CHAPTER-ONE

1.0 Introduction

1.1 General Background

Sikkim, a small mountainous state of India in the eastern Himalayas with an area of 7096 sq. km and the total population 5.4 Lakhs (2001 Census) is one of the nature's paradoxes being witnessed by magnificent snow capped mountain and riverine scenery. It derives its name from the Limbu word –"Sukhim", which means the "New House ".Lepchas, the original inhabitants of the State refer to as "Nye-mae-el" or Heaven and Bhutias called as "Bemyul Denzong", the Hidden "Valley of Rice". Whereas, some other, believes that the present name is of Nepalese origin meaning "The New Place".

Sikkim was earlier a protectorate of India with a monarchy government but after the 36th Constitutional Amendment, it has been metamorphosed to become the 22nd State of Indian Union in May, 1975(Bhasin, 1995).

Geographically, Sikkim is situated on the flanks of Eastern Himalayas in north –east India between 27° 00'46" to 28° 07' 48" N latitude and 88° 00' 58" to 89° 55' 25" E longitude. It extends over 115 kilometers from North to South and 65 kilometers from East to West , being surrounded by vast stretches of Tibetan Plateau in North, Chumbi valley to Tibet and the Kingdom of Bhutan in the East, Darjeeling Gorkha Hill Council of West Bengal in the South and the Nepal in the West . Sikkim shares 220 kilometers long border with Tibet, 100 k.m with Nepal, 30 Kilometers with Bhutan and 80 kilometers with West Bengal . Administratively the state is divided into four districts as follows:

1.North Sikkim, 2.South Sikkim, 3.East Sikkim and 4. West Sikkim.

North Sikkim lies at the latitude 88 ° 8' to 88° 53'N and longitude 27° 25' to 28° 8' E. The head quarter of this district is Mangan. South Sikkim lies at the latitude 88° 17 ½ ' to 88° 32 ½ 'N and longitude 27° 5' to 27 ° 27 ½ 'E with Namchi as its head quarter. East Sikkim lies at the latitude 88° 27 / ½ 'to 88° 55 'N and longitude 27°7 ½' to 27° 25 E with Gangtok as its head quarter. West Sikkim lies at the latitude 88 ° 2 to 88V 55'N and longitude 27° 7' to 27 ° 25'E with Gyalzing as its head quarter.

Topography

Sikkim, though small in size, but is amply compensated by formidable physical features and rugged topography. The state predominantly consists of highlands with no plain and nearly 2/3rd are partially covered with snow from which glaciers like Zemu, Chamsang,

Lhonak and Talung descend. Sikkim is a mountainous terrain with cliffs and valleys. The state being a part of inner ranges of mountainous of Himalayas, has no open valley and no plains but has varied elevations ranging from 244m at Melli Bazar to 8598m, the famous Kanchendzonga peak which is the third highest peak in the world. Besides the Kanchendzonga peak, the other major peaks are Kumba Karna (7111m), Pendem (6706), Narshing (5825m) Kabru Dome (6545m) etc.The peaks can be seen from almost all parts of Sikkim including Gangtok.

There are many glaciers in Sikkim but the most important are the Zemu glacier, Rathong glacier and Lonak Glacier. The two principal rivers of the state called Teesta river and Rangit river are originated fromthe Zemu and Rathong glaciers respectively(Subba, 1984).

Climate

The variation in the altitude from 310 m to 8000 m is less than 100 kilometers results in abrupt climatic changes in the state. Thus the state has been roughly divided into different zones as sub –tropical (260m-1524m MSL), temperate (1524m-2743m MSL), sub-alpine (2748m-3962m MSL) and alpine (above 3926m MSL). The flow of south-west monsoon wind from Bay of Bengal, has a great influence on the climatic conditions of the state. Pre monsoon rain occurs in April –May and the south –west monsoon begins usually from the month of May continuing up to early October. Due to rainfall, the climate of the state remains cool and humid in most of the periods of the year. During spring (March – May) and autumn (Sept-Nov) the weather is pleasant but there is torrential rain during the monsoon (June-Sept) (Venu ,1990).

Temperature

The temperature varies considerably with altitude .At low altitude, places like Singtam, Rangpo and Jorethang , the temperature varies between 10° to 35° C .In moderate altitude places like Gangtok with about 1800 m (5905 ft) temperature varies between 1°C to 25° C whereas at altitude above 4000 meters(13123ft), the temperature never rises above 15°C (Venu , 1990).

Rainfall

Sikkim is one of the heaviest rainfall regions in India. The state as a whole gets 80 to 90 percent of the annual rainfall because of its proximity to the Bay of Bengal and the mountains of this state lies directly in the path of the monsoon clouds. The weather remains clear during October to March as there is hardly any rain (Venu, 1990).

Recorded data show minimum annual rainfall at Thangu and maximum at Gangtok .An analytical data reveals that there are two

maximum rainfall areas i,e (i) south –east , including Mangan , Singhik, Dikchu Gangtok, Rongli etc. and (ii) south –west corner including Hilley. In between these two regions lies a low rainfall region like Namchi(Basnett,1989).

1.2 Water Resources of Sikkim

Water is one of the most important natural resources for all the living beings to support life. The natural sources of water are the rain, spring, ground water, river, sea and ocean. About 97% of global water resources are locked up in oceans, estuaries, and marshes; however, remaining 3% of balance water are available in the form of rivers, lakes, and glaciers. The water is balanced in earth by hydrological cycle.Sikkim, being a small mountainous state is blessed by nature with plenty of water resources, both lotic and lentic.The water resources of Sikkim are as follows :

1.2.1 Lake

Lentic system comprises of lakes at various altitudes(1550m to 5300mMSL). Some of the important and beautiful well known lakes of the Sikkim are Changu Lake, Menmoitso Lake , Bidang Lake, Kupup Lake and Aritar lake lying on the eastern part of the state. Kechropalri lake, Lampokhari are major lakes which lie on the western part of the state. Gurudongmar is the largest and beautiful lake lying at the highest region in Sikkim.Similarly, Chholhamu is the beautiful lake which is located in north Sikkim.

1.2.2 Hot spring

Among the hot springs, Phurcha Chu (Reshithatopani) Yumgthang hot spring, Borang and Ralong hot springs are quite famous in the state, which are even renowned for medicinal and therapeutic values.

1.2.3 River

In Sikkim most of the name of rivers ended in chu which literally means river or khola.Under the lotic system, Teesta and Rangit are the two important rivers with innumerable tributaries.

1.2.3.1 The Teesta and Rangit Rivers

The river Teesta is one of the main Himalayan rivers that originates from the glacier Cholamu at the elevation of 5400m (17716ft.) in the northeast corner of the state. At the origin, it is a very small stream but transforms into a thundering mighty river within less a hundred kilometers downstream. The river originates in mountain terrains and is formed mainly by the union of two hill streams Lachen Chu and Lachung Chu, at Chungthang in north Sikkim .The river runs westwardly from its source for about 25 km then virtually passes north to south

bisecting the State throughout its length and traversing through steep gradients(53m to 58.11m per km deep gorges) and V-shaped valleys with turbulent water up to 650m MSL. The river basin then gradually widens and passes through broader valleys. The upper catchments of the Teesta drainage enclose the state in a gigantic horse-shoe shaped configuration.

The important tributaries of the Teesta drainage are Zemu Chu, Bakcha Chu , Lachung Chu, Talung Chu , Lonak Chu, Dik Chu , Kanaka Chu, Rani Chu and Rangpo Chu. After the confluence of Rangpo, the river widens rapidly and finally confluences with river Rangit. This river enters Bangladesh 40 km south –east of Jalpaiguri town, West Bengal. After a long meandering course, it joins to River Brahmaputra (known as river Jamuna as it enters Bangladesh from Assam in India) at a place (25° 17" 08" N and 89° 29' 09"E) 20 km south of Chilmari in Bangladesh. Gradient wise, the riverine elevation ranges from 310m in the plains to 5300m in the alpine zone characterizing the sub-basin with steep gradient up to 650m and huge amount of silt depositing in the lower reaches (Bhasin,1995).

River Rangit , on the other hand, originating from Rathong glacier in west Sikkim flows towards South for about 51 km from its origin receiving various tributaries and passing through the deep gorges. The drainage runs eastward demarcating the south district of the state from Darjeeling Gorkha Hill Council of West Bengal and finally confluences with river Teesta. Rambi khola, Kalej khola, Roathak khola, Rangbhang khola and little Rangeet are some of the major tributaries of this river.

1.2.3.2 River Rani (Rani khola)

Rani khola (also known as Rongni Chu),a main tributary of the Teesta river, is one of the largest river in east district of Sikkim carrying an average annual water discharge of about 6-14 cumec. It forms an important left bank tributary of Teesta river. Rani khola originates from the glacier in the north - east corner of East- Sikkim and its main sources are**:** Ratey Chu and Lyang Kyong Chu.

Rani khola flows in north south direction for a distance of about 4-5 km from Liyang kyong Chu. Then it flows in south west direction and confluences with Maney khola (which originates from Ratey Chu). After meeting Kali khola, Rani khola flows steep downwards upto 3 kilometers and meets Rey khola. Rani khola which gradually increases its width at Adampool. In upper reaches Rani khola flows in east direction over a few kilometers and joined Reshi khola. Thereafter it flows in same direction up to Jalipool where it is joined by Bhusuk khola. Then it turns south

east direction over 3-4 kilometers and further meets Seti khola. After meeting Seti khola it flows in south west direction over a length of 5-7 kilometers and joins by a tributary Chhuba khola. Rani khola moves further slowly and joins with Martam khola on its right bank and flows at least 5 km before meeting Sang khola. From Sang khola Rani khola takes slow turn towards south-ward direction until discharging itself into the river Teesta near Singtam bazaar.

The major tributaries contributing their discharge into Rani khola are Kali khola ,Rey khola, Resi khola , Bhusuk khola , Seti khola ,Chubba khola and Sang khola. About 45% of the total area of east Sikkim falls under the catchments of this river. It is about 5.6 m in width and 1.4m deep with the average river bed slope of about 11m (32.81ft) per km.

The Rani khola has the great potential for hydropower development as the river descends from an elevation of 1381 ft. to 3000 ft (approx.) over a distance of 35 km .Sikkim Government has established few different phases of Hydropower projects in this river and Rani khola is also forms a good source for the development of other industries viz pharmaceuticals and beverage factories.

The Rani khola exhibits a wide range of fluctuation in its fluvial dynamic and phsico- chemical characteristics during different seasons. The river water is highly oxygenated under very low to moderate thermal regime .The temperature of water ranges between 6.3 – 16^0 C. Water is slightly alkaline with pH ranging between 6.2 to 8.2. Besides other natural foods of the fish red and green algae are also attached plenty to the stones(Bhasin, 1995).

1.3 Fish and Fisheries of Sikkim

1.3.1 Fish diversity in Sikkim.

The Icthyological scenario of Sikkim is very encouraging with forty-eight species of fishes. These fishes fall under five orders, nine families , twenty three genera and seven different groups, viz. Salmonids (1species), Mahseers (2 species) Cobitids (10 species), Catfishes (14 species) and Murrel (1species). Among these, only thirty species are commercially important and esteemed as food fishes by the Sikkimese people (Tamang, 2001).

Although the water bodies of Sikkim provide a lucrative field of Ichthyological importance, no attempts has been made to venture to study the fish and fisheries of Sikkim. Therefore, the authentic and

comprehensive data on the status of fish and fisheries of this state are lacking till date.

1.3.2 Status of Fisheries in Sikkim

The Department of Fisheries came into existence in 1947 in Sikkim under the Forest Department .But the real and scientific activities on fisheries started only after December 1976, when an experienced Fisheries Development Officer, Sir S.B Raizada, joined the Department on deputation from Himachal Pradesh, India. Thereafter a comprehensive plan and program for fisheries development was prepared and implemented with hectic and sincere efforts.

In the initial period of activities , much emphasis was given in the development of cold-water fisheries , especially Trout fish at Menmoitso with brood fish and rearing units at Lachung and Yumgthang. The objective was to produce and stock Trout(*Salmo trutta)* at various high altitude streams and lakes of the state. A separate research wing was also established in fisheries.

During 1991-92" The Sikkim Fish Farmer's Development Agency (SFFDA) "was also setup under the central sponsored scheme through Indian Fish Farmer's Development Association(IFFDA) for the intensive development of fish and upliftment of socio- economic condition of the farmers through financial assistance. Thus, the initial small office of fisheries wing is now developed into "Directorate of Fisheries "under the Secretary Animal Husbandry after 25 years of establishment (Tamang, 2001).

1.4 Justification of the Study

Rani khola is one of the important Himalayan water resources of Sikkim originating in the east corner of the state perennially fed by Ratey chu and Liyang kyong chu. It provides a good habitat for all the important hill steam fish of Sikkim. Study on fish diversity, fish population, status and habitat are lacking. Now a days it is experienced that the fish diversity and the fish population in this river are declining due to the several factors like illegal fishing practices, over exploitation, heavy flooding, siltation, erosion and dumping of sanitary waste product.

Therefore the present study entitled "**Fish Diversity and Fishery Resources of Rani khola,Sikkim**" has been undertaken to collect the baseline informations of the fish and fisheries resources of Rani khola. Moreover , it is also believed that the work will certainly provides necessary informations for further studies, research work and future management plan in this river.

1.5 Limitation of the study

This was a very general study and couldn't be reached to the very depth because of paucity of time and other resources viz study of planktons.

Topography of the river was inaccessible, so it was difficult to collect all essential data from upper reaches of river .Due to limited financial resource and tough topography the study was limited from mid section of the river .

CHAPTER-TWO

2.0-Objective of the Study

The overall objective of the study is to explore the fish diversity of the Rani khola, Sikkim, India where as the specific objectives of the present study are as follows:

- Explore the diversity of fish and invertebrate of Rani khola.
- Investigate the distributional pattern and frequency occurrence of Fish and invertebrates in Rani khola.
- Analyze some Physico–chemical and biological parameters (invertebrates) of the Rani khola and find out the correlation of Physico chemical parameters with fish and invertebrates distribution.
- Study the socio -economic condition of the Fishermen of the area
- Identify the fishing implements and techniques used by the local fishermen.

CHAPTER-THREE

3.0 Literature Review

The study of fish and fishery of India was in existence from the time immemorial, which revealed from the fish paintings on the earthen vases in the third millennium B.C (Hora, 1936). Again the knowledge concerning fishes of India is fairy old. The use of fishes as food is evidenced from the fish engraving and fish remains obtained from the excavations at Mohenjodero and Harappa of the Indus Valley (2500 to 1500 B.C).

