Fish Biodiversity as an Indicator of Riverine Status of Sikkim

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ABSTRACT

The torrential streams of Sikkim have shallow clear cold water in the foothills. Depending upon altitude the water temperature varies from 3.9 to 19.8°C. The dominant fish species in Teesta and Rangit tributaries are Schizothorax *spp* (Asala) *Neolissocheilus spp* (Katley), *Garra spp* (Buduna), *Pseudecheneis spp* (Kabrey), *Barilius spp* (Chirkay), *Semiplotus spp* (Chepti). Ornamental species available are *Barilius bendelisis bendelisis, Barilius vagra, Danio aequipinnatus, Danio naganensis, Garra lamta, Noemacheilus scaturigina* and *Noemacheilus sikkimensis*. Depending upon water current the percent availability of different species varies from one stream to other. However, a declining trend has been noted in fish gemplasm. The average catch fish is very low may be due to low productivity or destructive and over fishing. The water quality parameters i.e. air temperature (5.57-27.8°C), water temperature (3.9 -19.8°C), DO (5.0 - 9.9 mg/l), pH (6.2 - 8.4), alkalinity (20 - 25.2 mg/ l), TDS (24.4 - 52.7mg /l), hardness (14 - 24 mg /l) were found within the suitable range for cold water fishes.

KEYWORDS: *cold water, fish biodiversity, physico-chemical parameters, Sikkim*

Catch fishes from river Teesta tributary in the local market for sale (East Sikkim)

Fishing in river through rod and line in torrential stream

INTRODUCTION

Sikkim is bestowed with plenty of water bodies in the form of lakes natural springs, along with myriads of tributaries situated at various altitudes ranging from 400 to 4600 masl. The state has two major rivers Teesta, originating from the glaciers of North and Rangit, from lower hills in West district of Sikkim. The estimated length of the rivers of the state is 900 km, flowing through high mountains and steep hills of various elevation ranges. Majority of the lakes of the state are located in the alpine zone which remains frozen during winter.

There are 27 hydroelectric projects proposed and many of them are under construction throughout the state of Sikkim. The approach roads and bridges resulted into disturbance and destruction in the physical habitat of both forest dwellers and aquaculture. The construction of dams and reservoirs for water storage, power generation and diversion for other usage can affect flow and depth of the water. It also changes the drainage characteristics of watershed and may lead to more run off and fluctuation in river flow rate. There is variety of fish species found in the Himalayan belt and Sikkim is one of them recognized years back by many ichthyologists. Cold water fisheries and mountain aquaculture is one of the important promising natural resources to meet the protein demand of the region. In the present scenario it has become necessary to assess overall potentialities of the available water resources and fish biodiversity identification that may help conservation management for local people of the state for aquaculture sustainability.

Fish biodiversity

Sikkim State is drained by the two main rivers, namely Teesta and Rangit. Teesta is an important tributary of Brahmaputra, the greatest river of Assam Himalayas (Eastern Himalayas). Zoogeographically especially of the fish fauna found in the Teesta drainage system are as most of the Assam Himalayan forms.

Schizothorax species (Asala)

Schizothorax species (Asala)

Neolissocheilius hexagonolepsis (Katley)

