Ecology and Economics of Coldwater Inland Fisheries in Sikkim

A Thesis Submitted

To

Sikkim University

In Partial Fulfillment of the Requirement for the

Degree of Doctor of Philosophy

By

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Dedication

*This thesis is dedicated to my father **Lt. Purna Bahadur Chettri** who worked in the Department of Fisheries, Government of Sikkim w.e.f. 4th May 1977 to 18th August 2010.*

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DECLARATION

I declare that the thesis entitled **"Ecology and Economics of Coldwater Inland Fisheries in Sikkim"** submitted to Sikkim University in partial fulfillment of the requirement for the degree of **Doctor of Philosophy,** is my original work.This thesis has not been submitted for any other degree of this University or any other University.

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CERTIFICATE

This is to certify that the thesis entitled **"Ecology and Economics of Coldwater Inland Fisheries in Sikkim"** submitted to Sikkim University in partial fulfillment of the requirement for the degree of **Doctor of Philosophy in Economics**, embodies the result of bona fide research work carried out by **Mr. Kul Bahadur Chettri** under my guidance and supervision. He has fulfilled the requirements relating to nature, period of research and presentation of seminar talk etc.

It is also being certified that the research work brings to light the results of an original investigation made by **Mr. Kul Bahadur Chettri** and no part of the thesis has been submitted for any degree, diploma, associateship and fellowship.

All assistance and help received during the course of the investigation have been duly acknowledged by him.

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\- ***Kul Bahadur Chettri***

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List of Acronyms

BOD	Biological Oxygen Demand
CO_2	Carbon Dioxide
CVM	Contingent Valuation Method
CV	Coefficient of Variations
DCFR	Directorate of Coldwater Fisheries Research
DOF	Directorate of Fisheries
EC	Electrical Conductivity
ENVIS	Environmental Information System
FAO	Food and Agriculture Organisation
FFDA	Fish Farmer Development Agency
GDP	Gross Domestic Product
GPU	Gram Panchayat Units
GSDP	Gross State Domestic Product
HSL	Hariyali Sacred Landscape
ICAR	Indian Council of Agricultural Research
ITCM	Individual Travel Cost Method
LPG	Liquified Petroleum Gas
LR	Likelihood Ratio
LSDV	Least Square Dummy Variable
MLE	Maximum Likelihood Estimator
MOEF	Ministry of Environment and Forest

MSY	Maximum Sustainable Yield
NFDB	National Fisheries Development Board
NFHS	National Family Health Survey
NRCCWF	National Research Centre for Coldwater Fisheries
OBC (CL)	Other Backward Classes of Central List
OBC (SL)	Other Backward Classes of State List
OLS	Ordinary Least Square
PFCS	Primary Fishermen Cooperative Society
PIW	Paya Indah Wetlands
RKVJ	Rashtriya Krishi Vikas Yojana
SACON	Salim Ali Centre for Ornithology and Natural History
SC	Schedule Caste
ST	Schedule Tribe
TC	Travel Cost
TCM	Travel Cost Method
TDS	Total Dissolved Solids
TPM	Truncated Poisson Model
US	United States
WLS	Weighted Least Square
WTP	Willingness to Pay
ZTCM	Zonal Travel Cost Method

List of Abbreviations

˚C	Degree Celsius
cm	centimeters
et al.	and others
e.g.	for examples
eq.	Equation
ft.	Feet
ha	Hectares
i.e.	that is
IR £	Ireland Euro
Ltd	Limited
m	Meter
m^2	Meter square
mamsl	Meters above mean sea level
mg/l	Milligrams per liter
mt	Metric tonnes
kg	kilogram
km^2	Square Kilometers
₹	Indian Rupee
RM	Malaysian Ringgit (currency unit of Malayisa)
sq.	Square meters
%	Percentage
$	US Dollar
pH	Potential hydrogen
vis-a vis	in relation to or with regards to

CHAPTER 1

AN OVERVIEW OF INLAND FISHERIES IN INDIA

1.1 Introduction

Fisheries are an entity engaged in harvesting or raising fish which is determined by some authority to be a fishery (Fletcher et al., 2002). A fishery involves the capture of wild fish or raising fish through fish farming or aquaculture[1] (Madden & Grossman, 2004). According to the FAO (2009), fisheries include species or type of fishes, area of water bodies or seabed, methods of fishing, a combination of fish and fishers in the region and ecological surroundings of the environment. Fisheries are important for their commercial, recreational and subsistence value (FAO, 2009). It is considered as a system composed of three interacting components: the aquatic biota, the aquatic habitat and the human users of these renewable natural resources; it is a part of a complex and volatile ecosystem (Lackey & Nielsen, 1980). Ecosystem simply means ‘ecological system' which includes all living things (plants, animals and organisms) in a given area interacting with each other and also with their non-living environments (weather, earth, sun, soil, climate and atmosphere). Inland fisheries ecosystems offer an especially rich diversity of habitat conditions, plants and animal species. Whether forest ponds, mountains, rivers or lakes-the ecosystems play an important role in the interactions between organisms and water bodies. However, ecosystems are not only habitats - humans also use them for resources; for this reason, humans and ecosystems

[1] FAO (1988) define aquaculture is also called aquafarming is the farming of fish, crustaceans, molluscs, aquatic plants, algae and other organism. It involves cultivating freshwater and salwater populations under controlled conditions and can be contrasted with commercial fishing which is the harvesting of wild fish.
http://www.fao.org/3/x6941e/x6941e04.htm

are considered within an integrated approach rather than in isolation. Fish occupy almost all major aquatic habitats (Helfman et al., 2009) and play a critical role in the function of their ecosystems (Holmlund & Hammer, 1999; Dudgeon et al., 2006).

Inland fish species are present in almost every inland ecosystem on earth (Dudgeon et al., 2006) and these inland fishes are integral to ecosystem function and biodiversity (Allan, 2004). When functioning properly, inland ecosystems provide many valuable services to people (i.e. provisioning, regulating, supporting and cultural services (Holmlund & Hammer, 1999; Hassan et al., 2005). Ecosystems with high species richness exhibit increased resilience (Downing & Leibold, 2010) highlighting the importance of diverse inland fish communities. Fisheries are important for commercial, recreational and subsistence value (FAO, 2010). Economic valuation of fisheries has expanded beyond the value of commercial harvests to include environmental, ecological and eco-systemic values which have significant economic importance and social benefits while fish can be valued for their existence as part of the native fauna regardless of their exploitation (Mawle & Peirson, 2009). Apart from their commercial value, fisheries also provide cultural and recreational services. Cultural services provided by inland fisheries include spiritual services (e.g. sacred, religious), inspirational (e.g. art, folklore) and aesthetic (Tengberg et al., 2012). These services are considered 'priceless' and cannot be valued in market terms (Harris et al., 1989). Recreational services provided by fisheries include non-fishing sectors such as diving, snorkeling, boating and the public and private aquarium trade. In developed and developing countries, the measured economic value of recreational fisheries exceeds their subsistence and commercial value (FAO, 2010*a*) and inland fisheries provide a sense of community identification and occupational attachment beyond food value (Weeratunge et al., 2014).

Food production has become a major worldwide issue of concern due to an increase in the human population and reports of large numbers of undernourished or starving people especially in the developing countries (Okechi, 2004). There are three main groups of activities that contribute to food production: agriculture, aquaculture and fisheries. Research shows that the world's natural stocks of fish and shellfish, though renewable, have finite production limits which cannot be exceeded even under the best management regimes (Okechi, 2004). The increase in population coupled with the decline in the world's major wild fisheries has led to an increase in demand for aquatic food. Fish farming has been the fastest growing animal-based food production sector particularly in developing countries like India and other Asian countries (Green Facts, 2004). This sector can make an important contribution to poverty alleviation, food security and social well-being which already does so in many developing countries (Mbugua, 2008). Fisheries have thus drawn increasing attention from many quarters as a modern culture practice in both developed and less developed countries (Allen, 1984; Hopkins, 1995; Bardach et al., 1972; Bardach, 1976; Brown, 1983).

1.2 Inland Fisheries and Aquaculture in India

In India, inland fisheries are broadly categorised as freshwater aquaculture including pond culture of carp and trout, brackishwater aquaculture involving mainly shrimp culture and capture fisheries in rivers, lakes, reservoirs, estuaries etc. From the production view point, the major components of the fisheries sector in India are inland fisheries and aquaculture. The inland aquaculture is being practice in both the fresh water and brackish water. Ornamental fish farming is a nonfood activity although it has a favorable future which has prospect to contribute overall growth of the fisheries sector in near future. The fresh water aquaculture has arisen as a major contributing surpassing the other sub sectors in fish production. The inland fishery sector is tremendously diverse and dynamic and growing in absolute terms but its potentialities is yet to be grasped. The inland water resources such as rivers and canals, ponds and tanks, floodplain lakes, reservoirs and brackish water provide good opportunities for livelihood development.

The estimated wetlands and floodplain lakes in the country is 1.2 million ha of where fish and fisheries are considered as a traditional economic activity with tremendous socio-economic impact in the rural sector. The coldwater fisheries resources comprise rivers, streams, lakes, reservoirs with a combined riverine length of 8,253 km and 41,600 ha of sprawling lakes and reservoirs. Besides, there are vast sheets of inland saline water bodies lying unexploited in different states of the country mainly in northern and central India[2].

Inland fishery resources of India are diverse and plentiful. The vast and varied resources of Indian fisheries accounted to 1,73,285 km of rivers and canals, 1.098 million ha of swamps and other wetlands, 0.202 million ha of floodplain, 0.072 million ha of uplands lakes, 2.414 million ha of ponds and tanks, 0.357 million ha of mangroves and 0.285 million ha of estuaries resources, 0.191 million ha of lagoons,

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[2] see http://dof.gov.in/inland-fisheries

3.150 million ha of reserviours and 1.240 million ha of brackishwater offer great opportunities for livelihood development. The freshwater culture resources in the country comprise 2.36 million ha of ponds and tanks (Table 1.1)

Table 1.1: Inland Fishery Resources of India

Resource	**Size**
Rivers and canals	173287 km
Swamps and other wetlands	1.098 million ha
Floodplain	0.202 million ha
Uplands lakes	0.072 million ha
Ponds and Tanks	2.414 million ha
Mangroves	0.357 million ha
Estuaries	0.285 million ha
Lagoons	0.191 million ha
Reservoirs	3.150 million ha
Brackishwaters	1.240 million ha

Source: National Fisheries Development Board, Department of Fisheries, Ministry of Fisheries, Animal Husbandry & Dairying, Government of India. http://nfdb.gov.in/about-indian-fisheries.htm

India is the second largest fish producer in the world contributing to 6.3% of global fish production of which nearly 40% is from inland sector and 60% of the total production from culture fisheries. India is a major producer of fish through aquaculture and occupied second position after China in the world. The total fish production during 2017-18 is estimated to be 12.60 million mt. The inland fishery sector plays a great role in nutritional security and employment potential. Fisheries sector contribute to about 0.91% of the GDP and 5.23% to agricultural GDP of the country. The per capita fish availability is about 9 kg. The annual export earnings from the fishery sector is about ₹ 45,106.89 crores.

This sector is a source of livelihood for more than 14.49 million people engaged fully, partially or in subsidiary activities pertaining to this sector. In addition, this sector is also an important source of ancillary jobs for rural population, especially in marketing, retailing, transportation etc. However, the sector remains largely un-organised even today mainly due to scattered and diffused nature of activities (Table 1.2).

Table1.2: Inland Fisheries of India

Global Position	3rd in Fisheries, 2nd in Aquaculture
Production during 2017-18	12.60 million mt.
Contribution of Fisheries to GDP (%)	0.91
Contribution to Agricultural GDP (%)	5.23
Per capita fish availability (kg)	9.0
Annual export earnings (₹ in Crore)	45, 106.89
Employment in sector (million)	14.49

Source: National Fisheries Development Board, Department of Fisheries, Ministry of Fisheries, Animal Husbandry & Dairying, Government of India. http://nfdb.gov.in/about-indian-fisheries.htm

The other resources where fish farming can be practice include the natural lakes, irrigation canals and paddy fields. India is mostly a carp country with more than 75% of the production being contributed by carps alone. The other significant contributor in recent is Pangasius species. India is now the third largest producer of Pangasius in the world after Vietnam and Thailand.

The development of brackish water fish culture has gained importance during the early 80s. About 1.2 million ha has been estimated as acquiescent for brackish water aquaculture in the coastal areas of the country. Besides tiger shrimp (*Penaeusmonodon*), the exotic white leg shrimp (*Littopenaeusvannamei*) is also becoming a popular species. Farmed shrimps contribute a sizeable percentage to the total exports from the country.

Considering this, the Department of Animal Husbandry, Dairying & Fisheries (DADF), Ministry of Agriculture and Farmers Welfare (MoA&FW), Government of India formulated Vision-2022 for has formulated various Action Plans for focused attention on the identified activities for production enhancement and achieving the targets of Blue Revolution[3].

1.2.1 Coldwater Fisheries in India

Coldwater fisheries occupy an important resource for the people residing in the uplands of India. India has significant resources in terms of upland rivers/streams, high and low altitudes of natural lakes in addition to man-made reservoirs existing both in Himalayan regions and Western Ghats. There are 16 big and small rivers in

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[3] Blue Revolution: Integrated Development and Management of Fisheries' Foreseeing high potential, the Hon'ble Prime Minister has called for "a revolution" in the fisheries sector and has named it as "Blue Revolution". The Blue Revolution, with its multi-dimensional activities, focuses mainly on increasing fisheries production and productivity from aquaculture and fisheries resources, both inland and marine. http://dadf.gov.in/fisheries-blue-revolution

the Himalayan and peninsular regions having an area of about 3885 km. The coldwater fisheries sector in India is small but vibrant with potential for growth. Thrust areas have been identified for holistic development of all segments for enhancing coldwater fisheries production through cluster-based farming as well as conservation of natural resources. The vision is to develop coldwater fisheries in a big way by adopting new and innovative production technologies, management and utilisation of less utilised water resources and with proper market set-ups. Fish culture has been successfully carrying in certain lakes, ponds and reservoirs of Jammu and Kashmir, Himachal Pradesh, Sikkim, Uttaranchal, Nagaland, Meghalaya, Arunachal Pradesh, Tamil Nadu and Kerala. Government of India established National Research Centre on Cold Water Fisheries (NRCCWF). It has played a significant role in the improvement and conservation of indigenous as well as in the establishment of exotic species in this region.

DADF has plans for enhancement and strengthening of coldwater fisheries as one of the promising sectors. Therefore, Mission Coldwater Fisheries Development Action Plan-2022 has been formulated to conserve and enhance coldwater fisheries in an economically, socially and environmentally responsible manner and to promote fish farming in hill region. Mission Coldwater Fisheries Development Action Plan is expected to enhance the food and employment security of rural and urban areas of coldwater regions. Accordingly, Action Plan for five coldwater states like Jammu

Kashmir[4], Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh have formulated to enhance fish production in the hill states.

In the Himalayas, aquaculture is undergoing an exponential development due to a progressive reduction in natural fish stocks and catch fishery, coupled with an increasing demand for food fish. Freshwater aquaculture represents approximately one-third of the total world aquaculture production. The introduction of new fish species, translocation of commercially important indigenous fishes to aquatic habitats and innovations in culture technique have helped to achieve the substantial increase in fish production in the inland sector. Because of the limitations of capture fish caught and stagnation of warm water aquaculture, coldwater aquaculture is being given the highest priority in the fisheries development plans especially in the hilly regions. India is emerging as a major fishery country with vast resources in terms of water bodies and fish species. Coldwater fish resources spread in the mountain regions of India present an opportunity as well as challenges for harnessing the full potentials of the fisheries sector. The coldwater fishery sector in India is transforming and contributing to the livelihood of a large section of the economically underprivileged population of the country. The emerging production technologies, higher economic growth, population explosion and shifts in the dietary pattern are leading to rapid growth in production as well as demand for food of animal origin. In this emerging

[4] During the study period, Jammu and Kashmir was a state of India as it was administered by India as a state from 1954 to 2019 constituting the southern and southeastern portion of the larger Kashmir region But with effect from 31st October 2019, the state is reorganized into two union territories- Jammu and Kashmir in the west and Ladakh in the East. The study in this particular chapter was conducted before the formation of the union territories. Therefore, in the study, Jammu and Kashmir was referred as a state.

scenario, fish has become a commodity for trade and export besides a subsistence source of income. Taking into consideration the importance of coldwater fishery resources existing in the Himalayan and Peninsular regions of India, there has been undertaking resource assessment of the coldwater region for its optimum utilisation and enhancement. Inclusion of new candidate species in upland aquaculture, nutritional and feed requirement of coldwater species, health management, a breeding program with genetic selection approaches, ornamental and sport fisheries, value addition and post-harvest technology have been considered on high priority. The vast aquatic resources in the forms of streams, lakes, rivers and natural and manmade reservoirs in the hilly region of the country provide immense potential for the development of fisheries and fish based eco-tourism in the country. The major challenge in the coldwater sector is to increase production and sustainable utilisation of aquatic resources as well as upliftment of the socio-economic status of the people while preserving the fragile ecosystem. But on account of population expansion and urbanisation, upland aquatic resources once considered inexhaustible are under threat. Hence, sustainable utilisation and development of fisheries resources have assumed importance in the coldwater region of the country.

1.2.2 Coldwater Inland Fisheries in Sikkim

The fisheries sector of Sikkim's solely consists of inland water bodies. The state has various water resources in the form of rivers, lakes, perennial streams and springs which provides immense scope for the development of inland fisheries. There are 48 fish species recorded in the riverine system (Tamang, 1999). The most important species are Masheer (Sahar), Snout Trout (Asla), Rainbow Trout, Catfish (Ther, Gandi,), some carps (Budana, Nak Katua)[5] etc. There is a potential of coldwater fish farming in the state having good water quality and sufficient quantity of cool, clean and flowing water suitable for the cultivation of coldwater fishes like- Rainbow Trout, Chinese Carp, Common Carp, Grass Carp, Silver Carp, etc[6]. The development of fisheries is for the promotion of sustainable fish culture as an income-generating activity in the rural area, augmenting nutritious food production, generating a supplementary source of income to fish farmers and fisherfolk, promoting fishery for tourism and conservation of riverine fish species and development of sport fishing. The fisheries activity is linked with tourism and the educated unemployed youth are motivated towards fish culture practices which help them to uplift the economic condition of the people in the rural area[7].

1.3 Statement of the Problem

The environment is the most precious natural resource on this planet. It determines the availability of other resources for present and future generations, the well-being of all environmental stakeholders and ultimately the long run sustainability of all life. Naturally, the protection of fragile ecological environments is necessary for the sustainable flow of benefits to future generations. Mountain regions are characterised

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[5] Annual Report 2008-09. Department of Animal Husbandry, Livestock & Veterinary Service, Government of Sikkim.
http://www.sikkim-ahvs.gov.in/fisheries_development.html

[6] Annual Report 2013-14. Directorate of Coldwater Fisheries Research, ICAR, Bhimtal, Uttarakhand, India. https://www.dcfr.res.in/

[7] Annual Report 2013-14. Department of Animal Husbandry Livestock, Fisheries & Veterinary Services. Government of Sikkim.
http://www.sikkim-ahvs.gov.in/fisheries_development.html

by unique flora and fauna, due to the existence of distinct climatic conditions and terrain not easily replicated in other areas. Naturally, special measures are required to protect and sustain such special ecologies. Coldwater resources hold a considerable population of food, sport, and ornamental fish species. A few decades ago, these resources were considered to be inexhaustible and enough to sustain the population living in upland regions. However, from the middle of the last century, there has been population growth, income growth, and urbanisation, which have not left the hill regions unaffected. The large-scale developmental activities have resulted in degradation of the ecology of coldwater streams, lakes, and reservoirs and there has been a sharp decline in the availability of fishes from these ecosystems. Taking into consideration the importance of coldwater fisheries resources available in the Himalayan and Peninsular regions of India, it is necessary to provide proper thrust in the development of coldwater fisheries. In Sikkim, upland regions are ecologically fragile. They must, therefore, be conserved and used sustainably for their ecological viability. The snow trout, an endangered fish species in Himalayan rivers, is on the verge of vanishing from the rivers of Sikkim after the construction of several hydropower projects in ecologically fragile uplands in North Sikkim which is a major issue of concern[8]. The conservation of ecological niches has economic benefits.

Government sponsored fisheries programs in Sikkim commenced from the late 1970s, realising that a high potential existed for fisheries development given the abundant water resources in the state. Fish production has gradually increased from

[8] See https://energy.economictimes.indiatimes.com/news/power/teesta-hydro-power-project-may-hit-endangered-snow-trout-fish/58089806.

150 mt in 2005-06 to 440 mt in 2014-15[9] and local fish farmers now annually produces 400 mt of the total fish demand in Sikkim of 1300 mt per year (Rai, 2016). Recent government reports said that the growth of fisheries is low compared to other livelihood activities and that fisheries contributed 0.05 percent of GSDP at current prices in Sikkim during 2012-13[10]. However, since much of the Sikkim's GSDP is of urban origin, fisheries are an important livelihood activity in rural areas. Sikkim has to import a huge quantity of fish from West Bengal and other states to meet consumer demand. Proper utilisation of water resources with effective farmer's awareness and co-ordination are required to expand the role of fisheries in Sikkim. To fill the existing supply gap, an expanded role needs to be assigned to aquaculture and pond fishery. There are new market opportunities for local fish farmers to meet the fish demands of Sikkim. Support for this is being provided by the State Fisheries Department and by various Central Government schemes (Rai, 2016).

1.4 Objectives

The study attempted to understand the status of coldwater inland fisheries in the Himalayas of India with special reference to Sikkim.

The specific objectives are

i. To understand the ecology and economic performance of coldwater inland fisheries in the Himalayan states of India in general and Sikkim in particular.

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[9] Annual Report 2017-2018. Department of Animal Husbandry, Livestock, Fisheries and Veterinary Service, Government of Sikkim.
[10] Statistical Journal 2013, Department of Economics, Statistics, Monitoring & Evaluation, Government of Sikkim.

ii. To examine the socio-economic conditions of fish farmers and the role of fisheries in the rural economy of Sikkim.
iii. To examine the financial performance and environmental sustainability of fish farming across the different primary fishermen cooperative societies.
iv. To analyse the economic valuation of natural lake ecosystems of selected lakes of Sikkim having major fish habitat.

1.5 Research Questions

The following are the research questions of the present study

i. Are coldwater inland fisheries progressing in the Himalayan states of India in general and Sikkim in particular?
ii. What are the socio-economic conditions of the fish farmers and is fisheries sector helping in the improvement of conditions of the fish farmers?
iii. Are primary fishermen cooperative societies of Sikkim maintaining sustainability criterion in fish farming?
iv. Does the natural lake ecosystem provide recreational and amenity value to the people?

1.6 Hypotheses

Following are the hypotheses of the study

i. There is a significant progress and growth in the performance of coldwater inland fisheries in the Himalayan states of India.
ii. Fisheries play a significant role in the development of the rural economy and the socio-economic condition of the fish farmers in Sikkim.

iii. The performance of the primary fishermen cooperative societies is economically viable with maintaining the sustainability criterion.

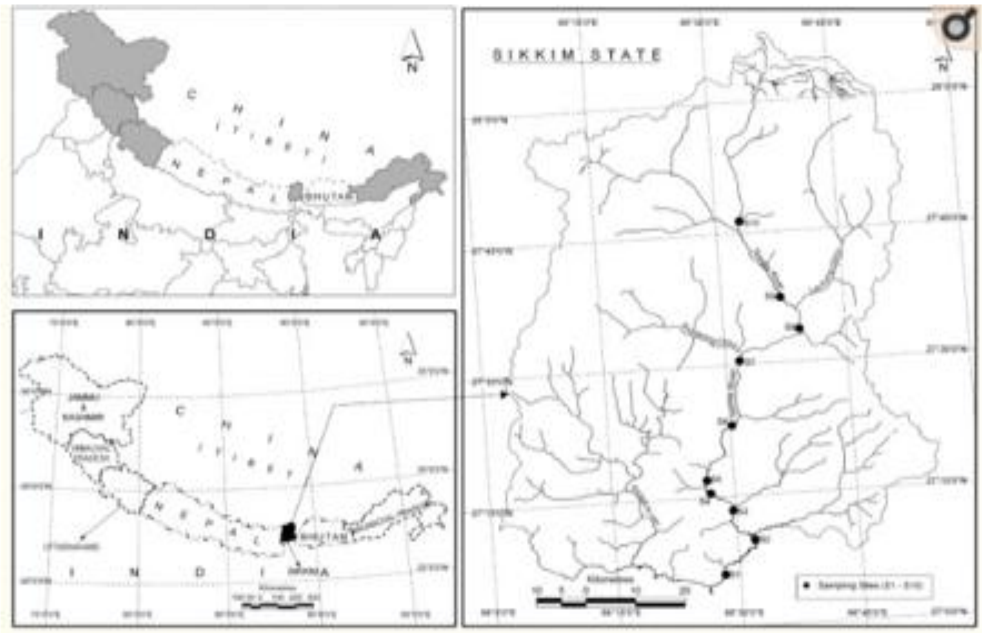
iv. The natural lake ecosystem of Sikkim provides recreational benefits and amenity value to the people.

1.7 Data and Methodology

1.7.1 Study Area, Sampling and Data Collection

Sikkim is a landlocked state situated in the lap of the Eastern Himalayas Region with sharing international borders with Bhutan in the east, Nepal in the west and the Autonomous Region of China in the north (Figure 1.1). Sikkim has a total geographical area of 7,29,900 ha out of which 10.02% (74,343 ha) is cultivable while the rest of the land area consists of forest cover, cultivable waste, barren, uncultivable land. Sikkim is enriched with natural resources and is a biodiversity hotspot. According to the data of 2013-14 obtained from the Directorate of Fisheries (DOF), Government of Sikkim, the total numbers of fish farmers were 1,665 and authorised fisherfolk numbering 1500 are located across the four districts of Sikkim.

Figure 1.1: Location Map of the Himalaya and Sikkim



Source: Map taken from Bhatt, J. P., Manish, K., & Pandit, M. K. (2012). Elevational gradients in fish diversity in the Himalaya: water discharge is the key driver of distribution patterns.

Table 1.3: District-wise Sample Size and Selection of Fish Farming Villages

Districts	**Study Area**	**Sample Size**
East	Rakdong- Tintek, Padamchen, Lingtam, South and North Regu, Pakyong, Nimachen and Zuluk	50
South	Rabitar, Dalep, Upper Lingee, Upper Payong and Sokpey	40
West	Uttarey, Upper Sreebadam, Upper Rimbi, Bermoik,Yuksom	70
North	Mangshila, Upper Dzongu, Lachung, Kabi, Theng, Singhick	40
Sikkim		200

Source: Field Survey

The study was based on both primary and secondary sources. The secondary data and information were collected from the different sources such as Food and Agricultural Organisation (FAO), North Eastern Development and Finance Corporation (NEDFi), Department of Animal Husbandry, Dairying and Fisheries (DADF), Government of India and Government of Sikkim, Fishery Survey of India, National Fisheries Development Board (NFDB), Central Coldwater Research Institute (CCRI), etc. Along with these various published books, handbooks, annual reports released by both state and central Government, statistical abstracts, and reports studied by various research organisations were also referred in the study.

i. To analyses the socio-economic conditions of the fish farmers and the role of inland fisheries in the rural economy of Sikkim, primary data was collected based on the pre-structured interview schedule directed towards the stakeholders concerning fish farming in Sikkim. The number of fish farmers in West, East, South and North districts are 497, 478, 382 and 312 respectively as on 2013-14. The higher number of fish farmers is in the West district whereas the lowest being in the North district. A total of 200 samples were collected comprising 50 respondents from East district, 40 from North district, 30 from South district and 70 from West district based on the availability of fish farmers in cluster form (Table 1.3). In Sikkim, fish farming activities are scattered in different locations and farmers are available in cluster form, therefore, the purposive random sampling method has been adopted to choose the location area, respondents and ponds. The district wise and Primary Fishermen Cooperative Society (PFCS) wise socio-economic study has been carried out to have better insight into the socio-economic conditions of the members and non- members fish farmers (see Chapter 5)
ii. For the analyses of financial performance and environmental sustainability across PFCS, the secondary data was collected from different sources such as cooperative societies, DOF and Department of Cooperation, Government of

Sikkim. The data were collected for the six years i.e. from the periods 2013-14 to 2018-2019 for the six PFCS located in four different districts of Sikkim. Three cooperatives have been selected from the West district and one each from East, South and North districts as per the existence of the number of cooperatives in each district. Of these six PFCS, four belong to trout farming and two belong to carp farming. The number of ponds under each cooperative and member is not the same; therefore, we have analysed the results by per an area of the pond. The size of ponds for producing trout and carp species are $34m^2$ and $120m^2$ respectively which are identical with the ponds of all the farmers. Hence, we have considered the yield of fish as kg per area of the pond.

iii. To know the recreational value of the lake and consumer surplus provided by the lake ecosystem, two natural lakes were selected which have major fish habitats. These lakes are Khecheopalri lake and Aritar lake. The study was based on a sample survey of 100 respondents from each lake. The respondents included the local community, pilgrims, and visitors from both within and outside the country. The outsider visitors were mostly from Nepal, Bhutan and few from European countries. The respondents were interviewed through a structured questionnaire (Bishop & Heberlein, 1992, Arrow et al., 1993) during the two peak tourist seasons from March to May and October to December in 2018-19. Along with these face-to-face interviews (Arrow et al., 1993) were also conducted at the lake sites. Only adult visitors, who had a defined source of income were interviewed because they are the ones who have more realistic ideas in making personal valuations of their recreational/sacredness experiences at the lake concerning their budget constraints (Brown & Henry, 1989). The visitors were asked to provide information on their Willingness to Pay (WTP) per year for the maintenance and conservation of lake, numbers of trips made to the lake, distance traveled to the lake, time taken to reach the lake, travel cost, WTP for entrance, socio-economic variables such as age, sex, educational level, occupation, and income, etc.

1.7.2 Analytical Tools

To analyses the above stated objectives, both qualitative and quantitative tools were applied. Let us now consider the methodology that we have followed in our analyses one by one.

i. The ecology and economic performance of coldwater inland fisheries in the Himalayan states of India in general and Sikkim in particular were based on the secondary data and the analyses was mostly done through tabular analysis, percentages, trend analysis and annual growth rate, etc.
ii. Assessment of socio-economic conditions of fish farmers and the role of fisheries in the rural economy were examined through descriptive statistics such as frequency distribution, tables, percentages, average (mean). Gini coefficient has been used to measure the extent of income inequality among the fish farmers of each district and each PFCS. Since income from the primary activities like agriculture, fishing and other allied activities yields annual or seasonal income, therefore, we have taken annual income from fish

farming as well as total annual income from all the sources for calculating Gini coefficients. A Logit model is used to ascertain the impact of diverse socio-economic factors on the perceived state of living conditions of the fish farmers, i.e. whether their socio-economic condition has improved or not over the periods (we shall find details in Chapter 5)**.**

iii. Financial performances of PFCS were examined through the construction of productivity, profitability and managerial efficiency indices using the concepts of cost, revenue and profit. Environmental sustainability of fish production associated with different PFCS was analysed by using the concept of Maximum Sustainable Yield (MSY) through the application of Gordon Schaefer Model. According to Schaefer, sustainability requires growth F(X) = harvest Y, where logistic specification sets F(X) = X (1-X/K) and Y = qEX, X being the stock of fish. Little manipulation yields the form Y/E = a – bE, providing the optimum effort as a/2b and MSY as $a^2/4b$, where a and b were estimated using the least square technique (detail methodology is discussed in Chapter 6)

iv. There are two methods of valuing environmental goods, namely, revealed preference [11] and stated preference methods [12] (Mayor et al., 2007). The revealed preference technique is based on the analysis of observed behavior that includes methods like Travel Cost Method (TCM), hedonic technique and demand dependency, etc. On the other hand, the stated preference technique

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[11] In revealed preference approach real choices of people are observed in some markets and information is inferred on the trade-offs between money and the environmental good.

[12] It basically involves asking people how much are environmental goods worth. This information is collected through polls or survey.

includes Contingent Valuation Method (CVM), choice experiments methods etc. which are based on individuals' responses to survey and questionnaires data relating to hypothetical situations (Mayor et al., 2007). There are several methods for evaluating the economic valuation of a natural ecosystem, but for the present study, we have used Individual Travel Cost Method (ITCM) for deriving the demand curve, estimating recreational benefits and consumer surplus. The ITCM defines the dependent variable as the number of site visits made by each visitor over a specific period, for instance, in a year, last two years, last five years etc. (Twerefou & Ababio 2012). The CVM was used for estimating WTP for the maintenance and conservation of lakes (Anderson & Bishop, 1986; Mendelsohn, 1987) (methodology in details is discussed in Chapter 7)

1.8 Limitations and Scope of the Study

The location of the study area i.e. Sikkim was selected based on the situation prevailing in the state regarding the fishery sector and also keeping in mind the mindset and working culture of the respondents. In addition to these, the researcher himself was born and brought up in Sikkim, therefore it was very convenient to interact with the respondents and to collect information from them in a local language. In this regard, there may be some research bias from other points of view. The study could take the sample size of only 200 fish farmers due to sparsely scattered fish farmers in the state. Furthermore, only 100 visitors could be selected from each lake for the valuation of lakes due to the time and financial constraints. Henceforth, sample size could be increased in future research. Economic performances and ecology of the coldwater resources were analysed by using the simple graphical and tabular technique depending upon the availability and nature of the data but in future, if data is available for diverse variables for the long periods then advanced time series and panel data analyses could be performed. Studies on this particular area can be explored by future researchers by employing advanced econometric tools, although we have applied good econometrics models in chapter 6 and chapter 7. Analyses of financial and environmental sustainability of capture fisheries such as rivers, lakes, etc. could not be carried out because of the non-availability of related data on it. Therefore, it has been observed that there is a lot of scope for exploring research in these particular areas in the future. In the present study, economic valuation such as recreational value and consumer surplus of Khecheopalri and Aritar lakes were evaluated. It is suggested that future researchers should explore research on other natural lakes of Sikkim to evaluate diverse economic values by employing different valuation methods.

1.9 Chapterisation

The work of this thesis is divided into eight chapters that deal with the various aspects of the research work. Chapter 1 is an introductory chapter that deals with an overview of inland fisheries in India, coldwater fisheries in India and inland coldwater fisheries in Sikkim. The chapter outline the importance of the fisheries sector, statement of the problem, objectives, research questions, hypotheses, data and methodology of the study, scope and limitations of the study. Chapter 2 gives a theoretical framework and extensive survey of previous literature on the study related issue to throw the light on issues that have been studied and research gap of the study. Chapter 3 discussed the ecology and the economic performances of coldwater fisheries resources and its environment, fish diversity found in the Himalayan belt of India, Aquaculture in the Indian Himalayas etc. Chapter 4 outlines an overview of the fisheries and fishery resources of Sikkim in particular. Chapter 5 deals with the socio-economic conditions of the fish farmers and the role of fisheries in the rural economy of Sikkim. Chapter 6 analyses the financial performances and environmental sustainability in terms of MSY across coldwater PFCS operating in the different districts of Sikkim. Chapter 7 is the economic valuation of natural lake ecosystem of Sikkim. This chapter analyses consumers' WTP for the conservation and management of the lake ecosystem and its recreational value and consumer surplus. The final Chapter 8 summarised the concluding observations and policy recommendations of the study.

CHAPTER 2

THEORETICAL FRAMEWORK AND

REVIEW OF LITERATURE

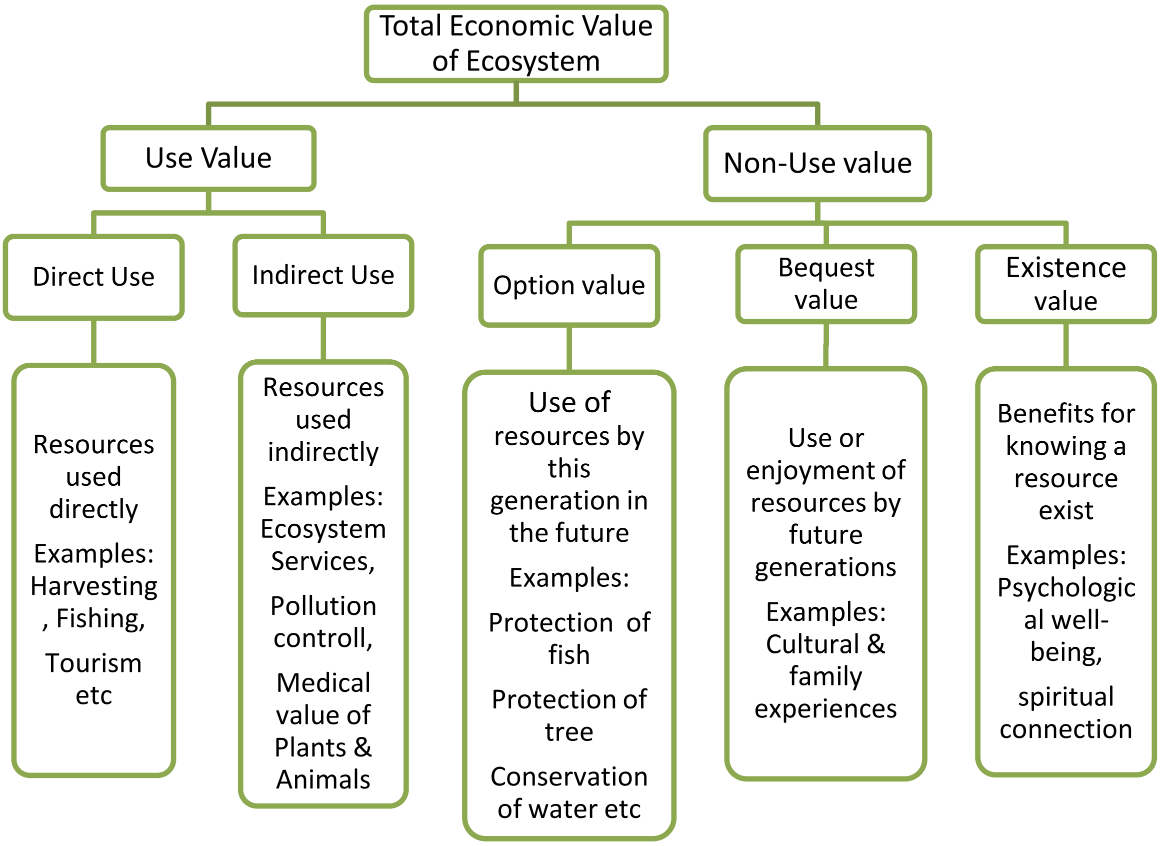
2.1 Theoretical Framework

Theories and concepts are very prerequisites for any research. Before starting any research, the theoretical background is very crucial. In theoretical background or framework, we define, discuss and evaluate the theories relevant to our study. It explains the major concepts, models and assumptions of the theories that guide our research and shows a grounded established idea. In this chapter, the theories such as economic valuation of an ecosystem viz. the economic theories of contingent valuation method and travel cost method; theory of financial analysis and bio-economic theory of sustainability and fisheries management have been discussed to support the present study.

2.1.1 Economic Valuation of an Ecosystem

The total economic value of an ecosystem and the ecosystem service it provides is the sum of both use values and non- use values. Although use values can be subdivided into direct use (resources directly used or enjoyed by an end user) and indirect use values (resources that are not directly used by people, but still provide measurable benefits). There was a debate regarding whether some ecosystem services involved a direct or indirect use. In the environmental literature, the option value is taken as the value of preserving threatened natural resources so that they might be available for future use. Many use values of ecosystems that can be quantified through widely employed non market valuation methods. Direct or indirect revealed preference methods, such as hedonic price and TCM, market pricing, opportunity cost; stated preference or hypothetical market method such as CVM could also be used.

Figure 2.1: Flow Diagram showing the Components Contributing to the Total Value of an Ecosystem



Source: Ministry of Environment, Government of India.

2.1.1.1 The Economic Theory of Contingent Valuation Method

The contingent valuation method was initially developed by Ciriacy-Wantrup during a series of studies undertaken on the positive externalities for non-markets goods and services realising that these externalities could be deduced from a sample of individual who undergo a survey concerning the WTP to take advantage of public goods and services without price. Later on, this technique was refined by Hanemann (1984,1985), McFadden (1976) and Arrow et al. (1993). During the 1990s, this technique has had widely spread in the US and it was applied to estimate the value of cultural heritage and to studies the feasibility of world bank for urban regeneration projects. Later on, it was widely used in other countries.

2.1.1.2 The Economic Theory of Travel Cost Method

The original idea behind the travel cost method was attributed to Hotelling (first reported in Prewitt, 1949), where he suggested that the costs incurred by visitors could be used to develop a measure of the recreation value of the sites visited. However, it was Clawson (1959) and Clawson and Knetsch (1966) who first developed empirical models along these lines. TCM is a survey technique where a questionnaire is often prepared and administered to a sample of visitors at a site to ascertain their place of residence; necessary demographic and attitudinal information; frequency of visitors to the site under consideration and other sites; and trip information such as purposefulness, length, associated costs, etc. From this data, visit costs can be calculated and related with other relevant factors to visit frequency so that a demand relationship may be established. In the simplest case, this demand function can then be used to estimate the recreation value of the whole site. At the same time, in more advanced studies, attempts can be made to develop demand equations for the differing attributes of recreation sites and values evaluated for these individual attributes (Das, 2013).

There are three major dimensions to travel cost analysis of the demand for environmental good. The first-dimension concerns how demand depends on the quality of the good, second is associated with the number and duration of trips during a period such as a year. The third concerns the treatment of substitute such as when a visitor to a lake faces the choice of several other lakes.

Following Bateman (1993) the demand function estimated by the TCM is an uncompensated ordinary demand curve incorporating income effects and the welfare measure obtained from it will be that of Marshallian consumer surplus. The TCM evaluates the recreational use value for a specific recreation site by relating demand for that site (measured as site visits) to its price (measured as the costs of a visit). A simple travel cost model can be defined by a 'trip-generation function' (*tgf*) such as;

$$V = f(C, X) \qquad 2.1$$

Where, *V* = visit to a site

C = visit costs

X= other socio-economic variables which significantly explain V

The literature on TCM can be divided into two basic variants of this model according to the particular definition of the dependent variable V. The ITCM simply defines the dependent variable is the number of site visits made by each visitor over a specific period, say one year. The Zonal Travel Cost Method (ZTCM) on the other hand, partitions the entire area from which visitors originate into a set of visitor zones and then defines the dependent variable as the visitor rate (i.e., the number of visits made from a particular zone in a period divided by the population of that zone). The ZTCM approach redefines the trip generating function (tgf) as:

$$\frac{V_{hj}}{N_h} = f(C_h, X_h) \qquad 2.2$$

Where, V_{hj} = Visits from zone h to site j

N_h = Population of zone h

C_h = Visit costs from zone h to site j

X_h = Socio-economic explanatory variables in zone h

The visitor rate, V_{hj}/N_h, is often calculated as visit per 1,000 populations in zone h

2.1.1.2.1 Individual Travel Cost Model

The individual travel cost model accounts for estimating individual's recreation demand functions. This is done by observing the visitation rate of individuals who make trips to a recreational facility as a function of the travel cost. The value of a recreation site to an individual is the area under each demand curve summed over all individuals. This model requires that there is a variation in the number of trips individuals make to the recreational site to estimate the demand function. The variation is not always perceived as all individuals do not always make a positive number of trips to a recreational site. The ITCM are preferred over the ZTCM. The ZTCM is statistically inefficient since it aggregates data from a large number of individual observations into a few zonal observations (Georgiou et al., 1997). Moreover, all individuals from within a zone are considered to have the same travel costs in the zonal model.

