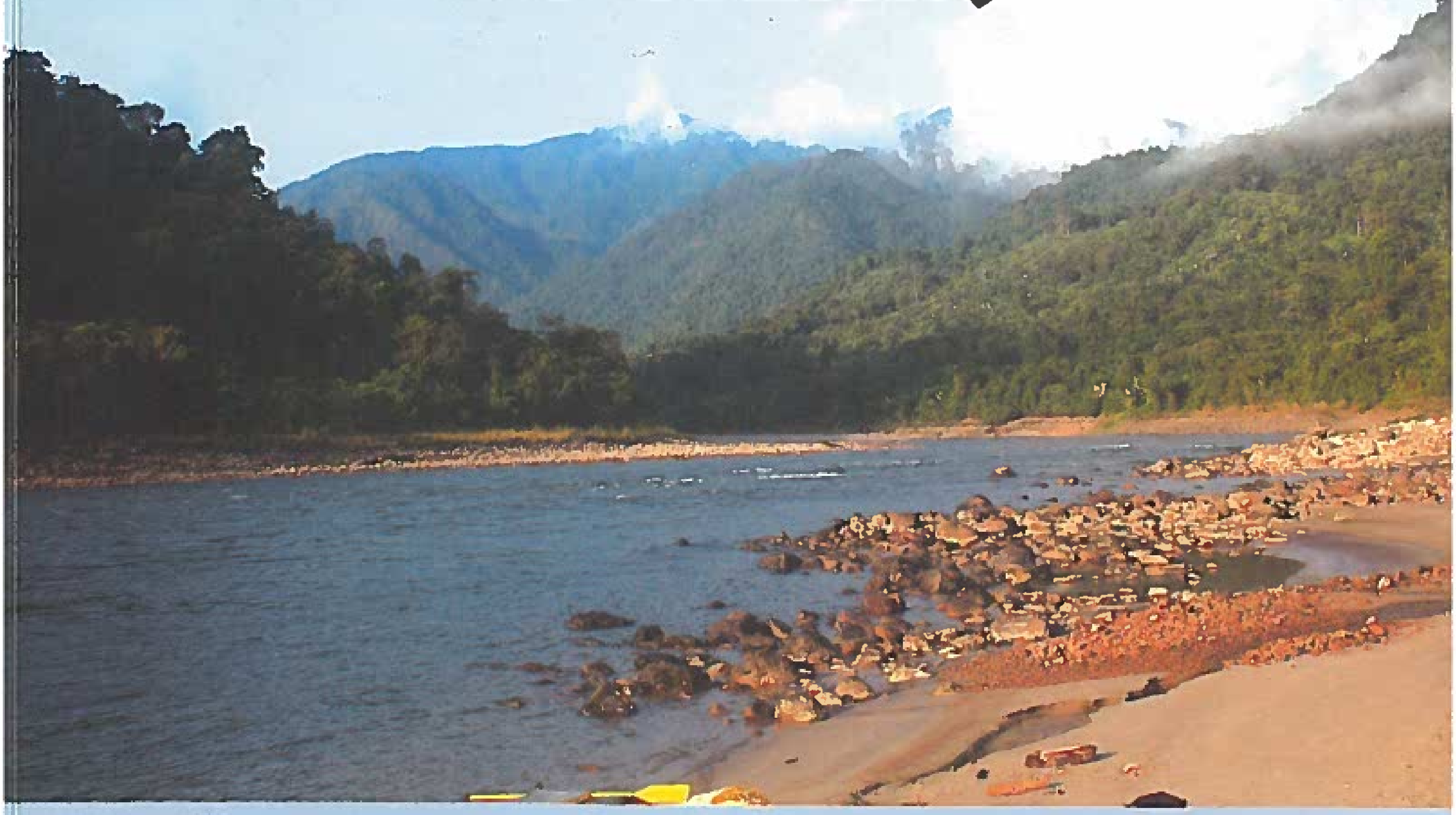
Workshop
on
Sustainable Utilization of Mountain Fishery Resources of North East Region

24-25 March 2012 :: Guwahati (Assam)

SOUVENIR



Organized by

Directorate of Coldwater Fisheries Research
(Indian Council of Agricultural Research)
Bhimtal-263 136, Nainital, Uttarakhand

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Editorial Committee

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Workshop
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Sustainable utilization of Mountain Fishery Resources of North East Region

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Directorate of Coldwater Fisheries Research, ICAR, Bhimtal, Nainital, Uttarakhand

24-25 March 2012 : : Guwahati (Assam)

Chief Patron
Dr. S. Ayyappan, Secretary, DARE and DG, ICAR, New Delhi

Patron
Dr. B. Meenakumari, DDG (Fy.), ICAR, New Delhi

Convener
Dr. P. C. Mahanta, Director, DCFR

सत्यमेव जयते

Tarun Gogoi

Chief Minister, Assam
Guwahati

Dispur
17-3-2012

MESSAGE

I am pleased to know that Directorate of Coldwater Fisheries Research (DCFR), Bhimtal is organizing a national workshop on "Sustainable Utilization of Mountain Fishery Resources of North East Region" from 24th to 25th March 2012 in Guwahati. I wish to compliment DCFR for bringing about interaction on sustainable development and utilization of fishery resources, which is an issue of great importance and relevance in the North East region.

I hope, the workshop will provide an opportunity for sharing experiences in research and development in the area of coldwater fisheries. Further the workshop would be especially focused on sustainable development and utilization of fishery resources in Northeastern region.

I convey my best wishes for the success of the workshop.

(TARUN GOGOI)

BASANTA DAS
Minister of State (Independent)

Government of Assam
Fisheries, Printing & Stationery
and Information & Public Relations
Tel : 0361 - 2237058 (O)

17th March, 2012

MESSAGE

It is my great pleasure to learn that Directorate of Coldwater Fisheries Research (DCFR), Bhimtal is organizing a National Workshop on "Sustainable Utilization of Mountain Fishery Resources of North East Region" during 24th-25th March, 2012 in Guwahati, Assam with the object of bringing together all the stakeholders of coldwater fisheries sector under a common platform for thoughtful deliberations, exchange of ideas and opinions for the development and sustainable utilization of coldwater fishery resources in North Eastern region. The programme will certainly focus on the emerging issues, challenges faced and opportunities available to the region and provide a road map for its sustainable development.

I am confident that this National Workshop will provide opportunity for the different stakeholders to exchange their views and experiences in improving the production and productivity of this region.

I congratulate DCFR and wish the workshop for a grand success.

(Basanta Das)

Block - B, 2nd Floor, Assam Secretariat, Dispur, Guwahati-781006

भारत सरकार
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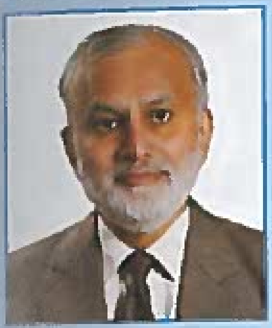

MESSAGE

It is pleasure to learn that a Workshop on 'Sustainable Utilization of Mountain Fishery Resources of North East Region' is being organized by the Directorate of Coldwater Fisheries Research (Bhimtal) at Guwahati, Assam during 24-25 March, 2012.

The North East Himalaya of the country, although endowed with rich aquatic diversity, needs special attention these days. The efforts of the R&D laudable. However, more focus is needed to address the issues and challenges of the region in a integrated approach so that the fruits are plan needs to be prepared from the deliberations in the workshop.

I wish the workshop all success

(S. Ayyappan)

Dated the 16th Marach, 2012
New Delhi

Dr. B. Meenakumari
Deputy Director General (Fy)

Indian Council of Agricultural Research
Krishi Anusandhan Bhavan-ii
Pusa, New Delhi 110 012

MESSAGE

The North Eastern Region of India comprising of eight states including Sikkim is identified as a prioritized area for conducting valued research under ICAR. The region is blessed with vast aquatic resources in the form of rivers, streams, floodplain lakes, reservoirs, ponds, tanks and wetlands. These water-bodies harbour rich fish biodiversity. Approximately 33% of the total Indian freshwater fishes have been reported from this region. This region possesses huge potential to fulfill the gap between demand and supply of fish. There has been drastic reduction in abundance of the freshwater fishes due to human interference. Therefore, sustainable utilization and development of fishery resources have assumed importance. We also need to make suitable strategy for the conservation of rich fish germplasm of the region.

In this perspective, I am happy to note that the Directorate of Coldwater Fisheries Research, Bhimtal has taken initiative in the North Eastern Region and thereby organizing a Workshop on "Sustainable Utilization of Mountain Fishery Resources of North East Region" during 24-25 March, 2012. It is hoped that workshop would address emerging issues of expansion of mountain fisheries and aquaculture practices, tools for enhancing the efficiency level and profitability of fish farming, critical R&D needs of the sector and the deliberations would bring out an action plan to address them in time bound manner for the benefit of all stakeholders.

I wish the workshop a great success.

Dated : 13 March, 2012
New Delhi

[B. Meenakumari]

PREFACE

The fundamental thought after transformation of NRCCWF to DCFR is to spread out the activities in the entire Himalayan region utilizing the recourses and manpower of various state fisheries departments and institutes located in the hilly region. In this direction, definite programme in partnership mode have been conceded in the XI five-year plan with the different state fisheries departments, universities and institutes in Sikkim, Assam, Manipur, Himachal Pradesh, J & K and Arunachal Pradesh with immense success and encouragement.

Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR emphasized, during his visits that the region has a huge potential of biodiversity and a great scope of integrated farming includes of agriculture, horticulture, livestock and fisheries. He also urged to develop linkages to streamline research strategies and priorities for holistic development of agriculture. In the line, DCFR has established linkages with universities, research institutes and State Fisheries Department of the Northeast hill region during the XI plan. The institute has plan of extensity activities in the region through KVKs located in high altitude area.

Further, sustainable utilization and development of fisheries resources have assumed importance in coldwater regions of the country. In this context, the changing global biodiversity management scenario, equal attention has to be given towards conserving the rich fish diversity and natural resources through partnership approach.

I wish the conclusions immerged out of this workshop will pave the way for holistic growth of coldwater fisheries development in this region.

(P. C. Mahanta)
Director, DCFR

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Mountain Fishery Development: Constraints and Remedies

B. Meenakumari* and P.C. Mahanta

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Introduction

On a global level, mountains are the world's largest repositories of biological diversity. Mountains cover about 24% of earth's landscape and home to at least 10% of world's population. They represent as much as 28% of world's forest areas sheltering about half of the world's biodiversity hotspots. The lakes and streams situated in the mountainous region are a source of freshwater for many of the riparian human communities residing in the hill, support many industries, provide water for storages for irrigation and hydropower electricity production and for fish. The long stretch of Himalayas of around 2500 km from west to east and 200-400 km from north to south comprising an area of 5,33,604 km^2 represents an entirely different eco-geographical entity. The most of the geographical area in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Mizoram, Meghalaya and Nagaland is under mountain covers while some part of Manipur, Tripura, Assam, Kerala and Tamil Nadu fall under mountains. The agro-climatic zones in the Indian Himalayan region is based on the altitudinal gradient, which are broadly classified as warm sub-tropical (< 800m) to arctic zone (> 3,600m). The mountainous region bestowed with vast and varied water resources in the form of rivers, rivulets, streams, streamlets, lakes, ponds, tanks and reservoirs. The Indian Himalaya is drained by 19 major river systems, which include the drainages of the Indus, Ganga, and Brahmaputra river systems. The snow-fed Himalayan rivers traverse from these physiographic regions. The cumulative length of the major upland rivers is estimated about 10,000 km. The lacustrine resources also varied from high altitude freshwater lakes, high altitude brackish to mid and lower altitudinal lakes. Total water area under lucustrine resources is about 20,500 ha and 2,65,000 ha water spread area is under reservoirs. The Coldwater Rivers and hill-streams are known for their high velocity, water falls, rapids, cascades, deep pools and substratum comprising with bedrock-boulder-sand. The diverse aquatic habitats of the hills region harbour rich piscine diversity. The mountain ecosystems are susceptible to accelerated soil erosion, landslides and rapid loss of habitat and genetic diversity. On the other side, there is widespread poverty among mountain inhabitants as about 80% of the people who live in these areas are impoverished. Due to burgeoning population coupled with habitat degradation most of the global mountain areas are experiencing environmental degradation. With the increasing realization that the natural resources of mountain areas are vital for the upland as well as lowland people, the global agenda for sustainable development has brought mountains to the sharp focus. Hence, proper management of mountain resources and socio-economic development of the people deserves immediate attention.

Table: 1. Major division of the Himalayan region

1. The Greater Himalayas (*Himadri*)	Longest and continuous, mostly north part of Nepal and parts of Sikkim. Average altitude of about 6100 m (20,000 ft) asl.
2. Lesser Himalayas (*Himanchal*)	In the south and north of Siwalik. Average altitude ranging from 3700m (12,000) - 4500m (15,000 ft) asl.
3. Siwalik (*Outer Himalaya*)	Siwalik is the lowest and narrowest section of Himalaya. Average altitude about 900m (3000ft) to 1200m (4000 feet) asl.
4. Trans-Himalayas	Stretches across Himalaya from West to East for about 1,000 km. Average altitude varies from 4500 to 6600 m asl.

Fish biodiversity

The water bodies of the Himalayan region inhabit diverse kind of fish fauna. Out of total fish fauna available in India 17% fishes were documented from the mountain ecosystem establishing the status of the area as a center of origin and evolution of biotic forms (Ghosh, 1997). About 36 species of freshwater fishes (out of 1,300) are endemic to the Himalayan region (Ghosh, 1997). For the whole Himalayas, 218 species are listed (Menon, 1962).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 flow is moderate and water current is soft. A number of fish species such as *Noemacheilus gracilis*, *N. stoliczkae*, *Glyptosternum reticulatum*, *Diptychus maculates*, *Noemacheilus* spp., *Schizothoraichthys esocinus*, *S. progastus*, *Schizothorax richardsonii*, *Schizopygopsis stoliczkae*, *Schizothorax longipinnis*, *S. planifrons*, *S. micropogon*, *Garra gotyla*, *Crossocheilus diplochilus*, *Labeo dero* and *L. dyocheilus* are found distributed in the different reaches of the river. The eastern Himalaya drained 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. The eastern Himalaya drained 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.

Mountain fisheries in India

On a global level, mountains are the world's largest repositories of biological diversity. Mountain regions are characterized by the presence of cold waters, many of which harbour fish and support largely subsistence fisheries. The farming or husbandry of trout has a relatively long history in Europe and North America. In the Indian Sub-continent two main types of trouts *viz.* brown trout (*Salmo trutta fario*) and rainbow trout (*Oncorhynchus mykiss* (Walbaum)) were transplanted from Europe by British settlers around the beginning of the last century primarily to meet their needs for sport fishing or recreational angling. The transplantation of brown and rainbow trout was attempted independently in the Himalayan and in the non-Himalayan States. In the Himalayan States the brown trout (*Salmo trutta fario Linnaeus*) was first brought in Kashmir through the private efforts of F.J. Mitchell in 1899. These introductions in the hill states could be considered as the formal beginning of Coldwater fisheries or mountain fisheries development in India. 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 setup for the production of seed. The development of hill fisheries thus started in the selected locations particularly in the Kashmir valley and some parts of the peninsular India. The breeding and culture techniques for the rainbow and brown trouts were standardized and now being practiced with greater success and accuracy.

Major constraints in mountain fishery development

In spite of harbouring vast and varied piscine diversity and enriched with huge aquatic resources, the mountainous region of the country has a number of inherent problems. The present exploitation of fishery resources in mountainous regions comes mainly from capture fisheries, though fish production through culture practices is gaining momentum. At present the total fish production from upland areas forms about 3% of total inland fish production of India which forms a very small contribution to the total fish production. Several constraints such as low productivity of upland waters, comparatively slow growth rate in almost all fish species, low fecundity in fishes and poor landing and marketing facility have been seen as major obstacles in the rapid development and expansion of coldwater fish production. The major issues concerning the development of coldwater sector in India are:

- Low level of fish production
- Lack of Infrastructure for aquaculture development
- Unavailability of quality seed for aquaculture production
- Limited numbers of candidate species for aquaculture
- Habitat destruction and wanton destruction
- Aquatic pollution and siltation of hill streams/rivers
- Lack of proper conservation and management policy
- Species rehabilitation and stock enhancement of natural water bodies
- Climate change

In order to address these challenges, there is an urgent need of reviewing the current approach of development policies. Although in last three decades significant achievements has been recorded in the development of upland fisheries and aquaculture but the pace of growth remained slow.

Possible Remedies

The aquatic resources in hills are quite valuable for the development of fishery both for food, sport, recreation and employment but scientific management of these resources is necessary to achieve the objectives. In order to manage these ecosystems, so that they can contribute to fishery development in remote hilly regions on a sustainable basis, the following issues need attention:

1) Resource mapping of the fishery resources in mountain/hill region needs to be taken up on priority basis for the integrated development of the coldwater sector.

2) In order to develop the riverine and lacustrine fisheries it is necessary to go for stock enhancement programme through ranching.
3) A legal framework should be formulated to stop all types of destructive fishing method.
4) The breeding grounds of the fish need special protection by declaring them as 'No-fishing Zone' or 'Protected Area'.
5) A balanced strategy for lakes, for tourism and fishery development is required.
6) Development of sport/recreational fishery for tourism and employment generation.
7) Education, training and extension support to the hill communities for resource conservation and utilization.
8) Promotion of mountain-specific policy formulation and legislation.
9) Promoting sustainable use of mountain natural resources and conservation of biological diversity and mountain ecosystems.

There is a vast scope and potential in improving fish production in hills by bringing natural Himalayan lakes located at different altitudes, under scientific management for fishery enhancement. This would actually reduce the gap between actual fish yield and production potentials. Through application of modern techniques, significant scope exists for promoting trout farming, which in long run, will have both domestic and export demand. There is also a great potential for sport fishery development and ecotourism in hill regions. Use of modern techniques such as molecular and biotechnological intervention, selective breeding programme for improvement of strains both of exotic and indigenous species, coldwater fish health management for the containment of diseases have now become imperative. Providing decision support system using GIS and remote sensing would be helpful not only for resource assessment but also for aquaculture development in the hills. Ornamental fish culture for small scale enterprises in the hills can provide an alternative source of employment. Presently DCFR has developed different technologies for the hill aquaculture, resource management and conservation. Three ponged fish farming has been standardized and also disseminated to the farmers of different hill states of the country. Chinese carp based polyculture technology has been popularized and also adopted by farmers in Arunachal Pradesh, Manipur and Uttarakhand. Trout farming and seed production technology has also been introduced in the state of Sikkim and Arunachal Pradesh. Aquaculture diversification is the key of fish production enhancement in the hill states and also one of the most important needs of the hour. DCFR has already initiated programmes in this direction with the culture and breeding of *Semiplotus semiplotus*, *Neolissochilus hexagonolepis*, and *Labeo dyocheilus*. To augment fish production from hilly areas two improved strains of Common carp from Hungary has been imported and presently under evaluation for later introduced into the culture system. Aquaculture potential site selection using geoinformatics has been developed for sustainable utilization of available resources. For the rehabilitation and stock enhancement of Himalayan mahseer, conservation programme such as breeding and subsequent ranching of seed has already been taken up. Thus with the development of location and situation specific technologies and participation of all stakeholders the mountain fishery has great potential for sizeable and visible contribution in nutritional security of the region in particular and nation in general.

Fisheries Development in Northeastern Region of India - An Overview

A. P. Sharma and B. K. Bhattacharjya

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The north-eastern region of India - comprising the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura - encompasses a geographic area of 262,179 km^2. It has vast and varied fisheries resources in the form of rivers, floodplain wetlands (*beels*), lakes, reservoirs, ponds and mini-barrages as well as low-lying paddy fields. The region presents diverse topographical conditions ranging from the plains of Assam and Tripura, upland flat lands of the Imphal valley in Manipur to predominantly hilly/mountainous regions of Arunachal Pradesh, Mizoram and Sikkim. The topography of is wholly mountainous with varying altitudes from 300 m in the sub-tropical belt to 5500 m msl in the temperate alpine zone. Hills and mountains comprise over two-third of the region's territory. Undulating topography, high rainfall and tectonic disturbances have given rise to numerous rivers, floodplain wetlands, lakes, ponds and low-lying areas, which form rich fisheries resources in the region. Further, a congenial environment for fisheries development prevails in the region by way of high demand and price of fish. However, fisheries development was not given due importance in the region till the recent past. As a result, fish production from the region is much below the requirement as evident from the daily inflow of substantial quantities of fresh and processed fishes (e.g., dry fish) into the region from states like Andhra Pradesh, Bihar and Uttar Pradesh. Thus, it is imperative that fish production from the fisheries resources of the region is increased by all possible means to satisfy its requirements as well as to improve livelihood and nutritional security. In the following, an overview of development of fisheries and aquaculture in the region is presented.

Fisheries resources and the present status of their utilisation

Rivers: The north-eastern region is criss-crossed by as many as 58 notable rivers/ tributaries besides numerous rivulets/hill streams. The mighty Brahmaputra (the largest river of the region) and Barak along with their tributaries form more than half of these rivers. The combined length of all rivers and their tributaries in Assam is 4,820 km, which includes R. Brahmaputra and Barak along with their tributaries. Major rivers of Arunachal Pradesh like Kameng, Dikrong, Ranganadi, Subansiri, Siang, Dibang, Lohit, Noadihing and Tirap - along with their tributaries - flow for 2,000 km. Estimated length of rivers in Manipur is 2,000 km including R. Barak, Imphal and their tributaries Meghalaya's 5,600 km of rivers mainly comprise the north-flowing (e.g., Umiam, Digaru, Dudhnoi, Krishnai, Jinjiram) and south-flowing ones (e.g., Balat, Kynchiang, Simsang). There are 21 rivers in Mizoram (e.g., Tuirial, Mat, Tlawng, Karnafuli, Tairei), which along with their tributaries run for 1,700 km forming an important fisheries resource of this hilly state. Jhanji, Dikhow, Diphu, Daiyung, Dhansiri (all tributaries of R. Brahmaputra), Barak and Tizu are the main rivers of Nagaland, which have a combined length of 1,600 km. Sikkim has two major rivers, Teesta and Rangeet, with a total length of 900 km. The total annual fish yield contributed by Sikkim's riverine fisheries is of the order of 150 t. Important rivers of Tripura (e.g., Longai, Juri, Deo, Manu, Dhalai,, Khowai, Howrah, Gumti, Mahuri, Feni) have a total length of 1,200 km. Thus, the combined length of rivers in the Northeast is 21,180 km.

Studies conducted by CIFRI in selected rivers in all the NE states indicated that most of the rivers had pristine environmental conditions especially in higher altitudes, were subjected to habitat modifications in foot-hill regions and had rich fish biodiversity, most of which were under- exploited in high altitudes because of inaccessibility, rocky/pebbly bottom, inefficient fishing gear, etc. However, the river stretches in plain areas were over-exploited and subjected to habitat modifications in most places. The upland stretches of these rivers support rich coldwater fisheries including snow-trouts *(Schizothorax* spp, *Schizothoraichthys* spp.), mahseers *(Tor* spp., *Neolissocheilus* spp.), korang (*Raiamas bola*) and minor carps (*Labeo dero*, *Labeo dyochelius*) most of which also act as commercially important food fishes.

Floodplain wetlands (*beels*), lakes and swamps: Floodplain wetlands (oxbow lakes, tectonic depressions and other wetland formations on the floodplains of rivers) and associated swamps constitute an important fisheries resource of the region, especially in the states of Assam (*c.* 100,815 ha) and Manipur (21,000 ha). Assam has the largest area under floodplain wetlands (locally called *beel*s) in the country. The Imphal valley of Manipur has a number of *pat*s (as the floodplain wetlands are known in the state), which along with the Loktak Lake (19,150 ha), making it the second most potential state in the region for fisheries development. Arunachal Pradesh, Meghalaya, Tripura, and Nagaland have 2500 ha, 375 ha, 500 ha and 215 ha of wetlands respectively. The region also has a number of upland lakes like the Psango Lake (Sikkim), Ganga, Shalley and Karko lakes (Arunachal Pradesh). The total area of *beel*s, *pat*s, lakes and swamps in the region is 144,555 ha. A number of these wetlands/ lakes have been converted to swamps as a result of continuous siltation and macrophyte infestation. As a result, the vast majority of these productive resources still form capture fisheries and have low fish yield rates (c. 14 to 200 kg $ha^{-1}yr^{-1}$). However, moderate (250.4-477.8 kg $ha^{-1}yr^{-1}$) and high fish production rates (1500 kg $ha^{-1}yr^{-1}$) have been reported from selected beels of Assam that are under stock enhancement and culture-based fisheries respectively (Bhattacharjya and Sarma, 2010).

Ponds and 'mini barrages': Assam (31,232 ha water spread area) has the largest area of ponds among the northeastern states. Of these, about 6,000 ha have been brought under semi-intensive fish culture (mainly carp). Tripura has 13,342 ha aquaculture ponds, of which 4,270 ha are improvised impoundments created by blocking the streams, which are locally called mini-barrages. This type of ponds is also found in Mizoram where there is a dearth of plain land for constructing dug-out ponds. Mizoram has 1,800 ha of ponds while Manipur, Meghalaya and Nagaland have 5,000 ha, 500 ha and 500 ha of ponds respectively. According to a recent report (Moda, 2008) Arunachal Pradesh has 1717 numbers of private ponds covering 1550 ha, which produces fish in the range of 1550-2000 kg/ha. It is estimated that 66,795 ha of ponds can be developed in the region against which 52,119 ha are already available for aquaculture.

Reservoirs: It is estimated that the Brahmaputra and Barak river basins together constitute 50% of the total hydel power potential of the country (Sinha, 1990). A few hydroelectric power projects covering 17,435 ha of reservoir area have already come up in the region. They include Umrang and Khandong reservoirs created under the Kopili Hydroelectric Project in North Cachar Hills district of Assam (1,713 ha), Umiam, Kyrdemkulai and Nongmahir reservoirs in Meghalaya (8,430 ha), Gumti reservoir (4,500 ha) in Tripura, Khopum dam (100 ha) of Manipur, Palak lake (32 ha) of Mizoram, Daiyang reservoir in Nagaland and Ranganadi reservoir (160 ha) in Arunachal Pradesh. A number of hydroelectric power projects like Tenga, Bishom, lower Subansiri (Arunachal Pradesh) and Teesta (Sikkim) are currently underway. In Arunachal Pradesh alone, 4,177 ha of reservoir area are likely to be developed under the ongoing/ proposed HE projects viz., Kameng (NEEPCO), Lower Siang (NHPC), Middle Siang (NHPC), Lower Subansiri (NHPC), Middle Subansiri (NHPC), Upper Subansiri (NHPC), Dibang (NHPC) and Lohit (Brahmaputra Board). However, detailed report on the fisheries of the existing reservoirs is scanty at present. Common carp ((*Cyprinus carpio*) introduced in Umiam reservoir (Meghalaya) in early 1970s reportedly forms the mainstay of fishery in the reservoir (Vinod *et al.*, 2006).

Low-lying areas: At present, traditional paddy-cum fish culture is practised in some appreciable extent in certain parts of Manipur (Ukhrul district), Arunachal Pradesh (Apatani plateau), Assam (Dhubri district) and Nagaland. But these culture practices are low yielding and mostly subsistence in nature. Even though there is enormous potential for developing paddy-cum-fish culture in the northeast, only 2,670 ha out of the existing 32,904 ha is developed for the practice. Further, another 22,280 ha of potential low-lying areas (mainly silted wetlands) is yet to be developed for the practice.

Suggested strategies for further fisheries development

The region has enormous potential for bringing unmanaged water bodies under fisheries enhancements including aquaculture (horizontal expansion) as well as for increasing fish production rates from water bodies under some form of fisheries enhancements (vertical expansion). There are many areas requiring management interventions to achieve higher fish production from the existing and potential fisheries resources of the region. Some of the broad strategies suggested for realising this potential are:

- Extending proven aquaculture technologies (warm/ cold water) to all unmanaged ponds/ mini-barrages,
- Increasing fish productivity from ponds under extensive/ semi-intensive aquaculture,
- Introducing improved varieties of candidate species (e.g, Champawat/ Amur varieties of common carp/ Jayanti rohu) for increasing productivity from aquaculture,
- Practicing fish stock enhancement/ culture-based fisheries in small wetlands/ lakes/ reservoirs,
- Bringing more areas under paddy-cum fish culture and increasing fish productivity from already under fish culture,
- Setting up of fish seed farms in seed deficit areas for ensuring adequate supply of quality fish seed,

- Setting up of fish feed plants (as per local/regional demand) for ensuring adequate supply of cost-effective fish feed,
- Development of ornamental fish culture and trade with stress on induced breeding and larval rearing of indigenous ornamental fishes for export,
- Development of coldwater/ sport fisheries in upland rivers including setting up of more trout and mahseer hatcheries,
- Development of planned organic aquaculture (from organic aquaculture by default) in selected areas of the region (e.g., Arunachal Pradesh which has a declared policy of organic farming),
- Conservation and sustainable utilization of large natural water bodies such as rivers, medium and large reservoirs, large and open wetlands/ lakes.
- Development/ refinement and popularization of induced breeding and grow-out culture technologies for potential candidate species having high consumer preference in the region (e.g., *Osteobrama belangeri, Clarias batrachus, Ompok* spp., *Monopterus kuchia, N. hexagonolepis*).

