from high Himalayan region in north to the plain or Terai Region in the south within a short distance of 160km to 270km in North-South direction (Nexant, 2002). The rivers mostly flow from north to the south direction passing through different physiographic regions. These regions that stretch north to south are the High Himalayas, High Mountains, Middle Mountains, Siwalik and the Terai. Depending on their sources, the rivers of Nepal can be classified into the following three types:

1. The major rivers originating from the Himalayas or the High Mountains,
2. The medium rivers originating from the Middle Mountains and
3. The southern rivers originating from the Siwalik range or the Terai.

The major rivers are the Karnali, Gandaki (Narayani), Koshi and the Mahakali along with their tributaries. These rivers have their sources in the snows and glaciers in the Himalayan Region. These rivers have substantial flow even in the dry season and they

provide reliable flow for irrigation, hydro-power, inland navigation etc. The medium rivers are the Kankai, Kamala, Bagmati, West Rapti and the Babai originating from the Mahabharata Ranges (Middle Mountains) below the snow line. These rivers are fed by ground water including springs and do not dry up in the dry season. These rivers are good for irrigation and hydro-power. The seasonal variations in these rivers are however higher, compared to the major rivers. The southern rivers originate in the Siwalik (Churia) range and the Terai and these rivers are normally dry in the summer season. Flash floods occur in the monsoon causing damages in these rivers.

All these large and small rivers give rise to about 6,000 rivers totaling about 45,000km in length. Approximately, 1,000 of these rivers are more than 10km long and about 100 of them are longer than 160km (Sharma, 1977).

Among the four major river system in Nepal, Saptakoshi in the East, Saptagandaki in the center, Karnali in the west and Makali in the far-west, three river system Saptakoshi, Saptagandaki and Karnali rivers originates from the Tibetian Plateau and crosses the Himalayas. Each river system has several tributaries, which are fed by snow and glacier.

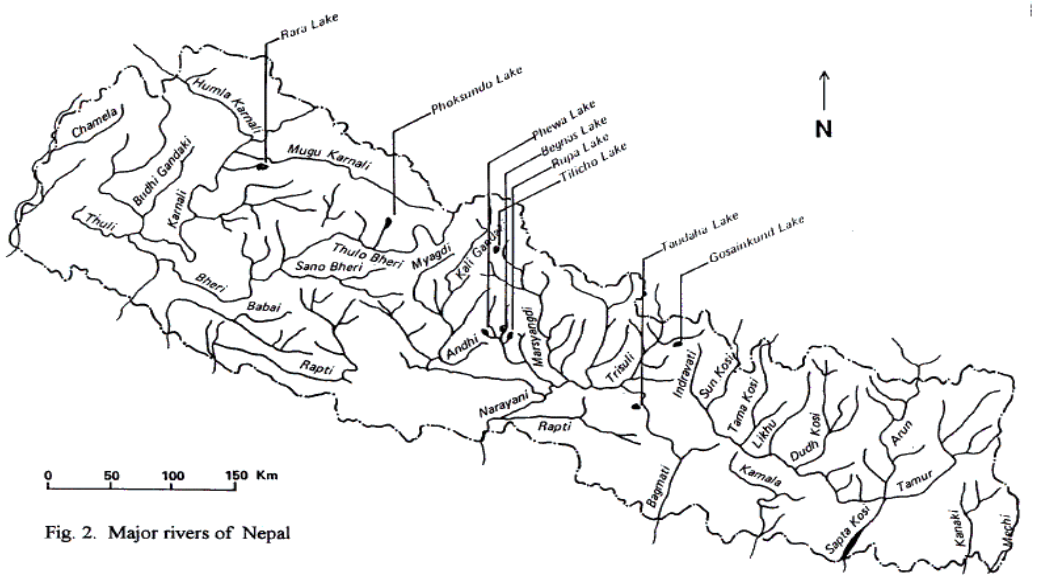


Fig. 2. Major rivers of Nepal

Map 1: River System of Nepal.

1.4.1 The Jhimruk River System

The Jhimruk River is one of the major among the tributaries of West Rapti River of Nepal. It originates from the Mahabharat range of Pyuthan and Rolpa district of Mid-Western Nepal. The total length of river is estimated 47 miles (Sharma, 1997). It flows from Pyuthan district towards southern direction and meets Rapti River. Jhimruk, itself has many tributaries approximately 17 khola (Sharma, 1997). The major tributaries of Jhimruk River System are as flows:Gaon Khola, Libang Khola, Dhoato Khola, Timru Chaur Khola, Gawdi Khola, Hangarh Khola etc.

1.5 Hydro-power Development in Nepal

Although Nepal is a landlocked country, there are many rivers and rivulets. The major rivers along with their tributaries have their sources in the snows and glaciers in the Himalayan Region. Rivers of Nepal have substantial flows even in the dry season and they provide reliable flows for irrigation and hydro-power. The high specific runoff and steep gradient of the rivers of Nepal provide a huge potential of hydro-power generation. The small tributaries in Hills and Mountains have been used or have the potential to develop many micro and small hydro-power schemes to provide much needed electricity. The major rivers and their tributaries, which are snow fed, have substantial flow even in the dry season and hence provide a favorable hydro-logical regime for the development of run-of-river type of hydro-power projects especially in the Middle Mountain Region where the river gradients are high. Some major storage type of hydro-electric projects with multi-purpose benefits are also planned and some are under construction such as – Koshi High Dam (4,000 MW), Karnali Multi-purpose Project (10,800 MW) and Pancheswar Project (6,000 MW). The medium rivers where the seasonal variations are high are mostly suitable for medium scale reservoir projects like the Khulekhani (92 MW), Kankai (60MW), Sharada (49 MW), Naumure (300 MW) (Regional Hydro-power Status, 2002).

The theoretical hydro-power potential of the country based on average flow available has been estimated to be 83,000 MW, out of which about 42,000 MW is estimated to be economically feasible under present condition. About 85% of the potential is based on reservoir protects. The reservoir projects will mostly also have other multi-purpose benefits like irrigation, low flow argumentation, flood control and navigation.

1.6 Jhimruk Hydro-power Project

12 MW Jhimruk Hydro-Power Project is one of the power plants of Butwal Power Company. It is located in Pyuthan district of Province- 5 of Nepal. The main component of the project (Power House) is located at Mandabi-3, Darimchaur, Pyuthan, on the left bank of Madi Khola whereas the headwork i.e. dam site is located in Mandabi-3, Khaira in the Jhimruk River. This hydro-power plant is run-of-river type with daily pondage. A tunnel of headrace $1050m \times 8.5m^2$ inclined shaft (45^0), fully lined with steel and concrete is made up to the power house, which is semi-underground, steel trusses from the dam. Thus, by the transfer of water from Jhimruk River to power house situated in the left Bank of Madi Khola through the tunnel power is generated.

This hydro-power construction was started in November 1989 and was completed in July 1994. The power generation was started from 17 August, 1994.

1.7 Jhimruk Hydro-power Dam

The diversion dam of Jhimruk Hydro-Power Project is located in 28.9N and 82.9E on the Jhimruk River in Pyuthan district. A curvilinear dam, the first of its kind in Nepal, across the wide Jhimruk River is made by trailing the river through 2km canal by gabian mattresses. The dam is 255m long, curvilinear with desilting basin and intake of $10,000m^3$ concrete. The spillway consists of three bays, each controlled by a 15m wide, 19m high radial gates. The

design discharge of dam is 7.05m^3/s. An inclined fish ladder is presents on the right side of the dam for the fish passage.

Damming and channelization on river obstruct the fish species in many ways such as : low flow of water or absent of water flow destruct the environment, loss of spawning ground, effect on fish migration of migratory species, chemical pollution etc. which directly hamper fish population and affect the native fishing people.

1.8 Justification of Study

Hydro-power development in Nepal can play a vital role in the overall development of the nation. But damming in river for power generation has caused different long and short term effects losing biodiversity.

Jhimruk River has usually running and flowing water. Construction of hydro-power dam across it turns the section of river immediately behind it into a dam-lake which the lotic water of the upper reaches becomes lentic as water approaches to the dam. Riverine ecology fauna gradually disappears and is replaced by typical lacustrine benthic fauna. Running water fish species become fever and slow water fish species pre-dominate. Dam interrupts the continuity of riverine flow and generates hydrological changes in river ecosystem. The changes are ultimately reflected in the life of indigenous fishes. Besides it, dams significantly block nutrient flow throughout the ecosystem, affecting fisheries production in the downstream reservoirs (Welcomme, 1985). Reservoir traps suspended solids to increase turbidity and limit primary production along with increase in depth and storage capacity (Sugunan, 1995). So, present study is an attempt to study the impact of dam on fish and fisheries of Jhimruk River. Attempts have also been made to study the water quality in this zone. The study will help the planners in improving ongoing mitigating measures, which are not up to the standard for the better management of the Jhimruk River ecosystem.

1.9 Limitations of the Study

The present study is mainly concerned with the impact of dam on fish and fisheries including water quality parameters. Due to the lack of well-equipped biological and chemical laboratory in project site, some of parameters like temperature, water velocity, DO, free CO2, alkalinity could only be studied. Limited financial resources and technical facilities had limited the study work.

Objectives:

General objective:

- To investigate the major impacts of the dam on the Jhimruk River ecology.

Specific objectives:

→ To access the status of fish species in Jhimruk River.
→ To examine the physico-chemical parameters of the Jhimruk River.

