Assessment of Nika Chu Freshwater Ecology under Jigme Singye Wangchuck National Park through using fresh water fish diversity and habitats as bio-indicator.

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LIST OF ACRONYMS

BAP	Biodiversity Action Plan
CNR	College of Natural Resources
FAO	Food and Agriculture Organization
FFSG	Freshwater Fish Specialist Group
GPS	Global Positioning System
ICS	Information and Communication Services, MOAF
IUCN	International Union for Conservation for Nature
NBC	National Biodiversity Center
NEC	National Environment Commission
SL	Standard length
SPSS	Statistical Package for Social Science
TDS	Total dissolved solid
THyE	Tangsibi Hydro Electric
TL	Total length
UPS	Uninterruptable Power Supply

Abstract

Studies on diversity and distribution of freshwater fish in the country are very low. Need of such studies have been highlighted by many fish biologists and ecologists from within the country. This study, which aimed to determine diversity and distribution of fish along the Nika Chhu stream, was conducted in two phases; in January and late March to early April, 2016. Temporary stream diversion and use of minimum voltage electric fishing in combination with catch–and-release method with various nets and locally improvised techniques were used during the field survey. A total of 244 individuals were enumerated during entire period of study, comprising 178 individuals of *Salmo trutta* Linnaeus, 1758, 65 individuals of *Schizothorax richardsonii* (Gray 1832), and 1 *Creteuchiloglanis* sp. Zhou, Li and Thomson, 2011. In January, *Salmo trutta* represented 63% (n = 41) of total abundance and *Schizothorax richardsonii* represented 37% (n = 24) of total. Latter in the month of March–April, the species composition has increased to three with addition of *Creteuchiloglanis* sp along with existing *Salmo trutta* and *Schizothorax richardsonii*. *Salmo trutta* represented 76.2% (n = 135) of total number, followed by *Schizothorax richardsonii* with 23.2% (n = 43) and *Creteuchiloglanis* sp by 0.6% (n = 1). Shannon diversity index (*H'*) was calculated to determine the diversity index. The *H'* values for the month of January and March were 2.363 and 2.825 respectively. Morphometric measurement was taken for each species of fish. Paired sample t test shows the significant ($p < .05$) between the morphometric readings of species in two phases. Lower section of the river adjoining Mangdi Chhu had a distribution of *Schizothorax richardsonii* only and the upper stream had a distribution of *Salmo trutta* and *Creteuchiloglanis* sp. While examining the distribution along various habitats, the *Schizothorax richardsonii* was found mostly distributed near the confluence (n = 24) and *Salmo trutta* was found in run habitat (n = 57). No significant ($p > .05$) association was found between the species, habitat types and environmental factors. Such observation could be attributed to lesser sampling area and shorter period of study

Key words: Catch-and-release, *Creteuchiloglanis* sp, Distribution, Diversity, *Salmo trutta*, *Schizothorax richardsonii*, Shannon diversity index (*H'*)

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CHAPTER ONE

Introduction

1.1 Background

Bhutan is situated in the southern slope of the Eastern Himalaya, 26^o and 29^o N latitude bordered by the Tibetan autonomous region of China to its north and northwest, and by the Indian states of Sikkim, West Bengal, Assam, and Arunachal Pradesh to its southwest, south, and east (NBC, 2009). It covers an area of 38,394 km^2 roughly measuring 140 km north to the south and 275 km east to west with altitudes varying from 100 metres above sea level (masl) in the southern sub-tropical region to 7550 masl in the Northern alpine region (Tshering and Tamang, 2004). By virtue of its geographical location, the country comprises of two major biogeographic realms. These two biogeographic realms are Indo-Malayan region in south east and Palearctic region in northwest (NBC, 2009). Such fact ensured rich biodiversity and put the country on a pedestal of being one of the ten biological hotspots in the world (Chhopel, 2014).

The country comprises of four major river systems; Dangme Chhu (Manas), Punatsang Chhu (Sunkosh), Wang Chhu (Raidak) and Amo Chhu (Toorsa) from east to west (Gurung *et al*., 2013). In addition, there are several small river basins which includes Samtse Area multi-river, Gelegphu Area multi-river, Samdrup Jongkhar Area multi-river, and Shingkhar-Lauri multi-river (NBC, 2009). Therefore, in total, 7,200 km length of river network is estimated (Petr, 1999). Moreover, NEC (2011) reported presence of 2,674 lakes in the country. Perennial flow of water in the swift flowing rivers and fair climatic condition with all rivers running north-south through steep terrains provide an ideal setting for harnessing hydropower energy (Tshering and Tamang, 2004). Meanwhile, east-west flowing rivers provide much of the water required for irrigation (Chhopel, 2014). In synchronous with the economical and agriculture services provided, Dubey (1978) reported that the aquatic fauna in the country is predominated by coldwater and torrential stream fauna except in foothills. Gurung and Thoni (2015) reported that there is 109 fish species in the country and the number continues to increase.

Although, the conservation of biodiversity and ecosystem in the country is given importance through unique social, cultural and development philosophy of the Gross National Happiness - GNH, (NEC, 2011), Bhutan has estimated hydropower potential of 30,000 MW in Bhutan’s Power System Master Plan (2003-22), which makes efforts to harness all hydropower energy potential. This is however of concern from the environmental and ecological perspectives. Tshering (2011) stated that, ever since the country started adoption of modernization in 1960s, river system of the nation played a pivotal role for developmental activities such as drinking, irrigation, industrial use, and generating hydropower energy. With increase in pollution of freshwater system through point and non-point sources, the quality of water can also be undermined and the habitat of aquatic fauna damaged.

The undergoing construction of Tangsibji hydropower at the proposed study site will have various impacts on aquatic life and riparian habitat. Rajvanshi (2012) mentioned that, although reservoirs positively affect certain fish species by increasing the area of aquatic habitat, the net impacts are generally negative as the dam blocks upstream fish migration and down river passage. Similarly, the construction of access road and residential accommodation will have adverse impact on riparian vegetation and quality of water. Quammen (1996) mentioned that humans have "succeeded extravagantly at the expense of other species" and played a major role in determining the fate of ecosystems around the world. Therefore, this research aims to create the baseline information on fishes and riparian vegetations of Nika Chhu in local scale before the developmental activities over shadows the value of natural freshwater ecosystem of Nika Chhu.

With such rapid addition in the diversity of freshwater fishes being recorded in the country and with rapid phases of development occuring in the country, the freshwater ecosystem, fish diversity, and its riverian habitats therefore is critical to be assessed thoroughly.

1.2 Problem Statement

Gurung *et al.*, (2013) stated that the list of fishes reported are underestimate for freshwater fish diversity of country with lesser sampling intensity. Upholding their recommendation on extending sampling efforts geographically, the current research covers the central-northern part of country. Dorji and Wangchuk (2014) also asserted that the freshwater ecology and fish habitats have not been well studied in the country.

Moreover, construction of Nika Chhu hydropower, which is undergoing at present, may have some adverse impact on the freshwater ecology. Eby *et al*., (2009) pointed out that, the construction of dam blocks the free movement of fishes and other organism, changes the natural flow of river and dams act as a reservior for sedimentation, pollutants and other materials transported by river water.

1.3 Rationale

Keeping in mind the above mentioned problem statement, it is important to study the freshwater fish and its ecology. Eby *et al*., (2009) mentioned that the ecological service provided by the freshwater is crucial for the healthy and happy human society. Also, Tenzin (2006) stated that the sound way of assessing freshwater ecology is through assessing the fish diversity as one of the bioindicator. Therefore, the need to initiate and create a scientific baseline data about aquatic lives and freshwater ecology of the Nika Chhu in the country is not only timely but critical.

1.4. Objectives

1. Assess the baseline status of fish diversity in Nika Chhu.
2. Assess the distribution of fishes in Nika Chhu.

1.5. Research questions

1. What types of fishes are found in Nika Chhu?
2. How are different types of fishes distributed in Nika Chhu?

1.6. Scope of the project

With the agreed objectives and problems, this research will serve as a baseline information for fish diversity and its ecology of Nika Chhu. It can serve as prediction for some ecological values and conservation strategies for fishes and its habitats. It will provide an holistic information on Nika Chhu freshwater ecosystem, through which the decision makers, Government and Local communities can have a varied options in win-win situation for implementing development activities without compromising the conservation of the river ecosystem. This research project will contribute to the nation in terms of making aquatic ecosystem information available in Bhutan. The findings can become a basis for making right policy decisions, rules and regulations, and implementing developmental by policy makers, ecoligists, and various agencies like the National Environment Commission and Department of Forest and Park Services.