We can specify the individual travel cost model as:

$$V_{ij} = f(C_{ij,}E_{ij,}S_{i,}A_{i,}Y_{i,}H_{i,}N_{i,}M_{i,}) \qquad 2.3$$

Where, V_{ij} = number of visits made per year by the individual i to site j

C_{ij} = individual's total visit cost of visiting j

E_{ij} = individual i's estimate of the proportion of the day's enjoyment which was contributed by the visit to site j

S_i = dummy variable; individual i's assessment of the availability of substitute sites

A_i = age of the individual i

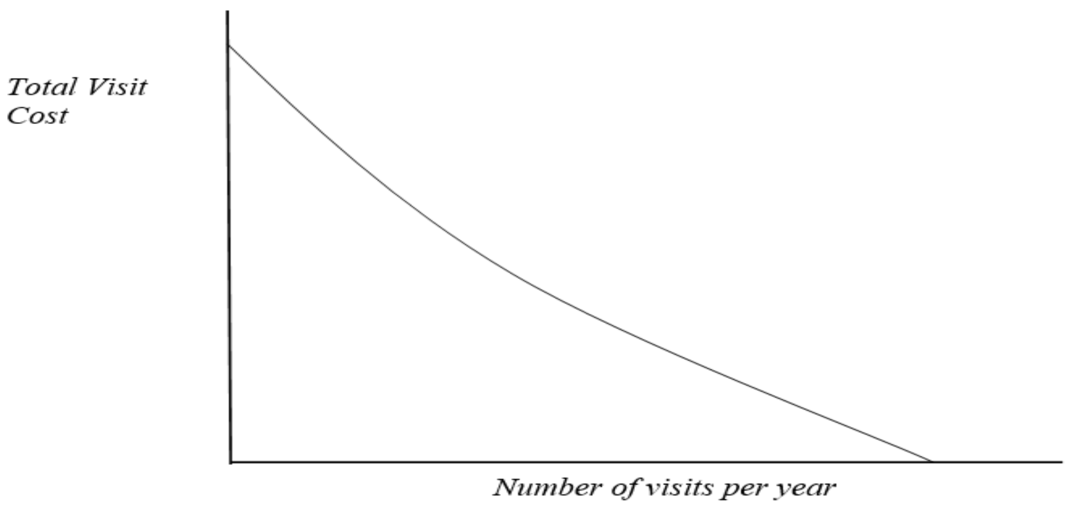
Y_i = income of the individual i's household

H_i = size of the individual i's household

N_i = size of the individual i's party

M_i = dummy variable; where individual i is a member of an outdoor or environmental organization.

Figure 2.2: Illustrative Demand Curve from the Individual Travel Cost Method



The demand curve for the site is illustrated in Figure 2.2. Integrating under this curve gives us our ITCM estimate of consumer surplus per individual. Consumer surplus for the site is then obtained by multiplying the individual consumer surplus with the number of individuals visiting the site annually.

2.1.1.2.2 Zonal Travel Cost Model

The zonal travel cost model was first applied and developed by Clawson at ‘Resources for the Future’ in the late 1950s and 1960s. The data needed include a sample of visitors to the site in question, identifying their origin. Having identified the origin of visitors, it is possible to estimate the number of visitors per year from each origin “zone”. Knowing the population of each origin zone gives a visitation rate for the zone. This visitation rate is explained by two factors: the travel cost from the origin to the site and the demographic/income characteristics of the population of the origin zone to the site (Das, 2013).

2.1.2 Theory of Financial Analysis

Financial analysis of any project refers to an assessment of the viability, stability and profitability of a business, sub-business or project. The landmark study of economic analysis of a project is “Security Analysis” by Benjamin Graham and David Dodd in 1934. Smith and Peterson (1982) reported that aquaculture profitability is commonly measured through an analysis of the costs and revenues of the enterprise. Engle and Hatch (1986, 1987) used financial analytical techniques to show that Panama’s resource-limited farmers benefited from the adoption of fish farming. Through the development of enterprise budgets, Hishamunda and Moehl (1989) demonstrated that Rwandan aquaculture correctly managed ponds, is a profitable activity that competes favorably with red bean, sweet potato, and rice production. Moehl (1993) used enterprise budgets to compare the profitability of four levels of fish production in Rwandan.

Cost-benefit analysis is a systematic process for calculating and comparing benefits and costs of a farm for the decision making and policy (with particular regard to government policy) or (in general) project (Hanley and Barbier, 2009). It determines if an investment/decision is sound (justification/feasibility) by verifying whether its benefits outweigh the costs, and by how much fish farming like any other business activity involves benefits and costs that are expected to occur in the future. One way of assessing how promising or successful fish farming enterprise might be is by conducting a cost-benefit analysis.

2.1.3 Bio-Economic Theory of Sustainability and Fisheries Management

Bio-economics is closely related to the early development of theories in the economics of fishery, initiated in the mid-1950s by Canadian economists Scott Gordon (1954) and Anthony Scott (1955). Their ideas were used in recent achievements in biological fisheries modeling, primarily by Schaefer (1957) on establishing a formal relationship between fishing activities and biological growth through mathematical modeling. These have been confirmed by empirical studies. It also relates itself to ecology and the environment and resource protection. In the bio-economic model, we shall use the concept of MSY[13] to analyses the economic and biological effect on fisheries management. Anderson et al., (2010) and Larkin et al.,

[13]Maximum sustainable yield is extensively used for fisheries management. MSY is theoretically, the largest yield (or catch) that can be taken from a species' stock over an indefinite period.

(2011) stated that bioeconomic theory in fisheries combines the biological and economic aspects of a fishery to explain stock, catch, and effort dynamics under different regimes and provides insights into the optimal management of the stock. The bioeconomic model provides an integrated approach for the evaluation of effective fishery management strategies. Sustainable management of the fishery resource whereby sufficient stock is left for future reproductive capacity is supposed to be the essence of the criteria of efficiency in fishery management. It should be environmentally friendly, technically feasible, economically viable and socially acceptable (Datta & Kundu, 2007). The application of this concept allows both culture[14] and capture[15] based fisheries to effectively regenerate their stock and ensure the continuation of the cycle of fish growth and harvest.

2.2 Review of Literature

The review of literature is an important part of any types of research. This part is considered as provider of foundation of knowledge in a particular area or topic of a research. It helps to identify gaps in research, conflicts in the previous studies, formulation of research questions, objectives, hypotheses and methodology in a research. The present study focused on the reviews of coldwater fisheries in the Trans Himalayan countries, coldwater fisheries in the Himalayan states of India, the

[14] In this type of fishery, the aquatic animals are captured from the natural water bodies like sea, river, lake pond, estuary etc. for food, ornamental and other purposes. In this fishery, a man has to reap without having sown, nature itself sowing the seeds through self propagation of species.

[15] Culture fisheries is the cultivation of selected fishes in confined areas with utmost care to get maximum yield. It is also called pisciculture, where fish seed has to be sown, tended and nursed, reared and finally harvested. It is undertaken in both inland and marine waters.

economic importance, problems and solutions of inland fisheries, economic and ecological viability of fish farming, determinants of fish farming and sustainability and management of fishery resources.

2.2.1 Review on Coldwater Fisheries in the Trans Himalayan Countries

The International Centre for Integrated Mountain Development (ICIMOD) defined the Trans Himalayan regions that cover the midland and highland areas of the Himalayas, Karakoram and in the Hindu Kush and Pamir regions of eight counties viz. Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. The parts of these regions are characterised by rugged terrain and very low levels of human development with full exploitation or overexploitation of the natural resources, fishery have been one of the important sectors in providing food and income to the people. These regions present an immense amount of water resources with large numbers of indigenous and exotic species having full potentiality for aquaculture. This section covers the reviews on fish and fishers in the region, fish species distribution, fishing strength, socio-economic conditions and livelihoods of fisher community, the impact of environmental degradation, conservation measure and aquaculture technologies developed for indigenous and exotic coldwater fish in the region. A review of coldwater fisheries of India and some of the Indian neighboring countries has been carried out.

Phillips et al. (2002) examined some environmental and socio-economic aspects in the development of aquaculture and coldwater fisheries in the Hindu Kush Himalayan region. The study revealed that indigenous fish species found within the

Hindu Kush Himalayan region present significant aquatic resources but regrettably this resource has not been recognised properly and undervalued and as a result, it has been given limited attention in rural development. The study suggested there is a huge potentiality for the development of fisheries and aquaculture sectors for poverty alleviation and contribution to rural development. They highlighted and identified aquatic resources as a part of a cohesive approach driven by concerns for poverty, livelihood and rural development. The paper conversed some of these issues and recognize some actions and initiatives to undertaken for rising profit from the aquatic resources.

Mahseer (*Tor putitora*), one of the well-known large freshwater gamefish of mountain rivers and lakes of most Trans-Himalayan countries, is reported to be declining in their natural habitats due to pollution, overfishing, industralisation, urbanisation and agricultural development causing ecological alterations and physical changes in a natural environment in lakes and rivers of mid-hills (Das & Joshi, 1994; Shrestha, 1994). Attempts to culture and conserve *Tor* spp. have been initiated in most Trans-Himalayan countries (Joshi, 1994; Shrestha, 1997). To replenish the declining populations of mahseer in its natural habitats' attempts are being made to breed and develop culture techniques of the *Tor* species.

Swar (2002) reported that Nepal is rich in cold water resources available in the forms of many rivers, lakes, streams, reservoirs and ponds. (Subba & Ghosh, 1996; Shrestha, 1999; Sharma, 2008) revealed that Nepal is a land of rich biodiversity where there habitats nearly 200 fish species around 190 species are indigenous and others are exotic of high economic, environmental and recreational value. Out of these, the cold-water fish species of Nepal consisted of 59 indigenous and 2 exotic species (Shrestha, 1999). Among them, 10 fish species have been found in endangered and vulnerable groups whereas 34 fish species come under threatened lists (Sharma, 2008). The most important indigenous coldwater fish species include Sahar, katle and snow trout. Fish farming is the traditional occupation of many tribes and they have adopted since time immemorial (Dahal et al., 2013). (Rajbanshi et al., 2002) stated that people in rural areas practice both capture and culture fisheries for their food and livelihood. Coldwater fisheries provide a great opportunity for income generation and self-employment to the poor people living along with the water bodies.

Karki (2016) analysed the availability of water resources, trends of fish production and yield, opportunities and constrained of aquaculture and fish farming in Nepal. The study revealed that Nepal has abundant water resources in the form of many rivers, lakes, streams, reservoirs and ponds making a country potentiality in fish farming and aquaculture but the fisheries sectors in Nepal have not been developing as expected. During the last 15 years, there is a steady growth in fish production with more than 37 thousand mt fish production and yield of fish raised by 2000 kg per hectare in 2013-14. Eastern Terai is the major fish producing region and some hilly districts are the good hub for coldwater fish species especially for rainbow trout. The fish growers are facing some major problems like scarcity of supply of fingerlings, disease problems, shortage of skilled manpower, lack of cold storage facilities and lack of marketing and infrastructural facilities (Karki, 2016; Gurung et al., 2010). There is also an absence of fish processing plants. Other major issues for sustainable fish farming in the country are loss of habitat and their degradation (Gurung, 2013).

According to Shrestha (2002) the stocks of fish in the natural water bodies have been declining due to overfishing, pollution, damming, poor management of lands that resulted in siltation and some other adverse natural and man-made impacts. Coldwater resources have not been properly assessed and utilised in Nepal, though it has considerable fishery resources for aquaculture and fish farming. With proper management of resources, the introduction of new innovative methods and techniques, habitat improvements and some other management measures could bring coldwater fishery resources to a sustainable harvesting level protecting further decline of fish stocks. The author also put forwarded 20 ideas to improve the ongoing situation in the country.

Gyeltshen (2002) revealed that the fish distribution in the water bodies of Bhutan is poorly known. However, Bhutan is rich in cold-water streams, rivers and lakes where brown trout dominates among coldwater species. The natural exploitation of fish is minimum and even they have not started that aquaculture of coldwater fish species. The breeding and culture of coldwater fish species has not been initiated so far and only very few people obtain fishing license that is compulsory for everyone fish catching. Besides, indigenous fish species like asla and mahseer, the exotic brown trout are also found in the river systems and it is self-producing species. Very few farmers are being involved in culture of warmwater fish species because aquaculture industry in Bhutan is in infancy period. Masheer angling is allowed for sport and recreational fishery. The catching of fish on the commercial scale is strictly prohibited as a result the fish catch data is not properly available in Bhutan.

Dubey (1978) reported that the rivers and lakes of Bhutan have predominantly Coldwater and torrential stream fauna apart from in the foothills and plains. Petr (2002) revealed that a total of 41 indigenous fish species have been identified from rivers and lakes of Bhutan, as compared to 179 species found in Nepal, which has alike geographic and climatic conditions. One exotic fish species (brown trout - *Salmotrutta*) was introduced in coldwaters, and seven exotic species are now used in warm water aquaculture in southern lowlands. Among the coldwater species, the indigenous asla (*Schizothoraxprogastus*) and Himalayan trout (*Barilius*spp) are the most common in all rivers. Other indigenous species of economic interest are katle (*Acrossocheilushexagonolepis*), found up to 1200 m altitude, and the mahseers *Tor tor and T. putitora*, which Dubey (1978) found in streams in the foothills. But unfortunately, Bhutan doesn't have any working coldwater fish hatchery or any fish production farms.

Yaqoob (2002) mentioned that the trout fishing is not only a part of the integrated development strategy of northern districts of North West Frontier Province but is also an essential source of recreation in these areas. Trout fishery as a sport has contributed a lot to the economy of local communities in the northern districts through the tourist trade. Direct and indirect economic benefits are accrued from trout fishing by tourists in Kaghan, Swat and Chitral and the number of anglers is steadily increasing. Consequently, the residents directly benefit and their income is increasing.

Aziz and Hossain (2002) reported that in Bangladesh biodiversity of aquatic animals including fish in open inland water bodies is threatened and several indigenous fish spices are either extinct or are on the verge of extinction. The impact of human intervention on aquatic ecosystems and eventually on the native coldwater fish community is viewed as a serious problem. Coldwater fish of Nepal are facing problems due to an increasing number of hydropower projects. Once abundant indigenous fish stocks have been declining due to overfishing, harmful fishing practices (electrofishing, dynamiting, and use of chemicals), pollution and developmental works, and urbanisation (Shrestha, 2002). Developmental works such as river damming have a major impact on river ecology, aquatic flora and fauna, including fish. Coldwater fish of Nepal are affected by the increasing number of hydropower dams in the country.

2.2.2 Review on Coldwater Fisheries in the Himalayan States of India

Singh et al. (2017) pointed out that in India, rainbow trout has been farming on a commercial scale since it is considered as one of the main cultivable coldwater fish species in the Indian Himalayan regions. During the last ten years of 2004-2014, the trout fish production has increased significantly from 147.0 to 834.0 tonnes along with a growth rate of 31% per annum. For the promotion of aquaculture of trout in the country the major factors that has been playing are technical knowledge, breeding and artificial diets etc. The major producer of rainbow trout of about 81.2 % is the Himalayan region where the contribution from other regions is negligible. There are many issues that needs to take care like infrastructural development and culture practices for management of broodstock, stock handling, feeding and health management despite an increase in production in the recent years. The other major identified constraints for the expansion of trout farming in the county are delay and insufficient supply of seed and feed and marketing facilities etc. The author suggested that for further expansion of total production needed scientific methods of trout farming and introduction of more indigenous species. The persistent support, togetherness of policy framers, research organisations and concerned ministry and department are the essential for the sustainable development of rainbow trout farming in India.

Gawa et al (2017) conducted a study to understand the economics of trout seed production in Jammu and Kashmir during the period 2014-15. The study revealed that the trout seed production is a capital-intensive activity, with huge cost incurred in the establishment of fixed inventories. It has been found that 20.35 % of seeds produced is utilised to stock the springs and streams for sports fisheries while 79.65% is used for fish culture. Around 90 lakhs which accounted 72.25 % of total capital investment was incurred for construction of hatchery. Cost and return analysis showed that fixed cost about ₹ 55.24 lakh and variable cost about ₹ 2.42 lakh which accounted about 95.63 and 4.37% respectively. The major restrictions faced in trout seed production was low demand for trout seed and lack of skill labour. The demand for trout seed is rising with increasing number of private trout farmers. With appropriate skill enrichment the trout hatchery business can modernize into a worthwhile livelihood option for entrepreneurs

Sharma (2019) examined the current status of trout farming in Himachal Pradesh and its potential for future expansion. The study highlighted that Himachal Pradesh is endowed with various lakes, streams and reservoirs with a huge capacity of fish production. The estimated fishery resources of the state comprise of 3000 km, among this 600 km is coldwater suitable for the trout culture. There are almost 762 trout farms of which 7 owned by the government which are located in Shimla, Chamba, Kinnaur, Kullu and Mandi districts. Of the five zones in the state, Zone 1 and Zone 2 have immense potentialities for producing high priced trout fish. The trout production in the state was 0.54 tons in 1996-97, increased to 25 tons in 2005-06 and further increased to 457.73 mt in 2017-18. The important factors that help in promoting the trout cultivation in the state are technical knowledge, breeding and artificial diet etc. Yet, there is a huge deviation of actual production to potential production, extension and developmental efforts have leads to an overall increase in trout production in the state.

Islam (2020) examined the growth of fisheries sector in Jammu & Kashmir union territory applying time series data from 2001-02 to 2015-16. He stated that during the past decades, fisheries sector is increasing with consistent growth in Jammu & Kashmir's economy. The fisheries are promising sector having potentialities to contribute state's economy. The length of rivers and streams is 27,781 km that enables farming of more than 2.01 lakh quintals of fish. The study results showed that fish production in Jammu & Kashmir has been raising considerably over the periods but in Kashmir Province production has declined unenviably. During the reference period, only trout species were found to have positive compound growth rate of 9.25 % but mirror carp and country fish displayed negative compound growth rate amongst the different species. The contribution share of fisheries sector to primary sectors NSDP has gone up imperceptibly from 1.84 percent during stage I to 2.14 percent during stage III, which suggests that there was about 0.30 percentage points increment in its share.

Studies on fish and fisheries upland in Sikkim were carried out by Talwar & Jhingran (1991) but details about fish catch and its commercial aspect were not available. Tamang (1993) reported about 48 species of fish from Sikkim. However, only 37 species were recorded in 2001 (MOEF, 2002). Hooker (1854) reported about Cyprinoids-big fishes that were abundantly found in crystal clear water of river Rangeet. However, during the study period, nowhere in the survey area, big fishes of Cyprinidae were observed. Anthropogenic as well as natural factors both influence the fish population in the rivers (Pant & Bisht, 1981). Overexploitation and faulty fishing techniques might be the major factors affecting fish germplasm. The most abundantly available members of the Cyprinidae family were Scizothorax spp. (Talwar & Jhingran, 1991). However, Das & Mukherjee (2005) observed a strong decline in the diversity of fish fauna in the river Teesta. According to the report of DOF, Government of Sikkim, 'Rainbow trout is introduced in Sikkim for cultural purposes. Farming rainbow trout is a profitable alternative to conventional agriculture that can be practiced with very limited land. Realising the importance of this farming system, the department is promoting trout farming among the rural masses as an income-generating activity. They have been providing financial as well as technical assistance for trout farming under the scheme named "Trout culture in raceways [16]". The integrated farming of trout and large cardamom is a newer concept that is being practiced by some trout farmers of the state with great success.

[16] A raceway is also known as a flow through system which is an artificial channel used in aquaculture to culture aquatic organisms. Raceway systems are among the earliest methods used for inland aquaculture. A raceway consists of rectangular basins or canals constructed of concrete and equipped with inlet and out let. Freshwater species as trout, catfish and tilapia are commonly cultured in raceways.
https://en.wikipedia.org/wiki/Raceway_(aquaculture)

2.2.3 Review on Economic Importance, Problems and Remedial Measures of Inland Fisheries

The fisheries sector occupies a very important place in the socio-economic development of the country and it is a source of livelihood for a large section of the economically backward rural population (Ayyapan & Krishnan, 2007; Jana, 2007). It ensures food security as well as tackles unemployment in these regions, which are predominately inhabited by the rural populace. Fisheries are next to agriculture in terms of providing employment and food supply (Rao, 1973). It has become an important activity and is recognised as a rich source of cheap nutritious food (Kumar et al., 2007; Sundararaj, 2007, Kumar et al., 2007) and a powerful income and employment generator (Sundararaj, 2007). This sector contributes to rural development, increase export opportunities, more effective administration of natural resources and conservation of biological diversity (Dagtekin et al., 2007). Thus, the sector has the potential to contribute substantially to the national economy through employment, gross domestic product (GDP), foreign exchange earnings, food security and poverty reduction.

Gopalan (1976) reveals that fisheries play a significant role in developing countries like India. It contributes fish protein to a large population that suffers from malnutrition. It is unlike the cereal protein. Fish contains amino acids such as lysine and this serves as an efficient supplement to the low protein, high carbohydrate diet of developing nations like India. From the above study, it is a fact that fisheries play an important role in the development of nations having immense water resources.

On the other hand, there are lots of problems and constraints in fish farming and the fishermen are also facing such problems. The following are some of the problems and constraints observed by the different authors in their study with suggested remedial measures to overcome such problems. Kumar et al. (2007) observed that fish farmers are facing the problem of inadequate supply of quality fingerlings, inadequate loan facility, high cost of feeds, seed, risk in marketing and high fish crate cost. Under this scenario, they suggested improvement in the efficiency of resources, an increase of activities, the supply of inputs, besides technical suggestions to the fishermen for increasing inland fish production.

Ele et al. (2013), Olaoye et al. (2013) revealed that the major constraints affecting the increased level of fish output in Calabar, Cross River state of Nigeria were the high cost of inputs, lack of adequate finance, access to credit facilities, security and farm labour problems.

Similarly, Kundu et al. (2006) pointed out that that inland fish production units in West Bengal often suffer from lack of financial resources, absence of motivation and knowledge about the ideal combination of inputs, improper monitoring of water quality, and inordinate aspects on economic aspects at the cost of environmental dimensions and MSY. While the importance of economic benefits cannot be belittled, this should not be raised at the cost of the neglect of pond water quality and fish health. It is often found that the water quality and other environmental aspects are relegated aside for generating quick returns. The government or local authorities should make provisions for the supply of adequate credit facility to economically weakfish production units, while also ensuring control of the damaging impact on pond water quality leading to deterioration in fish health and negative impact on society in general.

2.2.4 Review on Economic Viability and Determinants of Fish Farming

Hassan et al. (2007) estimated the cost of trout fish farming and its profitability in the Northern Areas of Pakistan during 2004. The results of the analysis show that total cost (capital and variable costs) of ₹ 234 was incurred to produce one kilogram of trout fish and its selling price was ₹ 310. The net revenue came to ₹ 76 per kg of fish. It shows that trout fish farming provides a great opportunity for exploiting the abundant source of cold water in Northern Areas and would be a major income-generating activity if rural people were made aware of such fish farming and a proper market is established in the area.

Prahadeeswar et al. (2004) observed that the intensity of fish culture is possible in small and manageable size ponds. When the size increases the fish, culture becomes traditional. The per-hectare total cost and return are very high in the case of intensive fish cultivation categories. In the case of tanks and reservoirs cost and return are comparatively lower because of the large size of water bodies.

Prahadeeswar et al. (2004), Sonawane et al. (2005), Ele et al. (2013), Olaoye et al. (2013), Tunde et al. (2015) analysed that the inland fish production is found to be a highly feasible and profitable venture and also a way to use effectively the water resources of all kinds, which are locally available. Sonawane et al. (2005) stated that more attention is required for the development of fishery resources through a better understanding of ecological principles, production and exploitation techniques. He further said that the co-operative sector has to be organised in such a way that it should become more competitive and better managed.

Ele et al. (2013), Olaoye et al. (2013) found that feed (kg), years of farming experience and stocking density have a significant effect on output levels. Their study recommends among others, that fish hatcheries and feed mills should be established in the study area and the government should provide credit facilities with small interest rates to fish farmers. A similar study conducted in the Saki-East Local Government Area of Oyo State, Nigeria and found that it is highly feasible and profitable.

Singh et al. (2015) estimated the efficiency levels of fish farms in North-East India using the data envelopment approach and has identified the fish production potential by improving the efficiency level of underperforming units. The variables, viz. fish farm area and occupation and fish farming with agriculture have been found to significantly influence the efficiency level of fish farms in this area. The study found that larger farms were more efficient. The average efficiency levels of fish farms in the study area being low, the scope for improvement in fish farming is immense in North-East India and Manipur through the adoption of better production practices.

Crentsil and Essilfie (2014) examined the level and determinants of technical efficiency of smallholder fish production in seven of the ten regions of Ghana. They employed the single-stage stochastic frontier approach in their study. Regional location, feed, fingerlings and labour are found to influence technical efficiency positively and significantly. However, formal education, marital status, membership in fish farmers groups and contracts with extensions services negatively influence in efficiency. The estimate result from the study also indicates that the average smallholder fish producer in Ghana is 73.88% technically efficient.

2.2.5 Review on Environmental Sustainability and Management of Fishery Resource

Ajayi (1982) estimated the MSY of the inshore fish and shrimp resources of the Nigerian continental shelf by using Schaefer's and exponential models for the periods 1965-1972. The study found that the MSY value for fish caught below 40 m and 50 m were 11684.09 and 13742.35 mt for 50000 ha and 55000 ha fishing respectively. For shrimp, the estimated MSY as 2008.02 tonnes. It was also observed that the inshore fishery had the probability for further expansion but on the other hand, the shrimp resources have been fully exploited under the prevailing circumstances. Therefore, further expansion of shrimp resources is possible only if the fleet size and fishing effort of foreign shrimpers are regulated.

Devaraj et al. (1987**)** used time series data for the years 1970-80 and 1970-71 to estimate the economically optimum catch and effort for the three major landing centers of Kerala i.e. Cochin, Shakthikulangara and Calicut by using cost, catch and price data. The authors have divided the total annual effort in boat hours by the average trawling hours per day i.e. 8 hours to change the effort into boat days. The estimated Maximum Economic Yield (MEY) was found to be 91323 tonnes of catch that comprises 44,931c tonnes of shrimp and 46392 tonnes of finfish. Similarly, the estimated MSY was observed to 96, 830 tonnes from the demersal stocks exploited by the trawlers and the biological optimum effort of 1503 trawlers per day for 215 fishing days a year needed for the attainment of MSY.

Ahammed (2000) applied the Gordon-Schaefer and Fox model for deriving an optimal level of catch and effort for demersal travelers in Thailand. The study mainly focused to determine the economically sustainable levels of catch and effort, to calculate net profit from the fishery and to deliver management advice at the macro level. The results obtained based on Schaefer and Fox models illustrated that about 4450 and 5291 trawlers respectively necessity to be phased out from fishery. According to Schafer and Fox models, the impact of unemployment of crew was expected at 44972 and 53447 respectively.

Bhatt and Bhatta (2001**)** analyse the sustainability of marine fish production in Karnataka marine ecosystem and its sustainability with the help of bio-economic analysis by using a single and species simulation model. Based on the single-species model, they have estimated the sustainable yield and Maximum Economic Yield (MEY) without taking into consideration the interactions between stocks, gears, labour, species, processing and marketing factors. The results obtained from the single-species model indicates that the species were harvested above MEY and near to MSY. The multi-species model incorporated the dynamic nature of the fishery and multi-gear technology interaction into a management plan for the assessment of the economic and biological sustainability. The results obtained from the optimal model showed a decline in stock levels of selected model species like Cephalopods, Stomatopods and Mackerel.

According to Bhaumik (2002), rational management of common resources like fishery water bodies is essential for attaining the goal of sustainable production rather than yield maximisation. Fruitful ecosystem management for increasing fish production is conditioned by the creation of lasting partnerships among different users and beneficiaries in a system of community-based management, user participation and co-management. Its primary function is to promote or motivate the member to actively participate in culture or capture fishery water bodies. He alludes in this respect to the tremendous impact of the first-generation method of participation like conscientisation approach innovated by Paulo Freire in the 1960s.

Mondal (2002**)** has demonstrated that one major aspect of fishery management is the assessment of the stock and adoption of suitable measures for optimising the sustainable yield. According to him, the derivation of a sustained catch of a renewable resource like fishery is based on the understanding of the dynamic of fish stock. In this context, he has named the two models of analytical and holistic models. The construction of analytical tools requires greater use of the quality and quantity of input data and a description of the stock. Holistic models requiring fewer population parameters like length and age structure of the stock are easily tractable. He has also emphasised the concept of MSY based on a holistic model like Schaefer and Fox.

Bhattacharya and Gupta (2007) analyse the fish biodiversity of Digha fishery in Eastern India with empirical analysis. In their paper, they studied the loss of biodiversity due to water pollution and the resultant impact on the fish harvested. These twin problems have been addressed simultaneously and modeled in an aggregate Gordon-Schaefer model for the Digha fishery. An economic biodiversity index and a variable for environmental quality have been included modifying the aggregate Gordon-Schaefer model. For estimating the parameters of the model, the Schnute method has been used. They focus on the dynamics of the profit maximising regime and explore the dynamic maximum economic yield and the net present value of profit by fishery is maximised. The small variation in discount rates and intrinsic growth rates have been done as a part of sensitivity analysis and their impact on optimal profit has been examined. This has been done under different biodiversity scenarios. They found that in the case of the Digha fishery, there exists a trade-off between economic biodiversity conservation and profit maximisation. Their study suggested that the government should framework the policy measures to minimise the level of conflict between them.

Datta and Kundu (2007) state that sewage fed fishery is considered to have some cost advantage over-application of fertilizer and artificial feed for the growth of fishery resources. This is supposed to promote the growth of phytoplankton and zooplankton which are the natural feed of fish resources. But the application of untreated and improperly treated sewage may instead of proving beneficial, vitiate the water quality in terms of reduced DO or even fluctuate the hardness of pond water. Fishermen’s joint WTP and initiative to contribute to the installation of the better sewage treatment facility may cater to the prospect and sustainability of fishery resources.

Ahamed et al. (2007) carried out a Bio-economic analysis with regards to overfishing in the Gulf of Thailand and their study revealed that in an open access fishery, the fishermen will raise their fishing efforts up to the level of its profitability.

The study suggested that the open-access equilibrium will be reached when the total cost is equivalent to the total revenue and due to which resource rent becomes zero.

Samuel et al. (2018) investigated for the estimation of MSY and the corresponding efforts of an artisanal fisheries resources of River Niger (RN) and River Benu (BN) in the Kogi state of Nigeria with the help of Schaefer's surplus production model. They have collected 180 samples from RN and 60 from RB by using the three-stage sampling procedure. They have used the well-structured questionnaire to collect data on the fishing effort and monthly catches kg/month. The empirical results indicate that the MSY of 47.8 kg was achieved E_{MSY} level of 10.3 hours/day in RN while in the case of RB, MSY of about 34.7 kg was obtained at the E_{MSY} level of 11.4 hours/day. The study found a negative impact of fishing effort on fish catch because catch per unit of effort has decreased with an increase in effort in the case of both the rivers.

2.2.6 Review on Economic Valuation of Ecosystem Services

A study was conducted by Schreiner et al. (1985) to estimate the recreational benefits of the McClekkan-Kerr Arkansas River Navigation System through a survey data of 1974-1975 applying the TCM. The study also developed generalization relationships for estimating recreational benefits and applying those relationships to a sample of other Corps projects. They have used weighted least square regression methods to estimate the recreational demand functions categorised by regional and local lakes. The study results revealed that the estimated visitor's day benefit ranged from $ 1.20 -

$ 3.68 and the annual recreational benefits were $ 50, 00, 000 for the Navigation System as a whole.

Maharana et al. (2000) estimated the valuation of ecotourism in a sacred lake of the Sikkim Himalaya based on a sample survey of 360 respondents through a well-structured questionnaire applying a TCM. Their study found that the demand for recreation increased with a decrease in travel costs and distance for the local visitors. WTP for the maintenance and preservation of lake by national and foreign visitors was US $ 0.88 and the US $ 7.19 respectively. They had also found that the lake has high recreational and sacredness values that were ascribed to the conservation of the site for pilgrimage and biodiversity. Their study suggested that if natural ecosystems are properly managed and marketed for ecotourism, a large number of lakes in the Hindu-Kush Himalayan region could bring economic development that can be linked with conservation.

Mayor et al. (2007) attempted to check the monetary value of the recreational services provided by the Irish forests based on the two different valuation methods like TCM and CVM on the one dataset to test the convergent validity. Their study found that the convergence cannot be established within this data. The WTP for entrance responses are stationary and tend to cluster around IR £1 per adult equivalent per trip. The TCM results of CS which should be the same as WTP, are more variable depending on which sample is analysed and range between IR £ 2.38 and IR £ 5.95 per adult equivalent per trip. The study didn't find any correlation between these two variables. It was observed that there were problems for people to state their actual WTP. This may be a misinterpretation of the question by respondents as well as a propensity to revert to a common number. Respondents likely practice their WTP answers to make a political statement against the enlargement of forestland by agricultural land. Lastly, forests in Ireland were considered to be public goods and accordingly there exists a stance among users that access to them should be free of charge, which might elucidate the larger of protest bids.

Tao et al. (2012) estimated the economic value of forest ecosystem services in a typical deforestation and afforestation area in Heshui watershed, Jiangxi province. They stated that the forest ecosystem in Heshui includes basic goods supply, soil water conservation, climate regulation, environmental purification and biological habitats. To estimate the value of the forest ecosystem, the CVM was used for 200 households in three typical countries i.e. Anfu, Yongxin and Lianhua. The respondents were asked to state their WTP for restoring and protecting the forest area by informing them about the current situation and the hypothetical market. The study found that respondents were willing to pay 238 yuan per mu yearly for forest restoration and protection. The results indicated that the WTP was significantly impacted by several factors like age, education level, occupation, household population, off-farm work members, income, forest area and whether respondents suffered from natural disasters.

Limaei et al. (2014) estimated the recreational value of Masouleh forest park in the North of Japan using the TCM or Clawson method. They have surveyed 96 visitors through a well structure questionnaire. Their study found that the variables such as travel time to the park, travel cost, age, education were highly significant for affecting the visitors' demand for forest tourism. The results show that there is a significant relation between travel cost and the number of visitors indicating an increase in travel time decreases the number of visitors. Furthermore, the study found a negative relation to travel cost with the number of visitors as travel cost increases, the number of visitors decreases. The results also indicated that the increase in entrance fees decreases the WTP. The average WTP was estimated to be 12,5000 Iranian Rials per visit. The average round trip travel cost was found to 85.5 US dollars or 10,000 Iranian Rials.

Siew et al. (2015) estimated the visitors' WTP for the economic value of conservation and recreation of Paya Indah Wetlands (PIW) using CVM. The result was analysed by the logit model to evaluate the visitors' WTP entrance fee to PIW. The study results found that the mean WTP of visitors was RM 7.12 as an entrance fee per person. The visitors' levels of income and bid price were significant variables that influenced the WTP. The result also found that the expected benefits of the conservation programme in PIW were estimated at RM 630,768 in 2012.

Sinha and Mishra (2015) conducted a study to examine the ecosystem services valuation for enhancing conservation and livelihood in a scared landscape of the Indian Himalayas. The study was undertaken in Hariyali Sacred Landscape (HSL) in the Himalayas of Garhwal to evaluate and rank the services provided by the ecosystem which was based on the perceptions of the people to explain the ecological, economic and cultural importance of the landscape. WTP for various ecosystem services was calculated by utilising the method of contingent valuation analysis. The number of respondents was 145 that includes villagers and outsiders. The study observed that the villagers had identified 6 direct and 7 indirect ecosystem services in

HSL. The perceived benefits from all the ecosystem services wee highest ranked by the nearby villagers. Nevertheless, WTP for the preservation and conservation was lowest by them. Such kind of divergence between the WTP and perception was expressively attributed by the difference in education and rights related to rituals and access to the use of the resource. The study suggested that a cautious intercession to assimilate the adjoining villagers in the rights and rituals of the temple and to develop a larger transparent means to accomplish the funds produced from religious sites and government will lead to larger participation and WTP for the conservation of the landscape.

Pirikiya et al. (2016) estimated the economic value of Zare Sari Forest Park as a recreational site in the North of Iran by using the ITCM for 302 individuals who visited the park in 2012-2013. Ordinary least squares method was used to estimate the result. The study result found that the consumer surplus was 12.53 US $ per each visit and the annual recreation value of 72,500 people who visited the park annually was 52,558 US $ ha-^{1}. The study also found that travel costs, visitor's distance negatively influenced the visitors' WTP for the park whereas income, family members and education had a positive influence on it. The result revealed that forest parks have a considerable recreational value that can help programmers and executives, social and economic managers in the preservation, planning and sustainable utilization of natural resources.

Islam and Majumder (2015) estimated the economic valuation of Foy's Lake, Chittagong by taking a total of 200 respondents using the TCM. The visitors of the lake were interviewed based on the day of the visit through a structured questionnaire.

Results have been analysed with the application of the multiple regression model. The variable like income, age, satisfaction with safety provided by the authority, family size and travel cost of the visitors were found to be significant for determining the recreational demand of the lake. The study found that the estimated recreational value for Foy's lake for 2014 was worth 294165270 BDT.

Alam et al. (2017) estimated the annual recreational value or consumer's surplus provided by the Foy's lake using ITCM and zero truncated Poisson regression model for 120 samples. A systematic sampling method was adopted by using a structured interview schedule. Based on their estimate, the consumer's surplus or recreational benefits per trip per visitor was the US $ 73.44 and counting the CS per trip per visitor, the annual recreational value i.e. total consumer surplus provided by the lake was observed to the US $ 40.2 million.

2.3 Research Gap and Justification of the Study

The research on coldwater fisheries has become a new dimension. There has been limited work on coldwater fisheries in the Himalaya. The indirect use value and non-use value of Himalayan fisheries have not been studied. There is also a dearth of studies on the conditions of mountain fish farmers and their livelihoods especially in the case of Sikkim. An empirical analysis of financial management and environmental sustainability of the fisheries resources has not been studied for coldwater fisheries though there are few studies conducted for warm and marine water fisheries. The empirical study on the recreational and aesthetic value of the lake ecosystem also lacks especially in the context of Sikkim. Only a few studies had explored the link between ecology and the economics of coldwater fisheries in the Himalaya, although such studies existed for other mountain regions. The present study addressed the above stated issues and filled the gap in the research.

Aquaculture has been the fastest-growing food production sector while capture fisheries have experienced a declining trend. Aquaculture, therefore, can contribute significantly to food security and poverty alleviation in parallel with the development of profit-oriented entrepreneurship. Though the magnitude of resources in the coldwater sector is small in comparison to tropical waters the fact remains that they have received low priority and investment; thus, it has remained underdeveloped in comparison to the warm water sector. Coldwater fisheries contribute meagerly to the inland fish production of India though the coldwater region has tremendous potential and its share can be improved to a greater extent through various fisheries development strategies like by conserving fishery resources including habitats, developing suitable fish species combination for fish farming at different altitudes of the Himalayan region and by adopting new aquaculture technologies. Although the contribution of coldwater fisheries is small in India, they play an important role in the breeding and migration cycles of fish species. Unique geographical and climatic conditions in the Himalaya sustain fish faunal diversity. Ecosystem and fish faunal diversity are a valuable treasure of India[17]. A vast potential exists for improving fish production by bringing natural water resources in the Himalaya under scientific fishery management. Through the application of modern techniques, the significant scope also exists for promoting trout farming, which will have long-run benefits.

[17] Annual Report 2013-14, Directorate of Coldwater Fisheries Research, ICAR, Government of India. https://www.dcfr.res.in/

There is also a potential for promoting sport fishery and ecotourism development in mountain regions. The state of Sikkim has various water resources in the form of rivers, lakes, perennial streams and springs which can support the development of inland fisheries. It is an important sector for generating subsidiary income, employment in the rural areas and promotion of the tourism industry. Most of the water resources are located in rural areas where employment opportunities are scarce. The adoption of fisheries will, therefore, open up new avenues for employment in rural areas by increasing self-employment opportunities; also help in meeting the nutritional needs of the people. The development of the fisheries subsector is expected to increase the full use of the resources while also create employment for the youth and women.[18] The researcher finds it worthwhile to study the ecological and economic importance of mountain fisheries which have various use and non-use economic values making them a viable economic option as a source of livelihood.

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[18] Annual Report 2006-07. Department of Animal Husbandry Livestock, Fisheries & Veterinary Services, Directorate of Fisheries, Government of Sikkim. http://www.sikkim-ahvs.gov.in/fisheries_development.html

CHAPTER 3

COLDWATER INLAND FISHERIES IN THE HIMALAYAN STATES OF INDIA

3.1 Introduction

The Himalayan regions have the most abundant biological diversity in the world characterised by the presence of coldwater, many of which harbour fish and largely support subsistence, ornamental and commercial fisheries. The aquatic resources located 914 m above mean sea level in the Himalayas, sub-Himalayan zone and mountains of the Deccan are known as coldwater. The temperature varies between 0-20˚C with an optimal range between 10-12˚C. The coldwater streams and lakes of high altitude are characterised by high transparency and dissolved oxygen and meager biota. Most of the fishes are small-sized showing a distribution pattern depending upon the rate of flow of water, nature of the substrate and food availability. The significant coldwater resources include upper stretches of Indus, Ganga, Brahmaputra rivers and their tributaries, coldwater lakes, and reservoirs of Himalayan and Deccanplateau harbour fishes belonging to six different families *Cyprinidae*[19], *Cobitidae*[20], *Salmonidae*[21], *Sisoridae*[22], *Psilorhynchidae*[23] *and Homalopteridae*[24].

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[19] The *Cyprinida* are the family of freshwater fish also known as *cyprinnids*, that includes the carps, the true minnows, and their relatives (for example, the barbs and barbels). Also commonly called the "carp family", or "minnow family". *Cyprinida is* the largest and most diverse fish family and the largest vertebrate animal family in general. https://en.wikipedia.org/wiki/Cyprinidae

[20] *Cobitidae* is also called True loaches is the family of old-world freshwater fish. They occurred throughout Eurasia and in Morocco and inhabit riverine ecosystems.

3.2 Historical Background

Coldwater fisheries in the Indian Sub-continent was initiated by British Administrator turned naturalist by introducing two main types of trout viz. brown trout *(Salmo trutta fario)* and rainbow trout *(Oncorhynchus mykiss)* around the beginning of the last century primarily to meet their needs for sport fishing or recreational angling. These introductions in India could be considered as the formal beginning of coldwater fisheries development in the country. For many decades the mere intention remained to develop recreational fisheries to satisfy the needs of anglers for sports. Later on, these species were started being cultured for food and hatcheries were set up for the production of seed. The development of hill fisheries thus began in the selected locations mainly in the Kashmir valley and some parts of peninsular India. The research on coldwater fisheries commenced with the establishment of the Coldwater Fisheries Research Centre of Central Inland Fisheries Research Institute in the year 1963 at Harwan, Jammu & Kashmir as a scheme under the III Five-Year Plan. Initially, the center assisted in providing the research inputs related to departmental

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The family includes about 260 described species. https://en.wikipedia.org/wiki/Cobitidae

[21] *Salmonidae* is a family or ray finned fish, the only living family currently placed in the order *Salmoniformes*. It includes salmon, trout, chars, freshwater whitefishes and graylings which is collectively known as the *salmonids.*
https://en.wikipedia.org/wiki/Salmonidae

[22] *Sisoridae* is a family of catfishes. The family includes about 235 species.
https://en.wikipedia.org/wiki/Sisoridae

[23] *Psilorhynchida* is a genus fish in the family *Psilorhynchidae* native to South Asia. They occur in rivers and streams with fastto swift currents. They are distributed in southern Asia, in the Indo-Burma region and the Western Ghats. There are currently 28 recognised species in this genus. https://en.wikipedia.org/wiki/Psilorhynchus

[24] *Homalopteridae* is a family of freshwater fish that have a slender body. They are bottom-dwellings fish inhabiting fast flowing mountain streams. There are 87 species found in tropical Asia.https://www.encyclopedia.com/science/dictionaries-thesauruses-pictures-and-press-releases/homalopteridae

trout hatcheries and other trout associated problems to the State of Himachal Pradesh and Jammu & Kashmir. The activities of the center increased rapidly and a good amount of investigation on coldwater fishery resources was carried out by the center. To utilise the available resources and opportunities in the coldwater fisheries sector the involvement of Indian Council of Agricultural Research (ICAR) in this sector which started during the late sixties subsequently culminated in the creation of the National Research Centre on Coldwater Fisheries (NRCCWF) as an independent Research Center on 24 September 1987 during the VII Five Year Plan.

This is the only national facility in the country to take up the research investigation on capture and culture aspects with a focus on exotic and indigenous coldwater fish species. Since its inception, the NRCCWF in spite constraints in terms of workforce and infrastructure has made a significant contribution for a proper appraisal of coldwater fishery resources and biology, culture & breeding, management practices for hill aquaculture, resource assessment, fish nutrition, fish health and species characterisation and development of molecular markers for important coldwater fishes.

3.3 Coldwater Fisheries for Sports, Recreation and Livelihood

Coldwater fishery encompasses broadly three significant objectives; resource assessment and sustainable utilisation, livelihood and nutritional security for uplands, sports and ecotourism for employment generation.

Figure 3.1: Coldwater Fisheries for Sports, Eco-tourism and Livelihood

SPORTS AND ECO-TOURISM	LIVELIHOOD
⇩	⇩
Fishery based Ecotourism	Fish Farming
Fish Angling	Ornamental Fish Trade
Fish Watching	Fish Feeds Units

An essential aspect of coldwater fish of the uplands is the opportunity the species provide for sport. Brown trout *(Salmo trutta fario),* rainbow trout *(Oncorhynchus mykiss)* and certain species of large-scaled barbels are the principal species of sports value in Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, North Bengal, Nilgiris, Kodai hills and Munnar ranges where Indian and foreign tourists annually visit in large numbers. In certain regions, sport fishery constitutes an important source of revenue. In Jammu & Kashmir trout alone contributes about 40-50% of the State's revenue from fisheries.