The first writer on Indian fishes was Bloch whose work was published in 1785 as "Naturgeschichte der aus landischen Fische." Schneider (1801) expanded this work by including several marine forms. Lecepede wrote "Histoire nautrelle des Poissons" (1798, 1803). Hamilton (1822) made a valuable report on 269 fish species from the Ganga river system. Likewise Cuvier and Valenciennes published"Histoire Naturelle des Poissons" in (1828-1849) that provided great impetus to the study of Ichthyology. Gunther (1880) published catalogue of the fishes of the British Museum, London in eight volumes. The work contains an account of 6847 species together with the description of another 1682 doubtful species. Indeed, the monumental work of Day (1878 and 1889) was considered as epoch making documents on the fishes of Indian including Burma, Ceylon and Pakistan.

In the 18^{th} and 19^{th} centuries, the science of Ichthyology received due recognition almost all over the world. Ichthyology devised new methods and techniques to develop and tap the resources of natural waters. These studies gave birth to a branch of Ichthyology called Fishery Biology. In the 20^{th} Century, Valuable works had been done by De(1910), Hora (1920-1953) Menon(1949-1974), Misra (1949-1976),Jayaram (1953-1981) and Prashad(1962)

Later Menon (1982 and 1986) had made important contributions on the classification and taxonomic status of teleostean fish dwelling in Indian waters. Fish geography of India, especially the fresh water species had been investigated by the workers only lately. Significant contributors were those of Gunthr (1880), Day(1885), Hora (1937, 1944,1951 and 1953),Hora & Nair (1941),Hora and Menon(1952 and 1953), Silas (1952),Menon(1951 and 1955) and Jayaram (1974 and 1977).

Although, the Brahmaputra and Barak river systems form lucrative fields of Ichthyology importance in North East India, very little work in the field had been attempted and were restricted to the works of Hora

(1921) and 1935) Menon(1954),Sehgal(1955), Joseph and Narayan (1965), Malhotra and Suri (1969),Yazdani(1972) and Sen (1982).

In sharp contrast to aforesaid investigations, report on the fish and fisheries of Sikkim remained fragmentary. In this context , reference may be made to Mc Clelland (1845) for 3 species; Day (1878)) for 4 species; Hora)1923-1935) for 3 species;Hora and Silas (1952) for 4 species and Menon (1954-1964) for 3 species. Tilak (1972) however, made a significant contribution and described 26 species. followed by Jayaram (1981) who mentioned only 2 species .Bhutia & Acharya (1987) however studied the fish fauna, certain physicochemical conditions and listed 25 species of fish from Rangit river.

Menon (1978) in his recent publication has included 2 species of *Noemacheilus* from Sikkim drainages. Venu et.al.(1990) made some limological studies of the Teesta drainage and Rangit and reported 20 species of phytoplankton from Rani khola . Talwar & Jhingran (1991) had however mentioned only 2 species of fish from Sikkim.

Fortunately, Tamang, 1903(Unpublished) has reported 48 species under 9 families, 23 genera from Teesta and Rangit river systems along with different physico-chemical parameters of the river . Tamang (1993) has also include four new species in fish science viz. *Glyptothorax basnettil, G. bhutia, G deyi* and *Clupisoma bhandari* along with 2 new sub –species viz *G sinense sikkemesis* and *Laguvia ribeiroi jorethangensis* from the drainages of Sikkim. Tamang has also reported Rani khola as a second principal river flowing north– east of the state with commercial fish species.

CHAPTER-FOUR

4.0 Materials and Methods

4.1 Study Period

The field study was carried out for nine months starting from September 2009 to June 2010 covering four different seasons: Autumn (September), Winter (December), Spring (March) and Summer (June). Each and every sampling station was visited four times in different seasons during the study period and thus the total of 20 different samples were recorded altogether.

4.2 Location and Study area

The present study was carried out in the "Rani khola" a principal feeder stream of River Teesta which is a largest river in the east district of Sikkim. Rani khola takes its origin from the Glacier at an elevation of about 3700 m in north –east corner of the east district of Sikkim and flows downwards for a about 80 km until discharging its content into River Teesta near Singtam Bazar. The present study was confined within about 35 km distance starting from Rey khola upto confluence point with river Teesta, near Singtam Bazar(Map 1).

4.3 Sampling site selection

A preliminary survey of the Rani khola was conducted from Rey khola to Singtam (Teesta Dovan) to fix the different sampling stations for uniform sampling and total representative coverage. The selection of the sampling stations were based on altitudinal differences, habitat differences, and confluence point of Rani khola with other tributaries and human impacts; as these factors influence the distribution and abundance of aquatic flora and fauna directly and indirectly. Altogether five different Sampling stations were established in the whole stretch of the river from Rey to Singtam , roughly covering about 35 kilometers.

4.4 Sampling stations and their morphological description

The field study was carried out in 2 kilometers upstream and 2 kilometers downsteams from confluence point of each station. The different sampling stations were named as stations-A, station-B, station–C, station-D and station E(Map 2 and Plate 1).

Plate I

Sampling Station A

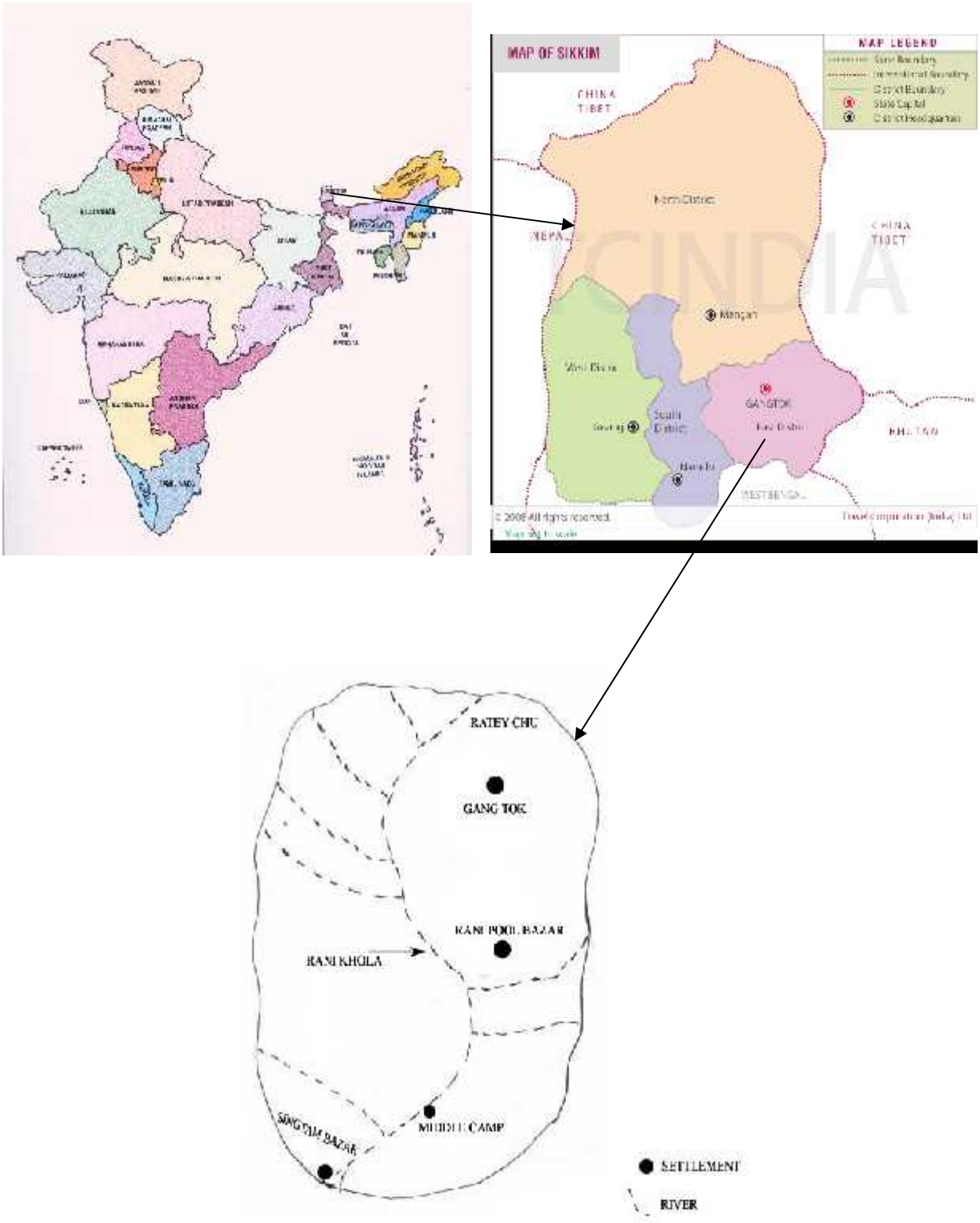
Sampling Station B

Sampling Station C

Sampling Station D

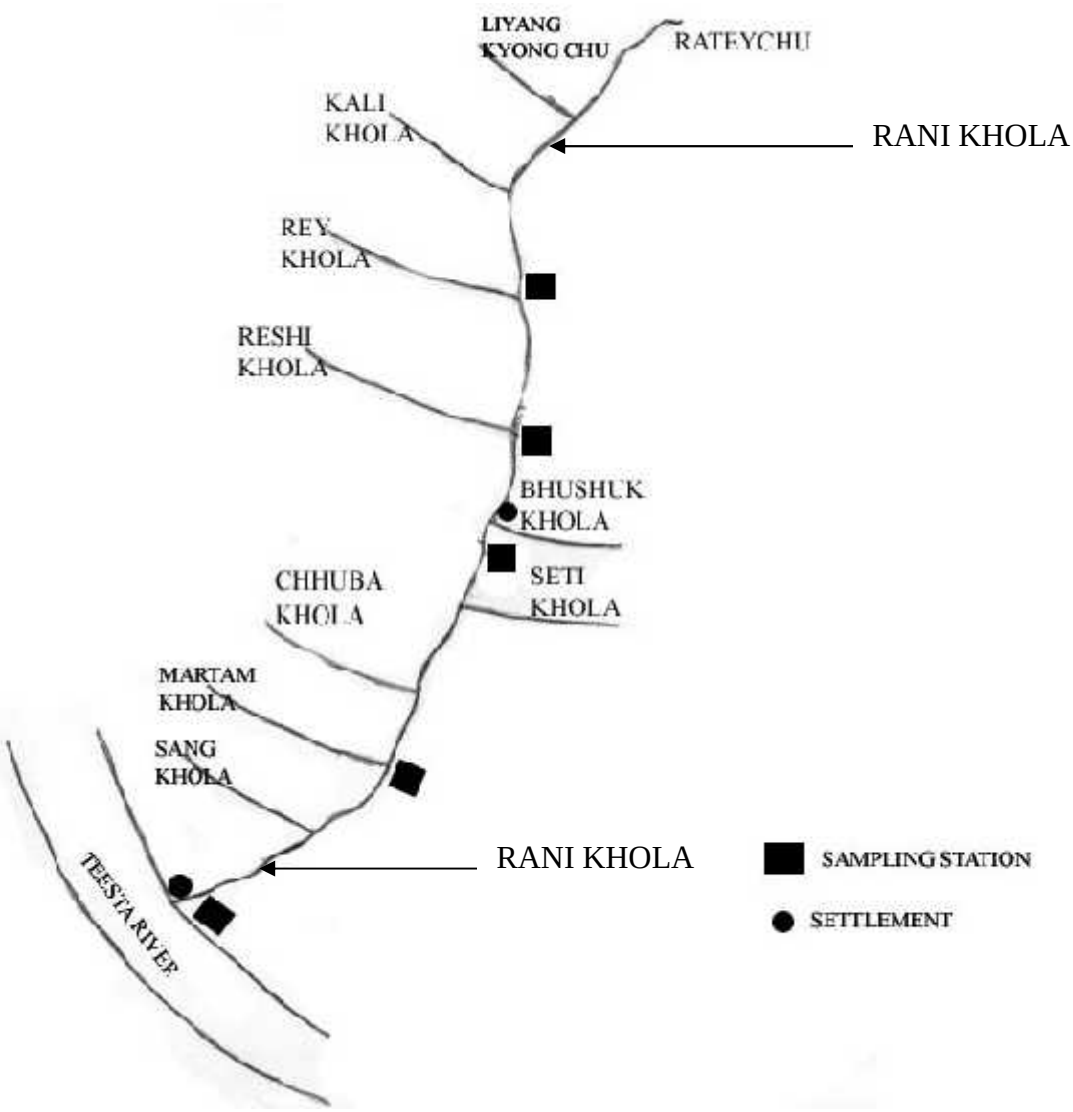
Sampling Station E

MAP 1
LOCATION MAP OF SIKKIM STATE AND THE STUDY AREA



Not to the scale

MAP 2
STUDY AREA AND SAMPLING STATIONS OF RANI KHOLA, SIKKIM, INDIA



Not to the scale

Station A (From confluence point of Rey khola with Rani khola, at Rey)

The first sampling station was established at confluence point of Rey khola with Rani khola at the altitude of 3028 ft .The river is narrow with high velocity along the deep gorges. Rapids, shallow riffles and pools are often seen at this region.The river is surrounded by slightly dense forest at the right bank and human encroachment including agricultural land and tourist spot at the left bank. The river bed is mainly composed of stones and boulders of different sizes(Plate 1A).

Station B (From confluence point of Reshi khola with Rani khola, at Marchak)

The second station was fixed at the confluence point of Reshi khola with Rani khola at an elevation of about 2873 ft .The distance between station –A and station-B is about 3 km .The riverbed is mainly comprised of stones, boulders and gravels. This station lies at very lonely place, just away from human encroachment being surrounded by thin forests and high sloppy hills. The velocity of the river starts decreasing slowly after this station but the volume of water increases abruptly. At this station, river is characterized by the presence of deep gorges, rapids, riffles and shallow pools(Plate 1B).

Station C (From confluence point of Bhushuk khola with Rani khola, at Jalipool)

The third station was established at the confluence point of Bhushuk khola with Rani khola which is about 6 km down the station-B. This station was fixed at an elevation of about 2747 ft being characterized by rapids, riffles and shallow pools.Huge human settlement areas are approached in this station therefore the water of this station is polluted. The river bed shows mainly stones, gravels and sands(Plate 1C).

Station D (From confluence point of Martam khola with Rani khola,at Middle Camp)

The fourth station was established at the confluence point of Martam khola with Rani khola at Middle Camp, at an elevation of about 1984 ft. Thin forest and grasslands from its left bank surround the river at this region whereas at its right bank there is low cultivated land and roads,settlement area. Runoff riffles and well developed pools are characteristics feature of this region (Plate 1D).

Station E (From confluence point of Teesta River with Rani khola, at Singtam)

The fifth station was established at Singtam near the confluence point with River Teesta, which is the terminating point of Rani khola. It was

the last station of the present study being located at an elevation of about 1381 ft.This station is surrounded by thickly populated settlement area. The riverbed at this area is characterized by the presence of stones, gravels, peebles, sand and mud. Well developed pools and riffles are the main components of this station (Plate 1E).