2. LITERATURE REVIEW

2.1 Fish Diversity

The history of ichthyology coincided with that of zoology which deals back from the time of Aristotle (384-322 BC). Aristotle distinguished various group of aquatic animals. His nomenclature of ichthyology was limited to 115 species of fishes, all of which were native of sea adjacent to Greece. The contribution of Pierra Belon (1517-75 AD) was based on his original observation of 110 species of Mediterranean Sea in Europe. Piso (1611-78 AD) was a one of the noteworthy scholars of ichthyology. The notable contribution was later made by Linnaeus (1707-78 AD), McClelland (1839), Bleeker (1853) etc. Gunther published catalogue of the fishes of British Museum, London in eight volumes. The work contained on account of 6847 species together with the description of another 1,682 doubtful species.

2.2 Historical Studies of fish in Nepal

The earliest record of fish and fishery of Nepal dates back to 1793 AD by Colonel Kirkpatrik. He reported fishes like Sahar (*Tor* spp.) from Rapti River, Eel (*Amphipnious* spp.), Asala (*Schizothoraichthys* spp.) and Fageta (*Barilius* spp). However, the credit of first scientific report on the fish fauna of Nepal goes to Buchanon (Later Hamilton 1822) for the work of 1822 "An Account of Fishes Found in the River Ganga and Its Tributaries". He reported 24 fish species from the Koshi River and 2 fish species from Rapti River of Nepal. Rajbanshi (2005) published a paper from RONAST where he reported 187 fish species under 10 orders, 30 families and 94 genera.

Some of the cold blooded vertebrates including fishes were reported by Gunther (1861). 35 fishe species were included in the report prepared by him. After that, Mc Clelland (1839), Beavan (1877), Day (1878-1881), Boulenger (1907) and Regan (1907) also reported different fish fauna of Nepal. Regan (1907) reported five species from Nepal. Hora (1920-1952) studied the Himalayan fishes with particular stress on paleogeographical distribution. Bailey collected 158 specimens comprising 22 different genera. He also included a full description of *Glyptosternum* collected from Pharping.

Menon (1949) reported 11 families of fishes comprising 26 genera and 52 species from Koshi River. Taft (1951) prepared a report on his survey "Fishes of Nepal" and described 94 species of fishes from Kathmandu.Thapa and Rajbanshi (1968) studied the ecology of hill stream fishes of Nepal. Majupuris and Shrestha (1968) published; paper on fresh water fishes of Nepal. Shrestha (1981) published a book entitled "Fishes of Nepal" enlisting the description of scientific data of 120 species.

Tarashima (1984) reported three endemic species of genus *Schizothorax macrophthalmus, S. nepalensis and S. rararensis*. Edds (1985) added a list of eight new records of fish previously not recorded from Nepal. Jha and Shrestha (1986) studied fishery resources of River Karnali and recorded 51 species of fishes. Joshi (1988) studied the fishery resources

of Sunkoshi River with particular references to dam and its impact on fishery. Shrestha (1991) reported 59 species of fishes from Mountains and Himalayan Regions of Nepal in "Cold water fish and fisheries of Nepal". Shrestha (1994) described 66 genera and 129 species of fish in her book entitled "Fishes, fishing implements and methods of Nepal". Shrestha (1995) reported 182 indigenous fish species of Nepal. Smith et al. (1996) reported 121 and 135 fish species in the Karnali and Narayani River respectively.

Shrestha (1997) in the book, "The Mahaseer, in the rivers of Nepal disrupted by dams and ranching strategies" indentified some environmental impacts of hydropower development on fish species. Malla (2004) studied on diversity, distributional patterns and frequency occurrence of fish and invertebrate species in Darim Khola, Baglung. A total of 21 fish species belonging to 16 genera, 8 families and 4 orders were presented. Shrestha (2008) reported a total of 232 fish species in the book "Ichthyology of Nepal".

2.3 Limnology Study in Nepal

Brehm (1953) was the first limnologist who studied some aquatic fauna along the limnology from Kalipokhari, Eastern Nepal. Ferrow (1978) studied limnology of the Lakes in Pokhara Valley. Limnology of Bagmati and Trisuli Rivers has been studied by Shrestha et al. (1979). Swar (1980) has described the status of limnological studies and research in Nepal.

Mahaseth (1988) studied the physico-chemical parameters of Tadi River in relation to fish production and management. Talling and Lamoala (1998) studied in tropical and temperate Lakes of Nepal. Rai (2000) studied about zooplanktons and phytoplanktons from various Lakes of Pokhara Valley and reported 26 species of phytoplanktons and 18 species of zooplanktons.

Pandey (2004) worked and studied the fish and fisheries resources of Kaligandaki River with particular references to impact of dam on the River and reported 14 species of fish species from Kaligandaki River.

3. MATERIALS AND METHODS

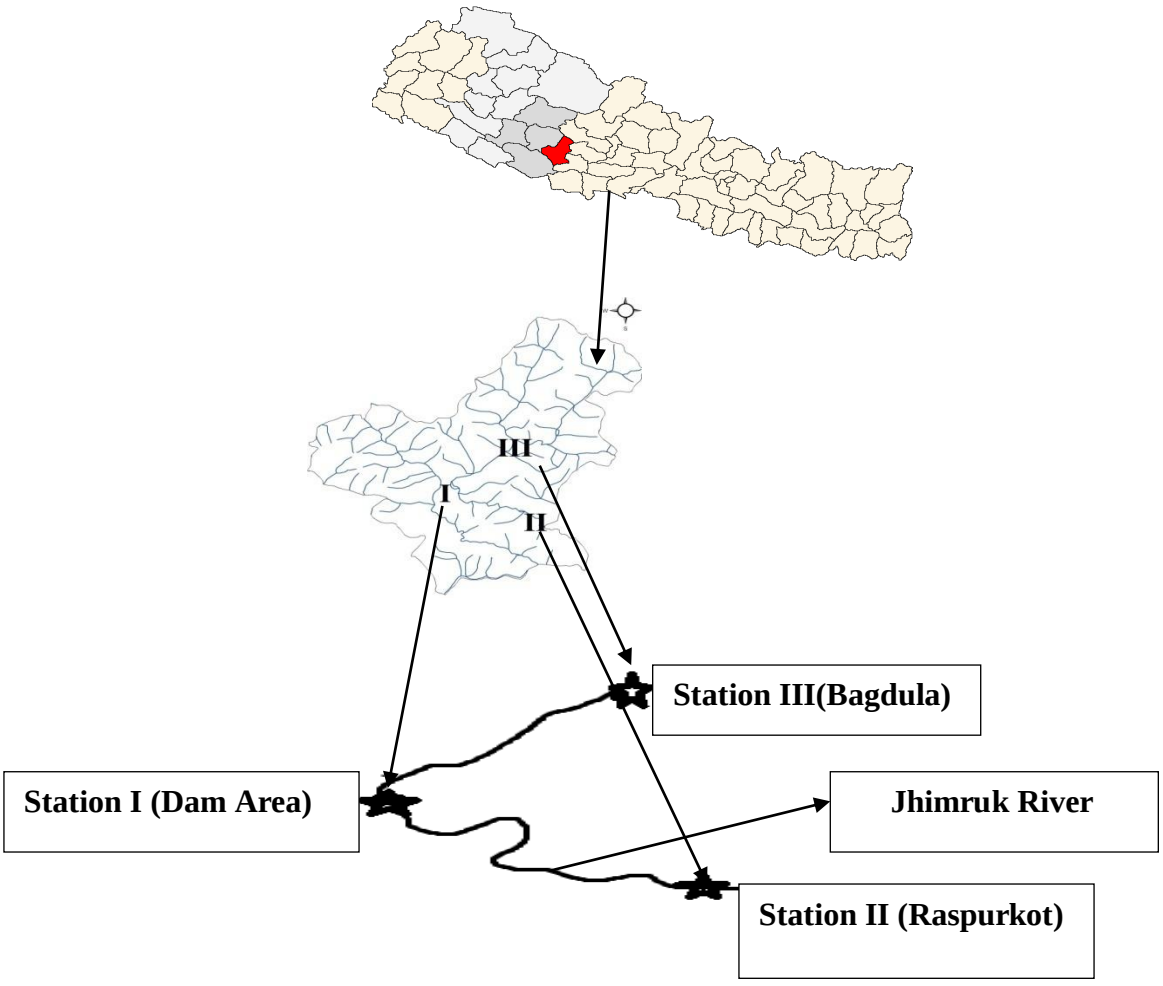
3.1 Study Sites

3.1.1 Location

The present study was carried out in Jhimruk River. The Jhimruk River is one of the main tributary of West Rapti River. Jhimruk Hydro-Power Project is located at Mandabi – 3, Darimchaur, Pyuthan.The length of dam is 255m. The dam is exactly located in 28.9N and 82.9E in Pyuthan district.The main study area of present work was on three representative sampling sites from different locations of Jhimruk HPP (Headwork, Upstream and Downstream). Headwork is the first sampling site, which lies just above the diversion dam. Upstream and downstream are other final sampling sites lying up and below the headwork dam 5km apart and each having a sampling area of 1km.

Name of the sampling sites or stations:

1. Station – I Headwork dam area (Khaira).
2. Station – II Downstream (Ruspurkot)
3. Station – III Upstream (Bagdula)



Map: 2 Study areas in Pyuthan district.