CHAPTER TWO

Literature Review

2.1 Regional historical trends of ichthyology

2.1.1 Nepal

Until recently, the fish diversity of Nepal had been poorly studied or understood, relative to other fauna (Shrestha *et al*., 2009). Shrestha (1981) reported 120 species in her publication titled Fishes of Nepal. FAO (n.d) compliment that Shrestha is one of the pioneer Nepalese to work comprehensively on fishes of Nepal although many non-native scientists have contributed earlier. Rajbanshi (1982) reported 181 species of fishes. Shrestha *et al*., (2009) stated that more than a decade, the study on fishes of Nepal has been isolated and were rather concentrated on fragmented region. For instances, Swar and Shrestha (1998) reported 19 fish species from Tamor River, while Swar and Upadhaya (1998) reported 21 fish species from Kabeli River. However, the major works on ichthyological studies in Nepal had been in the past 10 years (1998 - 2010). In 2001, Shrestha reported 182 fish species. Similarly, Rajbansi (2005) prepared a checklist of 187 species, later in 2008 she reported 202 species and 206 species in 2011. Similarly, Gurung (2012) compiled 227 species of fish. Shrestha *et al*., (2009) reported that the prominent fish of Nepal are *Barilius shacra* (Hamilton, 1822), *Barilius bendelisis* (Hamilton, 1807), *Barilius barila* Hamilton (1822), *Garra annandalei* Hora, 1921, *Neolissochilus hexagonolepis* (McClelland, 1839), *Psilorhynchoides pseudecheneis* Menon and Datta, 1964, *Schizothoraichthys labiatus* (McClelland, 1842), *Schizothoraichthys progastus* (McClelland, 1839), *and Schizothorax richardsonii*.

2.1.2 India

Bagra *et al*., (2009) reported 1,493 species of freshwater fish in India. This project has concentrated in reviewing the literature on northeast part of India like Assam, Darjeeling and Arunachal Pradesh (AP), due to its proximity to our country.

Although many ichthyologist like McClelland 1839; Chaudhuri 1913; Hora 1921; Jayaram 1963; Jayaram and Mazumdar 1964; Menon 1964; Dutta and Sen 1977; Choudhury and Sen 1977; Jhingran and Sehgal (1978) have studied the fishes of northeast states of India, they have been fragmented in the nature of their studies (Bagra *et al*., 2009). The pioneer comprehensive study on fishes of Arunachal Pradesh (AP) was published by Nath and Dey (2000) recording 131 species. Bagra *et al*., (2009) compiled all information's available on the fishes of AP from various publications in addition to their findings and recorded 213 species. The 11 prominent and native species are *Amblyceps arunachalensis* Nath and Dey, 1989, *Amblyceps apangi*, Nath and Dey, 1939, *Aborichthys kempi* Chaudhuri, 1913, *Garra kempi* Hora, 1921, *Garra rupecula* (McClelland, 1839), *Lepidocephalichthys arunachalensis* (Datta and Barman, 1984), *Nemacheilus tikaderi* (Barman,1985), *Pareuchiloglanis kamengensis* (Jayaram, 1966), *Pseudecheneis sirenica* Vishwanath and Darshan,2007, *Pterocryptis indicus* (Datta, Barman and Jayaram,1987), *Schistura tirapensis* (Kottelat, 1990).

Kar *et al*., (2006) reported that Sen (1985) compiled 187 species of fish from Assam and its neighboring northeast states of India. Further, Kar *et al*., (2006) compiled 69 species of fish from Sone Lake of Assam which comprises of 49 genera, 24 families and 11 orders. They asserted that icthyofauna of the northeastern region of India has an element of Indo-gangetic region in addition with Myanmarese and South-Chinese region. Baro *et al*., (2015) stated that

Nepal and Bhutan are two Himalayan countries contributing to the cold water fishery resources of India. Department of fisheries of Assam government updated the number of fish present under Assam state from 165 to 210 with the new species added from the study conducted by Baro *et al*., (2015) at Sonkosh river under Kokrajhar, Assam. Baro *et al*., (2015) reported that fish species belonging to following orders: Anguilliformes, Cypriniformes, Siluriformes, Beloniformes, Per-ciformes and Tetraodontiformes have high presence in the region.

Kottelat and Whitten (1996) reported that hilly himalayan part of the northern most Darjeeling district under Indian state of West Bengal is popularly known as Darjeeling himalaya. Being the integral part of the eastern himalaya, the place is regarded as one of the freshwater biodiversity hotspot. By virtue of its location, Hora and Gupta (1940) reported that icthyofauna of the region comprise of Chinese, Malayan and Indian elements of fishes of the oriental realm. Barat *et al.,* (2005) reported 21 species of fish which is economically viable for food purposes. Mukherjee and Sakar (2005) recorded 125 species of fishes from Darjeeling, many of which falls under category of endangered fishes of West Bengal. Acharjee and Barat (2013) reported 65 species of fishes from river Teesta, which belongs to 3 orders, 10 families and 39 genera. The ten families are Cyprinidae, Sisoridae, Balitoridae, Cobitidae, Psilorhynchidae Shilbeidae, Bagridae, Olyridae, Amblyciptidae and Mastacembilidae.

2.2 National historical trends of ichthyology

McClelland (1839) on his book titled "Indian Cyprinidae" recorded two species of fish found from Bhutan by William Griffith as *Oreinus guttatus* (*Schizothorax richardsonii*) and *Platycara maculata (Balitora brucei* Gray, 1830*)*. Thoni and Hart (2015) repatriated the *Cobitis boutanensis* McClelland, 1842, of Griffith's collection of 1842 *to Aborichthys boutanensis* (McClelland, 1842), which was infact collected from Bhutan rather than from Afghanisthan. Dubey (1978) carried out study on fish of Bhutan recording a total of 42 species with dominant species being Asla, a local trout (*Schizothorax progastus*). Petr (1999) reported 41 species of fish in the country with 8 exotic species. With discovering of *Triplophysa stoliczkae* (Steindachner, 1866) from Lingzhi reported by Dema (2007), the number was assumed to be almost 50. Latter NEC, (2011) formally reported 50 species of freshwater fishes including 8 introduced species, mentioning indigenous fishes as himalayan trout, *Barilius* sp., and *Tor tor.* The first intensive work on fish of Bhutan was published by Gurung *et al*., (2013) as "An annotated checklist of fishes from Bhutan" reporting 91 species of fishes. Tshering (2014) reported the increasing number of fish diversity from 50 to 93 with discovering new species of torrent catfish from Khaling Chhu, Khaling Torrent Catfish (*Parachiloglanis bhutanensis* Thoni and Gurung, 2015). Later, Gurung and Thoni (2015) reported 109 fish species and mentioned that number of fishes will continue to increase.

2.3 Roles of fishes

2.3.1 Food sources and livlihood improvement: A global perspective

With rapid increment in the world's population, many people have started depending on fisheries and aquaculture for food and as a source of income. About 158 million tons of fish was produced in 2012, which is more than 10 million tons compared to that of 2010 (FAO, 2014). Fish provides food and a livelihood for millions of the world's poorest people, and also contribute to the overall economic wellbeing (IUCN, 2015). In the Mekong River basin alone, over 55.3 million people depend on freshwater fish for nutrition and livelihoods, with an estimated average fish consumption of 56.6 kg/person/year (Baran *et al*., 2007). It is estimated that freshwater fishes make up more than 6% of the world's annual animal protein supplies for humans (FAO, 2014). Moreover, besides supplementing as a dietary source, the fish and its components have created a space for employment. FAO (2014) reported that some 60 million people were engaged in the field of fishery and fishes, of which, 84% are employed in Asia, followed by 10% in Africa.

2.3.2 Food sources and livlihood improvement: A national perspective

The fourth state of nation report of 2012 highlights the importance of freshwater fishes in the Bhutanese context. It was stated that within 2010-2011 plan period, the production of fish was 45 metric tons. Realizing the importances and scope of the fishes in the country, the government has legalized and supported establishment of few capture fishery groups in the country. Among these are the Hara Chhu Capture fisheries management group established in 2010 and Berti capture fisheries management group established in 2012, which aimed at increasing production of fish, improvement of livlihood and in generating employment.

2.3.3 Ecological services provided by fishes

Consumption of organisms by fish is a natural phenomenon, which actually regulates the trophic structure and nutrient balance of aquatic ecosystem. Therefore, it influences the stability, resilience, and food web dynamics of aquatic ecosystems (Holmlund and Hammer, 1999). Further, IUCN (2015) added that fish plays a vital role in regulating other services such as carbon flux and sedimentary process. Fish communities can regulate the carbon-fixing capacity of lakes through balancing the nutrient-rich organism in the lakes or stream. Therefore, indirectly it helps in maintaining the flux of carbon between a lake and the atmosphere. In the context of regulating the sedimentary process, Holmlund and Hammer (1999) asserted that bioturbation process of fish, which literally means a physical disturbance of sediments resulting due to foraging, burrowing or spawning activities by fishes, maintains the fish habitats. During the process, the fish removes many aquatic macrophytes, sediment particles and other organic matters. This in turn enables the sedimentation process in continuity at various rates. IUCN (2015) mentioned that fish as a bioindicator is another important ecological value of fish. Some fish communities are excellent indicators of biological and ecological integrity due to their continuous exposure to aquatic conditions. Fishes display many changes according to biotic responses, such as changes in growth, distribution and abundance related to water pollution, habitat degradation, eutrophication, organic enrichment, chemical toxicity, thermal changes, and food availability. All these processes indicate the ecological health of the aquatic environment.