Rani khola as a whole is characterized by the presence of pools, runs, rapids, shallow riffles of various shape and size and thus provides a good habitat for the varieties of hill stream fishes. Though the river shows steep gradient and deep gorges at its upper region but at its lower reaches there is low lands with agricultural fields, and open valleys. The different riverbed structures and habitat characterization at different sampling stations are being analysed by self observation method i.e Point method and recorded on percentage basis.

4.5 Sources of the data

The data were collected directly by field observations, interviews, and questionnaire and secondarily through literatures to analyze the present and the past conditions of the fish and fisheries resources of the Rani khola. The informations so collected also enabled to determine the various conventional and nonconventional fishing practices being adopted by the local fishermen along with their socio –economic conditions.

The primary data were collected directly by field observations and interviews with different class groups like fishermen, officials , local people, workers and fishery guards, while the secondary informations viz were collected from different reports, research papers, dissertations, magazines and journals etc. Besides, some standard methods were also used to analyze some physico -chemical and invertebrates of the water.

4.6 Water Quality Analysis

The various physico -chemical parameters of water analyzed during the present investigation include temperature, transparency , pH, free carbon dioxide, dissolved oxygen , total alkalinity and total hardness. The analysis were based on the standard methods after Adoni(1985), Trivedy and Goel (1986) and APHA (1998).

4.6.1 Physical Parameters

4.6.1.1 Temperature (Air and water)

The different physical parameters studied during the present investigation period are as follows:

Temperature of the water recorded by dipping directly standard mercury thermometer, graduated up to 50°C with a precision of 0°C, into the water for two minutes. While, the air temperature was recorded by

holding the thermometer in the air for two minutes avoiding direct sunlight .The result was expressed in Degree Celsius.

4.6.1.2 Transparency

Transparency of the water was measured with the help of a Secchi disc. The Secchi disc is a metallic device of 20cm diameter painted black and white in quadrant. It was designed by an Italian scientist named Secchi in 1965 and is used universally for studying the transparency of the aquatic bodies. The upper surface has black and white paints while the lower surface bears a weight tied in it. The upper surface also has a device to tie the rope.

For measuring the transparency of the water, the disc was first lowered in the water until it become invisible and the distance was noted down. Then the disc was pulled upward slowly until the metallic upper surface becomes first visible and again the reading was noted down .Now, the sum of the just invisible and just visible was divided by 2 and the final reading was recorded as transparency in cm.

$$\text{Transparency (D)} = \frac{X+Y}{2} \text{(cm)}$$

Where, D = Transparency in cm.

X = Depth at which Secchidisc disappeaers.

Y = Depth at which Secchidisc reappears.

4.6.2 Chemical Parameters.

Among the chemical parameters of water only pH of water was measured at the sampling stations during each field visit since it was really difficult to carry all the required chemicals and apparatus in the field. Chemical parameters like Dissolved Oxygen , Free Carbon dioxide, Total Alkalinity and Total Hardness were analyzed and recorded in the laboratory .For this, the water samples were collected from each and every sampling stations during each field visit and taken to the laboratory at Sikkim Government College, Gangtok after fixation.

4.6.2.1 Hydrogen ion Concentration (pH)

The Hydrogen ion concentration is one of the most important environmental factors that affects the composition and distribution of all the aquatic organisms. The pH of the water is defined as the negative logarithm of the reciprocal of Hydrogen –ion concentration which may be expressed mathematically as follows.

$\mathbf{pH} = \log\left(\frac{1}{\quad}\right)$ where, $[H^+]$ is the amount of Hydrogen –ion in a

H^+ solution in moles per liter.

The pH of water determines the chemical feature of acidity, alkalinity and neutrality of water. A battery operated portable digital pH meter was used to record the pH of water.

4.6.2.2 Dissolved Oxygen (DO)

Dissolved Oxygen(DO) is a paramount importance to all living organism and is considered to be the lone factor which to a greater extent can reveal the nature of whole aquatic system at a glance, even when the informations on other chemical, physical and biological parameters are not available. Dissolved Oxygen was determined by following the Winkler's Idometric Titration method,(1888).

The sample of water was taken in 250 ml BOD bottle avoiding the air bubbles. Then the Winkler's solution –A ($MnSO_4$ Sol [11]) and Winkler's Solution-B (Alkaline KI Sol[11]), 1ml each, was added well below the surface through the walls with separate pipettes so as to fix the Dissolved Oxygen. Then the Oxygen fixed water sample was taken to the laboratory with due care and the titration against Sodium thiosulphate (Na_2SO_3) of 0.025N strength was performed accordingly by adding Conc. H_2SO_4 sol" & Starch Indicator. The calculation was done by the following formula:

$$\text{DO. as mg/1} = \frac{(\text{ml x N of } Na_2SO_3 \text{ x } 8 \text{x} 1000}{\text{Volume of sample used}}$$

(Where, volume of sample used=50ml)

4.6.2.3 Free Carbon-dioxide (CO_2)

Carbon-dioxide in water is derived from the atmosphere through direct diffusion, bacterial decomposition of organic matter and the respiration by animals and plants. Its presence is essential for the aquatic vegetation and phytoplankton for photosynthetic activity but the excess is harmful to the animals like fishes.

Sample water of 100ml was taken in a conical flask and 3-4 drops of phenolphthalein indicator was added to it and titrated against the standard alkalin solution (i.e 0.05N NaOH) until the slight pink end point was resolved .The calculation was performed with the following formula.

$$\text{Free CO2 (as mg/1)} = \frac{(\text{ml x N of NaOH x } 44 \text{x} 1000}{\text{Volume of sample used in ml}}$$

4.6.2.4 Total Alkalinity

Alkalinity of the water is its capacity to neutralize a strong acid and is characterized by the presence of Hydroxyl-ions. The alkalinity in the water is generally imparted by the salts of Carbonates, Bicarbonates, Phosphates, Nitrates, Borates and Silicates etc. together with the Hydroxyl ions in free state.

To the 50ml of sample water, one drop of Phenolphthalein indicator was added and mixed thoroughly. Then 0.5 ml of methyl red bromo-cresol green indicator was added to it and finally titrated against standard sulphuric acid solution (0.02 N)until the colour changes from green to pink; Calculation was done with the following formula and the result was expressed in parts per million(ppm).

$$\text{Total alkalinity (mg/1 as}CaCo_3) = \frac{\text{Normality of } H_2SO_4 \text{ x } 50.50 \text{x } 1000}{\text{Vol. of sample used in ml}}$$

4.6.2.5 Total Hardness

Hardness is the property of water that prevents the lather formation with soap and increase the boiling point. Calcium and Magnesium are the major cations responsible for hardness, whereas anions imparting hardness are carbonates, bicarbonates, sulphates and chlorides.

The total hardness of the river water was estimated by EDTA Titrimetric Method. For this, 50ml of w ater sample was taken in a conical flask, 2 ml of ammonia buffer solution and 200mg of Erichrome Black-T indicator were added and mixed thoroughly by shaking the flask until the wine red colour appeared . Then the solution was tirated against the standard EDTA solution (0.01 N) till the clear blue colour was resolved. The total hardness was calculated as follows:

$$\text{Total Hardness (as mg/1 } CaCO_3) = \frac{\text{Vol Of EDTA used in ml x 1000}}{\text{Vol of sample used in ml.}}$$

4.7 Biological Parameters

4.7.1 Invertebrates Sampling and Identification

Invertebrates were collected using a Bin Sampler (diameter 40cm). The Bin sampler was pushed down 10cm below the surface of a muddy bed in the shallow water. Samples were extracted and passed through finer sieves (0.5-0.1 mm) progressively and preserved in 70% alcohol .The sample was examined under a 100x binocular microscope and invertebrate individuals were identified to genus level using keys after

COM Stock(1940), Borrer and Delong (1954), Elzinga(1978), Parker & Haswell (1990), Sedgwick (1990) and Fraser(1993).

4.8 Fish Sampling and Identification

The fishes were collected by employing local fishermen using cast net of mesh size 1.5cm .Sampling was conducted during the day period for four hours in each station.During sampling, the total number of fish, number of species and number per species in each station were recorded. The collected specimens were preserved in 10% formaldehyde solution and taken to the laboratory of Sikkim Government College, Tadong, for identification. The fishes collected there were brought to the college for identification to species level using standard taxonomic keys after Menon (1974and 1987); Jayaram (1981 and 1999); Talwar & Jhingran (1991), Shrestha (1981).

The local fishermen were also interviewed to gather informations about ecological behaviors of different fishes, the changing pattern of the river and fish distribution , general environment of the river like the changes in water level, and erosion, siltation, severe floods etc. Frequent visits were made at the fishing sites for direct observation on fishing methods and habitat conditions. In each visit, data on fish collection , fishing implements and methods were gathered and recorded.

4.9 Statistical Analysis

The Co- efficient of Correlation between some important physicochemical parameters of water with fish and invertebrates biodiversity in four different seasons were calculated by using formula given by Karl-Person as referred by Gupta ,(1988).

$$\text{Co- efficient of Correlation (r)} = \frac{N \quad xy\,\mathrm{Z} \quad x. \quad y}{\sqrt{(N. \quad x^2)\,\mathrm{Z}(\quad x^2)(N. \quad y^2)\,\mathrm{Z}(\quad y^2)}}$$

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

4.10 Analysis of Socio–economic Condition of Fishermen and Management policies of Rani khola.

A set of questionnaires (appended) were prepared and administered for collecting the informations regarding the distribution of fish species, fishing methods, fish market, ecological behavior of fish, fish yields, fishing implements, management policies and the socio-economic condition of fishermen. The interview was made with the fisher communities especially residing around the Rani khola.

CHAPTER-FIVE

5.0 Observations and Results

Following observations and results were made by examining 20 samples of different parameters collected from five different sampling stations covering four different seasons .

5.1 Physical Parameters

5.1.1 Temperature (Air and water)

The variation of air temperature as well as water temperature in each and every sampling site of the river were recorded regularly during the study period .The average air temperature ranges from17 -21 °C, 17.8 -22°C, 17.7 - 23°C, 18.1-25°C and 20.1-29°C at the stations - A,B,C,D and E respectively(Table 1) . The lowest air temperature recorded was 17°C in December at station-A as well as, the highest air temperature recorded was 29°C in June at station-E.

Likewise, the average surface water temperature of the Rani khola ranges from 6.3- 14°C, 7.8 - 16°C , 8.1 - 13°C, 8.9 – 11.1°C and 9.2 - 15.2°C at stations –A,B,C,D and E respectively(Table 1). The highest and the lowest surface water temperature recorded were 16.2°C and 6.3°C at station-A and station-E, during the month of June and December respectively.

5.1.2 Transparency

The transparency of the Rani khola recorded during the study period ranges from 38.6 cm – 42 cm, 40.0-47.2 cm, 39.2cm-44.3cm, 35.8-43.2 and 40.7-45cm at stations-A,B,C,D and E respectively(Table 1) . The maximum transparency of the water was recorded as 45.0 cm at station –E in June and the minimum transparency of the water was recorded as 35.8 cm at station D in June respectively. The average transparency of the river was recorded as 39.2 with the difference of 9.2 cm between maximum and minimum value.

5.2 Chemical Parameters

5.2.1 Hydrogen ion Concentration (pH)

The pH of natural water is an important environmental factor and its variation is linked with species composition and life processes of animals and plants community inhabiting (Jhingran, 1991). The average pH of the water of Rani khola ranges from 6.3-7.2, 6.5-7.5, 6.2-7.4-6.4-7.8 and 7.0-8.2 at stations-A, B,C,D and E respectively(Table 1) . The maximum pH recorded was 8.2 in the month of June at station –E and the minimum pH was 6.2 recorded in the month of December at station-C with the difference of 2. The average pH of Rani khola during

the study period remained as 7.2 and thus the river was found to be slightly alkaline.

5.2.2 Dissolved Oxygen (DO)

The dissolved oxygen is another important parameter of the water. It is the basic unit of aquatic life. Dissolved oxygen found in the river water is essential for animal community for respiration and other life processes. The river water gets oxygen directly from the atmosphere by the movement of water or by photosynthesis of chlorophyll bearing organisms inhabiting in the water body . The value of dissolved oxygen recorded during the study period almost same in all the stations with slight variation at few stations in different months.

The dissolved oxygen observed in the Rani khola during the field visit ranges from 8.1-11.2mg/l, 8.2-10.06mg/l, 8.2-10.1mg/l and 8.45-9.2mg/l at stations-A, B, C, D and E respectively(Table 1). The maximum dissolved oxygen recorded was 11.2 mg/l at station-A in the month of September and minimum dissolved oxygen recorded was 8.1mg/l at station-B in the month of June. The difference of dissolved oxygen recorded between maximum and minimum value remained as 3.1mg/l and the average dissolved oxygen of the river recorded was 9.7mg/l.

Table 1

Physico- chemical parameters of different stations of Rani khola

S. No.	Parameters	Station-A				Station-B				Station-C				Station-D				Station-D				Avg.	Max	Min
		Sep.	Dec.	Mar.	Jun	Sep.	Dec.	Mar.	Jun	Sep.	Dec.	Mar.	Jun	Sep.	Dec.	Mar.	Jun	Sep.	Dec.	Mar.	Jun			
1	Water Temp. (°c)	12	6.3	8.3	14	12.8	7.8	9.8	15	12.6	8.1	10	13	12.8	8.9	11.1	15	13	9.2	10.8	16.2	11.25	16.0	6.3
2	Air Temp. (°c)	19.2	17	19.1	21	20.3	17.8	19.5	20	20.8	17.7	19.2	23	22.5	18.1	19.2	25	26.4	20.1	21.2	29.0	24	31.0	17.0
3	Transparency (cm)	38.6	42	40.8	41	40.0	41	43	47.2	40.0	43.2	44.3	39.2	41.2	43.2	41.7	25.8	41.9	44.2	40.7	45.0	40.4	45.0	35.8
4	PH	7.2	6.3	6.8	7.2	7.5	6.5	7.0	7.3	7.4	6.2	6.9	7.4	7.8	6.4	7.0	7.5	8.0	7.0	7.2	8.2	7.2	8.2	6.2
5	Dissolved oxygen(mg/l)	11.2	10.5	9.2	8.2	10.06	9.8	9.1	8.2	9.35	10.1	9.1	8.2	8.85	9.8	9.0	8.3	8.65	9.2	9.20	8.45	9.7	11.2	8.2
6	Free Co_2 (mg/l)	2.15	2.85	3.0	3.7	2.73	3.1	3.5	4.3	3.16	2.65	3.1	3.85	3.42	2.8	3.2	4.1	3.65	2.55	3.18	4.22	3.15	4.22	2.15
7	Total alkanity (mg/l)	21.9	21.1	22.3	29.0	17.4	21.3	22.5	29.7	18.2	21.4	22.0	29.0	11.5	21.8	23.0	30.1	15.6	14.5	21.7	31.5	21.5	31.5	11.5
8	Total hardness (mg/l)	20.2	16.5	19.7	20.2	25.4	17.2	18.7	21.3	22.8	16.8	18.0	21.2	25.4	17.1	18.8	22.0	26.8	21.1	25.7	30.4	23.2	30.4	16.5

Source: Data Analysis using SPSS

5.2.3 Free Carbon Dioxide (CO_2)

The carbon dioxide in the water is derived from the atmosphere, bacterial decomposition of organic matter and community respiration. The free CO_2 of Rani khola ranges from 2.15-3.7mg/l,2.73-4.3 mg/l, 2.65-3.85mg/l, 2.82-4.1 mg/l and 2.55-4.22mg/l at stations-A,B,C,D and E respectively(Table 1). The highest free CO_2 was 4.22 mg/l recorded from station-E in the month of June and the lowest free CO_2 of was 2.15 mg/l recorded from station –A in the month of September .The difference of free CO_2 between the maximum and minimum value remained as 2.07mg/1with average free CO_2 of the river was recorded 3.15mg/l.