3.1.2 Climate:

The Pyuthan valleys have a subtropical climate with temperature reaching 35^0Cin May and falling to a single digit in the winter (Appendix I). Snow occasionally falls on adjacent peaks reaching 2400m but seldom lasts more than a day.There are four main climatic zones in Pyuthan district i.e. Upper tropical- 36% (300-1000m), Subtropical- 53% (1000-2000m), Temperate- 9.7% (2000-3000m) and Subalpine- 0.8% (3000-4000m) (DFO,2016).

Annual rainfall was recorded 6.64 mm to 422 mm with average rainfall of 107.22 mm. The monthly average rainfall was high in July followed by August, September, June and May. No rainfall was recorded in November and December while remaining months were recorded very less rainfall. Rainfall was found comparatively less in 2015 than other five years. At the severe cold, snow falls at the peak of hills each year (Appendix II), (DFO, 2016).

3.2 Materials:

- GPS (etrex10),
- Camera (NIKON D-3300),
- DO Meter (Lutron 5519),
- pH Meter (Adawa),
- Measuring tape,
- Nylon rope, Scale, Notebook, Pen, etc.

3.3 Research Design

3.3.1 Data collection

Primary data were collected from direct field observation, photography, questionnaire survey and information from different aspects i.e. reports, papers etc.

The present field study was conducted for a single year covering different seasons of the country from May 2016 to February 2017. The field work was performed once in every three month. Each sampling station was visited in May, August, November and February for sample collection.

3.3.2 Diversity

Direct field observation, photography and questionnaire (Appendix II) were conducted to collect the information on fish diversity. Fishes were collected from each sampling sites by employing local fisherman and local market near sampling station. Cast net, gill net, ghorlang, hook and line, simple net and other local available devices such as Bhaddu (bata) with thin cloth were used for collection of fish sample. The number of total fish species collected from each sampling site was recorded.

Most of the fish species were identified in the field with the help of standard field guide Shrestha (1981, 1994, 2001), Shrestha, T.K. (2008) and Jayaram (1981, 1999). Then these collected samples of fish species were preserved in 10% formalin solution. Some unidentified fish species were brought to the laboratory of Central Department of Zoology, Tribhuvan University, Kirtipur for identification and further investigation.

3.3.3 Physico-chemical parameters

Different limnological parameters such as temperature, P^H, free carbon dioxide, dissolved oxygen were tested following APHA (1998), Adoni (1885) and Trivedy and Goel (1986). The main physico-chemical parameters that were studied are as given below:

Water Colour

A simple method was used to determine the colour of water of the Jhimruk River. A beaker of water from the river was taken out and placed on a white paper and the colour was observed.

Water Temperature

Temperature of the surface water of the study area was recorded with the help of standard mercury thermometer graduated up to 50^0C. The recording was simply done by dipping directly the thermometer bulb into the water for two minutes at each station.

Depth

The depth was measured using nylon rope with weight and the nylon rope was measured by measuring tape in centimeters (cm).

Water velocity

The water velocity of the river was measured by simple floating method.

Hydrogen-Ion Concentration (P^H)

A portable P^H meter was used to measure the P^H value of the waterafter proper calibration. The P^H of water at different sampling stations was taken and mean value was noted.

Dissolved Oxygen (DO)

DO was measured with calibrated DO meter. DO meter was dipped simultaneously in five different places of each station for three minutes and average value was noted.

Free Carbon Dioxide

Free carbon dioxide was determined by taking water sample in a conical flask. Then this sample was titrated against 0.05N of NaOH. Calculation was made by using the following equations:

$$\text{Free } CO_2 \text{ (mg/l)} = \frac{\text{(M/N) of NaOH} \times 1000 \times 44}{ml \text{ of sample taken}}$$

Total Alkalinity

Water sample (50ml) was taken in a conical flask. Then, 2-3 drops of phenolphthalein and methyl orange were added to the sample. It was titrated with 0.1N of HCl. Total alkalinity is often expressed as mg/l, which was calculated by using the following formula:

$$\text{Total Alkalinity as mg/l} = \frac{\text{(ml normality) of } HCl \times 1000 \times 50}{ml \text{ of sample taken}}$$

3.4 Statistical Analysis

Both quantitative and qualitative data were compiled, tabulated and analyzed in MS-excel, 2010. Physicochemical parameters were analyzed and interpreted.

The relation of fish species with temperature, depth of water, water velocity, pH, free CO2, DO and alkalinity was calculated by using correlation coefficient formula given by Karl Pearson Method.

Correlation Coefficient (r) $= \frac{N.\varepsilon xy - \varepsilon x \varepsilon y}{\sqrt{N.\varepsilon x^2 - (\varepsilon x)^2}\sqrt{N.\varepsilon y^2 - (\varepsilon y)^2}}$

Probability Error (PEr) $= \frac{1-r^2}{\sqrt{N}} \times 0.6745$

3.5 Diversity Status

3.5.1 Species Diversity Index

The diversity of fish 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:

$H' = -\Sigma (ni/N) \log (ni/N)$

Where,

ni = Importance values for each species is the number of individuals in each species, the abundance of each species.

N = Total Importance value, the total number of individual observed.

4. RESULTS

4.1 Physical and Chemical Parameters

4.1.1 Water Colour

It was clear, transparent throughout the year except in monsoon, during which water colour was grayish muddy due to heavy flooding.

4.1.2 Water Depth

The depth of river varied during the study period in all sampling sites. Less depth of river was observed in downstream and upstream sites but at the dam sites the depth was measured highest. Thus, the water depth ranged from 24cm to 70cm in downstream and upstream sampling sites. In the dam site the depth ranged from 455cm to 680cm.

4.1.3 Temperature

Air temperature of three sampling sites remained more or less similar. The lowest air temperature was observed on February 2017 (16^0C) at Station – II, while the highest air temperature was recorded on August 2016 (27.5^0C) at Station – II.

The surface water temperature ranged from 12.8^0C – 21^0C with an average temperature of 16.9^0C during the study period. The highest temperature was 21^0C in May at station- II (Downstream) and lowest temperature was recorded 12.8^0C at Station – II(Downstream) in February 2017.

4.1.4 Water Velocity

The water velocity ranged from 0.5 to 1.9m/s. The highest water velocity was 1.9m/s recorded in August 2016 at Station – III(Upstream) and the lowest 0.5m/s recorded in May 2016 at Station I(Dam site). The average water velocity was 1.095m/s during study period.

4.1.5 P^H

The P^H ranged from 6.2 to 7.9 with an average P^H value of 7.22 during study period. The lowest P^H was 6.2 in February 2017 at Station – I (Dam site) and highest P^H was 7.9 in May 2016 at Station – I(Dam site).

4.1.6 Dissolved Oxygen

The range of dissolved oxygen (DO) of the study area was 6 to 8.8 mg/*l*. The highest DO was 8.8mg/*l* recorded in August 2016 at Station – III (Upstream) and lowest DO was 6 mg/*l*was recorded in May 2016 at Station – II (Downstream).

4.1.7 Free Carbon dioxide (CO_2)

The range of CO_2 of the study area was 2.02mg/*l* to 3.39mg/*l*. The highest range was recorded from Station – I in May 2016 and lowest was recorded from Station – I in Feb 2017.

4.1.8 Alkalinity

The alkalinity of water ranges from 130mg/*l* to 170mg/*l*. The highest range was recorded from Station – I (Dam site) in May 2016 and lowest range of alkalinity was recorded from Station – II in Feb 2017.

Table: 2 Physico-Chemical Parameters of Jhimruk River

S. N.	Parameters	Unit	Station – II				Station – I				Station – III				Max	Min	Avg
			Downstream				Dam site				Upstream						
			May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb			
1	Air Temp.	^{0}C	27	27.5	19	16	26.5	27	21.2	16.2	26.5	26.9	20.1	16.5	27.5	16	21.75
2	Water Temp.	^{0}C	21	18.5	15.1	12.8	18	16.2	14.3	13	18.3	16.1	14.9	13.1	21	12.8	16.9
3	Water Depth	Cm	24	70	40.1	30	455	680	550	480	35	70	55	40	680	24	210.76
4	Water Velocity	m/s	1.13	1.69	1.3	1.1	0.5	1.0	0.62	0.62	1.57	1.9	1.63	1.4	1.9	0.5	1.09
5	P^H		7.1	7.3	7.4	6.5	7.9	7.5	7.3	6.2	7.3	7.6	7.8	6.8	7.9	6.2	7.22
6	DO	mg/*l*	6	8	7.5	6.5	7.2	6.8	7.5	7.9	8.2	8.8	7.5	7	8.8	6	7.40
7	CO_2	mg/*l*	3.01	2.39	2.25	2.4	3.39	2.3	2.33	2.02	3.12	3.20	3.35	2.34	3.39	2.02	2.40
8	Alkalinity	mg/*l*	140	145	150	130	170	155	150	135	160	140	165	135	170	130	147.9

4.2 Fish diversity of Jhimruk River

17 different fish species were identified belonging to 3 order, 4 families and 10 genera. The study shows more diversity of fish species in station I (Dam site) and then in station III (Upstream) and lowest in Station II (Downstream). Among them the most common fish species recorded from the study area was *Barilius Bendelesis, Barilius vagra*. Apart from this, *Labeo* spp, *Puntius* spp. were quite common fish species (Table 4).