In India, angling has remained a favorite pursuit of the British in the first half of this century and it was mainly for this reason that brown trout and rainbow trout were introduced in the upland waters. In India, sport fishing is now a very popular outdoor recreational activity, which has given a boost to tourism in the Himalayas. The best sport fish are *Tor putitora, Tor tor and Salmo trutta fario.* One can expect that with fast increasing urbanisation in the country, recreational fishery will become even more popular as a means of escaping the crowded conditions of towns.

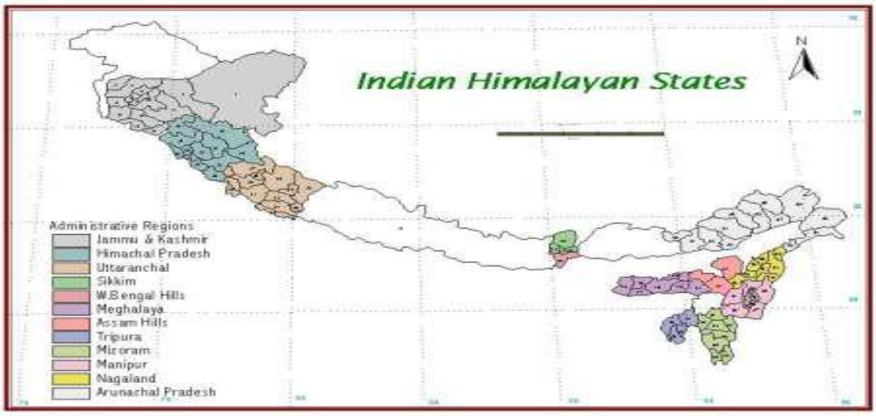
Fishery based ecotourism presents a sustainable form of resource use and also a means of environmental conservation. It is a non-consumptive use of biological resources that provides socio-economic benefits to the people. In the hill region, it gives an emerging area of employment generation through tourism generations. Many picturesque valleys, riverbanks, mountains are available for trout or mahseer based sport fishery development which also offers opportunities for the development of restaurants, transportation, parking, boating and angling facilities. The government has been working towards the development of suitable models for fish-based ecotourism development. Important spots were identified which have the potential to develop sports and angling facilities.

3.4 Coldwater Fishery Resources and Environment

The Indian Himalayan region spreading between 21^{o} 57' – 37^{o} 5' N latitudes and 72^{o} 40' – 97^{o} 25' E longitudes with a total geographical area of about 5,33,604 km^2 being inhabited by 3,96,28,311 people, representing approximately 16.2% of total area and 3.86% of the total population of India. India has significant coldwater/hill fishery resources in terms of the gene pool and some of them being suitable for food, sport and ornamental value extending from the long stretch of the Himalayas of around 2500 km from Jammu & Kashmir in the northwestern to Arunachal Pradesh in the northeastern and 200-400 km from north to south and some parts of western Ghats, comprising twelve states (FAO, 2003). The coldwater mountain fishery resources spread over the 12 hilly states of the Himalayan region are Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, and two partial hill states, namely Assam and West

Bengal and Peninsular India (Nilgiri hills in Tamil Nadu and Travan-core high ranges in Kerala) (Figure 3.2). Adjacent to India, Nepal and Bhutan are two Himalayan countries which are the major contributor of the coldwater fishery resources to India (Bora et al., 2015).

Figure 3.2: Map of Coldwater Fishery Resources in the Himalayan States of India



Source: ENVIS Centre on Himalayan Ecology, G.B. Pant National Institute of Himalayan Environment.

There are around 10,000 km long streams and rivers, 20,500 ha high and low altitudinal lakes and 50,000 ha of reservoirs both natural and manmade and 2500 ha brackish water lakes in the high altitudes (Table 3.1)

Table 3.1: Coldwater Resources of India

Waterbody	Area/length
Streams and Rivers	10,000 km
Natural Lakes	20,500 ha
Reservoirs	50,000 ha
Brackish water Lakes	2500 ha

Source: Directorate of Coldwater Fisheries Research, ICAR, Government of India.

The coldwater region is vast, uneven and versatile inhabiting rich biological floral and faunal diversity. These areas are broadly divided into eastern Himalaya, central Himalaya and western Himalaya, each of these having different physiography and faunal diversity. The Indian Himalayan region has vast freshwater resources primarily in its streams, rivers, lakes, and glaciers. The Himalayan region is drained by 19 major rivers. The main river systems draining the Himalayan region are the Indus, the Ganges, and the Brahmaputra. The Indus and the Brahmaputra are the longest, each having a mountain catchment of about 160,000 km^2. Five belong to the Indus system, of which the Beas and the Sutlej have a total catchment area of 80,000 km^2; nine (Ganga, Yamuna, Ram Ganga, Kali-Sharda, Karnali, Rapti, Gandak, Bhagmati, Kosi) belong to the Ganga system, draining nearly 150,000 km^2; and three (Tista, Raidak, Manas) belong to the Brahmaputra system, draining another 110,000 km^2. Most of these rivers flow in deep valleys until they exit the mountains. These lakes have diverse origins such as the retreat of glaciers, landslides and tectonic movements. The sizes of these lakes also vary as some are of the large area while others have small. In the Great Himalayan and Trans-Himalayan region, lakes are present at high altitude, with the highest lake situated at 5297 mamsl. some of them being brackish or saline.

The eastern Himalayan drainage by the Brahmaputra has a greater diversity of coldwater fish than the western Himalayan drainage. Among all these species, a few supports the capture fishery while some are being cultivated in the farm condition at different altitudes based on their temperature tolerances. This diverse natural resource-base, wide climatic diversity *vis-a vis* altitude is conducive to conserve and rear different fish species, developing the domestic market for high-value fish and growing interest of people aquarium pet keeping and eco-tourism including angling in different altitudinal regions of the country. The present exploitation of fishery resources in the upland areas comes mainly in the form of capture fisheries serving as subsistence fisheries. However, fish production through cultural practices is gaining momentum. These varied water resources in the uplands harbour are rich ichthyofaunal diversity comprising a large population of indigenous and exotic, cultivable and non-cultivable coldwater fish species having potential for aquaculture practices and capture fisheries. These coldwater resources are suitable for the cultivation of coldwater fishes like trout and exotic carp species (Bora et al., 2015). The aquatic resources available are quite valuable for the development of fishery both for food and sport. The mountain areas are mostly landlocked; fish in ponds, lakes, streams, rivers, and reservoirs play an essential role in providing food, income to people and source of animal protein (Kumar et al., 2012).

At present, the total fish production from upland areas contributes about 3% of the total inland fish production of India. The Directorate of Coldwater Fisheries Research (DCFR) being a national organisation catering to the research and development needs of the upland waters has achieved manifold success in the management of fish genetic diversity and the establishment of aquaculture in the hill regions of India. DCFR has also developed the technology of economically viable coldwater fish species such as mahseer, snow trout, minor carps and trout for enhancing production and productivity which has a positive impact on the employment generation and sustainable management of the aquatic resources and their piscine fauna of the hill region.

Table 3.2: Fishery Resources of the Himalayan Regions of India

Sl. No	Name of State	Length of rivers/canals (km)	Tanks & Ponds (lakh ha)	Lakes (lakh ha)	Reservoirs (lakh ha)	Total Water bodies (lakh ha)
1	Jammu and Kashmir	27781	0.170	0.060	0.070	0.300
2	Himachal Pradesh	3000	0.010	-	0.420	0.430
3	Uttarakhand	2686	0.006	0.003	0.200	0.209
4	Sikkim	900	-	0.030	0.006	0.036
5	Arunachal Pradesh	2000	2.760	0.420	-	3.180

Source: Handbook of Fisheries Statistics- 2014, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Government of India.

In these five Himalayan Indian states, the total length of rivers or canals is about 36,367 km, the area of tanks and ponds is 2.946 lakh ha excluding Sikkim, area of lakes and reservoirs are 0.513 lakh ha and 0.696 lakh ha respectively. The total water bodies are 4.155 lakh ha. Jammu and Kashmir have the largest length of the river or canals in this region and occupied the second position in India after Uttar Pradesh. The length of rivers in Sikkim is 900 km smallest amongst the other. Total water bodies are more substantial in the case of Himachal Pradesh of 0.430 lakh ha. These five Himalayan states contribute 18.64 percent of the length of the river/canals and 5.68 percent of total water bodies to India.

3.5 Ecological Scenario of Coldwater Fisheries

The coldwater fish fauna ranges from eurythermal to stenothermal regimes due to differences in microclimate conditions and habitat variations in aquatic biotopes and their thermal regimes. The fish species continuously inhabiting the different aquatic zones adopt different morphological characters to withstand the fast-flowing water currents. The occurrence and distribution of coldwater fishes apart from other habitat factors are largely governed by the temperature and altitudinal variations that dial other water quality parameters to sustain these fish species.

The distribution character of hill stream fishes is primarily dependent on water flow, substratum character, temperature profile, water quality and the availability of natural food. Of the 22, 000 fish species, over 40% live in freshwater and the majority of them live in tropics between latitudes of 2305' N and 2305’ S. Coldwater fishes are adapted to living in highly oxygenated water available in torrential streams in the mountains. Such an oxygen-rich environment has induced structural modifications in the respiratory organs such as reduced gills with narrow gill opening. Thus, the coldwater fishes of torrents cannot survive for long in the water poor in oxygen. The upper limits of oxygen for exotic trout and indigenous snow trout are 8 mg/l and above, whereas for carp and mahseer it is about 6.0 and 7.0 mg/l, respectively. The lower limits of oxygen for these coldwater fishes normally are 5-6 mg/l except for common carp which can survive at 3 mg/l oxygen concentration also.

3.5.1 Ecological Viability of Fish Farming and Aquaculture

The ecological viability of fish farming and aquaculture refers to the physical, chemical and biological characteristics of water and social quality that affect the production of fish. Appropriate site selection is one of the most important factors that determine the success of fish farms. Before the construction of a pond, water retention, capacity of the soil and soil fertility have to be taken care of because these factors influence the response to the organic and inorganic fertilisation in the farm pond. The selected site should have adequate water supply round the year for pond filling and other use. The pond construction has to be made based on the topographic area and the species of fish culture. The site should be free from pollution, industrial waste, domestic waste and any other harmful activities that affect the health of fish. The objective of pond management is to manage the water quality to provide a relatively stress-free environment that meets the physical, chemical and biological standards for the fish's normal health and production performance. Within a pond water quality consist of the quality of water at the water source, the quality of the pond soils and immediate environment and production technology and management procedures employed those associated with feeding, the maintenance of adequate dissolved oxygen as well as many other chemical or input applied.

3.5.2 Physio-Chemical Parameters of Pond Water for Trout and Carp Species

Water is the most key component for living things to exist on earth. Water is considered to be a cultural environment for fish and other aquatic organisms to perform all their body function. The aquatic animals like fish depend entirely upon water to breathe, feed and grow, excrete wastes, maintain a salt balance and for reproduction (Bronmark & Hansson, 2005). Water quality within aquaculture ponds can affect these functions and therefore, will determine the health of the fish and consequently the success or failure of a fish farming operations. The success of aquaculture and fishing enterprises depends on the optimum environment of the water ecosystem for the prompt growth species growth at the minimal cost of capital and resources. Even though the aquatic environment is a complex ecosystem comprises of multiple water quality parameters, the most crucial parameters are colour, odour, transparency, temperature, pH, dissolved oxygen, free CO_2, TDS, BOD, EC, hardness, acidity and alkalinity (Boyd, 1990). The maintenance of optimal and good water quality is vital for healthy fish culture. Other things being equal, a pond with good water quality will result in more and healthier fish than a pond with poor quality. The following table illustrates some of the important physiochemical characteristics of coldwater fish species for trout and carp.

Table 3.3: Suitability Levels of Water Quality, Soil Quality and Infrastructural Facilities for Trout and Carp Culture

Parameters	Suitability rating and scores		
Water Quality	Most suitable for trout	Moderately suitable for trout	Suitable for carp
Temperature (^oC)	12.0-16.0	16.0-22.0	>22.0
pH	7.0-8.0	6.5-7.0 & 8-8.5	6.5-7.0 & 8-8.5
Do (mg/l)	>8.0	6.5-8.0	<6.5
CO_2 (mg/l)	0-5.0	5.0-8.0	>8.0
Total Alkalinity (mg/L)	30-60	20-30 & 60-100	>100

Hardness (mg/L)	30-100	20-30 & 60-100	>100
Phosphate (mg/L)	0.05-0.25	0.25-0.40	>0.4
Nitrate (mg/L)	<0.5	0.5-1.0	>1.0
Transparency (cm)	80-120	60-80	<60
Soil Quality			
Soil pH	6.5- 8.5	6.5-8.5	6.5-8.5
Soil texture (% clay)	-	-	>35
Infrastructure Facilities			
Distance to water body (m)	<200	200-500	>500
Distance to road (m)	<500	500-1000	>1000
Distance to hatchery	10000	10000	10000 or > 10000

Source: Annual Report 2013-14, Directorate of Coldwater Fisheries Research, ICAR, Government of India. https://www.dcfr.res.in/

Fish and other aquaculture organisms are cold-blooded animals. Their rate of metabolism is directly influenced by water temperature. Temperature directly affects growth, oxygen demand, food requirement and food conversion efficiency of fish and other water bodied organisms. The species of fish that is culture depends on the optimum temperature condition. The optimal growth and reproduction success of these organisms depends on the optimum level of temperature. It is, therefore, important to select a culture species that is best suited to the climatic condition and environment for fish cultured. The optimum range of temperature most suitable for trout culture is 12^{o}C-16^{o}C, moderately suitable is 16^{o}C -22^{o}C and suitable for carps is > 22.00^{o}C. pH or the concentration of hydrogen ions (H^+) present in pond water is a measure of acidity or alkalinity. The pH scale ranges from 0 to 14 with 0 being the most acidic and 14 the most alkaline. pH of 7 being neutral. A pH below 7 is acidic and pH of above 7 is basic. An optimal range of pH is between 6.5 and 9 however this will alter slightly depending on the culture species. pH value of 7.0-8.0 is most suitable for trout, 6.5-7.0 & 8-8.5 is moderately suitable for trout and that of 6.5-7.0 & 8-8.5 is suitable for carp culture. Dissolved oxygen is an important water quality parameter because it gives an idea about the health of the water. Oxygen level in ponds depends on water temperature, stocking rates of aquaculture species, salinity and the amount of phytoplankton and zooplankton in the ponds. Clean water contains high dissolved oxygen whereas polluted water contains low dissolved oxygen. Low dissolved oxygen can be a serious cause of aquaculture species. Some of the effects include stress, increased susceptibility to disease, poor feed conversion efficiency, even poor growth and death. Most desirable range of DO for trout is >8.0 (mg/l), 6.5-8.0 (mg/l) is considered as moderately suitable for trout and < 6.5 (mg/l) is suitable for carp species. Cardon dioxide is found in the pond in the form of bicarbonate and carbonate. It serves as a chemical source required to buffer the environment against rapid shifts in acidity alkalinity status. The CO_2 helps to regulate the biological process in aquatic species. Another most important contribution of CO_2 is that it works as an important source of organic carbon for an aquatic organism. Most desirable range of CO_2 for trout is 0-0.5 (mg/l), 5.0-8.0 (mg/l) is considered as moderately suitable for trout and >8.0 (mg/l) is suitable for carp species. Total alkalinity measures the total concentration of hydroxides, carbonate and bicarbonate of substances such as calcium and magnesium which are naturally alkaline. It indicates the degree of variation of water pH and availability of CO_2 which is effective for the production of microscopic algae. The bicarbonate ions provide CO_2 to autotrophs for photosynthesis (Ruttner, 1985). Munawar (1970) stated that the concentration of carbonate is influenced by free CO_2 concentration in water. Used of organic manure in fish pond increases the values of alkalinity (Srisumantach et al, 1982). The ideal range of alkalinity most suitable for trout is 30-60 (mg/l), moderately suitable for trout is 20-30 (mg/l) and 60-100 (mg/l), and suitable for carp is >100 in a fish pond for providing best result in fish farming. The hardness of water is a measure similar to the total alkalinity. Dissolved solids and pH determine the level of water hardness. It usually measures the total concentration of calcium and magnesium and strontium dissolved in water. Proper liming can correct the level of water hardness but liming is not suitable in trout culture. The ideal value of hardness for trout is 30-100 (mg/l), moderately suitable for trout is 20-30 (mg/l) & 60-100 (mg/l) and for carp is greater than 100 (mg/l). Although the concentration of phosphate in water is small, it plays an important role for the production of phytoplankton that forms food for fishes. The optimum range of phosphate most suitable for trout culture is 0.05-0.25 (mg/l), moderately suitable for trout is 0.25-0.40 and suitable for carps is >0.4 (mg/l). Even in the large concentration of nitrate in water, it is not toxic to aquatic animals. The ideal range of nitrate for most suitable trout area is < 0.5, moderately suitable is 0.5-1.0 and for carp is >1.0. The water transparency most suitable trout for trout is 80-120 cm and moderately suitable for trout is 60-80 cm and that for carp is less than 60 cm. The ideal Soil pH most suitable for trout is 6.5-8.5, moderately suitable for trout is 6.5-8.5 and that of carp is 6.5-8.5. The soil texture for carp should be greater than 35 percent.

Infrastructure facilities are also crucial factors that affect the feasibility of any project to start. DCFR recommended that the ideal distance of pond from the water body for most suitable trout, moderately suitable trout and carp are < 200 m, 200-500 m and > 500 m respectively. The distance of road to the pond should be < 500 for most trout suitability, 500-100 for moderately trout suitability and for carp it is > 1000. Similarly, the distance of pond to hatchery should be 10000, 10000, 10000 or > 10000 for the above stated criteria. From these above facts, it can be said that the above stated infrastructural facilities should have in the nearby sites and for trout it should nearer than the carp farm.

3.6 Coldwater Fish Diversity in Indian Himalaya

The water bodies of the Himalayan region inhabit diverse kinds of fish fauna. Out of total fish fauna available in India 17% fishes were recorded from the mountain ecosystem establishing the status of the area as a center of origin and evolution of biotic forms (Ghosh, 1997). The mountain fishery resources of India consist of around 258 fish species distributed in the Himalayan and peninsular region of the country of which indigenous mahseer, snow trout, exotic trout, and common carp are commercially important (Singh et al., 2014). Out of these, a maximum of 255 species is recorded from North-East Himalaya, 203 from the west and central Himalaya and 91 from the Deccan plateau. About 36 species of freshwater fishes (out of 1,300) are endemic to the Himalayan region (Ghosh, 1997). The distribution of fish species in the Himalayan streams depends on the flow rate, nature of substratum, water temperature and the availability of food. The species distribution in the upper reaches of the stream/river where water has a torrential flow is different from the mid and lower reaches of the stream where the flow is moderate and the water current is soft. Following are the list of some of the important fish species both indigenous and exotic found in the Himalaya of India and other Himalayan countries (Table 3.4).

Table 3.4: Important Coldwater Fishes both Indigenous and Exotic found in the Himalaya

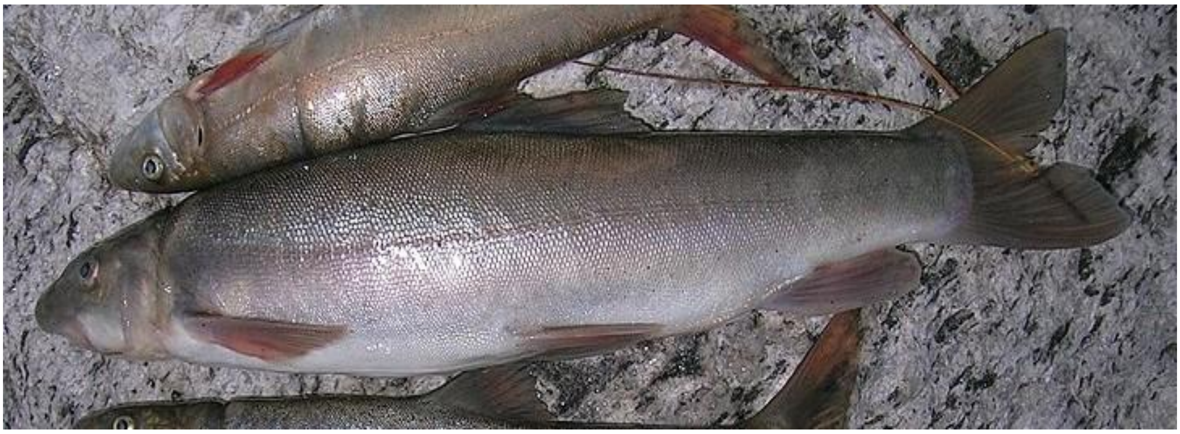
A. Indigenous Species		B. Exotic Species
1. Snow-trouts:	**3. Minor carps:**	**1. Exotic trouts:**
Schizothorax richardsonni	*Labeo dyocheilus*	*Onchorhynchus mykiss*
Schizothoraichthys curvifrons	*Labeo dera*	*Salmo trutta fario*
S. longipinnis	*Crossocheilus latius latius*	*Salvelinus fontinalis*
S. esocinus	*Gara gotyla*	**2. Other Exotics:**
S. niger	*G. hughi*	*Cyprinus carpio var. specularis*
S. plannifrons	*Puntius ophicephalus*	C. *carpio var. communis*
S. micropogon	**4. Barils/Minnows/Catfishesl Loaches:**	C. *Carpio vaT. nudus*
S. progastus	*Barilius .bendelisis*	*Tinca tinca*
S.nasus	*B. bakeri*	*Carrasius carrasius*
S. hugef/i	*B. vagra*	
Lepidopygopsis t	*B. barila*	
2. Mahseer:	*Raimas bola*	
Tor putitora	*Danio divario*	
T. tor	*Bofia birdi*	
T. khudree, T. musallah	*Glyptothorax pectinopterus*	
Neofissochilus hexagonolepi	*G. conirostre conirostre*	

Source: Directorate of Coldwater Fisheries Research, ICAR, Government of India.

Snow Trout

Snow trout is endemic to the Himalayas. It is found in streams, rivers, and lakes at high altitude which receive snow-melt water from the Himalayas. Most of the species are of Central Asian origin. Ten principal species belonging to two genera viz., *Schizothoraichthys* and *Schizothorax* inhabit the Himalayan region. *Schizothoraichthys esocinus* is endemic to Kashmir and Ladakh while S. *progastus* occurs in Eastern Himalayas. S. *richardsonii* is distributed almost all along the Himalayas. The other species of snow trout *viz. Schizothorax longipillnis, S.curvifrons,* S. *planifrons,* and S. *micropogon* are endemic to Kashmir and Ladakh.

Figure 3.3: Picture of Snow Trout Schizothorax (Aasla)



Mahseers

There are 4 species of mahaseer. Mahseer is a highly sporty and recreational game fish available in the foothills of the Himalayan river system. The principal species of mahseers which contribute to the sport fishery are *Tor putitora, Tor. tor* and *Tor. mosal.* Two of them are edible fishes and are of commercial use, they are Tor putitora and Tor tor. They exist from Kashmir to Assam. Mahseer is a migratory fish running in the main rivers for spawning' and its distribution has more to do with the water temperature prevailing in the streams rather than the altitudinal range. They are about 1.5m in length and breed from July to September. Tor mosal is available in Kashmir, Sikkim and in rivers of Assam. Tor khudree (Deccan Mahseer) are found in the rivers of southern part of India. It is found at an elevation of 875 below. In the past, there was a sharp decline in catches of the mahseers, which have been declared endangered fish in India. However, many angling associations have made an effort to create awareness among the fishing community and devoted anglers, in particular, to conserve the threatened genetic material in the Himalayas.

Figure 3.4: Picture of Himalayan Mashseer or Golden Masheer (Tor putitora)

Barilius

Barilius species such as Barilius vagra, B. bendelisis and, B. bola commonly called as mountain trout and Indian hill trout found throughout India, Nepal, Bhutan, Pakistan, Sri Lanka, Myanmar, Bangladesh and Thailand hills (Hamilton, 1807). It is also known to be one of the primary commercial hill stream fishes in maximum of the streams and rivers of eastern Himalaya, Ganga region and Arunachal Pradesh. This is a demanding food fish and has a very good potential in ornamental fish industry. Breeding season is March to May depending on environmental temperature.

Figure: 3.5: Picture of Barilius Species

Labeo

This fish comes under the family of minor carp species. The fishes are basically found in mountain rivers and streams and have no significance as commercial fisheries. The fishes of Labeo are L. dera, L. dyocheilus and Crossocheilus latius etc.

Figure 3.6: Picture of Labeo Species

Garra

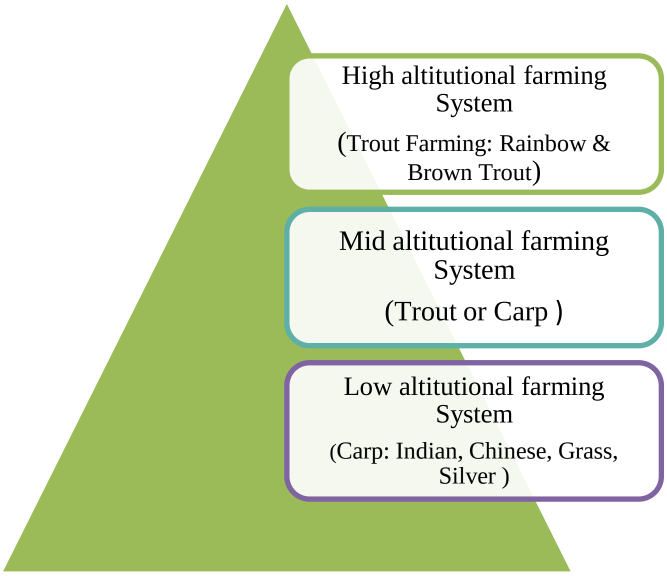
These species are not edible fishes but they are realised as food of fishes. The two species found in lakes of the Himalayas are Garra lamta and Garra gotyli.

Figure 3.7: Picture of Garra Species

3.7 Coldwater Aquaculture in Indian Himalaya

Coldwater fisheries in the Indian subcontinent was initiated by the British administrator turned naturalist by introducing two main types of trout viz. brown trout *(Salmo*trutta *fario)* and rainbow trout *(Oncorhynchus mykiss)* around the beginning of the last century. This was done primarily to meet their needs for sport fishing or recreational angling. Such initiatives in India could be considered as the formal beginning of coldwater fisheries development in the country. For many decades the mere intention remained to develop recreational fisheries to satisfy the needs of anglers for sports. Later on, these species began to be cultured for food and hatcheries were set up for the production of seed. The development of hill fisheries thus started in the selected locations mainly in the Kashmir valley and some parts of peninsular India. Gradually, an importance and the production of coldwater fishes also started in other fully or partially hilly states of India. In India, aquaculture of coldwater had been initiated in the three prolonged farming systems (Figure 3.8). At high altitudinal zone, production and conservation of trout species such as rainbow and brown trout were initiated and at mid altitudinal zone, production of both trout and carp species were encouraged as per the suitability. Similarly, at low altitude, carp species such as Indian, Chinese, common, grass and silver carps were initiated for cultivation.

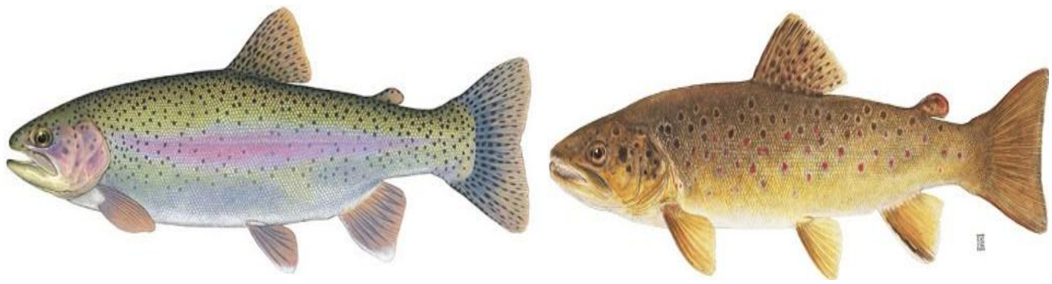
Figure 3.8: Aquaculture in the Himalayas: Three Prolonged Farming System.



Trout Fishery

Brown trout *(Salmo trutta fario)* and rainbow *(Oncorhynchus mykiss)* are the two species which constitute trout fishery in the streams, lakes and reservoirs in the Indian uplands. In the Himalayan region, *Salmo trutta fario* is the only trout that supports sport fishing while in the southern region, a rainbow is the principal one. Since trout fishery is only for recreation, catching them by the net is strictly prohibited in both the regions. To provide adequate stocks to anglers, the streams, lakes, and reservoirs are planted with eyed ova and fry of the two species of trout. But since the early 90s, the country has taken up farming of rainbow trout in several fish farms in Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Arunachal Pradesh, Sikkim and other hilly North-Eastern parts where fish is now available for food and farming. These species are now cultured in the pond to encouraged hilly farmers and they are fetching a good market price of these fishes.

Figure 3.9: Picture of Rainbow and Brown Trout

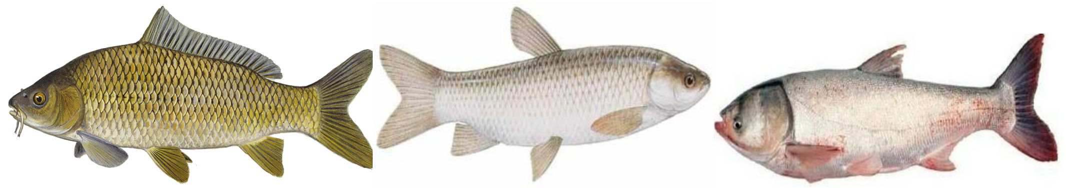


a. Rainbow Trout (*Oncorhynchus mykiss*) b. Brown Trout (*Salmo trutta fario*)

Carp Fishery

Carp fishes such as common carp, grass carp, silver carp and other minor carps have been culturing in the Himalayan hills and the peninsular regions of India. It constitutes the bulk of the commercial fishery of certain lakes, reservoirs and a large number of ponds in these regions. Except for Kashmir, the lakes and reservoirs in most other upland states have been stocked with silver and grass carp to increase yield. While in some cases, these practices have increased per-unit productivity, it has also resulted in a sharp decline in indigenous fishery. The majority of fish production from the upland regions is fundamentally based on the contribution made by these exotic trout and carps.

Figure 3.10: Picture of Common Carp, Grass Carp and Silver Carp



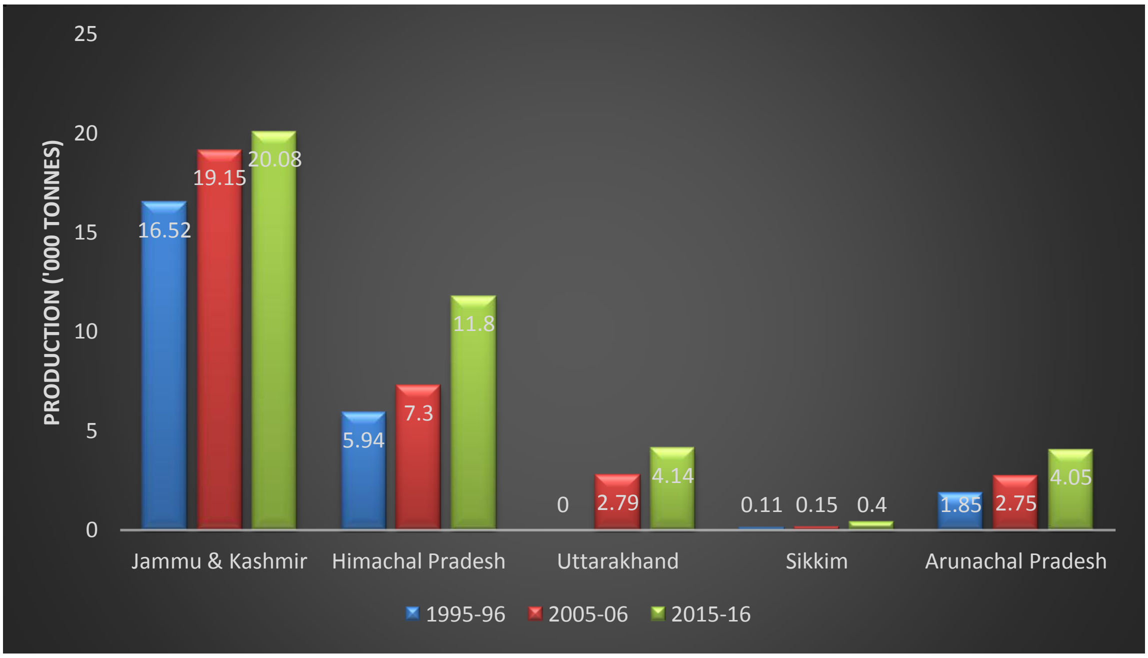
a.. Common Carp b. Grass Carp c. Silver Carp

Ornamental Fishery

The water resources both the streams and lakes hold a sizable population of ornamental fishes. In the western Himalayas streams and tributaries of river Ganga and Indus Systems, namely Alaknanda, Yamuna, Ganga, Bhagirathi, Kali, western Ramganga and Saryu drainages in Uttarakhand, Yamuna, Beas, Sutlej, Ravi, Tawi and Chenab drainage in Himachal Pradesh and Indus, Jhelum, Chenab and Ravi drainages in Jammu and Kashmir. The valley lakes and mountain lakes of these states are important resources of ornamental fishes. More than 100 varieties of fishes are known for their ornamental value. The important ornamental fishes are the barils (*Barilius spp*.), danios (*Danio devario, Brachydanio rerio, Esomus danricus and Rasbor spp*.), barbus (*Puntiusspp.*), catfishes (*Channa spp*.), loaches (*Botia spp., Nemacheilusspp*.), minor carps (*Crossocheilus latius labus, Garra spp., Labeo spp.)* and *sisorids (Glyptothorax spp*.).

At present North-Eastern Himalaya region is the stakeholder in the trade of ornamental fishes with 85% of the market share of India. In the western Himalayan states, Jammu and Kashmir, Himachal Pradesh and Uttarakhand, the ornamental fish trade is virtually absent. On the other hand, these states have great potential for the development of this trade. To develop an organised ornamental fish trade proper strategy, have to be devised beginning from the identification of the potential resources, selection of suitable species for artificial propagation and undertaking biological investigations of these species in regards to their food and feeding, growth, maturity, fecundity and reproduction.

Figure 3.11: Coldwater Fish Production in the Himalaya of India (in '000' tonnes)



Source: Data taken from the Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Department of Fisheries, Government of India.

Fish production in all the five Himalayan states is taken into consideration for two decade and it is observed that there is an increase in fish production in all the states. Jammu & Kashmir is the largest producer of coldwater fishes in India. During 1995-96, production was 16.52 mt which increased to 19.15 mt in 2005-06 and 20.08 mt in 2015-16. Himachal Pradesh is the second-largest cultivator and producer of coldwater fishes in India. Its production increased from 5.94 mt in 1995-96 to 7.3 mt in 2005-06 and 11.8 in 2015-16. In Uttarakhand, the production was 2.79 mt in 2005-06 which increased to 4.14 mt in 2015-16 with a growth of 38 percent. The production of fish in Sikkim was lowest amongst these states because it being a smallest state in terms of area as well fewer area are under cultivation than other states, although, production increased from 0.11 mt in 1995-96 to 0.15 mt in 2005-06 and 0.4 mt in 2015-16 with a growth of 166 percent during this decade. During 1995-96, fish production in Arunachal Pradesh was 1.85 mt which increased to 2.75 mt in 2005-06 and 4.05 mt in 2015-16. The coldwater fish production in all the five states have been increasing which witnessed from the production data of the two decades and Figure 3.11.

Table 3.5: Decadal Growth Rate of Fish Production (in %)

States	**1995-96 to 2005-06**	**2005-06 to 2015-16**
Jammu & Kashmir	15.92	4.86
Himachal Pradesh	22.72	51.99
Uttarakhand	-	47.31
Arunachal Pradesh	48.65	47.27
Sikkim	20.00	166.67

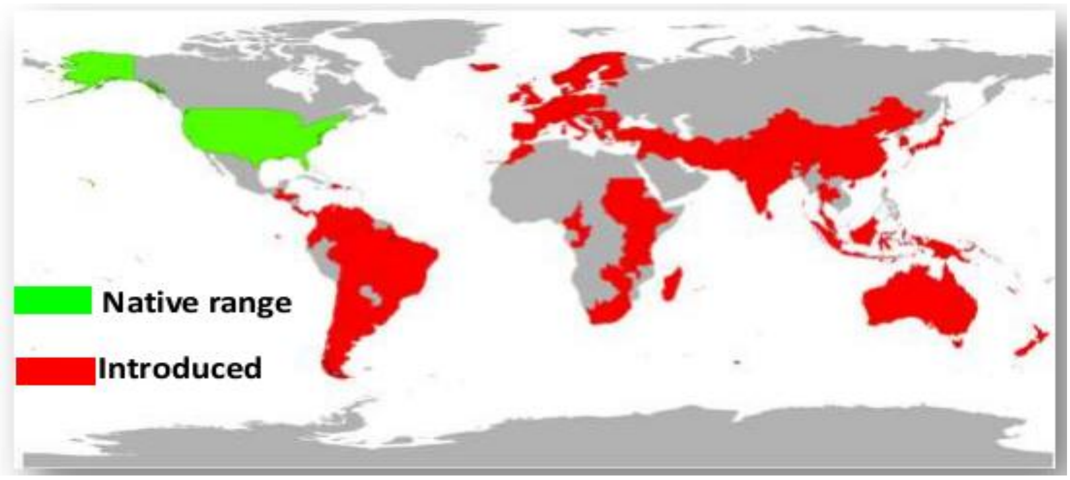
Source: Author's Calculation.

Table 3.5 shows the decadal growth rate of coldwater fish producing states of Indian Himalaya for the period 1995-2005 and 2005-2015. During the period 1995-2005, the growth rate of fish production was observed to be highest in Arunachal Pradesh (48.65 %), followed by Himachal Pradesh (22.72 %), Sikkim (20.00 %) and the lowest was Jammu & Kashmir (15.92 %). Moreover, during 2005-15, the growth rate was highest for Sikkim (166.67 %), followed by Himachal Pradesh (51.99 %), 47 % for Arunachal Pradesh and Uttarakhand and 4.86 % for Jammu and Kashmir. The growth rate extremely decreased for Jammu and Kashmir, slightly decreased for Arunachal Pradesh, increased for Himachal Pradesh and extremely increased for Sikkim. Though annual production was lowest but growth rate was observed to be highest in Sikkim. This would indicate that all the states are performing better in aquaculture and fish farming and Sikkim is also moving towards the growing phase of aquaculture development.

3.8 Global Introduction of Trout Species

The rainbow trout was originated from the west coast of North America which was first introduced by Richardson in 1839 from specimens collected in the Columbia river. Originally, rainbow trout was native species to the coastal areas of the United States and Canada ranging from Alaska as far as south of Mexico (Bromage & Cumaranatunga, 1988).

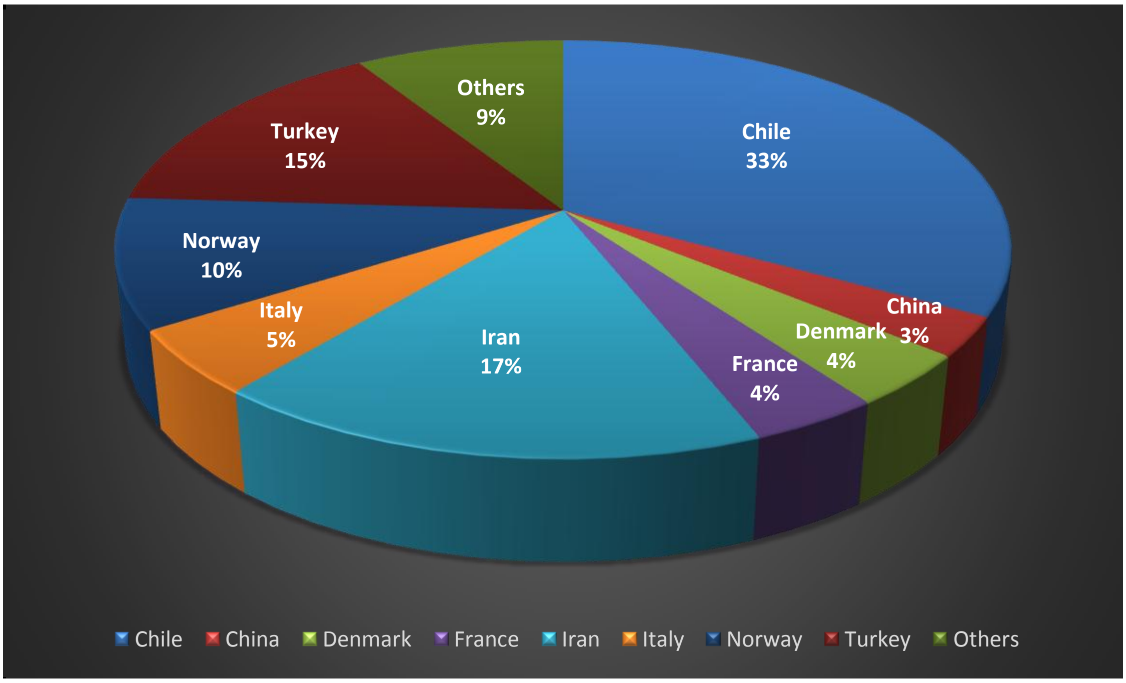
Figure 3.12: Map of Trout Producing Countries of the World



Source: Global Invasive Species Database, 2012

The first rainbow trout spawning station was established on the McCloud River in California in 1879. The first successful transfer of rainbow trout eggs out of North America was made to Japan in 1877. In 1885, eggs were sent to England and Scotland. Later on, species was also introduced in most southern and central areas of America, Africa, Austria and New Zealand and other European and Asian countries. Chile is the highest producer of rainbow trout in the world contributing 33 % of global production followed by Iran (17 %), Turkey (15 %), Norway (10 %), Italy (5 %), Denmark (4 %), French (4 %) China (3 %), Spain, and the UK, USA (2 % each) and Japan, Germany and Poland (1 % each) (Figure 3.13).

Figure 3.13: Major Rainbow Trout Producing Countries of the World



Source: FAO, 2014.
Note: Others includes like Spain 2%, Germany 1%, Poland 1%, UK 2 %, USA 2%, Japan 1

3.9 Trout Production in India

In the Indian subcontinent two main types of trout viz. brown trout and rainbow trout were transplanted from Europe primarily to develop sports fishing or recreational angling (Jhingran & Sehgal, 1978 and Singh & Lakra, 2011). Trout introduction in India dates back to late 19th and early 20th century under colonial rule by British, who made independent efforts in north-western and peninsular region of the country where suitable coldwater for trout is available (Vass et al., 2010).

In northwestern regions of India, most suitable climatic condition and topography for trout farming exist in Jammu and Kashmir and Himachal Pradesh which are important states where rainbow trout farming has progressed on large scale. In 1984, a Trout fish Farming Project was established in Jammu and Kashmir at Kokernag with the assistance of European Economic Council which is the largest trout farming project in Asia tremendously helped developing trout farming in the state. Trout farming in Himachal Pradesh started during 1989-91 through the assistance of Norwegian Government which was the next leading states in rainbow trout farming and seed production in India. In central Himalaya, Uttarakhand while in northeastern Himalaya, Sikkim and Arunachal Pradesh have now initiated producing trout. Recently many farmers and entrepreneur have adopted trout farming and thus contributing to the total trout production. In the state of Arunachal Pradesh trout broodstock and seed production is being done in two main hatcheries situated at Shergaon of west Kameng and Nuranang in Tawang district. Shergaon has ova production capacity of 100,000. However, rainbow trout farming is yet to reach private farmers in the state. In central Himalayan region, Uttarakhand is one of the promising states where trout farming has good prospects. In the early 1990s, farming of rainbow trout started on different fish farms located in the Himalayan region of India on a commercial scale.

In peninsular India, the very first attempt to introduce trout eggs and fry from New Zealand was made in 1863 by Sir Francis Day in Nilgiri and a hatchery was constructed in Avalanche in 1909-1910 (Jhingran & Sehgal, 1978; Gopalakrishnan et al., 1999; Sehgal, 1999a; Sehgal, 1999b). In the Munnar high range of Kerala, establishment of trout fishery started in 1909 with the introduction of brown trout which could not succeed and therefore, after 1938 the focus shifted towards rainbow trout farming for aquaculture production in coldwater areas in India.