By following such a combined strategy it will be possible to raise the region's fish production substantially, thereby narrowing the deficit down to modest levels from the current level of approx. 46% and also to conserve the pristine fisheries resources (including their rich ichthyo-faunistic diversity) for posteriority.

Preferences

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Fish Biodiversity of North Eastern Hill Region : Potentials and Efforts for Sustainable Management

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Introduction

Worldwide freshwater fishes are the most diverse of all vertebrate groups, but are also the most vulnerable due to anthropogenic activities, which includes river management activities, construction of dams and indirectly through developments and disturbances in the landscape of the watersheds (De Silva et al. 2007), besides indiscriminate fishing pressure. Freshwater fish biodiversity has declined faster than either terrestrial or marine biodiversity over the past 30 years (UNESCO, 2003) and are one of the most threatened taxonomic groups because of their high sensitivity to the quantitative and qualitative alteration of aquatic habits. As a consequence, they are often used as bioindicator for the assessment of water quality, river network connectivity or flow regime. Kottelat and Whitten (1996) considered the biological change that environmental degradation brings about, and enumerated pollution, increased sedimentation, flow alteration and water diversion, and introduced species as the main causes for decreased ichthyofaunal diversity. Therefore, conservation of freshwater fish germplasm resources should be given priority taking into consideration the distinct, diverse and fragile nature of aquatic habitat types.

The North Eastern Hill (NEH) Region of India possesses a unique potential of fishery resources and considered as one of the hot spots of freshwater biodiversity in the world. The region comprises the states of Assam, Arunachal Pradesh Meghalaya, Manipur, Mizoram, Nagaland, Tripura and Sikkim and lies between Lat. 21.57° to 29.3°N and Long 84.46° to 97.3° E, covering elevation of 200-900 m. The NEH region occupies a total geographic area of 2.62 lakh sq. km, which accounts for 7.97 % of the total land area of the country. The region has very diverse and distinct agro-climatic and geographical characteristics in relation to the topography, temperature, rainfall and soil types. The NEH region is also a priority area for NBFGR's research programme. In the present communication fish biodiversity potential of the region, NBFGR's efforts and issues for their sustainable management have been discussed.

Aquatic resources

Since the NEH Region is a hilly landlocked area, only freshwater resources are available which comprises several rivers, tributaries, streams, floodplains wetlands, lakes, ponds and large areas under rice fish culture system. The hill states are mostly dominated by rheophilic streams followed by slow moving potamogenic courses and stagnant lakes/wetlands The rivers Brahmaputra and Barak form the principal drainage of North East with its numerous tributaries flowing through the different states along with myriads of rivulets and lentic waterbodies. The region is endowed with vast fishery resources with 19,868 km of rivers and streams, 14,338 ha of beels and lakes, 23,792 ha of reservoirs besides about 79,360 ha rice- cum- fish cultivation areas. The maximum water area is explored for fisheries in Assam (87.39%) and the minimum in Nagaland (7.92%).

Fish biodiversity

The considerably rich fish diversity in the NEH region is attributed to many reasons, viz., the geomorphology, consisting of hills, plateaus and valleys, resulting in the occurrence of a variety of torrential hill streams, rivers, lakes and swamps; drainage pattern which include the Ganga-Brahmaputra, Koladyne and Chindwin-Irrawady systems. Another important factor is the tectonic setting in the Indo-Chine sub-region caused by collision of Indian, Chinese and Burmese plates, resulting in the formation of the mighty Himalayas and Indo-Burman ranges. Through NBFGR's collaborative research programme, a total of 296 species of 110 genera under 35 families have been described which also reports several new species (Viswanath et al., 2008) from this region. However, previous studies from this region reported a wide variation in number of fishes ranging from 172 (Ghosh and Lipton, 1982) to 267 fish species (Sen, 1985; Yadav and Chandra, 1994; Sinha 1996; Sen, 2000). So far economic value of the fishes is concerned a considerable percentage of fish (35%) are considered as food fish followed by 29% as ornamental.

Nation-wise, the most number of endemic freshwater finfish species occur in India contributing 27.8% of the native fish fauna followed by China, Indonesia and Myanmar. The NEH Region is characteristic in having several endemic fish genera, viz., *Aborichthys* Chaudhuri, *Akysis* Blyth, *Amblyceps* Blyth, *Badis* Hamilton, *Bangana* Hamilton, Chaca Gray, *Conta* Hora, *Erethistoides Hora*, *Erethistes* Muller & Troschel, *Exostoma* Blyth, *Meyersglanis* Hora & Silas, Olyra McClelland, *Parachiloglanis* Wu, *Pareuchiloglanis* Regan, *Pseudecheneis* Blyth and *Pseudolaguvia* Misra. Sen (1985) reported 48 species species to be endemic to Assam and the neighboring states of India. Ghosh and Lipton (1982) reported 33 species as restricted in their distribution to this region. However, the recent report (Viswanath et al., 2008) described 160 fish species as endemic to this region.

New species from the NEH Region

During the last decade several new species have emerged from the NEH region under exploration programme. Some of the new species described from this region includes *Puntius ater, P. khugae, Glyptothorax chindwinica, G. granulus* and *G. ngapang*. Under NBFGR's collaborative programme during 2008-10 *Glytothorax ater, G. patherinus, Batasio mizoramensis* and *Hara koladynensis* have been identified as new. Many other species emerged as new species viz., *Gagata gasauyuh* (Roberts & Ferraris, 1998), *Badis chittagongis, B. ferrarisi, B. kanabos* and *Mystus falcarius* (Chakraborty & Ng, 2005), *Sisor chennuah* (Ng & Lahkar, 2003), *Pseudolaguvia ferula* (Ng, 2005), *P. inornata* and *P. muricata* (Ng, 2005), *Batasio spilurus* (Ng, 2005), *Gogangra laevis* (Ng, 2005), *Pseudecheneis crassicauda* and *P. serracula* (Ng & Edds, 2005), *Amblyceps arunachalensis* and *A. apangi* (Nath & Dey, 1986), *Psilorhynchoides arunachalensis* (Nebeshwar et al., 2007), *Pseudecheneis sirenica* and *P. ukhrulensis* (Vishwanath & Darshan, 2007), *Puntius ater* and *P. khugae* (Linthoingambi & Vishwanath, 2007). Many more new species could be distributed in the drainages of the North-East and therefore, requiring more biodiversity exploration.

Threatened fishes

India contains 659 species of animals listed as globally threatened by IUCN (2008) which includes 42 species of Indian fishes have been listed as threatened under categories of endangered and vulnerable. NBFGR, Lucknow in 1992 had identified nine fishes of NEH region (*Ompok pabda, O. pabo, Labeo dyocheilus, Semiplotus semiplotus, Olyra longicaudata, Psilorhynchus homaloptera, Noemacheilus elongatus, Balitora brucci* and *Barbus dukai.*) as most 'threatened'. The most recent conservation assessment (NBFGR, 2009) of the freshwater fishes of India enlisted about 120 freshwater fishes of the country under threatened category, of which 57 species have been distributed in the NEH region. Out of 57 threatened fishes of the NEH region, 19 have been listed under endangered (EN) while 38 species listed under vulnerable (VU) category (Fig. 1). Focused research on the threatened species, therefore, is required for appropriate conservation planning.

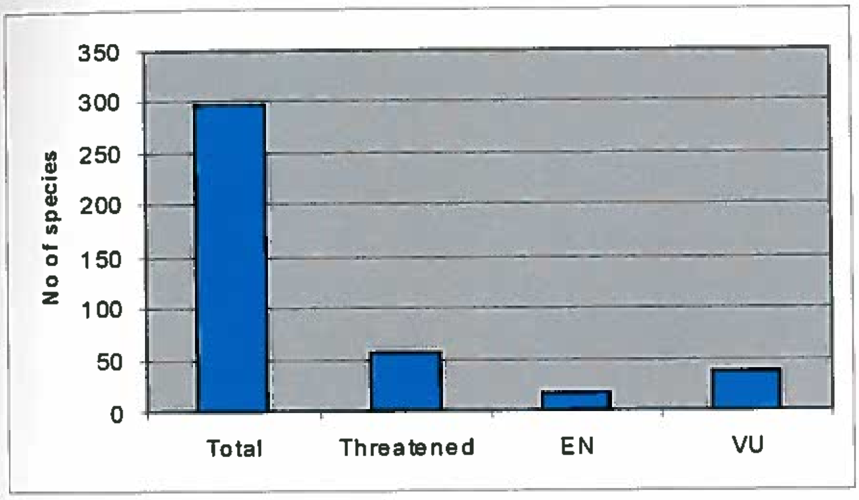

Fig. 1. Threatened fishes of the NEH Region

Genetic resources conservation in NEH and involvement of NBFGR

To address conservation issues a wide variety of factors must be taken into consideration in developing a comprehensive action plan including information on the taxonomy, biology, stock structure and their distribution, status of the target species in the area concerned. Since the long-term prospects for the conservation of rare and endangered fish species depend on the availability of genetic variation within population, it is therefore important to obtain information on the extent and distribution of such variation.

Under the broad mandate of conservation, maintenance and preservation of fish genetic material, collaborative projects were undertaken in the new frontier areas of research. During last decade significant achievements were made in inventory and phylogeny of fishes, exploration and propagation of threatened chocolate Mahseer (*Neolissichilus hexagonolepis*), exploration in the Wildlife Sanctuaries, gene banking, captive breeding and artificial propagation of the endangered fishes like *Osteobraama belangeri*, *Ompok* sp., *Chitala chitala* etc. The other areas include habitat mapping and development of spatial database for Mahseers and documentation of indigenous knowledge and policy issues related to fisheries.

Regional fish live gene bank

Live gene bank contributes to delisting of threatened species by captive breeding and restocking in species-specific recovery programs. Such gene banks can contribute to recovery and utilization of genetic diversity and its use in conservation programs and genetic enhancement. In the NEH region, two Live Gene Banks have been established at Gwahati in collaboration with Gwahati University and Department of Fisheries, Govt. of Assam with the objectives to explore the habitat of the threatened fish species in wild environment of the North East, their culture and study of the life-history traits and breeding behaviour of prioritized species. Success was observed in captive breeding for *Clarias batrachus, Heteropneustes fossilis, Ompok bimaculatus, Sperata seenghala, Chitala chitala, Ompok pabda, O. pabo, Channa* spp. and *Notopterus notopterus.*

Atlas on genetic resources

An atlas of the North East fish diversity consisting 296 species of 110 genera under 35 families with colored images has been prepared which includes brief description of genera, diagnostic characters, distribution and keys to identification and distribution. A separate atlas of the Ornamental Fishes of North East fish diversity consisting 92 species of with colored images has also been prepared.

State Fish

An innovative approach of conservation of some regionally important fish species was envisaged through inviting each of the State Fisheries Department to declare one fish species as state fish. With this process 17 states have become partners with the NBFGR in developing strategies for conservation and enhancement of their selected State Fish to achieve the real time conservation success which also includes five NEH states viz., Manipur for *Osteobrama belangeri* (*Pengba*), Tripura for *Ompok bimaculatus (Pabda*), Arunachal Pradesh for *Tor putitora* (Golden Mahaseer), Nagaland for *Neolissochilus hexagonolepis* (Chocolate mahseer) and Mizoram for *Semiplotus modestus* (Kingfish).

Indigenous knowledge and policies

In NEH, fishes have larger ramifications in relation to cultural life and sometimes in the therapeutic or curative domain which many traditional societies are still upholding. In that context, extensive studies were made by NBFGR's collaborative programme in the different tribal areas of Arunachal Pradesh for documentation of various indigenous knowledge systems related to fish and fisheries and their value in conservation of local fish resources. Various intricate issues related to fisheries and Indigenous Knowledge System (IKS) of the three tribes (Adi, Galo and Nyishi) who are passing through the phase of transition were documented and recorded information on the indigenous knowledge systems including fishing methods, post harvest processing and local fish biodiversity conservation policies developed by the tribal communities.

People's participatory programmes

Mass awareness programmes/ educational campaigns about sustainable utilization and conservation of fish germplasm resources were conducted in many areas. People's participatory programmes indicated positive impact for sustainable utilization and conservation of fish germplasm resources.

Human resource development

Keeping in view the need of developing trained manpower and capacity building for biodiversity conservation, the Bureau has taken due consideration that the research achievements developed are disseminated to other agencies including researchers and students. Training programmes were conducted in the field of fish biotechnology, molecular marker development and analysis, DNA barcoding and molecular taxonomy, genotoxicity assays and disease diagnostics and reporting in order to develop capacity building and create specialized human resource in the country that can spearhead research in the frontier areas of science.

Strategies and Action plans

It is important that millions of livelihoods are dependent on the fishery resources and the strategies that need to be adopted to protect the biodiversity will necessarily have to be different from the conventional approaches. Indeed, the development of such strategies will be a challenge and requires concerted efforts by integrating capture, culture fisheries and environmental programmes using latest technological innovations. It is expected that innovative research programmes are initiated on the priority areas involving different organizations, National Fisheries Development Board, Directorate of Coldwater Fisheries Research, State Biodiversity Boards, State Fisheries and other stakeholders which would be a significant beginning towards sustainable utilization of the indigenous fish diversity of NEH region. In this endeavour it is necessary that certain priority research areas viz., germplasm explorations; enhancement of hill-stream fisheries; valuation of goods and services provided by aquatic biodiversity; aquatic biodiversity management; bioregional management; threatened or endangered species designations; captive breeding, ranching and stock enhancement; conservation-based fisheries management; increase public awareness and local community actions; restoration/ mitigation efforts; climate change and interventions; capacity building for coldwater biodiversity research; and ecotourism and sport fisheries are taken up for sustainable management of aquatic resources in the region.

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Aquaculture for Sustainable Livelihood Development of Upland Communities

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Context

Declining natural fish stocks due to over-exploitation of limited water resources and loss of habitats resulting from discharge of toxic contaminants and other anthropogenic actions on one side and increasing demand of fish due to population increase on the other have necessitated the expansion of aquaculture development to upland aquatic ecosystems. In upland areas where saturation in agricultural production and intense pressure on agricultural land is increasingly felt diversification of agriculture through allied farming activities utilizing various aquatic ecosystems has also gained considerable attention. Besides, aquaculture is also viewed as an appropriate and additional development initiative for creating additional livelihood opportunities for upland communities by spreading risk, better use of locally available farm and household wasteas major inputs and integration with other family farm practices. Most of our upland areas has unique fisheries and aquacultural resources which offer good potential for productionof fish – a preferred food item of upland communities.

Upland farming systems in particular, are characterized by a high level of diversity. This diversity depends on several factors grouped under two broad categories- bio-physical and socio-economic factors. Biophysical factors, also termed agro-ecological conditions by agriculturists, include landforms, soils, climate, altitude, topography, flora and fauna. Socio-economic factors are more related to humans and human activities including ethnicity, culture,local history, population density, food preference, land use system, physical accessibility, marketing opportunities, access to government services including institutional finance, extension services, and development projects and programmes. This diversity has important implications for sustainable livelihood development.The rich aquatic resourcesin the form of river, streams, inundated depressions and smallimpoundments are integral component of most of the upland communities and their livelihoods. With appropriate use of indigenous traditional knowledge and improved technology these resources may be able to play even a much bigger role in upland areas by providing much needed nutritious food of their choice, employment and income. Aquaculture is also widely accepted as a robust and effective tool for poverty reduction and discouragingshifting cultivation.

Recent approaches employed in India and many other developing world embrace holistic views on transforming the livelihoodsof poor upland communities. In doing so policies seek more allocation of household resources to commercial enterprise, there are also concerns about basic food and nutritional security and the need to build incrementally on what already exists. Livelihoods are currently centred on the basic resource of household labour, which includes human knowledge, skills and health for harnessing the potential of natural resources – land, water and forests.

The Sino-Indian conflicts of 1962 and subsequent Indo-Pak conflicts of 1965 and 1971 along the Himalayas brought in the realization that there is urgent need for priority development initiatives in the Indian uplands especially the Himalayas. Development on priority basis in the areas interfacing neighbouring countries is a common strategy being adopted by many countries. In Vietnam, development of upland ethnic communities living along Chinese borders is a priority programme in which livelihood development through aquaculture is quite successful. The Himalayas is of course a precious gift of nature, which has moulded life, culture and history of this sub-continent since eras. Upland regions in India represent an important aquatic bioresource for the sub-Himalayan region. Unfortunately, this resource is generally under-recognized and undervalued. Its potential for rural livelihood development has been hardly realized. Some of the advertent and inadvertent anthropogenic operations and injurious results had produced by way of soil erosion, disintegrated hill sites, frequent land slides and even sinking of mountains, disruption of natural water channels and flooding of rivers, streams, irrigational canals, dams and reservoirs resulting into the present day status. These natural resources can be sustainably utilized and protected by creating awareness among the rural mass and involving them as partners in such programmes. Experiences available within highland areas in Asia suggest there is potential for aquaculture and fisheries development to contribute to rural development and poverty alleviation of upland communities. The overall development in a democratic society is not a matter of only plans and statistics, targets and budgets, technologies and methods, materials and professional staff or agencies and organization to administer them, rather it is an effective use of these mechanisms as educational means for changing the mind and action of the people in such ways that they help themselves to attain economic and social wellbeing.

Understanding traditional livelihoods of upland communities

Descriptions of traditional 'farming systems'of upland communities mentioned in policies and studies recognize that resources are allocated across a mix of opportunities,and usually result in a combination ofagricultural, animal husbandry, fisheries and forest products. However, farming systems form the core subsistenceactivities. Major options include:

- Hill slopes
- Paddy / wheat fields
- Various types of homegarden
- Small and large livestock
- Hunting and fishing

Households allocate their resources (labourand knowledge, land, inputs) among theseoptions, depending on access, availability, productivityand risk, as well as on their perceived needs,preferences, and opportunity costs. Systemoutputs can meet immediate subsistenceneeds or go into reserves, andany surplus can be traded or sold (ifpossible) to help meet subsistence,savings or capital investment needs.

Upland people depend on forests for subsistence and income generation.Benefits from forests include food, wood, fuel, land for cereal and horticultural crops, shifting cultivation,tree planting or regeneration, and livestock feed and fencing. Associated (often extensive) knowledge of wild species found in local fallows, forests, and waters, and how they can be used for human benefit, complements knowledge of cultivated species, providing a basis for the domestication processes that help livelihoods adapt as conditions and needs fluctuate.

Uplandfarm fields are very limited and available in the form of small fragments. They are the main source ofrice (wheat in some areas), along with other products. The degreeto which a household can or cannot meetits subsistence rice needs is considered amain indicator of poverty. However, sinceupland rice cannot be grown in a fieldcontinuously without yield decline,traditional technologies use forestregeneration to maintain productivitywithout chemicals.Hill slopes are also used extensively for maize production in some areas of South-east Asian countries.

Livestock provide food and draught poweras well as a growing store of wealth that can be mobilised for cash, trade, dowriesand meeting emergencies. Since feed is usually from cropresidues, scraps, and/or wild or volunteerplants, livestock cross householdcommunityland and domesticatedwildlandboundaries according toneeds, seasons or opportunities.Common barriers to livestockproduction are obtaining initialimproved stock and reliable feed sources,while risks are disease, weather andtheft.

Homegardens are a rich and often underestimated repository of germplasms, knowledge and familiarity. Homegardens have a variety of forms andlocations that can vary byseason and other conditions,and are frequently diversemixes of exotic anddomesticated species thatmeet nutritional, herbal,medicinal and even aesthetic or spiritualneeds. Thus, they are a pool of plants,knowledge and experience from whichlarger specialized commercial plantingscan be built if and when reliablemarketing opportunities emerge.

Upland areas are also bestowed with a range of aquatic ecosystems with rich fish diversity. These are in the form of rivers, streams, pools, inundated paddy fields, etc. In line with their inbuilt survival strategy of harnessing the potential of available natural resource for food, shelter and other human requirements they also fish in these waters using their age old traditional practice and indigenous crafts and gears. More importantly they have also integrated sustainability concerns in their approach and as such there are ample examples that show how meticulously they protect aquatic habitats and conserve resident biodiversity. Fish is a food of choice for upland communities and when fresh fish is not available they consume dried fish coming from low land areas. With the development of aquaculture technologies,for both impounded and running water systems, a wide ranging opportunitiesexist in upland areas for growing substantial amount of food and cash income for local communities.

As households, lineages and communities engage in various component enterprises over the years and through generations, they build a knowledge base about the land, crops, wild plants, fisheries and animals within their management and production domain. This continually evolving familiarity with how plants, animals and fisheries prosper or suffer under the range of conditions found in local domains is an important part of agro-ecosystem management practices, and a major resource for further transformation.

The overall mix of a household enterprise portfolioreflects current livelihood strategies.Whenever there is a disturbance or stress (ornew opportunity) that affects one component,the overall system seeks to compensate, adapt,or cope by readjusting allocations among thecomponents. Since disturbances by natural causes – fluctuating conditions weather andman made actionshave happened many times inthe past, mechanisms have been developed tomake it through hard times: wild ordomesticated 'famine crops', and social orkinship networks for emergency assistance. Such traditional / Indigenous technical and resource management knowledge are to be considered as their greatest wealth and strength. Any future development intervention will succeed if they are built upon these community traits.

The people of the Himalayan Upland Regionare characterized by very low levels of human development and their livelihoods have been summarized by the International Center for Integrated Mountain Development (ISIMOD) as follows:

- The lowest per capita incomes in the world - probably the lowest even within the country.
- Mountain economies are mostly subsistence-oriented and meet food requirements for only a part of the year, compelling household members to move out in search of income-earning opportunities, mostly to urban centres and agricultural areas in the plains.
- Women and children have to bear increasing burdens of agricultural and subsistence activities in the rural mountains because of the absence of male members from mountain households.
- Many parts of the mountains are not easily accessible, limiting the scope for development of various opportunities provided by a diverse, scenic but fragile environment and hampering the provision of health, education, and extension services.
- Many parts of the mountains experience rapid loss and damage of natural resources, resulting in further difficulties to households in meeting their subsistence needs.

These conditions represent a challenge for all concerned with poverty alleviation and development in the region.

Aquaculture based livelihood options

Based on a wide range of aquaculture practices prevalent among upland communities of the region a selected few may be appropriate for our upland areas. Culture of fish and some aquatic plants are extensively practiced in running water streams, rivers, impounded waters and ponds. In most cases aquaculture is integrated with other components of the family farming practices.

Fish culture in ponds

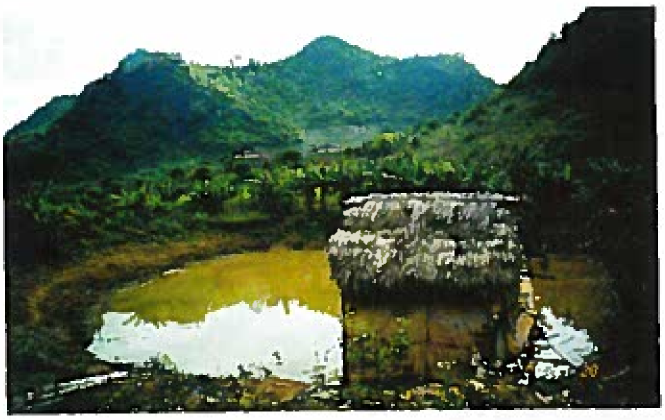
Household un-drainable ponds:

Ponds in upland areas are relatively smaller and shallower. They vary from few square meters to few hundred square meters and hold water depth between one to two meters. Many of them are seasonal while a good number are also perennial. In South-east Asian countries almost each household is provided with a small pond which acts a centre of all the family based farming activities – livestock (cow, buffalo, pig, ducks and chicken), agriculture (mainly rice) and horticulture (fruits, vegetables, etc). Ponds are de-silted one in two to three years and the bottom is allowed to be exposed to sun for few days. The silt thus removed is used for fertilizing homestead garden, vegetable crops and agricultural crop. Ponds are limed and allowed to be filled by rain water. Once stabilized, the ponds are stocked with fingerlings of major carps (both Indian and Chinese) at stocking density of about

8000-10000 fingerlings / ha. Ponds are manured at daily to weekly intervals with manures coming out of pigsty, cattle / poultry shed. At occasions kitchen wastes are also used in the pond, although major part of kitchen wastes are given to pigs and cattle. Portion of harvested surplus and wastes from vegetable garden (especially leaves) are also applied in the pond for feeding the grass carp. Ponds are harvested as and when there is domestic need and also when there is a good market demand. Surplus production is sold fresh or in live condition. Fish yield to the tune of 3 to 4 ton / ha is usually attained in such systems.

Flow-through ponds:

In upland areas small ponds are constructed like step farming fields one below another. Usually these ponds are constructed close to hill stream. The water from the streams are diverted to ponds from where it spills over to underlying ponds in the series. Usually water depth is maintained between one and two meters. These ponds maintain relatively high dissolved oxygen level and thus have potential for higher production. Both organic manure and supplementary feed are applied in these ponds. Depending upon the availability of vegetation in the area density of grass carp is maintained. Relatively higher stocking density is followed with predominance of grass carp. Fishes are harvested as soon as it reaches harvestable size (400g to 1 kg). Multiple harvesting / stocking is practiced to suit the needs of the farming households.



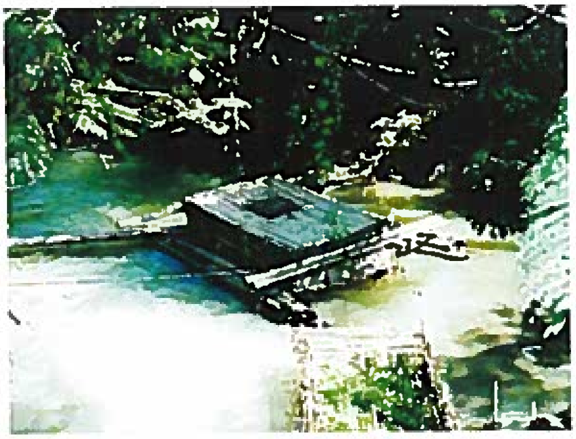
A typical fish pond in upland

House-hold integrated fish culture pond in Vietnam

Terrace fish ponds - Indonesia

Cage culture in rivers and streams:

Upland areas are also characterized by large number of small rivers, rivulets and streams. These are potential sites for intensive fish farming in cages where dissolved oxygen is not a limiting factor for densely stocked fishes. In many developing countries small-scale cage culture is highly prevalent among local ethnic communities. Cages are built using bamboos, logs and other locally available materials. They are kept fixed in flowing rivers. Carps dominated by grass carps of over 100 g (yearlings) are stocked in these cages and fed with locally available feed materials, grasses, boiled cassava and also dough of rice bran and de-oiled cakes. Fingerlings are stocked after the rainy season and allowed to grow till harvestable size. To avoid outbreak of diseases lime is applied and the cages are cleaned intermittently to allow free flow of water. High fish yield to the tune of about 100-200 kg are usually harvested from cage of about 20 cubic meter cages. Incidences of hemorrhagic septicemia are reported during the outbreak of monsoon especially in the grass carp. To prevent such outbreaks stocking is done during post monsoon period. Problems are also encountered when cages are placed too closed or excessive number of cages are put in a limited length of the river / rivulet. Grass carp attains the highest growth rate.



Culture of grass carp in cages - Vietnam

Fish culture in paddy fields

Inundated paddy fields hold good potential for fish culture – both fish for consumption and also for raising fish fingerlings for stocking in ponds and reservoirs. These are usually short duration culture of finfish such as common carp, tilapia and barbs. Depending upon availability of water and depth Indian major carps may also be cultured, especially rohu and mrigals as they feed on detritus and also periphyton that grow on submerged portion of paddy plants. Except for application of pesticides all other package of practices related to paddy are followed. Sometimes refuge in the form of deeper peripheral trenches or central pool is also constructed when long term culture is attempted. As appropriate feed is also applied. Fish yield to the tune of about 1 ton / ha / crop is attained. With stocking density of about 30,00 to 40,000 ha average survival rate of about 75% is obtained.