Table: 3 Fish species occurrence and diversity in Jhimruk River

S.N.	Family	Scientific Name	Local Name	Status
1.	Channidae	- *Channa orientalis*	Hile	Common
		- *Channa punctatus*	Hile	Common
2.	Cyprinidae	- *Barilius bendelisis*	Faketa	Common
		- *Barilius vagra*	Faketa	Common
		- *Garra gotyla*	Buduna	Common
		- *Garra annandalei*	Hohari	Common
		- *Labeo dyochelius*	Gardi	Common
		- *Labeo pangusia*	Kalacha	Common
		- *Neolissochilus hexagonolepis*	Katle	Common
		- *Puntius ticto*	Sidre	Common
		- *Puntius sophore*	Sidre	Common
		- *Tor tor*	Sahar	Endangered
3.	Mastacembelidae	- *Mastacembelus armatus*	Bam	Rare
		- *Macrognathus pancalus*	Guita	Common
4.	Cobitidae	- *Schistura horai*	Gadela	Rare
		- *Schistura savona*	Gadela	Unknown
		- *Schiustura parsadi*	Gadela	Rare

4.2.1 Systematic Position of Observed Fish Species of Jhimruk River

Seventeen different fish species were recorded from Jhimruk River. Among these, some were game fishes and some food fishes. All these fish species were edible and consumed by local inhabitants. *Tor tor, Labeo*spp., *Barilius*spp., *Garra*spp. etc. were popular game fishes of Jhimruk River.

1. Order: Cypriniformes

   Family: Cyprinidae

   Sub-family: Cypriniformes

   Genus: *Labeo* (Cuvier) 1817

   1) *L. dyocheilus* (Mc Clelland) 1839

2) *L. pangusia* (Hamiltan Buchanan) 1822

Genus: *Neolissocheilus* (Rainboth) 1985

3) *N. hexagonolepis* (Mc Clelland) 1839

Genus: *Tor* (Gray) 1833

4) *Tor tor* (Hamilton Buchannan) 1822

Genus: *Puntius* (Hamilton Buchanan) 1822

5) *P. ticto* (Hamilton Buchanan) 1822

6) *P. sophore* (Hamilton Buchanan) 1822

Sub-family: Rasboridae

Genus: *Barilus* (Hamilton Buchanan) 1822

7) *B. bendelisis* (Hamilton Buchanan) 1822

8) *B. vagra* (Hamilton Buchanan) 1822

Sub-family: Garrinae

Genus: *Garra* (Hamilton Buchanan) 1822

9) *G. gotyla* (Gray) 1832

10) *G. annandelei* (Hora) 1921

Family: Cobtidae

Sub-family: Nemacheilinae

Genus: *Schistura* (Hamilton Buchanan) 1822

11) *S. savona* (Hamilton Buchanan) 1822

12) *S. horai* (Hamilton Buchanan) 1822

13) *S. parsadi* (Hamilton Buchanan) 1822

2. Order: Perciformes

Family: Channidae

Genus: *Channa* (Hamilton Buchanan) 1822

14) *C. orientalis*(Bloch and Schneider)

15) *C.punctatus*(Bloch)

3. Order: Synbranchiformes

Family: Mastacembelidae

Genus: *Mastacembelus*

16) *M. armatus* (Laceped) 1800

17) *Macrognathus pancalus* (Hamilton) 1822

4.2.2 Fish Distribution and Frequency in Jhimruk River

The following table shows the distribution pattern and abundance of fish species in the study area. Among them the most common fish species recorded from the study area was *Channa* species and *Macrognathus pancalus*. Apart from this, *Barilius vagra, Labeo* spp, *Puntius* spp, were quite common fish species. The highest frequency occurrence of 18.79% was for *Channa orientalis* and lowest frequency occurrence of 0.16% was for *Mastacembelus armatus*.

Table: 4 Distribution and frequency occurrence of fishes in study sites.

S. N.	Name of Fish	Stations			Total No. of Fish	Frequency (%)
		I (Dam)	II (Down)	III (Up)		
1	*Barilius bendelisis*	+	-	+	59	9.72
2	*Barilius vagra*	+	-	+	68	11.20
3	*Channa orientalis*	+	+	+	113	18.79
4	*Channa punctatus*	+	+	+	87	14.33
5	*Garra gotyla*	+	+	-	24	3.68
6	*Garra annandalei*	+	+	-	26	4.28
7	*Labeo dyochelius*	+	-	+	25	4.12
8	*Labeo pangusia*	+	-	-	9	1.50
9	*Neolissochilus hexagonolepis*	-	+	-	5	0.82
10	*Puntius ticto*	+	-	+	88	14.50
11	*Puntius sophore*	+	-	+	23	3.80
12	*Tor tor*	-	+	-	3	0.50
13	*Mastacembelus armatus*	-	+	-	1	0.16
14	*Macrognathus pancalus*	+	+	+	33	5.43
15	*Schistura horai*	+	-	+	11	1.90
16	*Schistura savona*	+	-	+	19	3.13
17	*Schistura parsadi*	+	-	+	13	2.14
Total		14	8	11	607	100

+ = Present and - = Absent.

4.2.3 Fish Diversity in Site I (Dam site):

A total of 14 species of fishes under four families and seven genera were collected from the site I. This site is located at the reservoir of dam near Khaira village. *Puntius ticto* was the most frequent fish species found in site I.

Table: 5 list of fish species collected in Site I (Dam Area)

SN	Name of Fish Species	May 2016	Aug 2016	Nov 2016	Feb 2017	Total number of fishes
1	*Barilius bendelisis*	8	12	10	6	36
2	*Barilius vagra*	6	10	4	-	20
3	*Channa orientalis*	-	-	2	4	6
4	*Channa punctatus*	2	-	-	2	4
5	*Garra gotyla*	6	5	7	1	19
6	*Garra annandalei*	4	4	2	3	13
7	*Labeo dyochelius*	3	8	2	2	15
8	*Labeo pangusia*	2	4	2	1	9
9	*Puntius ticto*	10	18	6	7	41
10	*Puntius sophore*	2	8	4	2	16
11	*Macrognathus pancalus*	2	4	-	3	9
12	*Schistura horai*	-	4	-	1	5
13	*Schistura savona*	1	6	2	2	11
14	*Schistura parsadi*	2	5	1	3	11
	Total	48	88	42	37	**215**

4.2.4 Fish Diversity in Site II (Downstream):

Altogether eight species of fishes under three families and six genera were found among 97 collected specimens from the site II. This site is located below the dam area and most dewatered zone. *Channa* species were most frequent fish species in this site.

Table: 6 List of fish species collected in Site II (Downstream)

SN	Name of fish Species	May 2016	Aug 2016	Nov 2016	Feb 2017	Total number of fishes
1	*Channa orientalis*	4	18	12	5	39
2	*Channa punctatus*	-	12	8	4	24
3	*Garra gotyla*	-	4	1	-	5
4	*Garra annandalei*	-	10	3	-	13
5	*Neolissochilus hexagonolepis*	-	2	3	-	5
6	*Tor tor*	-	2	1	-	3
7	*Mastacembelus armatus*	-	1	-	-	1
8	*Macrognathus pancalus*	1	4	2	-	7
	Total	5	53	30	9	**97**

4.2.5 Fish Diversity in Site III (Upstream)

Altogether 11 species of fishes under four families and six genera were found among 295 collected specimens from site III. This site is located above the dam near Bagdula village. The most frequent fish species was *Channa* species in this site.

Table: 7 List of fish species in Site III (Upstream)

SN	Name of fish Species	May 2016	Aug 2016	Nov 2016	Feb 2017	Total number of fishes
1	*Barilius bendelisis*	3	10	8	2	23
2	*Barilius vagra*	5	25	12	6	48
3	*Channa orientalis*	10	15	18	25	68
4	*Channa punctatus*	8	13	16	22	59
5	*Labeo dyochelius*	-	6	4	-	10
6	*Puntius ticto*	10	25	8	4	47
7	*Puntius sophore*	-	5	2	-	7
8	*Macrognathus pancalus*	-	6	4	7	17
9	*Schistura horai*	-	4	2	-	6
10	*Schistura savona*	-	6	2	-	8
11	*Schistura parsadi*	-	2	-	-	2
	Total	36	117	76	66	**295**

4.2.6 Family Wise Distribution of Fish Species in Jhimruk River:

Altogether four families of fish species were recorded during the study period, among them 54.12% of fishes belonging to family Cyprinidae, 33.12% to Channidae, 7.17% to Cobitidae and 5.59% to Mastacembelidae were found.

Table: 8 Distribution of observed fish species according to Family

SN	Family	Name of fish species	Frequency distribution (%)
1.	Channidae	*Channa orientalis*	
		Channa punctatus	33.12
2.	Cobitidae	*Schistura horai*	
		Schistura savona	7.17
		Schistura parsadi	
3.	Cyprinidae	*Labeo dyocheilus*	
		Labeo pangusia	
		Neolissochilus hexagonolepis	
		Tor tor	
		Puntius ticto	
		Puntius sophore	54.12
		Barilius bendelisis	
		Barilius vagra	
		Garra gotyla	
		Garra annandalei	
4.	Mastacembelidae	*Mastacembelus armatus*	
		Macrognathus pancalus	5.59
Total			100

4.3 Migratory Status of Fishes

The following table shows the category of fishes on the basis of migration. Among them *Neolissochilus hexagonolepis* and *Tor tor* are migratory fishes, *Channa* spp, *Garra* spp and *Labeo* spp are short distance migratory and *Barilius* spp, *Puntius* spp, *Schistura* spp are found to be residential.