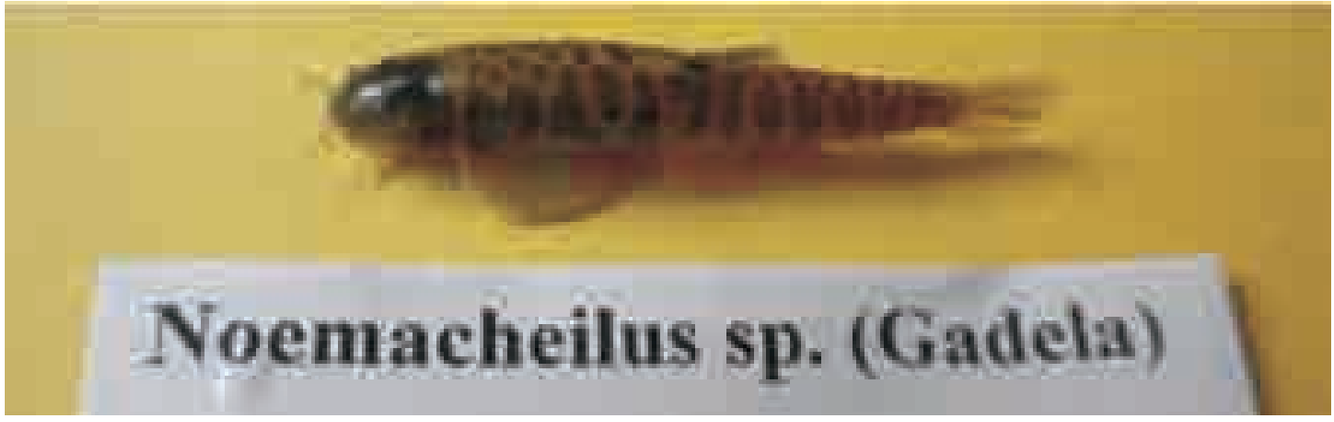
Garra spp. (Buduna)

Garra spp. (Buduna)

Pseudecheneis sulcatus (Kabrey)

Barilius spp. (Chirkay)

Semiplotus spp. (Chepti)



Noemacheilus spp. (Gadela)

Baralius vagra (Faktey)

Danio aquippinatus (Bhitti)

The fish species distribution in the Himalayan streams depends on the flow rate, nature of substratum, water temperature and the availability of food. In torrential streams Sehgal (1988) identified several zones on the basis of dominant fish species and the hydrographical features. Menon (1954) related the distribution pattern of Himalayan fish to morphological characteristics which enable them to inhabit the torrential streams. He recognized six major groups: (a) fish dwelling in shallow, clear cold waters in the foothills without any striking modifications to current: *Labeo*, *Tor*, *Barilius* and *Puntius*; (b) fish inhabiting the bottom water layers in deep fast current, with powerful muscular cylindrical bodies: schizothoracines and the introduced trouts; (c) fish sheltering among pebbles and stones to ward off the strong current: *Crossocheilus diplochilus*; (d) fish sheltering among pebbles and shingles in shallows, with special attachment devices: the loaches *Noemacheilus*, *Botia* and *Amblyceps*; (e) fish which cling to exposed surfaces of bare rocks in slower current, with adhesive organs on their ventral surface for attachment to rocks: *Garra*, *Glyptothorax* and *Glyptosternum*;

and (f) fish which cling to the exposed surfaces of bare rocks in fast current, with limpet-shaped bodies and mouth, gills and fins highly modified to suit the habitat: *Balitora*.

Studies on fish and fisheries in Sikkim have been carried out by Talwar and Jhingran (1991) but details about fish catch and its commercial aspect was 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 Rangit. However, during the study period, no where in the survey area big fishes of Cyprinidae was observed. Anthropogenic as well as natural factors both influence the fish population in the rivers (Pant and Bisht, 1981). Overexploitation and faulty fishing techniques might be the major factors affecting the fish germplasm. The most abundantly available members of Cyprinidae family were *Scizothorax spp.* (Talwar and Jhingran, 1991). Das and Mukherjee (2005) observed a strong decline in the diversity of fish fauna in the river Teesta. Menon *et al.* (2008) described 19 threatened species of India which also inhabit in Teesta waters in Sikkim. Of these 15 species are rare and 4 species viz. *Anguilla bengalensis, Puntius clavatus, Ompak bimaculatus* and *Pseudeutropius* are supposed to be endangered.