5.2.4 Total Alkalinity

The fluctuation in total alkalinity depends upon the location, season, plankton population and the nature of the bottom substratum or bottom deposits. The total alkalinity of the Rani khola ranges from 21.1-29.0mg/l, 17.4-29.7 mg/l, 18.1-29.0mg/l, 14.7-30.1mg/l and 11.5-31.5 mg/l at stations-A , B,C,D and E respectively(Table 1). The maximum total alkalinity recorded was 31.5mg/l at station-E during the month of June while the minimum total alkalinity recorded was 11.5mg/l at station-C in the month of September with the difference of 20mg/l. The average total alkalinity of the river was recorded as 18.2mg/l.

5.2.5 Total Hardness

The total hardness of the Rani khola recorded during the study period ranges from 16.5-20.2mg/l, 17.2-25.4mg/l, 16.8-22.8 mg/l, 17.1-25.4mg/l and 25.1-30.4mg/l at stations-A, B, C,D and E respectively(Table 1) . The maximum and minimum total hardness of the river was recorded as 13.4mg/l at station-E and 16.5 mg/l at station –A in the month of June and December respectively. The difference between the maximum and minimum value remained as 13.9mg/l while ,the average total hardness of the Rani khola throughout the study period was recorded as 24.1mg/l.

5.3 Invertebrates of Rani khola

5.3.1 Diversity of invertebrates in Rani khola

During the present study a total of one hundred thirty one invertebrates were collected belonging to three different phyla viz. Arthopoda, Annelida and Mollusca. Among these three Phyla, the phylum Arthopoda was found to be the richest fauna. The invertebrates of this phylum have been comprised to three classes and ten orders. While, Annelidia and Molllsca are composed only one genus each i. e. *Pheretima sp* and *Limax s*p. respectively.

The invertebrates collected and identified are listed with their taxonomic status :

1 Phylum - Arthopoda
Class - Insecta
Order - Odonata
Family - Aeshnidae
Aeshna cyanea

2. Family - Calopeterygidae
Genus - *Odonata* sp.

3. Order - Coleoptera
Family - Dytiscidae
Dytiscus sp

4. Order - Hemiptera
Family - Belostomatidae
Belostoma sp.

5. Order - Hymenoptera
Family - Mutillidae
Euperipatoides sp

6. Order - Orthoptera
Family - Acrididae
Melanopus sp

7. Order - Plecoptera
Family - Perlidae
Aeroneuria sp

8. Order - Diptera
Family - Culicidae
Culex sp

9. Class - Crustacea
Order - Decapoda

Family - Cancridae

Cancer sp.

10. Class - Archnida

Order - Araneida

Family - Aranoidae

Arnea sp

11. Phylum - Annelida

Class - Chaetopoda

Order - Oligochaeta

Family - Lumbricidae

Pheretima sp

12. Phylum - Mollusca

Class - *Gastropoda*

Order - Stylommatophora

Family - Limacidae

Limax sp

5.3.2-Distribution of invertebrates: Out of total twelve species *Culex* sp was common at all stations where as Euperipatoides was distributed at two stations only. The distribution of invertebrates of Rani khola(Table 2) is given below;

Table -2

Si.No	Name of Invertebrates	Sampling Stations				
		A	B	C	D	E
1	*Aeshna*	+	+	+	_	+
2	*Odonata*	+	+	+	_	_
3	*Dysticus*	_	+	_	+	+
4	*Belostama*	+	+	+	_	_
5	*Euperipatoides*	+	+	_	_	_
6	*Melanopus*	+	_	+	_	+
7	*Aeroneuria*	+	+	+	_	_
8	*Culex*	+	+	+	+	+
9	*Cancer*	+	+	_	+	+
10	*Arnea*	+	+	_	_	+
11	*Pheretima*	+	+	_	+	+
12	*Limax*	_	_	+	+	+

\+ = Present

\- = Absent

5.3.3-Frequency occurrence of invertebrates in Rani khola:

Out of the total twenty five numbers of invertebrates larvae of *Euperipatoides* sp, was the most common species of the Rani khola, having the highest frequency occurrence of 12.21% whereas, the *Melanopus sp* with the total count of seven and frequency occurrence of 5.34% was found to be the least common species of the Rani khola. Similarly the total number Arnea recorded was fourteen(Table-3 figure 1).

Out of twenty samples the maximum and minimum number of invertebrates collected were thirteen in March at station E and two in December at station –B .All the invertebrates found during the present investigation were uniformly distributed throughout the length of the study area.

Table- 3

Frequency Occurrence of invertebrates in Rani khola

S. No.	Name of Invertebrates	Station A				Station B				Station C				Station D				Station E				Total	Frequency (%)
		Se	De	Ma	Jun	Se	De	Ma	Jun	Se	De	Ma	Jun	Se	De	Ma	Jun	Se	De	Ma	Jun		
1	*Aeshna*	1	-	-	1	-	1	-	1	-	2	-	1	-	-	-	-	1	-	1	2	11	8.40
2	*Odonata*	1	-	1	1	1	-	1	2	1	-	1	-	-	-	-	-	-	-	-	-	9	6.87
3	*Dysticus*	-	-	-	-	2	1	1	2	-	-	-	-	1	1	1	-	1	-	2	-	12	9.16
4	*Belostoma*	1	1	-	1	1	-	1	1	-	1	1	1	-	-	-	-	-	-	-	-	9	6.87
5	*Euperipatoides*	2	3	1	3	3	2	1	2	-	-	-	-	-	-	-	-	-	-	-	-	16	12.21
6	*Melanopus*	1	-	-	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	3	-	7	5.34
7	*Aeroneuria*	-	-	-	-	1	-	1	-	1	-	1	1	1	-	1	-	1	-	2	1	11	8.40
8	*Culex*	1	-	1	1	-	1	1	-	-	-	-	-	1	1	-	-	1	1	1	-	10	7.63
9	*Cancer*	1	1	-	2	1	-	1	2	1	-	-	-	-	-	-	-	1	-	1	2	13	9.92
10	*Arnea*	1	1	-	-	1	-	1	1	2	1	-	-	-	-	-	1	1	-	1	2	14	10.69
11	*Pheretima*	1	1	-	1	-	1	1	-	-	-	-	-	-	1	1	1	1	1	1	-	11	8.40
12	*Limax*	-	-	-	-	-	-	-	-	1	1	1	-	1	1	-	1	1	-	1	-	8	6.11
Total																						131	100

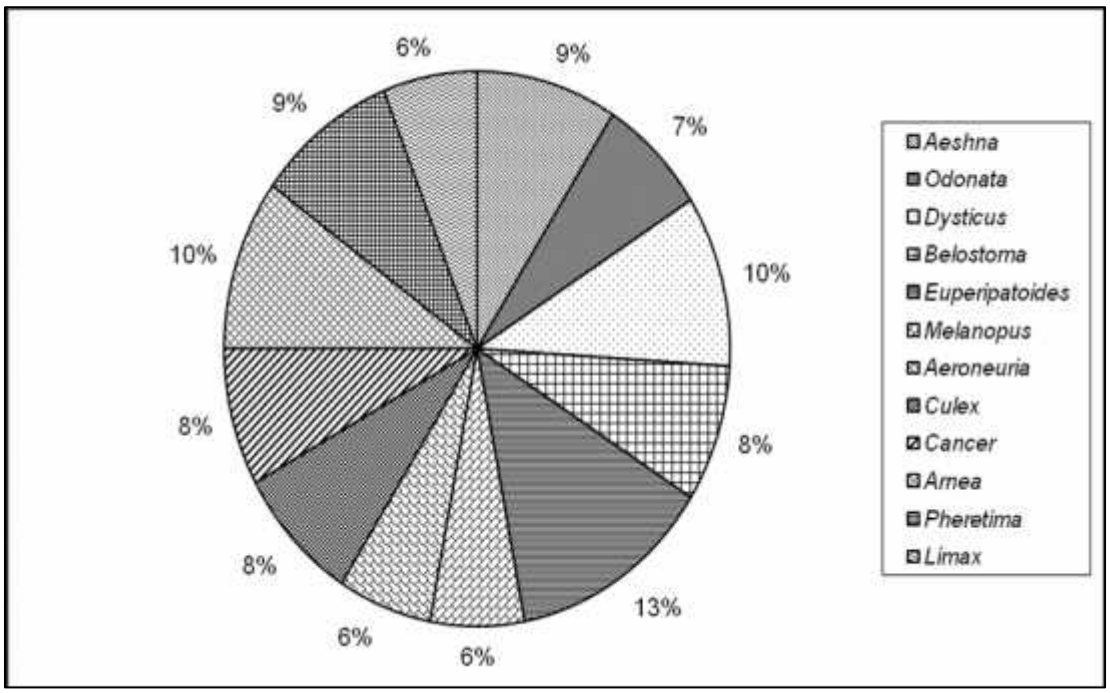


Figure 1: Showing Frequency occurrence of invertebrates in Rani khola

5.3.4 Correlation between Invertebrates Number and Physico-chemical Parameters of Water

The correlation of coefficient between temperature and invertebrates number was found negative at station-A and station –D with correlation coefficient of -0.234 and -0.179 whereas, it was found positive for stations-B, C, and E with the correlation coefficient of 0.699, 0.952 and 0.017 respectively (Table 4).This may be because temperature influences the sustainability of invertebrates, at stations A and D temperature were found high whereas number of invertebrates were found low.

The correlation between pH and invertebrates number was negative at station –A with correlation coefficient of -0.228 and positive for stations-B, C, D and E with correlation coefficient of 0.23, 0.889, 0.258 and 0.119.It means that pH value of station –A is unsuitable for invertebrates.The correlation between dissolved oxygen and invertebrates number was found negative at station-A ,B,C and D with correlation coefficient of -0.312, -0.519, -0.933 and -0.295 whereas it was found positive at station –E with the value of 0.346.It means that dissolved oxygen were found high whereas number of invertebrates were found low Like wise the correlation of invertebrate number with transparency, free CO_2, total hardness were also calculated (Table 4).

Table -4: Correlation between some physico- chemical parameters of water and invertebrates number in Rani khola

S. No.	Variants	Station –A		Stations – B		Stations – C		Stations – D		Stations – E	
		Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)
1	Correlation between Temperature and Invertebrates No.	-0.234	0.5544	0.699	0.5681	0.952	0.2213	-0.179	0.6585	0.017	0.6744
2	Correlation between transparency and Invertebrates No.	-0.224	0.5969	-0.608	0.4897	-0.857	0.3019	0.87	0.2961	0.003	0.6245
3	Correlation between pH and Invertebrates No.	-0.228	0.6271	0.23	0.6481	0.889	0.2723	0.258	0.6412	0.119	0.5243
4	Correlation between D.O. and Invertebrates No.	-0.312	0.6336	-0.519	0.5398	-0.933	0.2393	-0.295	0.6310	0.346	0.5184
5	Correlation between Free co_2 and Invertebrates No.	-0.124	0.6742	0.365	0.6079	0.946	0.2270	0.306	0.6277	0.35	0.5329
6	Correlation between total alkalinity and Invertebrates No.	0.012	0.6723	0.316	0.6246	0.894	0.2749	-0.328	0.6207	0.298	0.3128
7	Correlation between Total hardness and Invertebrates No.	0.31	0.5249	-0.21	0.5289	0.229	0.5491	-0.446	0.6192	-0.513	0.3248

CHAPTER - SIX

6.1 Fishery Resources of Rani khola

6.1.1 Fish Species Diversity

During the present study, a total of eight species under two orders, two families and seven genera were recorded. The most common species distributed in the Rani khola was *Schizothoraichthys progastus*, second common species was *Schizothorax richardsoni* and the third was *Garra gotyla*. Similarly, the rare species of the river was *Barilius bendelisis*(Table 5).

Schizothorax richardsoni was found at all stations throughout the year. Schizothoraichthys progastus and *Neolissocheilus hexagonolepis* were also found at all stations throughout the year except at station –C and station-D in December.

Table- 5

List of fishes collected from Rani khola

S. No.	Scientific Name	English Name	Local Name	Migratory Status
1	*Schizothoraichthys progastus*	Longnose Trout	Chuche asala	Migratory
2	*Schizothorax richardsoni*	Snow Trout	Buche asala	Migratory
3	*Neolissochilus hexagonolepis*	Copper Mahaseer	Katle	Migratory
4	*Garra gotyla*	Garra/Sucker Head	Buduna	Residential
5	*Garra annandalei*	Sucker head/ garra	Buduna	Residential
6	*Pseudecheneis sulcatus*	Torrent Cat Fish	Kabre	Residential
7	*Barilius bendelisis*	Barilius	Khasrey	Migratory
8	*Semiplotus semiplotus*	Semiplotus	Chepti	Migratory

6.1.2 Taxonomic nomenclature of fishes of Rani khola, Sikkim, India

The fishes collected were identified and classified as follows**:**

1.	Order	:	Cypriniformes
	Family	:	Cyprinidae
	Sub- Family	:	Schizothoracinae
	Genus	:	Schizothorax (Heckel) 1838
i.	Species	:	*S. richardsoni (Gray) 1833*
	Genus	:	Schizothoraichthys (Misra) 1959
ii.	Species	:	*S. progastus (Mc Clelland) 1839*
	Sub- Family	:	Cyprininae
	Genus	:	Neolissocheilus (Rainboth) 1985
iii.	Species	:	*N. hexagonolepis (Mc Clelland) 1839*
	Sub Family	:	Rasborinae
	Genus	:	Barilius (Hamilton-Buchanon) 1822
iv.	Species	:	*B. bendelisis (Hamilton-Buchanon) 1822*
	Genus	:	Semiplotus Bleeker 1859
v.	Species	:	*S. semiplotus (Mc Clelland) 1839*
	Sub Family	:	Garrinae
	Genus	:	Garra (Hamilton – Buchanon) 1822
vi.	Species	:	*G. gotyla (Gray) 1832*
vii.	Species	:	*G. annandalei (Hora) 1921*
2.	Order	:	Siluriformes
	Family	:	Sisoridae
	Genus	:	Pseudecheneis (Blythr) 1860
viii.	Species	:	*P. sulcatus (Mc Clelland) 1842*

6.2 Distribution Pattern and Frequency occurrence of Fishes in Rani khola

Out of the total four hundred and fifty-seven fishes collected during the study period, the maximum number was one hundred and seven for *Schizothoraichthys progastus*. Similarly, *Schizothorax richardsoni* were eighty-nine, *Garra gotyla* were eighty-two *Neolissocheilus hexagonolepis* were sixty-eight *Garra annadalei* were fifty-one and *Pseudecheneis sulcatus* were twenty-five(Table 6). *Barilius bendelisis* were seventeen and *Semiplotus semiplotus* were eighteen. The frequency of occurrence was highest for *Schixothoraichthys progastus* and lowest for *Barilius bendelisis*(Figure 2). .