In some areas dried up but prepared paddy fields are filled with water and stocked with early fry. They are reared for about two to four weeks prior to paddy transplantation. Limited availability and high cost of transport of fingerlings in upland areas makes seed rearing activities highly paying. In the subsequent cropping fish is also integrated with rice.

Culture of high valued plant species – water spinach in streams

Water spinach is considered as delicacy in certain part of high lands. Bamboo made frames are made and criss – crossed with ropes. Cuts of water spinach are planted between twists of ropes and placed in shallow and clear streams. Periodical harvesting is done by cutting the overgrown plants and again allowed to re-grow. Raft culture of high value water spinach is highly paying but needs clear and cool stream water. These type of culture is most suited to highland streams.

Eco-hatchery for highland areas:

The term Eco-hatchery is used extensively for all types of fish hatchery. However, in most of the cases such hatcheries do not fit within the local ecology and environment. Fish seed is one of the limiting factor for the growth of upland aquaculture. It is mainly due to high and difficult terrain for transport. Many villages are still far away from road and hence it is difficult to transport and save the seed being transported. Mini fish hatcheries can be appropriately designed based on available stream in the vicinity. A part of the stream water can be tamed and diverted through net-lined earthen water-holds where fertilized eggs may be kept for hatching. This approach will remove one of the greatest barrier of paucity of seed in far flung areas and will bring rapid growth of aquaculture in upland areas.

1. Summing up

Experiences gained from highland areas in India, northern parts of Vietnam and Lao PDR clearly demonstrate the benefits of small-scale aquaculture in the upland areas, which include:

- Improving farm productivity and water storage,
- Contribution to food supply in fish deficit upland areas and in seasons when wild fish are not available,
- Opportunity for additional source of flexible income,
- Means to diversify out of the wild fishery and rice farming,
- Providing a stabilizing source of aquatic animal protein and substituting a source of income.
- Additional income and food at the disposal of women members of the family.
- Re-greening effect in the area that encourages the local ethnic communities to anchor, thus dissociating themselves from shifting cultivation.

Challenges in Declining of Aquatic Resources

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According to the World Health Report (1998) water supply varies widely in terms of region and country. In India, ground water is being used as raw water for 85% public water supply. Maximum population inhabits in village and slum areas where there is no safe drinking water supply. So they are always prone to their lives or cost a big toll to save themselves from the occurrence of different water-borne diseases. In India diarrheal disease kills 6,000 children's every day apart from millions who are debilitated because of water born diseases which hinder their education and impair their ability to a decent livelihood in the future.

The United Nations Environmental Program (UNEP) stipulates that a country is considered "water-stressed" if its water availability is between 1000 to 1700 cubic meters per person. Per capita average annual availability of fresh water has reduced from 5177 cubic meters in 1951 to 1869 cubic meters in 2001 and predicted fall of up to 1341 cubic meters in 2025. 1.1 billion people in the word are still without access to "improved" drinking water sources, 84% of whom live in rural areas. 4 billion cases of diarrhea occur annually, of which over 3.5 billion are attributable to unsafe water, and inadequate sanitation and hygiene, accounting for 5.7% of the global burden of disease, placing diarrhea as the third highest cause of morbidity and sixth highest cause of mortality. 1.8 million people die every year from diarrhoeal diseases, the vast majority being children under 5 years old. Every day diarrhoeal diseases claim the lives of approximately 5000 children from these preventable causes, accounting for 21% of all their deaths.

Water contamination due to pathogenic agents, chemicals, heavy metals, pesticides, disinfectants and their by-products as a consequence of industrial and agricultural activities, leaching from soil, rocks and atmospheric deposition and other human activities has become a hazard to human health in several regions of the world. The chemicals commonly found in drinking water above the prescribed permissible limits are fluoride, nitrate, arsenic, cadmium, chromium, lead, mercury, manganese and iron producing serious problems to human health. Experience has shown that microbial hazards continue to be the primary concern in the developing and even in some of the developed countries. Lake Ari in the USA has vanished due to pollution. In Minamata Bay of Japan, 10,000 people were poisoned by mercury present in it from the industrial waste.

In India, in urban and peri-urban areas, water quality is critically affected because of intermittent supply systems. Given the poorly maintained water distribution systems, with innumerable leaks and unauthorized connections, ingression of faecally contaminated water occurs, when the pressure drops the situation is serious in the urban, peri-urban and rural areas which is reflected in the high endemicity of faecal and oral infections and other water and sanitation related diseases and periodic epidemics of the same.

Water quality, its impact on human health and the standards for public consumption are issues of vital importance. Both chemical and microbial standards are critically linked to the safety and acceptability of drinking water. Development of standards and their enforcement are linked to a number of social, epidemiological and techno-economic factors. Technical, economic and institutional issues related to the water quality surveillance and management need thorough review and evaluation for the development of a time bound strategy and action plan. Japanese encephalitis (JE) is a leading cause of viral encephalitis in Asia with 30,000- 50,000 clinical cases reported annually. JE distribution is very significantly linked to irrigated rice production combined with pig rearing. Chemical vector control is not a solution, as the breeding sites (irrigated rice fields) are extensive. In some rice production systems faced with water shortages, however, certain water management measures may be applied that reduce vector populations. Acute encephalitis syndrome (AES) is just broad categorization of the disease that kills scores of children each year. JE is almost preventable with proper vaccination. Encephalitis caused by several strains of entero virus is the chief cause of disease and death these days. It can, however, be avoided by ensuring clean drinking water and total sanitation. Everyone in the world depends on nature and ecosystem services to provide the conditions, for a decent, healthy, and secure life. Humans have made unprecedented changes to ecosystems in recent decades to meet growing demands or food, fresh water fiber and energy which has helped to improve the lives to billions, but at the same time they weakened nature's ability to deliver other key services such as purification of air and water, protection from disasters, and the provisions of medicines. Human activities have taken the planet to the edge of a massive wave of species extinctions, further threatening our own well being. The loss of services derived from ecosystem is a significant barrier to the achievement of the Millennium Development Goals to reduce poverty, hunger and disease. The pressures on ecosystems will increase globally in coming decades unless human attitudes and actions change. Measures to conserve natural resources are more likely to succeed if local communities are given ownership of them, share the benefits, and are involved in decisions. Even today's technology and knowledge can reduce considerably the human impact on ecosystems. They are unlikely to be deployed fully, however, until ecosystem services cease to be perceived free and limitless, and their full value is taken into account. Better protection of natural assets will require coordinated efforts across all sections of governments, businesses and international institutions. The productivity of ecosystems depends on policy choices on investments, trade, subsidy, taxation and regulation, among others. The integration of agriculture with land and water management, and with ecosystem conservation is essential for both environmental sustainability and agricultural production. An environmental perspective must guide the evaluation of all development projects, recognizing the role of natural resources in local livelihoods. This recognition must be informed by a comprehensive understanding of the perceptions and opinions of local people about their stakes in the resource base. There is both a need and a scope for regional and global cooperation in sustainable development. Some of the areas of common concern are marine and riparian issues, transboundary environmental impacts and management of bioresources, technology sharing and sharing of sustainable development experiences. Efforts must be made, especially by developing countries, to work towards synergizing experiences and raising shared regional concerns as a strong united front in international forums. "You have to decide whether development means affluence or whether development means peace, prosperity and happiness" (Sunder Lal Bahuguna).

Rice-cum-Fish Farming System : Wise Use of Land for Better Returns

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Introduction :

Rice-cum-fish Culture practices has a long tradition in many of the South and South-East Asian Countries for thousands of years. Its importance diminished after the advent of dwarf varieties of cereals and agricultural practices involving large-scale application of pesticides. Integrating aquaculture with agriculture as an improved production system assures more return from unit available land ran from cultivation of paddy alone. However, the integration is possible in the present context only in low-lying area subject to high rainfall. Traditionally this integrated system is possible in Assam, Manipur, Arunachal Pradesh, (Apatani belt), Tripura, Northern Bihar, Eastern Uttar Pradesh, Andhra Pradesh, Kerala and Western Bengal. In India an area of 2.3 million ha low lying water logged tracts area available where Rice-cum-fish Culture practice can be adopted which is the largest area in the World. Normally, one crop using deep-water fall variety of paddy is cultivated in these areas.

Types of Renovation needed for Paddy plot to integrate fish Culture:

Renovation of Paddy plot can vary according to the land contours and topography:

(1) **Perimeter type:** In this, the paddy growing area may be placed at the middle with moderate elevation and ground sloping on all sides into perimeter trenches (fig 1)

(2) **Central pond type**: Paddy growing area is on the fringe with slopes towards the middle (fig 2) and

(3) **Lateral trench type:** In this, trenches area provided on one side of the moderate sloping paddy field. In some plots two trenches are excavated as the two sides of the plots. Total water area of such renovation is about 1/3rd of the total land area. (fig-3) Deep-water paddy fields are very closely linked with as breeding and bearing spaces for many varieties of fishes and prawns. In case where paddy fields retain water for 3-8 months in a year paddy-cum-fish Culture provides an additional supply of fish crop.

In many Asian Countries like China, Taiwan, Bangladesh, Malaysia as well as India specially the North Eastern part, fish Culture in water logged-paddy fields is popular and generates employment as well as nutritional support for the vast majority of the rural poor. Few areas in West Bengal, Kerala, Arunachal Pradesh and Tripura are used in fish farming and rest offers tremendous scope for paddy-cum-fish Culture venture.

System of Farming: Generally, two types of system are adopted. One is Capture system and other is Culture system.

(1) Capture system: One just captures the wild stock of fish and prawns from paddy fields which gain entry into the system accidentally during the period flood and inundation. Fishes are mostly un-commercial natures such as *Esonus sp. Puntius sp. Chanda sp. Colisa sp.* etc. But some economic Indian major carps as well as air-breathing fishes also get entry into the system. Farmers collect the fishes using traps fixed at the inlets and outlets of the fields. Production from such system is about 300 kg/ha during inundation period of 3-8 months.

(2) Culture system: In this system, paddy fields are systematically stocked with fish seed and nursed in ponds in the paddy fields. Several species of fishes, prawns are used for the purposes which are raised either to table sized or only upto fry / fingerlings stages. Some time paddy fields are also used for breeding Common Carp (Apatani belt of Arunachal Pradesh), *Magur and Anabas sp.* etc.

Criteria for species selection for paddy fields:

- Can thrive well in shallow water (av. depth 15cm)
- Tolerate high temperature (upto $34^{\circ}C \pm 10^{\circ}C$)
- Withstand high turbidity and low oxygen
- Can feed on plankton as well as artificial feed

In culture system, the fishes are either raised in paddy fields as secondary crop after paddy along with the paddy during the period of cultivation.

The important systems are:

(a) Rotational Culture: In this Culture system, fishes are raised in paddy fields by rotation, in reality permits better care both paddy and fish. It allows the use of machinery, insecticides and herbicides for paddy cultivation and also leaves scope for greater water depth for fish production. In brackish water paddy fields of West Bengal and Pokkali paddy field of Kerala are examples of rotational Culture system. Production ranges between 785 to 2135 kg/ha/yr.

(b) Concurrent system or Synchronous system: In this system, fishes are grown concurrently i.e. along with paddy during the period of cultivation. In natural condition, due to shallowness the production potential is low. To overcome this problem, provision of rescue channel in the paddy field has been made where fishes can take rest / shelter during excessive heat and also evade predation. Rescue channels should be minimum one metre wide and 50 cm deep, which should be connected to a basin dug out as the outlet of the paddy fields. The fields are designed as follows.

1. Lateral trench
2. Perimeter trench and
3. Central pond (20×20×1m)

In order to save the fishes during dry season an additional rescue space in the farm of pit of about 10m× 10m ×1.5m in size is constructed one size of the plot, which is also used as feeding ground of the fishes. Locally the pit is called "Khadi" or "Doba". Proportionate allocation of land/ paddy plot under the above-integrated system may be as follows.

i. Total area of the plot-100m×100m
ii. Land under paddy cultivation- 82m×82m
iii. Area under perimeter trench -6m×352m
iv. Area under perimeter dyke base-3m×388m
v. Area under perimeter dyke crest-1m×388m
(Used under horticultural crop)

Perimeter trench:

Top width-6m
Bottom width-3.6m
Depth (max.)-1.2m
Side slopes -1:1m
Total length- 352m
Total volume of water at full depth – 2027-52 cu. m

Perimeter dyke:

Crest width -1m
Base width -3m
Height -1m
Side slopes 1:1

Land suitable for paddy cum fish Culture

- High rain fall area (> 800mm) with poor drainage system
- Uniform contour and high water retentively

Fish suitable for paddy field:

Rohu, Catla, Mrigal and Common Carp as major Carps, Botia different Punti as minor carps and prawn. 25% surface feeder; 30% column feeder and 45% bottom feeders @4000-6000 nos/ha. are stocked. Fingerlings size 3-6 inches and cultured duration is 3-8months.

Culture methodology: Normally composite fish culture is followed. Farmyard manure (FYM) is used along with supplementary feed @ 2-3% of the body weight of the stocked fish.

Paddy suitable for paddy –cum-fish Culture:

- Kharif aus- ARM, OR92, Kalinga
- Aaman- Jaladhi-2, Mahshri, Swarna Mahshri, Sabita (1E 5899) 1R8 and 1R80.
  Ravi- Jaya, Ratna, Pusa etc.

In this system, the fishes have excess to the entire area of paddy field for a period of 5-6 months and to the trenches only for 4-5 months. After the harvesting of paddy, when the paddy plots dry up. The fishes take shelters into the trenches till attain marketable size. Management practices are that of poly culture system.

Fish production ranges from 700-1000 kg/ha/yr.

Effect of fish on paddy:

- Culture of fish benefits paddy production upto 15 % increase reported in China and other Indo-Pacific Countries.
- The introductions of small herbivorous fishes help controlling weeds in paddy plots.
- Fishes also consume harmful organism.

Advantages of Paddy-cum-fish farming:

- Additional returns to the farmers and provide better and use patterns.
- Control mosquitoes, molluscs, mice terrestrial weeds and some harmful insect pests etc.
- Save 50% expenses on harrowing, used fish excreta as manures to paddy.
- Used FYM as source of natural food (plankton) for fish.
- Mono cropping paddy fields turned into multi cropping through integration with fish and horticulture.
- Water of pit and trenches is also used in agriculture field for irrigation.

Threats:

- Prone to predations like birds.
- Disease outbreak due to shallowness.
- Poor Survivality due to high temperature.
- Prone to insecticidal and pesticidal effect.

In spite of tremendous resources available in India organized Paddy-cum-fish Culture system could not achieve its expected status. In zero valley of Arunachal Pradesh community Paddy-cum-fish Culture system is going one year together. In some Govt. owned farms Paddy-cum-fish Culture practice is carried out for demonstration and better utilization of land. In Bangladesh community based Paddy-cum-fish Culture has gained momentum due to its profitability and acceptability to the poor farmers of that Country.

Community Rice-Fish farming in Bangladesh:

In Bangladesh more than 1.46 million ha of low land rice areas are available which provide scope for fish cultivation. Normally, farmers build dikes about two feet high and fish are grown in such rice fields. These small areas are becoming less attractive economically. To overcome the above problems in low and medium land areas, particularly during monsoon season community fish farming technology has been developed in Bangladesh. It is a collective effort of the people living largely in low and medium level land areas undertaking rice-fish cultivation by artificial stocking of fish into the environment. This is important in low-lying areas where heavy floods are more common. Low and medium rice fields are surrounded by strong elevated bunds by roads, so in it fish is not escaped. Proper inlets and outlets are maintained. In such groups besides the land owners landless are also includes who provides labour for different activities like netting and harvesting of fish and share equal status with the farmers.

Fish Diversity of Northeast India - A Glimpse

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Northeast India, criss-crossed with numerous river systems has rich freshwater fish diversity. The diversity is attributed to the past geological history and the Himalayan orogeny which played an important role in the speciation and evolution of groups inhabiting mountain streams (Kottelat, 1989). The evolution of river drainages in this part of the world has been the subject of several studies that utilize geological evidence to reconstruct the palaeodrainage patterns (Vishwanath et al, 2010). The species richness is also attributed to the diversity of habitats and environments existing between the plains of the Brahmaputra at a low altitude (120-200 m) to the upland coldwater regions (1,500-3,500 m) in the hill ranges in Arunachal Pradesh and also in Meghalaya and Assam within a short aerial distance of 200-500 km. Similar levels of richness is also expected in the Barak, Kaladan and the Chindwin drainages.

In the global map of ecoregions presented by Abell et al (2008), based on the distribution and compositions of freshwater fish, Northeast India encompasses six freshwater ecoregions, either in part or in full: the Ganga delta and plain, Ganga Himalayan foothills, Upper Brahmaputra, Middle Brahmaputra, Chin Hills-Arakan Coast and the Sittaung-Irrawaddy ecoregion. Kottelat and Whitten (1996) also estimated the Ganga River drainage to contain 350 and Brahmaputra-Irrawaddy to contain 200 species of fish respectively.

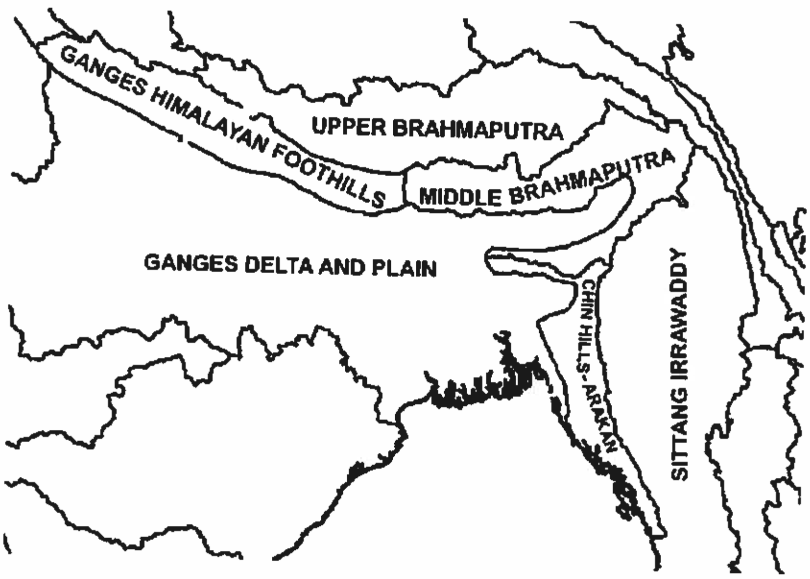

Fig. Freshwater ecoregions of the Eastern Himalaya [redrawn after Abell et al, 2008]

The fish fauna of the region may be subdivided into four drainage-based geographic units: 1. the Brahmaputra drainage, that flows in the Upper and Middle Brahmaputra and partly in the Ganga-Himalayan foothill ecoregions; 2. the Barak-Meghana-Surma drainage that flows in the Ganga delta and Plain ecoregion; 3. the Kaladan drainage that flows in the Chin Hills-Arakan ecoregion, and 4. the Chindwin drainage in the Sittaung-Irrawaddy freshwater ecoregion.

The rivers originating in the Himalaya mountain ranges are glacier fed and comprise the largest river run-off from any single location in the world. The rivers provide drinking water, food, transport, power and jobs for millions of people within the Eastern Himalaya, the Ganga-Brahmaputra alone sustains the highest population density in the world (WATCH, 2010).

Northeast India has about 300 fish species under more than 100 genera and 30 families. While the hill streams support diverse colourful small sized ornamental fishes, the larger streams, rivers and wetland support medium to large sized food fishes. Highly valued warm water fishes include species belonging to the genera, viz., *Chitala, Notopterus, Hilsa, Labeo, Cirrhinus, Rita, Sperata, Hemibagrus, Ompok, Clupisoma, Eutropiichthys, Bagarius, Monopterus, Mastacembelus, Anabas, Pangasius, Heteropneustes, Clarias* and *Channa*. Small to medium sized fishes of medium food value include *Gudusia, Salmophasia, Chela, Osteobrama, Puntius, Lepidocephalichthys, Mystus, Batasio, Ailia, Gagata, Rhinomugil, Sicamugil, Xenentodon, Chanda, Glossogobius* and *Trichogaster*.

Any type of small sized colourful species or those with interesting shapes and behaviour find their place in the ornamental fish trade. Nemacheilines, cobitids, psilorhynchids, sisorid catfishes, badids, danionins are good candidates of aquarium fishes.

Fig. Subsistence fishery : catch of snow trout from the Tista in Sikkim in a roadside vendor

Coldwater fish resources of the region include species of different genera, viz., *Tor, Neolissochilus, Schizothorax, Labeo, Cirrhinus, Semiplotus, Poropuntius, Barilius, Raiamas, Danio, Garra, Pteroryptis*. Most of these fishes inhabit uplands above 1,500 m. However, water temperature plays important role in their distribution.

In spite of the rich resources, the demand of food fish in the region is not fully met. Fishes are purchased from the neighbouring states to meet the demand. The reasons for the low production of fishes from the region may be due to the following facts: 1. most of the culture fishery in the region is based on Indian major carps and exotic carps. The data on the biology, particularly of feeding and breeding of the locally available promising candidate species are not available; 2. most of the capture fishery, particularly those of the uplands are still in the state of subsistence fishery. Thus most of the catches are consumed locally and never reach the main markets; 3. fishery resources of many water bodies have not been fully explored. It has been inferred from Abell et al's (2008) map that Chin Hills-Arakan ecoregion supports more than 200 fish species. However, the present data shows a fauna less than 50 species. Recently concluded IUCN freshwater fish assessment and evaluation for red listing (Vishwanath et al, 2010) shows more than 27% of about 500 fishes of the Eastern Himalaya to be data deficient which is because of the unavailability of the biology, population trend, threat status and taxonomic problems.

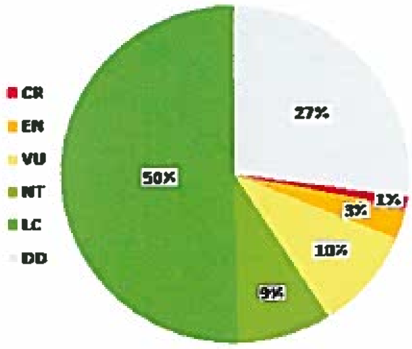

Fig. Threat criteria of fishes of Eastern Himalaya © IUCN

Most diverse fish fauna is exhibited in the Brahmaputra drainage in the Arunachal Pradesh, Meghalaya, northern Bengal and parts of Assam and the Himalayan foothills between Bihar and Nepal (Vishwanath et al, 2010). Accordingly, the endemic fish richness is also found maximum in the region. However, the most threatened fishes are in the Barak of Assam and Manipur and the Chindwin basin in Manipur.

The major threats on the freshwater habitats now are the five interactive categories, viz, overexploitation, water pollution, flow modification, habitat loss and exotic species invasion (Dudgeon et al, 2006). Central electricity authority and Ministry of Power's target of 50,000 MW power on the hydro-electric resources of the northeast based on flow modifications of the major rivers of the region are also of great concerns. In addition, the growing present threat on climate change have adversely affected the survival and distribution of coldwater fishery resources, which have not been properly exploited and on whose fishery, the alternative to warm water fishery lies.

The largest basin in the eastern Himalaya, the Ganga has fewer endemic fish while the Brahmaputra has a number of endemic fishes. All the species of *Aborichthys, Parachiloglanis, Pareuchiloglanis, Oreoglanis* are confined to the drainage. Many species of catfishes of the family Amblycipitidae, Sisoridae, Badidae are endemic in the region. Many genera of fishes, though widely distributed in the northeast are syntopic to a particular area and are not likely to be found anywhere else. Many species of the Kaladan are also endemic to the river drainage, since it is neither connected to the Chindwin, the Brahmaputra nor the Meghana drainages.

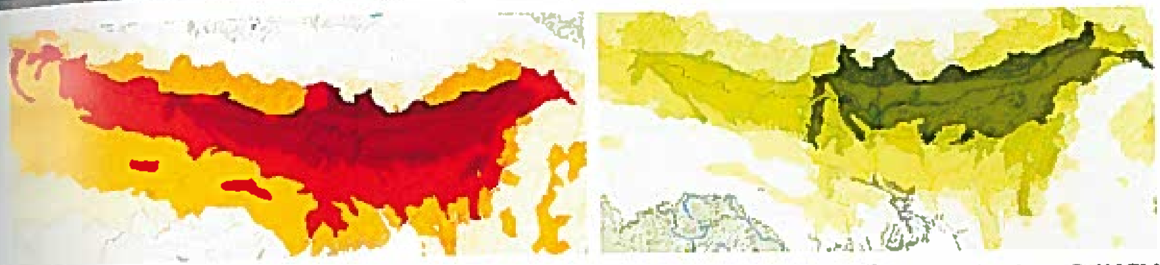

Fig. Overall fish species richness (L) and endemic fish species richness in the eastern Himalaya © IUCN

Anthropogenic pressures have caused 70 species of fishes threatened and 46, near threatened in the Eastern Himalaya. Fifty species are declared vulnerable while 15 are endangered. *Clarias magur*, the magur and *Tor putitora*, the golder mahseer are among the endangered.

In the midst of the manifold problems of food demand, environment protection, species conservation, threats, development activities, need of power generation for development activities, there are great challenges ahead to conserve the species and sustainably utilize these for human requirement. Intensive research on the biology of endemic food, sport and ornamental fishes are required in view of their captive breeding and culture. Programmes to reduce the rate of forest loss and degradation and promote forest restoration in the river catchments are necessary. Water quality need to be greatly improved across the entire northeast. Impact of dams on the migratory and commercially important valuable fish species and environmental flow requirements of the species should be considered. Restoration of natural flow regimes should be adopted by dam and river management authorities and technologies to mitigate the impact of barrages to migratory species. Local communities should be encouraged to participate in the conservation of fishes and their habitats including awareness programmes on the status and importance of fish.

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Coldwater Fisheries Development in India with Special Reference to North East India

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Introduction

Coldwater fishes occupy an important place amongst the freshwater fishes and its resources spread over the Himalayan and peninsular regions of India. Their importance is even far greater in Himalayan uplands where coldwater fish species have established themselves as an important candidate for sport and food. The country has significant aquatic resources in terms of upland rivers, streams, high and low altitude natural lakes, reservoirs both in the Himalayan and Western Ghats, which holds large population of both indigenous and exotic, cultivable and non cultivable fish species. The coldwater Streams and Rivers cover an area of 10,000 km, Natural lakes 20,500ha, Reservoir 50,000ha and Brackishwater lakes 2,500ha.

The coldwater fish fauna range from eurythermal to stenothermal regimes due to differences in microclimatic conditions and habitat variations in aquatic biotopes and their thermal regimes. The fish species continuously inhabiting the different aquatic zones adopts different morphological characters to withstand the fast flowing water currents. The distribution character of hill stream fishes is primarily dependent on water flow, substratum characters, temperature profile, water quality and the availability of natural food. The fish has also, as a taxonomic group, generated unlimited curiosity of naturalist and zoogeographer from the period as early as that of the great Aristotle. Of the 22,000 fish species, over 40% live in fresh water and majority of them live in tropics between latitudes of $23^{0}5'$ N and $23^{0}5'$ S. The coldwater fisheries harbour 258 species belonging to 21 families and 76 genera. Of that 203 species are found in Himalayas and 91 species are found in Deccan plateau.

Aquatic Resources and Fish Diversity in Jammu & Kashmir

Lakes

The largest floodplain lakes in the Kashmir Valley are Wular, Dal and Manasbal, all situated at 34^{o}N latitude. Rains are frequent during winter and spring, in late December-February. The precipitation in winter is mainly in the form of snow. These lakes are shallow, with the mean depth for all three ranging from 0.6 to 3.0 m, and the maximum from 5.8 to 13 m. Kashmir Valley lakes have water with alkaline character (pH 7.4-9.6), the high pH values in summer being the result of an intensive photosynthetic activity from rich phytoplankton. The vertical gradient of dissolved oxygen concentrations differs from lake to lake. In Lake Wular, which is mixed throughout the year, oxygen concentrations do not vary much from the surface to the bottom. Lake Manasbal and the Nagin basin of Lake Dal have a clinograde type of oxygen profile, i.e. with the depth the dissolved oxygen concentration decreases. The lower water layers of the two lakes get oxygen depletion during the summer period, which indicates that the lakes are eutrophic. This is further confirmed by high concentrations of phosphorus in summer. Further evidence of high inputs of nutrients in these lakes comes from the extensive cover of aquatic macrophytes. Macrophytes occupy nearly 80% of Lake Dal, with the dominance of *Myriophyllum*, *Ceratophyllum*, *Potamogeton*, *Hydrilla*, *Nymphoides* and *Salvinia*.

In Kashmir, wetlands called *sars* cover more than 4000 ha and serve as a natural refuge for a wide variety of organisms. The wetlands are situated on floodplains of the River Jhelum. While some wetlands, such as Haigam and Hokarsar, are maintained by the State Government as bird sanctuaries, as they provide excellent habitats for waterfowl, wild duck and geese migrating from China, Russia and other distant regions during winter, wetlands are also important habitats for fish.