CHAPTER THREE

Materials and Methods

3.1 Study Area

Nika Chhu is a tributary of Mangdi Chhu which eventually joins the Drangme Chhu river basin. It originates from the snow capped high mountain ranges of Gangkar Puensum. The river is located in the central part of the country. It flows along the Sephu *gewog* under Wangdiphodrang district as upper stream and Tangsibji gewog under Trongsa district as lower stream. Along the stream, 14 villages of 2 gewogs exist. With the nature of settlements along the stream, the stream plays a vital role. It serves different purpose for the livilihood of communities, such as drinking water, irrigation and non measurable aquatic ecosystem benefits. With existing forest dominated by cool broad-leaved species, the river serves as an ideal place or habitat for many wildlife, birds, and fishes.

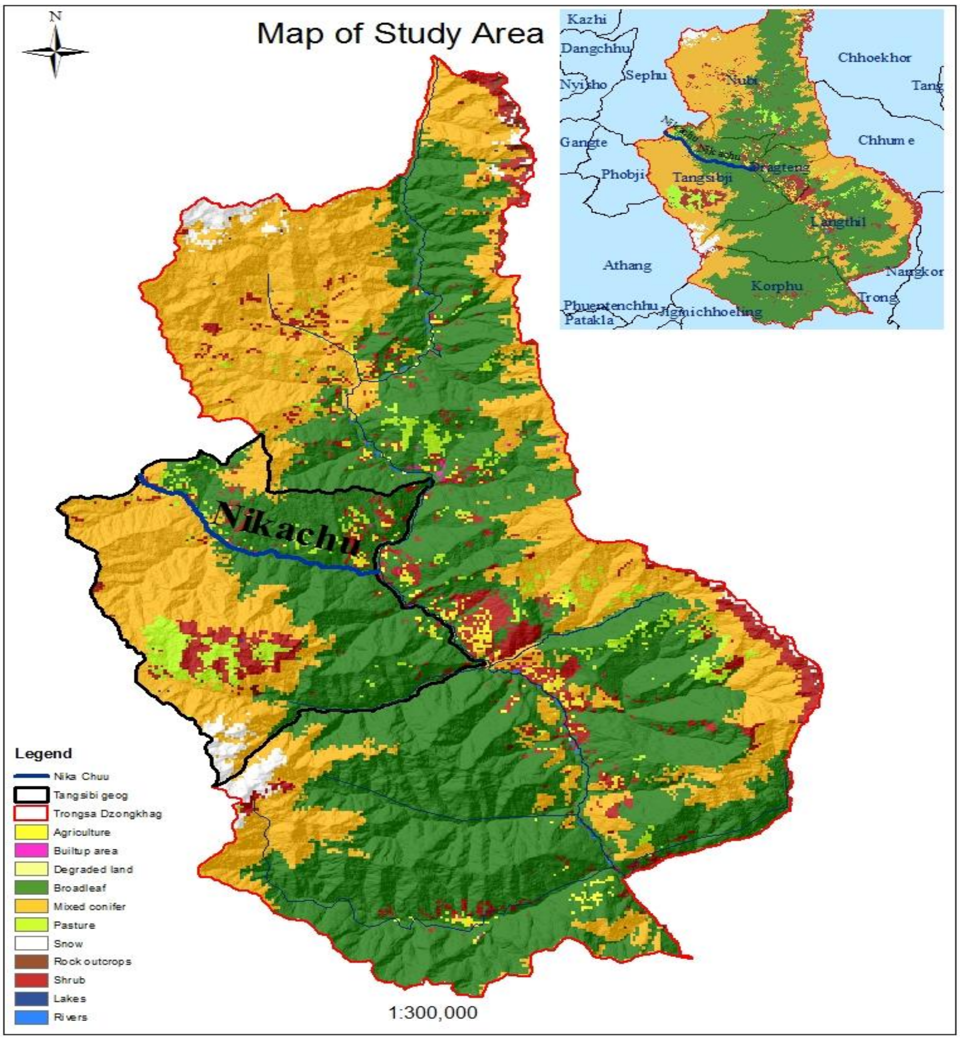

Figure 3.1. Study area

Nika Chhu stream is divided into three sections and various offices under Department Of Forest and Park Services (DOFPS) look after it.The upstream falls under Wangchuck National Centennial Park. In the midstream, each bank falls under the juridiction of Wangdi forest division and Zhemgang forest division respectively, where as the lower steam bank falls under Jigme Singye Wangchuck National Park and Zhemgang forest division. In present study, the stream was divided into two parts, upper and lower stream from the perspective of dam construction by Tangsibji Hydro Energy limited (THyE) project.

3.1.1 Lower stream

The lower stream for the study was designated from Mangdi Chhu-Nika Chhu confluence (N: 27°26'01.5", E: 90°27'48.7") till Nika Chhu-Tsheringma drup Chhu confluence (N: 27°26'99.7", E: 90°22'29.4"). There were presence of a gorge, high velocity of water, large boulders and bedrocks on the riverbed. Variables like altitude, temperature, pH, conductivity, TDS, and canopy coverage were recorded as additional information of the habitat. Presence of high forest dominated by *Quercus semicarpifolia* Rees, *Q. gluaca* Thunberg, *Q. griffithii* Hooker and Miquel, *Alnus nepalensis* Don, *Angelhardia spicata* Blume and *Castronopsis hyterix* A.DC, 1863 without any settlements along the river bank makes the area much suitable as wildlife habitat. Pug marks of Tiger, sloth bear, and leopard were found along the river stretch on sands. Further, we have seen many species of birds, of which Rufous necked hornbill (*Aceros nepalensis* Hodgson, 1829) was also present.

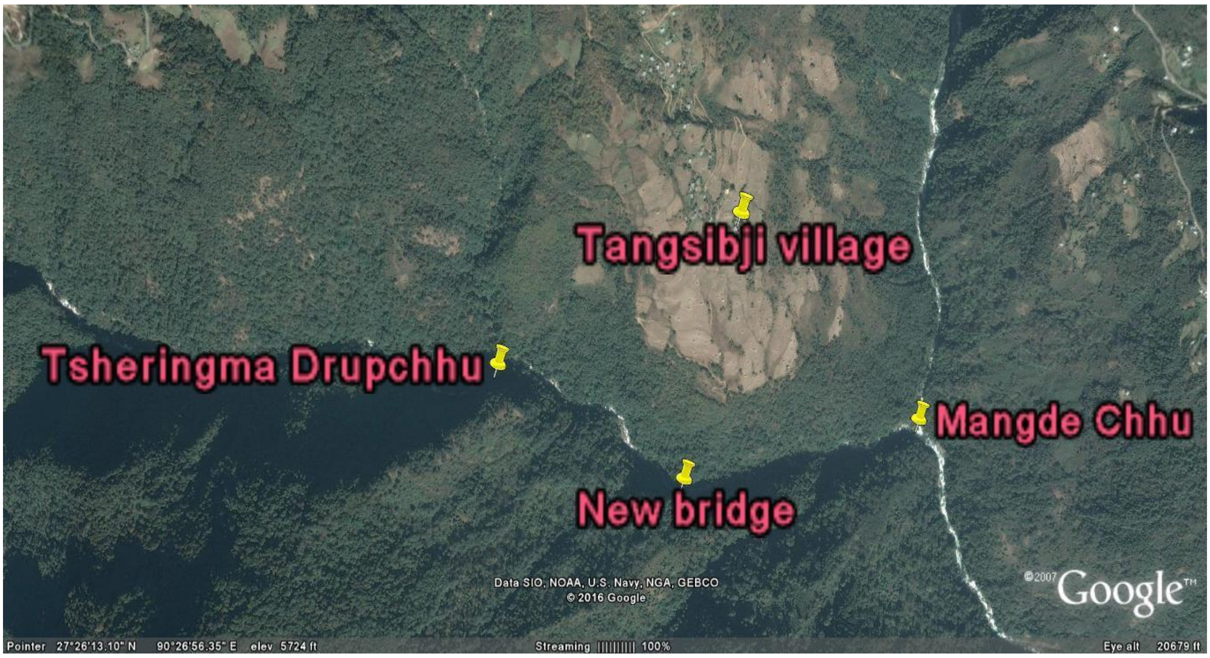

Figure 3.2. Study map of lower stream

3.1.2 Upper stream

The Upstream study site was selected from the dam construction site of Tangsibi Hydro Energy limited (THyE) with the cordinates reading of N: 27°27'03.9", E: 90°22'06.7" till Chhuserbu with coordinates of N: 27°31'.08.2", E: 90°16'58.7". The stream is relatively wide and shallow, and is predominated by cobble bottom, with several areas of gravel and coarse sand. Similar to the lower stream, additional information were recorded for this stretch of the rivers as well. This information is discussed thoroughly in the result section. *Quercus semicarpifolia*, *Pinus wallichiana* Jacks, *Populus ciliate* Royle and *Rhododendron kezangiae* Long and Rushforth, are the dominating species along the bank of the stream. Human settlements are present along the river valley. The harmonic relation between the aquatic ecosystem and society can be noticed through various ways. Building stupa (Chorten) on the bank of stream, adoption of stream by Chendepji Community Primary School and extraction of power energy through mini hydropower are some examples of such relationship.

