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किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद
Agrisearch with a human touch

Bulletin No. 19

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भारतीय कृषि अनुसंधान परिषद
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Message

Northeastern Himalayan region of the country is endowed with a rich aquatic biodiversity and the availability of fishery resources in terms of gene pool is diverse. Fish is mainly used as food, while a few of them are used for sport and ornamental purposes. In this context, documenting aquatic resources and biodiversity in hill states and generating information on ecosystem functions for developing ecologically sustainable strategies for fish yield enhancement are essential.

In this context, the bulletin *Coldwater lakes and rivers in Arunachal Pradesh, India* would be repository in order to draw strategies to develop the coldwater fishery of the region. The authors deserve appreciation for their efforts.

(S. Ayyappan)

Dated: the 16th March 2012
New Delhi

Dr. B. Meenakumari
Deputy Director General (Fy.)

Indian Council of Agricultural Research
Krishi Anusandhan Bhavan-II, Pusa
New Delhi -110 001

Message

Arunachal Pradesh is blessed with greenery and has been a hotspot of diversity of plant and animals and is characterized by the hilly terrain with a number of high altitude lakes and criss-crossed by plentiful rivers/streams. The low productivity of riverine system is due to steep gradient of the river coupled with strong current. The Himalayan aquatic resources, once considered inexhaustible are now showing the effects of indiscriminate exploitation of fishery resources in terms of unavailability of catches in many parts of the streams. The Directorate of Coldwater Fisheries research has taken works on priority basis to develop the riverine fisheries in the state through ecological studies of rivers in the state that would intern in estimating production potential of the rivers in order to harness rationally.

The effort of the Directorate in preparing the Bulletin "Coldwater lakes and rivers in Arunachal Pradesh, India" would help in developing location, situation and need specific technologies in the state.

(B. Meenakumari)

Foreword

Arunachal Pradesh is having wide variations in geological structure; aquatic habitats are also distributed in variable climates in accordance with the changed altitude ranging from 100m to 7000 m above msl. Therefore, fishery activities in Arunachal Pradesh are grouped accordingly in three distinct ecological zones based on land physiography and climate. These are lower altitude or tropical zone extends upto 300m from the mean sea level covering the foothills and plains with warm water aqua resources bordering Assam and Nagaland. The middle altitude or subtropical zone includes areas within 300-1200 m of msl having maximum fish diversity with both cold and warm water aqua resources of varying production level i.e. mid altitude fishery, the high altitude or alpine zone including the areas above 1200 m of msl i.e. suited ideally for coldwater fishery. Numbers of tributaries of six major rivers along with network of hill streams and rivers of the state drain in to the mighty river Brahmaputra and the rest drain in to Irrawaddy river drainage of Chindwin basin.

The Directorate of Coldwater Fisheries Research, Bhimtal has taken several efforts to develop the coldwater fisheries sector in Arunachal Pradesh. In this bulletin, a review has therefore been made upon different research activities carried out in the state of Arunachal Pradesh regarding analysis on the status of resources, level of productivity in lakes and rivers, potential, scope and future needs of R & D for sustainability. This document will become a knowledge base and an indispensable reference to the scientist, academician, teachers, students and other stakeholders to understand the coldwater fisheries of the state.

(P. C. Mahanta)
Director, DCFR

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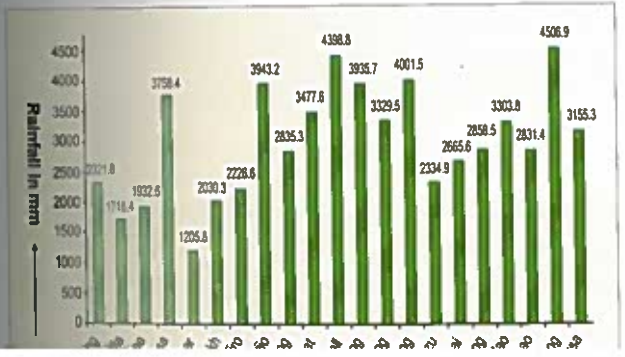
Mehao lake and Ganga lake, Arunachal Pradesh

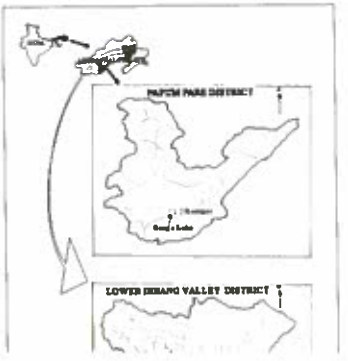
1. Mehao lake and Ganga lake

1.1. Background

The hill area development is now being given priority in India. Indian uplands, particularly the Himalayas, are bestowed with a great aquatic wealth. The investigations on the bioecological productivity of the upland lakes holding the coldwater biotic communities have been receiving much attention recently in Kashmir, Himachal Pradesh and Uttaranchal but such studies on the upland aquatic resources from the North Eastern Himalayas is lacking and deserves special attention as the needs of the day. The high mountain ecosystems are unique in biodiversity which can serve as conservation sites for indigenous fish species and development of their farming technology which can support the nutrition and food security for the people living in those areas. The state of Arunachal Pradesh (Lat. 27^0 and 29^0 $30'$ N and Long. 92^0 $8'$ $57''$ and 97^0 $12'$ E) located in the extreme east of India with an area of 83743 Km^2. Of this area about 79,000 Km^2 forms the Himalayan part.