Glacial Lakes

Twelve high-altitude lakes are located in Kashmir at a distance of 60 to 130 km from Srinagar. The 12 lakes are located from 3200 m to 3819 m in altitude, and they range from 1 ha to 157 ha in size. Some lakes reach a maximum depth of 80 m. The high mountain lakes have rocky watersheds, with little or no plant cover. Summer rains are scarce and the water in the lakes comes mainly from snowmelt from glaciers on the surrounding mountains. The lakes are covered with ice for six to nine months. Water transparency in the glacial lakes is determined by the concentration of suspended sediments, which are mainly glacial silt, and by plankton in summer months. Summer surface water temperature reaches 15°C, but the average summer water temperature does not exceed 13°C. Most lakes develop summer stratification, with a temperature difference of 8-9°C between epilimnion and hypolimnion. High values of dissolved oxygen, pH of 6.7-7.4, low concentrations of nitrogen and phosphorus, and conductivity of 15 to 130 µmhos are some other abiotic characteristics, which suggest that most of these lakes are oligotrophic.

Upland Rivers and Streams

The River Jhelum, which arises from lake Wular in India, is the major river of J & K. It receives three major tributaries, *viz*. Neelum, Poonch and Kunhar, the last river having only a negligible stretch in Pakistan before joining the River Jhelum.

The River Neelum (formerly known as Kishanganga) is the largest tributary of the Jhelum and receives a large number of tributaries itself. In summer, most of the inflowing streams are turbid and in flood. The Neelum water temperature ranges from 0 to 12°C. The river and some of its tributaries have been stocked with rainbow and brown trout. However, the indigenous snow trouts dominate the fish stocks. After about 245 km in J& K the Neelum confluences with the Jhelum at Muzaffarabad. Downstream of Muzaffarabad, the water temperature in the Jhelum increases, ranging between 8 to 30°C, until it reaches Mangla Reservoir. The stretch between Muzaffarabad and Mangla already harbours warmwater fish such as Indo-Gangetic major carps, but also mahseer (*Tor* spp), a popular game fish.

The rise in temperature in Kashmir streams from near-freezing level to 10-17°C during May-June induces *S. richardsonii*, *S. longipinnis* and *S. curvifrons* to spawn. In the Sutlej River, *S.*

richardsonii starts upstream migration with the rise in water temperature during March. During the upstream migration the fish still finds itself in waters of low temperature of 8.0-9.5°C, owing to the steady influx of snow-melt water. This induces the species to migrate to and spawn in side streams, which receive warm ground water of 17.5-21.5°C. In the Ravi River system the fish spawn in May. In the upper Beas, however, the fish spawn only in July-August when the stream water temperature warms up to 16.5-18.5°C. In the same drainage *S. richardsonii* migrates downstream to the lowermost reaches where it spawns from October to December at 19.0 to 22.5°C.

The fast-swimming species of mahseer, trout and schizothoracines expend much energy in maintaining an upright position in the turbulent and fast current. The frequent occurrence of spates has proved deleterious to breeding and propagation of coldwater fish. The scanty population as indicated by the low density of fish in the upper reaches of the Sutlej and Chenab rivers may result from the passage of these rivers through deep and narrow gorges, and the presence of cold glacier- and snowmelt water.

Fish Diversity

The important fish species, which exist today in the waters of J&K, are:

Cyprinus carpio communis (Punjabi Gad), *Cyprinus carpio specularis* (Punjabi Gad), *Carassius carassius* (Ganga), *Schizothorax esocinus* (Chhiroo), *Schizothorax planifrons* (Chaush Gad), *Schizothorax curvifrons* (Sattaar Gad), *Schizothorax oppogan*, *Schizothorax longipinnis*, *Schizothorax punctatus*, *Labeo dero* (Roput Gad), *Labeo dvocheilus*, *Crossocheilus latius*, *Pantius conchonius*, *Botai birdi*, *Nemacheilus kashmerensis*, *N.marmoratus*.

Most fishing is done by cast nets. Other fishing methods use long-lines, scoop nets and traps, which account for 5-7% of the total fishing gear. Fish production from floodplain lakes is not well documented. Available data show that prior to the introduction of common carp the fish yield was low. With its introduction in Kashmir, yields have increased spectacularly.

Of the twelve lakes, six contain fish. Four lakes (Gangabal, Nundkol, Kishansar and Vishansar) contain the exotic brown trout. Lakes Gadsar and Zumsar have an endemic *schizothoracine Diptychus maculatus*. This fish is also present in the inflowing streams. It is fished for subsistence by herdsmen during summer. Brown trout is allowed to be fished with fly, but only by licensed anglers.

Angling in Kashmir

Kashmir has been rightly called angler's paradise, with a network of glaciated streams, rivers as well as high altitude lakes, all carrying the bounty of trout, both brown and rainbow. The British introduced the trout to the streams of the valley in the 20th century and the varieties succeeded in establishing in the torrential mountain streams flowing down from the ranges of Pir Panjal and outer Himalayas. By 1920, the trout had successfully established in the waters of the Brinji, Lidder, Sindh, Nambal, Madhumati, Eric etc. The Lidder and Sindh streams proved best for the trout. Many beats are within a two-hour drive from Srinagar. The more adventurous can fish at one of the many high altitude lakes that are reached by trek. One requires a permit to be issued by the Department of

Fisheries; conditions also apply regarding use of bait, period of fishing etc. Only fly fishing and fly rods are permitted. Spinning rod/reel and live bait are not permitted.

Aquatic Resources and Fish Diversity in Himachal Pradesh

Coldwater Reservoirs

From the fishery point of view, Gobindsagar (elevation 560 m) and Pong (elevation 436 m) are the two most important reservoirs of the Himalayan foothills in Himachal Pradesh. These reservoirs are the leading sources of fish supply among the Himalayan States. Fish landings from Gobindsagar account more than 60% of the total fish production in Himachal Pradesh. Due to directly receiving cool water from the Himalayas, both reservoirs, in spite of being situated at a relatively low altitude, contain stocks of coldwater fish.

Gobindsagar Reservoir

This reservoir was created in 1963 as a result of the impoundment of the Sutlej river at Bhakra. The Sutlej receives cool, snow-melt water during the spring and summer months and water from monsoon precipitation in its lower catchment during July-September. Downstream of the reservoir, the Sutlej joins the Beas River and enters Pakistan. Blending of the cool Beas water and the warmer Sutlej water in the reservoir has led to a unique pattern in the thermal and oxygen regime and in dissolved chemical components, and this in turn has had an impact on the life and production cycle of aquatic organisms. At full storage level, the reservoir has a surface area of 15,867 ha, while at the minimum dead storage the level is 5063 ha. The reservoir is 168 km long, and 6 km wide near the dam.

Pong, Pandoh and Chandertal Reservoirs

Pong reservoir on the Beas river in Himachal Pradesh covers an area of 24,529 ha. The Beas and its tributaries are snowmelt or glacier fed. The reservoir is 42 km long and 19 km wide in its widest part; its mean depth is 35.7 m. While the surface water temperature varies between 22.2 and 25.1°C, the incoming river water has a temperature range of 6 to 26°C.

Pong is a shallow reservoir with a lower organic production than Gobindsagar and the fish fauna was originally dominated by catfishes, minor carps and a few coarse fish. On account of systematic stocking of common carp and Indian major carps, the catch structure of the reservoir was completely altered and carps eventually accounted for significant percentage of the total landings. Pong has the reputation for an excellent quality of fish. Pong fish get the highest per unit price. Pong is also a favorite place for anglers, who fish out about 60-70 t of golden mahseer annually.

Pandoh Reservoir (altitude 987 m, 200 ha) forms part of the Beas-Sutlej Link Project, diverting the Beas water into the Sutlej basin. The reservoir is used for occasional recreational/sport fishing. Brown trout, snow trout *Schizothorax richardsonii*, *Labeo dero*, *L. dyocheilus*, *Tor putitora* and some other hill-stream fish are present in its waters. Lake Chandertal (4270 m altitude), located in Lahul Spiti district of Himachal Pradesh, has been stocked with brown trout by the Himachal Pradesh Fisheries Department.

Coldwater Fish Diversity

The upper reaches of the Sutlej river used to have 30 species of fish, of which *Tor putitora*, *Labeo dero*, *L. dyocheilus*, *Schizothorax* and *Aorichthys seenghala* are the dominant species. It is reported to have 51 species, subspecies and varieties of fish present in Gobindsagar. The emergence of silver carp in the reservoir in 1979 marked the beginning of a radical change in the catch structure, with this fish establishing an overriding dominance over all other species, percentage-wise. The other commercially important fish are: *Catla catla*, *Tor putitora*, *Labeo rohita*, *Cirrhinus mrigala*, *Labeo calbasu*, *Aorichthys seenghala* and *Schizothorax plagiostomus*. Minor carps are represented mainly by *Labeo dero*, *L. dyocheilus*, *Cirrhinus reba* and *Puntius sarana*. From 1974 onwards there has been a moderate increase in the quantity of captured mahseer but its percentage declined with the increasing total annual fish catch.

Aquatic Resources and Fish Diversity in Uttarakhand

Aquatic Resources

Lakes Nainital, Bhimtal, Naukuchiatal, Khurpatal and Sattal are situated at an altitude from 1220 to 1937 m, and all are at latitude 29°N, within a short distance of each other, and within a 25 km radius of the town Nainital. All lakes are small, with the largest one, Bhimtal, covering 72 ha. Lake Naukuchiatal is the deepest, with a maximum of 40.8 m.

Major glaciers in the state are: Gangotri, Yanunotri, Pinderi, Kafni,Sunderdhunga, Nakuri, Milan, Baldhunga, Poling, Balati etc. The river system of Uttarakhand has a total length of 2,686Km. (Ganga,yamuna, Bhagirithi, Alaknanda, Kosi, Ramganga, Saryu, Gomti and Kali etc). Natural lake has total area of 300 ha. (Nainital, Bhimtal, sattal, Naukuchiatal, Khurpatal, Shyamtal, Deoriatal, Hemkund, Roopkund, Kagbhushandital, Kedartal, Sahastratal etc) and reservoir has total area of 20075 ha. (Nanaksagar, Tumaria, Baigul, Dhaura, Haripura, Tehri, Dhauliganga and Kalagarh etc).

The water of Kumaon lakes is mostly slightly alkaline. The water stratifies in spring and mixes during winter. Mahseers (*Tor tor* and *T. putitora*) dominated the catches in Bhimtal and Naukuchiatal, with 59.5 and 45.0% respectively of the total for the five-year period. Common carp followed, with 34.8 and 31.5% respectively, while in Sattal it formed 22.9% of the total catch. Indian major carps (*Labeo rohita*, *Cirrhinus mrigala* and *Catla catla)*, dominated the catches in Sattal with 64.1% of the total. Schizothoracines (e.g. *Schizothorax richardsonii*) represented 0.73 and 0.95% in lakes Bhimtal and Naukuchiatal, but were absent in Sattal. Silver and grass carps, introduced in Bhimtal in 1985-86, appeared in catches from that year onwards. The low yield for these lakes seems to result from the lower fishing intensity. As a remedy it has been proposed to regularly stock this lake with fingerlings of mahseer, common carp. Stocking the Kumaon lakes is considered essential for increasing fish yields. In the state of Uttar Pradesh trout transplants of eyed-eggs were successfully hatched in the Garhwal region at Talwari and Kaldhyani hatcheries and produced stocking material for the Pindar, Birehi.

Fish Diversity

There are 83 species belonging to 39 genera, 12 families and 3 orders have been reported from the state. Out of which, 40 species have food value, 8 species have ornamental value and 5 species have sport value. Further, fishes of the state are categorized as native -*Tor putitora, Tor tor, Labeo dyocheilus, Labeo dero, Garra gotyla gotyla, Schizothorax richardsonii, M. assamensis (Coldwater prawn)* etc, transplanted- *Catla catla, Labeo rohita, cirrhinus mrigala* etc and exotic- Silver Carp (*Hypopthelmychthyes molitrix*), Grass carp (*Ctenopharyngodon idella*) and Common Carp (*Cyprinus carpio, Communis* and *specularis*) and Rainbow trout (*Oncorhynchus mykiss*) etc. Species being used for culture in the state are- *Hypopthelmychthyes molitrix, Ctenopharyngodon idella, Cyprinus carpio, Oncorhynchus mykiss, Catla catla, Labeo rohita, cirrhinus mrigala* etc. along with *Tor putitora, Tor tor, Labeo dyocheilus, Schizothorax richardsonii* etc.

Aquatic Resources and Fish Diversity in Sikkim

Sikkim, the small but beautiful kingdom is situated in the Eastern Himalaya. Sikkim is termed as the Switzerland of the East, a heavenly paradise on earth. It covers an area of 2818 square miles 7325 square kilometers. Geographically it is 28 degree 07' 48" degree and 27 degree 04' 46" North latitude, and 88 degree 00' 58' and 88 degree 55' 25" East longitude.

The state has vast water resources in the form of lakes, snow-fed rivers and streams, some with marshy area. Sikkim has two major rivers, Teesta and Rangeet, with a total length of 900 km. These rivers originate from the glaciers of North and West Sikkim. Along with myriads of tributaries, the rivers harbour a diverse and rich fish fauna. The most important of these are the Snow Trout (*Schizothorax sp.*), Mahseer (*Tor putitora*). Cat fishes (*Glyptothorax spp., Bagarius sp., Pseudechencies sp.*) and a number of Cyprinids e.g. *Garra spp., Barilius spp.* etc. The total annual fish yield contributed by Sikkim's riverine fisheries is of the order of 150 t. About 1500-2000 villagers living close to the river banks are engaged in part-time fishing. The cold-water species are highly esteemed by the local inhabitants. They fetch a good price. This shows that Sikkim's fishery wealth serves as a source of additional income to the poor villagers.

Glaciers

Glaciers are moving mountains of ice. There are many of these in Sikkim among which the most important ones are Zemu glacier, Rathong glacier and the Lonak Glacier in North Sikkim. The Zemu glacier is the largest and the most famous glacier of the Eastern Himalaya. It is 26 km in length and is situated in a large U-shaped valley at the base of the Khangchendzonga massif in Northwestern Sikkim. The Teesta river rises from the snout of this glacier. Many tributary glaciers feed the trunk glacier. The side valley, which these glaciers lie open into the main Zemu valley from different directions. Icefalls and waterfalls have formed at the junction of the tributary glaciers with the Zemu glacier.

Lakes

Sikkim does have lakes though not very large in size on such a rugged terrain. These lakes are both spring fed as well as river fed. On the highway between Gangtok and Nathu La, 34 kms. from

Gangtok lies the serene Tsomgo(Changu) lake at an altitude of about 12,000 feet. Khecheopalri lake is another well known lake that lies on a bifurcation of the route between Gyalshing and Yuksom. Menmecho lake, Green lake and Samiti lake are some other beautiful lakes.

Tsomgo (Changu) Lake

Tsomgo literally means "source of the lake" in Bhutia language. 'TSO' means lake and 'MGO' means head. About 40 kms away from Gangtok, this serene and holy lake is situated at an altitude of 12,000 ft on the Gangtok - Nathu La highway. It is about 1 km. long, oval in shape, 15 meters deep. The lake remains frozen during the winter months up to mid-May.

Menmecho Lake

The lake lies between the mountains below the Jelep La Pass and is the source of river Rangpo-chu. It derives its water from melting snows around. The lake is famous for its Trout. Men Me Chu lake at an altitude of over 13 thousand feet, in East Sikkim near Indo-China border has been identified as the main breeding centre for exotic brown trout. The brooders collected from the lake and the streams are stripped artificially and reared in a regulated condition till it reaches the size of fingerling to be released in the lakes and streams.

Khecheopalri Lake

Khecheopalri lake is considered as one of the sacred lakes of this state both by the Buddhist and the Hindus. The lake remains hidden in the rich forest cover. It is believed that the birds do not permit even a single leaf to float on the lake surface. There is a motor able road from Pemayangtse right up to the lake area.

Karthok Lake

Kathok and Khecheopalri are two important lakes of this area. Khecheopalri, known as the "Wishing Lake", is one of Sikkim's most sacred lakes.

Samiti Lake

The lake Samiti- A glacial lake in the Onglathang valley is situated near Gochala Pass.

Tso Lhamu Lake

Tso Lhamu is a lake which lies on the plateau that juts into Sikkim into Tibet. From this moderately sized lake, the Teesta river takes birth as a trickle hardly a foot wide. The water in the lake flirts with ice before getting frozen in winter. A flock of birds, the cranes swim on the placid ice water of Chola Mu.

Lakshmi Pokhari

It is a big natural lake cupped in deep crater. The rim of the crater is so hard above the lake level that it is easy t o photograph the complete lake without using a wide angle lens.

Rivers

Flowing almost right across the length of Sikkim is the river Teesta. Teesta originates from the Cholamu la ke where it is hardly a stream. Meeting Teesta at the border between Sikkim and West Bengal is its major tributary the river Rangeet which originates from the Rathong Glacier.

During monsoons the otherwise innocuous looking rivers of Sikkim become swollen, swift, muddy and dangerous. The rivers are narrow, serpentine and full of rocks and hence are not navigable. Because of swift currents hitting rocks, the rivers are very noisy and can be heard for miles together. The Teesta finally joins the Bhramaputra in Bangladesh. The rivers are fed by snow melting on the mountains as well as rain that accumulate in the catchment areas during the monsoons.

Mahseer Fishery

The lower belt of the Teesta and toe Rangeet river harbour one of the most popular game fish, Mahseer (*Tor putitora*). But it is very unfortunate to note that this precious game fish population has already dwindled and the species is under the threat of becoming rare. Fishery has, however, now hopes of recovery with the construction of an experimental Mahseer breeding farm at Bagua by diversion of the course of river Rangeet in South Sikkim at an elevation of 300 msl. The hatchery project has been established in collaboration with DCFR, Bhimtal. The farm is for rearing of salvaged Mahseer fry, which will be stocked in the lower belt of the state in order to save this fish from getting extinct.

Trout Fishery

Since the majority of the rivers and streams of Sikkim originate from glaciers and are snow fed, about two third of the river length along with a number of high altitude lakes fall above 6000 msl and are virgin due to the absence of indigenous fish fauna. The fisheries department in collaboration with DCFR, Bhimtal has already established a Brown trout (*Salmo fario*) hatchery at Menmoitso at an elevation of 12000 msl. in East Sikkim. The hatchery is operational since 1979 and is producing 2 to 3 lakhs of trout fry every year. Trout is the only cold-water species that can thrive well in these waters. The seeds produced at the hatchery are transported and stocked in all the high altitude lakes and streams so as to enrich the waters of the State with this exotic game fish for popularizing sport fishery.

Angling

Sikkim with its massive bio-diversity is a paradise for adventure and nature lover. With the vast river system, Sikkim is an anglers delight. For an ardent angler - Mahseer, Carp & Trout provide fond angling opportunities. The River Teesta & Rangit provide ample scope for Mahseer and Carp. 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 opportunity for trout angling by fly fishing or spinning. Ideal month for angling are March to May and August to October.

Aquatic Resources and Fish Diversity in Arunachal Pradesh

Arunachal Pradesh, the land of 'Dawn Lit Mountain' (26° 28′ to 29° 30′ North latitude and 90°

30′ to 97° 30′ East longitude) covering an area of 83,743 km2 situated in the extreme North Eastern part of India has huge potential with its enormous lotic and lentic water bodies. The state drained with network of many rivers and numbers of mountain lakes like PT Tso lake, Mechuka lake, Mehao lake and Ganga lake have formed potential resources for mountain fishery based eco-tourism. All these network of rivers are habituated by unique sport fishes like Mahseer, Indian trout, snow trout and carps. The lakes are enriched with introduced exotic trouts like brown and rainbow trouts. The diverse ecological habitats formed due to variations of climate and altitude with massive mountain picturesque along with natural biological diversity and cultural diversity of various mountain tribes make it one of the few states in India endowed with an array of tourism resources.

High Altitudinal Lake

The Tawang district of Arunachal Pradesh has got 12 numbers of lakes. The upper Siang district with 11 lakes placed in second. Besides, some other lakes have been reported from scattered region, like Mehao lake (10.6 ha area and 1640 msl altitude) and Sally lake (2.5 ha area and 435 msl altitude) in Lower Dibang Valley District (Laskar and Pujen, 2004 and 2005), Lake Mechuka in West Siang and Lake Geker Sinyi (Ganga Lake) in Papumpare district. Few lakes are located near the roadside and the many are located at some trekking distance. This types of lakes will give a multidimensional importance as angling, scenic beauty, hill trekking etc. Boating and angling are among the plays' preferred by almost every tourists in a lake. For angling the fish resources have to be developed in the subjected lake. The suitable sport fishes are to be enriched in these lakes.

River and Reservoir

Most of the rivers coming down from hills and mountains, criss-cross the region and have a combined length of approx 2000 km. Major perennial rivers of Arunachal Pradesh are the Kameng, Subansiri, Dikrong, Kamla (Ranganadi), Siang, Siyom and their tributaries.

A reservoir covering an area of 10-15 ha approximately has been constructed as a dam over the river Kamla (Ranganadi) of lower Subansiri district of Arunachal Pradesh. The reservoir mentioned above has recently been handed over to the state fishery department for initiating commercial fishery activities.

There are many big tanks available in all the nine districts of Arunachal Pradesh. These tanks are basically reservoir tanks of mini-micro hydel project for generating electricity. The places are China Bridge, Keratang, Assam Hills, Lower Gompa of Tawang district, Rupa of West Kameng district, Tirbin of West Siang district and Mai and Tago of Lower Subansiri district.

Fish Diversity

Fish fauna of lower stretch of river Siang is comprised of 36 species belonging to 12 families. Ichthyofauna shows great affinities with fishes of Himalaya (*Tor* spp., *Schizothorax richardsonii* etc.), Assam (*Aorichthys aor, A. seengala, Mystus cavasius*) and other North-Eastern states (*Nemacheilus manipurensis, N. kangjupkhulensis, N. goroesis, N. kempi* etc.). Family Cyprinidae is largest, represented by 14 species while each of the families like Anguillidae, Synbranchidae, Belonidae, Psilorhynchidae and Clariidae, each represented by single species.*Labeo pangusia, L. gonius, Acrossocheilus hexagonolepis, Schizothorax richardsonii, Wallago attu, Aorichthys, seengala, Mystus cavasius* are abundant species of lower stretch of Siang. They inhabit mainstream while other species like *Barilius* spp., *Nemacheilus* spp. *Puntius* spp. and *Glyptothorax* spp. prefer to inhabit tributaries.

A total of 21 species were recorded from the Rana Ghat, proposed dam site in Siang river and near Along in Siyom river. *Chagunius chagunio, Labeo pangusia, L. gonius, Acrossocheilus hexagonolepis, Puntius ticto, P. sarana, Monopterus chuchia, Xenetodon cancila, Psilorhynchus balitora* were most common in lower stretch. *Chagunius Chagunio* accounted for 24% of total catch, followed by *Labeo pangusia*(13%), *Acrossocheilus hexagonolepis* (8%) and *L. gonius* (6%). In the upper ends of project areas, *Schizothorax richardsonii, Labeo gonius, Garra naganensis, G. tirapensis, Barilius shacra, B. tileo, Glyptosternum annandeli* accounted the major fish catch. *Schizothorax richardsonii* and *Labeo gonius* were predominant species of this zone accounting for 27% and 24%, respectively of total fish catch. The species like *Barilius shacra* and *B. tilieo* inhabited the tributaries.

Fishing and Angling in Arunachal Pradesh

Angling and fishing in Arunachal Pradesh offers lots of opportunities for angling and fishing lovers. The abundance of water and the simplicity of the sport has helped the sport to grow in Arunachal Pradesh. Arunachal Pradesh offers numerous possibilities to catch fish especially trout and Mahseer.

Arunachal Pradesh, Pasighat has a lot of places like Yingkiong, Bodak, Siom, etc., that provide good spots for Fishing and angling. The Mahseer being a favourite among anglers, getting a 20-30 kg over here is not uncommon. The colder water of the higher reaches of Arunachal have the golden and the rainbow trout and anglers can easily enjoy the traditional but effective methods of fishing while trekking in the jungles of Arunachal. The state is bisected by the Lohit river and a number of smaller streams, all of which offer plenty of opportunity for reeling in some of the biggest fish catch. Trout fishing is possible at many locations, Bhalukpong and Tipi on the river Kameng, Pasighat on the river Siang, and Tezu on the river Lohit.

Aquatic Resources and Fish Diversity in Manipur

Fish is the main food item of the majority of the people in the state of manipur. The largest source of fish is the Loktak Lake. About 15,000 ha of water areas have been brought under fish culture operation It is welknown that both the Brahmaputra and Chindwin systems of rivers drain Manipur and its fauna included both Assamese and Burmese elements.

The district of Ukhrul is a land of beautiful mountains interspersed by numerous tribal habitats echoing with rhythms of tribal culture and rich wild life. It lies between 94.0' and 94.45' East longitudes. The district is located at an elevation range between 388 and 2,740 meters msl. The district has got enormous potential of coldwater fish culture in terms of natural resources and aquaculture practices.

Upland Rivers

Maklang and Tuyeng are two important rivers for Kasom Khullen and Kamjong sub- division.

The Thoubal river starts from the district and run through the Ukhrul North and Ukhrul central sub-divisions. It is the longest and biggest river in the district. Chammu and Chingai rivers are running through Ukhrul North sub-division. These rivers are not useful for transportation as the current of the rivers are very strong and wild during the rainy season and very thin during winter. They are useful for fishing and irrigation.

Coldwater Fish Diversity

Many fishes were recorded new to India from the state. They are-*Mystus microphthalmus Garra gravelyi, G. kempi, Neolissocheilus stracheyi, Exostoma stuartii, Salmostoma sladoni, Chagunius nicholsi, Homaloptera rupecula, H. modesta, Mystus pulcher.*

Emerging issues for Fisheries Development in Special Reference to North- Eastern Region

Sustainable Development for Socio Economic Development

The socio economic condition and vast resources of the North East region present a solid case for diversion of work force to more productive sector for transferring the structure of economy and putting in one fast track towards development. Herein comes the pivotal role that fisheries can play the socio economic development of the region. A huge potential for development of fishery still remain untapped in the region. Though almost entire region are fish eaters there is a high demand of fish and there exit 45.8% between the demand and supply of fish in the North East region. Therefore, the development of fishery resources of the region assumes per amount significant for development of the region.

- **Conservation prospective:** The region harbours rich fish biodiversity several fish species and it is a well recognized fact that there has been a drastic reduction in abundance of the fresh water region due to various natural and anthropogenic factors (shrinkage wanton destruction of the habitat and ingestion of the human population etc). Therefore. The North East needs a strategy for sustainable utilization of the existing resources as well as development and enhancement of potential untapped fishery resources.
- **Approach for integration of conservation and development.**

  It is clear that NE region requires both developments of fisheries as well as the conservation of fish germplasm resources. Both have to go hand in hand. The issue assumes great significance when we consider the fact that due to hilly terrain, the topography of the region does not support fish culture in the way it is possible in plains. Hence, the pressure will be on natural fishery resources. Therefore, strategies need to be devised to initiate programmes with the inbuilt concept of integrating conservation and development of fisheries. Any such programme has to take into consideration following aspects:

  - ✓ Development of entrepreneurship, particularly among educated unemployed rural youths.
  - ✓ Ornamental fish resources of the region have great export potential. Presently, these resources are exploited in an unorganised way by the unscrupulous traders. With

proper education and technical guidance tribal folk can be organized and trained to sustainable exploit ornamental fishery. However, proper regulatory mechanisms need to be put in place to ensure that this exploitation remains within limits, which can be replenished.

- ✓ To supplement natural resources, culture of potential food having good demand and price as well as ornamental species would also be a good strategy. This requires development of suitable breeding technology, well tested culture practice packages as well as the availability of quality seed in time.
- ✓ Game and sport fishery is another area, which can be developed and linked with the eco-tourism. This will not only earn revenue for the region but would also go very well with the conservation goals.
- ✓ Involvement of financial institutions operating in the region, in planning as well as programme implementation will be required.
- ✓ People's participation right from the beginning is indispensable. Mechanisms need to be established to create awareness and generate interest among tribal communities towards following scientific management practices for sustainable utilization as well as conservation of fishery resources.
- ✓ Involvement of women in any program of conservation and development of fisheries needs special attention.
- ✓ Policy and legal aspects also need careful review from the fishery development and conservation point of view.