Figure 3.3. Study map of upper stream

3.2 Materials

Gobal Positioning System (GPS) was used mainly to obtain the coordinates of plots but was even used to obtain other information of the plots. Occasionally, GPS couldn't acquire satellite readings. In such senario, Sunto Compass and Sunto Clinometer were used to locate plots. Measuring tape played a vital role in measuring the depth and width of stream. Diameter tape was used to measure the diameter of trees. Various type of nets and locally produced nets were used to catch the fish. Digital camera was used to get first hand digital images of the fish, such as colour and texture, which get lost in longer duration. For identification of fish species, Annotated checklist of freshwater fish of Bhutan and Fishes of Bhutan: a preliminary checklist was used. To preserve the specimen in the field, 10% formalin solution was prepared and used. A Unit Processing System (UPS) of 12 volt with alternate current was deployed for electric shocking occasionally.

3.3 Data analysis

Shannon diversity index was calculated to find the diversity of fishes in Nika Chhu. The value of Shannon diversity index (*H'*) was calculated according to the two phase of survey (January and March). After computing the whole samples, the *H'* value was derived using following equation.

Shannon Diversity Index (*H'*)

$$\mathbf{H' = -\sum_{i=1}^{s} pi \ln pi}$$

Where,

H'= index of species diver

Ln = natural logarithm or log
S = species richness (total number of species present in a plot or in the study area)
Pi = proportion of individuals belonging to an i^{th} species in a plot or in a study area or is the number of individuals of a species divided by the total number of individuals of all

Species abundance and species richness were calculated. Species abundance can be defined in many ways. In simple, Kerkhoff (2010) defined as a number of individuals per species at a given area (how much of individuals in every species at given area). Similarly, species richness was defined as a number of different species found in a given area (How much of species at given area). However, many of us seems using this two different words for one purpose. In fact, species richness is simply a count of species, and it does not take account of abundances.

Person correlation, mean comparisons through paired sample *t* test and independent *t* test in SPSS software was executed to check the associations and significant differences amoung the variables, which determine the diversity and distribution of fishes. Other descriptive statistics such as cross tabulations and frequency distribution were also used. Graphics and visual interpretation of results were developed using Microsoft Excel 2007.

3.4 Sampling methods

To assess the diversity of fishes, Cast net, gill net, and locally improvised nets and techniques used by local fishermen were used (Shrestha *et al*., 2009). According to the habitat type of stream section, temporary diversion with locally availiable materials like stone and twigs was carried out for several numbers. In addition, a mild electro fishing equipment using UPS was also employed.

To assess the distribution of fishes along the stream, the systematic sampling plots were fixed at every 200 meter transect (Tshering, 2011). In total, 100 sample plots were collected and assessed for over the two different timings of January and March- earlyApril, 2016. Catch-and release method (Tshering, 2011), was conducted in every plots. In each plot, five times throw of cast net with three minutes gap between every throw was followed.

Habitat parameters were measured at each sampling plot. The pH, temperature, conductivity and TDS were determined by using a multi parameter water testing kid (Oakton PCS testr 35). Stream depth and width were measured physically through stream. Further, information like morphometric measurement of fish caught – such as weight, total length (TL) and standard lenght (SL) were also collected.

Specimens collected were identified in the sampling plots. Moreover, expertise from College of Natural Resources was consulted for confirmative identitifcation. Digital camera was used to have a record of any works digitally. Later, the specimen were transported to the College of Natural Resources for proper perservation and future records.

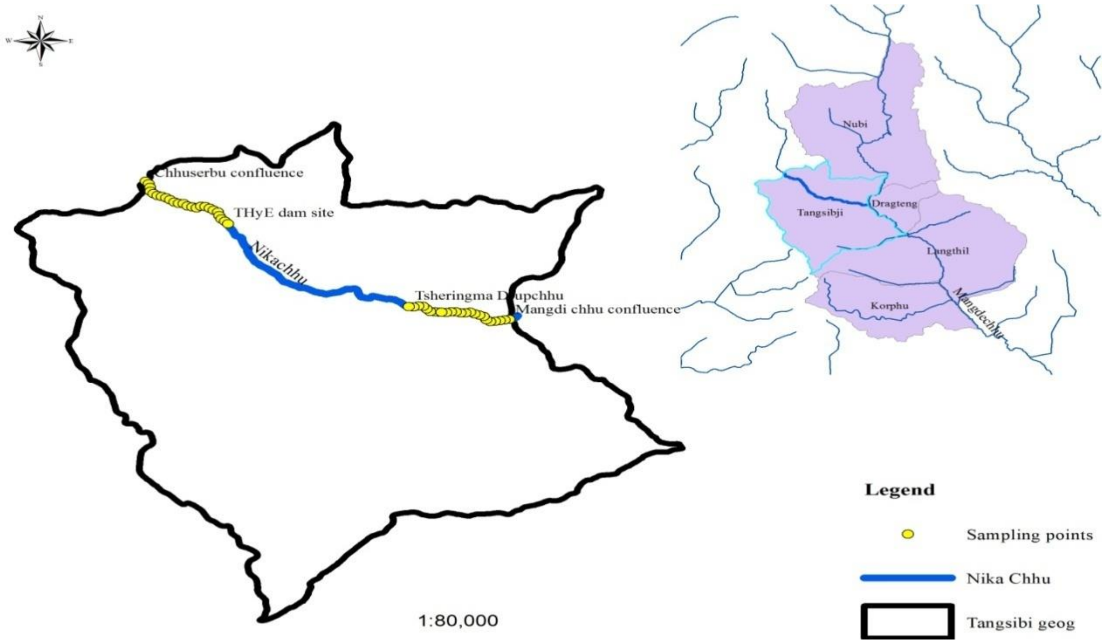

Figure 3.4. Map showing sampling points

CHAPTER FOUR

Results and discussion

4.1 Species abundance and Species composition

A total of 244 individuals were enumerated during the entire period of study. It comprises of 178 *Salmo trutta*, 65 *Schizothorax richardsonii* and 1 *Creteuchiloglanis* sp as shown in Figure 4.1. Survey was conducted twice (January and late March–early April, 2016), in which the abundance and species composition of fishes were different. In the month of January, species composition was only two with *Salmo trutta* and *Schizothorax richardsonii*. *Salmo trutta* represented 63% (*n* = 41) of total abundance and *Schizothorax richardsonii* represented 37% (*n* = 24) of total. Latter in the month of March-early April, species composition increased to three with addition of *Creteuchiloglanis* sp with existing two fish. *Salmo trutta* represented 76.2% (*n* = 135) of the total, followed by *Schizothorax richardsonii* with 23.2% (*n* = 43) and *Creteuchiloglanis* sp by .6% (*n* = 1).

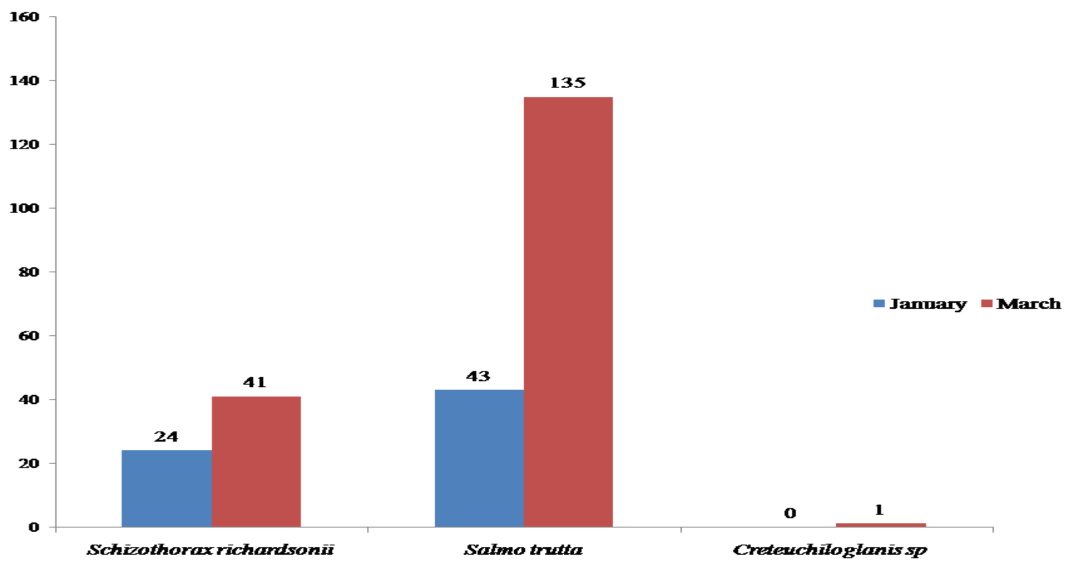

Figure 4.1. Abundance of fishes in Nika Chhu in two phases

4.2 Species Diversity

During the entire period of survey, the species composition of the fishes in the study area was three with *Salmo trutta* dominating the area. The *H'* value for the month of January was 2.363 and for the month of March were 2.825 as depicted in Table 4.1.