Arunachal Pradesh lying within the high precipitation (Fig. 1) zone is blessed with vast and variety of aquatic resources manifested in the forms of streams, falls, rivers and lakes. Amongst several coldwater lakes of the state, Mehao lake in lower Dibang Valley district (Fig. 2) and Ganga lake in Papum Pare district (Fig. 2) are two such water bodies where hardly any work undertaken in the context of lake limnology, fish production potential, resource dynamics etc. The Mehao lake lies at altitude of 1680 m asl and is located in the midst of





dense forest area of famous "Mehao Wild Life Sanctuary" and is situated at a hilly trekking distance of 8 hours (13.4 Km) from the human vicinity. On the other hand, Ganga lake (approx. 2.5 ha) is situated at the middle altitude (approx. 650 m asl) surrounded by semi-urban settlement of Itanagar. In regard to origin of the lakes both are natural lakes of tectonic origin and are sites for tourist attraction. Thus, the proposed study sites are comparable because one of the lakes is situated totally undisturbed high mountain temperate forest area and the other is located in close vicinity to urban area. Thus the proposed research project aims to study the ecology of the lakes, the status and sustainable utilization of biotic communities in the lakes and the future prospect of sport and food fisheries in the lakes.

1.2. General features of lakes in mountains

1.2.1. Types and origin

The lake may be defined like this "A large body of standing water which lacks continuity with the sea water". Geomorphologic formation of such water body may be of various types. On the background of altitude over earth crust Lakes may be categorized mainly as: Coastal Lakes, floodplain lakes and mountain lakes. These lakes ecosystem are prime example of lentic water system. Generally lakes may be formed in a variety of ways on the earth crust, the oldest and largest lake systems are the result of tectonic activities (Fig. 3), which may be found in any places of the earth crust. Tectonic lakes are formed by the movement of deeper portion of the earth crust which is an outcome of a process called faulting that occurs between the bases of a single fault displacement or down faulted troughs. This trough formation is the mode of origin of many of the most spectacular relic lakes of the world (eg. Baikal of eastern Siberia the deepest lake in the world). These processes of formation are referred as graben. The formation of the minor depression due to movement of tectonic plates also formed lakes both in mountains and flood plain areas and the cause of this type of formation are due to localized subsidence that result from earthquake activity. Many of this depression are dry or temporary water logged depending on the porosity of the basin material while others become permanent lakes usually open basin with outlet drainage. These tectonic lakes are not as deep as graben lakes.

Glacial lakes (Fig. 4) are common in mountain areas, the grinding weight and pressure of encroaching and retreating ice sheet curved much depression in earth surface where melting ice then connected to form lakes. When ice sheet moves flat rock surface with weaken areas of fissures, the rock could splinter and loosen to form the basin of "glacial scour lake" (eg. Great lakes in USA and Canada). Glacial lakes are often surrounded by other geological evidence of glacial scour. When glacial scour action form circular depression in a mountain valley is termed as "Tarn" or Cirque Lake. Occasionally a stream of Cirque Lake form "paternosters" Lakes in adjacent mountain valleys. These lakes are often extremely clear, cold and sensitive to environmental disturbance. Moraine lakes are also another form of glacial depression due to erection of bunds by glacial concentration of rocks and soils. The Moraine lakes may be kettle lakes sometimes referred as pothole lakes which are very common in Himalayan region. Periglacial lakes form when ice shapes part of lake margin restricting otherwise natural drainage of landscape (eg. Lake of Vostoc of Antarctica). Fjord Lake can also be formed from action glacier curving steep fjord valleys and depositing rocks, boulders, soils-Moraine-at one end of the valley forming a lake. In mountains volcanic activity indirectly controlled by tectonic activity can also create lake; such lakes are Maar lake, Crater lake etc. However in eastern Himalayan region these types of lake are hardly found. Besides lakes are also formed by river erosion particularly in connection to collection site of waterfalls and also by depositing sediments forming dams in the tributaries or streams. Another type of lake formation is caused due to bending of river course in floodplains as ox-bow lakes. However in Himalayan Mountains this ox bow lakes or fluvial type lakes are found rarely. In hilly mountain, lakes may also be formed because of dissolution of limestone deposit by slightly acidic water; these may also be called as solution lakes, which may occur in surface or below ground in the caves. Besides similar type of lake formation in limestone deposit may occur which may be termed as sink holes, cenotes or carsts on the basis of types of the mountain bedrocks where they form.

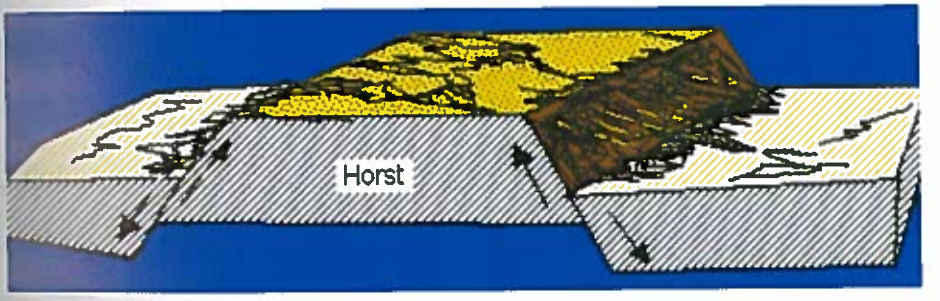
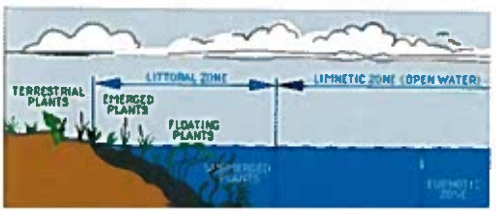