Today rainbow trout farming in India are existing in different parts of Himalayas such as Northwestern Himalayan region: Jammu and Kashmir, Himachal Pradesh; Central Himalayan region: Uttarakhand; Northeastern Himalayan region; Sikkim, Arunachal Pradesh. On a small scale, it is also cultured in Southern Uplands of Ooty in Tamil Nadu and Munnar in Kerala in Deccan Plateau. Trout is also cultured in some parts of Darjeeling and Kalingpong districts of West Bengal and some upland regions of Northeast India (Figure 3.14).

Figure 3.14: Map of Rainbow Trout Producing States of India

Source: Directorate of Coldwater Fisheries Research, ICAR, Government of India.

Table 3.6: Status of Trout Infrastructure in India

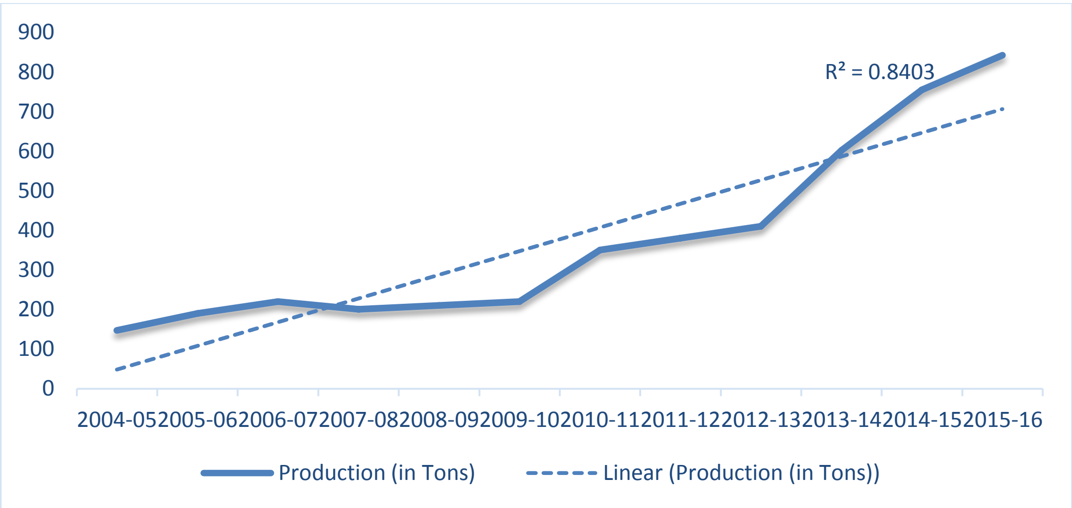
	No. of Govt. Farm	**No. of Private Trout Growers**	**No. of Govt. Hatcheries**	**No. of Govt. Feed Mills**	**Culture Status**
Jammu & Kashmir	42	343	14	3	Govt. & Private Sector
Himachal Pradesh	5	572	9	2	Govt. & Private Sector
Sikkim	8	249	5	Nil	Govt. & Private Sector
Uttarakhand	4	15	3	1	Govt. & Private Sector
Arunachal Pradesh	3	-	2	Nil	Govt. Farm only
Tamil Nadu	1	-	1	Nil	Govt. Farm only
Kerala	2	2	2	Nil	Farms (Private)

Source: Directorate of Coldwater Fisheries Research, ICAR, Government of India, and Census 2011

The trout production infrastructure has also been developed steadily in the country during the last 20 years and presently around 65 trout farms are under Government sector with 1181 numbers of raceways are spread over seven states in the western, northeastern and peninsular region of the country. A total of 36 trout hatcheries with an estimated eyed ova production capacity of 13 million are present in the country which have been mostly established by the various state governments. These hatcheries or seed production units cater the need of farmers, private entrepreneurs and also supply to different government agencies for building their stocks. Moreover, it is estimated that over 1181 numbers of trout units exist in the private sector mostly located in the Himachal Pradesh, Jammu & Kashmir and Sikkim states. There are only 6 Government trout feed mills in the country which needs to increase in the coming years.

Jammu and Kashmir have the largest number of Govt. trout farms in India of about 42 units, followed by Sikkim 8 units, Himachal Pradesh 5 units and Uttarakhand 4 units. Jammu and Kashmir have 14 units of hatcheries, 9 in Himachal Pradesh, 5 in Sikkim, 3 in Uttarakhand. A good number of farmers have adopted trout farming in Himachal Pradesh of 572, Jammu and Kashmir around 343 and Sikkim around 249.

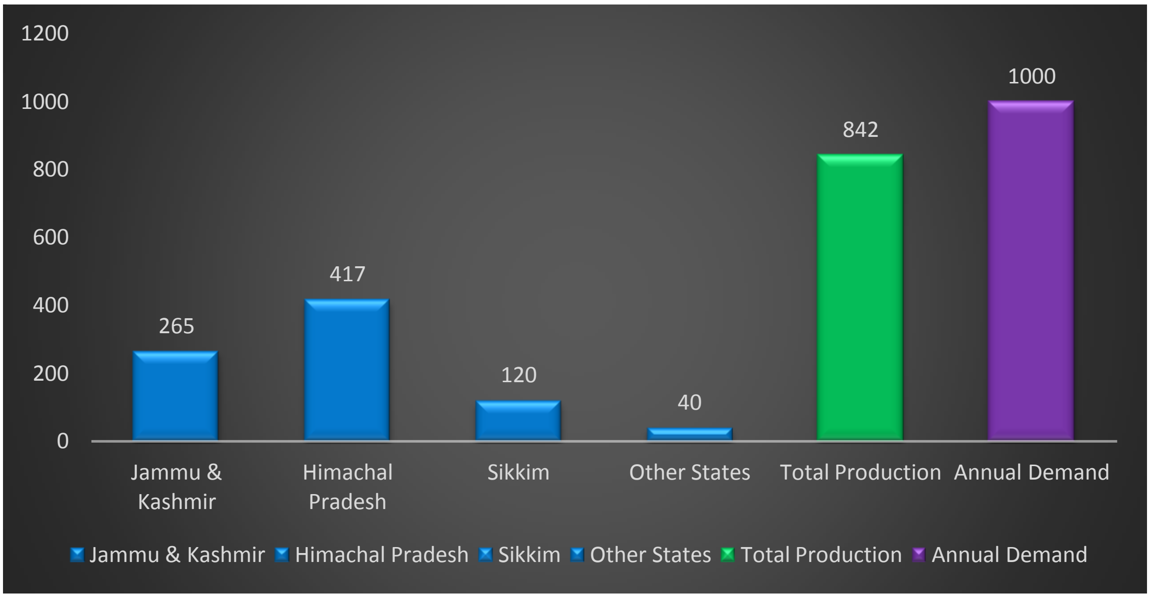
Figure 3.15: Rainbow Trout Production (in tonnes) in India 2004- 05 to 2015-16



Source: Data taken from the Directorate of Coldwater Fisheries Research, ICAR, Government of India.

From figure 3.15, it is apparent that the rainbow trout production in India is showing a positive and growing trend. Although, there are fluctuations in the production, the production of rainbow trout has progressed gradually during the last decades in the Himalaya of India. The total rainbow trout production in India has increased from a mere 147.0 tonnes in 2004-05 to 602.0 tonnes in 2013-2014, 755 tonnes in 2014-15 and 842 tonnes in 2015-16. The annual growth rate of trout production in this duration remained 25.42% in 2014-15 and 11.52 % in 2015-16. From this result, it can be said that there is potentiality in trout farming or trout culture in the mountain states of India. An increase in trout production during the last decades was due to the technical know-how of trout farming, breeding and artificial diets have immensely helped in promoting aquaculture of trout in the country. Further expansion of rainbow trout farming and intensification of production requires commercial involvement in inputs quality (seed and feed) and governance.

Figure 3.16: State-wise Rainbow Trout Production in India 2015-16 (in tonnes)



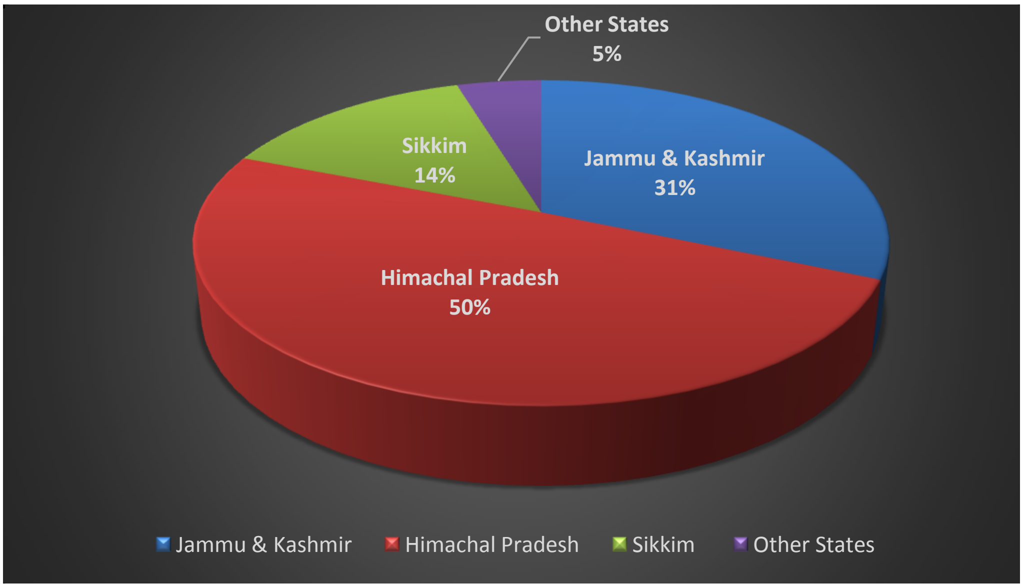
Source: Data taken from the Directorate of Coldwater Fisheries Research, ICAR, Government of India.

Himachal Pradesh, Jammu & Kashmir and Sikkim are the leading states where trout farming is undertaken in both private and public sectors. During 2015-16, Himachal Pradesh was the largest trout producer in the country which stood 417.23 tonnes followed by Jammu and Kashmir (265 tonnes), Sikkim (120 tonnes) and Uttarakhand and Arunachal Pradesh (40 tonnes). The northwestern Himalayan region (Jammu & Kashmir and Himachal Pradesh) remained the center of trout production in India. These two states contribute the bulk of India's trout production of about 81%

(50% from Himachal Pradesh and 31% from Jammu and Kashmir), Sikkim contribute 14% and other states contribute 5 % of total production in India (see Figure 3.17).

This is because trout farming in India was started initially in the states of Jammu & Kashmir and Himachal Pradesh having the larger water resources as well as the larger trout growers. Jammu and Kashmir and Himachal Pradesh are the hubs of coldwater fishery resources and fish species. Sikkim, another Himalayan state of India situated in the northeastern region is also performing well in trout farming and occupies the third position leaving behind Uttarakhand and Arunachal Pradesh. The total trout production in the country stood at 842 tonnes and the demands is around 1000 tonnes in 2015-16. At the present situation, the demand exceeds the supply, therefore, we can infer that there is a scope of trout farming in India

Figure 3.17: State wise Contribution to Total Trout Production in India in 2015-16



Source: Data taken from the Directorate of Coldwater Fisheries Research, ICAR, Government of India.
Note: Other states includes Uttarakhand, Arunachal Pradesh

3.10 Estimation of Fish Production for the year 2017-18 to 2020-21

To predict the fish production for the Himalayan states of India, let us consider a two-variable linear regression model as

$$Y_t = \alpha + \beta X_t + \mu_t \qquad 3.1$$

Where Y_t is fish production for period t

X_t is time period and

U_t is a random disturbance term.

In this equation production is regressed with the time period in years

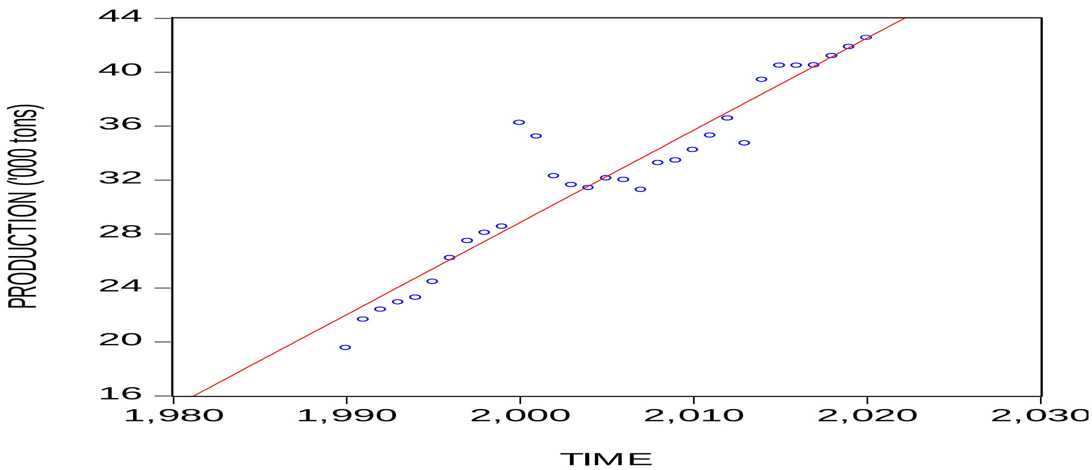
$$Y_t = -1336.71 + 0.6828X_t \qquad 3.2$$

t(value) (12.0627) (-11.7899)

p (value) (0.0000) *** (0.0000) ***

R^2 = 0.8533

Figure 3.18: Actual and Estimated Value of Fish Production (1990-91 to 2020-21)



Source: Data taken from the Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Department of Fisheries, Government of India.

The Indian Himalayan States have witnessed an increasing trend in fish production over the years although the production yield is less compared to plain land states. In 1990 -91, the total fish production of five states was 19.55 mt, 24.46 mt in 1995, 36.24 mt in 2000-01, 34.23 mt in 2010-11, 40.47 mt in 2015-16, which remained the same for 2016. The estimated production for 2017-18, 2018-19, 2019-20 and 2020-21 are 40.50 mt, 41.18 mt, 41.86 mt and 42.54 mt respectively. Not much difference is found in annual fish production for the years 2015 to 2017 and the predicted value for 2018 to 2020.

3.11 Conclusion

The Himalayan regions of India hold abundant water resources available in the form of rivers, lakes, tanks, reservoirs etc. which have diverse varieties of fish species that are exotic and indigenous, cultivable and non cultivable fish species. These water resources are suitable for the capture as well as culture fisheries. The Jammu & Kashmir have the largest river or canals i.e. 27,781 km while Arunachal Pradesh has the largest water bodies i.e. 3.180 lakh ha amongst these five Himalayan states of India. Jammu & Kashmir are the largest producer of coldwater fish followed by Himachal Pradesh and Uttarakhand. During 1990-91, the total fish production in these five states was 19.55 mt which increased to 36.24 mt in 2000-01 with a decadal growth rate of 85.37 %. But unfortunately, production slightly decreased by 2.01 mt with a negative growth of 5.54 %. In 2016-17, the production reached to 40.07 mt. It has been observed during 1995-96 to 2005-06, the growth rate was highest in Arunachal Pradesh and in 2005-06 to 2015-16, Sikkim had able to achieved a highest growth in fish production. As far as trout infrastructure in the Himalaya is concerned, Jammu and Kashmir have the largest number of Govt. hatcheries followed by Himachal Pradesh and Sikkim. On the other hand, the number of private trout growers are higher in Himachal Pradesh followed by Jammu and Kashmir and Sikkim. Himachal Pradesh contributed 50 % of the total trout production in India followed by Jammu and Kashmir 31 %, Sikkim 14 %, Uttarakhand and Arunachal Pradesh 5%

during 2015-16. The total rainbow trout production in India has increased from a mere 147 tonnes in 2004 to 602 tonnes in 2014 i.e. 309 % increase. Per annum the growth of trout production in India remained at 31%. The total fish production in five Himalayan states is estimated to 40.50 mt, 41.18 mt, 41.86 mt and 42.54 mt for 2017-18, 2018-19, 2019-20 and 2020-21 respectively. Coldwater fisheries have supported livelihood and earning of the people in both the rural and semi-rural areas through fish catch, fish farming, ornamental fish trade and fish feeds units. It also supported sports and fishery-based ecotourism in the form of fish angling and fish watching in the Himalayas. Overall, it has been observed that the Indian Himalayas is rich in water resources and home to diverse kind of fish species in the Northwestern, central and Northeastern regions. The states have considerable trout infrastructure and the number of trout growers are also increasing but the government should give more focus for further infrastructural development. The coldwater fish production is also increasing over the years in all the states and the states like Jammu and Kashmir, Himachal Pradesh and Sikkim are contributing maximum trout production in India.

CHAPTER 4

COLDWATER INLAND FISHERIES IN SIKKIM

4.1 Introduction

Sikkim is a landlocked state situated in the laps of the Eastern Himalayan Region. The total geographical are of Sikkim is 7, 29,900 ha out of which 74,343 ha (10.20%) is cultivable whereas the remaining land areas are forest, cultivable waste and barren and uncultivable land. Sikkim is blessed with beautiful natural resources and rich in a biodiversity hotspot. Mixed farming is practiced in Sikkim where agriculture and allied activities go in hand to hand for supplementing and complementing each other for income generation and livelihood of the farming communities. Among the major allied activities undertaken by Sikkimese farmers are cattle, buffaloes, sheep, goats, pigs, poultry, yak rearing and fish farming etc. In the view of the limited landholding in Sikkim, livestock and fisheries have emerged as the sole solution to provide sustainable economic upliftment of the rural masses. Nature has endowed Sikkim with the abundance coldwater resources and varied aquatic life. The state has various water resources in the form of rivers, lakes, streams and perennial springs which provides immense scope for the development of inland fisheries. It has a potential in the fishery sector both for capture and culture fisheries due to the abundance of coldwater resources. Fish farming has become an important source of livelihood for the rural people in the upland areas due to the hilly terrain, agriculture and other allied activities are not sufficient for the development of rural economy. Initially, the development programme of fisheries in the state was mainly on conservation of aquatic life and encouraged sport fisheries. But now fisheries activities have been expanded for the promotion of sustainable fish culture as an

suitable income-generating activity in the rural areas, augmenting nutritious food production, generating a supplementary source of income to fish farmers and fishermen, promoting fishery for tourism and conservation of riverine fish germplasm. The fisheries activity is linked with tourism and the educated unemployed youth are motivated towards fish culture practices which help them to lift the economic condition of the people in the rural area. Fisheries have been an important enterprise for livelihood security to the rural people of Sikkim.

4.2 Brief History of Fisheries in Sikkim

The establishment of fisheries in the state came into existence in 1974 as a wing in the Forest Department was a great milestone and it was the primary driving force for realising the high potential of fisheries development mainly on conservation of riverine fish species and development of sport fishing. While, the fisheries activities in a real sense started later than 1979 under the direction of Mr. S.B. Raizada, Mr. K.P. Bhutia, Mr. P.W. Bhutia, Mr. D.K. Pradhan and many others. From 1976 to 1992, a lot of major developments have been taken in the DOF for the promotion of trout fisheries in Sikkim.

During 1976-80, trout farm and hatchery at Memencho and trout rearing unit at Yumthang have been constructed. The development that took place during 1980-85 includes the construction of trout rearing unit at Uttarey and trout farm at Yuksum. In the same pace of development, the trout rearing unit at Lachung was constructed in 1985-90. Then from 1991-92, a major initiative took by the DOF with the formation of the Fish Farmers Development Agency (FFDA). After the formation of FFDA, the concept of fish farming in the state started quickly. Under this activity, a major initiative has been taken by the DOF to boost the culture of fish farming by identifying the physicochemical and environmental suitability conditions and potential fish farmers, providing them financial assistance for the construction of ponds, providing them seed and technical know-how along with giving them the training and skills in the science and art of fish farming.

Since 1995, the new direction has been taken place in the approaches to fisheries development and the conventional programme was revised with the following directive.

i. Enhancement of fish production and productivity from the available water resources.
ii. Protection and conservation of riverine fisheries resources in the mid and high altitudes.
iii. The breeding programme of mahseer, carp and trout fish for stocking in ponds rivers, lakes raceways and reservoirs in different altitudinal zones.
iv. Promotion of game fishing for sustainable ecotourism.
v. Encouragement of commercial trout farming in high and low altitude zones.
vi. Development of aquaculture with the help of technical and financial assistance to the farmers and unemployed youths in rural areas through various government schemes.

In the early time, the trout fish culture was not popular in the private farm although the farmers are culturing other fish species in the marginal amount. The DOF used to produce trout seeds mainly of brown trout for ranching in Memencho, Bethang Tsho, Rong chhu[25], Tshongmu lake, Rore chhu etc. for the breeding of brown trout and production of fry. During the 1980s and 1990s, the activities carried out by the DOF were to collect brooder from Memencho lake to breed brown trout at Memencho trout hatchery and to produce fry. For further rearing to fingerlings and ranching in high altitude lake and springs, fry produced from Memencho lake were carried to different trout farm of Uttarey, Yoksum, Lachung, Lachen etc. During the early 1980s, they started to bring rainbow trout seed in the form of eyed-ova from Himachal Pradesh; and these were then transported to hatcheries of Uttarey, Yoksum, Lachung and Lachen for final hatching, larval rearing to fry and fingerling size. During that time, the seeds were not used to distribute the farmers for growing in their private lands, instead of giving to them, seeds were taken for ranching in high altitudinal lakes and streams and the rest were used to rise in government farm for breeding in subsequent years. The activity of breeding seeds and fry production is still practiced by the DOF for the aforesaid purposes and to distribute seeds to the local private growers at a very minimal rate.

4.3 Fishery Resources and Fish Diversity in Sikkim

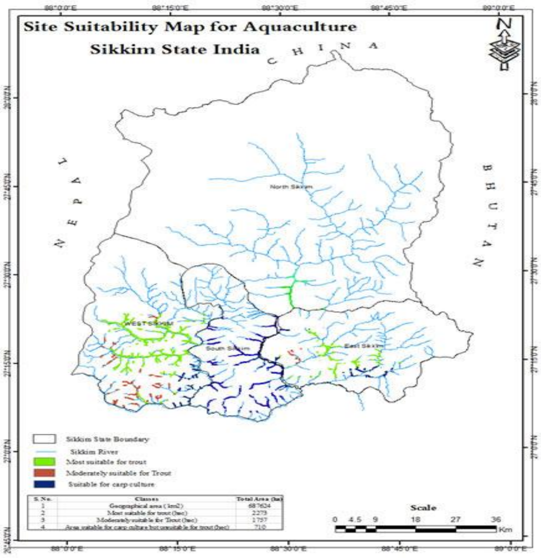
The estimated total inland water bodies of the state are 0.03 lakh ha, length of rivers is 900 km and area of ponds and lakes are 0.1 and 3.2 thousand ha, respectively. Teesta and Rangeet are the main river system with their numerous tributaries which support the major riverine fisheries resources of the state. The water resources of Sikkim contain 48 fish species belonging to 9 families under 23 genera (Table 4.1). Most of the species belong to Cyprinidac and Salmonidae family. The most important fish spices are Mahaseer (Sahar), Snow trout (Asla), Catfish (Ther, Gandi), some carps

[25] Tsho or Chhu means water in Bhutia Language. In Sikkim, water is commonly called as chhu or Tsho.

(Budana, Nak Kauta) etc. are found in rivers and streams. The fish cultivated area is categorised into two parts. The area which falls above 1500 m sea level is identified as coldwater zone and coldwater fishes like trout are encouraged for stocking in the streams and lakes for angling purposes and rainbow trout and brown trout are culture in the raceway in the private sector. Below 1500 m from the sea level is identified as carp zone and cultivation of carp fishes like grass carp, silver carp, common carp and other species are suitable for cultural purposes in the lower belt of Sikkim. The total annual fish yield from the riverine resources is about 120-150 tonnes annually and about 1500-2000 villagers living close to the river banks are engaged in part-time fishing.

The Figure 4.1 depicts the areas identified by the DCFR suitable for the aquaculture or fish farming in all the districts at different altitudinal regions of Sikkim.

Figure 4.1: Map showing Aquaculture Suitability Areas of Sikkim



Source: Directorate of Coldwater Fisheries Research, ICAR, Government of India.

The areas represented by light blue shows the rivers and its tributaries, green indicates the most suitable areas for trout, red shows moderately suitable areas for trout and dark blue shows suitability regions for carp species.

Table 4.1: Fish Species found in the Water Bodies of Sikkim

Sl. No	Scientific Name	Local Name	Sl. No	Scientific Name	Local Name
1	*Acanthophthalmus pangia*	n.a.	25	*Glyptothorax sinense manipurensis*	Kanray
2	*Anguilla bengalensis*	Rajabam	26	*Glyptothorax sinense sikkimensis*	Kanray
3	*Bagarius bagarius*	Gonch	27	*Glyptothorax trilineatus*	Kanray
4	*Balitora brucei*	Titay	28	*Labeo dero*	Gardi
5	*Barilius bendelisis bendelisis*	Khasray	29	*Labeo pangusia*	Theyr
6	*Barilius bendelisis chedra*	Chaley	30	*Laguvia ribeiroi jorethanensis*	Gona Machha
7	*Barilius vagra*	Chirkay	31	*Laguvia riberoi riberoi*	Gona Machha
8	*Channa orientalis*	Hilay	32	*Neolissocheilus hexagonolepis*	Katley
9	*Clupisoma bhandari*	Jalkapur	33	*Noemacheilus beavani*	Gadela
10	*Crossocheilus latius latius*	Lohori Buduna	34	*Noemacheilus carletoni*	Gadela
11	*Danio aequipinnatus*	Bhitti	35	*Noemacheilus corica*	Gadela
12	*Danio naganensis*	Bhitti	36	*Noemacheilus devdevi*	Gadela
13	*Euchiloglansis hodgarti*	Lulay	37	*Noemacheilus kangjupkhulensis*	Gadela
14	*Garra annandalei*	Buduna	38	*Noemacheilus multifasciatus*	Gadela

15	*Garra gotyla nakkatua*	Buduna	39	*Noemacheilus scaturigina*	Gadela
16	*Garra gotyla stenorhynchus*	Buduna	40	*Noemacheilus sikkimensis*	Gadela
17	*Garra lamta*	Buduna	41	*Noemacheilus spilopterus*	Gadela
18	*Garra mcclellandi*	Buduna	42	*Pangasius pangasius*	n.a.
19	*Garra mullya*	Buduna	43	*Pseudecheneis sulcatus*	Kabrey
20	*Glyptothorax basnetti*	Dhodray	44	*Salmo trutta fario*	Kashmiri machha
21	*Glyptothorax bhutiai*	Kanray	45	*Schizopyge progastus*	Chuchay Asala
22	*Glyptothorax conirostris*	Kanray	46	*Schizothorax richardsonii*	Dothey Asala
23	*Glyptothorax deyi*	Kanray	47	Semiplotus semiplotus	Chepti
24	*Glyptothorax racilis*	Kanray	48	*Tor putitora*	Mahseer

Source: Pushpa Tamang (1993). Fish Geography of Sikkim. Panda (Bi-annual Newsletter on Environment, Forest and Wildlife, Forest Department, Government of Sikkim), 1: 19 20.

Sikkim is very rich in fish biodiversity having indigenous and exotic species. There is a total of 48 species of fishes found in the water bodies of rivers, lakes, streams and reservoirs in Sikkim (Tamang, 1993). The local and scientific name of the species are depicted in Table 4. 1.

Table 4.2: Threatened Fresh Water Fishes of Sikkim

Sl.No	Species	Status	Sl.No	Species	Status
1	Anguilla bengalensis	EN	11	Chupisoma garuna	VU
2	Ompok bimaculatus	EN	12	Heteropneustes fossilis	VU
3	Pseudeutropius atherinoides	EN	13	Labeo dero	VU
4	Puntius devatus clavatus	EN	14	Mystus vittatus	VU
5	Anabas testudineus	VU	15	Nemacheilus multifasciatus	VU
6	Bagarius bagarius	VU	16	Nemacheilus scaturigina	VU
7	Barbodes sarana	VU	17	Osteobrama cotio	VU
8	Catla catla	VU	18	Puntius chola	VU
9	Cirrhinus reba	VU	19	Schizothorax richardsonii	VU
10	Clarias batrachus	VU	-	-	-
EN= Endangered; VU= Vulnerable					

Source: Sikkim Wetland, SACON publication

Table 4.2 shows the list of the fish species which are found to be endangered and vulnerable to extinction in Sikkim. This gives the alarming concern for the individuals and authorities to protect and conserve the natural fish biodiversity. This situation is happening due to the overexploitation, large scale developmental activities like construction of hydel power projects and pharmaceutical companies along the river sides. illegal fishing practices in rivers and the growing pollution and untreated sewage in the water bodies.

Table 4.3: Fish Cultured in Sikkim: Trout and Carp Species

	Trout Species	**Carp Species**
Fish species	Rainbow trout	Common carp, Grass carp & Silver carp, Chinese carp, Hungarian carp
Altitude	>1500 m	< 1500 m
Size of Ponds	$51m^3$	$120m^2$
No. of Ponds	1-5	1-2
Types of culture	Monoculture	Polyculture
Types of ponds	Cemented only	Earthen and concrete
Source of pond water	Perennial river, streams,	streams,
Stocking period	March-April	March- May
Stocking density (per tank)	1500 -3000	500-1500
Cost of fingerlings	10-20	3-8
Source of Fingerlings	Community hatchery, Government farm	Government farm and outsider seller
Type of Feed	Wheat flour, supplementary feed	wheat, rice bran, cooked rice, grass etc
Price in Rs (per Kg)	600-1000	200-250
Production /ponds	100-500	50-300
Harvesting period	July- August, December-February	October-November, February-March
Marketing	Local area, Hotels and Restaurants Namchi, Gayzing, Pelling, Jorethang, Singtam, Mangan and Gangtok etc.	Local villages and its adjoining areas
Source of finance	Financed by Government in the1st year and after that own savings and borrowing from friends and relatives	Financed by Government in the1st year and after that own savings and borrowing from friends and relatives
Scheme	NFDB, RKVJ, Blue Revolution	
Days of Work	30 days	15 days

Constraints	Irregularity of supply of feed, non- availability of feed in time, high cost of feed, scarcity of fingerlings, sometimes financial problems, no insurance facilities, disease and pest infestation	scarcity of fingerlings, water shortage during dry season, no insurance facilities disease and pest infestation absence of strong co-operative society, fish killed by wild animals, Sometimes theft.

Source: Field Survey

The areas which falls above 1500 m from the sea level is identified as coldwater zone and coldwater fishes like rainbow trout and brown trout are stock in the streams, rivers and lakes for angling purposes and culture in both private and government sectors. The most important factors for the success of trout farming are the proper construction of raceways. The raceways are cemented, an ideal and the recommended size of the raceway is 17m X 2m X 1.5 m i.e. $51m^3$. The number of raceways owned by the farmers varies from 1-5. Monoculture farming is practice in trout raceways. In a single pond different species of fishes are not encouraged for farming. The source of water is rivers, perennial springs and streams available within the vicinity. The water is available plentiful during monsoon seasons starting from May to October. Based on the water availability during the season the farmers can manage 7-8 tanks. During that season the temperature remains optimal due to which the locations and resources will have perfect and boon for the better growth of fish. The best months for the stocking of fingerlings are March- April and the farmers are maintaining the stocking density of 500-3000 fingerlings per tank base on the availability of seeds on time.

At present, the cost of the fingerling is ₹ 10-20 per piece and the main source of fingerlings for trout is community hatchery of PFCS and government trout farm.

On an average, the farmers are facing 20% of mortality during the stocking periods and it eventually goes off once they get acclimatised to feed of appropriate size. The mortality of fishes is happening because of the change in environmental conditions as well as a discontinuity in the pace of previous feed and feeding routine. The farmers reported that they are facing the maximum mortality during initial stocking, it may be because of being the first-timer and the lack of experience in handling it.

On the early stage of production, trout is feed with powered/crumbled feed, poultry liver, beef liver, egg yolk etc. And after that, wheat flour and supplementary feed is given. The farmers primarily depend on the feed supplied by DOF. But when feed is not available on time, they prepare feed by themselves using wheat flour, slaughterhouse waste especially beef liver and lungs, eggs refined oil etc. According to them, such ingredients are expensive and are not economical. They followed approximately 10 months of farming depending upon the feed availability and growth of fish. They keep the fish to reach optimal marketable size (table size) and after that, they started selling after the 5-6 months taking out the bigger one and letting the smaller to grow for the next harvest. If they can manage the good quality of feed continuously, on an average, they can produce 700-800g in the tenth months of farming. They started harvesting the bigger one from July-August and it will continue till December -January and even up to February depending on the existence of the stock.

The most common disease encountered in trout is a fungal infection. If it is not treated on time, later on, fungus-infected fish developed into skeletal deformity. This will appear if the tanks are not cleaned properly after feeding. During the time of stocking i.e. in the early stage of fry and fingerling, disease like whirling syndrome may notice along with erratic swimming, dark coloration etc. and its remedy is feeding them with poultry liver and egg yolk along with the crumbled feed.

The price of the fish is very lucrative of ₹ 600 – 800 and in some places, it goes up to 1000 per kg as per the demands which is very much promising in terms of yielding best profit margin due to which marketing goes smoothly without any difficulty. The farmers harvest and sell their products as per the demands, therefore, there is no chance of loss through spoilage and decay. They supplied their product in local homestays, hotels and restaurants, marriage functions, government official functions, different festival etc. Their markets include production village, Bazars of districts and Gangtok. They directly supplied to the persons on demand also. In the first periods, a farmer is provided with 50% subsidy for the construction of the fish ponds and first year inputs like fish seeds and feeds etc. and for subsequent periods the farmers have to finance themselves. They are managing from their own savings and sometimes borrowing from friends and relatives. The trout farming in under the scheme called 'Trout Culture in Raceways' which is supported by NFDB, RKVJ and recent scheme of Blue Revolution. The primary constraints faced by the trout growers in the state are irregularity of supply of feed, non- availability of feed in time, high cost of feed, scarcity of fingerlings, sometimes financial problems, lack of insurance facilities, disease and pest infestation etc.

Carp species such as Common carp, Grass carp, Silver carp, Hungarian carp etc. are cultivated in Sikkim. The area which falls below 1500 m from the sea level is identified as carp zone and suitable for the cultivation of the above said fish species. The ideal and recommended size of the ponds is $120m^2$. There are about 1-2 pond per farmers in Sikkim as far as carp production is concerned. Polyculture can be adopted in case of carp farming. The source of water is springs and streams available within the vicinity. The pond is earthen and cemented. The best month for the stocking of fingerlings are March- May and the farmers are maintaining the stocking density of 500-1500 fingerlings per pond base on the availability of seeds on time.

At present, the cost of the fingerling is ₹ 3-8 per piece and the main source of fingerlings for carp is government farms and seed sellers.

The feed for carp species is wheat, rice bran, cooked rice, grass etc. The price of carp fish goes in the range of 200-250 and the farmers are producing about 50-300 kg from a pond. They started harvesting from October-November and will continue till February-March depending on the existence of the stock.

The farmers are selling the fishes at their local villages and its adjoining areas. In the first periods, a farmer is provided with 50% subsidy for the construction of the fish pond and first year inputs like fish seeds and feeds etc. and for subsequent periods the farmers have to finance themselves. They are managing from their own savings and sometimes borrowing from friends and relatives. The carp farming is under the scheme called 'Running Water Fish Culture' supported by NFDB, RKVJ and recent scheme of Blue Revolution. The primary constraints faced by the carp growers in the state are scarcity of fingerlings, water shortage during dry season, no insurance facilities, disease and pest infestation, absence of strong co-operative society, fish killed by wild animals, sometimes theft etc.

4.4 Trout Fishery in Sikkim

Earlier, in Sikkim, trout fishery was confined to production and stocking of brown trout fish seed in the coldwater streams and lakes for promoting angling and later it was extended to rainbow trout farming as an economic activity in the private sector due to the growing population and demand of trout fish in the state. Farming rainbow trout is a profitable alternative to conventional agriculture that can be practiced within very limited land. Due to its taste and medicinal value, trout is highly preferred over other locally available fishes; hence the total demand for trout is very high. Realising the benefits of this farming system, the government is promoting trout farming among the rural masses as an income-generating activity. The government is providing financial as well as technical assistance for trout farming under the scheme named "Trout Culture in Raceways." Table 4.4 shows the villages where trout culture is mostly done and year wise trout raceways constructed in different districts of Sikkim from 2009-10 to 2016-17.

Table 4.4: Trout Raceways Constructed in Sikkim during 2009-10 to 2016-17

Year	East	West	North	South
2009 -10	Rolep, Lingtam, Lamaten, Nimachen,Tumin, Gangtok, Bhusuk	Upper Rubik,Yoksum, Ribdi Bhareng, Uttarey, Manebong, Hee Patal	Lachung	Shimkhola
2010 -11	Naitam, Zuluk, Rolep, Tumin, Lingtam, Nimachen, Dalapchand, Phadamchen, Upper Martam Bashilakha	Begha, Sopakha Simphok, Uttarey, Hee Patal, Upper Rimbik, Yuksom, Kyongbari, Sribadam	Baythulung, Sentam, Passingdam, Salimpakyel, Kalaus, Singhik	Ghurpisey, Rabitar, Temi, Damthang, Simkharkha, Upper Payong, Yangang, Salep, Parbing, Phalidara, Polok,
2011 -12	Rolep, Regu, Zuluk,	Manebong, Sopakha, Uttarey, Simphok, Hee Patal, Yuksom, Ribdi	Lachung, Salimpakyel, Tingchim,	Sada, Chitray

	Nampong, Pangthang, Tumin,	Bhareng, Sribadam,	Lingthem, Dzongu, Phamthang	
2012 -13	Padamchen, Navey, Bhusuk	Sribadam, Yuksom	Theng, Lachung	
2013 -14	Rolep, Regu, Pangthang, Tumin, Lingding	Uper Rubik, Okharey, Bakhim	Theng, Sarchok	Sada, Phamtam, Sokpey, Chourydara
2016 -17	Tenkilakha, Tintek, Regu	Sribadam, Uttarey, Upper Rimbik	Men-rongong	Upper Payong, Sokpey

Source: Directorate of Fisheries, Government of Sikkim.

Over the periods, most of the trout farms were constructed in the West and the East districts of Sikkim because these two districts have more availability of coldwater resources that suits basically for trout culture in the high altitude. The construction of raceways for the private stakeholders started in early 2009-10 through the various state and central government fish farming schemes. During that period, the raceways were constructed mostly in East and West districts. In the years 2010-11 and 2011-12, the trout raceways were constructed in large numbers in all the four districts of Sikkim which was a great landmark of the state. Subsequently, the DOF keeps on constructing the trout raceways in all the four districts for the rural farmers. DOF helped to create clusters of trout growers in all four districts which then help to form the district/village wise PFCS. In the East district, many areas developed farming in the cluster form such as Tumin (middle-Tumin and Dhanbari), Nimachen-Rolep-Phadamchen-Lingtam, Pangthang-Tintek, Tenkilakha, etc. In the West district, there are as many as Sribadam, Uttarey-Sopakha, Simphok-Maneypong, Upper Rimbik, Hee Patal, Yoksum, etc. In the North district, villages include Lachung, Salimpakyel, Men-Rongong, etc and in the South districts are Shimkhola, Sada, Upper Payong, Sokpey, etc.

Table 4.5: Year-wise increase in numbers of Rainbow Trout Raceways in Sikkim

Year	East	West	North	South	Total
2009-10	15	21	12	5	53
2010-11	30	36	20	20	106
2011-12	7	15	10	10	40
2012-13	4	5	11	11	20
2013-14	8	7	7	8	30
2014-15	-	-	-	-	-
2015-16	-	-	-	-	-
2016-17	29	56	7	7	100
Total	93	104	67	67	349

Source: Directorate of Fisheries, Government of Sikkim.

Table 4.5 illustrates the number of trout raceways constructed during 2009-10 to 2016-17 in all four districts of Sikkim. In the beginning, i.e., 2009-10, the larger number of raceways had been built in the West district and lowest in the South districts with a total of fifty-three raceways all over the state. In the subsequent year, the total unit rose to one hundred and six. But unfortunately during the three annual periods, i.e., 2011-12, 2012-13 and 2013-14, very fewer units were able to construct because the state had got very less financial support from the central schemes and between the years 2014-15 to 2015-16, the DOF was unable to provide financial support to the farmers; as a result, not a single unit had been constructed because DOF had not been granted any funds from the centrally sponsored schemes. Again, in the year 2016-17, the number of raceways increased by one hundred and more with the initiation of the Blue Revolution Mission in the country. As of 2016-17, there are a total of 349 units of raceways had been constructed, highest being in the West district followed by East district, North district and South districts respectively.

Table 4.6: Government Trout Farm in Sikkim

Name of the Trout Farm	Location	District	Hatchery Capacity (lakhs)	Rearing Tank (No.)	Area (ha)	Annual Seed Production (lakhs)
Men-Moi-Tso Farm (Brown Trout)		East	5	4	1	5
Kyongnosla trout Farm	-	East	2	4	-	-
Yuksom Trout Farm	Yuksom	West	2	24	0.50	0.50
Uttarey Trout Farm	Uttarey	West	2	8	0.10	0.50
Sharchok Trout Farm	Lachung	North	1	4	0.70	0.50
Lachen Trout Farm	Lachen	North	0.50	4	0.50	0.50
Rabum Trout Farm	Lachen	North	3	-	-	-
Denga Trout Farm	-	North	5	-	-	-

Source: Directorate of Fisheries, Government of Sikkim.

There are total eight trout farm along with the hatcheries had been set up in Sikkim for brown and rainbow trout seed production. Two trout farms were located in the West district, four in the North district and two in the East district. Although, there are trout growers in some places of South district but not a single government trout farm had been located so far because there are fewer suitability areas in the district. The west district has the largest number of rearing tanks than the others. The district wise trout farm is discussed as follows

East Sikkim

Memencho trout farm is located in the East district and it is the oldest trout farm of the state constructed in 1975. The farm has four raceways of standard size which are being used for rainbow trout fry rearing. Hatchery unit with a capacity of 5 lakhs green ova is used for breeding and seed rearing of brown trout for which brooders are being collected from Memencho lake. The area of this farm is about 1 ha with a capacity of 5 lakhs seed production. Brown trout seeds are used for ranching in suitable high altitudinal lakes and rivers. The feeding river is Memencho which feeds the Memencho lake as well**.** Kyongnosla trout farm was constructed in 2013 with a hatchery unit of 2 lakhs green ova. This farm has two units of fry rearing fiber tanks and seven feeding trays. Currently, water line to feed this farm has been damaged and the farm is under renovation and development. However, this farm is the nearest to the capital city.

West Sikkim

Uttarey trout farm was constructed in the 1980s, later it was renovated in 2012. It has an area of about 0.10 ha with 8 numbers of rearing tanks. The seed production capacity of the farm is 0.50 lakhs. The farm has the hatchery unit of 2 lakh green ova. It also has 4 fry rearing units with a capacity of 1 lakh fry in each tank and four brooder rearing units with a capacity of rearing 200 kg brooders. This is the most active farm of the state and it is catering all seeds required by the farmers of the west district. The farm receives water from the nearest stream which is perennial. Uttarey river flows through its vicinity towards its downhill, within a distance of approximately 100 m. Yoksum trout farm was constructed in 1984. This farm has a hatchery capacity of 2 lakhs, 24 rearing tanks with an area of 0.50 ha. The seeds production of this farm comes around 0.50 lakh annually.

North Sikkim

Sharchok trout farm is located in Lachung and it was built in 1990 and its hatchery was constructed in 2012. The hatchery unit has a capacity incubating 1 lakhs green ova. It has 4 rearing thanks of area 0.70 ha. The annual seed production capacity of this farm is about 0.50 lakhs. Lachen trout farm is located in Lachen with the hatchery capacity of 0.50 lakh green ova. This farm also has 4 functional tanks with an area of 0.50 ha. The annual seed production capacity is 0.50 lakhs. Rabum trout farm was constructed in 2014. The farm has the hatchery unit with a capacity of 3 lakh green ova. It also has multiple numbers of standard raceways for brooder rearing with a capacity of 400 kg brooders.

Denga trout farm and its hatchery were constructed recently. Its hatchery unit has a capacity incubating of 5 lakh green ova. All these trout farms were established for seed production and demonstration purposes. The fingerlings are distributed free of cost in the initial periods and at a very minimal rate in the subsequent periods to the fish farmers to encourage them for aquaculture.