Most of the species of fish are periodic in breeding and require specific ground throughout the life. Mahseer (*Tor putitora*) is an important migrant in Himalayan Rivers, which migrates from warmer plains to the high reaches in cold water regions. Mahseer is a true potamodromous migrating fish in Sikkim, travels a long distance from Teesta barrage (foothill) to Rangit, Teesta and Rangpo Chu during the late summer to monsoon months for breeding. The water turbidity, temperature and nature of river bed are considered to be important stimuli for the migration of mahseer. Most brooders of mahseer are found to prefer river Rangit for spawning. The fingerlings and juveniles live in these rivers till next September to mid October and descend to water of plains, while adults after spending whole summer and monsoon in these streams return back to warmer waters. The river Rangit up to Jorethang has been identified as breeding ground for mahseer while in the river Teesta they are found up to Singtam.

Neolissocheilus hexagonolepis (Katley) and *Schizothorax richardsonii* (Asala) are considered to perform local migration. *N. hexagonolepis* moves to small tributaries from main stream while *S. richardsonii* moves downstream during summer to monsoon. The exotic trout *Salmo trutta fario* (Brown Trout) is restricted to high altitude water for all time in Sikkim.

Some of the species available in Sikkim can be reared as ornamental fish species such as *Barilius bendelisis, Barilius vagra, Danio aequipinnatus, Danio naganensis, Garra lamta, Noemacheilus scaturigina* and *Noemacheilus sikkimensis*.

Fishing activities

In general the fishing activities in the lakes of Sikkim are very limited and majority of the population involved in fishing either are daily wage labour, farmer, serviceman or businessman. Thus fishing becomes secondary occupation for them. On an average one member from fishing family is engaged in fishing in the river and is able to catch one kg fish after covering a distance of 1.84 km per day. The catch fish observed during study in one of the Teesta tributary is being depicted in Table 2. The frequency of availability of fish in the river in descending order are Schizothorax *spp* (Asala) > *Neolissocheilus spp* (Katley) > *Garra spp* (Buduna) > *Pseudecheneis spp* (Kabrey) > *Barilius spp* (Chirkay) > *Semiplotus spp* (Chepti). Fresh water shrimp was also available. Frequency of other fish was negligible (Haque *et al.*, 2007).

Cast net and rod and line were the most commonly used gears in Sikkim. The cast nets used by the fishers were always of mesh size 1 cm or less, instead of mandatory mesh size of 2.5 cm. This might be considered as one of the most destructive methods which were in regular use by the fishers of the state. Other destructive methods recorded in the study were diversion of small stream, poisoning with pesticides, use of bleaching powder, copper sulphate, use of gillnet with small mesh, blasting with dynamites and use of generator for electrocution.

The fishing activities in terms of duration per day or annually or average catch of fish per day were higher in the South district. This might be due to lower elevation of South district with warm weather where no major mountains were

Fishing in river Rangit through cast net near Jorethang (South Sikkim)

observed and both the major rivers Teesta and Rangit and their tributaries extended their lower stretches through this district. During the month of May *Schizothorax spp* and *Neolissocheilus spp* comprised 78.82 percent of the catch. This could be related to the migratory behaviour of the fish during summer to monsoon. During this season *Neolissocheilus spp* moved to smaller tributaries from main stream and *Schizothorax spp* moved to down streams (MOEF, 2002) and caught in maximum number in the South district. Higher fishing durations were also observed in this district. Lower availability of fish catch during rainy season might be due to high current in the over-flooded rivers.

Survey during the month of May indicated that length of four types of fish (*Schizothorax spp*, *Neolissocheilus spp*, *Pseudecheneis spp* and *Garra spp*) varied from 95 to 320 mm. *Neolissocheilus spp* with average length of 302.5 mm was the largest and was legal for catching as per the regulation of the state. The length of other three species was smaller than the prescribed of size 230 mm as per the state legislation. About 60 percent of catch was sold though it was very small indicated the poor economic condition of the people involved in the fishing activities in the rivers.