Fig. 4: Formation of lakes by glacial activities

ancient lakes with endemic fauna, Volcanic lakes, Meromictic lakes and Polar lakes. In the former series lakes may be Oligotrophic when these are deep with hypolimnion larger than epilimnion and have low productivity showing scarce littoral plants and low plankton density due to low nutrient content. Oligotrophic lakes are considered very young geologically, Ecologist use the term Oligotrophic to distinguish unproductive lake. The 2nd category in this series is Eutrophic having shallow depth and high productivity encompassing abundant of macrophytes, plankton and periphyton due to presence of excessive nutrients especially phosphorous and Nitrogen. Intermediatory of this two are termed as Mesotrophic lakes with optimum organismal population, optimum nutrients, and density of primary producers. Under the special lakes types Dystrophic lakes are those, which are either deep or shallow rich in humus, poor in oxygen content, animal population is represented with insect larvae which are frequently found in mountain region. The Meromictic lakes are characterized by periodic mixing of bottom and surface water and instead of thermocline nature of other lakes these lakes are characterized by chemocline nature and oxygen and aerobic organism are absent in bottom water. On the other hand volcanic lakes represented by restricted biota because of extreme chemical condition. The Polar lakes shows the surface temperature always below 4°C but for a short period may raise above it with rapid growth of plankton population.

1.2.2. Zonations in lake

A typical lake has distinct zones of biological communities linked to the physical structure of the lake. The lakes in mountain having negligible anthropogenic interaction are generally considered as stable and divided into three zones. The physical structures of zone are made either with reference to depth of water and availability of light (Fig. 5A) or thermal behavior of lake (Fig. 5B) water (thermal stratification) with the seasonal change. However, the physical strata are the indicators for distribution of life forms. With reference to depth of water and light penetration, respectively these are **littoral zone** with more light and shallow depth of water, **limnetic zone** where light penetrates upto certain depth into its open water stretches and profound zone having bottom and deepwater area beyond the depth of effective light penetration .The littoral and limnetic zones together is called as **euphotic zone.** The thermal



stratification of lake water shows the layer of **epilimnion** at it surface with warm and circulating water, **hypolimnion** at bottom having completely non-circulating cool layer. In between these top and bottom a transition zone is present which is termed **as thermocline.**

1.2.3. Bio ecology and trophic status

The bio-ecology of the lake is directly dependent on the general water chemistry of the lake that influence the availability and distribution of the life forms. The water chemistry of any lake is fundamentally a function of its climate (which affects its hydrology) and its basin geology. Therefore, fundamental aspect, which needs proper characterization, is the rate of nutrient supply (bedrock geology of the watershed, soils, vegetation, human land uses and management), Climate (amount of sunlight, temperature, hydrology including precipitation and lake basin turnover time) and lake morphometry (ranges of depth, volume and surface area and watershed to lake surface area ratio)

The interacting factors which forms both biotic and abiotic environment of the lake and govern the energy trapping and flowing through the ecosystem and thereby determines over all status of the ecosystem is termed as bio-ecology. The trophic status in terms of energy is dependant on respective structural and functional attributes of primary producers (autotrophs) and consumers (heterotrphs) and material recycling through the actions of decomposers colonised in the lakes (Fig. 6). Human endeavour is to tap these functional resources and channelize the available energy to flow towards the autotrophic or heterotrophic productivity implementing a management protocol after exploring the status. If lake ecosystems are used for fishery activity, then pisciculture management protocol would set the optimum flow to cultivable species of fishes targeting their growth and development in the system.

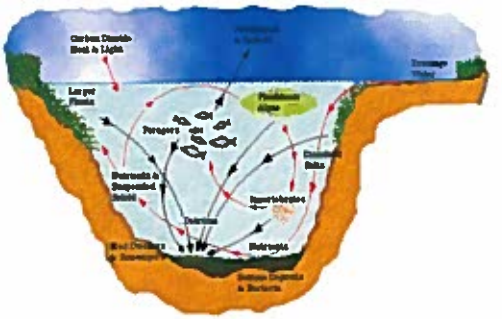


Fig. 6: Typical food web in a mesotrophic lake

1.3. Mountain lakes in Arunachal Pradesh: An overview

Arunachal Pradesh is the easternmost state of India with geographical area of 81,424 sq km. A total 1672 high altitude lake were delineated (Fig. 7). The total area under these lakes is 11863 ha, accounting for about 7.6 per cent of total wetland area of the state. Maximum numbers of lakes are small in size i.e. below 10 ha. There are no lakes of very large size (>500 ha) in the state. Altitudinal distribution pattern of these lakes showed that highest concentration

hardly been attempted to explore till today probably due to inaccessibility and principally for their occurrence in the border line of the country. Certain major lakes found in these two districts of Arunachal Pradesh are given below in Table 1(a). However, the lake Mechuka (1090 m amsl) of West Siang, Lake shally and Mehao of Lower Dibang Valley and lake Geker Sinyi or Ganga lake (plate II) of Papume pare are quiet accessible to human interaction. However, the lake Mechuka (1090 m amsl) of West Siang, Lake shally and Mehao of Lower Dibang Valley and Lake Geker Sinyi (commonly known as Ganga lake) of Papume pare are quiet accessible to human interaction (plate III). Besides these, Lake of No Return (Nawng Yang in Burmese) having body of water partially in Changlang district (at India-Burma border south of 'Pangsau'or Pansaung village) of Arunachal Pradesh and rest in Burma, lying in the area of the Pangsau Pass (1243m asl). The lake is 1.4 km in length and 0.8 km in width in its widest part. It is located 2.5 km to the southwest of the Ledo Road, formerly called Stilwell Road- the road the Western Allies started building in 1942 to supply the Chinese armies of Chiang Kai-shek. So, far it is known, the lacustrine system of Arunachal Pradesh has hardly been studied earlier by any of the scientific organizations of india stil. Further, there exists only scanty information regarding the bio ecology as well as tourism potentials respectively in view of fisheries and aesthetic context.