Table 4.1. Season wise, Species wise and zone wise diversity index

Season wise	Shannon's Diversity (*H'*)
January	2.363
March	2.825
Species wise	
Schizothorax richardsonii	2.602
Salmo trutta	2.825
Creteuchiloglanis	0.036
Zone wise in January	
Low stream	2.326
Upstream	2.4
Zone wise in March	
Low stream	2.602
Upstream	3.047

As the stream was divided into two zones of upstream and low stream, the value of *H'* for various stream zones was also derived. Of all, the highest Shannon diversity index (3.047) was found at upstream zone in the month of March as shown in Table 4.1. Lowest Shannon diversity index (2.326) was found at low stream zone in the month of January as referred in Table 4.1. Independent sample *t* test confirmed that there was no significant difference in diversity index between the upstream and low stream; $t_{(1)} = 2.48$, $p > .05$.

Kessler *et al.,* (2005) mentioned that greater the value of Shannon diversity Index (*H'*), indicates greater the species diversity. Kerkhoff (2010) explains that Shannon diversity index value generally ranges between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. In this context, Shannon diversity Index (*H'*) of Nika Chhu fishes ranges between 2.363 and 2.825 over the two times survey, cannot be considered to be high. However it is higher than the minimum of 1.5. Pearson correlation between species composition and Shannon diversity Index (*H'*) had a strong positive association; $r = 1$, $p < .01$.

Less diversity and species composition in the study area can be attributed to the presence of a water fall below the proposed dam site and the presence of an invasive exotic species *Salmo trutta.* Environment and Social Impact Assessment of Nika Chhu Hydropower Project (2014) reported the presence of *Schizothorax progastus*, *Schizothorax richardsonii*, *Acrossocheilus hexagonolepis*, catfish, carp, and some smaller resident fishes in Mangdi Chhu. Although the fishes can migrate from Main River to its tributaries, migration of fishes from Mangdi Chhu to upper stretch of Nika Chhu was not observed much. Several waterfalls are present in the lower part of stream and one of the waterfalls near Takshang Sangmey is higher than 30 metres. Burrill (2014) reported that distribution of fish is determined primarily by stream connectivity. If the fishes are stocked in a stream, where there isn't any connectivity or a presence of natural barriers such as waterfalls and cascades which exceeds more than 3 meters in height, the likelihood of their spread is greatly diminished. Furthermore, given the relatively high altitude, cold water, and rough conditions in Nika Chhu, these environmental factors could have played a role in low fish diversity.

Salmo trutta belongs to the order Salmoniformes and are classed with the family Salmonidae. This species is native to Europe, but have a native range in North Africa and Western Asia. Gurung and Thoni (2015) mentioned that it was imported and introduced in the rivers of Bhutan in 1940 and distributed mostly in the altitudinal ranging from 1000 – 3500 meters above sea level. Burrill (2014) stated that *Salmo trutta* have a nearly worldwide distribution and it is increasing in its distribution. Some unique characteristics of *Salmo trutta* such as high capacity of tolerance to low temperature (0.4^{o}c – 26^{o}c) and high pH ranging from 5 to 9.5 makes them ideal to spread faster. Moreover, with age, *Salmo trutta* becomes more carnivorous and tend to target larger prey species such as other fishes (including cannibalism), mice, small birds, and crayfish. This feeding behavior results in competition between *Salmo trutta* and other species of interest, given their predatory nature. Further, capacity to mature early leads them to early exploitation of resources, which result to increased likelihood of faster establishment.

4.3 Taxonomic classification

4.3.1 Salmo trutta Linnaeus, 1758

Order: Salmoniformes
Family: Salmonidae
Genus: *Salmo*
Species: *trutta*
Common names: Brown trout, German brown. Sea trout, Loch Leven trout

4.3.2 Schizothorax richardsonii (Gray 1832)

Order: Cypriniformes
Family: Cyprinidae
Genus: *Schizothorax*
Species: *richardsonii*
Common name: Snow trout, spotted trout, asaila, butte asala, yul nya, thing nya

***4.3.3 Creteuchiloglanis* sp Zhou, Li and Thomson, 2011**
Order: Siluriformes
Family: Sisoridae
Genus: *Creteuchiloglanis*
Creteuchiloglanis sp Zhou, Li and Thomson, 2011

4.4 Morphometric measurement

Although various measurements were taken to describe the morphometric data of fishes, only the basic standard measurements were used to describe the fish in this study. Author has taken in account of weight, total length (TL) and standard length (SL). Weight stands for overall weight of fish measured in kilogram, TL refers to the length of a fish measured from tip of snout to the tip of longer lobe of a caudal fin and SL refers to the length of the fish measured from the tip of snout to the posterior end of the last vertebra.

Table 4.2. Morphometric measurements of *Salmo trutta* and *Schizothorax richardsonii*

Species	Standard measurement	Max	Min	Mean	SD
Salmo trutta	Weight (kg)	0.4	0.04	0.13	0.07
	TL (cm)	40	10.3	19.82	5.4
	SL(cm)	32	8	16.65	4.74
Schizothorax richardsonii	Weight (kg)	0.35	0.02	0.12	0.07
	TL	32.5	9	19.72	8.19
	SL	6	25	15.99	6.64

Table 4.3. Morphometric measurements of *Creteuchiloglanis* sp

Species	Standard measurement	Measurement
Creteuchiloglanis sp	Weight (kg)	0.08
	TL	155.61
	SL	139.42

Table 4.2 and 4.3 provides the standard measurements of fishes studied. Out of 178 individuals of *Salmo trutta*, the maximum weight measured was 0.4 kg and the minimum was 0.04 kg. Mean weight of *Salmo trutta* was 0.13 kg with a *SD* ± 0.07 kg. Likewise, maximum total length was 40 cm and minimum 10.3 cm, with a mean of 19.82 cm (*SD* ± 5.40). Similarly, the standard length measured a maximum of 32 cm and minimum of 8 cm with a mean of 16.65 cm (*SD* ± 4.74). Additionally, for 65 individuals of *Schizothorax richardsonii*, weight was 0.35 kg with a minimum of 0.02 kg and a mean of 0.12 kg (*SD* ± 0.07). Maximum total length was 32.5 cm with a minimum of 9 cm, and a mean of 19.72 cm (*SD* ± 8.19). Likewise, the maximum and minimum standard lengths were 25 cm and 6 cm with a mean of 15.99 cm (*SD* ± 6.64). *Creteuchiloglanis* sp. had a weight of 0.08 kg with a total length of 15.56 cm and standard length of 13.94 cm. Paired sample *t* test provides the significant difference in the various morphometric measurement between two season for *Schizothorax richardsonii* as weight; $t_{(23)} = 4.039$, $p < .05$, total length; $t_{(23)} = 4.208$, $p < .05$, and standard length; $t_{(23)} = 3.706$, $p < .05$. It was due to occurrence of seasonal migration. Less number and small size fishes was obtained in January (residential fishes). More number with big in size fishes were got in March as the migration of fish from lower altitude to higher altitude was occurring. Bronmark *et al*., (2013) pointed that fishes migrate to spawn, take seasonal refuge from predators or adverse environmental conditions, or to feed. Similarly, Petr and Swar (2002) found in Sutley River that, *Schizothorax richardsonii* starts upstream migration with the rise in water temperature during March. Whilst only weight of *Salmo trutta*; $t_{(23)} = 2.823$, $p < .05$, was significant between two season. Total length; $t_{(23)} = 1.728$, $p > .05$, and standard length; $t_{(23)} = 0.744$, $p > .05$ was not significant. Absence of fish ladder due to presence of high water fall below the dam construction of THyE restricted the migration of *Salmo trutta*. Such physical barrier has led to similar results between two season without significant in their morphometric measurements.

4.5 Distribution of fishes in Nika Chhu

Distribution is an area or site occupied by individuals of an interest. In this study, the habitat type of Nika Chhu was classified into four types mainly depending on water depth, water velocity, gradient, flow regime, substrate, and presence of adjoining stream. Stream was divided into pool, run, cascade, and confluence. Results are presented based on how the species differed in distribution and what parameters constituted the habitat types.

4.5.1 Schizothorax richardsonii

As discussed earlier, due to the presence of a waterfall, distribution of this species was absent above the waterfall. Lower stream adjoining Mangdi Chhu had a distribution of *Schizothorax richardsonii*. Environmental factors present in the habitat of *Schizothorax richardsonii* are listed in Table 4.4.