The distribution pattern of the fish species recorded was two distinct type i.e. Uniformly distributed and residential. Out of eight species, five were uniformly distributed while the rest three species showed residential.

Table- 6:Frequency occurrence of fishes at different stations of Rani khola

SI. No.	Name of Taxa	Station-A				Station-B				Station-C				Station-D				Station-E				Total	Frequency (%)
		Se	De	Ma	Ju	Se	De	Ma	Ju	Se	De	Ma	Ju	Se	De	Ma	Ju	Se	De	Ma	Ju		
1	*Schizothoraichthys Pragastus*	2	3	6	9	2	4	7	12	3	1	8	10	2	-	6	9	3	1	8	11	107	23.41
2	*Schigothorax richardsoni*	1	-	4	5	2	3	5	6	2	3	6	4	3	2	4	9	3	4	8	12	89	19.47
3	*Neolissocheilus hexagonolepis*	3	1	6	8	2	1	5	7	1	-	4	8	2	2	3	4	1	1	3	5	68	14.87
4	*Garra annadalei*	-	-	2	4	-	-	1	3	-	-	3	5	2	1	5	6	3	2	6	8	51	11.25
5	*Garra golyla*	1	-	2	5	-	-	4	8	2	-	5	9	1	-	9	12	4	2	7	11	82	17.94
6	*Pseudecheneis sulcatus*	-	-	-	-	-	-	-	2		-	3	5	1	-	2	4	1	-	3	6	25	5.47
7	*Barilius bendelisis*	-	-	1	3	-	-	2	-	-	1	-	2	-	-	3	4	-	-	1	-	17	3.17
8	*Semiplotus semiplotus*	1	2	-	1	-	2	-	2	-	-	1	-	-	3	-	2	-	1	-	3	18	3.93
Total		8	6	21	35	6	10	24	40	8	5	30	43	11	8	32	50	16	14	36	56	457	100

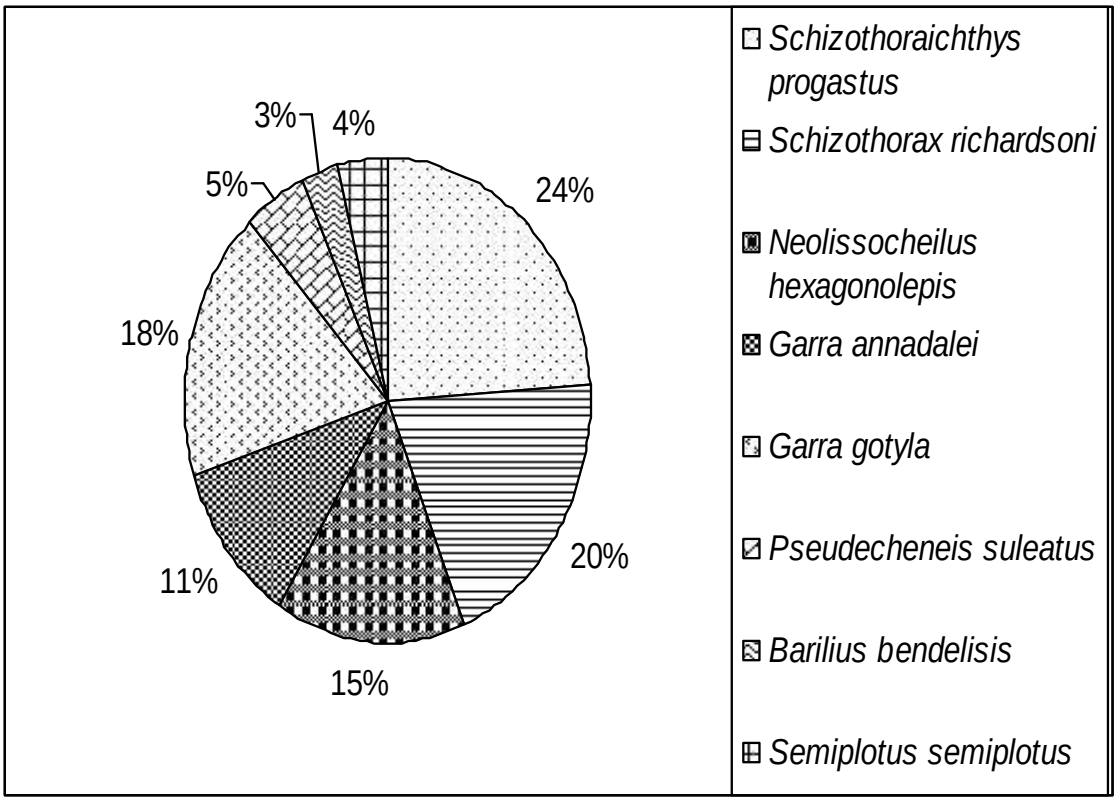


Figure- 2: Showing frequency occurrences of different fishes in Rani khola

6.3 Correlation coefficient between fish numbers and physico-chemical parameters of water.

The correlation between the fish number and temperature, pH, free CO_2 and total alkalinity were found positive at each and every sampling stations throughout the sampling period. This is because free CO_2 and total alkalinity all these parameters which positively favors the availability of fishes. Higher the value of these parameters higher will be the number of fishes.

Whereas the correlation between fish number and transparency was found negative except for station-D and stations –E. Transparency determines the productivity of river,at these stations transparency level decreases and fish number also decreases . Where as the station D and station E are the place where pollution of water may be possible because of human encroachment and industrial area so transparency level of water is minimum. Similarly, the correlation between the fish number and DO remained negative at stations-A,B,C and D with the correlation coefficient -0.724, -0.774, -0.952 and -0.837 respectively. At station-E it was found positive with the correlation co-efficient of 0.18. The correlation between fish no and total hardness was found positive at all stations except at stations except at station-E which was found negative with correlation coefficient of -0.387(Table 7).

Table-7

Correlation between some physico-chemical parameters of water and fish number in Rani khola

S. No.	Variants	Station –A		Stations – B		Stations – C		Stations – D		Stations – E	
		Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)	Coefficient of correlation (r)	Probable error (PEr)
1	Correlation between temperature and fish no.	-3.92	1.11	-2.78	-0.5262	-0.15	0.6012	-2.001	0.1245	-1.11	0.2232
2	Correlation between transparency and fish No.	-0.821	0.2031	-0.696	0.123	-0.759	0.3865	0.205	0.6535	0.223	0.6496
3	correlation between pH and fish no.	0.228	0.4447	0.827	0.4323	0.942	0.2308	0.871	0.2952	0.275	0.6367
4	Correlation between D.O. and Fish no.	-0.724	0.3955	-0.774	0.3325	-0.952	0.2231	0.837	0.3242	0.18	0.7263
5	Correlation between free co_2 and fish no.	0.842	0.3158	0.764	0.3750	0.943	0.2299	0.907	0.2632	0.922	0.2323
6	Correlation between total alkalinity and fish no	0.886	0.1884	0.913	0.3827	0.845	0.3175	0.908	0.2623	0.968	0.1923
7	Correlation between total hardness and fish no.	0.324	0.3609	0.15	0.2577	0.959	0.2147	0.936	0.2365	-0.387	0.5242

6.4 Important Fishes of Rani khola with their ecological behaviour

There are many fishes which are important in economical (as food,as educational value for research study), biological point of view. Among them few important fishes along with their ecological behaviour are given below:

I. ***Neolissocheilus hexagonaolepis (Mc Clelland)1839)***

Neolissocheilus hexagonaolepis (Copper Mahaseer) is an important golden colured game fish belonging to the family cypriniformes which is locally known as "Katle" in Sikkim.

Copper Mahaseer mid-range migratory fishes that migrates towards tributaries Martam khola during breeding season, this fish generally inhabits the rapids or pools and feeds on fresh water invertebrates and algae. According to the local fishermen the maximum size of this fish reported was about 5 kg .While, the size of the captured fishes during the present study period ranges from 20-35 cm and weighing about 100g to 500g.

As per the local people "Katle" migrates from Bhushuk khola during their breeding seasons. Small fingerlings were also observed at stations C, D and E which support, the above statement.

II. *Schizothorax richardsoni* (Gray) 1833

Schizothorax richardsoni is one of the most dominant species of Rani khola and is locally known as "Dhotey Asala" or "Buchche Asala" and is also known as snow trout. This fish is usually characterized by short head with blunt snout and suctoral disc in lower lip with minute golden scales.

The preferable habitat of *Schizothorax richardsoni* is clear water with swift flow and riffles or having stones , gravels or pebbles as substratum which is an ideal spawning ground for this fish. It is a local migratory fish which migrates towards upstream during breeding season. This fish mostly occurs in all snow fed feeder streams and rivers having low temperature and high dissolved oxygen. It is herbivorous fish feeding specially upon filamentous algae and small pieces of aquatic plants.

During the present study it has been recorded from almost all the sampling stations throughout the sampling period with high frequency at stations C and E. The captured fish varies from 12 cm to 35 cm in length and 100g to 38 g in weight.

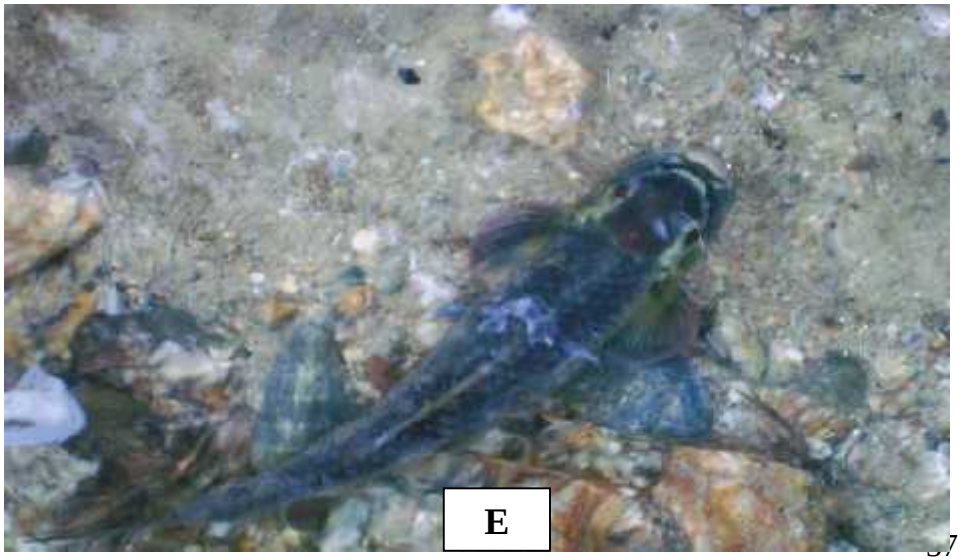
Plate II

A fisherman fishing with a cast net

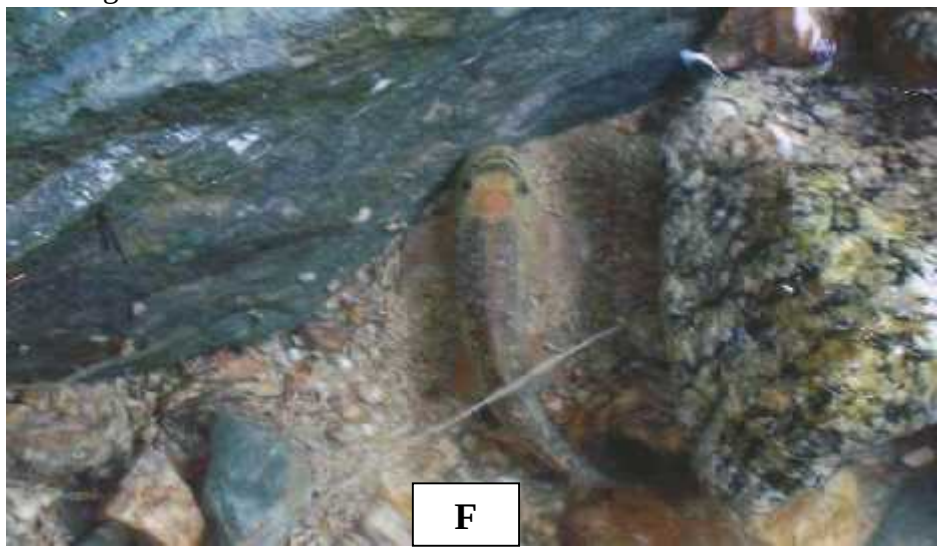
A fisherman fishing with a rod and line

A researcher fishing with a cast net

Fishes collected during the field visit



Garra gotyla



Garra annandalei

III. *Schizothoraichthys progastus (Mc Clelland) 1839.*

Schizothoraichthys progastus is a pointed nosed snow trout which is commonly known as "Chuche Asala .It bears pointed head with tubercles on snout and the body is elongated or cylindrical with slightly convex dorsal profile. The general body colour is uniform silverly with fine spots having rounded abdomen and non –suctorial lower lip.

It is a medium distance migratory fish and migrates to hill stream tributaries during breeding season and select the spawning den in the loose gravel or sand beds. Spawning period varies from April to September. It seems to be opportunistic omnivorous fish whose food usually includes algae, organic debris, aquatic invertebrates and eggs of other fishes. This attains the maximum size of about 50-70 cm in length and weighing upto 2-5 kg at its full maturity.

IV. *Garra gotyla* (Gray) 1832.

Garra gotyla is commonly known as "**Nak Katuwa Buduna" in** Sikkim. It is characterized by elongated and sub-cylindrical body with depressed head. It is generally bluish black in colour with greenish tinge and a distinct black dot occurring just behind the gill opening. Mouth is inferior and semicircular in shape with upper lip fringed. A characteristic suctorial disc is present on chin which is large and rounded .Two pairs of barbel are present viz. rostral barbel and maxillary barbell. (Plate II, E)

Garra gotyla is a resident fish of Rani khola generally inhabiting in swift runs and riffles feeding mostly on large amount of algal material like *Spirogyra* and *Oscillatoria.* According to the local fishermen this fish starts breeding with the advent of rainy season .And during the breeding season school of fish migrates in shallow brooks or creeks and the spawning is intermittent.