Table 1(a): Lists of major lakes along with their area (approx) & altitude from Tawang and Upper Siang, Arunachal Pradesh

Tawang			Upper Siang		
Name (No./s)	Approx. area(ha)	Altitude(m above msl)	Name (No./s)	Approx. area(ha)	Altitude(m above msl)
a) P.T Tso(2)	3-4	4333	a) Sinang	-	-
b) Sangeswar /Jongeswar (1)	4-5	4000	b) Pegu	0.3	960
c) Nakia (4)	4-6	4667	c) Gamin jiji	1.5	860
d) Saikio (1)	5-6	4667-5000	d) Yungar	NA	817
e) Bhimghar (1)	3-4	4667	e) Bone	NA	1126
f) Y-junction (6)	5-6	4667	Sereng	NA	800
g) Khelmata(4)	10-12	4667-5000	f) Ajor	NA	990
h) Nagula/ Gripehang (2)	5-8	3667-4000	g) Luying	NA	780-1200
i) Gessilla (1)	3-4	3334 -3667	h) Simar sigum	NA	780-1200
j) Lengme (1)	1-1.5	3334	i) Rueng	NA	780-1200
k) Bangjang(6)	10-20	4667-5000	i) Bopu	1	600-800

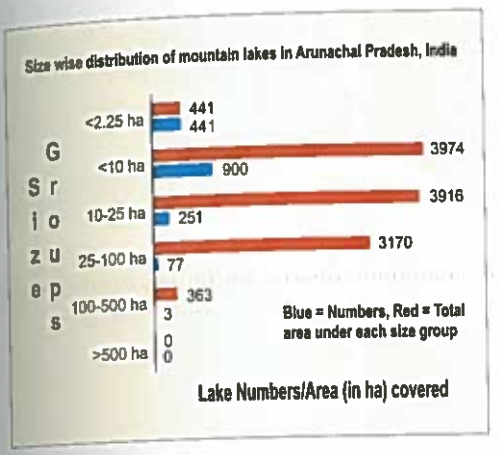


Fig. 7: Statistics of mountain lakes in Arunachal Pradesh, India

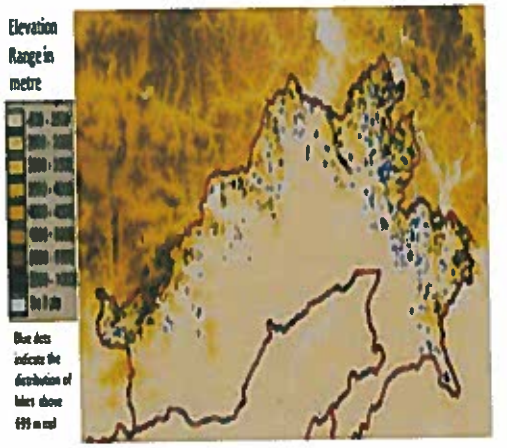
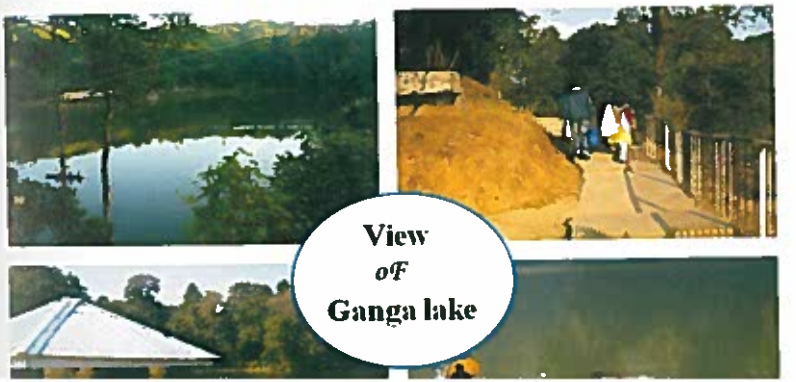


Fig. 8: Distribution of mountain lakes in Arunachal Pradesh, India

1.3.1. Origin of the study

The high mountain ecosystems are unique in biodiversity which can serve as conservation sites for indigenous fish species and development of their farming technology which can support the nutrition and food security for the people living in those areas. The state of Arunachal Pradesh (Lat. 27^0 and 29^0 $30'$ N and Long. 92^0 $8'$ $57''$ and 97^0 $12'$ E) located in the extreme east of India has several mountain lakes like Ganga lake (Plate 1) in Papum Pare district and



Mehao lake (Plate 2) in lower Dibang Valley district and were not ever studied for bio ecology of fisheries potentials. Thus the proposed research project was carried out to study the ecology of the lakes, the status and sustainable utilization of biotic communities in the lakes and the future prospect of sport and food fisheries in the lakes.

Plate 2: View of Mehao lake

1.3.2. Definition

Most of the available natural lakes in the state are geographically isolated from the natural fish habitats and not being used to enhance fish production because of the lack of basic ecological information on them. The physico-chemical dynamics of any water body has bearing on the choice of fishes to be grown with good growth and survival. Also, the status and constituents of plankton communities and the benthic organisms has direct impact on the fish production of the lakes. As an example, the hypothesis mentioned was tested on Mehao lake and Ganga lake.

The general objective of the study was to conduct bioecological study based model for fishery enhancement in the coldwater lakes located in Arunachal Pradesh.

2. Methodology

2.1. Locations of lakes under study & land topography

The altitude and coordinates of study sites were recorded with Global Positioning System (GPS) (Garmin eTrex Legend). However, Altimeter was also used in few locations where GPS navigation was obstructed by various factors and to cross check the altitude reading of

2.2. Bio-ecological status

The studies on bio ecological status of lake included the following preliminary aspects of both the lakes under investigations. During the project period standard procedures and recommended field equipments were used for generation of relevant data from the ecosystem from time to time.