Conclusion

The task of increasing fish production in the North East is riddled with many difficulties. Non-availability of quality fish seed in adequate numbers has always been a constraint in the region and the problem is further confounded by the low temperature regime of the high altitudes where breeding and rearing of fish are difficult. Nevertheless, the capture and culture fisheries in the area need to be developed, as they are environment friendly, employment generating and labour productive. Concerted efforts of all agencies at the Centre and States are needed to overcome these constraints in order to optimise fish production from the rich and diverse aquatic resources of the region and achieve the cherished goal of making the North East self sufficient in fish production.

Suggested Reading

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Some Aspects of Impact of Global Warming on Cold Regions of Eastern Himalaya

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The earth's climate has been changing throughout the geological history of earth due to the number of natural causes that have affected the radiation balance of the planet. Changes in the earth's orbit, the output of the sun, and volcanic activity (IPCC 2007a). Changes in the earth's climate during its geological history resulted in past ice ages. Glaciers advanced (glaciations period) when it cooled and glaciers retreated when earth warmed up (interglacial period). The most recent cooling episode commonly referred to as the Little Ice Age affected parts of North America, Asia and Europe from 1300 AD through the latter half of the 19^{th} century. The rate of warming during the past 50 years is unprecedented in at least the previous 1,300 years (IPCC 2007a). The Intergovernmental Panel on Climate Change (IPCC) concludes that recent human-induced increases in the atmospheric concentrations of greenhouse gases are expected to intensify changes in the earth's climate than previously experienced (IPCC 2007a).The global atmospheric concentration of carbon dioxide has increased from about 280ppm during preindustrial times to 379 ppm in 2005, which far exceeds the natural range over the last 650,000 years(180-300) as determined from ice core (IPCC 2007a). Snow, glaciers and permafrost are especially sensitive to changes in the atmospheric condition because of their proximity to melting conditions. In fact, changes in ice occurrences and corresponding impacts on the physical high- mountain systems could be among the most directly visible signal of global warming. This is also one of the primary reasons why glacier observations have been used for climate system monitoring for many years (Haeberli1990). Snow and glacial melt are important hydrological processes which have direct bearing on the hydrological characteristics of Himalayan Rivers. Now it is well established that the glaciers are retreating in many locations of the world, which has accelerated in recent decades. Glacier systems at highest elevations, 4000-7000masl, have not responded to recent climate warming in the same way as glaciers that extend to lower elevations, simply because glaciers at higher elevations remain below freezing during much of the year, even in the presence of warm climate. Therefore, although glaciers are retreating both in the European Alps and in the Himalayan region, one cannot always make direct comparisons and extrapolations from the well-studied lower elevation glaciers to the more poorly observed higher glaciers of the Himalayan region.

Himalayas have the largest concentration of glaciers outside the polar caps. With glacier coverage of 33,000 km^2, therefore this region is aptly called the "Water Tower of Asia" as it provides around $8.6X10^6$ m^3 of water annually (Dyurgerov and Meier,2005). Climate change has impacted the glacial ecosystem tremendously; sixty- seven percent of Himalayan glaciers are retreating at a startling rate due to climate change. Himalayan glaciers are important in sustaining seasonal water availability, are likely to be affected substantially by climate change, but to what extent is yet unclear (Immerzeel et.al.2010). Efforts to quantify the contribution of melting glacier ice to regional hydrology are in the early stages of development, but it is clearly clear that conditions vary significantly along the south east to north west transect of the Himalaya (Armstrong 2010). Immerzeel and his coauthors used Normalized Melt Index over the period 2001 to 2007 in an effort to quantify the importance of melt water from the upstream areas on overall basin hydrology of Himalayan river. This study indicate that for present day climate, melt water plays an important role in the Indus and Brahmaputra river basins. Snow and glacial melt accounts for 151% of total discharge of Indus basin, for Brahmaputra basin this amounts to 27%. Hydrological modeling approach taking into account temperature, rainfall and snow projections predicts a 19.6% decrease of upstream water flow to Brahmaputra by 2050 (Immerzeel et.al.2010).

Eastern Himalayas annual temperature is increasing at a rate of 0.01^{0}C/yr or more. There is progressively more warming with elevation, areas above 4000amsl are experiencing the greatest warming rates (Shrestha and Devkota 2010). The wetlands are most likely to be the first among the eco-hydrology systems to be affected by climate change. In fact, erratic weather situations are already being observed in many parts of the Himalaya. Water related hazards like glacial lake outburst floods, flash floods, and landslides are becoming more frequent at the cost of lives, property, and natural resources and these are likely to exacerbate by climate change (Xu et.al.2008).

Flora and fauna in lower reaches of mountains would migrate vertically to cop up with the changes forced by climate change. Species in high- altitude areas however may not have scope for vertical movement upwards after a certain point in the process of climate change. Fish living in cold clear water would not be able to adapt to the changes forced by climate change, species which are unable to adapt to changed environment may possibly get extinct from the region.

Glacial stream temperature pattern reflect the complex actions of hydrological and microclimatic processes. Water emerging from a glacier will be close to 0^0 C. In spring, these near- freezing water temperatures are typical of all the snow fed streams in high alpine zones. As summer progresses, however, non–glacial streams warm up as the contributing seasonal snowpack diminishes and disappears. While the glacier affect downstream water temperatures which depends in part on the glacial area, distance downstream, climate and flow conditions and the flux of non-glacial water to streams (Brown et.al., 2006). Increased stream temperatures are one of the primary, but not the only, potential outcome of a rapidly changing climate. Reduced snow pack, earlier spring runoff, reduced summer flow, increased floods and drought will pose additional stressors for freshwater fish population (Clark et.al. 2001; Poff et. al. 2002). Rapid changes in flood magnitude, timing create a mismatch between the hydrological regime and spawn timing or both would be negatively affected. It is likely that native population facing hydrological changes in their native habitats will face similar challenges (Williams et.al. 2009).

With the glaciers melting faster than before it has accelerated the rate of recession of glaciers, with this there is increase in suspended load melt water. Suspended sediment yield generally increase with glacial cover in the watershed (Hallet et.al. 1996). Condition favoring negative mass balance and glacial retreat can produce elevated suspended sediment concentrations in pro-glacial streams by variety of mechanisms, including sediment delivery via debris flow and other mass-wasting processes associated with glacial retreat. Rapid glacier retreat can also release sediments stored in ice near the terminus, near the bed of the glacier, as well as from recently de-glaciated moraines and fore-fields. In some catchments, mass-wasting associated with glacier retreat provide episodic inputs of substantial amounts of both fine and coarse sediments to downstream channels, disrupting a long-term decline. Increased sediment loading can be detrimental to stream fish production through habitat degradation and reduction of reproductive potential of fish (Sweka 1999).

Change of hydro chemical characteristic of glacial melt water with warming of glacial environment would have a direct impact on the cold water fish. Glacial melt water initially tend to be relatively dilute, and most solutes exported from glacier are acquired by the water following sub-glacial flow paths (Richards et.al. 1996) Firn and ice tend to be more dilute than snow due to the leaching of snowpack ions during melt (Fountain, 1996). As glaciers retreat, several processes may influence the chemistry of water exiting a glacier including shifts in the relative importance of sub, en and supra glacial flow paths.

North eastern Himalayan state of Sikkim has 449 glaciers and 266 glacial lakes out of which 14 lakes are identified as potentially dangerous (ICMOD 2003), and Arunachal has 161 glaciers. Bhutan is between these two ststes, has 677 glaciers and 2674 glacial lake out of which 24 are potentially dangerous. In event of bursting of glacial lakes and flash floods due to intense events of rain fall in Sikkim, Arunachal Pradesh and Bhutan would adversely affect the cold water fish by completely destroying the morphological characteristics of the rivers and stream which join of Brahmaputra and Tista rivers.

Changes in cold region environment are eminent with current rate of warming. Some species in certain context benefit from temperature increase, whereas other will experience habitat declines. As stream temperature increases it has different effect on thermal habitat of cold water in different height zones. Fish lower reaches of catchment may not be able live in warmer condition. They would move to higher reaches of watershed which was earlier thermally unsuitable. Impact of general warming on cold water streams need to be investigated from subtropical to alpine zones of Eastern Himalaya. Detailed studies of one of rivers in East District of Sikkim and one in Arunachal Pradesh may be carried out to ascertain the impact of global warming on cold water streams environment.

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Angling – A Tool for Sustainable Development of North East India through Fishery Based Eco-Tourism

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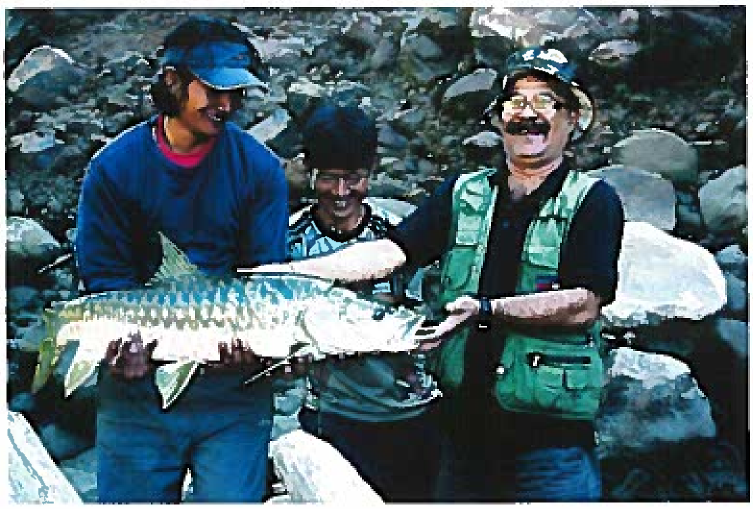
Introduction

Angling of sport fishing is one of the most fascinating outdoor physical activities which satisfies diverse taste and pursuits. It is a form of eco tourism promoting sustainable form of resource use, contributes to environmental conservation while proving accrued socio-economic benefits to the society through non consumptive use and provide high values to natural biological resources. Tourism is a big business globally accounting for 8 percent per the world's domestic product and 9 percent of the world's total employment as per WTO, 1998. According to world tourism and travel council, tourism industry is largest business sector employing about 225 million people, generated about 9.6 percent of global GDP in 2008. It is world's largest export industry, accounting for 10 percent of total world's product and more than 38 percent international trade-in services.

Angling holidays and sport fishing tourism is a booming international business opportunity. It is one of the most sought after adventure tourism activities and there is an ever increasing number of international angling itineraries throughout the world destination in search of big fish and thrilling sports fishing adventure in an un spoilt fishing destination.

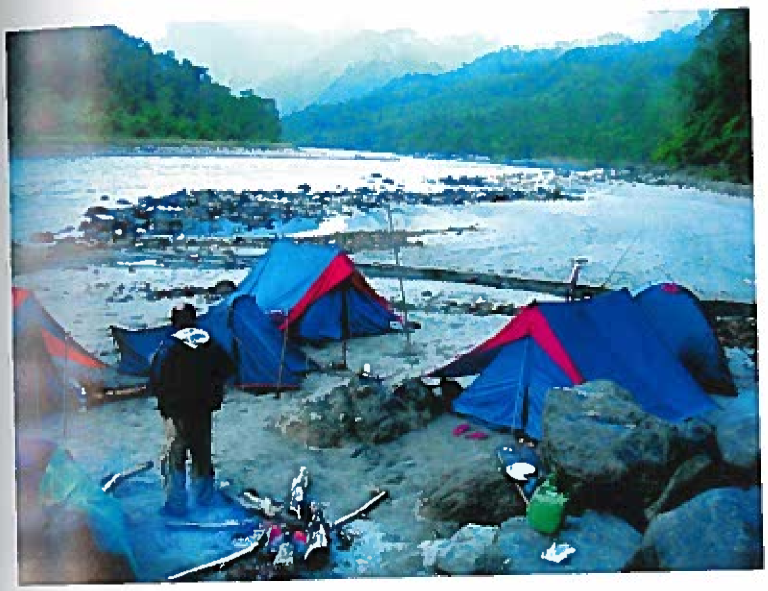
Economics of Sport Fishing

Sport fishing is one of the leading adventure tourism activities in Europe and USA. According to American Sport Fishing Association there is over 40 million anglers in USA creating worth 45 billion dollar in retail sales, it employs over 1 million people, with an impact of 125 billion dollar on US economy. In UK, there are 3.8 million anglers which accounts to 9 percent of total adult population spending about 7.5 billion pound per annum as per a study of 2006. The economic activity associated with recreational fishing trips, fishing holidays and sport fishing tourism is particularly beneficial to rural tourism areas – involving exploration or travel to remote areas, where the travelers "expects the unexpected" while seeking adventure holidays as



Prize catch of Subansiri River

an alternative to typical beach vacation. In USA on an average angling equipment worth 30 billion are sold annually. 25 million anglers spent about 25 billion euros in Europe in 2005. Estimated 2,900 companies trade in fishing tackle within the EU, and supports some 60,000 jobs and 12,900 tackle shops employs another 39,000 people. In Australia alone the sport fishing equipments worth 680 million dollar was sold in 2005. In 1999 angling license fee amounting to 29.6 million dollar was paid to US Government coffer. In Scotland, a single Scottish salmon cost about 500 pound (Rs. 40000) for an angler of which commercial market price is only about 20 pound (Rs. 1600). A small country like Sweden spend SEK 2730 million for 58 million sport fish, whereas, the commercial price of 79 million salmon cost only 240 million SEK. According to Noradic Council Ministry looking after the economic value of recreational fishing demonstrated that in 1998, 48 million kg of commercial fish cost FIN 320 million, whereas, same amount of fish taken on recreational fishing fetch worth FIN 1220 million in Norway.



Early morning in a fishing camp- Subansiri River

Near home, the average fishing trip for golden mahseer in Subansiri river of Arunachal Pradesh cost about Rs. 2600 per kg of which market price is only about Rs. 250/- per kg, calculated on an average of 4 fishing trip from Guwahati in 2010-2011. This price is not inclusive of equipment and other accessories used by the anglers. According to Planning Commission, Government of India, an investment of Rs. 10 lakhs creates 78 jobs in tourist sector as against 45 jobs in agriculture and only 18 jobs in manufacturing sector. Although, the sport fishing tourism is not yet well developed in India the potential exist as tourism sector accounts for 2.7 percent of the total employment providing 31 million job in India and tourist arrival is growing at an average of 5.6 percent contributing about 11.4 million dollar in 2009-10.

Nature and Angling

The essential elements of angling tourism (eco tourism) may be natural environment, optimum number of environmental friendly visitors and activities not causing serious environmental and cultural impact on ecosystem with positive involvement of local community i.e. "uniting conservation, communities and sustainable travel" for development of an relatively remote inaccessible destination. It is essentially a tourism activity which minimizes the conflict between resource of tourism and livelihood of the local inhabitants, their environment and socio-cultural life with major thrust for conservation and preservation of nature and culture. It is for the sport fishing interest itself the angler like to conserve the nature, the tree line, the riverbed, the clean and clear water bodies and springs with abundance of fish fauna, their spooning ground, the catchment area of the river, the nature and its surrounding as a whole. Unlike, beach / mass/ urban tourism, in sport fishing tourism a very limited number of anglers move at a time to one particular destination, they are naturally shy, love tranquility, quite in nature and are very environmental friendly for their own pursuit – even they don't need concrete infrastructure and have to spend huge cost per traveler and sometimes referred them as 'high end tourism' for creating environmental friendly and no footprint infrastructure inside nature. It is natural that anglers venture into deep jungles and remote areas for their hobby creating naturalist in him and it is basic human tendency to preserve what he loves – he becomes a natural watchdog for the rivers, water bodies in their own interest which definitely creates a wider impact in society and nature as a whole.

Scope and Potential for Sport Fishing in North East India

North East India is goldmine for angling tourism as this region is bestowed with more than 33 percent of the total water bodies of India and part of entire 3800 km length of Himalayan river and streams stretches in the upland country holding the sizeable mighty Golden Mahseer and about 714 km of Brown Trout stream for angling purpose are partially shared by this region. This region also boost to have 65 percent forest and hill terrain forming some of the finest river system with abundance of Mahseer and other sporting fish. The mighty Brahmaputra and its tributaries are excellent rivers originating from the glaciers of high Himalayan region, the spring fed streams and rivulets of the subtropical evergreen forests – this results in vast varied fishery resources in the form of rivers, flood plains, wetlands, reservoirs, lakes, ponds and low lying areas filled with seasonal and flood water.

The rivers of North East India are teamed with several varieties of sport fish and most prominent among them are the Mahseer group. The Golden Mahseer is popularly known as the Tiger of Indian rivers are very well sought after by the anglers for its excellent fighting ability and preferred more than the salmon of the west world.

Constraints in Sport Fishing Tourism

There are several constraints for which this particular tourism could not get proper focus among the policy makers as well as the local people of the region. These can be classified into the mapping of the sport fishery rivers, lack of awareness among the local people, non-availability of check list of fish and the places with the tour operators etc. The people's participation in conservation and angling is not in proper order. Difficulties of anglers to commute to remote areas and the red-tapism of the local administration and lack of NGO and angling clubs inhibits the westerners. Religious and community ownership of lakes and rivers prohibits angling in some of the most wonderful water bodies. Of late, coming up of several hydroelectric projects in this region will definitely wipeout the entire sport fish fauna.

Conclusion

Although there is tremendous potentiality of angling tourism in the region, it has not developed to the expected level till date. There is an urgent need to identify the sport fishery areas, policy formulation for sport fisheries including development of platform for promotion. The entrepreneurship development for promotion of eco-tourism with supportive and ancillary service development is a far cry. National and international publicity, awareness and marketing strategies for promoting tourism are important factors that need immediate attention for development of angling tourism.

"TIGHTLINE"

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Cold Water Fisheries Resources and their Habitat Ecology of Manas River, Bodoland Territorial Area District, Assam

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Introduction:

Conservation and sustainable use of biodiversity is fundamental to ecologically sustainable development. Biodiversity is part of our daily lives and livelihood, and constitutes resources upon which families, communities, nations and future generations depend. Every country has the responsibility to conserve, restore and sustainably use the biological diversity within its jurisdiction.

Biodiversity of upland Rivers and wetlands are threatened by climate change, deforestation, agricultural and urban land use, pollution, channel modifications, inter-basin transfers of water and modified flow regimes, loss of habitat and habitat connectivity, introduced species and fishing pressure.

The unique richness of bioresources in North East India makes it a potential hub of economy growth of the country to a competent level. Ecological environment with high humid conditions have resulted larger speciation and genetic diversity of plant and animal thus adding to high endemicity of the flora and fauna.

The majority of fish inhabiting rivers especially located in upland are extremely sensitive to modifications and to the environmental changes that occur in modified rivers. The exponential increase in human population is the root cause for the loss of biodiversity and the depletion of natural resources in Assam especially in upland region. In addition to that the fishers use different kinds of traditional fishing gear like nets, baskets, rod and line, spearing, fish traps and indigenous fish poison, as well as some destructive fishing methods such as insecticides, pesticides, dynamiting and electric fishing are also cause of the rapid depletion of aquatic resources of the region.

The River **Manas** and all its main branches, including all its tributaries, constitute the largest river system with a total length of 3200 km flows through Bhutan and India. The River Manas, drains about 18 300 km^2 in eastern Bhutan, rising beyond the Great Himalayan range. It enters Bhutan from the Kameng frontier district of India and runs southwest again it enters India via Manas National Park. Inside the Park, there are numerous rivers criss-crossing the reserve and finally meets River Manas, the Rivers are Sankosh, Saralbangha, Hel, Tanali, Gourang, Sidli (Bhor) Aai, Beki, Puthimari, kaladia, Tihunala, Morapagaldia, Nala, Baralia, Pub-bornodi and Dhansiri. In Assam, the river flows about 200 m above mean sea level and at the latitude and longitude of 26°48'N & 90°58' 'E respectively. The alluvial fan and associated floodplain marshes of the Manas River debouches on to the plains of the Brahmaputra Valley. There are extensive boulder, shingle and sand banks along the river.

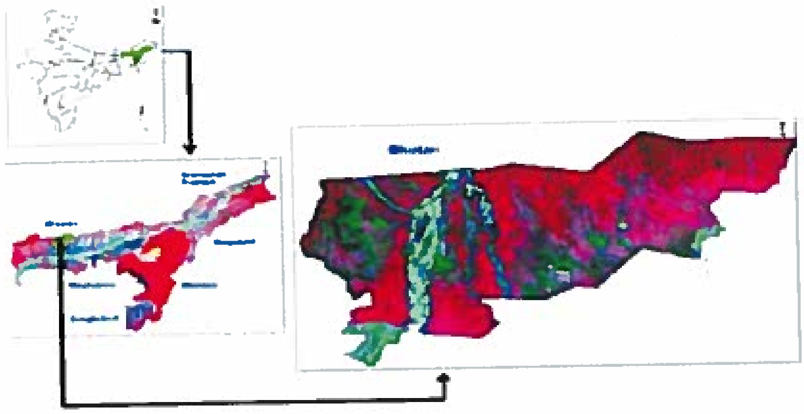

Fig: Map of River Manas and Manas National Park

It is reported that upper stretches of Manas River and its tributaries are predominantly in habited by cold-water fish species (Dubey, 1978) forming a major coldwater fisheries potential. Upland aquatic resources and habitats are always considered as sensitive zone subjected to threatened by climate change, deforestation, agricultural land use, pollution, channel modifications, inter-basin transfers of water and modified flow regimes, loss of habitat and habitat connectivity, introduction of exotic and predatory fish species and fishing pressure. In course of time, climate changes, natural calamities and anthropogenic activities have brought a vast change in biodiversity of flora and fauna of Manas River system.

The River is known to have predominantly cold water fish (Dubey, 1978). Species like *Schizothorax progastus, Schizothorax molesworthii, Schizothorax richardsonii, Neolissocheilus hexagonolepis, Crossocheilus latius, Tor putitora, Tor tor, Barilius barna, Garra annandalei, Garra gotyla, Neolissocheilus hexagonolepis, Crossocheilus latius, Tor putitora, Tor tor, Barilius barna, B bendelisis, Garra garra, Garra annandalei, Garra gotyla, Garra kempi, Hara hara, Labeo pangusia, Neolissocheilus hexagonolepis, Botia derio, N. botia, Conta conta, Barilus vagra, Gagata gagata, Gagata cenia, Barailius bendelesis, Sisor rabdophorus, C chagunio* were reported from the River (Dubey, 1978). The list of fish species is based largely on older literature as there has been no recent work done on fish and fisheries of this River System except few works on *Schizothorax moleswortthii, Schizothorax richardsonii* (Sarma & Dutta, 2000).

Photo: View of River Manas inside Manas National Park

In 2007, the preliminary survey conducted in certain areas of Manas River reveals 2⁰C to 3 ⁰C rise in annual average temperature with marked decrease in dissolve oxygen content 6.5 mg/l to 7.5mg/l as compared to earlier study done by Sen in 1985 (average annual temperature in between 15 ⁰C to 17 ⁰C, dissolve oxygen content 9.0 mg/l to 10 mg/l). Natural calamity such flood has brought a significant decline in high value indigenous fish fauna golden Mahseer, *Tor putitira* .Heavy flow of water during flood seasons has also originated prolonged siltation problem in different parts of river, causing destruction of breeding ground and loss of fish germplasm. The anthropogenic activity like over fishing using different kinds of traditional fishing nets, baskets, rod and line, spearing, fish traps and herbal poison has brought a rapid depletion in fish population of the region.

From the survey, it has been found that the Relative abundance of hills stream variety was found in decreasing trend than that of the plain water varieties.

The relative abundance of mud dweller species such as *Channa gachua*, *Monopterus cuchia* and *Nandus nandus* were recorded in increasing trend from one season to other which indicate alteration of River bed from rocky to muddy due to heavy siltation coming due to heavy flood. The analysis of the trophic structure of the fish diversity during the investigation indicates dominancy of omnivorous fishes in all sites followed by carnivorous herbivorous and planktivorous fish. The variations in the habitat attributes like Temperature, pH, DO_2, FCO_2 etc. across different sites was attributed to differences in habitat degradation, which was responsible for variation of species diversity and distribution.

From the survey, it has been felt that following are critical need for restoration of habitat and to define the factors and process that maintain and manage the cold water fisheries resources of the Manss River

1. Details morphometry of the river to find out distribution of fish species using historical baseline.
2. Seasonal distribution, abundance and microhabitat of endemic and exotic hill stream fish species along with the limnology and productivity of the river in correlation with the fish catch in a particular pocket of water body.
3. To prepare action plan for eradication of exotic species from the River.
4. To build up institutional and legal frameworks that consider and respond to climate change threats and uncertainties along with other pressures such as over fishing, illegal fishing, pollution and changing hydrological conditions. This requires effective public, private and NGO partnerships, integrating research and management across the sectors and ensuring that regulations limiting access to resources are appropriate to respond to both the threats and benefits of future climate variability.
5. To prepare action plan for prioritization of area of the river in side the Manas National park as ***aquatic sanctuary*** as well as to adopt strategy for mitigation of climate change and other threats.

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Cold Water Fisheries Resources of Dima Hasao District of Assam

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The North Eastern states have vast untapped potential for fisheries in terms of many rivers, streams, floodplain wetlands, lakes, ponds and large areas under rice-fish culture system. The North East Region shares its fish fauna predominantly with that of the Indo-Gangetic fauna and to a small extent with the Burmese and South China fish fauna (Yadav and Chandra, 1994).

Assam, the second largest province of N.E. India is a global hotspot for fish faunal diversity. The diversity of fish species in the North East India is attributed to the recent geological history, especially the Himalayan orogeny (Kottelat, 1989). Thus the fauna of the state includes both Assamese and Burmese elements (Hora and Mukherji, 1935).

But due to the absence of modernized socio-economic and public health-care systems along with lack of employment and good infrastructure facility, the poor people of this region are compelled to depend on fish-resources for their livelihood. This in turn poses a great degree of threat to the original biota making it one of the most hot spot critical eco-region.

In addition to that, the majority of fish inhabiting rivers especially located in upland are extremely sensitive to modifications and to the environmental changes that occur in modified rivers. The exponential increase in human population is the root cause for the loss of biodiversity and the depletion of natural resources in Assam. The fishers are also use different kinds of traditional fishing gear like nets, baskets, rod and line, spearing, fish traps and indigenous fish poison, as well as some destructive fishing methods such as insecticides, pesticides, dynamiting and electric fishing, which are cause of the rapid depletion of aquatic resources of the region.

Poor management of capture fisheries is threatening the fish supply in the near future. This means that more effective management is urgently required. But the management must be fitted to the prevailing fisheries status of the country. The approach to fisheries management must also change from the conventional system to a more appropriate management system. To provide effective support for management, river fisheries ecologists must analyse and predict processes and impacts at the level of species, assemblages and ecosystem processes, in systems of high spatial and temporal heterogeneity. It is not only sufficient to observe, identify and classify fishes present in rivers and other freshwater environment of the park but also it is essential to record their physical and chemical properties in order to help define ecosystem that leads to a sustainable fishery.

Poorly studied freshwater fish species of India must be studied and documented properly immediately so that we do not lose any of them anymore. This documentation will serve for further research and development activities. The documented information of freshwater fishes will also help us to understand, conserve, and exploit it for sustainable fishery.

The North Cachar Hills lies between 92'37 – 93'17 E longitudes and 23'30 – 25'47 N latitudes. The District is one of the twin Hill district of Assam with headquarter at Haflong. The district shares its boundaries with the states of Manipur, Nagaland, and Meghalaya. The people of this district practice jhum cultivation and are also the only source of livelihood. The district is blessed with many Hill Rivers, to name a few – The Jatinga River with its source at Borail range and joining the Barak River in Cachar. The Diyung River is also with its source at Barail range and joining the Kopili and the Kopili with its source at the N.C. Hills and Meghalaya border where the Khandom dam stands. The tributaries of the River Diyung are the Moti River and the Langting River. The river Diyung River passes by the district Headquarters, Haflong, with meandering course, Dihangi, Thaijuwari, Diyungmukh and joins the Kopili. The river as its passes along its courses springs up to beautiful waterfall of all shades, which has a unique tale of its origin. The habitat of cold water species (*Labeo dyocheilus dyocheilus Tor sp.* etc) of Jatinga, Dihangi & Diyung River of the district are also excellent site for tourist. The indigenous techniques for catching of *Clupisoma garua* and other species in the said rivers are unique beauty of the region.