Table: 9 Economic and Migratory status of observed Fish species of Jhimruk River.

SN	Name of Fish Species	Status	Economic Importance
1	*Barilius bendelisis*	Residential	+
2	*Barilius vagra*	Residential	+
3	*Channa orientalis*	Short distance migratory	+
4	*Channa punctatus*	Short distance migratory	+
5	*Garra gotyla*	Short distance migratory	-
6	*Garra annandalei*	Short distance migratory	-
7	*Labeo dyochelius*	Short distance migratory	+
8	*Labeo pangusia*	Short distance migratory	+
9	*Neolissochilus hexagonolepis*	Migratory	+
10	*Puntius ticto*	Residential	+
11	*Puntius sophore*	Residential	+
12	*Tor tor*	Migratory	+
13	*Mastacembelus armatus*	Short distance migratory	-
14	*Macrognathus pancalus*	Residential	-
15	*Schistura horai*	Residential	-
16	*Schistura savona*	Residential	-
17	*Schistura parsadi*	Residential	-

4.4 Coefficient of Correlation Between Different Variables

The coefficient of correlation was implied for analyzing statistically between various physiochemical parameters with the number of fish collected from each station using Karl Pearson's correlation coefficient method. Also probable error for each correlation coefficient was calculated for each station. The correlation coefficient between various physiochemical parameters and the number of fish collected in each station and the probable error is given in the table 10. The correlation between fish density and water depth, pH and water velocity was found positive in all sampling stations. The correlation between fish density and temperature, DO, CO2 and alkalinity was found to be negatives in some stations.

Table: 10 Correlations between physico-chemical parameters and fish number in Jhimruk River:

S.N	Coefficient correlation	Station I (Dam)		Station II (Downstream)		Station III (Upstream)	
		Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)
1	Water Temperature and F.D	0.429	0.275	0.080	0.335	-0.285	0.309
2	Water depth and F.D	0.994	0.036	0.978	0.014	0.957	0.028
3	Water velocity and F.D	0.902	0.062	0.975	0.016	0.754	0.145
4	pH and F.D	0.429	0.275	0.622	0.206	0.411	0.280
5	DO and F.D	-0.891	0.069	0.967	0.021	0.425	0.276
6	CO_2 and F.D	-0.046	0.336	-0.575	0.225	0.220	0.320
7	Alkalinity and F.D	0.305	0.305	0.625	0.205	-0.447	0.270

4.5 Diversity Status

The value of Shanon Weiner diversity index (H') was calculated according to the fish collected in the sampling stations. Highest Shanon-Weiner diversity index (2.43) was found in station I (Dam site) and the lowest value of Shanon-Weiner diversity index (1.63) was found in station II (Downstream). Similarly the Shanon-Weiner diversity index of station III (Upstream) was found to be 2.02.

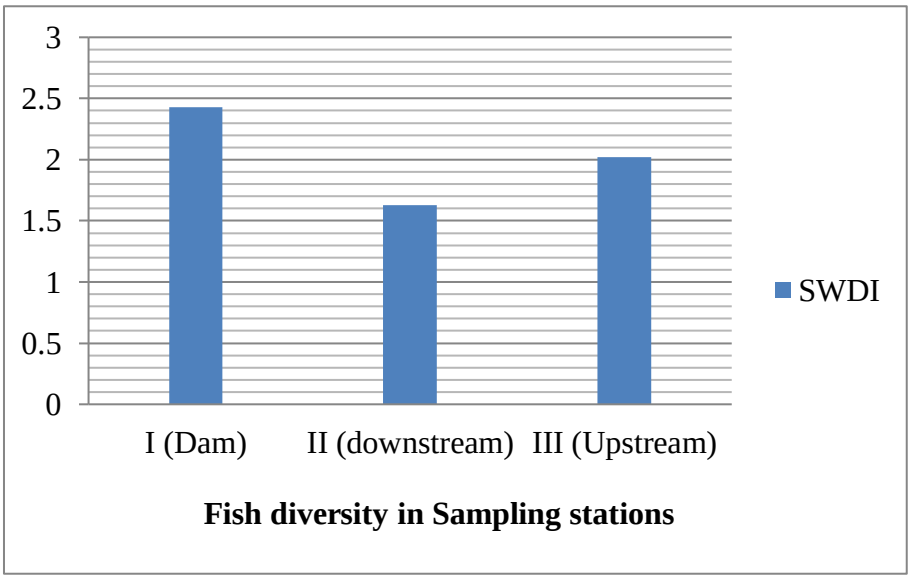


Figure: 1 Fish diversity status in sampling sites.

4.6 Mitigating Measures

Jhimruk Hydro- Power Project (12MW) has been built by impounding the Jhimruk River at Khaira of Pyuthan district, which provides basic needs to increase the GNP of the country. However, Impoundmenting River is known to impact adversely on fish biodiversity and fisher communities, who depend on fishing for their livelihood.

The project has undertaken different mitigation measures suggested in different levels of studies to minimize the adverse impacts due to construction of various components of the project. Three types of measures are particularly important for the protection of freshwater biodiversity – environmental flows, ecosystem restoration and fish loss mitigation.

Some of the mitigating measures that can be useful are as follows:

Impaired upstream fish migration mitigating measures:

- Constructing bypass channel
- Constructing fish pass upstream ex. Vertical sloft, lift etc.
- Constructing ramp
- Catch, transport and release

Impaired downstream fish migration mitigating measures:

- Installing fish friendly turbine
- Installing fish screens
- Constructing bypass channel
- Constructing fish pass upstream ex. Notch in small intake structure, ramp, Ladder, lift etc.

Extreme/extended low flow mitigating measures:

- Providing additional flow
- Optimizing river morphology for available flow
- Establishing variable discharge (Active) for ex. Timed release for dam

Ponding effect mitigating measures:

- Constructing bypass channel to provide additional flowing habitats
- Improving in channel habitats
- Reducing storage level. For ex. by raising bed or -lowering dam to increase -flowing water habitat
- Reconnecting tributaries, ensuring lateral connectivity.
- Sufficient flow below the dam during monsoon.

5. DISCUSSION

5.1 Diversity of Fishes in Study Area of Jhimruk River

Fish base assessment of the impact of dams and weirs on the integrity of rivers and streams is well established research work in most part of the world. In Nepal it is in the initial stage but could not be ignored since the biggest resource of the country is water. In Nepal, apart from the study of fish base assessment of the overall impacts of dams by Shrestha (1990), Jha et al.(2007), Shrestha and Chaudhary (2003), Pandey (2004), Gubhaju et al. (2012) only few EIAs reports exist on this regard. In the present study, 17 species of fishes were recorded among which 12 species were common, viz *Channa* spp, *Barilius* spp, *Garr* spp, *Labeo* spp, *Neolissochilus* spp, *Puntius* spp, *Macrognathus* spp etc. Three species were found to be rare i.e. *Mastacembelus armatus*, *Schisturahorai* and *Schistura parsadi*, one species *Tor tor* was found to be endangered and one species of *Schistura savona* was unknown fish species in Jhimruk River. Fish belonging to order cypriniformes, family cyprinidaeand family channidae were dominant. Cyprinidae was common among two comprising highest frequency of the total catch that was about 54.12%. Edd (1986) also reported the order cypriniformes as common order of Kaligandaki and Narayani Rivers. Shrestha (1996), Karki(2000) and Bajracharya (2001) has also found that cyprinidae as common family in Tinau, Karnali, Sunkoshi and Bhotekoshi rivers respectively. Family channidae comprised 33.12% of the total and followed by families cobitidae and mastacembelidae, comprising 7.17% and 5.59% respectively. During the study *Channa orientalis, Channa punctatus, Macrognathus pancalus* etc. were reported in all three sites (Table 4).

The number of fish species was recorded lower in station II (Downstream) and higher in station I (Dam area). Among 17 fish species recorded, 8 fish species were observed in station II, 11 fish species were observed in station II and 14 fish species were observed in station I. The diversity of fish species among the sampling stations in the Jhimruk River was calculated by using Shanon-Weiner bio-diversity index (Shanon and Weaver, 1949). The Shanon-Weiner biodiversity index was found highest in station I (2.43) and lowest value was found in station II (1.63). Similarly, the diversity index of station III was found 2.02 (Fig.1).

5.2 Impacts of Dam on Jhimruk River

Rivers throughout the world have been modified with locks, dams or weir to optimize water levels for agricultural land use or for generating electricity (Knaepkens et al., 2005). The creation of these man-made structures has resulted in the fragmentation of freshwater, rivers ecosystem, with the formation of impoundments just above the dam, isolating the aquatic populations (Winston et al., 1991; Labonne and Gaudin, 2005; Schilt, 2007). The 255m long curvilinear dam in the Jhimruk River have converted the river into pondage structure just above the dam(Plate VI). Such impounding structures pose threats to the maintenance of healthy ecosystem by disrupting sediments, altering biodiversity and blocking movements of migratory fishes (Renofalt et al., 2010). The

results of the present study also show that two migratory fish species such as *Tor tor* and *Neolissochilus hexagonolepis* were confined only to the downstream. Due to the formation of impoundment above the dam and less release of water below,physical and chemical parameters has altered, such as increase in water temperature (21˚C) and decrease in DO (6mg/l) and water velocity (1.1m/s). One of the major destruction by the dam was the deposition of sand and sediments on the agricultural land present just above the dam during the monsoon (Plate VI, Fig 5).