***V. Garra annandalei* (Hora, 1921)**

Garra annandalei is locally known as "Buduna". It is the very important fish of Rani khola being characterized by small cylindrical body with a disc on chin and smooth head. It bears a blunt snout and a suctorial disc on chin which helps for attachment to the subtrate. It prefers shallow and clear water having high dissolved oxygen accompanied by small stones and pebbles as substratum. (Plate II, F)

6.5 Status of fishery in Rani khola

According to the local fishermen, the frequency of occurance of the S*emiplotus semiplotus, Pseudecheneis sulcatus, Barilius* sp. is rapidly decreasing day by day .Most of the local people has even reported that the *Barilius* sp. and

Pseudecheneis sp are going to be disappeared from Rani khola . According to the local fisher man the main reasons for the disappearance of sahar are habitat destruction due to sand or stone mining, heavy erosion and unusual flooding. Moreover increasing fishing pressure and traditional fishing practices including unusual fishing methods like poisoning and blasting have also been identified as important causes for declination of fish population .

The local fishermen further complains that after the introduction of some exotic fishes in the source stream of Rani khola the population of some indigenous fish species of Rani khola at neat by station –A and upstream has been sharply decreased. The construction work of Hydroelectric Power Project which is going on in this River is likely to cause further depletion in fish population.

CHAPTER-SEVEN

7.0 Socio-Economic Status of Fishermen and Management Policies of Rani khola

The Socio-economic condition of the fishermen was studied in the vicinity of Rani khola throughout the study period. The present study has revealed that the majority of the fishermen are having average family members of 5 to 7 however, some fishermen also have small family size . Generally , the fishermen of the Rani khola can be classified into three categories viz. occasional fishermen, part time fishermen and full time fishermen. There are altogether 32 fishermen recorded in the study area among which only 11 fishermen were found as full time fishermen. The fishermen of the Rani khola predominantly belong to Pradhan, ,Rai , Chettri ,Sharma, Lepcha, Manger, Gurung, Damai and Sarki community.

Fishing is done throughout the year but the best time is from September to June. While, during the month of July and August it is very difficult for fishing due to the high volume of water and rainy season, as it makes difficult for the use of cast nets and gill gets. About 40% of the total fishermen of Rani khola were found totally illiterate while 40% can read and write and the remaining 20 % were found educated.

The full time fishermen were found quite literate and very poor. They don't have any idea of family planning and they can't even give proper education to their children. They do not possesses their own land for agriculture or any other alternative sources of income. They are therefore compelled to take fishing as a profession .The full time fishermen were found to prefer cast net or gill net for fishing .However , they were also found using other fishing implementing depending upon the seasons and their interests

The occasional fishermen are students, government jobholders, official or villagers who usually come to fishing for recreation. These types of fishermen were noticed mainly using rod and line for fishing but sometime they may also use explosives, poisoning or some other illegal fishing practices.

The part time fishermen are villagers, workers, labours, or low class government job holders who come for fishing usually at evening time, morning time, night or during holidays. The part time fishermen were observed quite poor than that of occasional fishermen and their income is not sufficient to fulfill their need .So during the leisure time they involve themselves in fishing. They were noticed to use all types of fishing implements.

The fishermen were found mostly between the age group of 20 to 50 years old. However , few boys children between the age group of 10-20 years olds were also seen fishing using rod and line, wide mouth aluminium pot covered with white cotton cloths having a small prominent pore at the middle or by bare hands diverting river water etc. But no women were found to be involved in fishing practices in Rani khola.

The present survey has revealed that the average catch per day contribution by full time fishermen ranges from 7 kg to 12 kg per man. Full time fisherman remain engaged in fishing activities is about 270-300 days in a year. Average annual income of full time fisherman is Rs. 126800 per year. Likewise, part timers' contribution in fishing activities is about 60-100 days per year and their average catch per day is 2 to 3.5 kg/man. .The occasional fisher spends about 20-60 days per year and their average catch is about 1.8 kg/man/day. The proper fish marketing system in the Rani khola were not found, rather the fishermen were observed carrying their catch to the road side to fetch the customer or they may have to knock door to door of the local communities . The fresh fish sold at the rate of Rs 80 to 130 per kg depending upon the size and condition of the fishes.

Sand and stone mining are one of the main problems of Rani khola .The present investigation has revealed that the local villagers , workers, labours, contractors or development committees are generally involved in this work for their personal or social benefits. The sand mining and stone mining were found common throughout the whole stretch of the river below station-B. But above station -A it was found quite difficult to establish sand mining or stone mining because of tough topography and lack of transportation facility. Other than sand and stone mining the human activities like dynamiting, swimming, washing cloths, vehicles and dumping of sanitary west were also found common especially in between station –B and station –E.

The present study has also revealed that the State Fishery Board of Sikkim has got the provision to issue strict licenses for Cast Net and Hook & Lines prohibiting fishing without license. The Fisher Board of Sikkim has also framed "The Sikkim Fishers Rule 1990" Gazzette No 143 **GANGTOK, MONDAY, SEPTEMBER** 16, 1990 for the conservation of fisheries resources in the State.

7.1 Fishing Practices and Fishing Implements of Rani khola

The various kinds of conventional as well as non-conventional fishing methods and techniques were noticed in operation in the Rani khola. Conventional fishing methods includes almost all the traditional fishing practices like netting operation, hook and line operation , trapping using devices other than nets and so on.

7.1.1 Nets (Jal)

A net is basically a piece of webbing in which the twines are intersected into regular meshes giving a certain form. Fine nylon threads or cotton threads and small metallic weights of iron or lead are generally used to prepare a net. In Rani khola , basically three different types of nets viz. cast nets, rectangular net and scooping net are used.

7.1.2 Cast Net /Encircling Net

It is locally known as " Jaal" It is circular net made up of cotton or nylon thread. The circumference of the net is wide which tapers gradually towards the apex. Along the rim of the net the metallic sinkers of iron or lead are attatched so as to make the net sinkable. The fishermen are generally found to operate cast net of two different sizes.i,e

a) Small size net locally knows as "BhureJal" with 1.5 m in diameter and 3 kg in weight having a mesh size of 15mm to 20mm.
b) Bigger size net locally known as "Today Jal" with 2m in diameter and 4 -5 kg in weight having a mesh size of 30mm.

Usually a net is operated in the smooth bed and shallow water areas while operating a net a fisherman holds a long rope extending from the apex or the center of the net in hand tightly and throws the net with a jerk into the water in a round way. The sinkers immediately settle down at the bottom of the river, as a result, the net encircle an area. After some times, the net is dragged out with the help of central rope and the catch is collected in the bamboo basket or cotton bag.

Fishermen usually carries a bamboo stick of 1.5 m to 2m length mainly to support himself against the water current and to pull out the entangled net from odd substratum.

7.1.3 Rectangular Net

This type of net is usually prepared out of a rectangular piece of cloth or wire mesh or mosquito net. While operating this net , two persons place it under stagnant water or running water holding the opposite ends and allows the water to flow over for some time. Generally the small fishes and fry of *Schizothorax reichardsoni, Schizothoraichthys progastus, Neolissocheilus hexagonolepis, ,Barilius sp, Semiplotus semiplotus* etc are caught when the net is lifted above.

7.1.4 Scoop Net /Dip Net /Kudulo

Scoop net is commonly known as "Ghorlang", It consists of a long wooden or bamboo handle of about 8-10ft in length, which is joined to a

circular frame, made up of bamboo or metal wire. In this circular frame mosquito net or nylon net of about 1 meter deep having mesh size of about 1 inch is tied or woven properly forming a dip bag like structure with elliptical mouth narrowing posteriorly.

Scooping net can be handled easily. A single man can operate it. Fisherman hold the net with the help of handle and dips into water and move here and there under water and finally pull it out with sudden jerk. The net is mostly used in rainy season (June to August) when the current of water is fairly rapid . All kinds of fishes can be collected including fingerlings to large sized fishes with the help of this net. This kind of net is also known as “Kudulo” or “Dip net”.

7.1.5 Fishing with Basket Cage or Basket Trap

Basket cage is one of the most unique catching methods. The basket cage also called “Phunga” made up of small bamboo sticks of about 1.2 m in length and 0.45m in breadth are used when the current of water is slow . The cage is made in such a way that fishes can enter through but cannot escape out .These cages are fixed in the water in which level is kept on little higher than the holes in diverting channel. Only small types of Fishes like *Barilius sp*., fingerlings of *Schizothorax* sp, etc can be caught by this method.

7.1.6 Rod and Line

7.1.6.1 Without Hook (Locally known as “Manew”)

At one end of the nylon string, two loops of desirable diameter (50mm to 150mm) are made opposite to each other and lure of bright paper is tied in the middle of the two loops. The loop is knotted at one end, which is called central Knot (Surkee Gantho). A small load is placed just vertically below the lure so that whole structure when dropped in water does not get carried away. The other end of string is tied to the bamboo. The pole is placed in an inclined position dipping the lure and loop in water where water flushes from higher gradient to lower gradient. As soon as the fish comes and attack on the lure, it gets entangled in the loop and is caught alive without any injury. This practice of fish capture is indigenous to Sikkim and is operated in clear water from December to March in all the rivers.

Schizothoraichthys progastus from 150g to 2kg are caught by this method.

7.1.7 With Hook

7.1.7.1 Balchhi /Tango

The fishing rod with a baited hook is locally known as “Balchi” or “Tango” It is generally made of long slender bamboo rod (length 3-4m)slightly curved at the tip, fine nylon thread or line of about 2 to 4 m length and a metallic hook along with a metallic sinkers of lead or iron.

The nylon thread is tied at the curved tip of rod (usually with a long elastic rubber) and a hook at the distal end of the thread. Just above the hook there lies a sinker. The hook is baited with different types of baits (living or non –living) including earthworm , aquatic insects (caddish larvae) small fishes, paste of wheat flour and turmeric etc. “Balchhi” is operated through out the length of the river irrespective of seasons. But the fisherman should handle it with great care because chances of escape are high.

“Balchhi” is operated to hook fishes like *Schizothorax richardsoni*, *Schizothoroaichthys progastus*, *Neolissochilus hexagonolepis*, *Barilius sp* etc. The size of the catch may ranges from 100g to 5kg .

7.1.8 Dhukuwa

The principle of mechanism of “Dukuwa” is similar to that of “Balchhi”. Stronger metal is used to make stouter and large hook, which is connected to a parachute thread of 40 cm length tied to a stone of 1- 1.5kg. The free end of the parachute thread is again connected to nylon thread of 30 meters length, which is tied around a rock or boulder. Natural baits of caddish larvae, earthworm etc are placed in the metallic hook. Once the fish attacks the bait , the upper jaw gets entangled in the hook and as it tries to get free ,the inner sharp hook pierces the plate. Larger fishes viz *Neolissocheilus hexagonolepos* etc. of 1 to 15 kg are caught by this operation.

7.1.9 Snare loop /Paaso /Laharee.

Snare loop is somewhat like a “Manew” in its working mechanism but it is a stout rope of remarkable length and is provided with many loops at equal distance. The stout rope with loops is stretched under the water just below the surface. The two opposite ends of the rope is tied to a big stone or to a wooden pole or iron rod stucked in the floor of river. It is mostly used at night time in the lower reaches of the river where the water becomes quite voluminous and shallow especially in the month of December to April. In this time, the river water becomes clear and cold and the fish starts upward migration.

The fisherman after setting the long loopline leave it for the whole night and next day , early in the morning the loop is drawn and fish is collected one by one in a collecting vessel. For setting long loopline the bed of river should be fairly regular.

7.1.10 Use of Hammer/ Hammering

The selected medium sized stones lying in the shoreline or just near by the shallow water or pools are hammered forcefully creating a great sound and vibration in the water. With this the fishes hiding under the stone or near by, loose their balance and gets paralyzed due to which fishes starts floating in the water , which are then caught immediately using scoop nets or bare hands.

This method of fishing usually needs two persons at a time , one for hammering and other for colleting fishes. Again the hammering person must be energetic enough to put maximum force. Such method of fishing is usually seen throughout the length of the river especially after rainy season.(Oct-May) when the water remains clear., *Schizothorax richardsoni, Schizothoraichthys progastus, Barilius sp., Neolissocheilus hexagonolepos* etc . of about 100g to 1000g can be caught by this method .

7.1.11 Fishing with Aluminum Disc

The village boys are often found using aluminum disc for fishing .For this a wide mouthed flat aluminum disc is firmly covered with a thin white cotton cloth. At the centre of the cloth a prominent small round hole is made and a flat stone is kept inside the disc on which the paste of flour and turmeric is pasted as fish bait in order to lure fishes. The disc is kept undisturbed for sometime under the shallow water. Fishes enters into the disc through the centre hole and trapped inside . The small fishes like *Barilius sp* .are trapped by this method.

7.1.12 Fishing without gear

Grabing

Shallow pools formed along the course of a steam or rivulets are best habitats of some of the smaller variety of fish. Some children are found of collecting fish by simple grabing with bare hand. This is a common phenomenon practiced specially in the lower reaches of the river. Besides *Noemacheilus* sp., fry of *Schizothorax richardsoni, Schizothoraichthys progastus, Garra sp., Neolissocheilus hexagonolepis, Barilius sp etc* are captured by this method.

Impound /Duwali Thunne

The natural course of the stream or river where is selected for the purpose and the water is diverted to flow through only one course by collecting a barricade of stones, silt, mud along with the shrubs in the other channels. As soon as the water flow is stopped completely, the channel gets dried up and the fishes are exposed and are thus collected with bare hand. All the different species of fish and their fry available in the stream gets collected by this method which mainly include *Schizothorax richardsoni, Schizothoraichthys progastus, , Pseudecheneis sulcatus, Garra sp, Neolissocheilus hexagonolepis etc* This method is usually practiced from late summer to late monsoon.

7.1.13 Miscellaneous methods

Use of explosive/Blasting /Dynamiting

Blasting method is very harmful as it destroys eggs, fingerlings and fries of many species along with incalculable number of fishes causing a serious. Decline in fish population. For this method people use a " oil cake" or "rice grain", which are thrown into pools to concentrate fish in a particular way then they throw explosive which explode after reaching the bottom and emit a violent sound killing innumerable numbers of fishes which are then collected by the scoop net or bare hand. This method also eliminates many benthic or organisms which are essential for the continuity of food chain in the aquatic ecosystem .

According to local people mostly young schoolboys or labours do such a harmful method.

Electro –fishing

According to local people this method is not so common but sometimes practice by the fishermen coming from surrounding area and Ranipul Bazaar particularly below the station-C .In this method an electric current is applied in the water , which not only kills the targeted fishes but also kills the whole aquatic fauna residing within the affected area .

For this a fisherman inserts an electric wire tied on a bamboo pole inside the water .The other end of the wire is connected to the battery and the electric current is passed. The affected fishes are then starts floating in water, which are collected immediately by scoop net or bare hand.

7.1.14 Use of Poisons

According to the local people , it is a rear practice often seen in the lower reaches of the river . This method is locally known as "BishRakhne" which is usually applied in shallow stagnant water or deep pools killing innumerable number of fishes along with various other aquatic animals.