Water quality and aquatic environment

Fish are genetically adopted to live in diverse water environment such as cold, soft, artic, warm and muddy water in tropics. Fish can easily tolerate the seasonal changes in temperature but abrupt change in water temperature affects the metabolic activity of fish. Water temperature has a direct or indirect influence on aquatic water ecosystems and it regulates fish distribution in rivers. Thus there is limited potential for transfer of fish between various water environments. Water temperature, quantity and quality plays a critical role and determines the distribution of fish species, stock catch and diversification of aquaculture i.e. presence of frogs, crabs, shrimps, mollusks etc. in the water body. Sikkim exotic trout fish are restricted to upstream of Teesta due to lower temperature profile. This species can not survive beyond 19°C temperature of water.

Selection of sampling site and data recording

Sikkim is the land of steep hills of varying altitude and there are hardly any flat lands of one square kilometer. All the springs and precipitated runoff from the hill terrains drained into the foothills becomes river tributaries. It is difficult to reach and collect samples from all tributaries, river belt and water bodies present in the state. Hence, sampling sites were selected considering approach roads as well as confluence and fishing sites.

Air temperature and humidity at sampling site during January and February varied from 5.57 to 27.8^{0}C and 39.73 to 60.18% where as during July and August it was 15.85 to 32.3^{0}C and 55.53 to 71.07%, respectively. Wind velocity observed was from zero to 2.56 m/sec.

In most of the tributaries during winter water was crystal clear and become dirty near township areas. Water temperature recorded during month of January to February and July to August ranged from 3.91 to 16.16^{0}C and 10.8 to 19.8^{0}C depending upon the weather condition.

Measurement of physical and chemical characteristics of riverine water quality in Sikkim

The pH is considered as a measure of environmental suitability and a range of 7.0 to 8.5 is considered to support a rich biota and fish (Bell, 1971). In Teesta, mostly alkaline ranges of pH are observed, which can be correlated with a presence of biocarbonate alkalinity in Teesta water. However, pH in acidic range was recorded in Ranipool during monsoon season. The surface runoff and high turbidity during monsoon slightly bring down pH in river Teesta (Shardendu and Ambasht, 1988).

A large number of inorganic salts and small amount of organic matter dissolved in water constitute the TDS in the water. Carbonates and bicarbonates are the chief constituents of TDS; however, chloride, nitrate, phosphate and sodium also contribute to it. In Himalayan water, its maximum concentration remains near 100 mg/l in normal conditions (Bhatt and Pathak, 1989). However, lower values are there in Teesta and its tributaries.

The water temperature, atmospheric pressure and contents of salts dissolved in water may affect the concentration of dissolved oxygen in the water. The Dissolved oxygen level was recorded to be ranged from 6.80 to 9.89 mg/l during pre-monsoon season (Table 3). However, it dropped to 5.50 and 5.04 mg/l in at Ranipool and Rangpo in rivers Rani Khola and Rangpo Chhu, respectively. Similar observations were also reported by MOEF (2002). Lower dissolved oxygen level might be due to drainage of sewage directly in the river Rani Khola and Rangpo Chhu from its nearby township Gangtok and Rangpo, respectively.

The total alkalinity is directly related to aquatic productivity more than 200 mg/l is good for the biological productivity. In most of the Himalayan river water alkalinity generally peaks up to 120 mg/l in normal conditions. As compared to monsoon (10-36 mg/l) and post-monsoon (18-32 mg/l) season total alkalinity was significantly higher during pre-monsoon (42-80 mg/l) (MoEF, 2002). Reduced alkalinity level during monsoon season might be attributed to dilution of river water due to heavy rain. Rain water increases the acidity and increased runoff adversely affects the alkalinity of Teesta water in monsoon season (Daborn and Clifford, 1974).