Table 4.4. Environmental factors of the habitats occupied by *Schizothorax richardsonii*

Environmental factors	Minimum	Maximum	Mean	SD
Altitude (masl)	1405	1852	1635.83	133.99
Temperature (°c)	4	15.8	10.06	4.7
pH	6.41	7.2	6.95	0.19
Depth of river (m)	0.9	1.9	1.36	0.28
Width of river (m)	28	38	34.1	3.05

Canopy coverage (%)	2	4	2.79	0.84

Canopy coverage index – 1 = >25%, 2 = 26-50%, 3 = 51-75%, 4 = 76-100%

In the entire study period, 65 individuals of *Schizothorax richardsonii* were examined for its distribution in four different habitat types. Out of 48 plots, only 12 plots representing 25% of total plots were found with fish. Remaining 36 plots representing 75% of total plots had no fish as shown in Figure 4.2. Presence of fish number in 12 plots varied among with ranging from 1 to 5 individuals. Mean number of fish present was 2.40 (*SD* ±1.29).

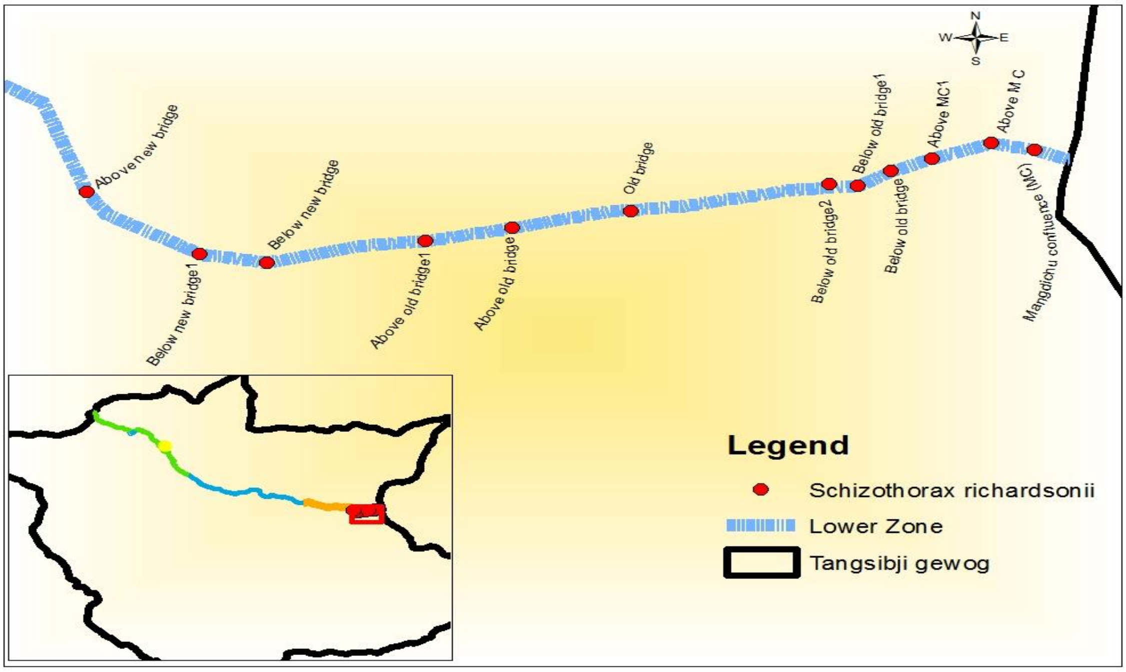

Figure 4.2. Location of plots found *Schizothorax richardsonii*

While examining the distribution of *Schizothorax richardsonii* in various habitat types (Figure 4.3), the presence of individuals in various habitat type ranges from a maximum of 24 to a minimum of 12. Highest number of individuals were found distributed in confluence habitat (*n* = 24). Lowest number of individuals were found distributed along the cascade habitat (*n* = 12). Pool habitat had 16 of individuals and the run had 13.

It is observed that *Schizothorax richardsonii* preferred confluence than other habitats. Confluence consists of high volume of water and pool like habitat. Chances of food availability could be more as the confluence comprises of two different streams, which can host various organism. Petr and Swar (2002) points that, in winter season when the water level is low and transparent, *Schizothorax richardsonii* are found in the habitats were maximum volume of water is present. Further, Shrestha (2009) mentioned that *Schizothorax richardsonii* being a column feeder needs high volume of water. Such adaptation makes *Schizothorax richardsonii* to prefer confluence as water volume in confluence is higher and deeper than other habitats.

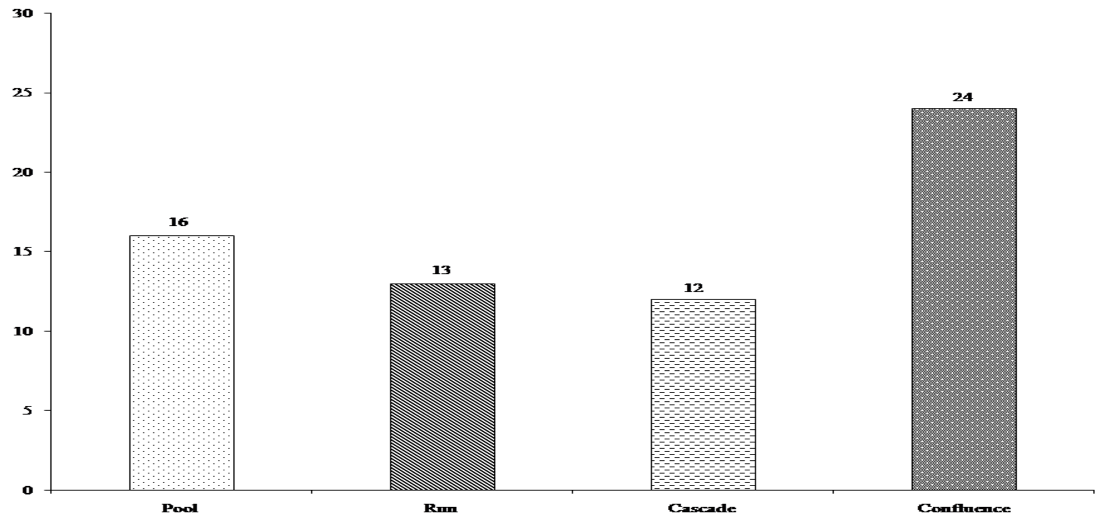

Figure 1.3. Total catch of *Schizothorax richardsonii* in various habitats

In confluence habitat (Table 4.5), Altitude ranges from 1405 – 1852 masl. Maximum temperature was 15.8 ^{0}c and the minimum was 4 ^{0}c. The pH ranges from 6.41 – 7.2. Depth of river ranges from 1.2 – 1.7 meter. Width ranges from 30 – 37 meter. Canopy coverage consists from 26 – 100%. Factors such as altitude, temperature, pH and canopy coverage plays a vital role in formation of habitat types of stream. Hauer and Hill (2006) suggested that temperature affects the movement of molecules, saturation constant of dissolved gases and metabolic rates of organisms. Similarly, with the increase in altitude, decrease in temperature is observable. Fish depends on temperature for emergence and spawning. Likewise, Mishra (2009) pointed out that pH values ranging from 6.5 – 8.4 are suitable for survival of fish.

Table 1.5. Descriptive information about confluence habitat

Environmental factors	Minimum	Maximum	Mean	SD
Altitude (masl)	1405	1852	1640.75	161.77
Temperature (°c)	4	15.8	9.98	4.92
pH	6.41	7.2	6.95	0.22
Depth of river (m)	1.2	1.7	1.42	0.17
Width of river (m)	30	37	34.67	2.35
Canopy coverage (%)	2	4	2.67	0.78

Pearson‘s correlation (Table 4.6) was conducted to find out the significance of habitat parameters influencing habitat distribution of *Schizothorax richardsonii*. It was found that there were no significant association (p > .05) between habitat types and various habitat parameters. It was observed that the association between habitat types and altitude is negatively associated; r = -.046, p > .05. Habitat and temperature was negatively associated by r = -.015, p > .05. Habitat and pH was negatively associated by r = -.038, p > .05. Habitat and TDS is r = 0, p > .05. Habitat and depth is positively associated by r = 0.017, p > .05. Habitat and Width is positively associated r = 0.197, p > .05, and between habitat and canopy coverage % is positively associated by r = 0.114, p > .05. Lack of associations between habitat types and various environmental factors could be because of taking short stretch of river and choosing habitat types from the same stretch of river. Lesser sampling duration also diminishes the chances of getting adequate information when studying the longer life individuals (Hauer and Hill, 2006).