4.5 Carp Fishery in Sikkim

With the objective to utilise the water resources of mid-altitude level, carp fishery is initiated under various beneficiaries' schemes in the private water bodies for carp fish production and in the public water bodies for carp seed production for availing to the farmers. The major carp species that have been cultivating are common carp, grass carp and silver carp. Recently a Hungarian strain of common carp and mirror carp have been introduced in the state which is said to have a 47% higher growth rate than the existing strain of carp available in the state. There are nine carp seeds production farms set up in Sikkim for the production of quality carp seed for distribution to the beneficiaries and to stock in village ponds and other different resources of the state. The district-wise farm and location are shown in the Table 4.7.

Table 4.7: Government Carp Farm in Sikkim

Name of the Carp Farm	Location	District	No of Tanks	Area (ha)	Annual Seed Production (Lakhs)
Rangpo Carp Farm	Rangpo	East	5	0.60	1.00
Rorathang Carp Farm	Rorathang	East	4	0.60	1.00
Makha Carp Farm	Makha	East	9	-	-
Gayzing Carp Farm	Gyaba	West	12	0.60	1.00
Rothak Carp Farm	Rothok	West	12	1.20	4.00
Soreng carp farm	Soreng	West	8	0.70	0.50
Kabi Carp Farm	Kabi	North	8	0.75	0.50
Heegyathang carp farm	Heegyathang	North	4	0.20	0.50
Lingdem carp farm	Lingdem	North	3	0.20	0.20

Source: Directorate of Fisheries, Government of Sikkim.

East Sikkim

The carp farms located in East district are Rangpo carp farm, Rorathang carp farm and Makha carp farm. The former two have an area of 0.60 hectares with 1.0 lakh seed production capacity. Makha farm is newly constructed for carp seeds which have 9 tanks but other details information has not been available.

West Sikkim

To distribute the fish seeds and to encourage the local farmers for fish production at mid-altitude, the west district has 3 carp farms located in different areas viz. Gayzing carp farm at Gyaba, Gayzing with an area of about 0.60 ha. The farm has a total of twelve tanks with annual seed production of 1.00 lakh. Rothak carp farm has an area of 1.20 hectare with 12 tanks which are producing 4 lakhs fish seeds. It is located in Rothak. For Soreng and to cover its adjoining areas, Soreng carp farm was constructed which has 0.70 ha. It has 8 tanks with the capacity of the production of 0.50 lakh seeds.

North Sikkim.

Kabi carp farm is located in Kabi which is nearest to the state capital. It has an area of 0.75 hectares with eight fish tanks. It produces 0.50 fish seeds annually. Hee-Gyathang carp farm was started for the benefit of the peoples of Dzongu and its surrounding areas. It has less area of 0.20 ha with only 4 tanks producing 0.50 fish seeds annually. Lingdem carp farm is also located in Dzongu which have an area of 0.20 ha. It has 3 thanks and the annual seed production capacity of 0.20 lakhs.

4.6 Mahaseer Fishery in Sikkim

Mahaseer is one of the very important game fish species which is available in the foothills of the Himalayan river system. It is also called the ‘King of Game Fish’ locally known as Sahar is available in the lower belt of the river Teesta and Rangit. It is observed that the population of mahseer has been decreasing in the river system due to habitat destruction by manmade activities across the river and diversion of river water and natural calamities. This species is declared as endangered fish species that are under the threat of becoming rare. The artificial stocking of mahseer seed is necessary to sustain the mahseer population in the river system and therefore one small mahseer farm has been constructed at Baguwa in South Sikkim.

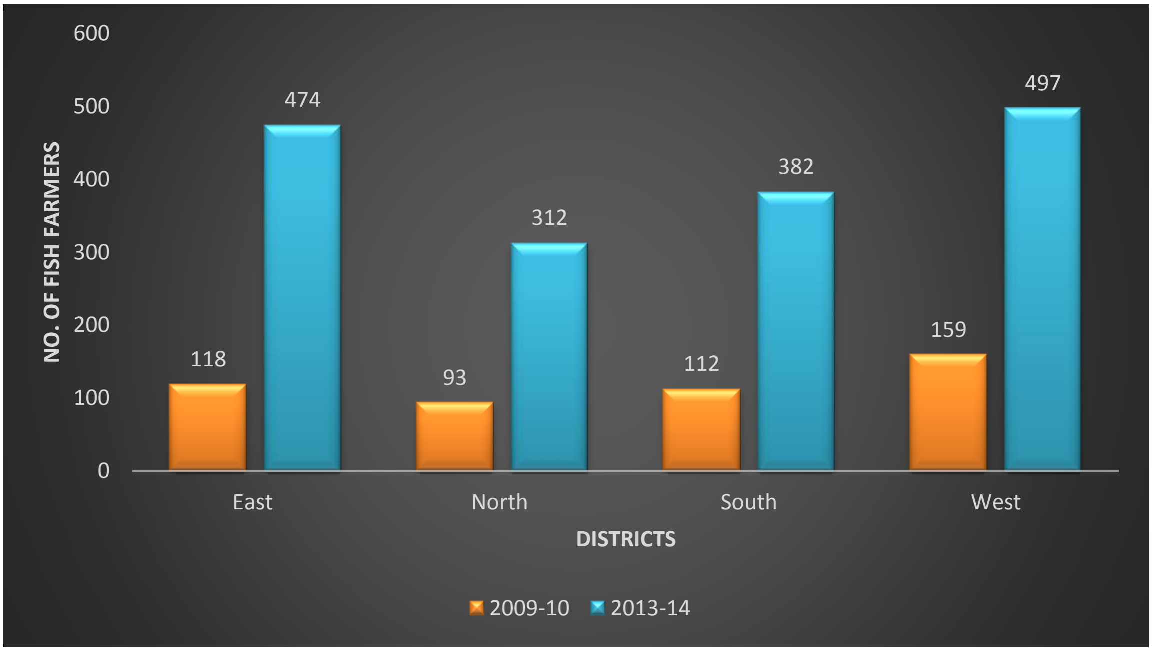
4.7 Angling in Sikkim

Sikkim has a large biodiversity and it is a paradise for adventure and nature lovers. With the vast river system, Sikkim is an angler's delight. Fish species such as masheer, carp and trout provide fond angling opportunities for the passionate angler. The river Teesta and Rangit provide ample opportunity for masheer and trout. During pre- and post-monsoon season, angling can be done by laagering or spinning. Amongst the alpine region in North, East and west Sikkim, there is ample scope for trout angling by fly fishing or spinning. The best suitable months for angling in Sikkim are March to May and August to October. The local people as well as domestic and international tourist enjoyed angling in Sikkim during the season.

4.8 Fish Farmer' Population and Fish Production in Sikkim

The figure 4.2 shows the number of farmers practicing fish farming in the hilly state of Sikkim. The aquaculture or fish farming has been an additional source of income, employment and protein in the rural and remote parts of Sikkim. Fish farming can be practice in the limited areas of land with other farming activities. In the hilly areas due to fragile and smallholding of agricultural land, agriculture and farming are done on a small scale which is based on seasonal. One particular farming cannot support the economy of the household unlike in plain farming. So, in the hilly, fish farming has become an additional economic activity that supports livelihood in rural areas.

Figure 4.2: Number of Fish Farmers' Population (2009-10 to 2013-14)



Source: Department of Animal Husbandry Livestock, Fisheries & Veterinary Services, Government of Sikkim. http://www.sikkim-ahvs.gov.in/fisheries_development.html

From the Figure 4.2, it is clear that fish farmers in all the districts of Sikkim had increased. There is a positive growth of farmers in the state of about 245.44 percent from 2009-10 to 2013-14. East district has the second largest number of fish farmers in the state. During 2009-10, there were only 118 farmers which were increased to 474 in 2013-14 and the percentage increase was about 301.69 percent. Also, in East district more lands are suitable for aquaculture. North district has the least number of fish farmers in the state because this district has very fragile land and less land is suitable for farming and habitation although the total areas is highest amongst all the districts. The slope of the land is very steep and the population is less as a result farming activity was less as compared to other districts of Sikkim. During 2009-10 the farmers were about 93 and it was increased to 312 in 2013-14. Southern parts of Sikkim have a scarcity of water in some of the places. In some parts of it, people are rearing carp and trout fishes but suitable areas are less as compared to other districts, because of such problem farmers are less in South district. In 2009-10, the number of people engaged in fish farming was 112 and it was increased to 382. West district of Sikkim has the largest fish farmer of about 497 as on 2013-14. This district has more potential of fish farming having the availability of fresh and cold water that supports rainbow trout farming and in lower belt carp farming. In 2009-10, there were only 159 farmers. Within the period of five years, there is 212.58% increase in farmers. Along with these, at present, there are more than 1500-2000 fisherfolk who are actively engaged in catching the fishes from the rivers and streams of Sikkim.

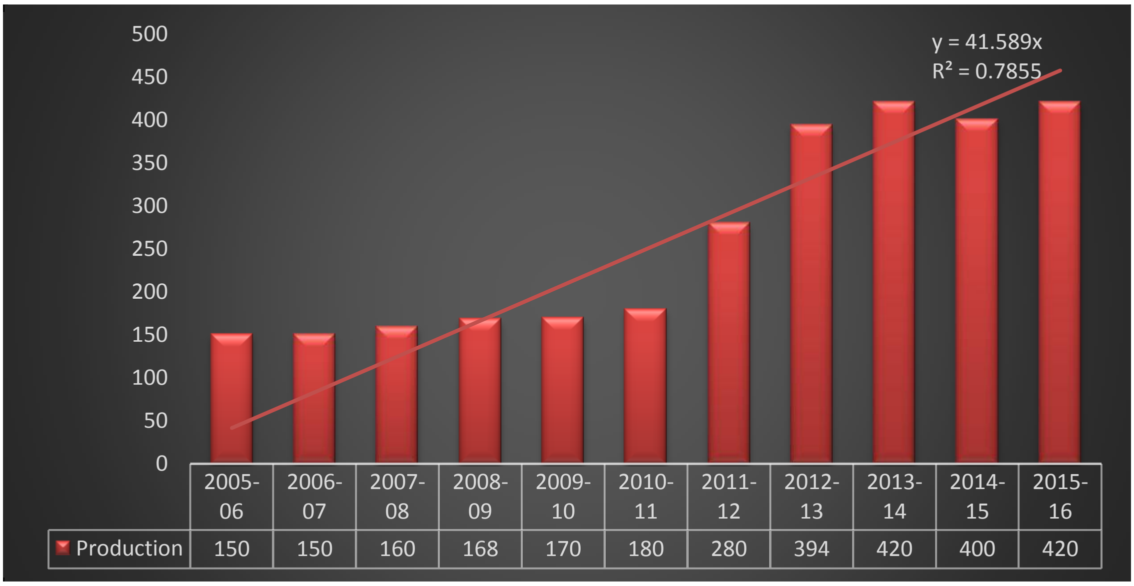
Table 4.8: Fish Production in Sikkim during 2010-11 to 2015-16

Year	Fish Seed Production (in millions)	Trout Fish Production (in tonnes)	Carp fish Production (in tonnes)	Capture (in tonnes)	Total Fish Production (in tonnes)
2010-11	3.00	10	50	120	180
2011-12	3.60	50	110	120	280
2012-13	2.10	90	184	120	394
2013-14	2.05	110	185	120	420
2014-15	2.00	100	180	120	400
2015-16	3.55	120	180	120	420

Source: Department of Animal Husbandry Livestock, Fisheries & Veterinary Services, Government of Sikkim. http://www.sikkim-ahvs.gov.in/fisheries_development.html

Under the beneficiaries' scheme 'Trout Culture in Raceways', so far 249 beneficiaries have been given financial support during the years 2010-11 to 2013-14. Furthermore, with the funding from the central government under the programmed of Blue Revolution 100 new units of trout raceways are being constructed throughout the state. With an increase in the number of trout growers, the total production has risen sharply in the past few years. In the year 2008-09, the total trout production in the state was negligible which had increased to 120 mt in the year 2015-16. To increase seed production in the state, the government is also implementing the project of community trout hatchery. At present, there are three community hatcheries are being constructed in the three different locations of West district. It is expected to produce around 80,000 numbers of trout fingerlings each year. Similarly, more than 1416 beneficiaries were provided financial assistance under the "Running Water Fish Culture" scheme till the year 2013-14. Moreover, with the funding from the central government under the programmed of Blue Revolution 50 new units of fish ponds are being constructed in the beneficiaries' sector. The carp fish production in the state increased from 50 mt in the year 2010-11 to 180 mt in 2015-16. The carp production was highest during 2013-14. The captured fisheries accounted to 120 mt annually. In addition, the total fish production in the state has increased from 180 mt in 2010-11 to 420 mt in 2015-16.

Figure 4.3: Year-wise Fish Production (in tonnes) in Sikkim



Source: Department of Animal Husbandry Livestock, Fisheries & Veterinary Services, Government of Sikkim. http://www.sikkim-ahvs.gov.in/fisheries_development.html

The production of fish in Sikkim is gradually increased from 150 mt in 2005-06 to 420 mt in 2015-16. If we see the overall trend within these ten years, it is observed that on an average fish production is moving on the positive trend although there was not much growth from 2005-06 to 2010-11.

4.9 Formation of Farmers' Cooperatives in India

For many decades, agricultural and allied farming activities have become avenues for profitable entrepreneurship in rural and semi-urban areas of India with functional improvements in means of operation. Prior to the formation of group-based farming, individual farmers had to face many challenges in farming activities like unavailability of good seeds and feeds on time, financial and technical constraints, lack of managerial and technical skills, problems of marketing, etc. With limited availability of resources, it was very difficult to deal with such obstacles at the individual level in the case of the small and marginal farmers. Realising such problems at the farmers' end, the government formally introduced the concept of cooperatives [26] in India in 1904. Cooperatives were started to overcome rural indebtedness along with the above-mentioned problems but later emerged in a more refined and entrepreneurial form with varied activities such as production, farming, marketing, and processing. There are many cooperatives in the different fields of agricultural activities such as cooperatives for cattle farming; horticulture farmers and fish farmers etc. were started at the village and block level in the Indian scenario. The cooperatives benefited from financial support to farmers at a very low rate of interest,

[26] A cooperative society is an autonomous association of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise. It is based on the values of self-help, self-responsibility, democracy, equity, equality and solidarity.
https://sikkim.gov.in/departments/cooperation-department

as well as the best quality of seeds, feed and medicines at a reasonable price. They also provide facilities like storing, transporting and marketing of farm products in a cost-effective manner.

As far as the fisheries sector in India is concerned, fishermen and fish farmers are socially and economically backward, driven by poverty and unemployment, and often remain isolated from public amenity provisions. Due to the availability of sufficient water resources in their premises and to utilised available water resources in a fruitful manner and to maintain and developed capture and culture fishery involving the common interest of different people associated with fishing activity, people have taken initiative to make fish farming as their subsidiary occupations and feel the urge to develop local waters resources on a sustainable fish farming basis through the formation of the cooperative. In India, the cooperative structure is based broadly on a three-tier system. At the village level there exist Primary Fishermen's Cooperative Societies, Central Cooperative Societies at the district or intermediate level and the Apex Cooperative Federation at the state level.

4.10 Primary Fishermen Cooperative Society in Sikkim (PFCS)

Sikkim is a mountainous state endowed with numerous coldwater resources in the forms of lakes, streams, perennial springs, rivers, reservoirs, etc. which support both capture and culture fisheries in the upland and lowland regions. Due to the hilly terrain, agriculture and other allied activities are not sufficient for rural development, therefore, fish farming has become an important source of livelihood and earnings for the rural people. In Sikkim, the concept of forming fisheries cooperative societies started late from 2012-2013. At present, the state has only PFCS at the village level. The water bodies are gradually being brought under aquaculture with the formation of

PFCS. DOF, Sikkim initiated the creation of fish farmers' cooperatives based on an available number of farmers in clusters. They helped in the formation of cooperatives, separately, for carp and trout growers. There is a total of eight PFCS registered under the DOF, Govt. of Sikkim. But two PFCS are not functioning properly because of the water scarcity faced during the winter season along with the management problems. The effectively functioning six PFCS are: -

i. Upper Sribadam Trout Rearing Co-operative Society Ltd.
ii. Maneybong-Sopakha Trout Fish Farmer's Co-operative Society Ltd.
iii. Upper Rimbik Nambu Trout Fish Farming Co-operative Society Ltd.
iv. 20th Chujachen Constituency Fish Farmer's Co-operative Society Ltd
v. Mangshila Fisheries Development Co-operative Society Ltd.
vi. Dalep Fish Farmers Co-operative Society Ltd.

Under these cooperatives there are 100 members, 72 members are associated with trout farming and 28 members are associated with carp farming. All these cooperative societies are registered with the Cooperation Department, Government of Sikkim. Each cooperative society constituted a managing committee consisted of a president, secretary, manager and members. Presidents and secretary look over the overall functioning of the cooperative society while the manager takes the responsibility related to the cost and budgeting. To form a cooperative society there should be at least ten members including the president, secretary, and manager. The ponds or raceways are owned by the individual member themselves and the source of funds is financed through their savings. All the profits of the individual's ponds or raceways go to the individual's hand who owns the pond. Yet, there is no provision of annual membership deposits and advances of loan to the members.

All the members of the societies are being supported through state and the central government schemes under 'Trout Culture in Raceways' for trout farming and 'Running Water Fish Culture' for carp farming with 50% subsidy for the initial construction of ponds along with first-year inputs, technical and financial supports, training and workshop within and outside the state etc. Moreover, the state Government is also providing them technical help, knowledge on stocking of fingerlings, marketing strategy and training in and outside the state on a timely basis The DOF has been availing funds from the different centrally sponsored bodies such as NFDB, Rashtriya Krishi Vikash Yojana (RKVY), and a recent Blue Revolution to encourage the fish farming in the state. Recently many more are being benefitted with the Blue Revolution Mission of the Central Government, and as a result, the number of farmers in the state has been increasing over the year. Furthermore, they helped the cooperatives to open two fish markets, through financial assistantship of NFDB at two locations; one at Gayzing for the West and South districts, and the other at Gangtok for the North and East districts. For selling their farm products, trout growers from Sikkim can send their farm output collectively through local cooperatives to the marketing cooperatives of Gayzing and Gangtok. In doing so, individual trout farmers in a cooperative society can sell their farm products at a lucrative maximum retail price fixed by the DOF. Further, this will help in ruling out the hassles created by unwanted middlemen. In these co-operatives, DOF has availed trout hatcheries (of 1 lakh capacities of eyed ova) through NFDB funding. Each hatchery will have concrete enclosed space for accommodating 12 hatching trays. Co-operative members can carry out breeding and seeds rearing collectively in their community hatcheries, and they can or will avail quality seeds to all the members of the group at nominal rates.

They can also sell the surplus seeds outside the cooperative members for revenue generation.

The details of each PFCS are discussed as follows

i. Upper Sribadam Trout Rearing Co-operative Society Ltd.

Sribadam is a small village located in Soreng sub-division in West Sikkim, situated at an altitude of about 7000 ft. above sea level (2100 meters). It is a land of tribal people and the main population are Bhutia, Subba and Gurung. The place is naturally adorned with green forest, milky white but pristine streams and waterfalls. The localities are mostly agrarian because the land is fertile for cultivation of cardamom, kiwi, maize, horticulture crops and medicinal herbs. Sribadam has earned a special position in the state for being the best in milk, fish and cardamom production. The farmland of this village has an abundant supply of free-flowing perennial water resources, a boon for Himalayan aquaculture; as a consequence, the number of trout farmers is growing year by year. The main sources of pond water are the streams and rivers. Upper Sribadam PFCS was formed in 2012 and registered in 2013 with registration number GOS/COOP/2012-13/152/DRCS/W. This cooperative is one of the actively functioning trout farmers' cooperatives in Sikkim. There are 12 members in this cooperative consisting of 9 males and 3 females members belong to Bhutia, Gurung and Subba Communities and has a total of 20 functional ponds in it. Farmers in this village are very optimistic about taking the trout farming to the next level, and they are even planning to sell their farm output to mainland India and abroad as well. By realising the potentiality of water resources and suitable climate for trout culture, the DOF, Government of Sikkim initiated and encouraged the people to go for trout farming. With both technical and financial support from the government, people started trout culture in their private land with cardamom cultivation since 2011. They also have one hatchery with the capacity of 1,00,000 eyed ova, and this will yield at least 80,000 fingerlings in one operational cycle, taking into account of 20% mortality. Their marketing area includes local homestays and hotels, Sribadam, Soreng, Gayzing, Namchi, Jorethang, Gangtok etc. They owned hatchery for fingerlings and excess fish seeds are sold to members of other cooperatives. In case of a shortage of seeds, members are required to bring seeds from the Uttarey government trout hatchery. Sometimes the members suffer from lack of capital but they are managing from their savings and borrowing from their relatives. Primary constraints faced by the farmers are an irregularity in supply and high price of feed or no-availability of feed in time.

ii. Maneybong-Sopakha Trout Fish Farmer's Co-operative Society Ltd.

Uttarey is a small village located on the northern slope of the Singalila range in West Sikkim at an altitude of about 6600 ft. It is located near the border of Nepal. The common agriculture and allied farming activities of the people of these areas include cardamom, fish farming, maize, broom grass, horticultural crops, cattle, poultry and piggery. It is the oldest village of Sikkim as far as the history of trout breeding and farming is concerned and it is one of the largest trout farming areas of West Sikkim. Under this cooperative, the villages include Sopakha, Simphok, Maneypong, Uttarey and Begha. Taking all these villages together we get a very big cluster of trout growers. Uttarey river is a boon for the village as it provides abundant cool-and-free flowing water appropriate for trout farming. Due to the availability of cool, clean and flowing water, Directorate of Coldwater Fisheries, ICAR, Bhimtal, Uttarakhand identified Simphok area of Uttarey is the most suitable and with the potentiality for farming. Maneybong-Sopakha PFCS was formed in 2013 under Maneybong-Sophaka GPU with registered vide no GOS/COOP/681/JRCS/W. This is also an actively functioning trout farmers' co-operative in Sikkim. Total membership in this cooperative society is 21 which includes 16 males and 5 female members and has a total of 26 functional ponds. Fish farmers of this cooperative society belong to Rai (13), Subba (7) and Lepcha communities (1), because the majority of the population of these villages are from Rai and Subba communities. Government trout farm i.e. Simphok trout farm cum hatchery center had been established by the DOF, Government of Sikkim for rearing, breeding, marketing and distribution of seeds to the people of different areas. Many farmers are culturing trout fish in their private lands with financial and technical support provided by the government to increase the production and to encourage more farmers in the field of fisheries. According to them, marketing is based on demand and the price is very much promising, i.e., Rs. 800-1000 per kg in the present time. The cooperative also owned community hatchery with the capacity of 1,00,000 eyed ova and that can yield at least 80,000 fingerlings, taking into account of 20% mortality (hypothetical). The market for selling the fish includes Uttarey, Dentam, Pelling, Gayzing, Jorethang and Gangtok. The cooperative has a larger number of members, advantageous of having nearby Uttarey farms and getting benefits early from the government. There is no problem of fish seeds for the members of this cooperative because the cooperative is run in the area where Uttarey government trout farm and hatchery are located. However, the farmers are facing the problems of fish feeds and sometimes financial problems.

iii. Upper Rimbik Nambu Trout Fish Farming Co-operative Society Ltd.

Upper Rimbik is a small village located at an altitude of 2000 ft close to a river in West Sikkim. It is mostly covered with lush green forests, ever-flowing perennial streams and a few waterfalls. The people here mainly undertake agriculture as an occupation. The main cash crops grown here are cardamom, ginger, etc., which flourish in cold and humid regions. People have also adopted aquaculture as a source of extra income because of the availability of water and the opportunity provided by DOF. It was registered on 17.03.2013 and able to make a good amount of earning and profit from the production of trout but after 2-3 years of its operations, the society could not function well for more than two years due to the massive landslides that took place in some of its adjoining areas. Farmers had to face lots of losses and other economic and environmental problems during that period. Due to the constant support and willingness of the people, they again decided to reform and registered under the Cooperation Department with No. W13/DRP/0029/COOPS in 2015. At present, there are 20 members in this society of which 19 are males and 1 is female. Since the village is inhabited by Limbo people, all the members belong to a single community. The produce is sold within the village, the markets of Pelling and Gayzing and also supplied to Gangtok as per the demand from customers, hoteliers etc. They do not have enough ideas regarding marketing at the peak tourist seasons like the farmers from Sribadam and Uttarey do. A community hatchery is under construction to produce fingerlings in their own premises; having a capacity of 1, 00,000 eyed ova, and this should be able to yield at least 80,000 fingerlings, taking into account 20% mortality. They are dependent in Uttarey government trout farm for the fish seeds. The main problems faced by the farmers are high cost and non-availability of fish feed on time, shortage of fish seed and transportation problems.

iv. 20th Chujachen Constituency Fish Farmer's Co-operative Society Ltd.

The fish farming villages of 20th Chujachen Constituency includes Dalapchand, North and South Regu, Rolep, Nimachen, Phadamchen, Lingtam, Kupup and Zuluk etc. This cooperative was formed and registered on 2013 with registration no. 49/DRCS/PAK under 20th Chujachen Constituency. The total memberships of this cooperative are 20 consisting of 18 males and 2 females and have 20 functional ponds. These places are famous for tourist destinations because of their natural beauty, luxury homestays and authentic cuisine. Due to this flourishing tourism, the value of agricultural farm output is rising. The price and market for trout in the region are very lucrative. Moreover, the environmental and climatic feasibility of trout farming is very much conducive to the availability of surplus cool surface water. On top of that, the market for trout is becoming promising in a sustainable manner due to growing rural tourism induced. There is a very good scope for opening barbecued trout eateries along the silk route during the peak tourist season by the local farmers themselves; this has ensured the best profit margins for them, but due to very highly altitude locations and connectivity problems, they are facing serious constraints like high cost and unavailability of regular trout feed and transportation problems. They depend on fish seeds supplied by the DOF and their nearest source is the Menmencho lake, Nathula.

v. Mangshila Fisheries Development Co-operative Society Ltd.

Mangshila FDCS is located in North Sikkim under Mangshila-Tibuk GPU. It is the only cooperative of North district and it was registered on 2013 with registration No. 228/JRCS/C/COOP. At present, there are 14 members in this cooperative society of which 13 are males and 1 female and they are managing 15 ponds. Since the village is dominated by Limbus, all 13 members belong from this particular community and one is from SC category. Besides, Bhutia and other Nepali communities are also the residents of Mangshila. The climatic condition and physiochemical characteristics of the water suit carp farming in the lands of Mangshila. Due to these, people of the village are engaged in carp rearing in their private lands. Since this cooperative does not have its hatchery, they have to depend on the government carp farms located in different places in the districts and seed traders for the seeds. They are selling fishes in the local and adjoining areas.

vi. Dalep Fish Farmers Co-operative Society Ltd.

Dalep is a village located under Kewzing-Bakhim GPU, South Sikkim. It is a low altitude area suitable for the cultivation of carp species like grass carp, common carp and Chinese carp. Dalep FFCS was formed in 2013 with memberships of 14 farmers of which all are males. 13 members belong to Rai community and one from SC community. The main occupation of the villagers consisted of agriculture and allied activities and they are also engaged in aquaculture and fish farming as an additional source of income and also for self-employment. They have to procure seeds from the government carp farm, Gayzing since they do not have a hatchery of their own. Sometimes they also purchase seeds from seed sellers. The primary constraint of this area is the scarcity of water during the winter.

4.11 Conclusion

Sikkim has only 10.20 % cultivable land and the remaining land are either forest, barren and uncultivable land. Due to the hilly terrain and less cultivable land, agriculture and other allied activities are not enough for the development of rural economy. Sikkim has abundant coldwater resource which supports for the cultivation of coldwater fishes as well as capture fisheries. The water resources of Sikkim encompass 48 fish species distributed in the various water bodies. The major cultivable fish species are Rainbow trout, Common carp, Grass carp and Silver carp. These species are being cultivated in all the districts of Sikkim, though there are water scarcity in some places of South Sikkim. It has been observed from the study that the fish farmers population and ponds have been increasing over the years. There are eight government trout and nine carp farms located in the three districts except south district. These farms were constructed for the for the demonstration purposes and to distribute fish seeds and encourage the people to take fishery as an economic activity. Sikkim also provided fond angling of masheer, trout and carp to the passionate angler. The total production of fish stood at 140 mt in 2005-06 and increased to 420 mt in 2015-16 with a decadal of 200 %. As far as trout fishery in Sikkim is concerned, the position of Sikkim in nation in both the infrastructure and production is good. Sikkim had eight government trout farm, 5 government hatcheries and 249 trout growers as on 2014-15. Sikkim stood third position in trout production and contributed 14 % to total country's production. Sikkim fisheries department had formed PFCS in the block level since 2012-13 onwards. As on 2017-18, there are eight fish cooperative societies located in all the districts. After the formation of PFCS in Sikkim, the number of growers and level of production have increasing and the water resources are being utilised on an efficient and proper ways. It has been observed in this chapter that fish farming has played an important role for the livelihood, helped to increase their level of earning and living conditions and provided self-employment in the rural places. It has been one of the sustainable incomes generating source and sustainable management of water resources in the villages. This sector is gradually growing in

Sikkim and to some extend helped to contribute to the primary activity and hence rural economy.

CHAPTER 5

SOCIO-ECONOMIC CONDITIONS OF FISH FARMERS AND ROLE OF FISHERIES IN RURAL ECONOMY OF SIKKIM

5.1 Introduction

In the hills where livelihood options are limited with the limited suitability of lands for agricultural farming, the fisheries sector has gained an important place in the rural economy. It has been playing a very important role in the socio-economic development of the people, serving as a source of livelihood for a section of the economically backward rural population in the hills (Ayyapan & Krishnan, 2007; Jana, 2007). It ensures food security, minimises unemployment, poverty alleviation and farm sustainability in parallel with the development of profit-oriented entrepreneurship and works as an effective administration of natural resources and conservation of biological diversity (Kumar et al, 2007; Sundararaj, 2007, Kumar, 2007, Dagtekin et al, 2007). In many areas of the Himalayas, it remains adequate for satisfying subsistence and even offer cash income for farmers. It has been a new horizon for hill prosperity. Fish farming in rural areas is considered to be labour intensive due to its smallholder operating size and the use of less advanced technology and machinery. It could be practiced with a limited landholding along with less one-time investment. In addition to this, villagers who did not had access to land can start by taking a small piece of land on lease or could at least earn a living by providing manpower to other fishery farms (Ahmed & Lorica, 2002).

The socio-economic status of the fish farmer and fish farming are interlinked with each other because the socio-economic factors may influence the farming practices and methods adopted by the farmers and it also determines the outcome of the farming practices and performances. The fish farmers are the key stakeholders of the fishery sector. Any policy measure to be successful needs a clear understanding of the status of its stakeholders. Therefore, to address the issues related to the development of the fishery sector of the state, the status of fish farmers needs to be understood. Hence, studies on the socio-economic indicators of the stakeholders are considered to be important factors for the efficient operation of farming or aquaculture.

5.2 Comparative Socio-Economic Status of the Fish Farmers of Different Districts of Sikkim

In this section, the details study on the socio-economic status of the fish farmers of North, East, South and West districts have been carried out. A comparative analysis has been done across the districts. The socio-economic parts have been divided into three categories viz. demographic profile, socio-economic conditions of the fish farmers and access to basic amenities to the fish farmers.

Table 5.1: Membership in Primary Fishermen Cooperative Societies

	North	East	South	West	Sikkim
Member	14 (35)	20 (33.33)	14 (46.67)	52 (74.71)	100 (50)
Non-member	26 (65)	40 (66.67)	16 (53.33)	18 (25.71)	100 (50)

Source: Computed by Author based on Primary Data

The figure given in parentheses denote the percentage

Table 5.1 depicts the number and percentage of fish farmers associated with PFCS in all the four districts of Sikkim and the state as a whole. In North district, only

35 percent of farmers are the members of PFCS while 65 percent are individual growers who are not members. Similarly, in the East district, 33.33 percent of farmers belong to PFCS while 66.67 percent are not members of cooperatives. In South district, 46.67 percent farmers are already the members of PFCS while 53.33 percent are not. The maximum numbers of farmers associated in PFCS are from the West district and nearly about 75 percent of the farmers are already under the umbrella of PFCS while the remaining 25 percent are not yet registered under any PFCS. Out of the sample size of 200, 50 percent of farmers are found to be the members of PFCS and the remaining 50 percent are not. The above result indicated that the West district has the largest number of farmers in PFCS followed by South, North and East districts. Besides this, water resources and infrastructural facilities are higher that lead to the formation of more cooperative societies and hence more memberships in West districts.

Table 5.2: Species wise Distribution of Fish Farmers

Species	North	East	South	West	Sikkim
Trout	21 (52.50)	33 (55)	10 (33.33)	52 (74.29)	116 (58)
Carp	19 (47.50)	27 (45)	20 (66.67)	18 (25.71)	84 (42)

Source: Computed by Author based on Primary Data

The figure given in parentheses denote the percentage

Table 5.2 shows the number of fish farmers involved in the cultivation of trout and carp fish species in Sikkim. Basically, in Sikkim, the species of trout and carp are cultured at high and mid altitudes respectively as discussed in the previous chapter. In our study, the maximum number of trout growers are found in the West district (74.29 percent) followed by the East district (55 percent), the North district (52.50 percent) and the South district (33.33 percent). This is because some of the areas of West, East and North districts are located at high altitudes where availability of coldwater is immense that is suitable for the trout species.

5.2.1 Demographic Profile of the Fish Farmers

This section discussed the demographic profile of the fish farmers of the four districts of Sikkim. The parameters like gender, age, social category, religion, caste and family size have been discussed. The details analyses are as follows:

Table 5.3: Demographic Profile of the Fish Farmers

	North	East	South	West	Sikkim
Gender					
Male	36 (90)	48 (80)	26 (86.67)	57 (81.43)	167 (83.5)
Female	4 (10)	12 (20)	4 (13.33)	13 (18.57)	33 (16.5)
Age					
21-30	6 (15)	8 (13.3	4 (13.3	11 (15.7	29 (14.5
31-40	9 (22.5)	20 (33.3)	12 (40)	19 (27.1)	60 (30)
41-50	17 (42.5	26 (43.4)	11 (36.7)	23 (32.9)	77 (38.5)
51-60	5 (12.5)	2 (3.3)	2 (6.7)	11 (15.7)	20 (10)
61- Above	3 (97.5)	4 (6.7)	1 (3.3)	6 (8.6)	14 (70)
Category					
ST	39 (39)	24 (40)	6 (20)	50 (71.43)	119 (59.5)
SC	1 (1)	0 (0)	1 (3.33)	0 (0)	3 (1.5)
OBC(CL)	0 (0	20 (33.33	22 (73.33	20 (28.57	62 (31)
OBC (SL)	0 (0)	16 (26.67)	1 (3.33)	0 (0)	17 (8.5)

Religion					
Hindu	14 (35)	31 (51.67)	21 (70)	41 (58.57)	107 (53.3)
Buddhist	26 (65)	23 (38.33)	6 (20)	21 (30)	76 (38)
Christian	0 (0)	6 (10)	3 (10)	8 (11.43)	17 (8.5)
Family Size					
1-4	5 (12.5)	8 (13.3)	5 (16.7)	8 (11.4)	26 (13)
5-8	26 (65)	42 (70)	18 (60)	50 (71.4)	136 (68)
9-12	9 (22.5)	10 (16.7)	7 (23.3)	12 (17.1)	38 (19)

Source: Computed by Author based on Primary Data

The figure given in parentheses denote the percentage

Age Structure

The age structure is one of the important variables that determine the number of potentially productive human resources in an economy (Hussain, et al. 2009). The age of the people can also help in the decision-making process in any activity. Most of the fish farmers in each district as well as in the state fall between the age groups of 31-40 years and 41-50 years, which indicates that the productive age groups are being participating in the fishing activity. These age groups are considered to be a productive and economically active age because they portend better management and production (Olowosegun et al., 2005). In the state, 38.5 percent of respondents fall in the age groups of 41-50 years, 30 percent in 31-40 years, 10 percent in 51-60 years and very young and old respondents are 14.5 percent and 7 percent respectively.

Gender

The results presented in Table 5.3 revealed that there is a dominance of males in fish farming in all the districts of Sikkim. The majority of the fish farmers in the state are males (83.5 percent) while 16.5 percent are females. This result can be justified by the study of Brummett et al., (2010) that fishery activities are mostly dominated by the male population. The North district consisted of 90 percent males and 10 percent females; in the East district, males comprised of 80 percent and 20 percent females; there are 86.67 percent males and 13.33 percent females in the South district. Similarly, the participation of males in the West district are 81.43 percent while that of females are 18.57 percent. Thus, the percentage of male participation was highest in the North district followed by the South, West, and East districts. Female participation was found to be the highest in the East and West districts. From this analysis, it could be said that fish farming in Sikkim is dominated by male members of society.

Social Category

From the study, it is found that nearly about 60 percent of fish farmers are from ST community, only 1.5 percent from SC, 31 percent from OBC central list and 8.5 percent from OBC state list in Sikkim. The percentage of ST farmers' population is found to be highest in the West district (71.43 percent) followed by 40.5 percent in the East district, 39 percent in the North district and 20 percent in the South district. In addition, OBC (CL) community occupied the second position and its percent share in the South, East and West are 73.33 percent, 33.33 percent and 28.57 percent respectively. The percentage shares of SC community are observed to be lowest in all the districts, this may be the cause of their lowest population in Sikkim. OBC (SL) community is observed to be 26.67 percent in East district and they are negligible in the other districts.

Religion

Religion is one of the important factors that play a vital role in the social and cultural interaction of people in a particular area or region (Khatun et al., 2013). Sikkim is a multicultural society and people have the freedom to practice any religion of their choice. In Sikkim, the local people practice three religions viz. Hinduism, Buddhism and Christianity. As per the census of 2011, Hindus constituted 57.76 percent of the population followed by Buddhists (27.4 percent) and Christians (9.9 percent). The results presented in Table 5.3 revealed that 53.3 percent, 38 percent and 8.5 percent fish farmers belonged to Hindu, Buddhist and Christian communities respectively. This is because Hindus are the majority in all the three districts except in the North district which is dominated by Buddhist people. In the past Buddhist people were not involved in the fishing activity because they were nature worshippers and worshipped the lakes, water bodies and fishes. According to their religious belief harvesting fish for commercial purposes is a sinful activity and still some of the Buddhist people worship the lakes and pond fishes. But after the last few decades, they are also getting involved in the fishing activity because it became one of the means for gainful subsidiary earning and employment opportunities in the hills. During the field visit, some of the respondents reported that though they are involved in this activity but they are not eating the fishes grown in their ponds.

Family Size

Family size is considered to be an important socio-economic indicator because it reveals the income, consumption expenditure and social well-being of the households (Hossain et al., 2009). Moreover, family size also decides the supply of labour force in the activities like agriculture, fish farming and other allied activities. It was found that the majority (68 percent) of the fish farmers have household sizes of 5-8 persons per home, 19 percent of households have reported having household sizes of 9-12 persons per home and only 13 percent of people are from small-sized families (Table 5.3). This is because fish farming is a primary based activity and mostly cultured in rural areas. Rural people tend to have larger family sizes due to ignorance concerning to family planning and support in farming activities.

Table 5.4: Caste Structure of Fish Farmers

Caste	North	East	South	West	Sikkim
Rai	-	14 (28)	21 (70)	16 (22.86)	51 (25.5)
Limboo	13 (32.5	1 (2	1 (3.3)	35 (50)	50 (25)
Bhutia	-	5 (2	2 (6.8)	13 (18.57)	20 (10)
Lepcha	26 (65	7 (14	-	1 (1.43)	34 (17)
Sherpa	-	11 (16	3 (10)	-	14 (7)
Gurung	-	5 (6	1 (3.3)	4 (5.71)	10 (5)
Tamang	-	-	-	1 (1.43)	1 0.5
Chettri-Bhaun	- -	12 (22)	1 (3.3)	-	13 (6.5)

Pradhan	-	5 (10)	-	-	5 (2.5)
Kami-Damai	1 (2.5)	-	1 (3.3)	-	2 (1)

Source: Computed by Author based on Primary Data

The figure given in parentheses denote the percentage

Caste

Singh (2003) pointed out that caste is considered to be an important factor that affects the choice of the occupation and proprietorship of skill in different rural economic activities. In the present study, it was found that Rai (25.5 percent) and Limboo (25 percent) constituted the major fish farming communities in Sikkim followed by Lepcha (17 percent) and Bhutia (10 percent). A major part of the North district is dominated by the indigenous Lepcha community in the mid and low altitudinal zones while in the high-altitude areas is mostly inhabited by Lachungpa, Lachenpa and Sherpa. Lachungpa, Lachenpa and Sherpa are not very much involved in aquaculture or fish farming activities because they are mostly focusing on agriculture and tourism activities. The study found that about 65 percent of fish farmers are Lepcha and the remaining 32.5 percent belonged to Limboo community. Mangshila is one of the places in the North district which is almost dominated by the Limboo people. The cluster form of aquaculture is found here with the presence of only fish farmer's cooperatives in the districts.

In the East district, the majority of fish farmers consisted of Rai (28 percent), Chettri-Bahun (22 percent), Sherpa (16 percent) and Lepcha (14 percent) and so on. The population of Rai is highest in the State as well as in South district. It was found that 70 percent fish farmers belong to Rai community and remaining 30 percent belong to Limboo, Bhutia, Sherpa and others communities. West Sikkim is known for trout farming in the state with three trout cooperative societies operating each at Upper Sribadam, Uttarey and Upper Rimbik. Several non-member farmers are also present in different villages of the district. This district has the highest percentage of farmers in the state as compared to other three districts. The largest fish farming community is Limboo which constituted 50 percent of the total population followed by Rai (22.86 percent), Bhutia (18.57 percent), Gurung (5.71 percent).

5.2.2 Socio-Economic Status of the Fish Farmers

The parameters like marital status, education, occupations, training and experiences, annual family income, improvement in economic conditions have been discussed in this section.

Table 5.5: Socio-Economic Status of Fish Farmers

	North	East	South	West	Sikkim
Marital Status					
Single	5 (12.5)	10 (16.7)	7 (23.3)	12 (17.1)	34 (17)
Married	33 (82.5)	42 (70)	21 (70)	54 (77.1)	150 (75)
Widow	0 (0)	3 (5)	2 (6.7)	2 (2.9)	7 (3.5)
Separated	2 (5)	5 (8.3)	0 (0)	2 (2.9)	9 (4.5)
Education					
No formal education	4 (10)	5 (8.3)	2 (6.7)	7 (10)	18 (9)
Primary (1-5)	12 (10)	14 (23.3)	9 (30)	20 (28.6)	55 (27.5)
High School (6-12)	20 (50)	31 (51.7)	16 (53.3)	31 (44.3)	98 (49)
Graduate & above	4	10	3	12	29

	(10)	(16.7)	(10)	(17.1)	(14.5)
Occupation					
Agriculture	18 (45)	17 (28.3)	10 (33.3)	12 (17.1)	54 (27)
Fisheries & Allied Activities	15 (37.5)	34 (46.7)	14 (46.7)	49 (70)	117 (58.5)
Govt. Employees	2 (5	4 (6.7	3 (10	4 (5.7	13 (6.5)
Private Employees	2 (5)	2 (3.3)	1 (3.3)	2 (2.6)	6 (3)
Business	3 (7.5)	3 (5)	2 (6.7)	3 (4.3)	10 (5)
Training					
Trained	21 52.5	37 61.7	14 (46.7)	45 (64.3)	117 (58.5)
Untrained	19 (47.5)	23 (38.3)	16 (53.3)	25 (35.7)	83 (41.5)
Experience					
1-5	18 (45)	23 (38.3)	12 (40)	8 (11.4)	61 (30.5)
5-10	14 (35)	25 (41.7)	14 (46.7)	50 (71.4)	103 (51.5)
10 & above	8 (20)	12 (20)	4 (13.30)	12 (17.2)	36 (18)
Annual Income from Total Sources (₹ in lakhs)					
0 -1.0	8 (20)	10 (16.7)	7 (23.3)	13 (18.6)	38 (19)
1.0 -2.0	18 (45)	25 (41.7)	15 (50)	24 (34.3)	82 (41)
2.0 -3.0	5 (12.5)	16 (26.7	6 (20)	15 (21.4)	42 (21)
3.0 – 4.0	5 (12.5)	3 (5)	2 (6.7)	11 (15.7)	21 (10.5)
4.0 – 5.0	3 (7.5)	1 (1.7)	0 (0)	4 (5.7)	8 (4)
5.0 – 6.0	1	4	0	1	6

	(2.5)	(6.7)	(0)	(1.4)	(3)
6.0 – 7.0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
7.0 – 8.0	0 (0)	1 (1.7)	0 (0)	2 (2.9)	3 (1.5)
AMITS (₹)	16906	17029	13280	19169	16596
AMIFF (₹)	4831	6046	3023	13098	6749
Economic Condition					
Improved	26 (65)	44 (73.3)	18 (60)	54 (77.1)	144 (72)
Not improved	14 (35)	16 (26.7)	12 (40)	16 (22.9)	(56 (28)

Source: Computed by Author based on Primary Data

The figure given in parentheses denote the percentage

AMITF means average monthly income from total sources and AMIFF is average monthly income from fish farming.