Photo 1 : View of the Haflong Lake

As the species diversity of the district is concerned, it is more peculiar than the other cold water resources of India due of its richness in endemic variety of the fish species. Fresh water fishes belonging to almost all the major families are reported from this River. Some of the major genera are as follows: *Tetradon, Labeo, Catla, Cirrihinus, Notopterus, Chitala, Aorichthys, Wallago, Channa, Eutropiichthys, Clupisoma, Heteropneustes, Clarias, Puntius, Mastacembelus, Macrognathus, Anabas, Xenentodon, Glossogobius, Pangasius, Puntius, Rasbora, Chela, Amblypharyngodon, Aspidoparia, Mystus, Chanda, Badis, Danio, Chaudhuria, Gagata, Garra, Lepidocephalus, Schizothorax, Anguilla, Barilius, Nandus, Colisa, Rita, Botia, Monopterus, Nemacheilus, Sisor, Ailia, Semiplotus etc.*

But it has been observed that the number of plain water species increasing day by day because of rapid changes of physicochemical properties of the river due to rising in temperature. Changes in global temperature will affect fish communities and the fisheries dependent on those communities through direct effects on fish physiology and indirectly through effects on water quality, water chemistry, and hydrographs. Even when the increase in temperature is not sufficient to prove acutely or even chronically lethal, the sub-lethal impacts on fish physiology, particularly on growth and reproduction, may be sufficient to cause significant changes in the structure and composition of fish faunas. The impacts of global climate change on the critical physical and chemical characteristics will likely prove to be the driving factors in determining the well-being and composition of fish communities. The species diversity of the district has also witnessed severe damage due to various activities like over fishing, pollution, poisoning etc.

A preliminary survey was conducted in 2011 in certain selected spot of Diyung and Jatinga River reveal that physicochemical parameters like Temperature (10^0C to 27^0C), pH (7.7 to 8.9), DO_2 (6.84 mg/l to 12.96mg/l) FCO_2 (3.4mg/l to5.1mg/l), Alkalinity (45 mg/l to85 mg/l), Acidity (7.5 mg/l to 15.4 mg/l) were found conducive in upstream sampling site, however, in down stream the parameters were found slightly deviating from permissible limit might have resulted due to organic pollution and other anthropogenic activities. A total of 75 species of 52 genera have been recorded from the two Rivers, out of which 27 species were cold water variety. It has been observed that cold water species has been reducing from the Rivers very rapidly due to habitat destruction.

Photo: View of the Jatinga River

Therefore, it is critical need for detail survey of all possible water resources of Dima-Hasao district for restoration of habitat of cold water fisheries resources and to define the factors and process that maintain and manage the fisheries resources of the region as well as it is urgent need to develop and promote certain water area into tourist attractions for providing gainful employment avenues to thousands.

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Application of Molecular Makers for Studies of Fish Genetic Diversity

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Introduction:

Among all the aquatic animal and plant resources fish is the most valued and important human food. They are the major source of protein for many people and thus play an important role in the nutritional security. Fish and fisheries not only provide a cheap protein for the human consumption but they are also an economically significant activity, providing employment and investment opportunities for many countries all over the world. The North East region of the country forms a part of Eastern Himalayan zone and has a unique topographical conditions. The region is also blessed with vast aquatic resources and varied fish genetic resources. NE region harbours around 267 fish species belonging to 114 genera under 38 families and 10 orders, which is approximately 13.13% of the total Indian freshwater fishes (Sen, 2000). Most of the fish used for the human consumption is obtained through wild capture or through exploitation of natural populations. The commercial or sport fisheries present the genetic problems which are unique to fisheries management. There is a reduction in the genetic resources of natural fish population which has become an important fisheries management problem. Most of the reduction is due to pollution and various anthropogenic activities such as over fishing exploitation, destruction of habitat, blockage of migration routes and other human developments (Ferguson, 1995). This has resulted in the alteration of genetic diversity of many fish populations and species. Most of the fishery management approach target on the numbers and size reduction problem keeping in view the immediate resource of interest. This short-term focus may be economically advantageous in the short run, but in the long term may cause extinction of the population. Reduction of genetic resources in fish is now become a global concern for the genetic resources of the biosphere. In such a scenario molecular genetic research has now become imperative the long-term management of fisheries resources (Park and Moran, 1995). This approach addresses two slightly different aspects of genetic resources: conservation of gene pools and conservation of genetic diversity.

Population Genetics and Fisheries Management

Genetics has wider application in fisheries management and thus many tools have been developed over a period of time for the study of genetic variation and diversity of the natural fish populations. When the genetic population structure of a species is known, the distribution of subpopulations in mixed fisheries can be estimated (Utter, 1991). The study of population genetics thus helps in finding how genetic variation is distributed among species, populations and individuals. Fundamentally, it is concerned with how the different evolutionary forces such as mutation, selection, random genetic drift and migration affect the distribution of genetic variability (Hansen, 2003). Patterns of *genetic* *diversity* or *variation* among populations can provide clues to the populations' life histories and degree of evolutionary isolation. Measuring genetic diversity in wild fish populations or aquaculture stocks is essential for interpretation, understanding and effective management of these populations or stocks. Variation at the population level can provide an idea about different genetic classes, the genetic diversity among them and their evolutionary relationship with wild relatives. Measures of genetic diversity are relevant in assessing extinction risks for populations while the genetic variability within population is extremely useful to gather information on individual identity, breeding pattern, degree of relatedness and disturbances of genetic variation among them (Ciftci and Okumus 2002).

Genetic diversity can be measured indirectly through controlled breeding and performances studies or analysis of phenotypic traits. Apart from this diverse characteristics and methods used to analyze stock structure in fish populations are tagging, parasite distribution, physiological and behavioural traits, morphometrics and meristics, cytogenetics, immunogenetics and blood pigments (Ihssen *et al.*, 1981). However, applications of DNA sequencing and the Polymerase Chain Reaction (PCR) based technologies during the last two decades have revolutionized the science of generating high throughput genetic markers. The PCR has provided the potential to encompass large genomic regions both coding and noncoding.

Molecular Markers Used in Fisheries and Aquaculture

It is known fact that all organisms undergo mutation because of normal cellular operations or interactions with the environment, leading to genetic variation (polymorphism). Genetic variation in a species enhances the capability of the organism to adapt to the changing environment which is vital for their survival. Apart from different evolutionary forces such as selection and genetic drift, genetic variation arises between individuals leading to differentiation at the level of population, species and higher order taxonomic groups. Molecular genetic markers are powerful tools to detect genetic uniqueness of individuals, populations or species. The conclusion obtained from genetic diversity data has application in research on evolution, conservation and management of natural resources and genetic improvement programmes (Chauhan and Rajiv, 2010). Vast array of molecular markers is available as tools in several areas of aquaculture; from broodstock selection and monitoring to quantitative trait loci (QTL) mapping. Application of DNA markers is finding wide acceptance in population genetics. Both genomic and mitochondrial DNA is used for varied applications. The commonly used technique are allozyme analysis, types of restriction fragment length polymorphism (RFLP), randomly amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), microsatellite typing, single nucleotide polymorphism (SNP), and expressed sequence tag (EST) markers, etc.

Molecular markers can be classified into type I and type II markers. Type I markers are associated with genes of known function, while type II markers are associated with anonymous genomic regions. Allozyme markers are type I markers because the protein they encode has known function. RAPD markers are type II markers because RAPD bands are amplified from anonymous genomic regions via the polymerase chain reaction (PCR). Microsatellite markers are also type II markers unless they are associated with genes of known function. In general, type II markers such as

RAPDs, microsatellites, and AFLPs are considered non-coding and therefore selectively neutral. Such markers have found widespread use in population genetic studies to characterize genetic divergence within and among the populations or species.

Allozyme markers

Allozymes are allelic variants of proteins produced by a single gene locus, and are of interest as markers because polymorphism exists and because they represent protein products of genes and are thus these are the type I markers. In the early sixties, starch gel electrophoresis of allozymes had been the most commonly employed molecular method in fishery genetics. Still, allozymes are found use in aquaculture for tracking inbreeding, stock identification, and parentage analysis by many researchers. Correlations were tried to develop between certain allozyme markers and performance traits. Their use in linkage mapping has been demonstrated in studies of salmonids and poeciliids. Although 75 isozyme systems representing several hundred genetic loci are currently available (Murphy et al., 1996. Low levels of genetic variation revealed in many allozyme studies of marine fish populations (Liu and Cordes 2004) prompted a continued search for markers with greater genetic resolution. But recently with the development of other codominant markers like microsatellites the use of allozymes in fish genetics has become limited.

Mitochondrial DNA markers

Mitochondrial DNA (mtDNA) of vertebrates can be formally classified as repeated DNA, since a cell can contain hundreds of mitochondria and each mitochondrium can have two to ten copies of DNA molecules. DNA of human and animal mitochondria is a closed circular molecule of the size of 20000bp. Complete sequencing of mtDNA in vertebrates revealed 37 genes (2 ribosomal, 22 genes for transport RNAs and 13 protein-coding genes) and non coding control region that participates in replication and known as the D-loop. Almost the entire mtDNA molecule is transcribed except for the approximately 1-kb control region (D-loop), where replication and transcription of the molecule is initiated. In general, non-coding segments like the D-loop exhibit elevated levels of variation relative to coding sequences such as the cytochrome b gene. Analyses of mtDNA markers have been used extensively to investigate stock structure in a variety of fishes including eels, bluefish, red drum, snappers, and sharks. Mitochondrial markers are widely and successfully used in various studies of evolution and phylogeny.

Random amplified polymorphic DNA (RAPD)

RAPD is a random amplification of anonymous loci by PCR. It has several advantages and has been quite widely employed in fisheries studies. The method is simple, rapid and cheap, it has high polymorphism, only a small amount of DNA is required, no need for molecular hybridization and most importantly no prior knowledge of the genetic make up of the organism in question is required (Hadrys *et al,* 1992). RAPD markers allow creation of genetic markers from species of which little information is known about target sequence to be amplified. It is helpful in addressing a wide range of evolutionary problems including the determination of paternity and maternity. This methodology has some disadvantages, which include difficulty in reproducing results, subjective determination of whether a given band is present or not, and difficulty in analysis due to the large number of products. This is because RAPDs are not sensitive to any but large-scale mutations.

The technique is based on the PCR amplification of discrete regions of genome with short oligonucleotide primers of arbitrary sequence. First of all RAPD is generated by PCR. A small amount of genomic DNA, one or more oligonucliotide primer (usually about 10 base pair in length), free nucleotide and polymerase with a suitable reaction buffer is major requirements. The main drawback with RAPDs is that the resulting pattern of bands is very sensitive to variations in reaction conditions, DNA quality and the PCR temperature profile. RAPDs have gained considerable attention particularly in population genetics, species and subspecies identification, phylogenetics and genome mapping, analysis of interspecific gene flow and mixed genome fingerprints. RAPD analysis has been used to evaluate genetic diversity for species, subspecies and population/ stock identification in Guppy, tilapia, Brown trout and Atlantic salmon, Largemouth bass, Ictalurid catfishes, Common carp. The possibility of assessing the genetic differentiation among populations has plays important implications for understanding the ecology of this species and formulation of suitable breeding strategies.

AFLP (Amplified Fragment Length Polymorphism)

It is based on selective amplification of fragments obtained by restriction digestion of genomic DNA. The method includes i) DNA digestion by two selective restriction enzymes and binding sticky fragment ends with oligonucleotide adapters by a ligase enzyme, ii) selective PCR amplification of the set of restriction fragments, and iii) electrophoretic analysis of the amplified fragments. PCR amplification of restriction fragments is achieved by using the adapter and restriction site sequence as target sites for primer annealing. The selective amplification is achieved by the use of primers that extend into the restriction fragments, amplifying only those fragments in which the primer extensions match the nucleotides flanking the restriction sites. Using this method, sets of restriction fragments may be visualized by PCR without knowledge of nucleotide sequence. The method allows the specific co-amplification of high numbers of restriction fragments. The number of fragments that can be analyzed simultaneously, however, is dependent on the resolution of the detection system. Typically 50-100 restriction fragments are amplified and detected on denaturing polyacrylamide gels. The AFLP technique provides a novel and very powerful DNA fingerprinting technique for DNAs of any origin or complexity.

RAPD and AFLP markers are supposed to be located mostly in the non-coding DNA regions since these regions constitute an overwhelming part of the eukaryotic genome. Mutation rates in non-coding DNA are about two times higher than in its coding part. In addition, RAPD and possibly AFLP markers are sometimes amplified from the repetitive DNA regions and thus reflect high rates of their mutation.

Microsatellite Markers

A microsatellite is a simple DNA sequence that is repeated several times at various points in the organism's DNA. Such repeats are highly variable and can be used as a polymorphic marker. Microsatellites have been estimated to occur approximately once every 10 kbp, and useful for genome mapping studies (O'Connell and Wright, 1997). They are one of a class of highly variable, non-coding and considered to be selectively neutral. Microsatellites are co-dominant, inherited in a Mendelian fashion and tandem arrays of very short repeating motifs of 2-6 DNA bases that can be repeated up to ~100 times at a locus. Their high polymorphism, and PCR based analysis has made them one of the most popular genetic markers (Wright and Bentzen 1994). With current molecular methods it is feasible to score microsatellite length polymorphisms in large numbers of individuals for genetic analyses within and between populations. Some microsatellite loci have very high numbers of alleles per locus (>20), making them very useful for applications such as parent-offspring identification in mixed populations, while others have lower numbers of alleles and may be more suited for population genetics and phylogeny (O'Connell and Wright, 1997; Estoup and Angers, 1998). Primers developed for one species will often cross-amplify microsatellite loci in closely related species (Estoup and Angers, 1998). Microsatellite loci are typically short, this makes it easy to amplify the loci using PCR, and the amplified products can subsequently be analysed on either "manual" sequencing gels or automated sequencing. Microsatellites are relatively easy to isolate compared with minisatellites, sample DNA can be isolated quickly because labour- intensive phenol-chloroform steps can generally be eliminated in favour of a simpler form of DNA extraction. Only small amounts of tissue are required for typing microsatellites and these markers can be assayed using non-lethal fin clips and archived scale samples, facilitating retrospective analyses and the study of depleted populations (McConnell *et al.*, 1995). Moreover, there is potential for significant increases in the number of samples that can be genotyped in a day using automated fluorescent sequencers. For applications where a large number of loci are required, such as genome mapping or identification of Quantitative Trait Loci (QTL), microsatellites offer a powerful alternative to other marker systems. There are two main techniques for microsatellite analysis. The first one requires probing complete digests of genomic DNA with simple sequence repeats (di-, tri-, or tetra- nucleotide repeats). Alternatively they are genotyped using the PCR using primers targeted to the unique sequences flanking the microsatellite motif. PCR can easily be semi automated. The resulting PCR products are separated according to size by gel electrophoresis using either agarose gels or more commonly (higher resolution) denaturing polyacrylamide gels. This amplification presents a significant advantage over other non-PCR based methods because it allows the use of relatively small amounts of tissue, including that from preserved otoliths, scales, larvae, and small fry. Even though microsatellites have already proven to be powerful single locus markers for a variety of genetic studies (Queller *et al.*, 1993), the need to develop species-specific primers for PCR amplification of alleles can be expensive. However, primers developed to amplify markers in one species may amplify the homologous markers in related species as well (Morris *et al.*, 1996). Another important disadvantage of microsatellite alleles is that amplification of an allele via PCR often generates a ladder of bands (1 or 2 bp apart) when resolved on the standard denaturing polyacrylamide gels. These accessory bands (also known as stutter or shadow bands) are thought to be due to slipped-strands impairing during PCR (Tautz, 1989) or incomplete denaturation of amplification products (O'Reilly and Wright, 1995). The practical outcome of PCR stutter is that it may cause problems scoring alleles. However, trinucleotide and tetranucleotide microsatellite typically exhibit little or no stuttering (O'Reilly *et al.*, 1998). Nuclear DNA exhibits the greatest variability of all genetic markers related to fisheries science and will be highly productive avenue for research and applications in wild and aquaculture stocks. Main applications in fisheries and aquaculture are phylogenetics and phylogeography, population genetic structure, conservation of biodiversity and effective population size, hybridization and stocking impacts, inbreeding, domestication, quantitative traits, studies of kinship and behavioural patterns. Microsatellites are also becoming increasingly popular in forensic identification of individuals, and determination of parentage and relatedness, genome mapping, gene flow analysis.

ESTs (Expressed Sequence Tags)

Expressed sequence tags (ESTs) are polymorphism of the expressed, coding genomic sequences. These are usually partial fragments or complete sequences of cDNAs which is obtained with reverse transcriptase from mRNA isolated from specific tissue types and representing the genes expressed in these tissues. Using the EST sequences, PCR primers are designed to amplify EST from the individual genomic DNA and then polymorphism of this DNA is estimated by means of some methods of amplification product analysis. The EST approach is an efficient way to identify genes and analyze their expression by means of expression profiling. ESTs are useful for the development of cDNA microarrays that allow analysis of differentially expressed genes to be determined in a systematic way, in addition to their great value in genome mapping. Therefore, ESTs are useful for mapping in aquaculture species only if polymorphic ESTs are identified. ESTs also can be mapped to genetic linkage maps if they are found to be associated with microsatellites. Microsatellite repeat-containing ESTs are rich resources of type I markers.

SNP (Single Nucleotide Polymorphism)

Single Nucleotide Polymorphism, is a polymorphism of a single nucleotide site. It is represented by two allelic variants of a single nucleotide in a DNA sequence. These variants can be detected employing PCR, microchip arrays and fluorescence technology. Major applications of SNPs in fisheries are genomic studies and diagnostic markers for diseases. Since they are main part of the many gene chips, they are considered as next generation markers in fisheries.

Conclusion:

These rapidly developing markers can identify closely related species, populations/stocks, genetic strains, families and individuals. Thus, it is becoming increasingly important for fisheries and aquaculture stock managers to understand and evaluate genetic data. The types of molecular markers described here seem to be suited for different levels of applications. So far many fish species are being studied regularly at the molecular and genome level, as for example, EST sequences are available for carp, catfish, trout, salmon, killifish, tilapia etc along with large BAC libraries of several species of fishes which generates lot of interest for fish genome research.

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Application of Geoinformatics in Fisheries Management

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What is Geoinformatics?

Geoinformatics is the combination of Geographical Information System (GIS), Remote Sensing data and computer technologies. The technology can answer for generic questions like locations, conditions, trends, patterns and modelling. These answers support in making authentic decision, which are purely based on realities on the ground and can be used for scientific management of water bodies and explore the suitable in hand information for proceeding aquaculture development. It also provides a long-term outline for sector development including all sub sectors like aquaculture, fish market etc. providing guidance to the farmers and planners where really it can be implemented. Management of the resources requires enormous data, based on reality since the planning is done after their interpretation. Handling and analyzing of vast information is not practicable manually due to chances of biasness, involvement of high cost and manpower and require more of time. It is wise to prefer to use of Geoinformatics, which comprises of a collection of integrated computer hardware and software. The system is used for inputting, storing, manipulating, analyzing and presenting a diverse variety of geographical data. The advancement of computers in its higher speed and storage of data provided a suitable base for information analysis and presentation more accurately and attractively. This helped decision-makers for a quicker assessment, planning and management of resources. The present need is to manage the resources scientifically and to assess sustainability of the resources for future generations by adopting Geoinformatics for supporting decisions.

Why it is needed in Fisheries Management?

It has been estimated that fish production in India has to be raised by 13.0 million tones to meet minimum protein demand of Indian population. Indian fishery resources have already been overexploited due to pressure of ever increasing population. Therefore a situation exists whereby many individual fish stocks have been or are being fished beyond their sustainable yield with the consequences that many stocks have crushed alarmingly. The fisheries resources are in crisis with a wide range of problems like pollution, overexploitation and habitat destruction, which directly affect not only socio-economic status of the fishermen but also to the bio-diversity. These problems are aggravated due to poor prior planning in absence of non-availability of the scientific database. The supply of anticipated fish production could only be compensated by aquaculture and allied activities. Management of the resources requires enormous data, based on reality since the planning is done after their interpretation. Handling and analysing of vast information is not practicable manually due to chances of biasness, involvement of high cost and manpower and require more of time. It is wise to prefer to use of Geographical Information System (GIS), which comprises of a collection of integrated computer hardware and software. The system is used for inputting, storing, manipulating, analysing and presenting a diverse variety of geographical data. The advancement of computers in its higher speed and storage of data provided a suitable base for information analysis and presentation more accurately and attractively. This helped decision-makers for a quicker assessment, planning and management of resources. The present need is to mange the resources scientifically and to assess sustainability of the resources for future generations by adopting Geoinformatics for supporting decisions.

Elements of GIS

Hardware, software, data, and live ware are the four elements of GIS. The details of these are been presented in the following table:

S. No.	Elements of Geoinformatics	Particulars
1.	Hardware	High performance Computer, Input Devices, Scanners, Digitizer, CD, Graphic Monitor, Global Positioning System and Plotters
2.	Software	Input Modules, Editing, Manipulation/Analysis Modules and Modelling Capability
3	Data	Spatial (Remote Sensing & Toposheet) and Non-spatial Data
4	Live Ware	Skilled Personnel

History of Geoinformatics in Fisheries

A sound and stable data structures to store and analyse map data became dominant in the early 1970's. This has lead to the introduction of topology into GIS. Topology and the related graph theory provide to be effective and efficient tools to provide logically consistent two-dimensional data representations. Another significant breakthrough occurred with the introduction and spread of personal computers in 1980's. The 1990's can be characterised as a period of the breakthrough of object-orientation in system and database design, recognition of Geoinformatics as a professional activity, and spatial information theory as the theoretical basis for GIS. Use of GIS for fisheries management started during mid-1990's. Potentiality of GIS is realised in the recent past and now it has become popular among many users for variety of applications. In India the major developments happened during last decade with significant contribution coming from Department of Space emphasising applications of GIS for Natural Resources Management. Notable among them are Natural Resource Information System (NRIS), Integrated Mission for Sustainable Development (IMSD) and Bio-diversity Characterisation at National Level. IIRS is also playing major role in GIS through education and training programmes at the National and International level. Recently the commercial organisations in India have realised the importance of GIS for many applications like natural resource management, infrastructure development, facility management, business/market applications etc. and many GIS based projects are taken up according to the requirement of user organisation.

Application of Geoinformatics in Fisheries Management:

Bio-resource mapping with remote sensing and Geoinformatics applications naturally points at fisheries studies. Fisheries management has become wedded to biomass as the principal measure of resource status and the key to sustainability is to maintain the geographic distributions of each species. Applications of Geoinformatics in fisheries is so diverse that relevant data can be collected, co-located and displayed in a way as to enhance understanding beyond that which existed before the exercise. Some existing use of Geoinformatics in fisheries management is discussed hereunder.

Resource Inventory:

Coldwater fisheries occupy an important place amongst the freshwater fishes of India. Its importance is even far greater in Himalayan uplands where the coldwater fish species have established themselves as an important candidate for sport and food. The coldwater regions of India are bestowed with valuable indigenous fish germplasm and pristine water resources with tremendous range in their thermal regime. These systems hold large population of both indigenous and exotic cultivable and non-cultivable fish species. The biological productivity in high altitudes is constrained by number of factors; however, in the foothills the biological productivity is quite high which can suitably be harnessed into fish biomass. The per unit production of coldwater fisheries to the total inland production catch is not very significant but it has the natural resources/potentials to contribute to biodiversity wealth of this region and the economy of hill States. Because of the difficult terrain in which these fishes are found, they have not been collected and studied so well as other fishes in the plains. Lack of database on the fisheries resources regard to planning and decision-making for long-term management is the major difficulty faced by many fishery managers. There are certain limitations to collect, analysis, storage and retrieval of data manually, basis which planning are to be made. Therefore, the techniques develop in the recent past to exploit the individual water bodies are necessarily required to implement so that sufficient database can be obtained for management purposes.

Geomorphological Studies

A Reservoir has to assure supply for different specific purposes for which it is designed and created. But irrespective the type of basin it begins to receive sediment, the moment water is impounded. Sediment deposited encroach not only the dead storage portion but also the live storage of the reservoir. The rate of sedimentation in a reservoir and the manner of its deposition are based on various interrelated factors such as physical geological features of the basin, magnitude of runoff, effectiveness of sluicing conditions etc. Siltation from the catchment areas, besides changing the ecology due to construction of dams, has destructed the feeding and breeding grounds of many fishes (Sehgal, 1994). It is estimated that about 5,334 million tons of soil is eroded annually from the cultivable land and forests of India. Our rivers carry nearly 2,050 million tons of silt, depositing approximately 480 million tons to the reservoirs causing eutrophication and reduction in the productivity of the water bodies. Habitat alterations in Himalayan waters have affected distribution and abundance of native fishes in mountain streams of India (Sehgal, 1994; Raina, 1996). According to Jain *et al.*, (2002), remote sensing techniques are being increasingly employed to provide cost and time effective estimation of loss in live storage capacity. Multidated satellite remote sensing data provide information on elevation contours in the form of water spread area. Hence, it helps in determining the new reservoir capacity and establishing new storage-area-capacity curve. Several workers such as Rao *et al.* (1985); Mohanty *et al.* (1986); SPARC (2002) and NRSA (2003) used satellite images to estimate the area as well as capacity loss due to sedimentation. The present study on the assessment of sedimentation rate of Sarda Sagar reservoir has been made in order to make a record of an another use of satellite data than of the Geoinformatics analyses for fisheries. Kumar *et al.* (2001) described the geomorphological changes in Sagar Island through Remote Sensing data. The study shows the considerable changes in geomorphology of Sagar Island. They further reported the usefulness of remote sensing data in order to calculate the area of coastal vegetation and health through Normalised Differentiated Vegetative Index (NDVI).

Aquaculture Site Selection:

Required parameters can be collected from the different locations having known latitude and longitude. The theme of the individual parameter as a distribution map can be made through interpolation and can be used for different modeling purposes (Kumar, 2000). Rajesh *et al.* (2000) studied the temporal and spatial distribution of benthic diatoms in brackish water ponds. Meenakumari and Kumar (2002) described the application of Geographical Information System (GIS) in fisheries including identifying the Potential Fishing Zone (PFZ), Aquaculture Site Selection and Conceptual Modeling. The remote sensing data can be used for establishing the spatial database as Kumar (2000) developed for physico-chemical parameters of water and soil of Sagar Island, West Bengal. Bahuguna and Nayak (1994c) and Bahuguna *et al.* (1995) proposed the suitable site for brackish water aquaculture in coast of Orissa and Andman & Nicobar group of Islands respectively by using IRS LISS II data of land use map on 1:50,000 scale. Engineering, biological, meteorological, socio-economic and infrastructural aspects were considered as criteria for suitable sites. The more weightage was given to conveyance, water supply and seed availability. Kumar *et al.* (2002) selected the Aquaculture Site through Geoinformatics in Sagar Island, Hugli Estuary, Sundarbans.

Development of Decision Support System (DSS) for Aquaculture in Hills

There are certain criteria established for physico-chemical parameters of soil and water that were used for selecting suitable site for aquaculture productivity. Considering the required criteria and according to AHP model, water quality suitability is the most important for assessing site suitability for aquaculture development. It contributes 54% importance and soil quality having 24% where as infrastructure facilities having 22% importance for aquaculture site suitability assessment in this region. Infrastructure facilities were also taken into the consideration before preparing the final suitability map. Based on these criteria suitable sites for aquaculture development in Nainital district was prepared and a front-end tool for production estimation in pond aquaculture was developed. A modeling was carried out with all thematic maps using these criteria which suitable sites for aquaculture in Nainital district. An area of 51112 ha falls in most suitable, 61164 ha hectare as moderately suitable and 13844 ha are found as not suitable for aquaculture development in the region.

Conceptual Design of an Information System

Most operational fisheries forecasting services have adopted a statistical approach to the use of satellite data in fisheries research. This approach seeks to correlate fish distributions with oceanographic features detectable from space and then to make predictions of the probability p of finding species at position x, y based on the statistical relationships established. Statistical or empirical models are driven by data and for this reason they are specific to the location and the system studied. Japanese Fisheries Information Service (JFIS) described empirical models for fisheries resources. The approach can be adopted in other areas also but the statistical relationships that are established to Japanese fisheries may not be relevant to the other part of the world. It is extremely difficult to find statistical relationships that hold well in highly variable environments. This theoretical approach has its emphasis on identifying mechanisms of interaction between organism and environment, allowing cause and effect relationships to be established and used to make predictions that may be better founded than those based on projection of past trends into the future. The level of mechanistic detail required to develop such process-oriented models is usually high and simplifications and assumptions have to be made in order to progress.

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Present Status and Further Scope for the Development of Trout Farming with Special Reference to Sikkim State

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Introduction

On a global level, mountains are the world's largest repositories of biological diversity. Mountain regions are characterized by the presence of cold waters, many of which harbour fish and support largely subsistence fisheries. The farming or husbandry of trout has a relatively long history in Europe and North America. In the Indian Sub-continent two main types of trouts *viz.* brown trout (*Salmo trutta fario*) and rainbow trout (*Oncorhynchus mykiss* (Walbaum)) were transplanted from Europe by British settlers around the beginning of the last century primarily to meet their needs for sport fishing or recreational angling. The transplantation of brown and rainbow trout was attempted independently in the Himalayan and in the non-Himalayan States. In the Himalayan States the brown trout (*Salmo trutta fario* Linnaeus) was first brought in Kashmir through the private efforts of F.J. Mitchell in 1899. These introductions in the hill states could be considered as the formal beginning of Coldwater fisheries or mountain fisheries development in India.