Table 4.6. Pearson's correlation among habitats and other environmental factors

		Altitude	Temperature	pH	TDS	Depth	Width	Canopy %
Habitat	1	-0.046	-0.015	-0.038	0	0.017	0.197	0.114
Altitude		1	-0.097	.390**	0	0.032	-0.106	-0.519
Temperature			1	-.745**	0.981	0.112	0.012	0.005
pH				1	-0.692	-0.194	.011**	-.260**
TDS					1	0.128	0	.000**
Depth						1	-0.701	-0.272
Width							1	0.237
Canopy %								1

**. Correlation is significant at the 0.01 level (2-tailed).

4.5.2 Salmo trutta and Creteuchiloglanis sp

Upper stream consist of *Salmon trutta* and *Creteuchiloglanis* sp. Overall environmental factors of the habitat are shown in Table 4.7. The altitude of the upstream habitat occupied by *Salmo trutta* and *Creteuchiloglanis* sp. ranges from 2234 – 2631 masl. The pH ranges from 7 – 7.4. Temperature ranges between 2 – 13.2 ^{0}C. Depth of stream ranges from .2 – 1.5 meter. Width ranges from 9.5 – 38 meter. Canopy coverage comprises from 1 – 75 %.

Table 4.7. Environmental factors of the habitats occupied by *Salmo trutta* and *Creteuchiloglanis* sp

Environmental factors	Minimum	Maximum	Mean	SD
Altitude (masl)	2234	2631	2438.25	103.75
Temperature (°c)	7	7.4	7.15	0.13
pH	2	13.2	8.2	3.76
Depth of river (m)	0.2	1.5	0.75	0.35
Width of river (m)	22	38	20.14	8.9
Canopy coverage (%)	1	3	1.54	0.58

In the entire study period, 178 individuals of *Salmo trutta* and 1 *Creteuchiloglanis* sp was caught and examined their habitat distribution. Numbers of fish present in plots ranges from 1 to 12 individuals. Mean number of fish present was 4.9722 (*SD* ± 2.92) as shown in Figure 4.4.

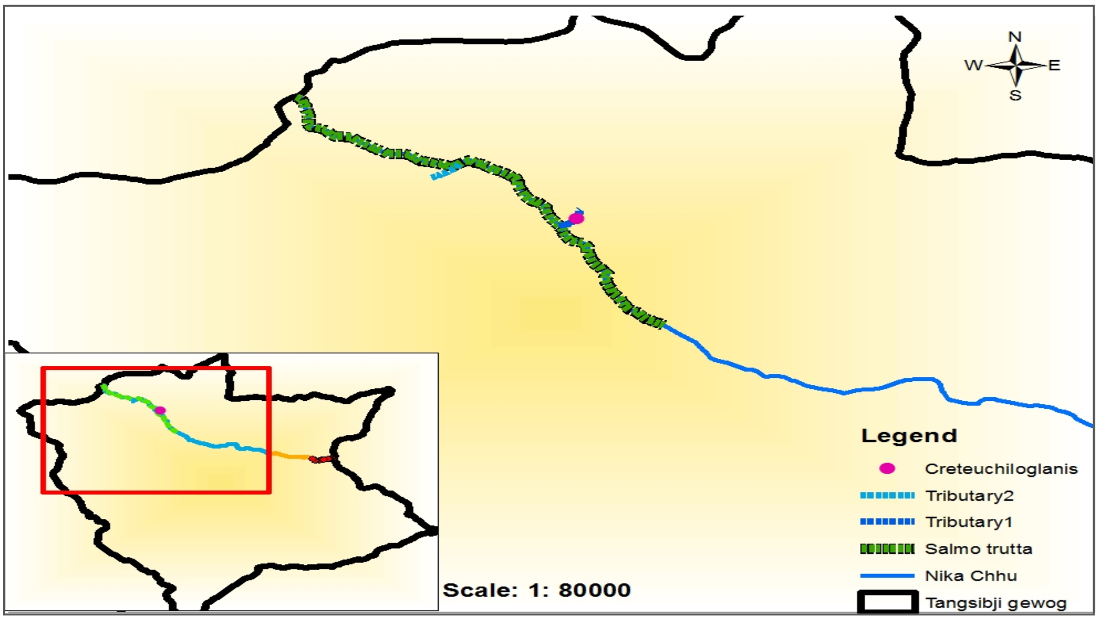

Figure 4.4. Location showing the *Salmo trutta* and *Creteuchiloglanis*

Distribution of *Salmo trutta* in different habitat types (Figure 4.5), ranges from a maximum of 56 to a minimum of 37 individuals. Highest number of individuals were found distributed in run habitat (*n* = 57). Lowest numbers of individuals were found distributed along the cascade habitat (*n* = 37). Pool and confluence habitats have 42 individuals equally. Unlike *Schizothorax richardsonii*, *Salmo trutta* was observed preferring run habitat than other habitats. Run habitats consist of wide width, shallow depth, and low current and direct sunlight.

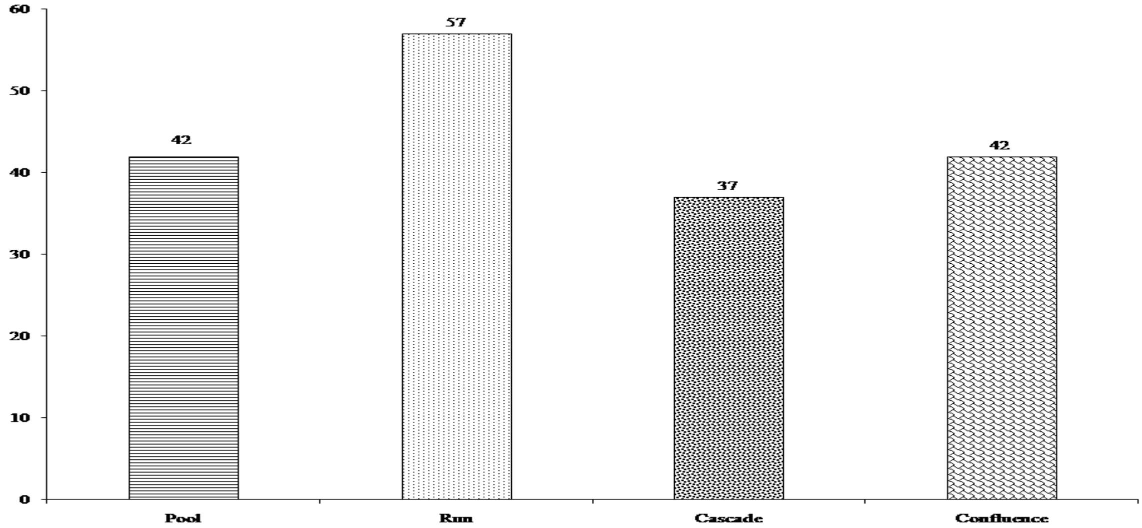

Figure 4.5. Total catch of *Salmo trutta* in various habitats

Highest numbers of *Salmo trutta* individuals were distributed in the run habitat. Table 4.8 shows the descriptive information about run habitat, in which the Salmo trutta prefer most. The altitude of this habitat type ranges from 2234-2631 masl. Maximum temperature was 13.2 ^{0}c and the minimum was 2^{0}c. The pH ranges from 7-7.4. Depth of stream ranges from .2 – 1.5 meter and the width of the river ranges from 30-37 meter. Canopy coverage consisted from 26-100%. High adaptation rate for *Salmo trutta* makes them adapt in varied stream and lakes. Such as Burril (2014) mentioned that *Salmo trutta* have higher temperature tolerances than other species of trout. Ideal incubation temperatures ranges from 8-10 ^{0}c. Similarly it is observed that it performs well under a pH that ranges from 5 to 9.5.

Table 4.8. Descriptive information about run habitat

Environmental factors	Minimum	Maximum	Mean	SD
Altitude (masl)	2234	2631	2438.25	103.75
Temperature (°c)	2	13.2	8.2	3.76
pH	7	7.4	7.15	0.127
Depth (m)	0.2	0.9	0.75	0.35
Width (m)	22	38	20.14	8.89
Canopy coverage (%)	1	12	2.15	1.99

Similarly with the lower stream, Pearson's correlation between the upper stream habitat types and environmental factors were observed (Table 4.9). There was no significant association ($p > .05$) between habitat types and environmental factors, which is similar to that of the lower stream.

Table 4.9. Pearson's correlation among habitats and other environmental factors

	Habitat	Altitude	pH	Temperature	TDS	Depth	Width	Canopy%
Habitat	1	-0.103	0.037	-0.058	0	-0.001	0.02	0.227
Altitude		1	0.159	-0.091	-0.018	.535**	-.291*	-.323*
pH			1	.521**	.679**	-0.157	-0.214	-0.217
Temperature				1	.952**	-0.04	.441**	0.041
TDS					1	-0.022	.377**	-0.004
Depth						1	.477**	.312*
Width							1	.291*
Canopy%								1

** Significant at 0.01 level (2-tailed) *Significant at 0.05 level (2-tailed)

Although there was no significant relation ($p > .05$) between habitat and environmental factors, theoretically, there could be differences. Factors such as altitude, temperature, pH and canopy coverage plays a vital role in formation of habitat types of stream. Such environmental factors influence the distribution of fish along the habitat types (Burrill, 2014). Direct sun light with less canopy coverage can also increase the temperature of stream.