Marital Status

Fakoyo (2000) and Oladoja et al. (2008) ascertained that marriage confers some level of responsibility and commitment. Married people may have a greater sense of responsibility for their work. Ekong (2003) pointed out that marriage in our society is highly cherished. In the present study, it is found that 75 percent of fish farmers are married while 17 percent are unmarried; very few farmers are widowed and separated. This would suggest that married people are actively involved in fish farming compared to others. In all the districts, it is observed that the majority of the fishing activities are undertaken by married followed by unmarried youth.

Literacy and Education

Education plays an important role in any type of activity for the better and proper functioning of the projects and also for generating income. An increase in the educational standards of the farmers may lead to acquiring better knowledge in a farming activity that will help in the efficient management of fishery resources and enhance their level of earnings. In this study, it is found that the majority of the respondents (49 percent) have attained up to the high secondary level of education (6-12) followed by primary education (1-5) of about 27.5 percent; 14.5 percent are graduates and above and very few (9 percent) are still illiterate. The state wise observations revealed that most of the farmers have attained either high school or primary level in all the districts. Overall, we found almost 90 percent farmers are literate and very less are still left behind in terms of schooling.

Occupations

The occupational status of the people measures the standard of living and earnings in the society (Goswami et al., 2002). In our study, the primary occupations of the majority of the respondents are found to be fisheries and other allied activities (58.5 percent) followed by agriculture (27 percent), government service (6.5 percent), private service (3 percent) and small local business (5 percent). In district-wise analysis, it is found that fish farming and other allied activities as a primary occupation were observed to be maximum in West, East and South districts respectively. The study clearly stated that a primary activity such as fish farming and agriculture constituted the main occupation of the people of the sample villages. Thus, education and occupational choice can have a major impact on the adoption of fish farming.

Training

Training plays a vital role in the efficient management and operation of fish farming because more and larger the trained people in the farming activities better outputs may be expected. In our study, it is observed that the majority (58.5 percent) of the people have acquired training while the remaining 41.5 percent have still not availed training provided by the government. In all the districts, it is found that the majority of the respondents are trained. The government is providing extensive training facilities free of cost to the village farmers to enhance the fishery sector as a source of income and employment generation.

Experience

Experience is another important factor that plays a major role in the efficient utilisation of resources and acquiring optimum output in any venture, particularly in the primary sector, as it can be considered as a major factor in traditional knowledge. In the present study, maximum farmers (51.5 percent) fall under 5-10 years of experience which is a good sign in an economy, 30.5 percent have the experience of 1-5 years and rest 18 percent have experience of 10 years & above. The most experienced farmers are found in larger proportions in the West and East districts.

Income pattern

The income of the family is the most important index for getting an idea about the socio-economic condition of the people. Income is interrelated with several other parameters like consumption pattern, educational level, livestock holding, asset holding, house type, occupational status and general living conditions. Therefore, by analysing the income level of the sampled groups we can draw broad conclusions about the socio-economic structure of the surveyed area (Datta and Kundu, 2007). The majority of the fish farmers (41 percent and 21 percent) fall in the income groups of ₹ 1-2 lakhs and ₹ 2-3 lakhs per annum respectively. The average monthly income is found to be highest in the West district of about ₹ 19,169 followed by East district (₹ 17,029), North district (₹ 16,906) and the South district (₹ 13, 280). The average monthly income of the farmers as a whole is ₹ 16,596. The average monthly income from fish farming is found to be highest in the West district of about ₹ 13,098 followed by East district (₹ 10983), North district (₹ 4831) and South district (₹ 3023). The average monthly income is higher in West and East districts because in these two districts the number of trout growers is higher which yields higher prices and revenue. After investment in fish farming, it is important to study whether the economic condition of the farmers has improved or not. In the present study, we found that more than 70 percent respondents' economic condition has improved while 28 percent reported that there is no improvement. District-wise observations revealed that most of the farmers' economic condition has improved in West and East district which is also reflected in their monthly income. Overall, in all the districts more than 60 percent of the farmers have reported an improvement in their economic conditions.

5.2.3 Access to Basic Amenities

The access to basic amenities is one of the important things that determine the socio-economic conditions of the people. In the present study the parameters like house type, electricity, drinking water facilities, fuel sources and type of defecation have been discussed.

Table 5.6: Access to Basic Amenities

	North	**East**	**South**	**West**	**Sikkim**
House Type					
Pucca	24 (60)	38 (63)	17 (56.7)	43 (61.4)	122 (61)
Semi pucca	13	15	10	19	57

	(32.5	(25	(33.3	(27.2	(28.5)
Kachha	3 (7.5)	7 (11.7)	3 (10)	8 (11.4)	21 (10.5)
Electricity					
Electrified	40 (100)	60 (100)	30 (100)	70 (100)	200 (100)
Drinking water					
Owned source	25 (62.5)	40 (66.7	20 (66.7)	48 (68.6)	133 (66.5)
Govt. Supply	15 (37.5)	20 (33.3)	10 (33.3)	22 (31.4)	67 (33.5)
Fuel Sources					
Firewood	7 (17.5)	10 (16.7)	7 (23.3)	14 (20)	38 (19)
LPG + Firewood	33 (82.5)	50 (83.3)	23 (76.7)	56 (80)	162 (81)
Defecation					
Pucca	30 (75)	43 (71.7)	22 (73.3)	48 (68.6)	143 (71.5)
Kachha	10 (25)	17 (28.3)	8 (26.7)	22 (31.4)	57 (28.5)

Source: Computed by Author based on Primary Data

The figure given in parentheses denote the percentage

Housing Condition

Housing condition is one of the important factors that determine the living conditions of the people. According to the methodology adopted by National Family Health Survey (NFHS-3), 2005-06, houses have been categorised into three types viz., pucca, semi pucca and kachha. Houses made from cemented high-quality material that includes the floor, roof and exterior walls are defined as pucca houses while a house that uses partly low-quality and partly high-quality materials is defined as a semi pucca house. Kachha houses are made from mud, thatch or other low-quality materials. From the study, it is found that the majority of the respondents (61 percent) have a good quality houses while 28.5 percent have semi-pucca houses and very few respondents (10.5 percent) have low-quality houses. Similar types of results are found in all the districts of Sikkim. Such results would indicate that the majority of the fish farmers in Sikkim have good housing condition and this suggests development in the lifestyle of the rural people. In our sample study, it is found that all the houses in all the districts have been electrified which is a good indication of social and economic development.

Drinking Water

Drinking water facilities is another basic human need for survival. In the rural areas of Sikkim, people obtain drinking water from their premises and water supplied by the Public Health Engineering Department, Government of Sikkim. The premises of fish farming areas have sufficient water; therefore, most people have their source of drinding water. It is observed in this study that 66.5 percent have managed their drinking water from their own sources while 33.5 percent respondents have access to government supplied water in Sikkim and in all the districts more than 60 percent of respondents are found to have their own drinking water source. Districts-wise variations are found to be almost negligible.

Fuel Sources

In the rural part of Sikkim, people mostly use firewood and LPG as a source of cooking fuels. Most of people in Sikkim obtain LPG either by self-purchase or through government supplied. In our study, it is found that 81 percent of respondents used both LPG and firewood for cooking purposes while 19 percent people are using only firewood for cooking food. For cooking animal food all respondents used only firewood. Districts wise variations are found to be almost negligible.

Sanitation Facilities

The Ministry of Drinking Water and Sanitation reaffirmed that Sikkim has already achieved 100 percent sanitation either in pucca or kachha form. In our study, 71.5 percent of people have access to pucca toilet facilities while 28.5 percent have kachha toilet facilities. From the district wise observation, it is found that percentage of pucca toilet facilities is highest in the North district, followed by the South, East and West districts respectively.

5.3: Gini Measures of Income Inequalities

The Gini coefficient is a statistical measure of economic inequality in a population. It measures the dispersion or inequality of income amongst the sample population. The coefficient can take any value between 0 and 1. The Gini coefficient of zero means perfect equality where every population has the same level of income whereas value 1 express perfectly inequality in income amongst the populations. Generally, in most cases we find the values between 0 to 1. There are different methods of measuring income inequalities like Lorenz curve, Decile ratio, Palmo ratio etc. but for the present study the degree of income inequalities across the fish farmers of the four districts is assessed by Gini coefficient.

Table 5.7: Gini Measures of Income Inequalities

Districts	Gini coefficient calculated from fishery led income	Gini coefficient calculated from total income (fishing + others sources)
North	0.450	0.341
East	0.511	0.660
South	0.486	0.365
West	0.403	0.315

Source: Computed by Author based on Primary Data

Table 5.7 represents income inequality calculated from fishery led income as well as income from all other sources in terms of Gini coefficients. From the above results, we can say that income inequality is not severe among the fish farmers of three districts except the East district when Gini is calculated from the fishery led income as well as from the total source of income. This is the indication of a relative uniformity in status among the farmers of the districts and a reflection of uniformity in decision making, common interest and ease in management decisions. Moreover, income inequality is lowest in the West district as compared to the other districts. In the case of East district, Gini coefficients calculated from both the fishery led income and total source of income is higher as compared to the other districts. This may be because the percentage of membership in East district is less compared to the other districts; hence it is quite obvious that there are differences in earning levels amongst the members and non-members. Even those who are carp growers are getting lower returns compared to trout growers. In addition to this, it has been also observed that in the East district most of people reported that other occupations as their primary sources of income other than fishery. Hence, those who took fishery as a subsidiary source of income along with their primary activity have higher earnings as compared to those who are only involved in fishery activity. Therefore, income inequality is stronger in this case.

5.4 Perceived State of Living Condition of Fish Farmers

Logit analysis has been carried out to explain the fish farmer's perception on improvement or no improvement in living conditions compared to the previous few years. It is considered as a qualitative dependent variable represented by 1 in case of perceived improvement and 0 in case of no improvement or even deterioration in living standard. It has been regressed on several explanatory variables like per capita family monthly income, number of family members, age of the respondent, type of house and the number of members with above primary education relative to the total number of family members. The following regression model is used for this purpose:

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_1 + \beta_2 PCMI_i + \beta_3 NFM_i + \beta_4 AGE_i + \beta_5 HT_i + \beta_6 RPETM_i + \mu_i$$

(5.1)

Where, P_i = 1 if there is an improvement in the perceived socio-economic condition of the fish farmers, 0 otherwise. The explanatory variable PCMI stands for per capita monthly income of the family from fisheries, NFM represents a number of family members in a family, AGE is the age of the respondent, HT means the type of house where HT = 1, if the respondents have pucca house, 0 otherwise, RPETFM represents the ratio of above primary education to total members of the family and μ_i is the error term. Since the dependent variable is a binary outcome that may not give an appropriate result by the OLS or Weighted Least Square (WLS), therefore, non-linear estimation procedure viz. method of maximum likelihood is applied. The result of logit estimation is given in Table 5.8

Table 5.8: Logit Estimation to the Perceived State of Socio-Economic Living Condition

Explanatory Variables	Coefficients	Standard Error	Z-statistics
$PCMI_i$	0.0003343**	0.0001332	2.51
NFM_i	-0.016	0.094	-0.18
AGE_i	-0.021	0.019	-1.10
HT_i	2.195***	0.378	3.80
$RPETM_i$	1.549*	0.889	1.74
Constant	-1.065	1.225	-0.87
No. of Obs. = 200	LR $\chi^2(5)$ = 56.56	Prob> χ^2 = 0.0000	
Pseudo R^2 = 0.2348		Log Likelihood = -92.152	
No. of correct predictions = 156		Count R^2 = 0.78	

Source: Estimated by Author based on Primary Data

Note: ***, **, * represents significant level at 1%, 5% and 10% level of significance.

The coefficient of PCMI is statistically significant at 5 percent level suggesting a positive relationship between the per capita income and perceived socio-economic condition of the households. PCMI is an important variable that influences the perceived socio-economic conditions of fish farmers. Thus, an increase in the per capita income of the households increases the estimated perceived socio-economic condition of the households.

Similarly, the type of house viz., whether the respondents have a good condition of house or not will determine their socio-economic conditions. It is observed that house type is highly statistically significant at 1% level indicating a positive relation with the perceived view regarding better socio-economic status. The result suggested that better housing condition enhances the estimated perceived view regarding the better socio-economic conditions of the household. In addition to these, the ratio of above primary education to total members is also significant at 10 percent level showing a positive relationship with the dependent variable and this would imply that an increase in the educational level among the family members improves the estimated perceived socio-economic status of the households. The number of correct predictions is found to be 156 while the value of count R^2 is 0.78. The implication is that 78% of the cases the finding of marginal probabilities supports the actual perceptions. The significant value of count R^2 indicates that the considered socio-economic variables adequately influence the perception of the living conditions of the fish farmers. In the surveyed households it was found that the families have a considerable high amount of average monthly income or per capita income and these reflect that they are generally enjoying good conditions. Income from fish farming has been an additional source of income for the farmers. Most of the respondents owned either pucca or semi pucca houses while very few households are in poor housing conditions. During field visits, some of the respondents stated that fishery led income helped them in constructing their new houses and even in purchasing the basic household goods. The majority of the households have all the basic amenities like drinking water, conditioned toilet facility, electricity and LPG cooking fuel etc. Generally, fish farmers of the study areas are leading their lives in better conditions and this is since fish farming has been a gainful income generating activity and creating employment opportunities in the rural areas.

5.5 Comparative Socio-Economic Status of the Fish Farmers of Different PFCS

In this section, a comparative socio-economic study has been undertaken for the members of Sribadam, Maneybong-Sopakha, Upper Rimbik, Chujachen, Mangshilla and Dalep PFCS. The formers 4 are trout farming and the latter 2 are carp farming cooperatives. The sample size consisted of 12 from Sribadam, 21 from Maneybong-Sophaka, 19 from Upper Rimbik, 20 from Chujachen, 14 each from Mangshilla and Dalep cooperatives.

5.5.1 Demographic Profile of the Fish Farmers of PFCS

The fish farming activity is mostly dominated by the male members and such a report has been found by many authors in many studies. In the present study, it has been found that male members have dominated in fishing activity in all the PFCS. It is observed that all the members in Dalep society are males and societies such as Mangshilla and Chujachen have a higher percentage of male members than Sribadam, Maneybong-Sopakha and Upper Rimbik. The percentage of female members is very less in all the PFCS, although, it is higher in the trout PFCS like Uttarey, Sribadam and Upper Rimbik as compared to carp PFCS. Annually, the female participation rate is increasing in trout farming and this is because of the higher returns from the trout and greater awareness amongst women. .

Table 5.9: Demographic Profile of Fish Farmers of PFCS (in percent)

	Trout Growers PFCS				**Carp Growers PFCS**	
	Sribadam	**Maneybong-Sopakha**	**Rimbik**	**Chujachen**	**Mangshilla**	**Dalep**
Gender						
Male	83.3	71.4	89.5	90.0	92.9	100
Female	16.7	28.6	10.5	10.0	7.1	0
Age						
21-30	16.7	4.8	21.1	10	14.3	14.3
31-40	25.0	19.0	31.6	45	57.1	14.3
41-50	25.0	47.6	21.1	40	21.4	42.9
51-60	25.0	14.3	21.1	5	7.1	14.3
61 - Above	18.3	14.3	5.3	0	0	14.3

Category						
ST	66.7	28.6	100	50.0	92.9	0
SC	0	0	0	0	7.1	7.1
OBC(CL)	33.3	71.4	0	40.0	0	92.9
OBC (SL)	0	0	0	10.0	0	0
Religion						
Hindu	8.3	80.9	94.7	35.0	100	85.7
Buddhist	91.7	4.8	0	40.0	0	0
Christian	0	14.3	5.3	25.0	0	14.3
Caste	Limboo: 8.3 Bhutia: 58.3 Gurung:33.3	Rai: 71.4 Limboo:23.8 Lepcha: 4.8	Limboo: 100	Rai: 25 Lepcha: 10 Sherpa: 40 Gurung:10 Chettri: 5 Pradhan:10	Limboo:92.9 Kami: 7.1	Rai: 92.9 Kami: 7.1
Family Size						
1-4	16.7	14.3	21.1	25	21.4	14.4
5-8	83.3	80.9	73.7	50	64.3	50
9-12	0	4.8	5.3	25	14.3	28.6

Source: Computed by Author based on Primary Data

The maximum people of the age group of 31-40 and 41-50 are found to be being involved in this activity. The PFCS like Maneybong-Sopakha and Dalep have maximum farmers in the age group of 41-50 whereas in the case of the other four PFCS the maximum farmers fall in the category of 31-40 age groups. Overall, it has been observed that productive working people have been participating in the fishery activities which is a good sign in an economy. The majority of the farmers viz. 66.7 percent are SC in Sribadam, 71.4 percent OBC (CL) in Maneybong-Sopakha, 100 percent ST in Upper Rimbik, 50 percent ST and 40 percent OBC (CL) in Chujachen, 92.9 percent ST in Mangshilla and 92.9 percent OBC (CL) in Dalep. In general, the maximum percentage of either ST or central list OBC communities' people are being participated in the fishing activity in Sikkim. Religion wise distribution of people showed that the percentage of Buddhists is higher in Sribadam and in Chujachen all the religious people are being involved and, in the PFCS, such Maneybong- Sopakha, Upper Rimbik, Mangshilla and Dalep have major Hindu community. The study revealed that except Sribadam, Hindu community dominates in other five PFCS. Caste distribution of the people revealed that 58.3 percent farmers are Bhutia, 33.3 percent Gurung and 8.3 percent Limboo in Sribadam, 71.4 percent Rai, 23.8 percent Limboo and 4.8 percent Lepcha in Maneybong-Sopakha, 100 percent Limboo in Upper Rimbik and mixture of six communities in Chujachen, 92.9 percent Limboo in Mangshilla and 92.9 percent Rai in Dalep. The study revealed that the Limboo and Rai communities are larger in fishing activity in Sikkim. As far as the size of the family in fishing activity is concerned, the majority of the fish farmers of every PFCS have a family size of 5-8 members and the percentage is mostly higher in Sribadam, Maneybong-Sopakha and Chujachen.

5.5.2 Socio-Economic Status of the Fish Farmers of PFCS

Table 5.10 shows the result of the socio-economic status of fish farmers in each PFCS. In all the PFCS, the majority of the farmers are married and the percentage of married people is highest in Sribadam followed by Dalep, Maneybong-Sopakha, Upper Rimbik, Chujachen and Mangshilla whereas the percentage of unmarried people are less in every PFCS and in comparison it is found to be higher in Upper Rimbik, Mangshilla, Uttarey and Dalep. Few widows and separated people have also taken fisheries as their economic activity in some of the PFCS.

Table 5.10: Socio-Economic Status of Fish Farmers of PFCS (in percent)

	Sribadam	Maneyb	Rimbik	Chujachen	Mangshilla	Dalep
Marital Status						
Single	8.3	14.3	21.1	20	21.4	14.3
Married	91.7	76.2	73.7	70	64.3	78.6

Widow	0	4.8	0	5	7.1	7.1
Separated	0	4.8	5.3	5	7.1	0
Education						
No formal edu.	0	4.8	10.5	15	7.1	7.1
Primary (1-5)	25	47.6	31.6	25	42.9	28.6
High School (6-12)	58.3	33.3	47.4	50	42.9	57.1
Graduate & above	16.7	114.3	10.5	10	7.1	7.1
Primary Occupation						
Agriculture	16.7	14.3	26.3	20	14.3	21.4
Fisheries & Allied Activities	66.7	61.9	52.6	50	57.1	42.9
Govt. Employees	8.3	9.5	10.5	10	14.3	14.3
Private Employees	0	4.8	5.3	5	7.1	14.3
Business	8.3	9.5	5.3	2	7.1	7.1
Training						
Trained	100	61.9	52.6	60	64.3	57.1
Untrained	0	38.1	47.4	40	35.7	42.9
Experience						
1-10	83.3	66.7	84.2	85	78.6	71.4
11-20	16.7	33.3	15.8	15	21.4	28.6
Annual Income from fisheries (₹ in lakhs)						
0 -1.0	8.3	9.5	78.9	65	100	100
1.0 -2.0	50	38.1	10.5	25	0	0
2.0 -3.0	25	42.9	10.5	5	0	0
3.0 – 4.0	0	4.8	0	0	0	0
4.0 – 5.0	8.3	4.8	0	5	0	0
5.0 – 6.0	8.3	0	0	0	0	0
AMITS (₹)	25305	23327	15456	19033	18854	11157
AMIFF (₹)	19055	16603	7456	9033	2282	1443
Economic Condition						

Improved	92	88	70	78	63	58
Not improved	8	12	30	22	37	42

Source: Computed by Author based on Primary Data

The majority of fish farmers in all PFCS have attained either primary and high school education level and the graduate people are also taking participation in this activity. The major primary occupation of the farmers of each PFCS is fisheries and allied activities. And apart from this activity, few people are also being engaged in agriculture, government and private job and business. The majority of the people are found to be trained and the percentage of trained farmers in each PFCS are 100 percent in Sribadam, 61.9 percent in Maneybong-Sopakha, 52.6 percent in Upper Rimbik, 60 percent in Chujachen, 64.3 percent in Mangshilla and 57.1 percent in Dalep. In overall, we can say the maximum farmers of the PFCS are trained. All the farmers of PFCS are well experienced in fish farming and the majority have gained experience of 6-12 years and few 12 & above years. 83.3 percent farmers in Sribadam, 66.7 percent in Maneybong-Sopakha, 84.2 percent in Upper Rimbik, 85 percent in Chujachen, 78.6 percent in Mangshilla and 71.4 percent in Dalep have gained an experience of 6-12 years. In the present study, the minimum experience of the farmers is 6 years because only PFCS which have completed 6 years have been taken into consideration in the study. The average monthly income from total sources as well as from fish farming is observed highest for Sribadam followed by Maneybong-Sopakha and that of lowest is found for Dalep PFCS. In case of Sribadam and Maneybong -Sopakha more than 80 percent, in case of Upper Rimbik and Chujachen more than 70 percent and in case of Mangshilla and Dalep more than 50 percent members have stated their economic conditions has improved after the adaptation of fish farming.

5.5.3 Access to Basic Amenities to Farmers of PFCS

Table 5.11 represents an access to basic amenities by the farmers of PFCS. The majority of the farmers of each PFCS have pauca houses. The maximum number of pucca houses is found in Sribadam whereas the minimum is in Upper Rimbik. More than 50 percent of members of all PFCS have pucca houses except in Upper Rimbik. Only less percent of the farmers of each PFCS have Kachha houses lowest being found in Mangshilla and Sribadam. Overall, we can state that the majority of the fish farmers of each PFCS have better housing conditions. 100 percent of electrified houses were found in the sampled areas. All the villagers have access to electricity and even 100 units free in rural areas.

Table 5.11: Access to Basic Amenities by PFCS Members

	Sribadam	**Uttarey**	**Rimbik**	**Chujachen**	**Mangshilla**	**Dalep**
House Type						
Pucca	75	61.9	42.1	60	64.3	57.1
Semi pucca	16.7	23.8	31.6	30	28.6	28.5
Kachha	8.3	14.3	15.8	10	7.1	14.3
Electricity	100	100	100	100	100	100
Drinking water						
Owned source	75	76.2	78.9	70	57.1	64.3
Owned +Govt. Supply	25	23.8	21.1	30	28.6	21.4
Fuel Sources						
Firewood	0	9.5	10.5	15	14.3	7.1
LPG + Firewood	100	90.5	89.5	85	85.7	92.9
Toilet Type						
Pucca	83.3	80.9	73.7	85	85.7	78.6
Kachha	16.7	19.1	26.3	15	14.3	21.3

Source: Computed by Author based on Primary Data

There is no problem of drinking water facilities in fish farming premises in Sikkim because without the sufficient availability of water farming is not possible. In rural parts of Sikkim people have access to their own drinking water facilities and in some area's government has also provided. More than 70 percent members of fishing community in Sribadam, Maneybong- Sopakha, Upper Rimbik and Chujachen and more than 50 percent in Mangshilla and Dalep have access to their own drinking water facilities. Approximately 20 to 30 percent of members of the PFCS have access to both owned and government-supplied drinking water facilities. The use of firewood alone as a source of fuel for cooking food is very less of about varying between 5 to 15 percent only. Basically, in rural areas of Sikkim people prefer to use both firewood and LPG for cooking purposes which constituted more than 80 percent in the members of the fishing community of all PFCS. But for cooking fodder, they use only firewood which is a cheap source of fuel.

5.6: Gini Measures of Income Inequalities across the Fish Framers of PFCS

In this section, income inequality across these six PFCS has been evaluated. Table 5.12 depicts the Gini measures of income inequalities calculated for both fisheries led income and total source of income. The Gini concentration measures the degree of homogeneity or heterogeneity in the economic condition of the fish farmers of the respective members of PFCS.

Table 5.12: Gini Measures of Income Inequalities for PFCS

PFCS	Gini coefficient calculated from fishery led income	Gini coefficient calculated from total income
Sribadam	0.324	0.505
Maneybong-Sopakha	0.227	0.203
U. Rimbik	0.290	0.227
Chujachen	0.339	0.492
Mangshilla	0.268	0.374
Dalep	0.280	0.304

Source: Computed by Author based on Primary Data

The Gini coefficient calculated from the fishery led income is not much difference and severe across the PFCS except little higher in the case of Sribadam and Chujachen. This implies that there existed some extent of income inequalities amongst the members of PFCS and little bit higher in the above stated two cooperatives. Similarly, when we observed Gini coefficient from the total source of income, there is some heterogeneity amongst the members of PFCS, highest being observed for Sribadam and Chujachen followed by Mangshilla and Dalep while lowest for Maneybong-Sophaka and Upper Rimbik. If we compared Gini coefficients from both the parts, it has been found that Sribadam and Chujachen have the higher income inequalities amongst the members as compared to rest of the cooperatives and this is because there was a huge differences in the fish production amongst the members and there also existed difference in their other occupations apart from the fishing activity. Some members of the Chujachen also running tourism-based activities which gives higher earning than the other informal economic activities. Similary, in Sribadam, it was found that there was a diversity in member’s occupations like cardamom cultivators, local business and government jobs etc. Due to such reasons, income inequalities were higher amongst the members of these two cooperatives.

5.7: Perceived State of Living Condition of Fish Farmers of PFCS

Table 5.13: Logit Estimation to the Perceived State of Socio-Economic Living Condition of Members of PFCS

Explanatory Variables	Coefficients	Standard Error	Z-statistics
PCMI	0.0024711**	0.000987	2.50
NFM	-0.248	0.162	-0.53
AGE	0.023	0.034	0.69
HT	0.607**	0.378	2.38
RPETM	1.436*	1.573	1.62
Constant	0.964	1.861	0.52
No. of Obs. = 100	, LR $\chi 2(5)$ = 48.09	Prob> $\chi 2$ =0.0000	
Pseudo R2 = 0.3192		Log Likelihood = -92.152	
No. of correct predictions = 71		Count R2 = 0.71	

Source: Estimated by Author based on Primary Data

The PCMI is statistically significant at 5 percent level signifying a positive relationship with the perceived socio-economic condition of the members of PFCS. An increase in the per capita income of the household members of PFCS leads to an increase in estimated perceived socio-economic condition of the members.

The housing conditions of the respondents is one of the important factors that affects their socio-economic conditions. It has been found that conditions of house are statistically significant at 5 percent level representing a positive relation with the perceived view regarding better socio-economic status. The result suggested that the better housing status improves the estimated perceived socio-economic conditions of the household. Furthermore, the ratio of above primary education to total members is also found to be significant at 10 percent level with a positive relationship with the dependent variable implying an increase in the educational level among the family members improves the estimated perceived socio-economic status. The number of correct predictions is 71 with the value of count R^2 of 0.71. The implication is that 71% of the cases the finding of marginal probabilities supports the actual perceptions. The significant value of count R^2 indicates that the considered socio-economic variables adequately influence the perception of the living conditions of the fish farmers.

5.8 Conclusion

The study results of 200 samples which includes both the members and non-members of PFCS revealed that 50 percent of the selected sample fish farmers are members of PFCS and remaining 50 percent are non-members. Amongst these, 58 percent of the fish farmers are trout growers and the remaining 42 percent are carp growers.

In Sikkim, the fish farming activity are mostly dominated by male members and the females' participation rate is less. The maximum farmers fall in the age groups of 31-40 and 41-50 which indicates that productive active age group people are being engaged in fishery activity. The maximum farmers belong to OBC (CL) and schedule tribe. The majority are from Hindu and Buddhist and they belong to Rai and Limboo, Bhutia and Lepcha communities. The majority of the fish farmers are married which holds a greater social responsibility in the community. As far as the educational level is concerned, the maximum farmers have attained primary and high school standard and percentage of non formal education is negligible. The main occupations of the fish farmers are fishery and allied activities and agriculture. Some farmers are also engaged in government and private jobs and business apart from fishing activities. The majority of the farmers are trained and have an experienced of 5-10 years and above 10 years in fish farming. The fish farmers are earning considerable amount from the fishing as well as from other source of activities.

As far as access to basic amenities in Sikkim is concerned, the majority of the sample respondents have either pucca and semi pucca and very few farmers have kachha housing conditions. The majority of the farmers reported to have their own drinking water sources and there are no problems of drinking water in the fish farming premises. The maximum numbers of farmers are using the combinations of LPG and firewood as a source of cooking food. Although there are frequent power cuts in the rural and urban areas of Sikkim, all the sample households have access to electricity. The income inequality was found to be highest in East districts in case of fishery led income and total source of income. Similarly, across the PFCS, income inequality was highest for Sribadam and Chujachen etc. Per capita income, housing condition and family members who have attained education level above the primary are the major factors that affect the estimated perceived socio-economic conditions of the households. Overall, it can be said that the majority of the fish farmers of Sikkim have realised improvements in their economic condition.

CHAPTER 6

ANALYSIS OF FINANCIAL PERFORMANCES AND ENVIRONMENTAL SUSTAINABILITY OF COLDWATER INLAND FISHERIES IN SIKKIM

6.1 Introduction

In the hills, aquaculture has become the fastest growing food production sector while capture fisheries have been showing a declining trend. Fish farming, therefore, contributes significantly to food security and nutritional value and poverty alleviation in parallel with the development of profit-oriented entrepreneurship. Though the area under coldwater fisheries and its contribution is small as compared to the Indian fisheries scenario, it has significant importance in the tender ecological regime of the Himalayan region. The unique geographical and climatic conditions sustain entirely different fish faunal diversity. The fish faunal diversity as well as the ecosystem diversity of the region is considered to be the great wealth of our country. A few years ago, these resources were considered to be inexhaustible and enough to sustain the population living in upland regions. However, from the middle of the last century there has been population growth, income growth and urbanisation which have affected the coldwater species (Shrestha, 2002). The large-scale developmental activities such as an increase in the number of hydropower projects, factories, dams, (Shrestha, 2002; Aziz & Hossain, 2002); harmful fishing practices like electro-fishing, dynamiting and use of chemicals, and aquatic pollution (Shrestha, 2002); large and illegal extraction of fishes for the higher profits motives have resulted in degradation of the ecology of coldwater streams, lakes and reservoirs and there has been a sharp decline in the availability of fishes from these ecosystems. Thus, taking into consideration the importance of coldwater fishery resources and declining trends, it is necessary to conserve, manage and harvest the pond fishery on a sustainable basis.

To utilise the available water resources fruitfully and to maintain and develop capture and culture fishery involving the common interest of different people associated with fishing activity, people have taken an initiative to make fish farming as their subsidiary occupation and feel the urge to develop local water resources on a sustainable fish farming basis through the formation of the cooperatives. The main motives behind the formation of cooperative societies in Sikkim were: to increase the level of fish production and to expand fish marketing in Sikkim; to generate employment opportunities and to ensure a sustainable source of livelihood for the people; to supplement fish protein and other nutrients; to utilise the water resources for getting some economic benefits and prevent it from being left unproductive; to render service for the benefits of the members and non-members of the society; to raise adequate revenue such that reinvestment can be undertaken in this sector and to manage and conserve the fisheries resources on a sustainable basis.

Despite all the facilities like financial, technical and infrastructural support provided by the government, these cooperatives have not been able to achieve all their objectives satisfactorily. In many places, water bodies are virgin and unutilised. The perennial springs and streams in the hills flowing from the uplands to low lands are not properly and fully utilised. The primary constraints faced by the farmers in the hills are poor accessibility, irregularity in supply of feed or non availability of feed in time, high feed and transportation cost, lack of required fish seeds, a fungal infection in fish etc. Such problems may result in a mismatch between financial achievements in terms of productivity and profitability etc. Moreover, the motivation of higher profit may induce less concern for environmental sustainability and its management.

6.2 Evaluation of Financial Performances

Economic and financial evaluation of any investment can be carried out by analysing its productivity, profitability and managerial efficiency. The productivity and profitability analyses are the major ways of assessing or evaluating the feasibility or viability of an investment project. Before making any investment in aquaculture, it is very crucial to assess whether or not the proposed investment yields positive returns or not (Olasunkanmi, 2012). The primary purpose of forming fisheries cooperative societies or groups is to utilise the available resources efficiently and to become gradually productive over time and this is generally reflected in its productivity and profitability (Datta & Kundu, 2006). In the simplest terms, a farm’s productivity is defined as the ratio of the farm’s output to inputs. Profitability also indirectly reflects the managerial efficiency of a farm as it ultimately expresses the success or failure of the projects. The higher the profit, the greater is the scope for its reinvestment and the expansion of its functioning. But despite having a positive index of productivity in real terms, location and topography specific factors may cause high input costs due to which profitability of the farm may be adversely affected. The efficiency of financial management is likely to be determined by the level of dispersion of productivity and profitability over time (Datta & Kundu, 2006). In this chapter, we desired to examine the performances and management of fish farming operating under different coldwater PFCS to evaluate whether the investment in aquaculture or fish farming in Sikkim is worthwhile, feasible and efficient or not. Financial performances of the

PFCS have been evaluated in terms of productivity, profitability and managerial efficiency in the following way (Olasunkanmi, 2006; Datta & Kundu, 2006):

$$Productivity = \frac{Total\ output\ of\ fish\ in\ monetary\ terms}{Total\ inputs\ in\ monetary\ terms}$$

$$Profitability = \frac{profit}{cost}$$

If the profitability ratio is greater than 1, investment in fish farming is profitable

Profit (Π) = Total revenue – Total cost

Total Revenue (TR) = Total fish output X unit price of fish in ₹ .

Total Cost (TC) = sum of labour cost, input cost and other costs (maintenance cost, fishing cost etc.) in ₹

Managerial efficiency is reflected by the level of dispersion of productivity and profitability aspects and it is measured by

$$Coefficient\ of\ Variations\ (CV) = \frac{Standard\ Deviation}{Mean}\ X\ 100$$

Table 6.1: Evaluation of Financial Performances of Trout Growers' PFCS

PFCS	**Year**	**Production**	**Productivity**	**Profit**	**Profitability**
Upper Sribadam	2013-14	175	4.883	69583.333	3.883
	2014-15	250	3.546	89758.333	2.546
	2015-16	195	3.052	91775.687	2.052
	2016-17	175	3.288	85245.875	2.288
	2017-18	206	4.189	125660.210	3.189
	2018-19	254	4.063	153199	3.063
Maneybong-Sopakha	2013-14	140	4.560	54651.995	3.560
	2014-15	219	3.408	77394.369	2.408
	2015-16	165	3.684	72130.840	2.684
	2016-17	200	4.462	108625.347	3.462

	2017-18	220	4.009	132104.618	3.009
	2018-19	192	4.235	117524.378	3.235
Upper Rimbik Nambu	2013-14	145	3.128	49325	2.128
	2014-15	47.5	0.772	-7000	-0.227
	2015-16	83.333	0.942	-2520.833	-0.057
	2016-17	150	2.769	47916.66	1.769
	2017-18	146.666	2.476	52466.666	1.476
	2018-19	100	2.258	54500	1.258
20th Chujachen Constituency	2013-14	125	2.463	42000	1.463
	2014-15	132	2.587	44242	1.587
	2015-16	120.5	2.689	56369.75	1.689
	2016-17	84.2	2.567	39885	1.567
	2017-18	126	2.682	67725	1.682
	2018-19	158.88	2.970	104540	1.970

Source: Author's Calculation.

Table 6.1 illustrates the results of the financial performances of four trout growers' PFCS from the periods 2013-14 to 2018-19. The analysis such as productivity and profitability are carried out. The cooperative wise study has been undertaken as follows: -

In the case of Sribadam cooperative, the maximum output was recorded in the year 2018-19 followed by the output level in 2014-15, it slightly dropped during 2015-16 and 2016-17. Along with this, productivity and profitability of the cooperative are also showing a more or less growing trend except for a slight decline for both in 2015-16. This is because the cooperative had to bear extra costs for maintaining ponds and purchased materials such as water pipes, fishing gears and as a result, the profit increased by a very small margin. Profit declined during the period

2016-17 because of the decline in production of fish and increase in inputs cost but there was a slight improvement in productivity; this might be because of the better coordination and proper management of ponds. However, if we observe the overall performance of the cooperative there is an indication of improvement in all the above-mentioned indicators and got positive returns from the investment. The cooperative was able to manage the consistency and efficiency in financial management as is evident from the fact that there is less variability in productivity and profitability over the periods. In Manebong-Sopakha PFCS, the production has increased over the periods but slightly declined in 2015-16 and 2018-19. During these two periods, it was reported by the president of the cooperative that the government had distributed less fish seeds to the members due to the less production of fish seeds in the hatchery; however, there were improvements in productivity and profitability because the members nurtured fish and managed their ponds effectively. Conversely in the period 2017-18, productivity and profitability had decreased as a consequence of the rise in labour wages and inputs cost, though, production has increased. It is observed from the Table 6.1 that production has increased except for the periods 2015-16 and 2017-18.

Unfortunately, during the late 2013-14 major landslides occurred in Upper Rimbik. As a consequence, many raceways and fish were washed away by the landslides due to this productivity and profitability had declined significantly during the periods 2014-15 and 2015-16. Profitability became negative and the rate of productivity was also less than 1 during those periods. The Government refinanced and provided financial and technical support to this cooperative for its quick resuscitation. In 20th Chujachen PFCS, the production was lowest in the year 2016-17 and it is also found that production had declined for the periods 2015-16 and 2016-17 due to some biological causes but because of the hike in prices of fish, there were hardly differences in productivity and profitability. There was not much variability in productivity and profitability of the society over the periods.

Table 6.2: Evaluation of Financial Performances of Carp Growers' PFCS

PFCS	Year	Production	Productivity	Profit	Profitability
Mangshila	2013-14	120	5.419	19571.428	4.419
	2014-15	128	7.314	22100	6.314
	2015-16	110.33	6.572	23386.071	5.572
	2016-17	93.2	4.807	18453.333	3.807
	2017-18	102.6	5.463	25146.666	4.463
	2018-19	120.024	5.374	29307.2	4.374
Dalep	2013-14	90	5.688	11126.66	4.688
	2014-15	63	3.705	9200	2.705
	2015-16	79.5	3.816	11733.333	2.816
	2016-17	93	3.838	13754	2.838
	2017-18	63.2	3.019	10566.666	2.019
	2018-19	76.8	3.217	13233.333	2.217

Source: Author's Calculation.

Table 6.2 depicts the results of the financial performances of two PFCS of carp growers' during the period 2013-14 to 2018-19. Productivity and profitability are calculated to analyse the financial performances of the aforesaid cooperatives. The cooperative wise analyses are as follows: -

In the case of Mangshila PFCS, the production was recorded lowest during the year 2016-17 and 2017-18 due to the non-availability of required fish seeds on time by the members of the cooperative. This cooperative has the highest level of productivity and profitability among all other cooperatives because the cost of inputs such as the price of seeds and feeds are very less for carp farming compared to trout farming and basically fish eat grasses and locally made feeds. This indicates that their costs of production are less every year and can be produced at a minimum cost. Similarly, for Dalep PFCS, there was less variation in profitability and productivity ratios. This cooperative had the lowest level of fish production compared to all cooperatives across all the considered years; this is because it is the only cooperative located in the south district and it has fewer fish farmers and ponds due to water scarcity. Besides this, it has a smaller number of members in cooperative as well as couldn't raise the number of members in the succeeding years. Due to such reasons the production, productivity and profitability are lesser than the Mangshila cooperative. From the analysis of Table 6.1 and Table 6.2, it is found that fish farming is profitable except for the periods 2014-15 and 2015-16 in the case of Upper Rimbik. Sribadam, Moneybong-Sopakha and Mangshila are the highly profitable cooperatives than the others.

For assessing consistency and managerial efficiency among the PFCS, the coefficient of variation (CV) has been calculated. As we know the higher the CV the greater is the level of dispersion around the mean and lower the CV, the more precise the estimates. The degree of variability of the respective indicators for the considered PFCS are presented in Tables 6.3 and 6.4

Table 6.3: CV for Trout Growers' PFCS

PFCS/Economic indicators	Production	Productivity	Profit	Profitability
Upper Sribadam	16.865	17.570	30.107	23.762

Maneybong- Sopakha	16.647	11.078	32.078	14.699
Upper Rimbik Nambu	37.564	47.426	89.216	92.257
20th Chujachen	19.113	6.517	41.628	10.443

Source: Author's Calculation.

The analysis of Table 6.3 shows that the least variability for productivity and profitability is found for Chujachen followed by Manebong-Sopakha and Upper Sribadam. This indicates that there is consistency in their performance in terms of these two indicators. But if the production is concerned, less variation is observed for Upper Sribadam and Manebong- Sopakha not for Chujachen. On the other hand, high variability is observed in all the above indicators for Upper Rimbik implying instability in the managerial efficiency of the farm.

Table 6.4: CV for Carp Growers' PFCS

PFCS / Economic indicators	**Production**	**Productivity**	**Profit**	**Profitability**
Mangshila	11.454	15.941	17.152	19.245
Dalep	16.462	24.410	14.615	32.884

Source: Author's Calculation.

From Table 6.4, it is observed that less variability in production, productivity and profitability are found for Mangshila. So, in case of culturing the carp species, Mangshila is managerially efficient than Dalep

6.3 Environmental Sustainability and Fisheries Management

Fishery resources are renewable natural resources but natural stocks of fishes have been decreasing day by day because of the rapid explosion of the human population and the resultant persistent and indiscriminate fish harvest (Narayankumar, 2017). The management issue gains more significance in India, wherein species diversity is very high along with the difference among the fishing communities engaged in such operations (Narayankumar, 2017).

Sustainable fishing and fish farming are the means to harvest fish at a sustainable rate, where the stock of fish does not decrease over time because of fish catch and fishing practices. Sustainable management of the fishery resources whereby sufficient stock is left for future reproductive capacity is supposed to be an essential criterion for efficiency in fishery management. This should be environmentally friendly, technically feasible, economically and ecologically viable and socially acceptable. The concept of sustainability is applicable in both the capture and culture fisheries for the effective regeneration of their stock and continuous cycle of growth of fish and harvest. Water bodies like ponds, lakes, beels, tanks, etc. are governed based on culture-based fisheries or various other forms of enhancement which are intermediate to both culture and capture fishery. Such kind of management can be taken up in more eco-friendly ways maintaining the stock of fish. In this context, the analysis of the operation of fish cooperatives in terms of whether their annual catch lies below the MSY or falls in the borderline case, or surpasses them becomes very crucial.

The production sustainability of the different cooperative societies is examined by using the concept of maximum sustainable yield (MSY) of fish production associated with PFCS through the application of the Gordon Schaefer model[27] (Ajay, 1982; Kundu et al., 2006; Bhattacharya & Gupta, 2007). According to Schaefer's model, catch per unit of effort $\left(\frac{Y}{E}\right)$ is assumed to be proportional to the density of fish. The density of fish is supposed to be proportional to stock whereby the harvest level is written as Y = qEX, where q represents the catchability coefficient. This is known as the Gordon-Schaefer production function. It is assumed here that the yield rate is positively related to the index of inputs which is termed as effort E. So, the sustainability of fish farming across the different PFCS is analysed by using the concept of MSY based on a simple bioeconomic model developed by Gordon and applied by Schaefer (1954). Let X = total amount of fish population (kg); K = environmental carrying capacity or saturation level which is a positive constant; Y = harvest rate or yield rate (kg /year); E implies the index of effort. The effort index is defined as the fishing labour cost (rearing and harvesting) per fishermen as a percentage of other inputs cost. Other input costs include the cost of seeds, cost of fish feeds, maintaining and repairing cost and miscellaneous costs.