The commonly used organic poisons are:

a. Khirre *(Sapium insigne)*
b. Titeypati *(Artemesia vulgaris*)
c. Barks of Angeri
d. Saw dust

The commonly used inorganic poisons are:

a. Bleaching powder
b. Lime stone
c. Thiodine
d. BHC (Benzene Hexachloride)
e. DDT(Dichloro Diphenyl Trichlroethane)

CHAPTER –EIGHT

Discussion

Sikkim, a small Himalayan state of the Republic India being located at the north- east part of the country is endowed with a wide range of renewable water resources providing shelter, nourishment and sustenance for many valuable fish stocks. It is rich in biological diversity due to its spectacular topography , geographically location and water resources.

Rani khola is a largest running water system in east district of Sikkim with an average annual discharge of about 6-14 cumec within the running water system considerable differences occur in water currents , depth, volume and substrate. Change in different physical and chemical parameter give to a running water system a wide and diverse range of habitats and ecology for fishes. The value of many ecologically significant factors like, substratum, flow velocity , temperarture , dissolved oxygen and hardness etc may change the morphological characteristics of the river along the whole length of the river (Whitton,1975).

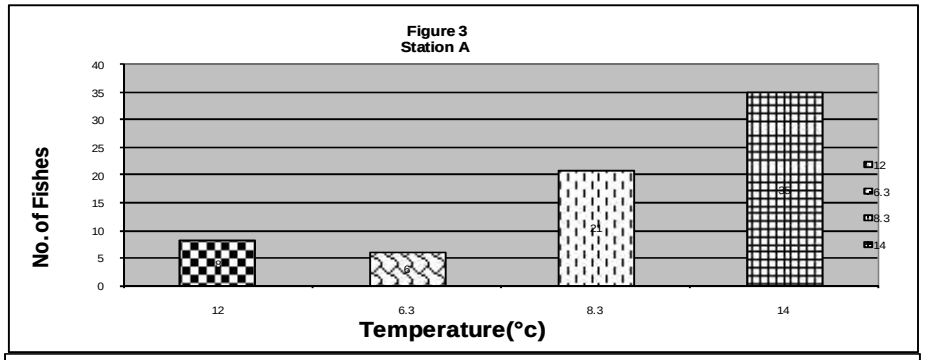
Water along with its contained substrates and energies, constitutes the important environment of aquatic organism .The physico-chemical parameters in an aquatic environment of aquatic environment exhibits as influencing factors for the quantity and quality of the total biota and their life processes highly regulate the physical properties of water in an aquatic ecosystem . The interactions of these create favorable or unfavorable circumstances for the growth and development of any particular biotic element (Dutta and Malhotra, 1986) .

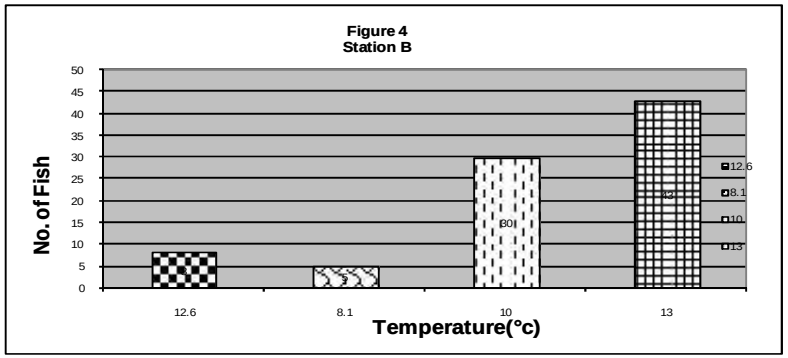
Predictable spatial pattern of channel morphology (Leopold, etal 1964) and flow regime(Horwitz , 1978) exists in natural water system .Shallow pools , riffles and race ways occur in upstream areas with addition of dippe pools, riffles and raceway downstream (Leopold,et al., 1964 and Yang, 1971). In many respects the physical quality of the water environment appear to be basically more important than the chemical ones in governing the distribution of fishes(Hynes,1970)

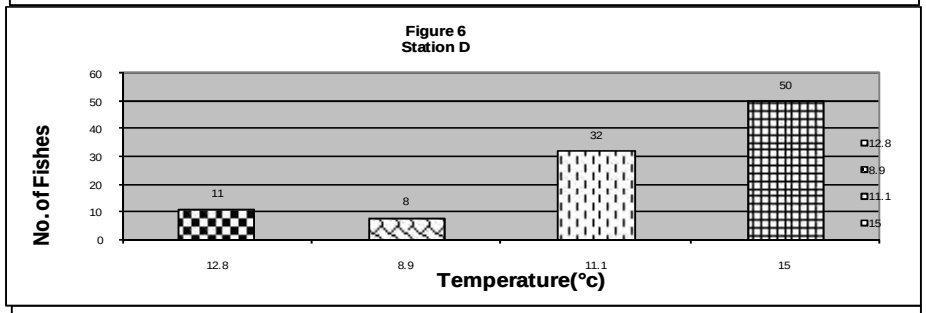
All the aquatic organism including fishes have very limited temperature tolerance .Temperature has an important influence on the physical and physiological activities . Among the physical parameters, temperature is very important factor which affects the growth rate of the fishes. The water temperature of the Rani khola, ranges from 6.3-14,7.8-16,8.1-13,8.9-11.1,and 9.2-15.2 with the average temperature of 11.25ºC. The correlation value of water

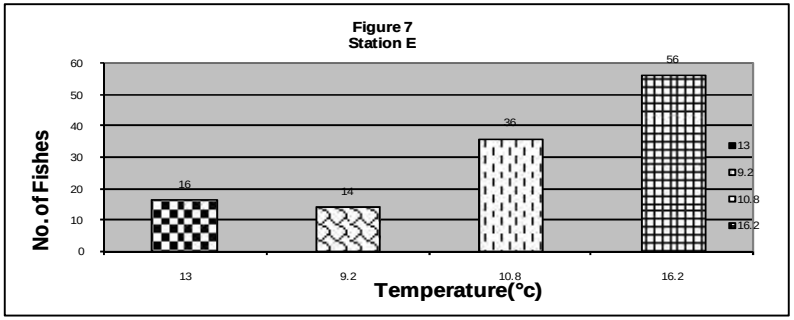
temperature with the fish number was found to be positive at each and every sampling station which explains the increase in fish number with the increase of

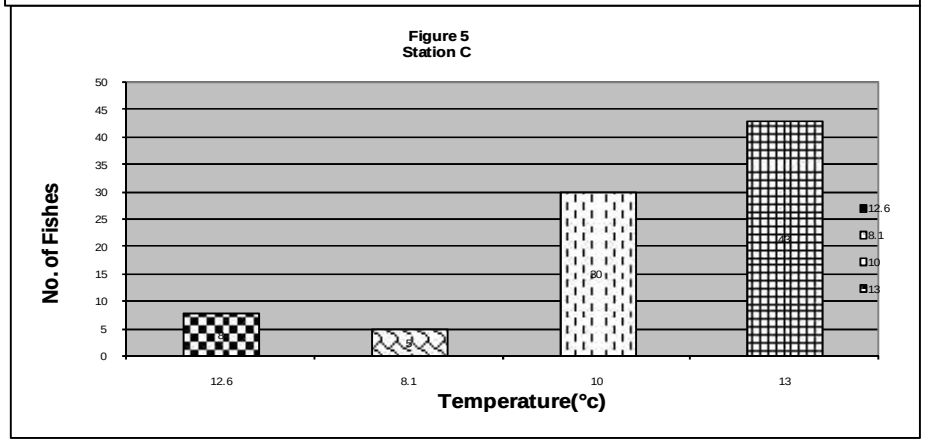
Figure 3-7 showing the relation between temperature and number of fishes in different seasons











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Sept
Dec
Mar
June

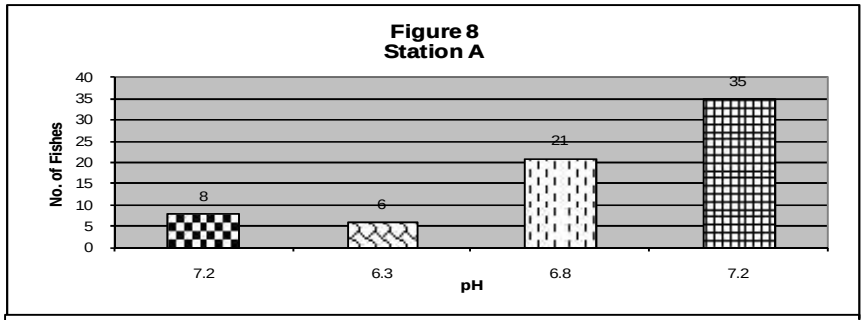
water temperature to a value of correlation coefficient -3.92,-2.78,0.18,-2.008,and 1.11 in stations A,B,C,D and E respectively with probable error of 1.11,-0.5262,0.6012,0.1245 and 0.2232.The findings shows that water temperature increase slightly from station-A to station-E .The correlation coefficient between temperature and invertebrates was negative at station-A and station-D -0.234 and -0.179 and with their probable error 0.5544 and 0.6585 respectively (Table 3-7).

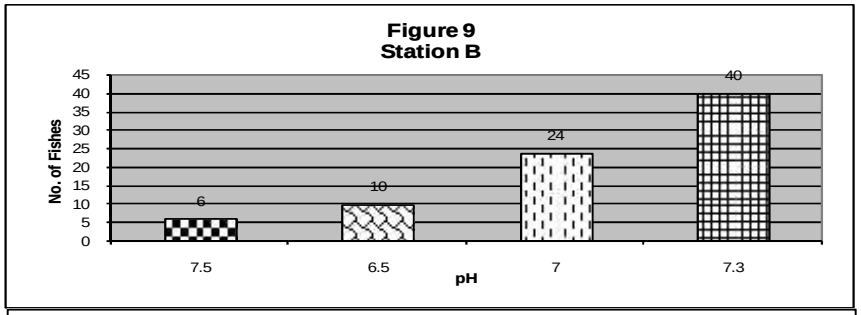
The oxygen content of water generally decrease with the rise in temperature and oxygen increases at low temperature .The variation in temperature also affects the fish composition and fish catch in the water body. The present data also shows that the fish catch in the month of June and September was high as there is increase in water temperature in comparisons to month of December and March.

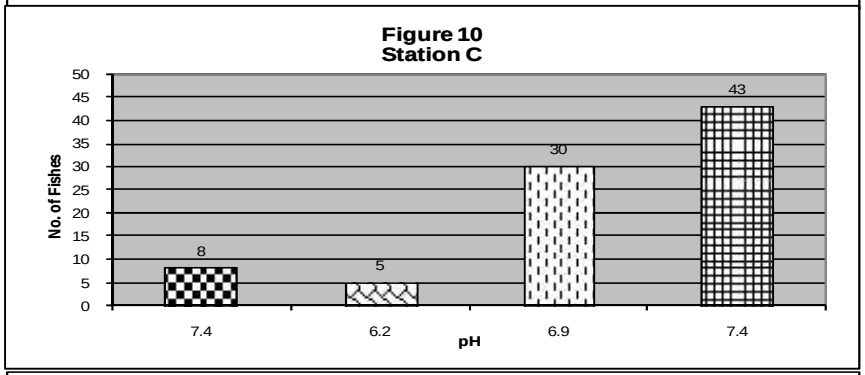
The transparency that directly or indirectly determines the productivity or the river by controlling the penetration of solar radiation, which seems to be one of the major physical parameters. During the present investigation period the water remained transparent throughout the year except late summer and rainy season, which was due to flooding .

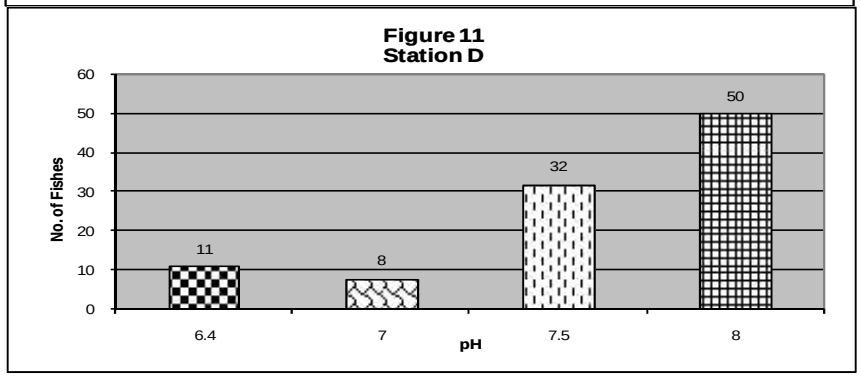
The chemical parameters of the water also shows great affect on the distribution of fish species in the river. Among all the chemical factors the concentration of dissolved oxygen of water is the most important factor. Dissolved oxygen above 5mg /1 is suitable to support diverse biota(APHA,1976). The dissolved oxygen of Rani khola ranges from 8.1-11.2mg/l,8.2-10.06mg/l,8.2-10.1mg/l,8.4.5-9.2mg/l with the average of 9.7mg/l. It looks from the result that temperature, pH, free carbon dioxide and alkalinity showed positive correlation with fish number favoring the distribution but transparency showed no definite correlation as sometimes at some stations the value were positive as well as negative. But dissolved oxygen showed negative values at stations A, B, C and D containing dissolve oxygen positive correlation at station E where as total hardness gave positive correlation with fish number at stations A, B, C and D and negative at station E as shown by dissolve oxygen content. (Table 13-17).

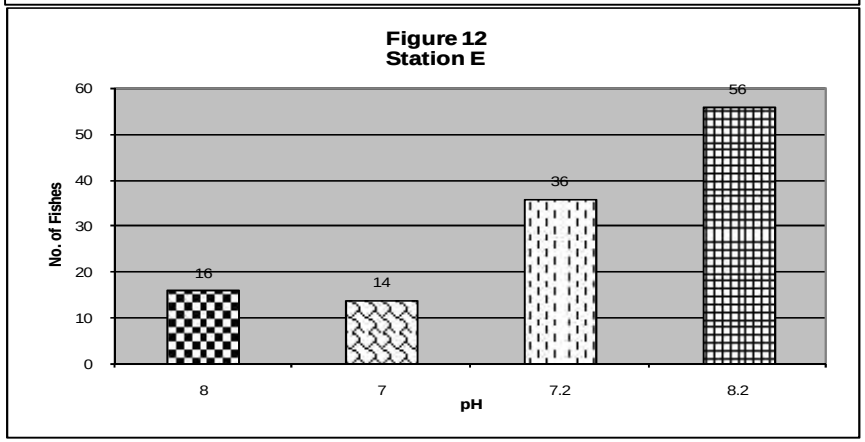
Figure 8-12 showing the relation between pH and number of fishes in different seasons











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Natural water may be neutral , acidic or alkaline. It is an important environmental factor influencing the metabolism of all the animals and plants inhabiting in it . The pH of water is not constant but varies in relation to the other chemicals in water(Khanna, 1989). But under many circumstances the variation of pH value has very little effect on fishes which can tolerate the normal daily pH range (Whitton,1975). The current of lotic environment tend to keep pH uniform over considerable distance (Welch, 1952). Generally alkaline water upto suitable for fish growth and good habitat creation.