CHAPTER FIVE

Conclusion and Recommendation

This project provides important baseline information on the diversity of fish, its habitats, and distribution along Nika Chhu. The study was conducted in two phases; January and March-early April. It was found that diversity of fish in Nika Chhu was low with three species only. The species are *Schizothorax richardsonii*, *Salmo trutta* and *Creteuchiloglanis*. A total of 244 individuals were enumerated during entire period of study, comprising 178 individuals of *Salmo trutta*, 65 individuals of *Schizothorax richardsonii* and 1 *Creteuchiloglanis* sp. Morphometric readings were recorded. Morphometric significant ($p < .05$) was observed between two seasons for every species of fishes. The study indicates that there is no significant relation with various habitat types and the environmental factors.

This study could manage to get only one *Creteuchiloglanis* sp. Therefore, a long term study with larger sampling intensity is suggested to really determine the abundance of it. Moreover, incorporation of more factors such as presence of substrate and percent rock covers can really determine fish distribution in various habitat types.

Presence of exotic brown trout (*Salmo trutta*) is a common concern among many fish biologists and ecologists in the country. Nevertheless, no single biologist or ecologist has studied on the biology, behaviors such as adaptation, migration, reproduction, and invasiveness in Bhutan. Therefore, it is suggested that such studies are conducted to understand the impact of brown trout introduction in the country.

Tangsibi Hydropower plant is under construction. Many environmentalists have raised the overall negative impacts of damming the river and stream. In order to withstand the negative impacts of such construction on fish and other aquatic organisms, it is important to maintain a minimum flow of stream below the dam at all times of the year.

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Annexure 1. A. Shannon diversity index (H') of the study area in January					
Lower Stream January			Upper stream January		
Total Catch	pi	pi(ln)pi	Total Catch	pi	pi(ln)pi
4	0.167	-0.299	5	0.122	-0.257
3	0.125	-0.26	3	0.073	-0.191
1	0.042	-0.132	1	0.024	-0.091
1	0.042	-0.132	5	0.122	-0.257
1	0.042	-0.132	1	0.024	-0.091
1	0.042	-0.132	2	0.049	-0.147
4	0.167	-0.299	3	0.073	-0.191
3	0.125	-0.26	3	0.073	-0.191
1	0.042	-0.132	2	0.049	-0.147
1	0.042	-0.132	3	0.073	-0.191
2	0.083	-0.207	2	0.049	-0.147
2	0.083	-0.207	3	0.073	-0.191
24	**H**	2.326	3	0.073	-0.191
			1	0.024	-0.091
			4	0.098	-0.227
			41	**H**	2.602

Annexure 1. B. Shannon diversity index (H') of the study area in March					
Lower Stream March			Upper stream January		
Total Catch	pi	pi(ln)pi	Total Catch	pi	pi(ln)pi
1	0.023	-0.087	4	0.029	-0.104
2	0.047	-0.143	3	0.022	-0.084
2	0.047	-0.143	6	0.044	-0.138
7	0.163	-0.296	3	0.022	-0.084
5	0.116	-0.25	7	0.051	-0.153
7	0.163	-0.296	4	0.029	-0.104
3	0.07	-0.186	5	0.037	-0.121
2	0.047	-0.143	5	0.037	-0.121
4	0.093	-0.221	5	0.037	-0.121
4	0.093	-0.221	3	0.022	-0.084
2	0.047	-0.143	11	0.081	-0.203
3	0.07	-0.186	5	0.037	-0.121
1	0.023	-0.087	7	0.051	-0.153
43	**H**	**2.400**	9	0.066	-0.18
			7	0.051	-0.153
			12	0.088	-0.214
			3	0.022	-0.084
			3	0.022	-0.084
			2	0.015	-0.062
			6	0.044	-0.138
			12	0.088	-0.214
			7	0.051	-0.153
			6	0.044	-0.138
			1	0.007	-0.036
			136	**H**	**3.047**

Annexure 2A. Sampling locations in lower stream				
Plot no	Locality	N	E	Altitude
1	MangdiChhu confluence	27°26'01.5"	90°27'48.7"	1405m
2	Above M C	27°26'03.4"	90°27'39.9"	1420m
3	Above MC	27°26'09.0"	90°27'21.5"	1462m
4	Above MC	27°26'21.1"	90°27'13.2"	1489m
5	Below old bridge	27°26'28.9"	90°27'01.4"	1493m
6	Below old bridge	27°26'34.2"	90°26'53.1"	1515m
7	Below old bridge	27°26'38.9"	90°26'32.7"	1534m
8	Below old bridge	27°26'42.3"	90°26'21.0"	1539m
9	Old bridge	27°26'48.1"	90°26'21.0"	1579m
10	Above old bridge	27°26'53.6"	90°25'43.3"	1583m
11	Above old bridge	27°26'58.1"	90°25'31.4"	1610m
12	Above old bridge	27°26'60.2"	90°25'19.2"	1618m
13	Below new bridge	27°26'67.9"	90°25'09.0"	1649m
14	Below new bridge	27°26'75.6"	90°24'56.1"	1676m
15	Below new bridge	27°26'79.9"	90°24'44.6"	1691m
16	New bridge	27°26'84.2"	90°24'24.2"	1704m
17	Above new bridge	27°26'89.9"	90°24'16.3"	1721m
18	Above new bridge	27°26'92.3"	90°24'05.9"	1728m
19	Above new bridge	27°26'96.6"	90°23'56.2"	1753m
20	Above new bridge	27°26'97.4"	90°23'31.6"	1779m
21	Above new bridge	27°26'98.2"	90°23'19.2"	1802m
22	Above new bridge	27°26'98.9"	90°23'06.9"	1823m
23	Below Tsheringma	27°26'99.1"	90°22'30.5"	1835m
24	Tsheringma DrupChhu	27°26'99.7"	90°22'29.4"	1852m

Annexure 2B. Sampling locations in Upper stream				
Plot no	Locality	N	E	Altitude
1	Below dam site	27°27'03.9"	90°22'06.7"	2234m
2	Below Yala	27°27'12.8"	90°21'59.5"	2286m
3	Yala	27°27'16.0"	90°21'57.2"	2322m
4	Below Drangla	27°27'23.6"	90°21'47.8"	2324m
5	Drangla	27°27'35.7"	90°21'30.9"	2393m
6	Drangla	27°27'41.2"	90°21'21.5"	2424m
7	Drangla	27°27'51.2"	90°21'16.0"	2343m
8	Chendepji	27°28'00.9"	90°21'13.4"	2406m
9	Chendepji	27°28'09.1"	90°21'07.9"	2397m
10	Chendepji	27°28'19.7"	90°21'04.7"	2417m
11	Chendepji Chorten	27°28'22.3"	90°20'59.9"	2399m
12	Above Chendepji chorten	27°28'31.0"	90°20'54.2"	2403m
13	Near FMU Chendepji	27°28'47.4"	90°20'44.4"	2431m
14	Below Pasture land	27°28'57.3"	90°20'32.6"	2439m
15	Below Chendepji Bridge	27°29'09.2"	90°20'25.6"	2457m
16	Above Chendepji Bridge	27°29'14.8"	90°19'54.7"	2472m
17	Below Chhuserbu	27°29'19.4"	90°19'49.0"	2505m
18	Below Chhuserbu	27°29'29.0"	90°19'17.7"	2372m
19	Chhuserbu	27°29'53.6"	90°18'48.5"	2507m
20	Above Chhuserbu	27°30'23.4"	90°18'10.9"	2567m
21	Above Chhuserbu	27°30'.32.3"	90°17'52.3"	2583m
22	Above Chhuserbu	27°30'.49.0"	90°17'25.6"	2596m
23	Above Chhuserbu	27°30'.53.6"	90°17'09.2"	2610m
24	Above Chhuserbu	27°31'.08.2"	90°16'58.7"	2631m

Annexure 3. Dominating vegetation along the Nika Chhu				
Binominal name	Genus	Family	Order	Local Name
Quercus semecarpifolia	Quercus	Fagaceae	Fagales	Gumseng
Quercus glauca	Quercus	Fagaceae	Fagales	Creseng
Castronopsis hystrix	Castanopsis	Fagaceae	Fagales	Shaquaw
Alnus nepalensis	Alnus	Betulaceae	Fagales	Gangseng
Quercus Griffithii	Quercus	Fagaceae	Fagales	Pising
Rhododendron kesangiae	Rhododendron	Ericaceae	Ericales	Aeto meto
Populus ciliata	Populus	Salicaceae	Malpighiales	Jashing
Pinus wallichiana	Pinus	Pinaceae	Pinales	Changseng
Salix wallichiana	Salix	Salicaceae	Malpighiales	Changma

Annexure 4. Data collection form

Plot no	Date	Time	Species name		Sampling location			
			Scientific	Local	Locality	N	E	Altitude

Habitat type					
Pool	Run	Cascade	Confluence	Vegetation type	Canopy %

Water parameters						
Stream order	PH	Temperature	Conductivity (µs)	TDS (ppm)	Depth	Width

Capture method	Throw count														
	1			2			3			4			5		
	WT	TL	SL	WT	TL	SL	WT	TL	SL	WT	TL	SL	WT	TL	SL