2.2.1. Physico chemical properties of lake water

Surface water sample for determination of Dissolve Oxygen (DO) was collected in BOD bottle carefully from each selected study sites after spot fixation as per winker method (APHA, 1998). Besides, multipametric water analyzer kit (Systronics water Analyser371) was used for direct data collection on surface DO, $_{p}$H, temperature, conductivity etc., mainly from the surface water depth of the lakes where water temperature was also recorded using the mercury thermometer. For determination of Alkalinity, Hardness, pH of water 2.5 liters of water sample was collected from each study sites every month continuously for a period of two years (2008 and 2009). Transparency of lake water was determined following Sacchi disc (20 cm in diameter, painted with black and white quarters) method, which was lowered into lake water from boat carefully until it disappeared from view and then lifted till it reappeared. The distance between the surface layers of water to the last visible point under water was recorded. Transparency of lake water was measured every month continuously for two years from each study sites. Besides these, nitrate and phosphate levels of lake water were measured from the collected sample with same time interval in the laboratory following standard methods (APHA, 1998).

2.2.2. Plankton, periphyton and macro-organisms

Plankton though constitutes an important food item in an aquatic ecosystem but has lesser impact in upland lakes. In this study plankton in lake habitats were not considered, but the lake habitat has been examined for the occurrence and abundance of plankton. The samplings were done following standard methods (APHA, 1998) and the sampling periods were similar to other studied ecological parameters as described earlier. Planktons were collected by a truncated cone shaped plankton net made of bolting silk. At each sampling, fixed quantity of water (50litres) was filtered gently through the net. The concentrates were preserved in sampling tubes at 3% formalin concentration. Phytoplankton and zooplankton counts were made using 'drop count method'. All possible efforts were made to identify the microscopic organisms up to the genera level only. A single colony in case of colonial forms, a single filament in a filamentous forms and a single organism were considered as single unit. The phytoplankton and zooplankton were identified and finally the counts were computed on unit per litre. The periphyton is an assemblage of bacteria, filamentous algae, diatoms and animalcules including

samples were then preserved in 3% formaldehyde. The samples were allowed to settle for 24 hours and the supernatant solution were decanted and volume was recorded. The settled portion were then suitably diluted and counted using standard methods (Edmondson, 1992). Besides, qualitative observations were taken on macro invertebrates like, larval forms of aquatic insects, various crustaceans, annelids, moluscs etc., during each visit to each of the lakes and their level of abundance is expressed as unit/m^2 following standard methodology of enumeration. Some othese macro invertebrates were found in the benthic samples of the lakes taken mostly from littoral zones.

2.2.3. Benthic community

The organisms are collected randomly but mostly in the littoral and occasionally in profundal zone of the lake wherever possible. Identification of the collected samples was made using standard manuals on the subject. The information is expressed as unit/m^2 qualitatively for seasonal abundances based on the groups encountered because of the frequent confusion in genera or species level identity being larval/nymphal forms.

2.2.4. Primary production

It was estimated using Gaarder and Grans's method of primary productivity where 'light and dark' bottle is the technique for estimation. It was carried out in both lakes but sequential estimation per month was done only in Ganga Lake for the whole study period. The exposure time was maintained 4 hours and usually after 10.0 A.M. For measurement of DO (mg/l), in addition to normal titrametric method (APHA, 1998), standard DO meter (Cyberscan –DO 300) was also used to verify the accuracy of the titration.

2.3. Fishery status and assessment of production potential

Fish specimens were collected from lakes using cast net, gill nets and electro-fisher. The cast net having dimension of 5 m diameter, 2.25 m length and 10-15 mm mesh was used frequently. The gill nets were 15 to 25 m length having 35 to 60 mm mesh size. The electro-fisher used for the fishing operation was an electric generator fuelled with diesel oil and was fitted within a small country boat. Cast netting was performed randomly in the lakes mostly at the sites of pebble substratum or muddy bottom. Gill nets were fixed along the lakes mostly at the sites with less disturbance and stand still. During sampling the gill nets were fixed at various suitable sites followed by random cast netting up to certain length of the stream for continuous fish collection. At the end, the fishes trapped in different nets and sites were taken out collectively. The electro-fishing was done during the season when the water level of the lakes was sufficiently suitable for boating. However, electro-fishing was avoided

Talwar and Jhingran (1991), Jayaram (1999), Menon (1999), Nath and Dey (2000) and Kottelat (2001). Other literatures have been consulted as and when required. Measurements were taken up to the one tenth of a millimeter using dial calipers. The percent composition of collected fish species based on seasons was calculated from the total seasonal catches. Besides, fishery potentials of the lakes were assessed on the background of the growth and well being of prestocked / autostocked cultivable species of the fish in both the lakes during the period of study. All the observations were mostly taken for obtaining the conceptual idea of the potentiality of fish production from such lacustrine ecosystem of the state.

2.4. Assessment of eco-tourism potential

For the assessment of tourism potentials, empirical accounts of visitor's encounters in both the lakes were taken into consideration during the period of each field visits. In addition, comparative ranking of each site was made introducing a five point indexing scale (Mitra, 1998) in the context of site specific features of natural beauty, leisure/adventure facility, infrastructure, price level of visit, adjoining area services & level of comfort.