Change in Flow Regime

Jhimruk hydropower project is a kind of run-of-river hydropower schemes. There is therefore a requirement for sufficient abstraction of water for hydropower generation, which ultimately has result with depleted release of water below the dam. This also shows adverse impacts on the ecology of depleted flow reaches, including an altered availability of habitat features (Whiting, 2003) with a reduction of fish species in downstream than in dam and upstream in this study (Table 4). Low flow below the dam changes the behaviors of migratory fish species. It has been suggested that fish movements may occur in direct response to the change in water flow (Vehanen et al. 2000). Such like that, in the present study the migratory fish species like *Neolissochilus hexagonolepis* and *Tor tor* have been found only in downstream station and various residential and short distance migratory fishes like *Barilius* spp, *Schistura* spp, *Puntius* spp, *Labeo* spp etc were more common in dam and upstream sites.

Change in Water Quality Parameters and its Effects on Fish Diversity

The various physico-chemical parameters which were examined during this study were also found to be influenced by the construction of dam in the Jhimruk River. Ecological factors such as velocity, temperature, transparency, dissolved oxygen, pH, free CO2 of the running water systems are interdependent on ecological niche of fishes, invertebrates and other aquatic lives (Whitton, 1975). Water temperature is one of the most important factors in aquatic environment as it affects the organism, as well as the chemical and physical characteristics of water (Delience 1992). In this study, the least temperature (12.8˚C) was recorded in station II in February and highest temperature (21˚C) was recorded in station II in August (Table 2). Water temperature showed the positive correlation coefficient 0.429 and 0.080 with the fish collected at station I and station II but was negative –0.285 with the fish collected at station III.

The developments like construction of dam and barrage along the river result in low water flow (Hassan et al. 1998). Thus the depth of water in river above and below the dam is found to be different. The water depth is important physical parameter which directly and indirectly affects the diversity of fish species (Shrestha, 2008). During this study it was observed that water depth (24cm) in the downstream was too less but was more (680cm) just above the dam and in upstream. The small fish species like *Barilius* spp, *Channa* spp etc were found to be distributed in shallow water habitat and larger sized species like *Tor* spp, *Labeo* spp were recorded in deeper area. The depth of river was found ranging from

24 – 680 cm. the least water depth was measured in downstream and highest depth was measured in dam area. The correlation coefficient between water depth and fish collected was found to be positive during study period at all sampling stations II, II and III with the value of 0.994, 0.978 and 0.957.That shows the water depth and fish diversity and number are strongly correlated.

The water velocity plays major role in determining abundance of flora and fauna in a river by maintenance of high levels of dissolved oxygen (Whitton, 1975). The velocity of water in Jhimruk River ranged from 0.5m/s to 1.9m/s. the correlation between the water velocity and the fish collected was found to be positive in all three sampling sites with the values 0.902, 0.975 and 0.754 respectively.

The chemical parameters of the water also show great effect on the distribution of fish species in river (Swingle, 1997). Among the chemical factors, the concentration of dissolved oxygen of water is the most important factor and dissolved oxygen above 5mg/l is suitable to support diverse biota (APHA, 1976). The dissolved oxygen of Jhimruk River ranged from 6mg/l to 8.8mg/l. The DO observed in station I showed the negative correlation (-0.891) with the fish collected, but was positively correlated (0.967 and 0.425) with the fish collected from station II and station III respectively.

According to Swingle (1997) pH range 6.5 - 9.5 is suitable for fish and pH more than 9.5 is unsuitable, because free CO2 is unavailable in this condition. The average pH value of Jhimruk River was observed to be higher at station I and III which was 7.3 and 7.2 respectively and lower (7.0) at station II. Positive correlation was observed between pH and fish collected in Jhimruk River in all sampling sites. Most of the CO2 in the water is the result of decomposition of organic matter and from respiration of organisms (Cole, 1975). Free CO2 more than 20ppm may be harmful to the fish species and even lower concentration of 3-5 ppm may be equally harmful (Lagler, 1972).The average free CO2 was found higher at station III and lower at station I. The coefficient of correlation between the free CO2 and fish collected showed the negative correlation (-0.046 and -0.33) in station I and II but showed positive correlation (0.220) at station III. The range of alkalinity was recorded 130 - 170mg/l with an average of 147.9 mg/l at the study sites. High range of alkalinity (170mg/l) was recorded at station I (Dam) and low (130mg/l) was recorded at station II (Downstream). The coefficient of correlation of alkalinity was positive (0.305 and 0.625) to collected fish number in station I and II respectively but was found negative (-0.447) in the station III.

A biodiversity index seeks to characterize the diversity of a sample 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. Shanon-Weiner diversity index considers the richness and proportion of each species. The value of Shanon-Weiner diversity index (H') was calculated according to the fish collected in the sampling stations. Highest Shanon-Weiner diversity index (2.43) was found in station I (Dam site) and the lowest (1.63) value of Shanon-Weiner diversity index was found in station II (Downstream). Similarly the Shanon-Weiner diversity index

of station III (Upstream) was found to be 2.02. The Shanon-Weiner biodiversity index values obtained from the present study is not so very high and don't show the huge differences in the fish diversity occurring among the station either. Therefore it may conclude that the slight difference in biodiversity of fish species among the sampling stations was due to the construction of dam and changes in physical and chemical parameters by the dam. Similar study by Joshi (1998) in Sunkoshi River described that the dam had obstructed the seasonal migration of fishes. He also described that the construction of dam brought many changes in structure and function of natural water courses as well as in physical, chemical and biological characteristics of the river. Pandey (2004) studied the impact of dam in fish resources of Kaligandaki with particular reference to Kaligandaki – A Hydroelectric project and found that there was decrease in fish species with slight change in water quality.

6. CONCLUSION AND RECOMMENDATIONS

Conclusions:

- A total number of 17 species of fish fauna was collected from the different section of Jhimruk River belonging to 3 orders 4 families and 10 genera.
- *Barilius bendelisis, Barilius vagra, Channa orientalis, Channa punctatus, Garra* spp*, Puntius ticto* were dominant fish species in the Jhimruk River as they were found more in numbers. Present study includes endangered fish species *Tor tor*.
- The impoundment due to the dam affected the water quality parameters. The temperature and CO2 content of water was found to be increased below while pH, DO, water velocity was found to be decreased.
- Damming in the river have seemed to obstruct the water flow below and affected the migratory fishes, which have caused its declination and reduction in number.
- Differences in the fish diversity status were obtained during the study period above and below the dam. It may be due to the construction of dam in the river.

Recommendations:

The basic construction of run-of-river hydro power dam and the key impacts on fisheries of Jhimruk River were reviewed. A major problem associated with reviewing such dams was the relative paucity of the information on such schemes. It is recommended that detail studies on the impacts of both upstream and downstream run-of-river schemes on fisheries and other aquatic biota are carried out matter of urgency.

So, the following recommendations are suggested:

- The development of effective fish ladder across the dam especially for the passage of migratory fish species should be made.
- Since the natural fish stocks may be deplete rapidly due to overfishing, it would be better to make efforts for conservation of habitats and establishment of fish hatchery.
- Regular monitoring and further studies on the native fish populations can give foresight to develop strategies to sustain the fish diversity.
- The release of water during the dry season should be increased as recommendation by EIA and strictly followed.
- Poisoning of water bodies, illegal fishing and other destructive fishing practices should be controlled.
- The aquatic animals protect act (AAPA) should be implemented effectively through the concerned government agencies.