According to Saweyer's classification, the water of Teesta and its tributaries can be categorized as soft water (hardness less than 75 mg/l). The water in the Himalayan rivers and lakes are observed to be soft to very hard (more than 200 mg/l). Hardness of water in Rani Khola and Rangpo Chhu was observed to be 18.0 (mg/l) each during pre-monsoon season (Table 1). However, at other sampling points it was observed to vary from 9.5 to 20 mg/l.

Cold water fisheries

The water resources located above 900 masl are generally known as cold waters. The temperature limits of the water vary from 9-25° C. Himalayan rivers above 1400 masl are said to be dominated by exotic trout are termed as trout zone. The stream of middle zone from 850 -1400 masl are mainly inhabited by snow trout and called trout stream. The lower zone below 850 masl is inhabited by carp species and termed as mahseer stream. Among the 59 indigenous cold water fish species of Nepal, *Neolissocheilus hexagonolepis*, *Schizothoraichthys* spp, *Schizothorax* spp and *Tor* spp have been identified as the most important fish from the economic and sport fishery point of view. These are also an excellent food fish. Trouts (*Salmo trutta fario, Salmo gairdneri, Salvelinus fontinalis* and *Barilius bola*) Mahseer (*Tot tor, Tor putitora* and *Neolissocheilus hexagonolepis*) and Snow trout (*Schizothorax richardsonii, Schizopyge progastus*) have been identified as important culturable species in cold water.

Salmo trutta fario and *Salmo gairdneri* (rainbow trout) have been introduced in the upper stretches of the rivers and in a few high altitude lakes. However, no study has been conducted on the interaction between exotic and native fish in Sikkim.

Fish production in mountain streams is very low because of smaller in size and slow growth rate therefore commercial fishery is on a low scale. Small irrigation tanks, ponds are sometimes used for fish farming for household consumption and as recreational activity. However, lack of awareness and availability of stocking stock seems to be the major constraints among them.

Fish Value

Fish in natural hill streams and lakes are the main source of protein for local dwellers and also a potential source of sport fishing, recreational activity, self employment and income generating activity.

The best sources of omega-3 fatty acids are cold-water, fatty fish as salmon, mackerel, sardines and anchovy. These cold-water fish provide rich amounts of EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), which are the long-chain fatty acids, responsible for most of the health benefits. Fish oil omega-3 improves blood circulation, reduces the tendency of blood to clot, improves vascular functions and reduces the risk of heart diseases. It is also helpful in reducing the risk of premature and underweight babies and essential for brain, eyes and other tissues. Small cold water fish are also preferred because they provide a natural balance of both EPA and DHA with less risk of mercury contamination.

Fisheries management

Fisheries management recognizes the interrelationships between air, land, water, and all living organisms, rather than focusing on a single aspect. Ecosystem-based fisheries management tries to move beyond political boundaries and look at natural boundaries, such as watersheds (drainage basins), as the unit of management and includes the concept of sustainability. Strategies that can be used successfully by ecosystem-based fisheries management include temporary fishing bans, catch limits, size limits, and habitat improvement. In addition, captive breeding and restocking may be used to rebuild depleted populations. Strict enforcement of laws and catch limits also may help.

The diversity of fish germplasm in the rivers of Sikkim showed a decreasing trend. High altitude water bodies are suitable for trout production. The temperate and the sub-tropical regions of the State (300-600 masl) are suitable for warm water fish culture.