Trout Farming in India

The general concept of trout as a highly expensive fish to cultivate in the farms and as a luxury food beyond the reach of the common man still holds good amongst the fisheries planners. Research and development carried out in India by State and Central organizations during the past three decades have shown appreciable achievements in trout farming practices. Adoption of the techniques that are currently in vague with suitable modifications to suit the prevailing conditions in trout farming of the country has led to achieving very high survival rates in the hatcheries and nurseries as well as the increased production of trout. Development of the some artificial diets based on locally available ingredients resulted in efficient food conversion and enhanced growth. The research in this area has clearly shown that trout farming can be done in this country by achieving high production at moderate cost of feeds. Presently the bulk of trout production is contributed by the Jammu & Kashmir and Himachal Pradesh, while the other hill states like Uttarakhand, Sikkim and Arunachal Pradesh are lagging behind in the trout production. In order to popularize trout production in other hill states, the Directorate of Coldwater Fisheries Research, (DCFR), Bhimtal has made concerted efforts towards the development of location specific trout farming practices. However, there is ample scope for further enhancement of trout production in these states through participatory approach. The present trout production of the country is around 500 tons against an annual demand of around 800 tons, which may increase during the coming decade. Being a low volume high value commodity, the trout has good potential for domestic consumptions as well as foreign export. Presently the rainbow trout has been established in Indian water and is now introduced successfully as a cultivable species having many positive traits such as:

- Trout farming provided excellent opportunity for utilizing the abundant resources of coldwater having the temperature range of 0-25⁰C in different hill states.
- Small scale trout farming provides a great opportunity for livelihood and nutritional security to the hill community.
- Despite of its low production trout fetch a very good market price, thus, trout farming has been one of the highly profitable coldwater aquaculture practice.
- Trout has higher export potential having high demand in international market.

Rainbow trout (*Oncorhynchus mykiss*) is one of the most suitable fish to cultivate in coldwater. It can survive in coldwater having a water temperature range from 0-25⁰C, but perform relatively well for growth at 16-18⁰C. The water temperature range from 9-14 ⁰C is considered suitable for hatchery operation. To grow the trout at commercial scale water volume, quality and constant water temperature play important role. Trout culture is intensive type of farming require more input resources compared to other species for survival and growth. The feasibility of achieving required production naturally depends on a number of factors including seed, feed, health management and environmental consideration. Potential success in trout production requires better governance and significant improvement in the management practices. Therefore, it is necessary to have strategic plan to address technical, social and environmental constraints including:

- Availability of high quality seed at an affordable price.
- Good quality low cost feed.
- Control of disease and health management practices.
- Suitable culture system for efficient use of water resources.
- Development of market channel.

In order to achieve the goal of enhancing trout production, it is quite necessary to focus on improving existing technologies or developing new ones for increased and sustained production. Seed availability is the main bottleneck in the trout production. The transportation of seed is only possible at eyed ova stage therefore, a feasible technology is required to develop for the transportation of live trout seed at fry or fingerling stage. This is important because most of the fish farmer do not have facility for the incubation of trout eggs. Trout feed is also a second most important constraint in increasing the productivity and profitability of trout farming. At present the cost of trout production is high mainly due to high cost of feed. It is a major factor limiting the development of trout farming among the small and marginal farmers. Therefore, the development of low cost feed based on locally available ingredients would be helpful to reduce the cost of feed without reducing their efficacy. Disease plays a key role in sustaining aquaculture. Most of the disease in trout culture belongs to parasite, fungal and bacterial. The main strategy for the health management of trout is required to reduce the level of risk and accelerate the trout farming. Currently the cemented raceways are the dominant culture system for the trout cultivation. It may provide limited opportunity for expansion as it involves high investment cost. Strategy is necessary to develop the other production system such as cages, earthen raceways and tanks at various level of intensity as practices in many other countries, which would help in achieving national goal. Current trout production and demand suggests that there is high market demand for trout. Research is required to study the market demand and supply with projection for the future and how farmer should target consumer group for the future success of trout industry. Therefore, technologies to produce trout at competitive price adding value and regulation to maintain product quality and sanitary standards acceptable to world market are inevitable. Currently the trout farmers have fragmented production units. Strategy is required to promote for collective production and marketing in pocket areas/cluster to ensure that input transportation and delivery of harvested fish to market at a cheaper price.

Trout Farming in Sikkim

Sikkim, the small but beautiful kingdom is situated in the Eastern Himalaya. Sikkim is termed as the Switzerland of the East, a heavenly paradise on earth. It covers an area of 2818 square miles 7325 square kilometers. Geographically it is 28 degree 07' 48" degree and 27 degree 04' 46" North latitude, and 88 degree 00' 58' and 88 degree 55' 25" East longitude. State Fisheries Department of Govt. of Sikkim is associated with Directorate of Coldwater Fisheries Research, Bhimtal under the project entitled "Sustainable Utilization of Mountain Fishery Resources: A Partnership Mode. The Directorate has taken all possible initiatives to promote trout culture in the state considering the suitable climatic condition and abundance of water. As desired to the state, programme on brood stock management and seed production have taken on the priority basis since last four years. Brood stocks of the trout were maintained at State trout farm Uttarey and Yuksom with technical guidance of the Directorate.

Presently, three trout breeding units are functional for production of sufficient trout seed in order to stock in various Govt. farms and supply to the private farmers in the vicinity. This programme has given a boost in adopting technology in private sector, as there are 199 farmers in the state (52 in East district, 72 in West district and 42 in North and 33 in South district) at present compared to 2008-09 when there was only one private farmer in the state.

DCFR, Bhimtal has imparted training on the brooder maintenance, trout breeding and transportation of green eyed ova to the department personnel and farmers. During this year they have produced about 150,000 of eyed ova those are being reared under incubation. Significant achievement is that the state fishery personnel and farmers are made able to maintain the brood stock and bred by their own. The impact of training was observed during the visit of different locations that the farmers have started trout breeding and maintaining good brood stock. Hon'ble Minister of Fisheries (Govt. of Sikkim) is pleased to see the progress and sought for developing 700 more trout farmers in the coming two years.

Role of Nutrition in Aquaculture

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Introduction

Aquaculture is the fastest growing food production sector in India, providing food security and livelihood to the millions of people. Indian aquaculture production increased many folds during the last decade and India has become the second largest producer of freshwater fish in the world after China. It is mainly the carps which contribute maximum to the aquaculture production basket of India. About two decades of research investigations resulted in the development of a high yielding technology popularly known as "Composite Fish Culture" involving a combination of indigenous (*C. catla, L. rohita* and *C. mrigala*) and exotic carps (*Hypophthalmichthys molitrix, Ctenopharyngodon idella* and *Cyprinus carpio*). The principle behind this culture system is the utilization of all available natural food recourses at different trophic levels to achieve maximum production per unit area of water body. But further demand of fish resulted in horizontal and vertical expansion of the industry through semi-intensive, intensive and small-scale aquaculture. The natural food present in the pond is not enough to sustain high fish production, hence supplementary feeding with proper diet is required to get desired production rates. Since culture of carps is mainly under semi-intensive pond culture conditions using relatively low-cost artificial diets, so far, little attention has been paid to the optimization of production under practical conditions. Certainly, such transformations make the role of nutrition more and more important and development of low-cost diets a necessity through nutritional research and management. Nutrition and supplementary feeding play a vital role in sustainable aquaculture and feed constitutes about 40-50% of total cost of aquaculture production and also the use of nutritionally balanced and complete formulated feed will continue to play a dominant role in carp production (Hasan, 2001). The main goal of fish nutrition as a scientific discipline is to produce feeds that support good growth rates while maintaining fish health and quality, resulting in a safe and healthy product for the consumer. Considerable advances have been made in understanding the nutrient requirements of intensively farmed finfish and intensive production offers opportunity for increasing growth efficiency and controlling product quality through correct nutrient supply.

Nutrient requirements:

Protein and amino acids

Protein is the very important constituent of fish diet as major portion of expenditure in feed preparation is incurred on protein sources. The studies on carps revealed that feeding fry, fingerlings and adult ones require correct knowledge of their protein demand as protein requirement ia maximum during fry stage and decreases with the increase in fish size. The optimal dietary protein requirement is affected by the nutritional value of the dietary protein and the level of non-protein energy in the diet as well. When sufficient energy sources, such as lipid and carbohydrates, are available in the diet, most of the ingested protein is utilized for protein synthesis. Adults of carps require 30% dietary protein for proper growth and survival. Fingerlings and fry of these carps require 35% and 40% protein respectively for good growth (Sen *et al.*, 1978). Carps like other animals, do not have an absolute requirement for protein but require a balanced mixture of indispensable and dispersible amino acids (Murthy and Varghese, 1998). Based on the data of whole body amino acid profile of carps (Mohanty and Kaushik, 1991), it is suggested that amino acid requirements of carp species do not vary largely. The quantitative requirement (g/16gN) for the ten essential amino acids as reported by Ravi and Devraj (1991) are presented in Table 1.

Table 1: Quantitative essential amino acid requirement of carps

Amino acid	Requirement	Amino acid	Requirement
Arginine	4.3-4.8	Methionine (M)	3.1-3.6
Histidine	2.1-2.5	M-with 2% cystine	2.1
Lysine	5.7-6.2	Phenylalanine (P)	6.5
Isoleucine	2.5-3.7	P-with 1% cystine	3.4-3.7
Leucine	3.3-3.7	Threonine	3.9-5.0
Valine	3.6	Tryptophan	0.8-1.0

Lipids and fatty acids requirements

Determination of quantitative requirements for essential fatty acids has been difficult with carp. It has been difficult to induce signs of fatty acid deficiency in young carp even after long-term feeding with fat-free diets. Lipids or fats are required as a source of energy and essential fatty acids. Further lipids serve as a carrier for fat soluble vitamins. Fatty acids and phospholipids help to maintain the structural integrity of cell membrane. The gross lipid requirement of carps is 7-8 % of the diet. Carps were found to grow well when the diet contained 1 % n-3 and 1% n-6 fatty acids. The needs of essential fatty acids for grass carp and common carp are reported as 1% 18:2 (n-6) and 0.5-1% of $18{:}3_n$-3 as also 1% 18:2 (n-6) and 1% 18:3 (n-3) respectively. About 4% inclusion of phospholipids (soy lecithin) both in semi-purified diet (Geurden *et al.*, 1995) and practical diets, (Paul *et al.*, 1998) showed beneficial effect on larval rearing of carp larvae. Current estimates show that a dietary supply of 1% of both 18:3n-3 and 18:2n-6 leads to best growth and feed efficiency of juvenile common carp (Satoh, 1991). Essential fatty acids (EFA) needs of grass carp were also recently estimated by Takeuchi et al. (1991) to be in the same range as that found for common carp: 1% 18:2n-6 and 0.5-l% of 18:3n-3. Recent studies with first-feeding common carp larvae fed purified diets appear to show that (a) the requirements for n-3 fatty acids are lower than those generally recommended as above, (b) the quantitative need for n-6 fatty acids is about 0.25% of the diet and (c) a dietary supply of phospholipids is beneficial to common carp larvae (Radtinz-Neto, 1993). Once EFA needs are met through proper lipid sources in the diet, additional fat supply increases the digestible energy values of the diet. Optimal dietary fat levels have been suggested to be below 12% in the practical diets of many cyprinids.

For grass carp, the recommended dietary level of less than 4% (Ding, 1991) is comparatively lower than that for most other teleosts. At any given crude protein level in the diet, an increase in dietary fat content was found to lead to reduced growth and decreased feed efficiency or protein retention in juvenile carp (Murai et al., 1985). While dietary fatty acid composition is reflected without much change in the neutral lipid (triglyceride) fractions, in the phospholipids, fatty acids undergo elongation and desaturation to a greater degree in order to maintain vital membrane functions or increase membrane fluidity (Behar et al., 1989). In this sense, high levels of fish oil in the diets of all fish including carp are recommended to improve the physiological status of fish and to obtain muscle tissue composition rich in polyunsaturated fatty acids (PUFA).

Carbohydrate requirement

Carbohydrate is cheapest nutrient and also a less expensive energy source for carps. Being herbivorous/omnivorous feeders, carps easily digest appreciable quantities of carbohydrate in the diet. A dietary level of 22 – 28% of carbohydrate has been found to be optimum for the growth of Indian Major Carps (Sen *et al.,* 1978). Starch and dextrin are readily accepted by carps. However, in practical diets, wheat flour, wheat bran, rice bran, mustard oil cake, soybean meal, groundnut meal etc are used as cheap sources of carbohydrate in diet formulation. Carbohydrates spare some protein when protein is not available. Absence of adequate dietary carbohydrate in carp diets may results in utilization of protein as an energy source. Unlike mammals, dietary carbohydrate is less utilized in fish because of their inherent low ability to utilize carbohydrate (Roberts, 1989; Lall, 1991), but herbivorous fish like carps have high potential to utilize more carbohydrate in their diet (Kumar *et al.*, 2007). Dietary level of carbohydrate in commercial feed for fish ranges from 5% to 50% depending on the species and life stage (Webster and Lim, 2002).

Energy and P/E ratio

Protein and lipid are primary sources of metabolic energy followed by lipid and carbohydrate. The energy level in carp diet is normally maintained at 3.5-4.0 kcal/g. Under the conditions where energy intake is inadequate fish derive energy first from protein sources at the cost of fish growth explaining the reason for high obligatory needs of amino acids. Excess protein is not only wasteful but also causes stress to fish while excess energy is known to induce lipogenesis. These necessitate to strike a balance between protein and energy in diet formulation and hence the need of optimum dietary P/E ratio. At expected, the carp fry has higher requirement of dietary P/E ratio which is 113 (mg protein/kcal energy) as observed in rohu. The dietary P/E ratio for optimum growth of rohu and catla fingerlings are reported as 95 (Das *et al.,* 1991).

Vitamin and mineral requirement

The research on vitamin and mineral requirement of carps has not been done extensively so far. But we do consider it as a speculative requirement. The vitamins and minerals requirement by carps is represented in table-4 (Murthy, 2002; Lall, 1991). Vitamins are organic compounds which are required in trace amounts and are provided along with minerals as premix in the supplementary feeding. Fish require eleven water soluble vitamin, namely thiamine, riboflavin, pyridoxine, niacin, pantothenic acid, inositol, folic acid, choline, biotin, ascorbic acid cyanocobalamine and B_{12} as also four fat soluble vitamins such as vitamin A, D, E and K.

Table 2: Vitamins and minerals requirements of carps

Vitamins	***Requirement***	***Minerals***	***Requirement***
Thiamine	8-12 mg/kg diet	Calcium	4000-5000 mg/kg diet
Riboflavin	6-8 mg/kg diet	Phosphorus	5000-6000 mg/kg diet
Niacin	10-12 mg/kg diet	Magnesium	500 mg/kg diet
Pantothenic acid	9-11 mg/kg diet	Copper	3-4 mg/kg diet
Ascorbic acid	100-300 mg/kg diet	Cobalt chloride	0.1 mg/kg diet
Pyridoxine	6 – 8 mg/kg diet	Zinc	15-30 mg/kg diet
Vitamin B_{12}	0.01-0.02 mg/kg diet	Selenium	15-30 mg/kg diet
Inositol	300-350 mg/kg diet	Iron	13 mg/kg diet
Biotin	5-8 mg/kg diet	Manganese	13 mg/kg diet
Folic acid	0.5-1.0 mg/kg diet	Iodine	13 mg/kg diet
Choline	500-600 mg/kg diet		
Vitamin A	1500 IU		
Vitamin D	400 – 500 IU		
Vitamin K	5 - 10 mg/kg diet		

The minerals required by fish are calcium, chlorine, magaesium, phosphorus, sodium and potassium along with a number of trace elements such as cobalt, copper, iodine, iron, manganese, selenium, zinc, aluminium, chromium and vanadium. Calcium and phosphorus are closely related in metabolism. About 99% calcium and 80% phosphorus are found in bones, flesh and scales. The ratio of calcium and phosphorous in bone is approximately 2:1. Even marginal deficiencies in some of the minerals, trace elements or vitamins lead to severe morphological deformities and other pathological signs in addition to poor growth of carp. Some information is available on the mineral and vitamin requirements of carps. Mahajan and Agarwal (1980) found that one of the Indian major carps, mrigal, required ascorbic acid at a dietary level of 700 mg/kg diet. Of late, phosphorus (P) requirements (estimated at 0.7% of dry diet for carp), availability and supply have received much attention not only as an essential nutrient but also because of its potential importance in eutrophication, especially in static water culture systems. Availability of P from fish meals has been found to be lower in carp than in the rainbow trout such differences probably originating from the lack of gastric (low pH) digestion in the stomachless carp (Satoh, 1991) With some practical diets which contain low levels of available P, a supplementation is indispensable. An addition of 3% of dicalcium phosphate was found to be necessary to obtain maximum growth of carp fed practical diets containing soybean meal (Viola et al., 1986). Similarly, Takeuchi et al.(1989) demonstrated that increasing the available P level in the diet from 0.5 to 1% led to an almost two-fold weight gain of common carp. However, an excess supply of P has some adverse effects on the availabilty of P as well as of other micronutrients. Satoh et al. (1983) observed that deletion of manganese (Mn) had a much greater growth-depressing effect than removal of magnesium (Mg) , copper (Cu) , zinc (Zn) or cobalt (Co). Although Mn availability from fish meals was high in carp, dietary supplementation was found to be necessary (Satoh et al., 1989). Availability of Mg from fishmeal is also apparently low in carp. Satoh et al. (1983) found that Zn deficiency had much less deleterious effects in the common carp than in the rainbow trout. Excess dietary Zn also will decrease the absorption of Zn by carp (Brafield and Koodie, 1991). The above results justify greater attention to the adequate supply and balance of trace elements in the development of practical diets for cyprinids.

Conclusion

Aquaculture is one the fastest growing food sector and has been contributing to food security and livelihood in the world. Nutrition plays a vital role in aquaculture development. There are many nutritional areas which are yet to be explored such as quantitative dietary vitamin and mineral requirements of many cultivable species of fish and shellfish whish is probably the least studied area in fish nutrition. To ensure sustainability of aquaculture, the development of low cost environment friendly feed should be the main focus of nutritional research. Hence, use of plant and animal by-products as alternative protein sources need to be perfected through research.

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The Declining Food Fish Resources in Lotic Waters of Arunachal Pradesh, India

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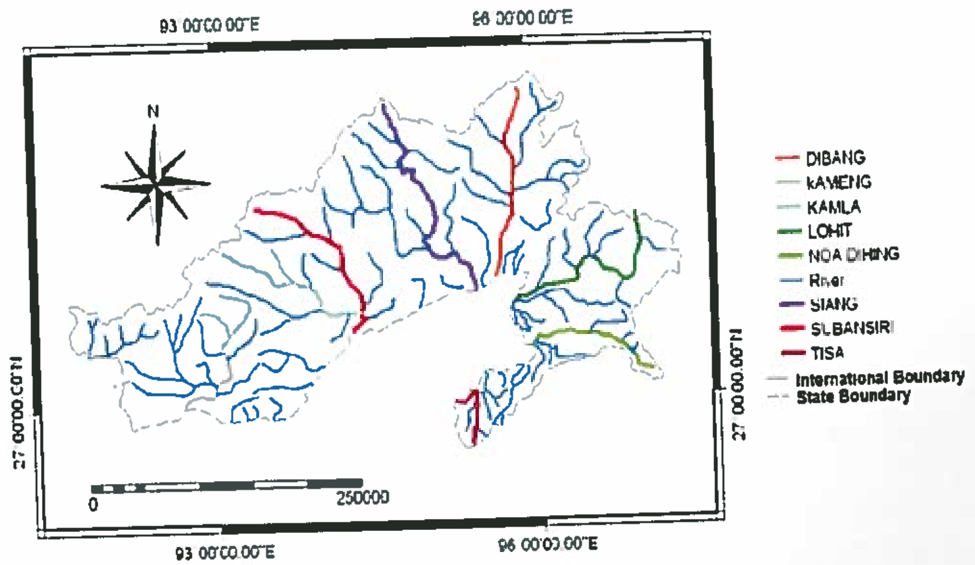
Arunachal Pradesh is the land touched by the first rays of the sun in Indian soil has a 'highly precipitous and varied terrain' which has provided the state distinct identity amongst all other mountainous state of India.In food fish diversity into its vast drainage system also reveals its unique feature of distributional pattern because of altitudinal variation. The elevation of the region ranges from 120 meter (m) on the edge of Assam to above 7000 m above mean sea level (asl) on its northern part bordering China. It is a land of lush green forests, deep river valleys and beautiful plateaus. The land is mostly mountainous with Himalayan ranges along the northern borders criss-crossed with mountain ranges running north-south. These divide the state into five river valleys: the Kameng, the Subansiri, the Siang, the Lohit and the Tirap. All these rivers are fed by snows from the Himalayan ranges except the Tirap which is fed by Patkai range. The land is unparalleled in the world for the concentration, isolation and diversity of tribal cultures it contains. This unique geographical extent of India is blessed with rich floral and faunal diversity for which the region has been identified among the two biodiversity 'hot spot' of the country. It is also one of the last reserves of exceptional biodiversity, which has been preserved for centuries by its indigenous communities, aided by its remoteness and relative isolation. This diversity is attributed to the meeting of different continental plates in the past, which had distinct fauna, and an additional factor, the recent geological history, especially the Himalayan orogeny, which played an important role in the speciation and evolution of groups inhabiting mountains streams. The state is blessed with forest wetlands, numerous rivers, streams and lakes that are home to innumerable species of fishes of which many are endemic to the region. Many fish species available in the region are the part and partial of tribal culture. It plays important role in the socio economic life of the tribal people of the state. In the context fisheries, this mountainous state of India is still at subsistence level where capture fishery is the main activities among the indigenous people.

In recent years the numbers of studies have been carried out on fishery resources of Arunachal Pradesh that expanded earlier facts on the subject from this remotest hilly tract of eastern Himalayan biodiversity hotspot. For example, Nath and Dey (2000) published their pioneering works on systematic account of fish resources of Arunachal Pradesh revealing 131 species in total.Exploration of fish diversity and documentation of fish germplasm resources in Arunachal waters initiated systematically in Rajiv Gandhi University (RGU) under CEP (Biodiversity) programme,UGC, New Delh alongwith ICAR sponsored several such programmes implemented by NBFGR, Lucknow and DCFR , Bhimtal w.e.f. 2002. A fish museum i.e. Rajiv Gandhi University Museum of Fish (RGUMF) has also been established in RGU for the purpose in the year of 2003. A total of 138 fish species were collected and examined from 40 randomly selected stations in 35 rivers (Figure 1) of Arunachal Pradesh and are being maintained in RGU museum of fish. From this total, 111 species were identified and confirmed at the species level, including 16 new occurrences for the state. The remaining 27 species of the total collection are yet to be confirmed at species level. Comparing with previous studies and based on the valid name of both examined and consulted species, the RGU museum documented a current checklist of 213 fish species included in 11 orders, 31 families and 93 genera from the state.The vast inaccessible aquatic habitats with diverse altitude and physiography in near future may add more new fish species along with new occurrences in the state checklists. The inhabitant tribal people are dependent only on the naturally available fish from the lotic waters. So, the fishery practices predominantly being captural type, the people in general indiscriminately exploit whatever species available in the drainage systems as their source of protein nutrients. However, common target remains over larger sized river or stream fishes. For family level consumption most of tribal groups of Arunachal generally perform fishing using their tribe specific local contraptions. However, in connection to festival or recreational community fishing, huge catching of fishes is often done. It is reported that indigenous fishing among the Arunachal people may be of various categories that are governed by socio- cultural festivals, community practices etc., and in most cases this practices were ecofriendly, however, due to transitional impact on social life and increasing family level demands the traditional fishing patterns are mostly internationalized with performance based fishing efforts at all the level where option towards destructive fishing had also been intensified till early part of this decades. Moreover, leasing practices in the lotic water bodies (known as Mahals) had already been initiated either under community or under departmental possession where fishing is allowed for revenue generation. Among the fish germplasm resources available in the wild, Mahseers ,snow trouts, river carps, bagarid catfishes, barbs and eels are most important food fishes in the open water of the state. Besides, a huge population of berrils, catfishes, loaches, nandids & minnows constituted unique piscine biodiversity resources of the state. Many members of these rich populations hold the potentiality to catch the ornamental as well as commercial food fish market of the world if their culture methods are developed. Furthermore, there are certain endemic species still unseen to the rest of the world because of their restricted distribution in the drainages of the state.

Figure 1. Major lotic systems of Arunachal Pradesh, Inda



This captural fishery of Arunachal is now under tremendous threat due to following reasons.

1. Indiscriminate catches by the people as common property resources
2. Habitat degradation and geomorphologic changes in flowing water bodies due to developmental and deforestation activities
3. Illegal means of fishing using electricity, dynamiting and poisoning
4. Erection of bundhs and barrages over the rivers for generation of hydroelectricity

These are the factors that gradually declining the abundances of many food fishes and many fish become restricted with particular drainage system passing through undisturbed rainforests of the state. The decline of food fishes in natural water is a matter of great concern and immediate measure for their conservation and propagation is the need of the hour. Particularly endeavour should be augmented for domestication of some of the wild species .Most justified groups for such efforts will be Mahseers (*Tor tor,Tor puttitora, Neolissocheilus hexagonolepis* etc.,) Snow trouts (*Schizothorax richardsoni, S. progastrus*, etc.,), carps (*labeo pangasia, L.dero, Cirrhinus reba*, etc.,) and barbs (*Semiplotus semiplotus*) at this moment.

On the back ground of above discussion following are some of the priority issues to be under taken immediately for the state

1. Biology and life history strategies of wild food fishes for future domestication
2. Bioecological assessments of species specific riverine habitats for development of hill aquaculture through simulation of environment.
3. Location specific technological refinement of different 'package of practices' of fish farming in hill streams and rivers of Arunachal Pradesh.
4. Domestication of alternative cultivable fish from the wild and production potentials of wild food fishes in culture systems.

Prospect of Coldwater Ecotourism at Manas River

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Bodoland Territorial Council was formed with 4 nos. of districts Kokrajhar, Chirang, Baksa & Udalguri district in 10th Feb/2003 with an area of 8970.00 Sq. Km. having population of 28,55,836 nos. Most of area of the BTC is at the foot hill of Bhutan. The entire forest landscape along the Indo Bhutan Boundary is almost contiguous and its biogeography has Indo-Tibetan Indo-Malayan and Indo-Gangetic influences. The rich biodiversity of this area is attributed to this factor. Out of the entire Forest, Manas National Park is our basic plate form and its suitable Eco system of grass land, three land and water may be utilized for establishing cool water Fish culture with Eco-Aqua-Tourism system.

Manas the Nature's abode is at the foothills of Bhutan with unique biodiversity, landscape and declared as National Tiger project in 1973 and it the biggest resource and asset of Bodoland of Assam. It covers the eastern belt of Baksa and Chirang district. The enchanting beauty of the park spreads across an area of 519 Sq. Km. from Sankosh river Vh/the west and to Dhansiri river in the east with 43 reserved Forest. Manas was originally a Game Reserve since 1928.

Manas National Park is 176 Km. away from Guwahati Airport. It is located at the foothills of Bhutan on the eastern coast of Himalayas Latitude 36°30'N - 27°00'N and Longitude 91°51'E-92°E. The average rain fall is 333 every year and weather temperature ranges from 30°C (Max) and 9°C (Min) in winter. It is rich with wet alluvial grassland, swamp forest, semi Evergreen Forest, Riparian forest and Tropical most and dry deciduous forest with 543 species of Flora, 60 species of Mammals, 350 birds, 42 Reptiles, 7 Amphibians, 54 Fish species and 100 species of Insets as Fauna. The park is a home for major wild animals Elephant, one Horned Rhino, Tiger, wild Buffalo, Deer, Birds etc. and Mohasheer-Puthitor is the major fish Fauna taking the shelter in the water grips of Mother-Manas River having the mosaics of stones.

Manas river eco-system :

The sparking river Manas flows into the National park from the gorges of Bhutan. The river Dang-Me-Chu becomes the picturesque Manas river before entering the Indian side of Manas National Park and drains into the Brahmaputra. Manas river splits into two major streams of which the main course comes out of the National Park about 30 Km. giving rise to river Beki, the down stream part. This river system with stunning natural view, biodiversity and geomorphology earned Manas inscription in the list of world Heritage sites. The culture, peace and tranquility of the people and wild romantic play ground, Life struggle of the wild animals starts on the bank of the river Manas and in water in her core of the stony heart. The culture and wild beauty of Mans is conserved and glaced by the active participation of Bodo Community in Land.