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PLATE I: Family: Cyprinidae

Fig 1: *Labeo dyocheilus*

Fig 2:*Tor tor*

Fig 3: *Barilius bendelesis*

PLATE II - Cyprinidae

Fig 1:*Neolissocheilus hexagonolepis*

Fig 2:*Garra annandale*

Fig 3:*Puntius ticto*

PLATE III- Cyprinidae

Fig 1:*Barilius vagra*

Fig 2:*Puntius sophore*

Fig 3:*Labeo pangusia*

Fig 4:*Garra gotyla*

PlATE IV: Family- Cobitidae

Fig 1:*Schistura savona*

Fig 2:*Schistura horai*

Fig 3:*Schistura prasadi*

PlATE V: Family- Mastacembelidae

Fig 1:*Mastecembelus armatus*

Fig 2: *Macrognathus pancalus*

Family - Channidae

Fig 1:*Channa orientalis*

PLATE VI: Sampling Sites

Fig: 1**Jhimruk River**

Dam

Fig: 2 **Impoundment above dam**

Fig: 3**Primary data collection in site**

Fig: 4 **Dam areas**

Fig: 5 **flood in agricultural land**

PLATE VII – Sampling sites

Fig: 1**Fish ladder in dam**

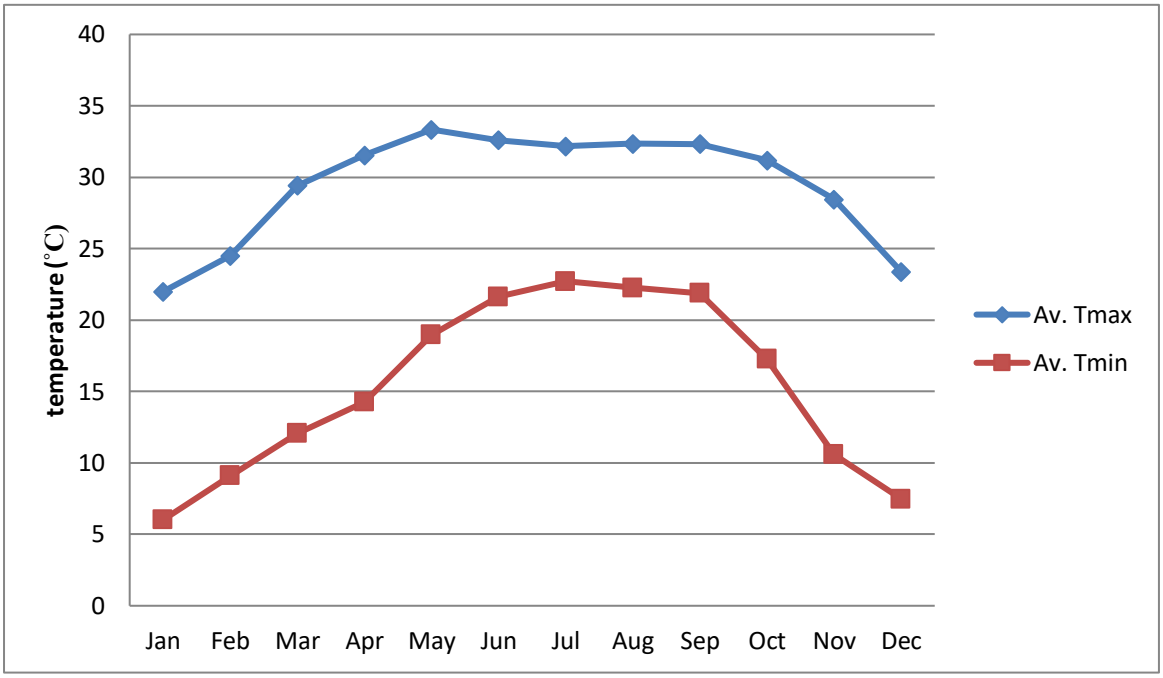
Fig: 2**upstream to the dam**

Fig: 3**Downstream to the dam**

Fig: 4**Mahajaal net**

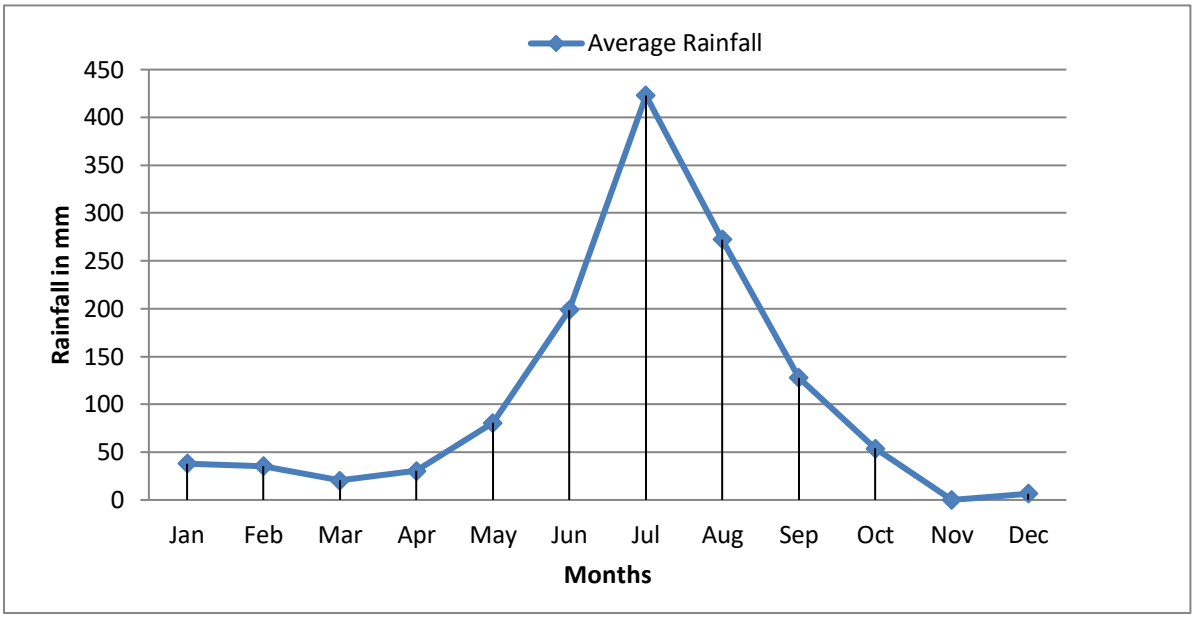
APPENDICES

APPENDIX I



Average maximum and minimum monthly temperature in Pyuthan Meteorological Station 2012 to 2016 (Data Source: DHM).

APPENDIX II



Average monthly rainfall in Pyuthan Meteorological Station 2012 to 2016 (Data Source: DHM)

APPENDIX III

A list of questionnaire used in interview with fisherman and local people around Jhimruk River.

Date: **……..**

Name: ……

Age: ……

Sex: ……

Address: ……

Zone: …….

District: ……..

VDC/ Municipality: …….

Ward No: ……

Village/ Tole: …….

1) How many members are in your family?
   Total: …….
   Male: …….
   Female: …….
2) Have you studied or not?
   Standard: …….
3) How many of your family are educated?
   ……..
4) Is fishing your main occupation?
   Yes/ No……..
5) What do you do beside fish catching?
   …….
6) How many members are involved in fishing from your family?
   …….
7) How much time do you spend in fishing within a day?
   ……..

8) Which fishing implements do you use mostly?

……

9) How many fisherman/ people come for fishing usually?

…….

10) What do you do with the captured fishes?

a. Consume b) Sell c) Both

11).Where do you sell fishes?

a) Market b) village

12) Which fish species are mostly captured by you?

……..

13) Which is the biggest fish you captured?

……..

14) How many fish species are there in the River in your opinion?

……..

15) What do you think fish population has increased or decreased due to building of dam?

……

16) What are the effects of dam in the river?

……..

17) What are the advantages and disadvantages of dam, you faced?

……

18) Do you know about fish ladder or not?

…….

Impacts of Jhimruk Hydropower Dam on Fish and Fisheries of Jhimruk River, Pyuthan, Nepal

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ABSTRACT

This study examined the impacts due to construction of hydropower dam in Jhimruk River. Jhimruk River is one of the major tributaries of west Rapti River, which originates from the Mahabharat range of mid-western Nepal. A range of physical and chemical water quality parameters of three sampling sites in the river around the project were studied. It recorded increased temperature (21˚C), reduced pH (6.5), dissolved oxygen (6mg/l) and water velocity (1.69m/s) upstream to downstream. Dissolved oxygen ranging from 6 to 8.8 mg/l, due to very less release of water from dam during dry season was observed. Altogether 17 fish species belonging to three order, four families and ten genera had been recorded. The status of fish species was analyzed on the basis of fish composition and their number. Shanon-Weiner biodiversity index showed slight difference in diversity status of fish species below (1.63) and above the dam (2.43). *Barilius sps, Channa sps, Garr sps, Puntius sps* were found to be dominant fish species and also includes the endangered *Tor tor* fish species in Jhimruk River.

Key words: Fish diversity, Hydropower, Dam, Impact.

INTRODUCTION

The Jhimruk River is a major tributary of West Rapti River and one of the important fresh water resources of mid-western Nepal. It originates from the Mahabharata range of Pyuthan and Rolpa districts of mid-western Nepal and total estimated length is about 47 miles (Sharma, 1997). The construction of dam in the riverine system changes the biological and ecological conditions of rivers. The developments like construction of dams and barrages along the river results in low water flow (Hasan et al., 1998). Dams causes physical alteration of tail waters or downstream areas, changes in water

temperature, river morphology and loss of spawning and rearing habitat due to upstream flooding, thus impacting indigenous fishes (Shrestha, 1981). The greatest danger occurs to the migratory fishes, as the dams obstruct their migratory path, and so they may be totally displaced (Naidu, 1993; Shrestha, 1997; Shrestha et al., 2001; Arya et al,. 2001). Fisheries resources of Nepal have been drastically reduced due to the barrier effects of dams, environmental changes and pollution in waterways. Damming sets a blockage to fish movement, upstream or downstream. In passing through the turbines, spillways or in the diversion, fishes are subjected to injury by physical contact, pressure change; shear force (Naidu, 1993; Moss, 1998). It may change the flow downstream by making it more irregular. The nature of the river bottom will change, the water quality may change too (Moss, 1998; Gutzer et al., 2002).

MATERIALS AND METHODS

Study Area

Jhimruk River flows along in the Pyuthan valley of mid-western region of Nepal and drains into the lower Deukhuri valley. The 225m long dam in the Jhimruk River is located at Khaira village. Different sampling stations were determined considering the project impact area. Headwork is the first sampling site, which lies just above the diversion dam. Upstream and downstream were other final sampling sites lying up and below the headwork dam 5km apart and each having a sampling area of 1 km (Fig. 1). Water quality parameters like temperature, depth, pH, DO, free CO2, alkalinity etc. were measured in the sites by using, a thermometer, nylon rope, pH meter, DO meter and for free CO2 and alkalinity titration method was used. Fish were collected by using various local fishing gears. Both quantitative and qualitative data were compiled, tabulated and analyzed in Ms-excel 2010 by using correlation coefficient and Shanon-Weiner biodiversity index was used to find out the biodiversity status of collected fish species in the sampling sites of Jhimruk River.