3. Bio ecology and ichthyofaunal diversity

3.1. Morphometry and related details of the lakes

3.1.1. Ganga lake, Itanagar, Papumpare District

The location of Ganga Lake (locally known as *Gyakar Sinyi* meaning 'confined water' by Nishi tribe) is near Itanagar in Papum Pare district of Arunachal Pradesh. It is about 6 km away from Ganga market (capital complex) at Itanagar and situated at altitude of 336 m above sea level and 93° 34´ 07.60½ E longitude and 27° 04´ 28.46½ N latitude. The Ganga Lake is positioned at the western part of the Itanagar capital complex and represents a unique topography with an ovuculate-triangular shape amongst the highly dissected rugged hills in the outer Himalayan ranges. The lake has an areal coverage of about 67,500 m^2 and is located very close to the boundary of the Pachin and Pam watersheds. The drainage around the lake shows a subdendritic to sub parallel pattern. Of these, the higher order streams show more or less trellis drainage pattern, indicating structural control of the drainage. The lineaments and the channel segments of the surrounding area have been studied by the geologists of WIHG, Itanagar in detail. Regarding origin, it is concluded that most of the streams are structurally controlled and others are carving out their own path. The Ganga Lake seems to have been formed from ponding of a tributary of the Budhibeta stream during neotectonic activity. Its peculiar triangular shape signifies its structural trauma in the Quaternary period of geological time. Abrupt deflection in the course of the Chimpu and Senkhi streams, presence of faults and

The Ganga Lake or Gyaker Sinyi is a naturally made lake and is located at a distance of 6 kms from Itanagar, the capital city of the north-eastern state of Arunachal Pradesh. This beautiful lake is situated at the foothill region of the great Himalayan range. The presence of Ganga Lake enhances the beauty of Itanagar and mesmerizes tourist with its clear waters, verdant greenery, imposing scenes of lush green mountains and the beautiful Itanagar city surrounding it. It is major wetland in Itanagar Wild life sanctuary. Itanagar Wildlife Sanctuary is unique in the sense that the state capital, Itanagar, is located inside the Sanctuary! The major business town of Arunachal Pradesh was Naharlagun, but the capital was shifted to Itanagar. As the town grew, large-scale deforestation took place. For the expansion of the Itanagar capital complex, *c.* 43 sq. km area is proposed to be excluded from the Sanctuary, while on the western border, an area of equal size is proposed to be added to the Sanctuary. Out of 14,080 ha, we have designated about 10,000 ha of forest area, excluding the capital city and other settlements, as the important bird area (IBA). The Sanctuary is located north of the Drupong Reserve Forest. Poma, Pam, Pachin, Neorochi and Chingke are the major streams. The area is entirely hilly, with a few valleys. The forest is a heterogeneous mixture of evergreen and semi-evergreen forest types. Pure stands of bamboo occur all over this IBA. Ganga Lake is often chosen by tourists as a picnic spot as there are some amazing activities for everyone to enjoy and spend the whole day in the lap of Mother Nature. Boating is a popular activity at Ganga Lake of Itanagar and one can cross the lake by theboat and enjoy the scenic waterway, vegetation and amazing birdlife in and around the lake. The lake covers about 4 sq km and shelters a number of birds. The eye-catching greenery of the lake is just to be seen to be believed and one may be tempted to call it a forest lake since it is surround by the primeval vegetation, groves of tall and graceful forest trees and orchids masses. First reaching Itanagar can reach Ganga Lake of Arunachal Pradesh. The closest airport to Itanagar is located at the place called Lilabari in the neighboring state of Assam. The distance between these two places is about 67 kms. One can also avail trains from the railway station at Guwahati, which travel as far as Harmuti.

3.1.2. Mehao lake, Mehao WLS, Lower Dibang valley district

The Sanctuary was named after the Mehao Lake. The terrain of the Sanctuary is hilly, clothed with tropical evergreen forests. The under-storey is also thickly covered with undergrowth. There are two major lakes inside the Sanctuary, Mehao and Sally. The Mehao lake is huge in size and situated at an altitude of 1,640 m and smaller sized Sally (2 ha) is at 520 m. The Mehao Lake originated as a result of the 1950 earthquake. Mehao WLS is thinly populated and most of the areas have not yet been named. There is only one all-weather road

rainfall both from the southwest and the northeast monsoons. It rains nearly half of the year. Areas converted due to *jhum* cultivation earlier, are being covered with bamboo and other secondary vegetation. Cane is common in humid areas. As the important bird are this sanctuary harbours atleast 175 bird species. Most interestingly, White-winged Duck *Cairina scutulata* was also recorded from Mehao lake. Due to altitudinal variation from 400 m to 3,560 m, this site has three biomes: Biome 7 (Sino-Himalayan Temperate Forest), Biome-8 (Sino-Himalayan Subtropical Forest), Biome-9 (Indo- Chinese Tropical Moist Forest). A total of 60 biome species are found in this sanctuary .On the back ground of rich avian diversity as well as diversity of other animals in the sanctuary, the lake itself is playing an important role for migratory species of bird and it is realized here to incorporate a short description of the lake. The Mehao Lake is an upland lake bowled between 28°82 48.512 2 N and 95°562 9.332 2 E at an altitude of 1778 m above mean sea level. The lake comprised of two unequal segments both connected through a 'link-stream' of length around 200 m, bigger one flows into smaller. The source of large volume of water in the lake is purely reaped from rainwater, as there is no inlet. The only outlet sweep out from smaller one. The lake is located within Mehao Wild Life Sanctuary area and such positioning has made this lake highly alluring to the adventure tourists. The approach to the lake is via Roing, head quarter of the district. There is no roadway from Roing to the lake but a trekking of around 15 Km reaches the lake. The trekking continues on a riverside (named river Deopani) for about an hour and then goes upward for another one hour through a valley, which ends, to a stream. The lake has an apparent linking with the river by this stream. The stream is trickled down directly from Mehao Lake through the steep cascade. After crossing the stream the trekking through the dense forest becomes more enjoying and the striding continues for an additional two hours to reach the Mehao Lake. The entry to the lake is from West to East direction. The lake has no any geometrically definable shape.