Manas river as cool water fish culture center:

The water floes from Bhutan hills to Manas river and drains to River Brahmaputra. The covering area of Manas river in Manas National Park is about 30 Km. The water temperature is about 4^0C to 9^0C during winter season. About 54 nos. of species of fishes are found in the river Eco-system. Out of the species Mahseer is the major component of fishes available in the river. Eco-system of the river and National Park is suitable for establishing cool water Aquaculture center in Manas National Park which will extended the activities of cool water Aquaculture development in North Eastern Region, generate employment generation and enrich the asset of Bodoland.

Manas river scope for eco-aqua-tourism :

With the establishment of cool water Aquaculture center in Manas National Park Eco-Tourism system can be set up with water sports. Angling offish and river rafting can be introduced for tourist attraction and other device of income and employment generation.

Manas National Park with the bless of river Manas with its resources Green Forest, Wild Animals, Flora Fauna Fishes in the heaven of North East and closing kiss of Bhutan hills has given the rarest gift of nature of Bodoland as well as Assam.

Promotion of Aquaculture Through Carp Seeds Production Under Mid Altitude Condition in Meghalaya

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The state of Meghalaya is rich in natural water resources in the form of rivers, lakes, reservoirs, bheels, pond and tanks for fisheries development. However, these resources are not tapped fully for fisheries and aquaculture development although a great potential exists. The district council or local bodies control some of these water bodies and thus a good coordination between the parent department (Fisheries) and local bodies or other govt. departments is required to utilize these water bodies for fish production.

Table 1. The fishery resources of the state of Meghalaya (Approx)

Sl. No.	Water bodies	Area/Length(Ha/KM)
1.	Rivers & Streams	3329 km.(Approx)
2.	Reservoir	8489 ha .(Approx)
3.	Lakes	41 ha .(Approx)
4.	Bheels	358 ha .(Approx)
5.	Swamps & Low lying area	25 ha .(Approx)
6.	Ponds & Tanks	2500 ha .(Approx)

The state of Meghalaya with 22,429 sq.km area has two drainage systems namely Brahmaputra in the north and Barak in the south. Important rivers of Brahmaputra drainage are Umiam, Kopili, Myntang, Jingiram and Simsang, Kynshi, Umngot and Myntdu of Barak drainage. The state also has a few reservoirs namely Kydermkulai (80 ha), Nongmahir (70 ha), Umiam (500 ha) and Khandong falling in both Meghalaya & Assam (1335 ha). The state is known to harbour 165 fish species belonging to 85 genera under 31 families and 9 orders. Endemic fish species of the state are *Aborichthys garoensis* Hora, *Schistura elogatus* (Sen and Nalbant) and *Mesonemacheilus sijuensis* (Menon). Among the fish species of the state, 2 are reported to be critically endangered, 23 are endangered and 41 are vulnerable. The Umiam is the largest reservoir in Meghalaya, however there is no organized fishery in the reservoir. The common carp, *Cyprinus carpio* is the predominant species that is sustaining the fishery of reservoir, due to its cold-tolerant nature and propensity for auto stocking. *Neolissocheilus hexagonolepis* is an indigenous, cold water and threatened fish species, found in almost all the streams and rivers of Meghalaya. This is mainly a riverine species, also found in ponds, lakes; in fact it is one of the main components of the fishery in Umiam, Kyrdermkulai and Nongmahir reservoirs.

Their growth is faster in the first 6 months period attaining an average size of 14 cms. and thereafter gradually declines. Hence, it takes at least 3 years to reach to a size of 20- 25 cm. It is highly esteemed by the anglers. Compared to last two decades, the catch per unit effort (CPUE) has drastically decreased.

The state of Meghalaya produces about 5000 MT annually against an annual requirement of about 11,000 MT. To meet the requirement, the state imports mostly the fresh water fish from neighboring states, Assam, and Andhra Pradesh, West Bengal etc.

Fish seed is the basic input for any fish culture operations. During the period 2005-06 the northeastern states produced the highest number of fish seeds amounting to 3970.76 million fry. Bulks of these seeds were produced by Assam followed by Tripura and Manipur. Contribution of Meghalaya is very little. However, in past 2-3 years, the fish seed production in the state of Meghalaya has improved significantly with establishment of carp hatcheries in the Govt. sector and at the ICAR Research complex, Barapani. During 2008-09, the state department reported a production of 1.13 million fry. Besides Indian major carps, other species cultured in the poly culture system are Silver carp, Grass carp, Common carp, *Labeo bata, Labeo gonius, Puntius javanicus* etc. Among all the cultured species; Silver carp, Grass carp and Common carp are reported to perform better in composite culture system in the mid altitude conditions. The Fisheries division of the ICAR Research complex of NEH Region at Barapani, Meghalaya in past few years has been making a sincere effort to address the issue of seed availability in order to promote aquaculture for augmenting fish production in the region. The Fisheries division, ICAR RC-NEHR, Barapani which is located at about 900 meter above mean sea level (MSL) produced more than 1 million carp seeds of desirable size for stocking in various water bodies. Unlike the other states in the region, fish breeding season is relatively shorter due to low temperature regime. June -July months are found to be the best for undertaking fish breeding activities under the mid altitude condition. The seeds produced are distributed to the fish farmers at reasonable price fixed by the constituted committee of ICAR.

Scientific fish farming is slowly expanding to newer areas of Meghalaya with availability of required knowledge and fish seeds. Among all the districts of Meghalaya, Ribhoi is the best known district for fish culture activities as the temperature is relatively warmer. Since the Indian major carps do not perform very well in hill aquaculture, there is therefore need to find alternate candidate fish species which can grow well in shorter period of time. In this regard the ICAR at Barapani is making an effort to produce seeds of some of the indigenous minor carps and cold water fish species such as mahseer, *labeo dero, semiplotus* etc. for introducing in the culture system. Further, effort has also been made to introduce the genetically superior common carp variety in the culture system for augmenting overall fish production of the state.

Unfortunately, exotic species of undesirable varieties namely bighead carp *(Aristichthys nobilis)*, Nile tilapia *(Oreochromis niloticus)* and African catfish (*C. gariepinus)* have already entered in the ecosystem of the region. These species were brought in by farmers and seed traders illegally and transplanted in the culture systems. Introduction of these species may cause serious threat on the indigenous species as well as on the legally introduced exotic carps. Further, there is possibility of hybrid fish production between Silver and bighead and, African catfish and Asian cat fish *(Clarias magur)*. If such hybrid becomes fertile, it will cause serious effect on the cultivable and native fish species of the state.

Ecology and Ichthyofauna of Upland Waters of the Brahmaputra Basin

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Introduction

The north-eastern Himalayan region roughly constitute the entire north-eastern part of India comprising the seven states and is situated between 21°57' N and 29°30' N latitude and between 89°46' E and 97°30' E longitude. The area of this region is 2,55,000 km^2 and barring the two valleys of the Brahmaputra and the Barak, is mostly hilly, with an altitude range of 500 to 2000 meters above sea level. The high altitude areas bordering China and Myanmar have temperate climate whereas the rest of the region except the Shillong plateau may be designated as sub-tropical region. The region is a typically rain forest area experiencing heavy rainfall averaging over 400 cm. annually. Naturally, a large number of snow-fed streams and rivers form a network throughout the region. These streams and rivers are the habitat of a large variety of game and ornamental fishes. However, carps form the major fishery in the upland waters of the north-eastern region.

Of late, emphasis is being given to examine the influence of physico-chemical factors on the distribution of aqua fauna, including their structure and function. The flora and fauna of a large river vary widely, and often unpredictably, in its different reaches depending on the terrain through which the river flows and also to several limnological factors. The Brahmaputra River, the seventh largest river system in the world and the largest in the Indian sub-continent, is the habitat of a wide variety of organisms, but their distributional pattern is yet to be properly understood. The river is a major part of the Ganga-Brahmaputra-Meghna basin and, along with its 47 tributaries and numerous flood plain lakes, extends over an area of 5,80,000 km^2 covering Tibet (China), India, Bhutan and Bangladesh. Arising from the Himalayas in Tibet – the youngest mountain range of the world, it is geologically and topographically highly unstable as it experiences intense rainstorms and tectonic movements. Due to these activities the river is characterised by high rates of basin erosion, sediment yield and channel aggradation (Goswami, 1985). This has given rise to severe change in the hydrodynamics of the river along its course, which has an adverse effect on its biodiversity. A good number of an estimated 200 species of ichthyofauna reported from the Brahmaputra system has either disappeared or migrated elsewhere mainly because of the unstable channels of the river in the plains.

Materials & methods

The study area includes the Brahmaputra and Barak drainage systems which almost covers the entire north-eastern part of India. The Brahmaputra drainage system is considered to be the lifeline of this region having a catchment area of over 50 million hectares. The river Barak originates from the Barail range along with a number of smaller rivers and drains water from the western parts of Manipur, Mizoram and the southern parts of Assam and ultimately combines with the Ganga-

Brahmaputra system in Bangladesh. In the catchment areas, melted snow and rainfall combine to provide both the river Brahmaputra and the Barak a constant supply of water around the year. Another drainage system, the Chindwin-Irrawaddy system, drains the plains of eastern and central Manipur and also the excess waters of the Loktak Lake (Biswas, 1978).

Result & Discussion

A general description of the Brahmaputra drainage system: Its topography, geology and climate: The river Brahmaputra (having a total length of 2906 km) along with its 47 tributaries and having a combined length of 4023 km, flows through Tibet (China), India, Bhutan and Bangladesh (Rao,1979). The main river originates from the Kanglung Kang glacier (82° 10' E and 30° 30' N) at an altitude of 4877 m in the Kailash Range of the Himalayas in Tibet – the youngest mountain range of the world. The Brahmaputra (the *Tsangpo* as it is known in Tibet), traverses 1625 km eastward, keeping a course roughly parallel to and about 160 km away from the main Himalayas and then suddenly cuts across the mountains and reaches the Indian territory. The Tsangpo changes its name to Siang or the Dihang after entering into Arunachal Pradesh. This reach of the river from Indo-China border to Kobo in Assam-Arunachal border covers a length of 268 km and the gradient of the river is relatively steeper. At Kobo (27°45' N latitude and 95°30' E longitude), the Siang is joined by two other rivers, namely, the Dibang and the Lohit and henceforth, the combined rivers are known as the Brahmaputra. The river system also supports numerous flood plain lakes, locally called *beels* (wetlands), which are scattered throughout the Brahmaputra basin covering an estimated area of 0.1million hectare. Generally, the monsoon reaches the north-east India around mid-May which is about a month ahead than the rest of the country (Biswas, 1982). The pre-monsoon rain experienced in April-May inundates the low-lying and recharges the wetlands which provide an ideal habitat and breeding ground for a large number of fishes.

The geological history of the Brahmaputra valley indicates that the Brahmaputra is a very young river and its present configuration took shape only during the Pleistocene and recent times. The Brahmaputra valley is rather narrow, the average width is only about 80 km from foothill to foothill, of which the river itself occupies 6 to 19 km (WAPCOS, 1993). During the rainy season there, the river often floods to 8 km wide, rises 9-12 m and deposits the sediments carried down from the mountains. Drastic morphological changes in the river course have taken place in geological time and the river has acquired an intense braided pattern which is attributed principally to the overabundance of sediment load (Coleman, 1969). As the river emerges out of the mountain gorge (the gradient ranges from 4.3 to 16.8 m km^{-1}) and enters the Assam valley, and the gradient of the river is reduced to 0.09-0.17 m km^{-1} near Dibrugarh (Goswami, 1985).

The climate of the study area is sub-tropical. The average annual rainfall over the Brahmaputra basin in upper Assam is around 2300 mm. Nearly 80% of the rainfall occurs during the monsoon months (mid- May to mid-October) and the rest during December-April. The temperature of this region ranges between 10°-35° C and it rarely exceeds 36° C even during the hot and sultry summer months when the relative humidity is more than 85%. As this region falls under the path of the monsoonal winds (both north-west and south-west monsoon), the climate of this region is highly influenced by it. Basically there are three main climatic seasons: – winter (November-February), summer (March-May) and Monsoon (June-October). However there is no sharp demarcation between the summer and monsoon seasons as thunderstorms or cyclones) and pre-monsoon showers in early April is a usual phenomena. Therefore three sub seasons are associated with the summer and monsoon of Assam – Pre-monsoon (March to May), Monsoon (June to September) and Post-Monsoon (October).

Based on habitat preference and tolerance to various physico-chemical parameters of the habitat, fish species of the Brahmaputra basin have been categorized in to six groups – (a) Hill stream dwellers comprising the genera like *Garra, Balitora, Erethistes, Hara, Conta, Amblyceps, Glyptotorax, Olyra* etc. that are adapted to fast current of the torrential streams with higher concentration of dissolved oxygen and low temperature regime found in the upland streams. True hill stream dwellers are typically streamline bodied; possessing adhesive organs for clinging to substratum; (b) Upland pool dwellers such as *Barilius, Danio, Gagata, Psilorhynchus, Sisor, Labeo* and *Tor* found in relatively deeper water characterized by substrates made up of pebble and fine gravel with sand with moderate water velocity. Obviously, these species are being exploited as compared to others.

The commercially important cyprinids available in the hilly region of north-east India are *Barilius barila, B. bendelensis, B. tileo, Cirrhinus reba, Crossocheilus latius, Danio acquipinnatus, D. dangila, D. deverio, D. rerio, Garra gotyla, G. lamta, G. lissorhynchus, G. nasuta, G. rupecola, Bangana dero, L. pangusia, Neolissocheilus hexagonalpis, Puntius clavatus, Raiamas bola, Schizothorax richardsonii, Semiplotus semiplotus ,Tor putitora* and *T. tor.* However, barring *Labeo* and mahseer (*Tor* and *Neolissocheilus*) others form a very insignificant fishery. It was estimated that the total fish catch in the hilly region of the north-eastern states would be about 10,000 t annually (Biswas and Phukon, 1986). The major fisheries of the region comprise *Bangana dero, L. pangusia, Neolissocheilus hexagonalpis, Tor putitora, T. tor* and *Barilius* sp. contributing about 80% of the commercial fisheries in the higher altitudes. Incidentally, almost all of them are cold water species, inhabiting the deep pools of snow-fed streams (Biswas, 1982). Traditionally, fishes are caught by cast net from the pools. In shallow streams, various types of bamboo traps and plant extracts are used to catch small sized carps like *Barilius* sp., *Danio* sp., *Puntius* sp., etc. The catch per unit effort (CPUE) is very low (0.12 - 0.15 kg/hr/head).Traditional means of catching were not as lethal as the carps being a high fecund group, the stock used to get replenished (Biswas, 1994). However, due to certain natural and anthropogenic causes the carp fishery has been depleted alarmingly. But the most disturbing aspect witnessed in recent years is the intentional killing of fishes by using pesticides and explosives. As a result, some of the highly prized carps are fast getting depleted from this region. The depletion in fisheries has been recorded in the Lubha River near Sonapur, Simsang River near William Nagar and Lohit River in Arunachal Pradesh in recent years. The depletion of carp fishery in the upper stretches of Burhidihing and Dikhow River was also reported by Biswas and Michael (1992). Moreover, intentional poisoning and dynamiting cause tremendous loss to the hill stream biota, the restoration of which may not be possible even after several years. Unfortunately, very limited attempts have so far been made to propagate high altitudinal fish species or to stock them in protected water bodies. Lack of expertise is another hurdle to restore the degraded habitats. But, paucity of fund is probably the biggest constraint in implementing conservation policies in the remote and rugged terrain.

Habitat loss, degradation and fragmentation are the most important influencing factors on species depletion/extinction rate. The changes made by hydrologists or engineers on the rivers have left a severe impact on the bio-diversity as there was no advanced knowledge on the hydrological impact of their work on the biological/ecological environment. But now, the scenario has changed due to accelerated knowledge from the biological point of view that biota possess the capacity to regulate water flow through the landscape (Biswas & Boruah, 1997). The evaluation of how and to what extent biotic processes can modify the flow of water, nutrients, sediments and pollutants into an aquatic ecosystem has led to the integration of the two branches of science- hydrology and ecology, thereby providing a new insight into the interrelationship of water and biota. This integrated approach, or ecohydrological approach, creates a new background for the assessment and management of freshwater resources (e.g. river restoration) and accelerates the implementation of new ideas to sustainable development, i.e., elimination of threats and amplification of chances (Zalewski *et al.*, 1997).

As far as artificial propagation of fishes is concerned, very limited efforts have so far been made to breed fish species of high altitude or to conserve them in protected water bodies. Lack of expertise is another hurdle to restore the depleted population or degraded habitats. Fishing is no more a primary occupation of the majority of the population living by the streams. As a consequence of gradual depletion in fishery, most of the fisher folk families have taken fishing as a secondary profession. Fisheries Co-operatives are also virtually defunct in the hilly regions. So it is not surprising that middlemen have the field day as far as control of fisheries is concerned. The need of the hour is a vigorous campaign against the illegal methods of killing fish. Paucity of fund is probably the biggest constraint in implementing conservation measures in the remote and rugged terrain. Regulation of mesh size of fishing net, proper implementation of the Fisheries Act as well as The Wildlife Act, revival of fisheries Co-operative societies and provision of loan and subsidies to the poor fisher folk will go a long way in resting the fisheries and conserving the ecosystem.

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Prevention and Control of Fish Diseases

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Introduction:

Scarcity of water, increase in temperature due to global warming, eutrophication and pollution of the water bodies, contribute to tremendous alteration in the environment of the fish. Such adverse conditions lead to diseases in aquatic environment. Fish diseases can cause severe losses in aquaculture. As coldwater water aquaculture is gaining momentum in the hill states of India, the threat of diseases in fish cannot be ignored. Therefore, fish in this ecological zone might be susceptible to diseases caused by pathogens like fungi, bacteria, viruses, besides protozoan and metazoan parasites. In order to prevent the diseases in the first instance, implementation of effective preventive measures are of prime importance. Some of the important ways of prevention and control are being discussed in this overview.

Prevention of Disease

The concept that "prevention is better than treatment" is fundamental to the maintenance of a healthy stock of fish. Since fish are schooling animals, they are hard to observe individually, making the diagnosis and treatment of disease difficult. In addition, some fish diseases are still essentially incurable. Therefore, preventive measures are essential to the control of disease.

Pond regulation

Pond regulation is effective in improving environmental conditions, preventing disease and raising fish yields. There are two main aspects to pond regulation: pond trimming and pond disinfection.

Rearing management

A reliable person should be responsible for the daily management of the pond (stocking, feeding, disease prevention, etc.). The scheduled feeding procedure, which benefits fish yield and disease prevention, should be used. Variations in water quality must be observed carefully. Pond inspection is essential in the morning, particularly in dismal weather or after a torrential rainfall during the epidemic season (May to September). Besides, it is necessary to remove the weeds along the pond sides and clear the feeding platforms to prevent the occurrence of disease. Netting, transferring, and transporting should be performed with great care.

Disinfection of fish seed

Fish seed can be disinfected during their transfer or prior to stocking. The procedure can be done in a bucket or in a jar depending on local conditions.

Disinfection of feed, feeding platform and equipments

Contaminated or spoiled feeds may introduce pathogenic bacteria to the pond. Leftover feeds, which decompose in the water, facilitate the rapid multiplication of pathogenic bacteria. For this reason, feeds must be stored in dry and ventilated place. Use of prolonged storage of feed should be avoided.

The equipment used during the epidemic season (nets, pails, dip nets, etc.) must be disinfected after each use. Large nets can be exposed to sunlight for 1 or 2 days and wooden pails can be sterilized by immersing them in a quicklime solution or in a 1 ppm potassium permanganate solution for 15 min.

Pond treatment

Spreading chemicals over the entire pond is a common method of disease prevention. Before seed stocking ponds should be cleaned properly and must be disinfected with 1ppm potassium permanganate.

To improve deteriorated pond water, quicklime should be added. This will improve water quality and thus prevent disease. The quicklime chunks should be dissolved in a little water and the diluted solution be stirred and sprayed evenly over the pond.

Establishing a quarantine system

Geographic and climatic conditions can produce epidemic diseases in certain regions. However, as the freshwater farming industry develops rapidly and the transportation of fry and fingerlings among provinces becomes more frequent, local diseases tend to spread. Under such conditions quarantine should be strictly followed and transportation of diseased fish be prohibited.

Diagnosis

Disease diagnosis is the first step toward effective treatment, therefore due care must be taken. The fish must be alive or recently dead and the body must be kept damp. The dissected organs must be kept as complete as possible. Instruments used for post-mortem must be kept clean and disinfected to avoid contamination of pathogens among organs. Distilled water for microscopic observation of the skin and use 0.85 per cent normal saline for microscopic observation of the internal organs. Samples should be preserved for further identification if there is any doubt about the pathogens or the clinical signs. If complications are observed during the diagnosis, diagnose the primary and secondary disease and implement the appropriate treatments separately or simultaneously.

Methods of diagnosis include surveying the pond and examining the fish with the naked eye and microscopic examination of suspected material.

Survey the diseased pond

Determine if the water source is seriously polluted. If it is, find the source of the pollution. Observe the behaviour of the diseased fish and take an inventory of the rearing status (pond clearing, stocking density, feeding, preventive methods, and mortality, etc.).

Naked-eye observation

Body- Put the diseased fish on an enamel ware plate and examine the head, eyes, gill cover, scales, and fins for visible pathogens such as nematodes, *Argulus, Glochidium*, and *Saprolegnia*. It is also possible to see the pathogens of bacterial erythrodermatitis, albinoderm, stigmatosis, and furunculosis with the naked eye.

Gills- Inspect the gills, with an emphasis on the gill filaments. Observe the colour of the gill lamella, the quantity of mucus, and the congestion and putridity of filament tips after an opercular incision is performed. Normal gills will appear bright red colour and healthy.

Internal organs- Mainly check the intestines. Begin to observe abdominal hydropsy and visible parasites, (e.g., *Ichthyoxenus, Nematodes*, cysts of *Myxosporidia, Ligulos*, then observe other internal organs. Extract the internal organs with a knife and scissors and separate the liver, gall bladder, air bladder, etc. Finally, open the intestine to search for any signs of pathological change.

Microscopic examination

Normally, only the skin, gills, intestines, eyes, and brain need be observed microscopically.

Skin — Scrape a little tissue and mucus from the skin, put them on a slide with a drop of distilled water, and observe the combination under a microscope after pressing with a cover-slip. One should always start with the low power objectives. Samples from at least three different points on the skin should be inspected. Common parasites on the skin are *Trichodina, Ichthyophthirius, Chilodonella, Costia, Glochidium*, and *Myxosporidia*.

Gill — Place some gill filaments and mucus onto a slide. The following parasites may be identified through microscopic observation: *Dactylogyrus, Gyrodactylus, Cryptobia*, and *Myxosporidia*.

Intestines — Transfer a little mucus from the anterior intestinal wall to the slide. Nematodes, *Eimeria*, and *Myxosporidia* may be seen.

Eyes- Observe the eyes for presence of cataract and other moving objects. Press the entire ocular bulb or crystalline body on the slides if cysts of *Diplostomum* are seen, it is an indicator of diplostomiasis.

Brain- Open the central cavity of a fish with whirling disease. White cysts of myxosporidia in the lymphatic fluid beside the brain will be observed. Remove the cysts and place them on a slide. After crushing with a cover slip, the spores can be seen.

How to cure a diseased fish?

Selection of Chemotherapeutic agents: While choosing a treatment following important criteria should be taken into consideration:

- Fish Species to be treated
- Age group of the fishes
- Economics
- Detail about critical tolerance limits, toxicity of the medicine/chemical

Methods of treatment

In order to effectively control the health problem, desired dose of therapeutics could be given in three ways e.g. (i) adding medicine in the water (ii) through feed (iii) through injection. First method is again divided into flush, dip, bath and pond treatment.

Flush Treatment

Higher concentration of chemical is added at the inlet or incoming water site and allowed to pass through the tank. Uniform distribution of chemical depends on the flow of water.

Dip Treatment

In this method fishes are collected by net from the tanks or nurseries and dipped for 1-3 minutes in high dose of medicine and released back in tanks. In this process, attached parasites detach from the body and get killed. Dip treatment is extremely useful in small fry and fingerlings facilities.

Bath Treatment

Employed in small experimental tanks under controlled conditions and after adding chemical/ medicine left for specified time. The fishes are kept under observation and as soon as fish shows stress symptoms, either fresh water is added or fishes are taken out from the tanks and released in freshwater.

Pond Treatment

In bigger grow out fish ponds smaller dose of chemical/medicine is used. This method although widely used however before application of medicine economic return of the fish pond should also be taken care of.

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TECHNICAL SESSION

Day 1
24 March 2012

12.30–12.40 hrs	Introduction to DCFR	:	Dr. P.C. Mahanta, Director, DCFR
12.30-13.30 hrs.	***Technical Session-I Resource Management***		
	Chairman	:	Dr. P. Das
	Co-Chairs	:	Dr. M. Sinha Dr. Krishna Gopal
	Rapporteur	:	Dr. Dandadhar Sarma
12.40-12.50	Theme presentation	:	Dr. Prem Kumar
12.50 – 13.00	Invited speaker	:	Dr. W. Vishwanath
13.00-13.10	Invited speaker	:	Dr. Krishna Gopal
13.10-13.20	Invited speaker	:	Dr. J.T.Gergan
13.20 – 13.30	Invited speaker	:	Dr. B.C. Jha
13.30-14.30	Lunch Break		
14.30-15.30	***Technical Session-I Discussion contd...***		
15.30-17.30 hrs.	***Technical Session-II Upland Aquaculture***		
	Chairman	:	Dr. Dilip Kumar
	Co-Chairman	:	Dr. M.L.Bhowmik Dr. M.M.Goswami
	Rapporteur	:	Dr. Dipjyoti Baruah
15.30 - 15.40	Theme presentation	:	Dr. Debajit Sarma
15.40 – 15.50	Invited speaker	:	Dr.A.K.Sahu
15.50 – 16.00	Invited speaker	:	Dr. S.K.Das
16.00 - 16.15	Tea break	:	
16.15 – 18:00	Discussion		
19.00	Dinner		

Day 2
25 March 2012

9.30 -11.30	***Technical Session-III*** ***Nutrition, Disease & Biotechnology***		
	Chairman	:	Dr. S.D. Singh
	Co-Chairman	:	Dr. M.K. Das
	Rapporteur	:	Dr. R.N.Bhuyan
09.30-09.40	Theme presentation (nutrition)	:	Dr. M. S. Akhtar
09.40-09.50	Invited speaker	:	Prof. U.C. Goswami
09.50 – 10.10	Discussion		
10.10 – 10.20	Theme presentation (disease)	:	Dr. S. Ali
10.20- 10.30	Invited speaker (disease)	:	Prof. Debasish Kar
10.30 – 10.40	Invited speaker (disease)	:	Dr. Manas Kumar Das
10.40 - 10.50	Discussion		
10.50 – 11:00	Theme presentation (biotechnology)	:	Dr. P. K. Sahoo
11.00 - 11.20			Dr. Mukunda Goswami
11.20 – 11.30	Discussion		
11.30-11.45	Tea		
11.45-13.00	***Technical Session-IV*** ***Fish Based Eco-tourism***		
	Chairman	:	Dr. M. Sinha
	Co- Chairman	:	Dr. Usha Moza
			Dr. J.R.Dhanze
	Rapporteur	:	Dr. B.C.Bora
11.45-11.55	Theme presentation	:	Dr. Atul Borgohain
11.55 –12.05	Invited speaker	:	Dr. P. Nautiyal
12.05 -12.15		:	Dr. M.H.Balkhi
12.15-12.30	Discussion		
12.30-15.30	***Technical Session-V*** ***Human Resource Management and Livelihood Security***		
	Chairman	:	Dr. C. Vasudevappa
	Co- Chairman	:	Dr. K. Kalita
	Rapporteur	:	Dr. Rupak Nath
12.30 - 12.40	Invited speaker	:	Dr. J.R.Dhanze
12.40 – 12.50	Invited speaker	:	Dr. B.K. Bhattacharya

12.50 - 13.00	Invited speaker	:	Dr. S. P. Biswas
13.00 - 14.00	Lunch Break		
14.00 - 14.10:	Invited speaker	:	Dr. D. N. Das
14.10- 14.30	Discussion		

14.30 – 15.30: Summary Session and Recommendation

Day – 2 SPECIAL PARALLEL SESSION: 11.00 – 13.00 hrs

"Best Paper Presentation Award For Young Researchers"

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