Effort index is calculated as follows:

$$Effort\ Index = \frac{Labour\ cost\ per\ fishermen}{Other\ input\ cost}\ X\ 100$$

$$= \frac{\frac{Total\ cost\ of\ labour\ in\ a\ year}{Total\ number\ of\ labour}}{Other\ input\ cost}\ X\ 100$$

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[27] The Gordon-Schaefer model is a bioeconomic model applied in the fishing industry. It may be used to compute the maximum sustainable yield. It takes account of biological growth rates, carrying capacity and total and marginal costs and revenues. This model can be applied in three primary scenarios: Monopoly, Maximum Sustainable Yield (biological optimum) and Open Access.

The growth of fish population X can be expressed mathematically by the well-known logistic equation

$$= \frac{\mathrm{dX}}{\mathrm{dt}} = \mathrm{rX}(1 - \frac{\mathrm{X}}{\mathrm{K}})$$

Subject to harvest at rate Y, we rewrite the net rate of growth as

$$\dot{\mathrm{X}} = \frac{\mathrm{dX}}{\mathrm{dt}} = \mathrm{rX}\left(1 - \frac{\mathrm{X}}{\mathrm{K}}\right) - \mathrm{Y}$$

However, using the production function we can rewrite the equation as

$$\dot{\mathrm{X}} = \mathrm{rX}\left(1 - \frac{\mathrm{X}}{\mathrm{K}}\right) - \mathrm{qEX}$$

Here r = intrinsic growth rate of fish stock (1/year) and $qE = \frac{Y}{E}$ implies catch standardized with respect to fish stock or catch per unit of biomass.

Here the criterion of sustainability requires the equality $\frac{dX}{dt} = Y$ which implies

$$\mathrm{r}\dot{\mathrm{X}}\left(1 - \frac{\mathrm{X}}{\mathrm{K}}\right) = \mathrm{qEX} \text{ whereby we get}, \mathrm{X} = \mathrm{K}(1 - \frac{\mathrm{qE}}{\mathrm{r}})$$

After some mathematical manipulation, we get

$$\mathrm{Y} = \mathrm{aE} - \mathrm{bE}^2$$

$$Y = E(a - bE)$$

It implies that

$$\left(\frac{Y}{E}\right) = a - bE \qquad (6.1)$$

$$Y = aE - bE^2 \qquad (6.2)$$

The optimum effort level and MSY corresponding to this equation can be found by using the first-order condition as

$$\frac{dy}{dE} = 1 - 2bE = 0$$

$$\hat{E} = \frac{\hat{a}}{2\hat{b}} \qquad (6.3)$$

Substituting equation 6.3 into equation 6.2, we get

$$Y = a\left(\frac{a}{2b}\right) - b\left(\frac{a}{2b}\right)^2$$

$$\text{or } \frac{a^2}{2b} - \frac{a^2}{4b}$$

$$\text{or } \frac{2a^2 - a^2}{4b}$$

$$\hat{Y}_{MSY} = \frac{\hat{a}^2}{4}$$

$$\hat{Y}_{MSY} = \frac{\hat{a}^2}{4\hat{b}} \qquad (6.4)$$

$$\text{Hence, } \hat{E} = \frac{\hat{a}}{2\hat{b}} \text{ and MSY} = \frac{\hat{a}^2}{4\hat{b}}$$

Since all the cooperative societies are located in Sikkim and it is expected that there will be fewer variations in ecological and environmental factors for culturing the species, hence, in this case, we have assumed that intercept and slope coefficient is constant across time and species and the error term captured difference over time and species. These are highly restricted assumptions due to which we may call this model as restricted Gordon Schaefer model

$$\left(\frac{Y}{E}\right)_{it} = a - bE_{it} + \mu_{it} \qquad (6.5)$$

Despite its simplicity, the restricted pooled regression may not be able to explain the true picture of the relationship between catch per unit of effort and the effort across the species. Because a particular species-specific fixed effect may exist and can influence the yield effort relationship. Therefore, to take into account, the species-specific effect we carried out regression analysis with a categorical dummy. Hence, we have used the Least Square Dummy variable (LSDV) model where the slope coefficient is constant but intercept varies across species and time. Therefore, we may call eq. (6.6) as the unrestricted Gordon-Schaefer model

$$\left(\frac{Y}{E}\right)_{it} = a_1 - bE_{it} + a_2 D_i + \mu_{it} \qquad (6.6)$$

where the subscript $i = 1 \ldots, N$ indicates the PFCS and subscript $t = 1 \ldots, T$ indicates the periods. In the regression model, *a* and *b* are the constants, the dependent variable $\left(\frac{Y}{E}\right)$ is the yield per unit of effort, E represents effort index, u_{it} represents the error term. In our study we are dealing with two types of species, i.e. trout and carp. It is quite natural that particular species may have some effect on the level of effort and as well on the harvest level and hence it may be correlated with the error term. Therefore, to overcome that we have used dummy variable D_i for capturing species-specific effect where we have assigned $D_i = 1$ if the fish species belongs to carp family, 0 otherwise. The intercept value (a_1) represents the mean yield per unit of the effort of the trout species and the slope coefficient attached to dummy variable (a_2) tells us by how the mean yield per unit effort of carp species differs from the mean yield per unit effort of trout species.

Hence, the coefficients a_1, a_2 and b are estimated by applying the above modified Gordon-Schaefer model using the least-squares technique. The yield of fish is taken as an annual harvest of fish in kg per area of the pond.

Table 6.5: Results of Pooled Regression and LSDV Model

Variables	Restricted Model		Unrestricted Model	
	Coefficient	**t-value**	**Coefficient**	**t-value**
effort	-19.077**	-2.24	-16.587**	-2.14
D_i	-	-	-29.863***	-2.91
constant	102.933***	4.43	116.839***	5.42
F -statistic	5.04***	-	7.31***	-
R^2	0.129	-	0.307	-

Source: Author's Calculation.

Note: *, ** and *** indicates the significance levels at 1%, 5% and 10 % respectively.

In the restricted model, given in eq. (6.5) we have considered that the effect of ecological and environmental factors remains the same over time irrespective of species and PFCS. It represents the results of the pooled regression analysis where yield is regressed on the effort index. The estimated results showed that the intercept is significant at 1 percent level and effort at 5 percent level indicating a negative impact on yield per unit of effort. The negative sign before the value of $\hat{b}$ implies that for a unit increase in the effort level the estimated average yield per unit of effort falls by 19.07 units. The F test statistic is found to be significant at 5 percent level and the estimated equation is also found to be a good fit.

Like, the unrestricted model represented by eq. (6.6) represents that the effort is statistically significant with its expected sign. The constant term is also found to be statistically significant. More interestingly dummy variable is found to be statistically significant, which indicates that species-specific effect exists on the level of effort as well as on the harvest level; this is quite natural because firstly, trout is a very high-value species with rich nutritional value. Secondly, the trout culture has been promoted extensively by the government. Thirdly the fishermen prefer trout culture compared to carp due to factors like profitability and nutritional value. The estimated mean yield per unit of the effort of the trout species is about 116.8397 kg while that of estimated mean yield per unit of the effort of the carp species is lower by 29.86 kg, i.e., 87 kg. The result is found to be a good fit as the R^2 value is rather high and have a statistically significant impact of effort and dummy variable on yield per unit of effort. The F statistic is also found to be statistically significant.

Now, the question arises regarding which model is suitable for estimating MSY. For this purpose, we have set the following hypothesis:

H_0: There is no difference between the restricted and unrestricted models.

H_1: There is a difference between the restricted and unrestricted models.

To test the above hypothesis, the following test statistic is being used.

$$F_{(1,33)} = \frac{(RRSS - URSS)/q}{URSS/(N-K)}$$

where *RRSS* represents the residual sum of the square of the restricted model, *URSS* represents the residual sum of the square of the unrestricted model, *q* is the difference between the parameters of the restricted and unrestricted models, *N* is the number of observations and *K* is the number of parameters of the unrestricted model.

$$F = \frac{(138585.19-110267.156)/1}{110267.156/(36-3)}$$

$$F_{cal} = 8.4748$$

F_{cri} for (1,33) df at 1 % and 5 % level of significances are given by 7.48 and 4.143 respectively. Since the values of F_{cri} are less than the F_{cal} at both 1% and 5% level of significances, hence, we may reject the null hypothesis and accept the alternative hypothesis which implies that model 2 is appropriate to estimate MSY. It is also confirmed from the statistically significant impact of the dummy variable on yield per unit of effort (LSDV model).

Based on the results obtained from the LSDV model we performed the following calculations to find out the MSY for trout and carp growers' PFSC separately. As we know, in the LSDV model, it is assumed that the slope coefficient remains constant but the intercept varies across individuals. Therefore, the slope coefficient of both trout and carp species are the same i.e. $\hat{b}$ = 16.5866 but the intercept varies between them. Thus, for trout, $\hat{a}_1$ = 116 and for carp, $\hat{a}_2$ = 116 + (-29) = 87.

Table 6.6: Results of Estimation of the Yield–Effort Equation for PFCS

PFCS	**Constant (a_1, a_2)**	**Coefficient (b)**	**R^2**	**F**	**MSY**	**Average Yield**
Trout	116*** (5.42)	-16.587** (-2.41)	0.30	7.31***	202.814	158.80
Carp	87*** (-2.91)	-16.587** (-2.41)	0.30	7.31***	114.069	91.95

Source: Author's Calculation.

Note: *, ** and *** indicates the significance levels at 1%, 5 % and 10 % respectively and figures within the brackets represent the t- statistics

Table 6.6 shows the results of the estimation of the yield effort estimation of the six PFCS operating in different districts of Sikkim which are involved in the production of trout and carp species. The MSY for each trout and carp species has been found by applying the formula given in equation (6.6). The result indicates that the value of MSY is equal to 202.8143 for trout species which implies the maximum amount of fish that can be extracted per pond taking into consideration the needs for the future generations. The average yield of trout fish is 158 kg per pond. Similarly, in the case of carp species, the value of MSY is equal to 114.0693 implying that the maximum amount of fish that can be extracted or harvested per pond taking into consideration the future stocks and sustainability of the fish resource. The average yield of carp fish is found to be 91.95 kg per pond.

Table 6.7: Comparative Results for Actual Yield and MSY for Trout Growers' PFCS

PFCS	Year	Actual Yield	MSY (Y_m)	Ratio of Y_a to Y_m	$\lvert Y_a/Y_m-1 \rvert$
Upper Sribadam	2013-14	175	202.814	0.862	0.137
	2014-15	250	202.814	1.232	0.232
	2015-16	195	202.814	0.961	0.038
	2016-17	175	202.814	0.862	0.137
	2017-18	206.315	202.814	1.017	0.017
	2018-19	254	202.814	1.252	0.252
Maneybong-Sopaka	2013-14	140	202.814	0.690	0.309
	2014-15	219.047	202.814	1.080	0.080
	2015-16	165	202.814	0.813	0.186
	2016-17	200	202.814	0.986	0.013
	2017-18	220	202.814	1.084	0.084
	2018-19	192.307	202.814	0.948	0.051
Upper Rimbik Nambu	2013-14	145	202.814	0.714	0.285
	2014-15	47.5	202.814	0.234	0.765

	2015-16	83.333	202.814	0.410	0.589
	2016-17	150	202.814	0.739	0.260
	2017-18	146.666	202.814	0.723	0.276
	2018-19	100	202.814	0.493	0.506
20th Chujachen	2013-14	125	202.814	0.616	0.383
	2014-15	132.142	202.814	0.651	0.348
	2015-16	120.714	202.814	0.595	0.404
	2016-17	84.285	202.814	0.415	0.584
	2017-18	126	202.814	0.621	0.378
	2018-19	158.888	202.814	0.783	0.216

Source: Author's Calculation.

Table 6.7 illustrates the year-wise variation of actual yield from MSY and their implications for four different trout growers' PFCS operating three in West district namely Upper Sribadam, Maneybong-Sophaka, Upper Rimbik Nambu and one in East Sikkim namely 20th Chujachen Constituency.

It is observed that in case of Upper Sribadam, the actual yield is higher than the MSY and the ratio of actual yield to MSY exceeds 1 for the periods 2014-15, 2017-18 and 2018-19 and the remaining years it is close to 1 indicating that there is a greater threat of actual yield surpassing the MSY. A harvest level greater than or close to MSY indicates that there is less concern for environmental sustainability, future growth of fish resource and stock generation. The mean actual yield is found to be rather high at a value of 209.22. It is also found that the absolute deviation of the ratio Y_a/Y_m from 1 for the respective years is rather low while the mean absolute deviation of the ratio from 1 is 0.1358 indicating that on an average 86.42% of MSY is harvested keeping a relatively smaller portion of 13.58 % for a stock generation.

Similarly, for Maneybong-Sopakha, the actual yield is higher than the MSY and the ratio of actual yield to MSY exceeds 1 for the years 2014-15 and 2017-18 and is very close to 1 for the remaining years. Harvest levels exceeding the MSY indicate a disregard for environmental sustainability and complete unconcern regarding the future stock of resources. The mean actual yield is found to be high with a value of 189.39. The result also shows that the absolute deviation of the ratio Y_a/Y_m from 1 is lower and the mean absolute deviation of the ratio from 1 is 0.1211, indicating that on an average 87.89 percent is harvested leaving relatively smaller stocks for future generations of about 12.11 percent.

Considering the case of Upper Rimbik Nambu, the actual yield is lower than the MSY in all the respective years and the ratio of actual yield to MSY is also less as compared to the previous two societies. The Table 6.7 revealed that the mean actual yield is found to be rather low at 112.08. The result also showed that the absolute deviation of the ratio Y_a/Y_m from 1 is rather high except for the years 2013-14, 2016-17 and 2017-18 and the mean absolute deviation of the ratio from 1 is 0.4474 indicating that on an average 55.26 percent is harvested leaving 44.74 percent for a future stock generation.

Similarly, in the case of the 20th Chujachen Constituency, it is observed that actual yield is lower than MSY and the ratio of actual yield to MSY is moderate for all the respective years. The result showed that the average of actual yield is 124.51. The absolute deviation of the ratio Y_a/Y_m from 1 is moderate while the mean absolute deviation of the ratio from 1 is 0.3308 indicating that on the average 66.92 percent of MSY is realised keeping 33.08 percent for a future stock generation.

As compared to the first two cooperative societies, the latter two are relatively much more concerned with the stock generation and sustainability and hence, it was deemed necessary to leave a substantial amount of stock for breeding in the successive periods for the better maintenance of sustainability. There is a greater threat to sustainability in the case of the former two cooperatives because of the surpassing of their actual yield over the MSY in some of the years.

Table 6.8 depicts the year-wise variation of actual yield from MSY and their implications for the two carp growers' PFCS operating each in North district and South district namely Mangshila and Dalep PFCS respectively.

Table 6.8: Comparative Results for Actual Yield and MSY for Carp Growers' PFCS

Name of PFCS	**Year**	**Actual Yield**	**MSY (Y_m)**	**Ratio of Y_a to Y_m**	**$\lvert Y_a/Y_m - 1 \rvert$**
Mangshila	2013-14	120	114.069	1.051	0.051
	2014-15	128.88	114.069	1.129	0.129
	2015-16	110.33	114.069	0.967	0.032
	2016-17	93.22	114.069	0.817	0.182
	2017-18	85.5	114.069	0.749	0.250
	2018-19	100.02	114.069	0.876	0.123
Dalep	2013-14	90	114.069	0.788	0.211
	2014-15	63	114.069	0.552	0.447
	2015-16	79.5	114.069	0.696	0.303
	2016-17	93	114.069	0.815	0.184
	2017-18	63.2	114.069	0.554	0.445
	2018-19	76.8	114.069	0.673	0.326

Source: Author's Calculation.

Considering the Mangshila PFCS, the actual yield is higher than the MSY for the years 2013-14 and 2014-15 and also exceeds the value 1 in the ratio of actual yield to MSY while for the remaining years, it is close to 1. As we know from the preceding analysis that the implication of this would mean that the greater the closeness of the aforesaid ratio to one, the higher is the threat of the actual yield surpassing the MSY line. The mean actual yield is found to be rather high at a value of 106.325. It is also observed that the absolute deviation of the ratio Y_a/Y_m from 1 for the respective years is rather low and the mean absolute deviation of the ratio from 1 is 0.1285 signifying that on the average 87.15% of MSY is harvested keeping a relatively smaller portion of about 12.85 % for a further stock generation. Furthermore, from this result, we can infer that the stakeholders of this society should be more aware of the inadequate performance in terms of sustainable harvest.

Lastly, taking into consideration the Dalep PFCS, the average yield of fish is less than the MSY level in all the respective years while the ratio of actual yield to MSY is higher for the years 2013-14 and 2016-17; it is moderate for the remaining years and not exceeded in any of the aforesaid periods. The mean actual yield is observed to be rather low at about 77.58. The result also indicates that the absolute deviation of the ratio Y_a/Y_m from 1 is lower with the mean absolute deviation of the ratio from 1 being 0.3198 revealing that on the average 68.11% of MSY is being reaped leaving 31.98 percent for a future stock generation as compared to the Mangshila PFCS.

6.4 Conclusion

The results of this chapter revealed that the PFCS such as Upper Sribadam, Manebong- Sopakha and Mangshilla had reached higher financial achievements in fish farming; at the same time, it is observed that there is a threat of sustainability as in some of the years the actual yield surpasses the MSY. These cooperatives have paid more attention to financial management and relatively less to environmental sustainability. They have harvested beyond the MSY level keeping a relatively smaller portion for stock generations which would mean that they are more concerned with profit motive rather than environmental sustainability. On the other hand, PFCS like Upper Rimbik, Chujachen and Dalep have not been able to keep their financial management up to the mark because of several kinds of natural, environmental and biological problems they have encountered during the periods; even then they had put more concern to the sustainability criterion and maintained relatively substantial amount for the future generations as compared to the former three cooperatives. Their actual yield is less than the MSY in all the periods. More financial achievements like more productivity and profitability mean more extraction of existing resources implying less scope of regeneration for the future which indicates a trade-off between the financial management and environmental sustainability of resources. It is to be noted that although sustainability is maintained by the cooperatives, there is a lack of stability in the sustainability factor as it is evident from the observed fluctuations in the considered ratio of actual yield to MSY. The reason is that neither the fish population is in equal proportions nor is the harvesting done at a uniform level among the different cooperative societies over the years. It is a fact that there cannot be a stable condition in all these production units. The fish population in the ponds is subject to continuous change and it is hardly in a state of equilibrium or general stability. A better and efficient practice of fishery supported by adequate financial and other social inputs can bring environmental conditions in ponds closer to a balanced population thus helping to achieve steady MSY. Positive returns from investment in fisheries is very essential for proper functioning and also for reinvestment for succeeding periods; however the coldwater resources are located in upland fragile regions of the hills and during the past few years coldwater fish species in the Himalayas have greatly shrunk due to manmade activities, illegal and harmful fishing practice, larger extractions beyond MSY for higher profit motives, natural factors etc. have resulted the degradation of ecology and hence fishes from water ecosystems. Therefore, it has become very crucial to conserve, manage and utilise fishery resources on a sustainable basis. Aquaculture or capture fisheries have been a promising sub sector of fisheries and it has been growing rapidly to meet the demand of the fish food. But there should maintain production sustainability with the sustainability of earning to keep the resources for the next generations.

CHAPTER 7

ECONOMIC VALUATION OF NATURAL LAKE ECOSYSTEM OF SIKKIM

7.1 Introduction

Nature can be regarded as a public good which is priceless, yet is worth a lot. While the ecosystem reinforces all human life and activity, people are often not aware of the benefits they receive from nature nor their value. An ecosystem is a dynamic complex of plants, animals, microbes and physical environmental features that interact with one another. Ecosystem services are the benefits that humans derive from ecosystems. These include provisioning services like water, food, fiber and timber; regulating services that affect water quality, climate, floods, wastes and disease; social and cultural services that provide aesthetic, spiritual and recreational benefits; and supporting services such as photosynthesis, nutrient cycling and soil formation etc. (Costanza et al. 1997; MEA 2005). Aquatic ecosystems accomplish many interrelated environmental functions and offer varieties of essential goods and services for human consumption and benefits that comprise both market goods and services like drinking water and aquatic animals including fish and non-market goods and services such as biodiversity (Gleick 1993, Naiman et al. 1995, Postel & Carpenter, 1997). An aquatic ecosystem such as a lake is home to many aquatic animals including fish species. Lake ecosystem provides many use and non-use values. It supports commercial fishing, agriculture and functions as a natural source for providing recreation, enjoyment, aesthetic and spiritual value to the people. The Himalayan region has many lakes situated at different altitudes. Several of these are sacred that attract visitors and pilgrims from all over the world for their aesthetic, cultural and spiritual significance. Sikkim Himalaya has more than 150 lakes located at different altitudes and most are considered sacred (Roy &Thapa 1998). The natural lakes such as Tsongmo lake, Khecheopalri lake, Menmecho lake, Aritar lake etc. are habitats for coldwater fish species. However, fishing in the lakes is not allowed because lakes in Sikkim are considered to be very sacred and worshipped by the people (Roy &Thapa, 1998).

The aesthetic and ecological advantage of lake ecosystem have been recognised for over a century, yet rarely quantified. It is crucial to start the economic valuation of the benefits to be derived from preserving natural systems in developing countries. Recreational and commercial values of some sites have been estimated in both developed and developing countries within the last ten years (Bergstrom et al., 1990; Claugh & Meister, 1991; Tobias & Mendelsohn, 1991; Willis & Garrod, 1991; Balick & Mendelsohn, 1992; Moran, 1994; Lansford & Jones, 1995; Menkhaus & Lober, 1996; Wilson & Carpenter, 1999). It is complicated to find the worth of any ecosystem and natural resources by using traditional economic measures because the scenic beauty or use value of such amenities is not usually priced in markets (Islam & Majumder 2015). The absence of market demand for such services leads to the introduction of precise non-market valuation techniques. The CVM and the TCM are the most generally utilised techniques developed for the measurement of the value of non-market goods. Now a days, ecosystems may be evaluated in terms of total economic value. The usually applied methods for assessing the valuation of an ecosystem include WTP for ecosystem benefits and CVM. The values of outdoor recreation resources are not directly observable in the marketplace. Some economists (Freeman, 1993; Smit et al., 1986; Feenberg & Mills, 1980) prefer the resource valuation methodology used for nonmarket goods to be based on observed consumption behavior. One such class of nonmarket valuation methodologies is termed as travel cost models in which a recreationist is viewed as choosing one or more sites, site qualities and site visit rates based on relative travel costs from home to reach site. In our study, we have used CVM and TCM for evaluating the economic value of two lakes of Sikkim which are primarily fish habitat.

7.2 Brief Description of Study Area

Sikkim is a Himalayan state located in the Eastern Himalayan region of India demonstrating high biodiversity and abundant natural resources with mountains peaks, rivers, streams and lakes making it suitable for coldwater fisheries with attractive tourist destinations for both national and international tourists. The potential area of the lake is about 100 square miles. The lakes are situated in scattered form in temperate alpine and subalpine zone. The majority of the lakes are in Northern most region which abounds in glaciers and deep forests. These lakes are stocked with brown and rainbow trout, carps etc. Out of the total area of 32 square miles of the lakes covered under the Fisheries Development Programme.

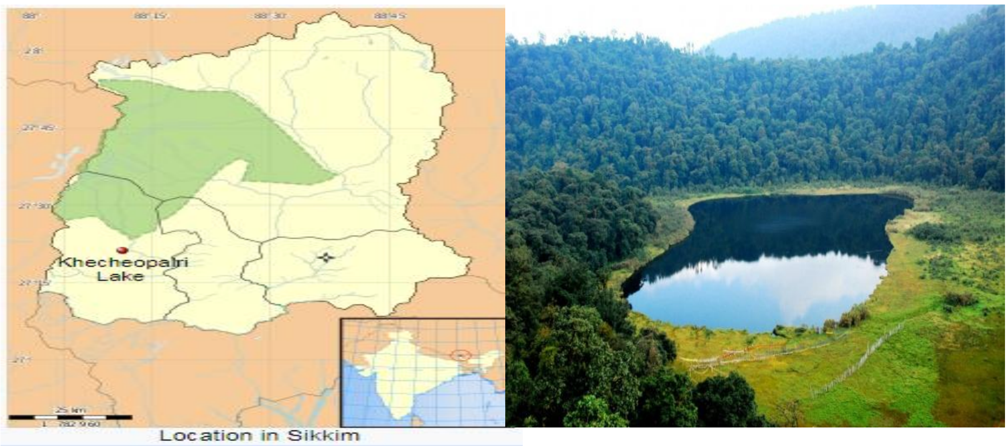
7.2.1 Khecheopalri Lake

The Khecheopalri lake is situated at an altitude of 1700 m (5,600 ft) having surfaces are of about 3.79 ha (9.4 acres). The depth of water in the lake varies from 3.2-11.2 m (10-37 ft) with an average depth of 7.2 m (24 ft.) and a water volume of 272,900 m^3.[28] Khecheopalri Lake, originally named as Kha-Chot-Parli (meaning the heaven of

[28]"Folklores of sacred Khecheopalri Lake in the Sikkim Himalaya of India: A Plea for Conservation" Shubken publication.

Padmasambhava[29]), is a sacred lake located near Khecheopalri village, 147 km from Gangtok and 34 km from the Pelling town in west Sikkim.

Figure 7.1: Location Map and Picture of Khecheopalri Lake



Source: Wikipedia

The lake is considered holy by both Buddhists and Hindus and is believed to be a wish-fulfilling lake.’[30] Folklore and many legends are associated with its formation and shape. The water of the lake is used for rites and rituals. A festival known as the Khecheopalri Lake Festival is observed every year during March where a large number of local pilgrims and tourists visit the lake. The lake has different species of a large number of fishes, but fishing and other recreational activities such as boating on the lakes are strictly prohibited. It is believed that any disturbances and unhealthy activities on the lake may bring calamities and unwelcome events. The Khecheopalri Lake and Khangchendzonga National Park are conserved from the biodiversity standpoint along with a focus on ecotourism and pilgrimage. As a result,

[29] *Padmasambhava* also known as *Guru Rinpoche* was an 8th century Buddhist master from the Indian subcontinent.

[30] Wetland Inventory.Sacred Khechopalri Lake.Envis: National Informatics Centre. P. 369.

their recreational and sacredness values are enhanced.[31] The maximum and minimum temperatures recorded in the lake regions are 24 °C (75 °F) and 4 °C (39 °F) respectively with a monsoonal climate.

The lake is enclosed by a broad-leafed mixed temperate forest; however, the vegetation in the lake includes *Phytoplankton,*[32]*Zooplankton,*[33]*Macrophytes.*[34]

MacrophytesincludeAponogetonmonostachyon,Ceratophyllum sp., MonochariaVaginalisScirpus sp. The Phytoplankton species are composed of different families such as *Chlorophyceae (18), Chrysophyceae (15), Cyanophyceae (11)* and one species each of *Charophyceae*, *Euglenophyceae*, *Dinophyceae and Cryptophyceae*. *Zooplanktons*

recorded are seven *rotifers*, five *protozoans*, two each of *copepods* and *cladocerans*, and each of *ostracods* and *isopods*. The species of fish found in the lake are Danioaequipinnatus [35] ,Cyprinuscarpio [36] , Schziothorax sp [37] Garra sp [38] . and Schistura sp[39]. necessary offshoots.

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[31]"Our Views". Brief Overview of valuation of Ecotourism in the Sikkim Himalaya. Environment Centre on Ecotourism in Sikkim: National Informatics Centre. Archieved from the original on 28 July 2010.Retrieved 5 May 2010.

[32] Phytoplankton are the autotrophic (self feeding) components of the plankton community and a key part of oceans, seas and fresh water basin ecosystems. https://en.wikipedia.org/wiki/Phytoplankton

[33] Zooplankton are a type of heterotrophic plankton that range from microscopic organisms to a large species such as jellyfish. Zooplankton are found within large bodies of water, including oceans and freshwater systems. It is drifting ecologically important organisms that are an integral component of the food chain. https://biologydictionary.net/zooplankton/#:~:text=Zooplankton%20(pictured%20below)%20are%20a,including%20oceans%20and%20freshwater%20systems.

[34].

[35] The giant danio (*Devarioaequipinnatus*) is a tropical fish belonging to the minnow family Cyprinidae. Originating in Sri Lanka, Nepal, and the west coast of India. It is characterized by a blue and yellow, torpedo-shaped body with gray and clear fins. https://en.wikipedia.org/wiki/Giant_danio

[36] The common carp or European carp (*Cyprinuscarpio*) is a widespread freshwater fish of eutrophic waters in lakes and large rivers in Europe and Asia. The

7.2.2 Aritar Lake (Lamphokhari)

Aritar Lake is one of the oldest natural lakes. It is also known as Lamphokari lake. It is located in Aritar village in the East district of Sikkim. It is situated at an altitude of 4600 ft and is 1120 ft long and 240 ft wide having boot-like shape. The location of the area makes it easily accessible to the visitors as it is about 85.9 km from the capital Gangtok and 49.2 km from Rangpo town and also not far from Rhenock town.

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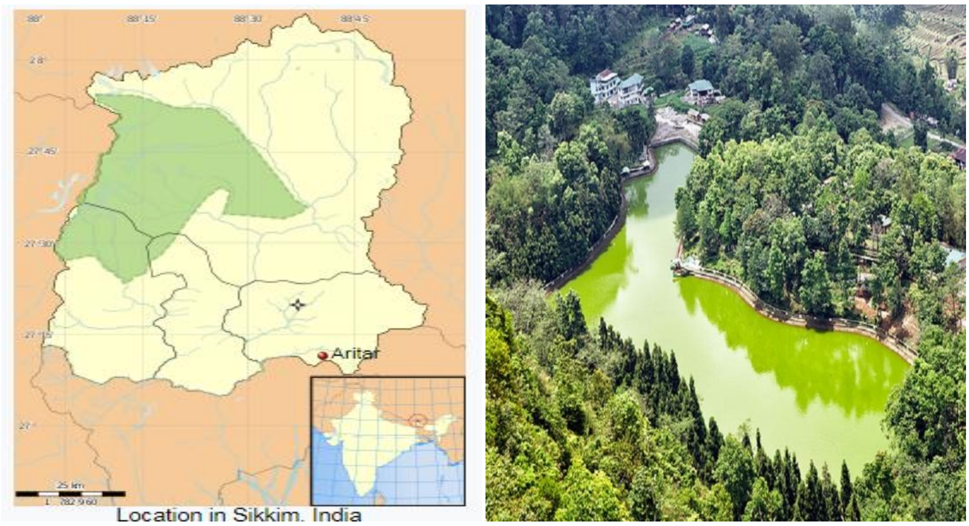
native wild populations are considered vulnerable to extinction by the International Union for Conservation of Nature (IUCN), but the species has also been domesticated and introduced (see aquaculture) into environments worldwide, and is often considered a destructive invasive species, being included in the list of the world's 100 worst invasive species. It gives its name to the carp family, Cyprinidae. https://en.wikipedia.org/wiki/Common_carp

[37] Schziothorax sp is the Snowtrout fish. *Schizothorax* is a genus of cyprinid fish found in southern and western China, through northern South Asia (Himalaya) and Central Asia, to Iran, with a single species, *S. prophylax*, in Turkey. They are primarily found in highland rivers, streams and lakes, although a few species occur in lower-lying locations, like Lake Balkhash and lakes of the Sistan Basin. https://en.wikipedia.org/wiki/Schizothorax#:~:text=Schizothorax%20sp.&text=Schizothorax%20is%20a%20genus%20of,prophylax%2C%20in%20Turkey.

[38] *Garra* is a genus of fish in the family Cyprinidae. The majority of the more than 140 species of garras are native to Asia and Africa. https://en.wikipedia.org/wiki/Garra

[39] *Schistura* is a genus of fish in the stone loach family *Nemacheilidae* native to the stream and rivers of the southern and eastern Asia. Some of these species are troglobitic. There are currently over 200 recognised species in this genus. https://en.wikipedia.org/wiki/Schistura

Figure 7.2: Location Map and Picture of Aritar Lake



Source: Wikipedia

It is surrounded by green pine forests and has boating facilities and a pathway that has been constructed all around the lake for enabling the tourists to have views of the lake from different angles. Lampokhri Lake has a very popular bird-watching trail. There is also a small shrine on the banks of the lake dedicated to Guru Padmasambhava. The best time to visit this lake is from March to May and October to December since the weather remains pleasant and cool.

7.3 Recreational Activity of the Visitors at Khecheopalri and Aritar Lakes

The primary purpose of the visitors is to enjoy the recreational activities provided by the lake. As we know that the lake offers many recreational pleasures in the form of beautiful surroundings and scenery, fishing, swimming, fish and bird watching, boating, photography etc. In Sikkim, most of the lakes are considered to be sacred and provide spiritual and religious value to the people. For the pilgrimage visitors, temples and monasteries were built around the lake sites. The major recreational activities provided by these two lakes are shown in Table 7.1. The visitors were asked to state the major recreational activities enjoyed by them based on their preference. The percentage of visitors based on their most preferred recreational activities are summarised as follows

Table 7.1: Most Preferred Recreational Activity of the Visitors at Khecheopalri and Aritar Lakes

Most Preferred Recreational Activity	Khecheopalri Lake	Aritar Lake
	Percentage	Percentage
Enjoying pleasant weather and the beautiful scenery of the lake	50	40
Worship	20	12
Boating	-	30
Watching fish	15	8
Photography	15	10

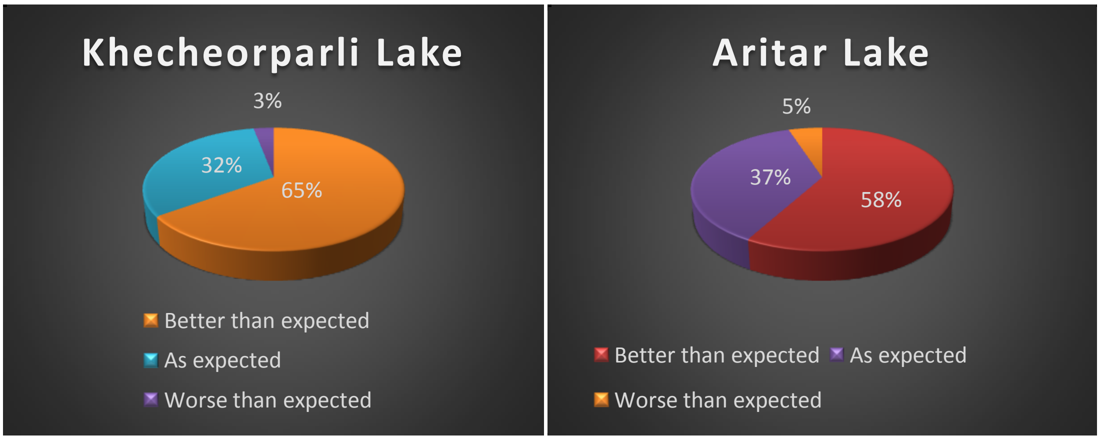
Source: Field Survey

In the Himalayas, tourists are mostly attracted by beautiful scenery and pleasant weather although there are many limitations concerning transport and communication amenities. Based on a sample size of 100 from each lake, it was found that 50 percent of visitors in the case of Khecheopalri and 40 percent in the case of Aritar stated that enjoying pleasant weather and beautiful scenery of the lake were their most preferred recreational activities. Based on this feedback, we can say that ecotourists are mostly attracted by its natural beauty. 20 percent of visitors in Khecheopalri and 12 percent in Aritar reported that they are mainly visiting for worshiping lakes who are the local people of the state. Boating is not allowed in Khecheopalri because it is believed that any form of human pollution in the lake may cause natural disasters and even the death of the people. On the other hand, boating is permitted in Aritar and it was found that 30 percent of people chose it as their most preferred activity. There are many lakes in Sikkim which provide a habitat for various species of coldwater fishes but these two lakes are located in easily accessible areas. 15 and 8 percent of visitors in the study indicated that watching fishes and birds gave them the most recreational pleasure in Khecheopalri and Aritar lakes respectively. Some people have a passion for photography and it is found that 15 and 10 percent of visitors stated that they came to lake for photographic purposes.

7.4 Visitors' Expectations and Perceptions on the Quality of Lakes

The general perceptions of the visitors' experience at the lakes for outdoor recreation has been evaluated by categorising the experience into three parts, namely, better than expected, as expected and worse than expected. The visitors were asked to rate their experience in the above-mentioned categories. The percentage share of the visitors is presented in the following pie-diagram

Figure 7.3: Visitors' Experience at Khecheopalri and Aritar Lakes for Outdoor Recreational Site

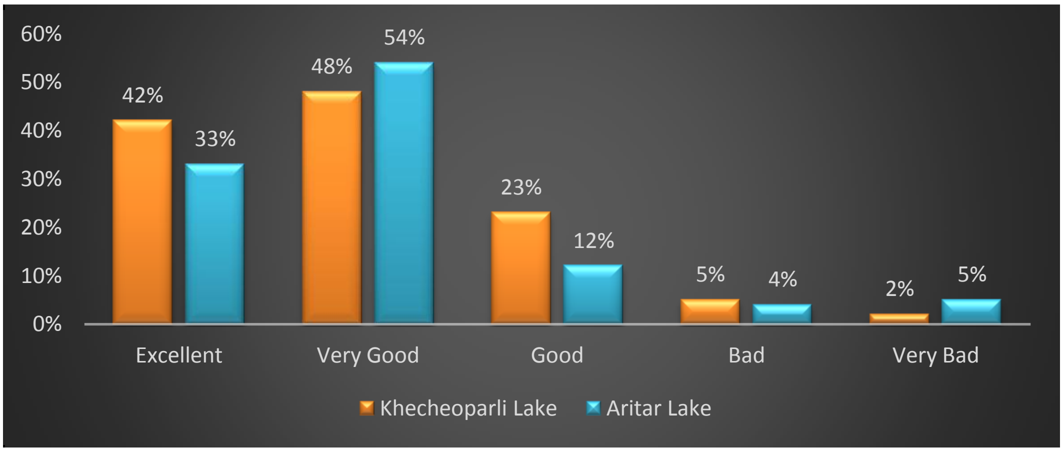


Source: Field Survey

The above pie charts represent the visitor's experience on the lake site for Khecheopalri and Aritar lakes. It is observed that 65 percent of the visitors in Khecheopalri lake and 58 percent in Aritar lake have experienced better than their expectation. Similarly, 32 percent visitors in Khecheopalri lake and 37 percent visitors in Aritar lake reported their recreational experience as they had expected. On the other hand, 3 percent and 5 percent visitors stated that their experience was worse than they had imagined for these two lakes respectively. Only a small percentage of visitors have expressed their experience as worse than they expected for these two lakes. The majority of the visitors and the researcher himself believed that these two lakes are good for outdoor recreations and fun but some of the visitors during the field survey have stated different problems like unhygienic toilet facility, poor network communication and road conditions and lack of other recreational facilities due to which their expectations may not have been met as they expected.

The environmental quality of the lake is a major concern nowadays and it is considered to be one of the important factors that lead to the arrival of tourists. The visitors were asked to rate the quality of lake based on their judgment. Quality-wise the lakes were divided into five categories namely excellent, very good, good, bad and very bad. The percentage share of the visitors' perception on the quality of the lakes are shown in the following bar diagram.

Figure 7.4: Visitors' Perceptions on the Quality of Lakes



Source: Field Survey

It is clear from the Figure 7.4 that 42 percent in the case of Khecheopalri lake and 33 percent in the case of Aritar lake, visitors have expressed an excellent quality of the lakes. Similarly, 48 percent and 52 percent of these two respective visitors stated recreational sites as very good. Moreover, 23 percent and 12 percent visitors of these two lakes have rated the environmental quality of the lakes as good. Very few visitors have expressed dissatisfaction regarding the quality of the recreational services of the lake in case of both the lakes.

7.5 Economic Valuation of Lake through Contingent Valuation Method

The environmental goods and services provided by natural lake ecosystem such as scenic beauty, hydrological functions, wildlife habitat and ecotourism services and use-value of such amenities are generally not priced in the market. Due to the absence of efficient markets for these natural resources, many economic valuation techniques were developed for the valuation of non-market goods. Among them, the most widely used is the CVM (Siew et al., 2015; Jala & Nandagiri, 2015). The CVM is a survey-based method for estimating economic values for all kinds of ecosystems and environmental services, including both use and nonuse values (Swanson 1999; Bateman et al. 2002). The use-value is that value where we are directly involved in an ecosystem while the non-use value includes bequest value, option value and existence value. The CVM is most widely used for the estimation of nonuse value. It uses a questionnaire or survey to ask people how much they would be willing to pay (WTP) for specific environmental services for recreation, option, existence and bequest value (Mitchell & Carson 1989, Mullarkey & Bishop 1995). Therefore, it assumes that the value of a site is reflected by how much people are willing to pay to get a service. It is called "contingent" valuation because people are asked to state their

WTP, contingent on a particular hypothetical scenario and description of the environmental service. In the present study, the visitors were asked whether they are willing to pay for the lake and if they said yes then again, they were asked how much amount they are ready to pay for it.

The visitors' WTP for the better management and conservation of these two lakes and the determining factors that affect WTP is obtained from the multiple linear regression models using the Ordinary Least Square (OLS) method.

$$WTP_{ij} = \beta_0 + \beta_1 RV_i + \beta_2 AGE_i + \beta_3 RELIO_i + \beta_4 EDU_i + \beta_5 MINC_i + \beta_6 OCCUP_i + \beta_7 TSL_i + \beta_8 NFM_i + \beta_9 RECEXP_i + \beta_{10} DSATIS_i + \mu_i \qquad (7.1)$$

In the regression equation, the dependent variable WTP represents the willingness to pay (in ₹) while the independent variable RV represents realised visit in the past years, AGE is the age of the visitors' (in years), RELIOG indicates religion where 1=Hindu; 2=Buddhist; 3=Christian; 4=Others, EDU stands for education level measured in terms of years of schooling, MINC is the monthly income (in ₹), OCCUP represents occupation where 1=Student/Scholar; 2=Farmer, 3=Govt. Employees, 4=Private Employees; 5=Business; 6=Ohers, TSL stands for time spent at the lake (in an hour), NFM stands for a number of family members in a trip, RECEXP is the recreational experience perceived by the visitors where 5 = Excellent, 4 = Very Good, 3 = Good, 2 = Bad and 1 = Very Bad; DSATIS is the dummy variable whether the visitors were satisfied or not for the visiting sites; DSATIS = 1, if the visitors are satisfied in visiting the lakes, 0 otherwise. β_0 is the intercept term, $\beta_1, \beta_2 \ldots\ldots\ldots, \beta_{10}$ are the coefficients of independent variables and u_i is the error term.

Table 7.2: Estimated Results on WTP for Khecheopalri and Aritar Lakes

Explanatory Variable	Khecheopalri Lake		Aritar Lake	
	Estimated Coefficient	t- value	Estimated Coefficient	t- value
RV	17.213**	2.28	43.308***	2.96
AGE	-0.093	-0.16	0.244	0.26
RELIOG	2.629	0.44	12.684	1.10
EDU	0.583	0.27	13.026***	3.21
MINC	0.001***	3.30	0.001***	3.45
OCCUP	-1.916	-0.41	0.244	0.03
TSL	52.047***	3.09	64.540***	3.23
NFM	4.583	1.26	3.961	0.49
RECEXP	27.189***	3.89	21.189**	2.09
DSATIS	45.967***	2.99	46.315**	1.95
CONS	118.569**	2.33	102.588**	2.35
R2	0.848		0.664	
F (10, 89)	49.95***		17.61***	

Source: Author's Calculation

Note: *, ** and *** indicates the significance levels at 10%, 5% and 1% respectively

The average per person per visit WTP for the better management and conservation of the Khecheopalri and Aritar lakes are estimated to ₹ 227.5 and ₹ 235 and that of total WTP are ₹ 22,750 and ₹ 23,500 respectively. The multivariate regression analysis is carried out (eq 7.1) to determine the factors that influence the WTP for the management and conservation of the lake. From the results of Table 7.2, it is clear that the realised visit is significant at 5 percent level for Khecheopalri lake and at 1 percent level for Aritar lake being positively related to WTP. This indicates that when the visitor's level of desire to visit the lakes increases, his/her WTP goes up for the better management and conservations of the lakes.

The education level of the visitors measured in terms of years of schooling is found to be highly positively significant at 1 percent level in the case of Aritar lake. This would suggest that as the people become more educated and aware of the environment, the more they understand the need for conservation and management of natural resources and ecosystem like lakes, forest, rivers etc. for the future generations; as a result, they would be prepared to pay a higher amount for it.