Name of the sampling sites or stations:

5. Station – I Headwork dam area (Khaira).
6. Station – II Downstream (Ruspurkot)
7. Station – III Upstream (Bagdula)

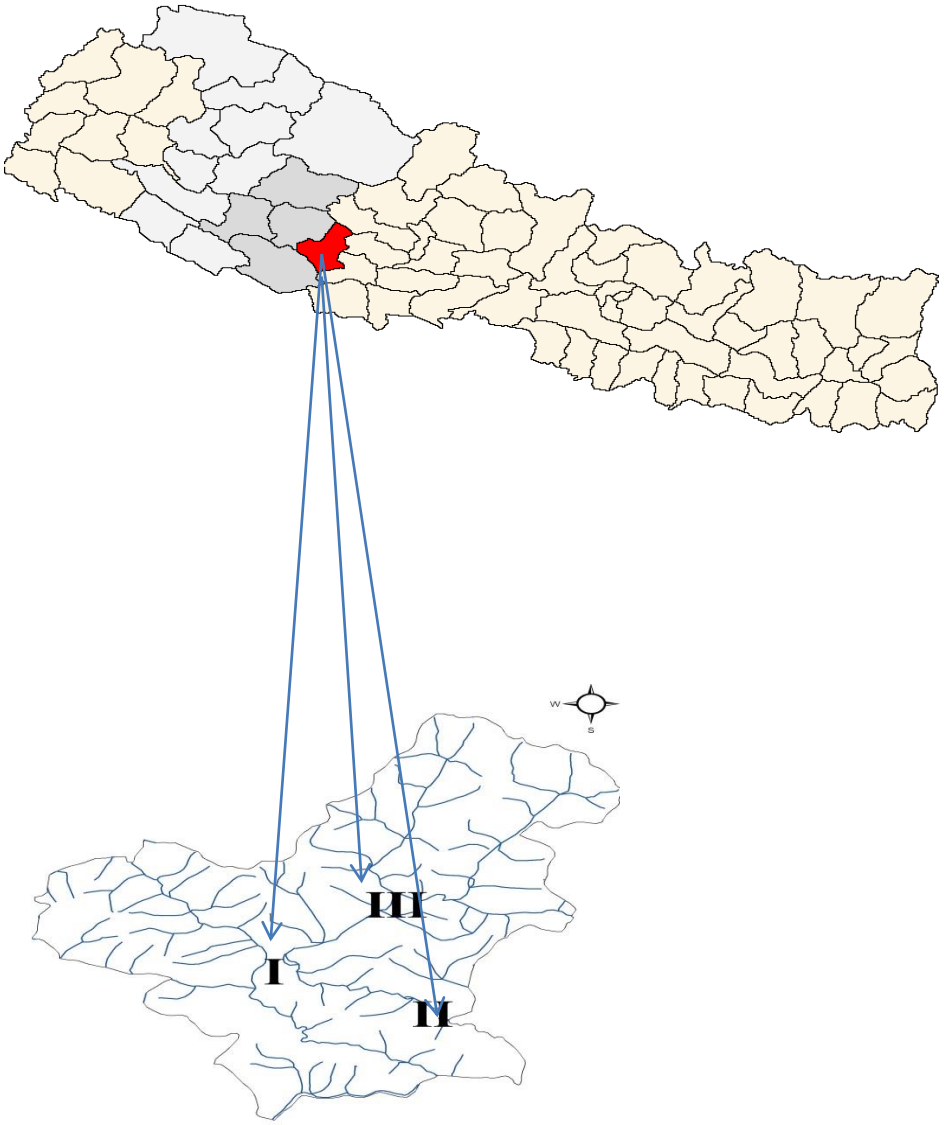

Figure: 1 Study area in Jhimruk River, Pyuthan Nepal

(Source: Google map)

RESULTS

The water quality test results of seven parameters of three sampling stations collected are presented below in the Table 1. The river was clear, transparent throughout the year except in monsoon in which it was grayish muddy due to flooding. The depth of river varied during study period and ranged from 24 – 680 cm. Depth in dam area was more than downstream and upstream. Temperatures ranged from 12.8 to 18.50˚C, both highest and lowest temperature were measured in station II in August and February respectively. The water velocity ranged from 0.5-1.69 m/s. 1.9m/s water velocity was measured in upstream and 0.5m/s was measured at dam area in May 2016. The pH ranged 6.2- 7.9 with an average value 7.22 during the study period. The highest DO (8.8mg/l) was measured in upstream during Aug 2016 and lowest (6mg/l) was measured in downstream during May 2016. The free carbon dioxide ranged from 2.02 - 3.39 mg/l with an average value of 2.40 mg/l.

Table: 1 Physico-Chemical Parameters of Jhimruk River

S. N.	Parameters	Unit	Station – II				Station – I				Station – III				Max	Min	Avg
			Downstream				Dam site				Upstream						
			May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb			
1	Air Temp.	^{0}C	27	27.5	19	16	26.5	27	21.2	16.2	26.5	26.9	20.1	16.5	27.5	16	21.75
2	Water Temp.	^{0}C	21	18.5	15.1	12.8	18	16.2	14.3	13	18.3	16.1	14.9	13.1	18.5	12.8	15.65
3	Water Depth	Cm	24	70	40.1	30	455	680	550	480	35	70	55	40	680	24	210.76
4	Water Velocity	m/s	1.13	1.69	1.3	1.1	0.5	1.0	0.62	0.62	1.57	1.9	1.63	1.4	1.9	0.5	1.09
5	P^H		7.1	7.3	7.4	6.5	7.9	7.5	7.3	6.2	7.3	7.6	7.8	6.8	7.9	6.2	7.22
6	DO	mg/*l*	6	8	7.5	6.5	7.2	6.8	7.5	7.9	8.2	8.8	7.5	7	8.8	6	7.40
7	CO_2	mg/*l*	3.01	2.39	2.25	2.4	3.39	2.3	2.33	2.02	3.12	3.20	3.35	2.34	3.39	2.02	2.40
8	Alkalinity	mg/*l*	140	145	150	130	170	155	150	135	160	140	165	135	170	130	147.9

17 different fish species belonging to 3 orders 4 families and 10 genera were collected from the three sampling sites in this present study. More number of fish species was collected from dam area and upstream site than downstream. That means there was slight difference in fish diversity in three sampling sites according to Shanon-Weiner diversity index. This may be due to the construction of dam in the river and obstruction or migratory route of migratory fishes and also due to change in water quality parameters.

The coefficient of correlation was implied for analyzing statistically between various physiochemical parameters with the number of fish collected from each station using Karl Pearson's correlation coefficient method. Also probable error for each correlation coefficient was calculated for each station. The correlation coefficient between various physiochemical parameters and the number of fish collected in each station and the probable error is given in the table 2. The correlation between fish density and water depth, pH and water velocity was found positive in all sampling stations. The correlation between fish density and temperature, DO, CO2 and alkalinity was found to be negatives in some stations.

Table: 2 Correlations between physico-chemical parameters and fish number.

S.N	Coefficient correlation	Station I (Dam)		Station II (Downstream)		Station III (Upstream)	
		Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)	Coefficient correlation (r)	Probable error (PEr)
1	Water Temperature and F.D	0.429	0.275	0.080	0.335	-0.285	0.309
2	Water depth and F.D	0.994	0.036	0.978	0.014	0.957	0.028
3	Water velocity and F.D	0.902	0.062	0.975	0.016	0.754	0.145
4	pH and F.D	0.429	0.275	0.622	0.206	0.411	0.280
5	DO and F.D	-0.891	0.069	0.967	0.021	0.425	0.276
6	CO_2 and F.D	-0.046	0.336	-0.575	0.225	0.220	0.320
7	Alkalinity and F.D	0.305	0.305	0.625	0.205	-0.447	0.270

DISCUSSION

Brain and Kinsolying (1993) and Larinier (2001) mention that the construction of dams on rivers block or delay upstream migration and thus contributes to the decline and even the extinction of species that depends on longitudinal movements along the streams continuum. Hydropower generation enhances the development of the nation, but the river ecosystems are adversely affected especially to the fish species by damming which changes the water quality (Shrestha, 2008). Present study also showed the differences in fish species above and below the dam and physico-chemical parameters were also found to be influenced by the construction of dam. . A range of physical and chemical water quality parameters of three sampling sites in the river around the project were studied. It recorded increased temperature and free carbon dioxide, reduced pH, dissolved oxygen, water velocity upstream to downstream. Dissolved oxygen ranging from 6 to 8.8 mg/l, as well as very less release of water from dam during dry season was observed. Altogether 17 fish species belonging to 3 order, 4 families and 10 genera had been recorded. The status of fish species was analyzed on the basis of fish composition and their number. Shanon-Weiner biodiversity index showed slight difference in diversity status of fish species below and above the dam. *Barilius sps, Channa sps, Garr sps, Puntius sps* were found to be dominant fish species and also includes the endangered *Tor tor* fish species in Jhimruk River.

CONCLUSION

The present study showed that the dams have potential to alter the health and integrity of the rivers. This result was backed by statistical tests as well as the simple visible observation on the abundance and the diversity of fish species. It was found that the downstream or the section after the dam was more impaired ecologically mainly because of the less release of water from dam. Downstream, at a time in summer season remain totally dry due to the diversion of water. Thus, the longitudinal corridor for the migration of fish and other aquatic organisms should be maintained through effective fish ladders and bypass channels for ecological integrity of the river ecosystem.

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