The peripheral area of the lake also rarely contains soil. Mostly the undercut bedrocks, boulders and rocks form the periphery of the lake, due to which, roaming around the lake provide amusement to the visitors. There are much dense overhanging vegetation of trees, shrubs and creepers at almost 80% of the lake's periphery. The lake water is very much clear, drinkable and safe for life. During daytime the transparency of the water is visible up to chest height of an average tall man. The upper surface of the lake water is total open and there is no any floating vegetation in the lake. The wind flows from the East to West direction creates webs on the water surface and agitation is continuously visible throughout the day except for few hours in the morning. During the silent state the lake becomes a mirror for the nearby snow covered mountain (winter season only) and surrounding jungle/ forest. The open blue sky during daytime gives a beautiful colour to the lake water. Some wild animals drink the lake water, which is evidenced from the observation of the presence of hoof marks near the

distance of 30m from shoreline was measured to be 10.4m; however, the maximum depth as recorded by the District Fishery Development Office is 65m. The lake water is very much clear, drinkable, and safe for life. During daytime, the light transparency of the water was measured up to 7.0m, which provided the pristine clarity. The upper surface of the lake water is total open and there exists hardly any floating vegetation in the lake. The Mehao Lake is situated near Roing in the Lower Dibang Valley district of Arunachal Pradesh. It is located at 95° 56′ 6½ E and 28° 09′ 18½ N longitude and latitude respectively. The Mehao lake does not have any road communication for vehicles and to reach the site one has to track about 17 km from Roing, the district Head Quarter of Dibang valley District (Fig. 2).

Plate 3: Satellite Photo of Ganga Lake

Topography of the surrounding areas of both the lake is highly undulating. Ganga Lake is situated on the middle slope of the hill whereas the Mehao Lake is situated on the plateau of a hilltop. The satellite photograph of the lakes suggests the morphology of Ganga lake is triangular (Plate 3) and that of Mehao lake is somewhat round (Plate 4).

Plate 4: Satellite photograph of Mehao Lake

3.2. Lake environment and aquatic life forms

Periodic surveillances and sampling from both the lakes were undertaken to record the seasonal changes in the lake environments and to understand how it's biotic and abiotic factors have been influencing each other since the initiation in early part of 2008 till to end of the tenure in 2009. We have been collecting water samples, plankton samples, hydrophytes, fish samples, benthos etc. and also taking reading of different parameters on the field itself. Additionally, the visual changes in and around the lake along with the activities done in the lakes during period were sequentially photographed time to time.

3.2.1. Physico chemical qualities of lake water

3.2.1.1. Ganga lake

in water quality parameters of Ganga lake in 2009

Pre monsoon				Monsoon				Post monsoon			
February	March	April	May	June	July	August	September	October	November	December	January
7.44 ±0.26	7.2 ±0.43	7.04 ±0.20	6.95 ±0.32	6.85 ±0.26	6.81 ±0.36	7.11 ±0.17	7.11±0.45	7.42 ±0.33	7.82 ±0.49	8.1 ±0.34	7.55 ±0.41
12.72 ±1.13	16.33 ±1.43	18.98 ±1.02	21.73 ±1.62	22.11 ±1.28	21.67 ±1.98	22.63 ±1.53	22.78 ±1.20	21.45 ±1.23	21.06 ±1.41	15.73 ±2.11	12.27 ±1.21
38.53 ±1.58	37.9 ±1.51	51.01 ±2.86	54.79 ±1.14	72.83 ±6.53	86.39 ±5.17	91.77 ±1.58	94.17 ±2.30	72.91 ±8.79	59.89 ±3.63	44.13 ±4.44	34.23 ±4.14
45.8 ±0.13	45.1 ±0.22	44.6 ±0.25	44.4 ±0.32	43.2 ±0.22	42.9 ±0.36	42.6 ±0.33	42.6 ±0.28	43.8 ±0.15	45.5 ±0.12	45.5 ±0.18	45.6 ±0.12
8.91 ±1.68	8.16 ±1.17	7.82 ±1.00	8.10 ±0.81	8.04 ±0.68	7.81 ±0.91	7.91 ±0.92	8.21 ±0.95	8.44 ±1.40	8.84 ±1.77	9.11 ±2.02	9.13 ±1.96
6.1 ±1.58	6.15 ±1.10	6.22 ±0.85	6.08 ±0.72	6.23 ±0.69	6.2 ±0.74	6.33 ±0.69	6.38 ±0.78	6.18 ±1.55	6.38 ±1.66	6.72 ±1.92	6.32 ±1.77
60.20 ±1.87	60.34 ±2.56	57.58 ±1.30	56.15 ±2.12	54.61 ±1.49	53.10 ±1.99	50.48 ±1.57	53.03 ±1.90	54.03 ±2.82	56.03 ±2.82	58.36 ±2.89	59.11 ±1.64
16.01 ±1.05	15.15 ±0.43	23.21 ±3.34	24.76 ±0.67	25.83 ±0.71	28.74 ±5.44	28.92 ±0.68	30.98 ±5.45	24.63 ±1.39	22.79 ±0.75	16.22 ±1.86	13.89 ±0.95
18.89 ±1.14	17.89 ±0.47	25.66 ±2.98	26.16 ±0.89	30.21 ±1.19	34.32 ±1.38	37.89 ±1.15	30.18 ±1.52	25.86 ±1.33	17.89 ±2.36	16.01 ±1.12	16.88 ±0.34
15.22 ±0.93	20.89 ±1.58	25.33 ±1.58	27.89 ±0.76	32.13 ±1.58	37.49 ±1.58	37.22 ±1.21	38.52 ±1.13	29.33 ±2.73	19.92 ±3.16	17.13 ±0.9	14.48 ±1.19