The pH value more than 9 is unsuitable beause in this condition carbonate is not available (Swingle ,1867).According to Jhingran (1991) fish dies at about pH 11. Ellis (1937) reported that water having pH value of 6.67 to 8.4 is most suitable for aquatic life. During the present investigation the pH of the water of Rani khola recorded ranges from 6.2 to 8.2 with an average of 7.2, which indicates the water is alkaline(Table 8-12).

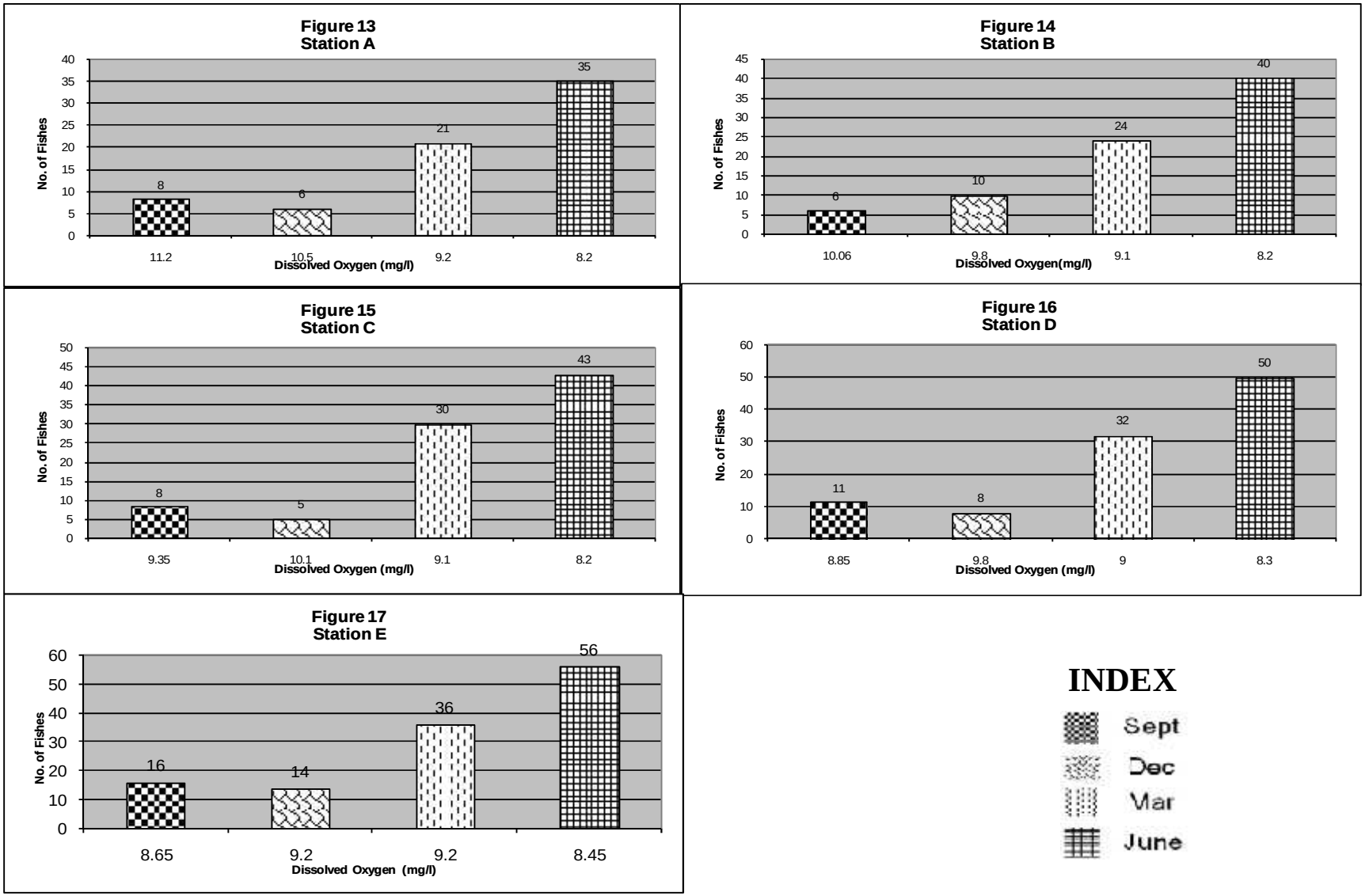
Acidic water is unsuitable for fish and other aquatic organism .Acidic water reduces the appetite of fish, their growth and tolerance to toxic substances. Acidic water may directly influence other aquatic organism by similar harmful effect, thus weakening its biogenic capacity .The fish gets prone to attack of parasite and diseases in acidic water(Jhingran,1991)

The correlation co-efficient(r) between pH and fish number was found to be positive with the value of 0.228,0.827,0.942,0.871,and 0.275 with the probable error of 0.4447,0.4323,0.2308,0.2952 and 0.6367 station –A ,B, C,Dand E respectively. While the correlation co-efficient (r) between pH and invertebrates number at station –A was found negative with the value of 0.228 having probable error of 0.6271.

Most of the carbon dioxide in the water comes from the decomposition of organic matter and from respiration of organism. Carbon dioxide stands at the threshold of all production(Cole,1975). The distribution of carbon dioxide in surface water varies both seasonally and vertically . In the present study , carbon dioxide showed an inverse relation with oxygen. Free carbobdioxide of Rani khola throughout the present study period remained 3.15mg/l and the correlation between free carbobdioxide and fish catch number showed positive correlation at all the station.

The total alkalinity of water recorded from Rani khola ranges from 11.5-31.5mg/l with an average of 21.5mg/l.The correlation between Total alkalinity and fish catch number showed positive correlation at all the stations whereas , the correlation between total alkalinity and invertebrates number remained negative at station –D.

Figure 13-18 showing the relation between dissolved oxygen and number of fishes in different seasons



The total hardness of water ranges from 16.5-30.5mg/l at station-A in December to at station –E in June . The correlation co-efficient between total hardness and fish catch number remained positive at all stations except at station –E , which is negative with the value of -0.387 having probable error of -0.5242.

In the present investigation the total of eight species which falls under two families and two orders were recorded. Among which *Schizothoraichthys progastus* was found to be most dominant species where as *Barilius bendelisis* was found to be rare species of Rani khola . Sherpa (2005), had reported *Schizothoraichthys progastus, Schizothorax richardsoni, Neolissocheilus hexagonolepis*, *Garra annandalei, Garra gotyla* and *Semiplotus semiplotus* from Rangpo khola, Sikkim, India. This river also shows boulder, pebbles, stones, gravers, deep gorges and pools with velocity, temperature, dissolved oxygen, free carbon dioxide, total alkalinity, pH and total hardness. Similar fish species were also recorded from Tamor, Eastern Himalyan region of Nepal by Shrestha et. al (2009). This is because both this river have similar gradient, flow, river habitat and limnological parameters. All most all the different species reported presently were already been reported by Tamang (1993). But,among them the two species *Schizophyge progastus* and *Accrossocheilus hexgonnolepis* reported by Tamang,(1993) has been renamed after Jayaram K.C (1999) as *Schizothiraichththys progastus and Neolissocheilus hexagonolepis,* respectively.

The socio- economic conditions of the fishermen living in the vicinity of Rani khola were found very poor. The source of income for their livelihood is moderate. Majority of the fisherman were having family members of 5 to 7. About 40% of the total fishers were found totally illiterate .The fish marketing system is also very poor in the whole area, which compel fishermen to fetch the customer at the roadside or they may have to knock from door to door.

The seasonal catch composition of fish species in Rani khola revealed that the size of fish catch increases from March to June then decreased in September to December and again increased showing highest catch during June.

Although , physico –chemical parameters are the primary factors for the distribution and catch composition of fish community in the water body, various other factors such as ongoing ecological changes of the aquatic ecosystem and physiological nature of biotic community also might have effected on the distribution and catch compostion of the fish fauna during the present investigation .

Fishing implements used in Rani khola includes indigenous fishing devices like ,cast net rectangular net , basket cage, rod and line (with or without hook),snare loops, hammer etc. But, some times the fishermen were even found to use improper mesh sized nets leading to the indiscriminate fishing, catching the young one of large sized fishes along with the adults of smaller sized ones. They were also been found to catch the females with fully ripe ovaries during breeding season. Besides these the other unconventional fishing practices like blasting, poisoning, grabing or making impoundments were also found in this river.

Sand and stone mining are the other main problems found in Rani khola .Local villagers, contractors and workers were found operating such activities particularly below the station-C for various purposes. Because of such activities the natural habitat is deteriorating day by day which is then causing a major disasters on the existing fish population , leading to the depletion of many fish species from the river. The main reasons behind such activities are lack of awareness.

In conclusion, the Rani khola, which is a very important feeder stream of Teesta River is most important from the point of view of conservation, management and development of fishery resources . The good management of Rani khola may help in increasing the total population of the capture fishery along with the conservation of many important fish species .

SUMMARY

The present investigation entitled “Fish Diversity and Fishery Resources of Rani khola, Sikkim” was conducted for a period of September 2009 to June 2010 covering four different seasons i,e September (Autumn), December (Winter), March (Spring) and June (Summer).

The study was focused mainly to know the water quality of Rani khola ,distribution diversity, and frequency occurrence of fish and invertebrate in Rani khola . No published literature available on diversity of fishes of Rani khola. The study has included the socio- economic condition of fishermen of Rani khola area and fishing practices used in Rani khola.

Based upon the twenty different samples collected from five different sampling stations covering four different seasons, a total of eight species of fish fauna belonging to two orders, two families and seven genera were collected. Twelve species of invertebrates belonging to three phyla, three classes and ten orders were also collected from Rani khola.

The present work has been divided into eight chapters The primary data were collected directly through the field observation , interviews with different class groups like fishermen, local people and fishery guards. While the secondary information were gathered from different reports , researchers papers , dissertations , magazines and journals.

The coefficient of correlation between physico-chemical parameters of water with fish and invertebrates diversity in four different seasons were being calculated . The water of Rani khola a was found always saturated with dissolved oxygen and the total hardness of the water was sufficient for riverine fishes . The water was found alkaline with the average pH value of 7.2.

A total number of eight species under two orders, two families and seven genera were recorded in which most common species was S*chizothoraichthys progastus* having highest frequency occurrence of 23.41% of the river was *Barilius bendelisis* with lowest frequency occurrence of 3.17 %.

The correlation of invertebrates with various physico-chemical parameters were also calculated and tabulated.The correlation coefficient between the fish number and temperature, pH, free CO_2 and total alkalinity were found positive at each and every sampling station throughout the sampling period.

The study has also revealed that the fishermen inhabiting in the vicinity of Rani khola are poor and quite literate. The popular fishing practices of Rani khola recorded during the present investigation were using rod & line, nets, snare loop, hammer, etc along with some other non-conventional methods like electro –fishing , poisoning , grabing or making impoundment etc.

Thus , the present investigation provides baseline information regarding the fish and fishery resources of Rani khola along with the necessary information for future development, management and conservation of the fishery resources in Rani khola.

CONCLUSION AND RECOMMENDATION

The present investigation has revealed that there is a rapid degradation in the riverine environment of Rani khola due to both natural and man made causes leading to the sharp declination in fish population and their diversity . The main problems of this river are over exploitation, illegal fishing practices, construction of roads along the length of the river, land slides, soil erosion, unusual flooding , sand and stone mining.

The population density and frequency occurrence of catch of many fish species like *Semiplotus sp and Barilius sp* are rapidly decreasing day by day. Thus, it can be assumed that most of the fish species in Rani khola are threatened today. Therefore, the immediate steps for effective conservation and management of the biodiversity in Rani khola are necessary .

The improvement of fisheries in natural water offer a great opportunity for self –employment and income generation among poor people living along the river. One main advantage is that poor landless people can turn other agriculture farming by providing training,beneficieries and other capacity building training to make them self employed, which would benefit poor rural people by raising their economic status. But no steps has been so far taken for the conservation , management and development of riverine fisheries in Rani khola.

Therefore the important management actions for the betterment of Rani khola could be listed as:

- Strict legislative regulations and Aquatic Animal Protection Act should be implemented to promote biodiversity conservation programme in and around the Rani khola.
- Sand and stone mining should be strictly prohibited throughout the Rani khola but it may be allowed only in particular area of river.

- Use of inappropriate mesh sized nets should be strictly avoided.

- Regular training and awareness programmes should be conducted at local level for the conservation and management of river and biodiversity through government as well as non- governmental organization agencies.
- Rehabilitation of important fishes or Ranching programme should be done by the introduction of hatchery reared fry and fingerlings.
- Local fish conservation groups should be formed involving affected fisheries community by encouraging people's participation for the development of Riverine and cold water fishery and eco-tourism in Rani khola.

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APPENDIX- I

A list of questionnaire used in interview with Fishermen of the Rani khola to study their Socio –economic condition:

1. Name of the Fisherman:

   ……

2. Caste of the fisherman :

   ……..

3. Weather SC/ST/MBC/OBC?

   .....

4. Age:…….. Sex……

5. Address ……

6. How many members are in your family?

   Male :…… Female:…… Total……

7. How many members do livelihood work in your family?.....

8. How much money does each member spend per month? Rs…….

9. For how many years you are been involved in this occupation?

   ……

10. Is it your full time or part time work?.....

11. Are you literate? Yes/No. If yes, level…….

12. Are you giving school educations to your children?

    ……

13. If not, reasons……..

14. Do you know about family planning?.....

15. Do you have own land?.....

16. What do you do besides fish catching ? …….

17. What is your income per month by fishing?.....

18. How many members are involved in fishing in your family?.....

19. How many days do you spend in fish catching in this river within a week……?

20. How much time do you spend fishing within a day?

……

21. Which implements do you use mostly for fishing?

…….

22. How much of fish do you catch in a day?

……

23. How many fishermen use to come for fishing in this region?

……

24. What do you do with the capture fish?

Sale /Consume/Both

……

25. What is the selling rate of fish?.....

26. Is there any fish market in this area?.....

27. If Yes, Where?.....

28. If no, than how do you manage to sale the captured fish?.....

29. Are you independent to buy construction materials of fishing implements?

.....

30. Which fish species do you mostly capture?

31. How many species are there in the river in your opinion? Can you name them? .....

32. Which season is best for the fishing?……..

33. Does the other persons who involve in other professions also use to come for fishing in this river? If Yes, Does they affect in you business?

34. Is the population of fish in this river declining? If yes,

Reasons(if any)

……
……
……
……

35. Is there any fish disappeared from this river?

……

36. Any suggestion would you like to give for the improvement of fishery of the Rani khola?

……
……
……
……
……..