Future Prospects

- Culture fisheries should be emphasized in the region to minimize fishing loads on natural water resources.
- The aquaculture research and artificial breeding should be encouraged
- A live gene bank can be established, in suitable natural reservoirs.
- Some of the species available in Sikkim can be reared as ornamental fish species

Table 1. List of fish available in Sikkim

Sl. No.	Scientific name	Local name
1	*Acanthophthalmus pangia*	Not known
2	*Anguilla bengalensis*	Rajabam
3	*Bagarius bagarius*	Gonch
4	*Balitora brucei*	Titay
5	*Barilius bendelisis bendelisis*	Khasray
6	*Barilius bendelisis chedra*	Chaley
7	*Barilius vagra*	Chirkay
8	*Channa orientalis*	Hilay
9	*Clupisoma bhandari*	Jalkapur
10	*Crossocheilus latius latius*	Lohori Buduna
11	*Danio aequipinnatus*	Bhitti
12	*Danio naganensis*	Bhitti
13	*Euchiloglansis hodgarti*	Lulay
14	*Garra annandalei*	Buduna
15	*Garra gotyla*	Nakkatua Buduna
16	*Garra gotyla stenorhynchus*	Buduna
17	*Garra lamta*	Buduna
18	*Garra mcclellandi*	Buduna
19	*Garra mullya*	Buduna
20	*Glyptothorax basnetti*	Dhodray
21	*Glyptothorax bhutiai*	Kanray
22	*Glyptothorax conirostris*	Kanray
23	*Glyptothorax deyi*	Kanray
24	*Glyptothorax gracilis*	Kanray
25	*Glyptothorax sinense manipurensis*	Kanray
26	*Glyptothorax sinense sikkimensis*	Kanray
27	*Glyptothorax trilineatus*	Kanray
28	*Labeo dero*	Gardi
29	*Labeo pangusia*	Theyr
30	*Laguvia ribeiroi jorethanensis*	Gona Machha
31	*Laguvia riberoi riberoi*	Gona Machha
32	*Neolissocheilus hexagonolepis*	Katley
33	*Noemacheilus beavani*	Gadela
34	*Noemacheilus carletoni*	Gadela
35	*Noemacheilus corica*	Gadela
36	*Noemacheilus devdevi*	Gadela
37	*Noemacheilus kangjupkhulensis*	Gadela
38	*Noemacheilus multifasciatus*	Gadela
39	*Noemacheilus scaturigina*	Gadela
40	*Noemacheilus sikkimensis*	Gadela
41	*Noemacheilus spilopterus*	Gadela
42	*Pangasius pangasius*	Not known
43	*Pseudecheneis sulcatus*	Kabrey
44	*Salmo trutta fario*	Kashmiri macha
45	*Schizopyge progastus*	Chuchay Asala
46	*Schizothorax richardsonii*	Dothey Asala
47	*Semiplotus semiplotus*	Chepti
48	*Tor putitora*	Mahseer

Source: Tamang, 1993

Table 2. Percentage availability of catch fish at survey area during February-March 2009

Name of fish	Common name	Percentage (%)
Acrossochelus hexagonolepis	Katle	27.69
Schizothorax richardspnaii	Dothay asala	23.08
Gara annandalei	Buduna	7.69
Barilus bendelisis	Chaley, chirkay	7.69
Gara lamta	Buduna	6.15
Gara gotyla	Nak-katua buduna	6.15
Gara kempi	Buduna	6.15
Schizothorax esocinus	Asala	3.08
Pseudecheneis sulcatus	Kabre	3.08
Barilus barila	Chahale	3.08
Semiplotus bendelisis	Cheptey	3.08
Schizothorax progastus	Chuchay asala	1.54
Glyptothorax hori	Kafrey	1.54

Table 3. Physical and chemical characteristics of riverine water in Sikkim

River/ Stream/ Lakes	Place and Altitude	Season	Water temperature (°C)	TDS (mg/l)	pH	Dissolved oxygen (mg/l)	Alkalinity CaCO3 (mg/l)	Hardness (mg/l)
Teesta (lower stretches)	Melli, 240 m	Pre-monsoon	20	52.7	7.7	9.53	24	24
Teesta (middle stretches)	Dikchu after reservoir, 719 m	Pre-monsoon	14	32.0	7.8	8.60	22.4	20
Teesta (upper stretches)	before confluence of Knanka, 931 m	Monsoon	15	40.7	8.0	7.08	25.2	16
Rangpo Chhu	Near Rangpo, 300 m	Pre-monsoon	17	43.5	8.4	9.89	20	18
		Monsoon	18	24.4	8.0	5.04	20	14
Rani Khola	Ranipool, 690 m	Pre-monsoon	17	33.8	6.8	6.80	24	18
Rani khola		Monsoon	19	29.8	6.2	5.50	22.4	14
Rangit	Near Teesta – Rangit Confluence, 288 m	Pre-monsoon	19	44.2	8.3	8.45	21	24