Income is considered to be the most crucial factor that affects the people's WTP and it is highly statistically significant at 1 percent level for both the lakes with the expected sign indicating that an increase in the income of the visitors tends to increase the visitor's WTP for the lakes.

The number of hours devoted by the visitors at the lake is one of the important factors that have a significant impact on the people's WTP. It is found to be highly significant at 1 percent level for both the lakes, thus explaining the positive relationship with the WTP. If the visitors spend more hours at the lake sites then their WTP will tend to rise; this is because spending more time in the sites means greater enjoyment and hence higher the keenness to pay for it.

Recreational experience and satisfaction being at the lake are significant at 1 percent level for Khecheopalri Lake and at 5 percent level for Aritar lake with the expected signs. The significance of these two factors means that an increase in the recreational experience that the visitors felt and satisfaction level perceived by the visitors tends to raise the visitor's zeal to pay more for the lakes.

From the above analysis on the WTP and its determinants, it has been found that the visitor's aspiration to visit a site, monthly income of the visitors, education, time spent by them at the site, recreational experience perceived by them and their satisfaction level are the major factors that have determined their WTP for the management and conservation of lakes. R^2 is found to be high in both cases which indicates that the model is a good fit in both cases.

7.6 Evaluation of the Recreational Value of Lake: A Travel Cost Analysis

The TCM is used to estimate economic use values related to ecosystems or sites that are used for recreation (Datta & Kundu, 2007; Mayor et al., 2007). It is based on the principle of observed behavior (expenditure on travel) that can be used to derive a demand curve for the non-priced environmental goods and services by considering the price of access to the site by time and travel cost expenditure that people incur to visit a site. It is called a revealed preference method because actual behavior and choices are used to account for the environmental values. It uses the visitors' travel costs as a proxy for the price that they have incurred in visiting the sites. The demand for ecotourism or visiting spot is represented by the number of realised visits/year to a site. Therefore, the demand of the people to visit the site can be estimated based on the number of trips that they make at different travel costs (Datta & Kundu, 2007; Mayor et al., 2007). The ITCM uses survey data collected from visitors on their number of visits, travel costs and socio-economic characteristics. The two models are traditionally used to analyse TCM data - the Poisson model and the Negative Binomial model (Mayor et al., 2007). It is expected that the realised visit to the site (demand for ecotourism) is inversely related to the size of the travel cost (price) and WTP for entrance.

7.6.1 Count Data

This model assumed the dependent variable as the count data which can take only non-negative integer values: (0, 1, 2…….). The count data models are best for the estimation of recreational demand for eco-tourism because, in the present study, the dependent variable, i.e., the number of realised visits to the lake in the past assumes only the non-negative integer values. Hence the count data model is a good fit for this study. There are various count data models but as per the suitability of data, we have used the Truncated Poisson Model (TPM) for estimating the recreational demand for the lake.

The probability distribution that is specifically suited for the count data is the Poisson probability distribution. The probability density function of the Poisson distribution is given by

$$\Pr\left(Y_i = \frac{y}{\lambda}\right) = \frac{e^{-\lambda}\lambda^{y}}{y!}; (y_i \; = \; 0, 1, 2,)$$

where Pr (y) denotes the probability that the variable y takes non-negative integer value and where y! stands for factorial of $y; \text{y}! = \text{y x } (\text{y} - 1)x\ (y - 2)x \ldots\ldots x\ 2\ x\ 1$

The parameter λ_i is both the mean and variance of a Poisson distribution.

$$E(y) = \lambda \text{ and Var } (\text{y}\,) = \lambda,$$

So, its variance is same as its mean value. The Poisson model is best suited for the distribution that is free from overdispersion, i.e. when the variance is less than the mean of the number of visits, which is a phenomenon when few people make many trips and the majority of the visitors make only a few trips. However, the data is free from the problem of overdispersion and hence TPM is employed in this study which is disused in the following sections.

7.6.2 The Truncated Poisson Model

To estimate the outdoor recreational demand of the lakes Khecheopalri and Aritar, we have applied the truncated poison regression. The dependent variable which is a realised number of visits takes only values that are equal to or greater than one, i.e., a number of visit does not assume zero which means that the visitors interviewed have already made at least one visit to the site and who do not visit the lake in a year are excluded from this model. Therefore, our dependent variable i.e. number of the realised visits to the lake in the past is truncated above zero. A simple ITCM model can be defined by a 'trip-generation function' (*tgf*) as

$$RV_{ij} = \beta_0 X_i + \varepsilon_i \qquad (7.2)$$

Where RV_{ij} is the number of realised visits to a recreation $site_j$ (lake),

X_i is a vector of explanatory variables for individual i that determine RV_{ij}

ε_i is an error term.

Let us assume that $\frac{RV_{ij}}{X_i} \sim \mathrm{N}(\mu, \delta^2) and\ \mu = \beta X'_i\ where\ \mu = \beta X'_i$, is the mean and δ is a standard deviation. With truncated sampling, RV_{ij} is only observable if

$RV_{ij} \geq 1$. This implies $\beta Xi + \varepsilon_i \geq 1$ or $\varepsilon_i \geq 1 - \beta X'_i$. Clearly, it is, $E(\mu_i) \geq 1 - \beta X'_i$ and is not equal to zero. It is a function of Xi. Thus, the residual is correlated with the explanatory variables X_i and we get inconsistent estimates of the parameters β if we use OLS method.

Given that RV_{ij} is truncated from below at $RV_{ij} \geq 1$, the probability density function of the truncated variable $RV_{ij}$with mean $\mu = \beta X_i$ and standard deviation δ is given as

$$f(\frac{RV_{ij}}{RV_{ij}} \geq 1) = \frac{f(RV)_{ij}}{Prob(RV_{ij} \geq 1} = \frac{\left(\frac{1}{\delta}\right)\phi[\frac{RV_{ij} - \beta_i}{\delta}]}{1 - \phi(\alpha_i)}$$

Where: ϕ (.) is standard normal probability distribution function and Φ (.) is the standard normal cumulative distribution function

$$\alpha_i = (1 - BX_i)/\ \delta)$$

$$Therefore, E(\frac{RV_{ij}}{RV_{ij}}) \geq 1 = \ BX_i + \frac{\delta\phi[1 - BX_i)/\ \delta]}{1 - \phi[1 - BX_i)/\ \delta]}$$

$$Var(\frac{RV_{ij}}{RV_{ij}}) \geq 1 = \ \delta^2[1 - \delta(\alpha_i)]$$

The conditional mean is, therefore, a non-linear function of X and β and so is the variance. Here neither OLS nor WLS gives fruitful results. Therefore, we have to resort to nonlinear estimating procedures using the method of Maximum Likelihood Estimator (MLE). MLE is preferred to OLS for this type of data set. Hence in the estimation of the truncated model for estimating the outdoor recreational benefit of lake, MLE is used. The following equation is employed for the estimation

$$RV_{ij} = \beta_0 + \beta_1 TC_i + \beta_2 DIST_i + \beta_3 AGE_i + \beta_4 EDU_i + \beta_5 MINC_i + \beta_6 WTP_i + \mu_i \quad (7.3)$$

Where RV_{ij} is the dependent variable i.e. realised visits in the past whose value is greater than or equal to 1, TC represents to and from traveling cost, food and accommodation cost incurred by the visitors in ₹ , DIST means the one-way distance from the visitor's place to the lake, AGE is the age of the visitors in years, EDU means education level of the visitors, MINC is the monthly income of the visitors in ₹ , WTP means the amount of willingness to pay for the entrance in ₹ , β_0 is the intercept term, $\beta_1, \beta_2 \ldots\ldots\ldots, \beta_6$ are the coefficients of independent variables and u_i is the error term.

Table 7.3: Estimated Results of the Travel Cost Analysis for Khecheopalri and Aritar Lakes

Explanatory Variables	Khecheopalri Lake		Aritar Lake	
	Truncated Poisson Coefficients	**t- value**	**Truncated Poisson Coefficients**	**t-value**
TC	-.0000171***	(-2.48)	-.0000179**	(-2.40)
DIST	-.005102**	(-2.30)	-.0009442***	(-2.51)
AGE	-.0185417*	(-1.86)	-.0079132**	(-2.31)
EDU	.0010173	(0.40)	.0262864	(0.51)
MINC	5.77e-06**	(2.13)	5.92e-06**	(2.22)
WTP	-.00959	(-1.60)	-.0015369*	(-1.81)
CONS	1.710823***	(3.39)	1.477601***	(4.47)

Number of obs = 93, Log likelihood = -111.582 LR chi^2 (6) = 68.43 Pseudo R^2 = 0.2347 Prob > chi^2 = 0.0000	Number of obs = 95 Log likelihood = -96.568 LR chi^2 (6) = 82.76, Pseudo R^2 = 0.3000 Prob > chi^2 = 0.0000

Source: Author's Calculation

Note: *, ** and *** indicates the significance levels at 10%, 5 %, and 1 % respectively and figures within the brackets represent the Z- statistics

7.6.3 Test for Significance of the Model

Following hypothesis is used to test the significance of the model.

H_0= All the concerned explanatory variables may not have a significant impact on recreational demand for lake

H_1= All the concerned explanatory variables may have a significant impact on recreational demand for lake

The log-likelihood test is used to test the significance of the model. It is estimated in the following ways:

$$LR = -2(Restricted\ log - Unrestrcited\ log) \qquad (7.4)$$

The restricted log is the log-likelihood only with the constant term whereas unrestricted log is the log-likelihood of the full model. The value of the restricted log in case of Khecheopalri Lake is - 145.7978 while for Aritar Lake it is – 137.963; on the other hand, unrestricted log in case of former is – 111.582 and for the latter, it is -96.568. The LR is equal to 68.43 and 82.76 respectively.

Furthermore, the tabulated or critical value of the test with 6 degrees of freedom ($\chi^2 6$), at 1% significance level is 16.812; hence the calculated LR value is found to be higher than the critical value. Therefore, we may reject the null hypothesis and accept the alternative hypothesis implying that all independent variables are relevant at a 1% significance level. Therefore, it is confirmed that the model employed is found to be appropriate.

Table 7.3 shows the estimated results of the truncated Poisson regression analysis of the TCM for Khecheopalri Lake and Aritar Lake. The results show that the travel cost, distance, age, income of the visitors and WTP for entrance (in case of Aritar Lake) are significant variables that affect the demand for outdoor recreation but the education level of the visitors and WTP for entrance (Khecheopalri lake) are found to be insignificant in determining the demand for ecotourism.

Travel cost which is the important variable that determines the demand function is negatively related to the demand for ecotourism, as expected; and it has a significant effect on realised visit to the lakes at a 1 % level for Khecheopalri lake and at 5 % level for Aritar lake. It indicates that other things being constant when TC increases, the demand for visits to the lakes will fall. The result is also supported by the demand theory which implies that as price (TC) increases the quantity demanded (number of realised visit) falls.

Distance is also one of the important factors that affect the demand for a site. It is found to be significant at 5 percent level with negatively related to the number of visits for both the lakes. This indicates that as distance rises peoples' keenness to visit the site falls. This is because if the visiting site has a larger distance from the visitor's place then the demand for other spots having lesser distance may rise. In such cases, the demand for substitute sites may increase and hence reduce that for the given site.

Age is found to be significant at a 10 percent level in the case of Khecheopalri lake and 5 percent level for Aritar lake indicating a negative effect on the demand for the lake. The result suggests that as the visitors become older their zeal for traveling a long-distance decrease thus reduces the demand for ecotourism. On the other hand, we can say that young people tend to travel more than older ones.

Education level, which is measured in years of school attended, is found to be insignificant in both the cases, suggesting that the education level does not affect the demand for lakes. Visitor's income is found to have a significant positive impact on the demand for ecotourism at 5 percent level in the case of both the lakes as expected and is consistency with the theory. For every visiting plan, the income of the people played a vital role in the success of any trip. As income is the means for covering every cost of recreation, it is expected that as their income increases, the visitors may have more demand for recreation for travel lovers and adventures.

The visitor's reflection about WTP for entrance is found to be significant at 10 percent level in the case of Aritar lake and insignificant for Khecheopalri lake indicating negative relation to the demand for the site. This is because people generally visit spots in a group and perhaps ask for the lower entrance fee in a group. Increase in entrée fee may discourage the urge to visit these places.

The model used for the TCM is found to be a good fit. The F statistic is found to be highly statistically significant for both the lakes indicating the overall significance of the independent variables.

From the above analysis of the two lakes, we can infer that travel cost, distance, age and income are the main factors that determine the demand for lakes.

A linear demand function for the demand for the lake can be written as

$$RV_{ij} = \beta_0 - \beta_1 TC_i + \varepsilon_i \qquad (7.5)$$

where RV_{ij} is the realised visit to site j by the i^{th} individual, TC_i is the travel cost of the i^{th} individual, β_0 is the intercept of the demand function, β_1 is the coefficient of the travel cost and $\boldsymbol{\varepsilon_i}$ is the error term which is assumed to be normally distributed with (0, δ2). This function was used to find out the effect of an independent variable over the dependent variable assuming that there was no multi-collinearity among the independent variables.

7.7 Demand Function and Estimation of Recreational Benefits of Khecheopalri and Aritar Lakes

The main purpose of this section is to estimate the recreational benefits and visitor's consumer surplus of Khecheopalri and Aritar Lakes, which is derived from the demand function (eq 7.5). The estimated demand function of these two lakes for the outdoor recreational benefits relating to the realised visits in the past and travel cost are as follows

$$RV_{ij} = 1.710823 - 0.0000171TC \qquad 7.6$$

$$RV_{ij} = 1.477601 - 0.0000179TC \qquad 7.7$$

The per person recreational benefits of the lakes are estimated by calculating the area under the demand curve. The area under the demand curve is calculated through transforming the original demand functions into inverse demand functions and then integrating between 0 and the average number of visits as shown in eq. (7.8) and (7.9)

$$= \int_0^{2.44} (\frac{1.710823}{0.0000171} - \frac{RV_{ij}}{0.0000171})\, RV \qquad 7.8$$

$$= \int_0^{2.21} (\frac{1.477601}{0.0000179} - \frac{RV_{ij}}{0.0000179})\, RV \qquad 7.9$$

The Table 7.4 depicts the results of the estimated recreational benefits and consumer surplus of the visitors.

Table 7.4: Estimated Recreational Benefits and Consumers Surplus

	Khecheopalri Lake	**Aritar Lake**
Per person recreational benefits	₹ . 70,035.57	₹ . 46002.7
Per person per visit recreational benefits	₹ .28703.10	₹ 20815.70
Per person per visit recreational benefits calculated from the actual average time spent by the visitors at the lake	₹ 43915.74	₹ 36427.47
Total annual recreational benefits	**₹ 43,91,57,400**	**₹ 1,09,28,24,100**
Per person per visit consumer surplus	₹ 1348.06	₹ 1089.70
Individual consumer surplus/ person	₹ 3289.27	₹ 2408.24
Total consumer surplus	**₹ 1,34,80,600**	**₹ 3,26,91,000**

Source: Author's Calculation

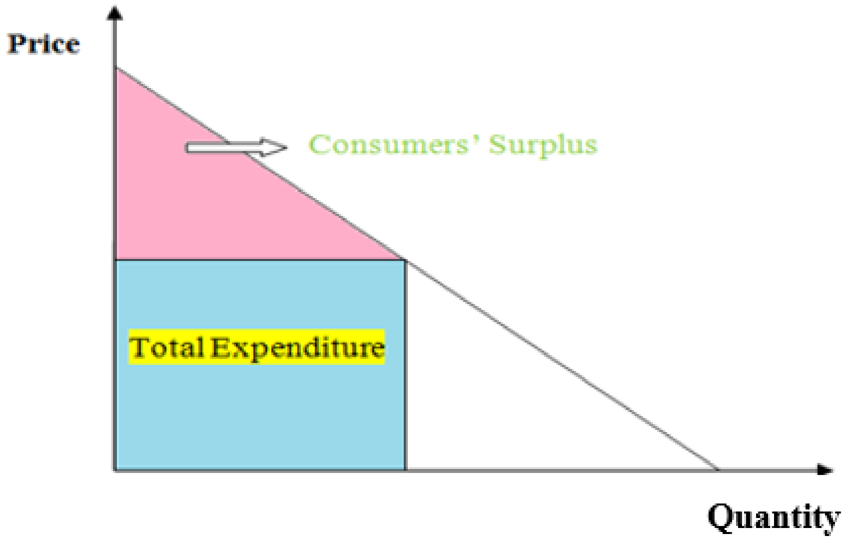
The average realised visit at the Khecheopalri and Aritar lakes per year is 2.44 and 2.21 respectively. After some calculations, the estimated area of these two inverse demands functions is found to be ₹ 70,035.57 and ₹ 46002.7 for the average number of visits. The per person per visit recreational benefits are obtained by dividing the per person recreational benefits by the average number of realised visits. Moreover, per person per visit recreational benefits of these two lakes are found to be ₹ 28703.10 and ₹ .20815.70.

The travel cost itself does not reflect the actual recreational benefits that the visitors got from visiting the sites; therefore, to avoid the overestimation of the recreational benefits, we have taken actual time spent on the sites. The average time spent on recreational site (lakes) by the visitors is found to be 1.53 hours and 1.75 hours for these two respective lakes. Therefore, we have calculated the better approximate recreational value of these two lakes by multiplying the per person per visit recreational benefits with the average time spent at lakes i.e. (1.53 X 28703.10) = ₹ 43915.74 in case of Khecheopalri lake and (1.75 X 20815.70) = ₹ 36427.48.

The total annual recreational benefits of these two lakes are calculated by multiplying the per person per visit recreational benefits by the total number of annual visitors to lakes in the past one year. The total annual visits to these lakes obtained from the office of the lake authority are 10000 and 30000 respectively. Hence, the total annual recreational benefits of Khecheopalri lake is (10000 X ₹ 43915.74) = ₹ 43,91,57,400 and that of Aritar Lake is (30000 X 36427.47) = ₹ 1,09,28,24,100.

The TCM is commonly used to estimate the consumer surplus associated with traveling cost to recreational sites like parks, beaches, religious and heritage sites (Hailu et al., 2005). The consumer surplus is the difference between the amount of money that the consumer is willing to pay and the amount that consumer actually pays. It can be calculated as the area under the demand curve and above the price line as illustrated in Figure 7.5.

Figure 7.5: Consumer Surplus



The average total cost of the Khecheopalri and Aritar lakes is estimated to be ₹ 27355.04 and ₹ 19726 respectively. The consumer surplus of the visitors for the average number of visits is calculated as the area under the demand curve and above the average travel cost. The per person per visit consumer surplus is estimated to be ₹ 1348.06 (= 28703.10 – 27355.04) and ₹ 1089.70 (= 20815.70 - 19726) respectively. The individual consumer surplus per person was obtained by multiplying per person per visit consumer surplus with the average number of visitors and it was found to be ₹ 3289.27 and ₹ 2408.24. The total consumer surplus is estimated by multiplying the total number of visitors by per person per visit consumer surplus. Therefore, the total consumer surplus of visitors for these two lakes for outdoor recreation were estimated to be ₹ 1,34,80,600 (= 10000 X 1348.06) and ₹ 3,26,91,000 (= 30000 X 1089.70) respectively.

The per person recreational benefits and per person per visit recreational benefits are higher in the case of Khecheopalri visitors but the total annual recreational benefits are found to be higher in the case of visitors of Aritar. Similarly, per person per visit consumer surplus and individual consumer surplus are higher for Khecheopalri visitors but the annual consumer surplus is larger for Aritar visitors. This is because an annual visitor is higher in Aritar than Khecheopalri lake and most of the tourists make the capital city Gangtok as their destination. The distance of Gangtok to Aritar is less than Khecheopalri. Moreover, road, communication and infrastructural facilities are better at Aritar lake.

7.8 Conclusion

An ecosystem provides diverse kind of services to mankind that we need in our day to day life. A lake ecosystem supports life to many flora and fauna and also provides essential services like water, clean air, fishing etc. and indirectly support livelihood to many people in different ways. It is considered as one of the natural sources of providing recreation, enjoyment and aesthetic and spiritual value to the people. The values that we are getting from natural ecosystems such as indirect and non-use value are invisible to the human eyes although it worth a lot. People are getting different benefits at free of cost or at a minimal cost in the form of entrance fee. But the conservation and maintenance of such public goods is a major concern for its sustainability.

It is evident from the study that the majority of the people or visitors are visiting the lakes for the recreational activities (like enjoyment of pleasant weather and beautiful scenery) and for religious or spiritual purposes. It is found that visitors are willing to pay for the maintenance and conservation of the lakes for the benefits they received from visiting the sites. The average per person per visit WTP are estimated to ₹ 227.5 and ₹ 235 and that of total WTP are ₹ 22,750 and ₹ 23,500 for

Khecheopalri and Aritar lakes respectively. The factors like visitation rate, income, time spent at the lake, recreational experience at the lake, satisfaction level are found to be positively impacted the visitor's decision for WTP. Furthermore, the demand for the lake is negatively impacted by travel cost, distance and age of the visitors. In contrast, the income of the visitors is the main factors that have the positive relationship with the demand for the lake. The total annual recreational benefits received from the two lakes are ₹ 43,91,57,400 and ₹ 1,09,28,24,100 and that of total consumer surplus are ₹ 1,34,80,600 and ₹ 3,26,91,000 respectively.

CHAPTER 8

CONCLUSIVE OBSERVATIONS AND POLICY RECOMMENDATIONS

8.1 Conclusive Observations

It has been observed from the Chapter 3 and Chapter 4 that the coldwater resources of India holds different large varieties of fishes which are indigenous and exotic, cultivable and non-cultivable fish species. Therefore, the Himalayan regions have abundant coldwater resources with the diverse varieties of coldwater fish biodiversity. Coldwater fisheries have been steadily progressed in the Himalaya during the last two decades and there was an increment in fish production in all the five Himalayan Indian states. During 1995-96, production was 16.52 thousand tonnes which increased to 19.15 thousand tonnes in 2005-06 and 20.08 thousand tonnes in 2015-16. Jammu & Kashmir is the leading producer of coldwater fish followed by Himachal Pradesh, Uttarakhand, Arunachal Pradesh and Sikkim. The decadal growth of coldwater fish production in the Himalaya was 31.61% during 1995-96 to 2005-06 and 25.92% during 2005-06 to 2015-16. Arunachal Pradesh had achieved the highest growth during 1995-96 to 2005-06 while in 2005-06 to 2015-16 Sikkim had achieved the highest growth in coldwater fish production.

One of the most important commercial and sport cultured fish species is rainbow trout in the Himalayas. It is cultivated in different parts of Himalayas such as Northwestern Himalayan region (Jammu and Kashmir, Himachal Pradesh), Central Himalayan region (Uttarakhand), Northeaster Himalayan region (Sikkim, Arunachal Pradesh). On a small-scale, hills of Darjeeling and Kalingpong districts of West

Bengal, upland regions of Northeast India. It is also cultured in Southern Uplands of Ooty in Tamil Nadu and Munnar in Kerala in Deccan Plateau. Although there are production fluctuations over the years, the production of rainbow trout has progressed gradually during the last decades in the Himalaya of India. The total rainbow trout production in India has increased from a mere 147.0 tonnes in 2004-05 to 602.0 tonnes in 2013-2014, 755 tonnes in 2014-15 and 842 tonnes in 2015-16. The annual growth rate of trout production in this duration remained 25.42% in 2014-15 and 11.52 % in 2015-16.

Himachal Pradesh, Jammu and Kashmir and Sikkim are the leading trout producer in India which contributed 50%, 30% and 14% respectively to total production in India during 2015-16. The trout production infrastructure has also been developed steadily in the country during the last 20 years and around 64 trout farms are under the Government sector with 1181 numbers of raceways spread over seven states in the western, Northeastern and peninsular region of the country.

The fisheries sector has played a vital role in enhancing the socio-economic conditions of fish farmers in Sikkim. Farmers are earning additional income from fishing activities that have helped to raise their living conditions. The chapter 5 revealed that the majority of the farmers have realised improvements in their economic condition. All the fish farmers of the state have access to basic minimum civic amenities like housing, potable drinking water, sanitation, electricity and cooking fuels etc. The results also depicted that the males have traditionally dominated this activity and more female members should be encouraged. Productive and economically active age groups are being participated in this sector. The maximum percentage of ST and OBC (CL) communities are engaged in this activity and they belong to Rai, Limboo, Bhutia and Lepcha communities. As they are tribal and backward classes, they avail maximum government schemes and benefits. The maximum respondents were found to be married which may have led to a greater sensitivity towards their work and responsibilities. The maximum respondents have attained 6-12 years of schooling; fish farming, other allied activities and agriculture are their primary activities because fish farming is a rural activity and rural places are mostly dominated by the primary activities. Income inequalities was highest is East districts followed by South, North and West districts. Similarly, higher income inequalities were also observed across the PFCS like Sribadam, Chujachen etc. The logit regression model suggested that per capita income, housing condition and family members who have attained education level above the primary are the major factors that affect the estimated perceived socio-economic conditions of the households.

It has been observed from the Chapter 6 that the fish farming in Sikkim is a viable economic activity in the rural areas. In case of trout growers PFCS, all the cooperatives have been achieved financial gain from the fish farming, though there was a fluctuation in the productivity and profitability ratios over the years across the PFCS. They had made profits from fish farming in all the years except for Upper Rimbik which had to borne losses during 2014-15 and 2015-16. Amongst these, Upper Sribadam and Maneybong-Sopakha have realised greater financial achievement than the Upper Rimbik and 20th Chujachen. Similarly, in the case of carp growers, both the cooperatives such as Mangshilla and Dalep have experienced gain in financial value but Mangshilla has achieved more financial gains in comparison to Dalap. Along with these, all the PFCS are operating efficiency though there are variations in the indicators across the PFCS. The overall analysis revealed that fish farming is one of the worthwhile economic activity amongst others. On the other hand, as far as environmental sustainability is concerned, it has been observed that Upper Rimbik and 20th Chujachen are relatively much more concerned for the stock generations or environmental sustainability in trout farming in comparison to Upper Sribadam and Maneybong-Sophakha. There is a great threat to sustainability in the case of Upper Sribadam and Maneybong-Sophakha because these cooperatives surpassed their yield over the MSY in some of the years. Similary, in the case of carp growers PFCS, Dalep has leaved relatively more amount of fish stock for the future generations as compared to Mangshilla. From the analysis it came to know that all the PFCS have been able to maintain sustainability criterion in the present situation but if it is not wisely and properly maintained then there might be a great threat of sustainability for Upper Sribadam, Maneybong-Sophaka and Mangshila in the future because in some of the years their actual yield surpassed the MSY. More financial achievements like more productivity and profitability mean more extraction of existing resources implying less scope of regeneration and availability for the future which indicates a trade-off between the financial management and environmental sustainability of resources. The producer needs to harvest the output level taking into consideration the MSY. Thus, it has become very crucial to conserve, manage and utilise available resources on a sustainable basis.

There is a potential for the enhancement of fish production in Sikkim by bringing natural water bodies under scientific management for fishery enhancement through bridging the gap between actual fish yield and production potentials utilising more endemic and local species. Development of harvest, post-harvest and value addition packages for the coldwater fishes will also enhance productivity and profitability. Sikkim and other Himalayan states are bestowed with an abundance of coldwater resources and hill fishery; potential exists for developing sport fishery based on exotic trout and indigenous mahseer. Besides only harvesting for the selling purposes, individual farmers and some of the cooperatives can linked fishery activities with ecotourism, sport fishing and angling for generating income and employment in the remote hilly regions. As a result, more revenue will be generated as well as resources will be utilise on a sustainable basis.

The lake ecosystem provides several kinds of values directly or indirectly to mankind as well as other terrestrial and aquatic species but its monetary value is rarely quantified. In the Himalayas, particularly in Sikkim, lakes are considered to be sacred and worshipped by the people. Commercial fishing activities and any form of pollution are highly restricted in the lakes because the lakes are rich in spiritual, aesthetic, ecological and recreational value. It has been observed from the chapter 7 that the visitors who are coming from the different parts of the country as well as from abroad are willing to pay for its management and protection because in today's world most people are well educated and concerned about global climate change and environmental degradation. The average WTP for the conservation and maintenance of the lake are recorded to be ₹ 227.5 and ₹ 235 while the WTP for entrance was ₹ 55 and ₹ 60 respectively for Khecheopalri and Aritar Lake. These would suggest that visitors are showing their concern for the cause of environmental protection of lakes. The factors that mostly affected the visitors' WTP for the conservation and maintenance of lakes are visitors' aspiration to visit a site, monthly income of the visitors, education, time spent by them at the site, recreational experience perceived by them and their satisfaction level. The demand curve for recreational benefits indicated that the probability of visitation rate increases with the decrease in travel cost and distance for the outstation visitors. Other important factors that have influenced the demand for lakes are age and income of the visitors. Age is negatively related while income is positively related to the demand for the lake. The per person per visit recreational benefits and consumer surplus are high in the case of Khecheopalri lake while annual recreational benefits and annual consumer surplus are higher in Aritar lake because of the lower visitation rate in the former. However, the sacredness value and rich biodiversity remained high in Khecheopalri lake. Growth in the visitation rate may increase the consumer surplus but this may be at the cost of the environment. Therefore, a balance between visitation rate and conservation and maintenance of the environment has to be taken care of.

8.2 Policy Recommendations

The following are the some of the suggested policy for implications.

i. In Sikkim, water resources are available in abundance but there are many places where these resources have not yet been brought under aquaculture or fish farming. Proper aquaculture with the formation of more fisheries cooperatives helps to enhance income and contributes to efficient conservation and management of resources.

ii. Although water resources are plentiful, many problems need immediate attention from the government as well as the management teams of the cooperative societies to get better results in terms of steady growth in production, productivity, profitability and sustainability etc.

iii. To minimise the major problems faced by the farmers such as non availability of feed on time and high feed cost, the government should frequently monitor or establish at least a feed mill plants within the state to redress such problems.

iv. More cooperative societies should be formed across the districts; as a result, the production of fish can be increased while also ensuring better utilisation of water resources.

v. The government should also emphasis the strengthening of marketing channels, development of cold storage facilities, processing and product development which will help in better management of PFCS, encourage new farmers and also facilitate the expansion of fish farming in Sikkim.

vi. The retail local fish shop should be started at the district level so that the local fishes will be easily available in the market and this will also encourage fish farmers to produce local fishes.

vii. More attention needs to be given to the enhancement of fish production, productivity and profitability through the expansion of aquaculture, species diversification for production enhancement; fish-based entrepreneurship for livelihood security, genetic improvement of commercially important species, disease monitoring and control, value addition and market development, etc.

viii. To strengthen and to enhance their living conditions and income, more need-based infrastructural and institutional support should be extended by the government to encourage more people in farming activity. The infrastructural resources are not equally distributed across the districts; therefore, equitable distribution of resources may attract new farmers in coming generations resulting in further growth of fish farming, thus contributing to the overall economic development of the state.

ix. Around 85 percent fish farmers in the state are males therefore more female's participation could be encouraged because it is the less laborious activity than other primary activities and females can be easily take participation in this activity.

x. The percentage of OBC communities such as Chettri, Bahun and Pradhan and SC communities are very minimal in fish farming therefore it is suggested to encourage more people of this communities by providing more government benefits and assistance.

xi. There is a huge potential to increase production in the state. Besides private tanks and ponds, currently there are eight government trout farms where 48 tanks and nine government carp farms where 62 tanks, total 110 tanks owned by DOF. But all these government farms were established for seed production to distribute to the farmers and demonstration purposes. The farms are not producing fishes on a large scale for selling purpose, therefore it is suggested to the government that theses farms can do production on a large scale and sell fishes in the market as a result the revenue of the DOF will increase.

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Appendix A

Tables

Table 1: Fish Production in the Himalayan States of India in (in ‘000’) tonnes

Year	Jammu & Kashmir	Himachal Pradesh	Uttarakhand	Sikkim	Arunachal Pradesh	Total of Himalayas
1990-91	13.00	5.20	-	0.10	1.25	19.55
1991-92	14.05	6.02	-	0.09	1.49	21.65
1992-93	14.30	6.39	-	0.09	1.60	22.38
1993-94	14.50	6.63	-	0.10	1.70	22.93
1994-95	16.10	5.29	-	0.10	1.80	23.29
1995-96	16.52	5.94	-	0.11	1.85	24.46
1996-97	17.80	6.27	-	0.15	2.00	26.22
1997-98	18.53	6.69	-	0.14	2.13	27.49
1998-99	18.85	6.79	-	0.14	2.30	28.08
1999-00	19.01	7.00	-	0.14	2.40	28.55
2000-01	17.51	7.02	9.07	0.14	2.50	36.24
2001-02	18.85	7.22	6.42	0.14	2.60	35.23
2002-03	19.75	7.24	2.55	0.14	2.60	32.28
2003-04	19.75	6.53	2.56	0.14	2.65	31.63
2004-05	19.10	6.90	2.57	0.14	2.70	31.41
2005-06	19.15	7.30	2.79	0.15	2.75	32.14
2006-07	19.20	6.89	3.00	0.15	2.77	32.01
2007-08	17.33	7.85	3.09	0.16	2.83	31.28
2008-09	19.27	7.79	3.16	0.168	2.88	33.27
2009-10	19.30	7.85	3.49	0.17	2.65	33.46

2010-11	19.70	7.38	3.82	0.18	3.15	34.23
2011-12	19.85	8.05	3.83	0.28	3.30	35.30
2012-13	19.95	8.56	3.85	0.39	3.71	36.53
2013-14	19.98	9.83	3.89	0.42	0.61	34.73
2014-15	20.30	10.74	3.94	0.40	4.00	39.42
2015-16	20.08	11.80	4.14	0.44	4.05	40.07
2016-17	20.08	13.00	4.14	0.40	4.00	40.07
2017-18	21.00	13.00	5.00		4.00	40.50
2018-19						

Table 2: Fish Production Prediction for the year 2017 to 2020

Year	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Production (‘000 tons)	19.55	24.46	36.24	32.14	34.23	40.47	40.47	40.50	41.18	41.86	42.54

Table 3: State wise major Trout Production in the Himalayan as on 2013-14

States	**Production (in Tons)**
Jammu and Kashmir	262
Himachal Pradesh	220
Sikkim	100
Other States	20
Total Production (Annual Supply)	602
Annual Demand	800

Table 4: Total Trout Production in India in 2004-05 to 2013-14

Year	Production (in Tons)
2004-05	147
2005-06	190
2006-07	220
2007-08	200
2008-09	210
2009-10	220
2010-11	350
2011-12	380
2012-13	410
2013-14	602

Appendix B

1. Coldwater Fisheries Resources of Sikkim

Coldwater fisheries resources of Uttarey, Upper Rimbik, Upper Payong & Sokpey, Upper Sribadam and River Teesta and Rangit

2. Government Trout and Carp Farm

Uttarey trout farm and Gayzing and Kabi carp farms

3. Private Carp Farm

Private carp farms at West, East, North and South Sikkim and carp fishes.

Carp and Trout Fish

Private Trout Farm

Private trout farms of East, West, South and North Sikkim

Field Visit conducted during 2017-18 and 2018-19

Field Survey at West, East, North and South Sikkim

Practical Training

Practical Training given by the Officers of Directorate of Fisheries, Government of Sikkim to Trout Farmers

Fish Selling

Fish selling at Lall Bajar Gangtok, Namchi, on the way to Singtam to Gangtok and fro the farm of Mr. Aita Hang Subba.

Appendix C

INTERVIEW SCHEDULE OF FISH FARMING FOR BOTH INDIVIDUAL & MEMBERS OF PRIMARY FISHERMEN COOPERATIVE SOCIETY

Name of the village / place______________ Block____________ District: ___________

PART I: Socio-Economic Characteristics of Fish Farmer

1. Name of the Farmer: ________________________________
2. Are you a member of the Primary Fishermen Cooperative societies? □ Yes □ No

   If yes, Name of the Primary Fishermen Cooperative Societies________________

   Total number of members_____________ When it was established? __________
3. Are you by birth fish farmer? □ Yes □ No
4. Age: ____, □ Below 20, □ 21-30, □ 31-40, □ 41-50, □ 50-6, □ 61-70.
5. Sex: □ Male □ Female
6. Marital Status: □ Single □ Married □Widow □Separated
7. Religion: □Hindu □ Buddhist □Christian □Others
8. Category: □ ST □ SC □ OBC(CL) □ OBC (SL)
9. Educational Status: _______ □ Illiterate □ Functional Literate □ Primary □ Secondary □ Graduate □ Post Graduate & above
10. Type of Family: □ Joint Family □ Nuclear Family
11. Household Particulars
12.

Sl. No	Name of Family Members	Relationship with head	Age	Gender	Years of Schooling	Occupations	Annual Income
1							
2							

14. Occupation: □ Agriculture □ Fisheries & Allied activities □ Govt Job □ Private Job □ Causal Laborer □ Govt. Employees □ Business □ Others ___________

15. Is fish farming your traditional occupations? □ Yes □ No

16. Name your traditional occupation____________________________________

17. Income of the Family

Source of Income	(Annual income Rs)
Job	
Business	
Agriculture	
Livestock	
Milk	
Fish farming	
Others	

18. Types of House: □ Pakka □Semi Pakka □Kachh

19. Toilet facility: □ Pakka □Semi Pakka □Kachha

22. Drinking water source: _____________

23. Fuel source: □ Firewood (purchased /collected) □Kerosene □LPG

24. Whether the house is electrified or not________________. If yes, When_______

PART II: General Information on Fish and Fisheries

25. Who and what motivated you for fish farming? ___________________________

26. Are your other family members also participated in fish farming? _____________

27. Fish Farming Experience (Years)_________________________

28. Is fish farming your primary occupation/ subsidiary occupations______________

29. Have you undergone any training? □ Yes □ No. If Yes, how many times?______

How many days?_________and from where you got training?___________

30. Mode of land Acquisition: □Inheritance □ Purchase □Lease/ Rent □ Gift □ Others

31. No of ponds____________ and Size of each pond: _________

32. Types of ponds: □ Concrete □Earthen □ Both

33. Source of pond water: _________

38. Stocking period__________

39. Number of fish population in a pond: ______________________________

40. Types of Culture: □ Monoculture □Polyculture □Integrated

41. Types of Cultured Species: □ Common Carp □Grass Carp □Silver Crap □Rainbow Trout □Brown Trout □ Others_______________

42. At which rates you are selling your fish? Trout: Rs ____per kg, Carp: Rs __kg.

43. Sources of Fingerlings: □ Own fish hatchery □Government fish farm □ Others source_______

44. Culturing Months: _____ Harvesting months______

45. Culturing Period (Year): □ Once □ Twice □ Thrice Harvesting Period (Year): □ Once □ Twice □ Thrice

46. Fish feed: □ Rice bran □ Mustard oil cake □ Atta □ Supplementary feed □ Grass

47. Gear used: □ Encircling net □ Dragnet □ Cast net □Gill net □ Buckets

48. Source of Finance: □ Personal saving □Friends/ Relatives □Cooperative Society □ Bank Loan
49. Did you get any help from the government or any other sources? _____
50. What is the help that you are getting?
    □ Financial help □ Technical help □Knowledge on Stocking / Fingerlings □Training □Marketing help □ Other______
51. How much amount that you got from the government as financial assistant? ___
52. What scheme is being supported by the Government? _______________
53. Where you sold fish: □Self Consumption □ Village itself □ Local Market □ Hotels/ Restaurants
54. In which months or seasons you sell fish? ________________________
55. Do you save from fish farming? □ Yes □ No, If, yes specified the amount: ___/annum.
56. What are the other activities that you are doing along with fisheries?
    □ Goatery □ Poultry □ Duckery □ Dairy farming
57. Whether these activities are helping for fish farming? □ Yes □ No
58. Fish consumption from your own ponds: □ 1- 2 times in a week □ Twice in a month □ Once in a month □ No
59. Fish consumption from the market: □ 1- 2 times in a week □ Twice in a month □ Once in a month □ No
60. What are your average days of work per months for fish farming______________?
61. How many hours do you work at fish pond? __________________________

PART IV: Problems Constraints and Prospects of Fish Farming

62. What are the problems and constraint that you are facing in fish farming? ____

63. What could be the solutions of these problems according to your point of views?

64. Is there growing demand for fish? □ Yes □No □ Don't know

65. Is price of fish increasing over years? □ Yes □No □ Don't know

66. Is there vast scope for increasing fish production? □ Yes □No □ Don't know

67. Extension of fish culture is possible ? □ Yes □No □ Don't know

68. Is fish culture fetches good income? ? □ Yes □No □ Don't know

69. Whether income and standard of living have improved after fish farming? □ Yes □ No

70. Whether you are thinking to leave fish farming? □ Yes □ No, if Yes give reasons____

71. Do you know any information about other fish farmers made exists from fish farming? □ Yes □No □ Don't know. If yes, reason behind it_________

Appendix D

QUESTIONNAIRE FOR THE LAKE VISITORS

VALUATION OF LAKE THROUGH CONTINGENT VALUATION METHOD & TRAVEL COST METHOD

Part I: Respondents' Personal Information

1. Name of the Visitor / Respondent:
2. Visitors' identity: □ Local, □ National □ Foreigner.
3. Place or location of the visitor's home: _______________________
4. Age: ________, □ Below 20, □ 21-30, □ 31-40, □ 41-50, □ 50-6, □ 61-70
5. Sex: □ Male □ Female
6. Marital Status: □ Single □ Married □Widow □Separated
7. Religion: □Hindu □ Buddhist □Christian □Others
8. Educational Status: _______ □ Illiterate □ Formal Literate □ Primary □Secondary □ Graduate □ Post Graduate & above
9. Occupations: □ Student/ Scholar □ Causal Workers □Farmmer □Govt. Employees □ Business □ Vocational Job □ Others _____________________
10. Average monthly income of the visitor: ____________________

Part II: Respondents' Travel Cost Information

11. Have you ever visited Sikkim? Yes No, If Yes, how many times_______
12. Did you visit other lakes of India? If Yes_________________
13. Did you visit other lakes of Sikkim? If Yes_________
14. From where you got information about this lake?_________
15. Why you have selected this site as your visiting place?________

16. How many times you have visited the site in the past year or past season?_______

17. Distance of site from your place___________________

18. Time taken to reach the destination from your place____________ hours

19. How long will you stay on the site? __________days. (From arrival to departure)

20. How many hours do you usually stay on the lake site? __________ Hours.

21. Since when did you know about Lake? __________Years

22. Which mode of transportation did you use to & from Lake? (Please tick the mode of transport you used)

1. Own vehicle (private car) 2. Rented vehicle (Luxurious vehicle / Ordinary vehicle) 3. Public transport 4. Travel agent's vehicle 5. 6. Others (please specify) _

23. How many family members is with you this trip? ____________

Distribution of family member

Sl. No.	Name	Age	Gender	Years of Schooling	Occupations
1					

24. Cost of the current trip to lake site:____________________

25. Travel cost to the lake:

Sl. No	Particulars	Costs (Rs)
1	Cost for two way travel	
2	Entrance ticket	
3	Food & Beverage	
4	Sight- seeing & recreating photographs	
5	Boating	
6	Accommodation	
7	Miscellaneous cost	

26. Have you visited other locations during the same trip? □ Yes □ No, if yes, specify the locations______________

27. The amount of time spent at other sites? _________________________

28. Is this trip only to visit the site or for several purpose?_________________

29. Which are the substitutes sites that you might visit instead of this site?_____

Part III: Respondents' General Perception of and Observations of Lake

30. Purpose of Visiting the site: □ Ecotourism □ Recreation / fun □ Worship □ Boating □ To see the Fishes/ aquatic animal □ To study nature and wildlife □ Other____________

31. Quality of the recreational experience at the site: □ Excellent □ Very Good □ Good □ Bad □ Very Bad

32. Perceptions of environmental quality at the size: □ Excellent □ Very Good □ Good □ Bad □ Very Bad

33. Quality of water in the lake: □ Very Clean & Clear □ Clean & Clear □ Moderately □ Bad □ Very Bad

34. Quality of the site: □ Excellent □ Very Good □ Good □ Bad □ Very Bad

35. How do you describe your experience of Lake?

    1. Better than I expected 2. As I expected 3. Worse than I expected

36. State problems that you encountered and observed during your visit?

    ____

37. Why do you choose to visit Lake?

    ____

Part VI: Respondents' Willingness to Pay

38. Are you willing to pay for maintenance and preservation of the lake? □ Yes □ No
39. What are the things that insist you to pay for conservation and preservation of the lake?

    □ Natural beauty and cleanliness □ Religious and Spirituality □ Boating □ Recreation & fun.
40. If yes, what is the maximum amount you are willingness to pay per trip?_____________
41. Whether you considered yourself as environmentalist? Yes No
42. Are you interested to visit again? Yes No