Source: Haque *et al.* 2010

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REFERENCES

Bhatt, S. D. and Pathak, J. K. (1989). Hydrological profile of river Sarju draining upland of Kumaun (Greater Himalaya). Journal of Freshwater Biology, 1 : 33 42.

Bell, H. L. (1971). Effect of low pH on survival and emergence of aquatic insects. Water Resource, 5 : 313.

Daborn, G. R. and Clifford, H. F. (1974). Physical and chemical features of an aestival pond in Wesern Canada. Hydrobiology, 44 : 255 264.

Das, R. C. and Mukherjee, A. B. (2005). Important fish fauna of river Teesta, their biodiversity and the need of their conservation. In: P. C.Mahanta and A.K. Singh(eds).Proceeedings of the National Symposium on Reassessment of Fish Genetic resources in India and Needs to Evolve sustainable methodology for conservation, organized by Asian Fisheries Society, Indian Branch and NBPGR, Lucknow, from 26-27 th April 2005, pp 39-40.

Haque, N., Saroj Toppo and Rahman, H (2007). Impact of fishing on riverine fish diversity of Sikkim. Bioinformatic Centre Sikkim. www.bioinformaticssikkim.gov.in

Haque, N., Saroj Toppo and Rahman, H (2010). Aquatic environment and riverine fish diversity in Sikkim. In: Cold Water Fisheries Management, edited by P.C. Mahanta and Debajit Sharma pp. 141-156.

Hooker, J. D. (1854). Himalayan Journals. Vol. 1. Project Gutenberg Literary Archive Foundation, PMB 113, 1793 University Avenue, Oxford, MS 38655 4109, p 151. www.scribd.com/doc/ HimalayanJournals-Volume-1-by-Hooker-J-D-Joseph Dalton-18171911

Menon A. G. K. (1954). Fish geography of the Himalayas. Zoological Survey of India. Communicated by S L Hora, FNI.
Menon A. G. K., Singh, H. R. and Kumar, N. (2008). Present Eco status of Cold water fish and fisheries. In: H.R. Singh and Lakra (eds). Coldwater Aquaculture and Fisheries. Narendra Publishing House, New Delhi.

MOEF (2002). Carrying Capacity Studies of Teesta Basin in Sikkim. Volume VI. Biological Environment Terrestrial and Aquatic Resources. Ministry of Emvironment and Forests, Government of India. National Hydroelectric Power Corporation Ltd, Faridabad. Centre for Inter-Disciplinary Studies of Mountain and Hill Environment, University of Delhi, pp 1 259.

Pant, M. C. and Bisht, J. S. (1981). In: Science and Rural development in Mountains, Singh, J. S., Singh, S. P. and Shastri, C. (eds). Gyanodaya Prakashan, Nainital, pp. 473 482.

Shardendu and Ambasht, R. S. (1988). Limnological studies on a rural and an urban tropical aquatic ecosystem Oxygen forms and ionic strength. Tropical Ecology, 29: 98 109.

Sehgal, K. L. (1988). Ecology and fisheries of mountain streams of North West Himalayas. Thesis for award of D. Sc degree, Univ. of Meerut, India

Talwar, P. K. and Jhingran, A. G. (1991). Inland Fisheries of India and Adjacent Countries. Oxford and IBH Publishing Co. 66 Janpath, New Delhi, pp 1-1158.

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