trends. The mean surface water temperature fluctuated within ranges of 12.58 °c -22.75 °c respectively in January and August in the year 2008 and within the ranges of 12.27 °c -22.78 °c in the year of 2009. The maximum mean value of specific conductivity of water ranged from 94.17 - 95.66 μ mhos/cm in 2008 and minimum 34.23 -35.44 μ mhos in 2009 with highest values in December and lowest in August respectively. The mean value of Secchi disk transparency ranged within 42.0 – 46.0 cm. The dissolved oxygen varied form 7.81- 9.13 mg/l in both the year whereas dissolved CO_2 showed maximum level of 6.51mg/l - 6.72mg/l in December and minimum level in 6.08mg/l in May. In the context of alkalinity maximum range were 58.02mg/l - 60.34 mg/l in March and February whereas these were variable within 50.39mg/l - 50.48mg/l within August of both the year. Hardness of the water of Ganga lake showed mean highest value of 30.48 -30.98mg/l in September and minimum of 13.22-13.89 mg/l in January of both the year. Similarly Nitrate concentration had the mean higher value ranging from 37.89-38.29mg/l in August and minimum of 15.78-16.01 mg/l in December whereas Phosphate concentration exhibited 38.52-40.69mg/l as higher value respectively in September and August with minimum value 14.25-14.48mg/l respectively in January and February of both the Year. The result of the systematic observations is presented in Table 1(b) & Fig. 9.

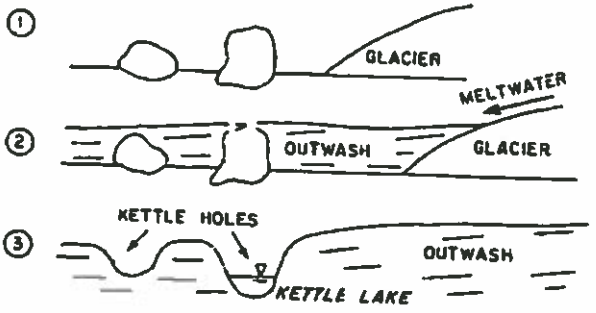
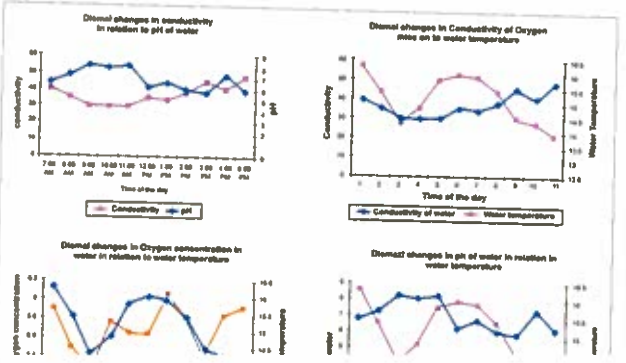


Fig. 9: Monthly fluctuation of water parameters in Ganga Lake

3.2.1.2. Mehao lake

The lake water is slightly acidic, with 6.2-6.8mg/l mean range of lower value respectively in the month of July, 2009 and August, 2008. Similarly higher mean value of pH was 7.8 respectively in December, 2008 and January, 2009. The water temperature of the Mehao Lake showed the lowest mean value in December 7.11° c with highest mean value 18.43-18.56 °c in the month of August of both the year.



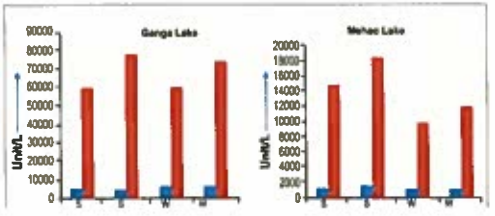
interestingly the Secchi disc transparency showed uniform value throughout both the year ranging from 586.2-597.8 cm. The DO content of Mehao lake showed higher mean value of 9.29 to 9.19 mg/l respectively in December and January of 2008 and 2009, whereas lowest mean value ranged between 7.73-7.66 mg/l respectively in July 2008 and August,, 2009. The mean content of Dissolved CO_2 showed maximum range 6.98-7.84 mg/l respectively in December, 2009 and January, 2008. However, minimum mean value ranged within 6.02 -6.1 mg/l respectively during August 2008 and March, 2009. Alkalinity of Mehao lake water ranged in between 14.1-19.89 mg/l in 2009 and 13.8 -19.24 mg/l in 2008. Similarly Hardness was highest in August with mean value 29.66- 30.03 mg/l respectively in 2009 and 2008 and minimum mean Hardness were 16.33 mg/l in December, 2009 and 16.45 mg/l in December, 2008. The mean Nitrate content of the Lake water varies between 0.51 -0.84 mg/l for both the year showing similar trend of Phosphate content ranging from 1.18 -1.80 mg/l respectively in the month of December and August for both the year. The result of the systematic observations is presented in Table 2 & Fig. 10.

Table 2: Seasonal abundances (Unit/ m^2) benthic macro-invertebrates in Ganga lake & Mehao lake

Organisms (Unit/m^2)	2008			2009		
	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon
Ganga Lake						
Insect larvae	280	450	210	180	210	350
Insect adults	138	200	110	186	300	96
Molluscs	15	60	10	10	120	15
Oligochaets	25	15	20	45	25	35
Others	-	-	-	-	-	-
Mehao Lake						
Insect larvae	364	574	651	383	567	668
Others	20	31	11	25	19	08

3.2.2. Aquatic life forms

The aquatic life forms of both the lakes comprised of diversified groups of Planktonic, Periphytic, Benthic and Neustonic life forms. However due to distinctness of the topographic locations as well as variability in physic chemical parameter particularly temperature regimes of



lower altitude Ganga Lake contains dispersed population of Macrophytes in different Littoral areas particularly with introduced groups. It is also to worth mention here that both the lakes have dropped of leaf litters into the water body due to presence of dense forest around the lake periphery. Particularly Ganga Lakes in its three sides of the periphery possesses overhanging vegetation (Fig. 11, 12 & 13).

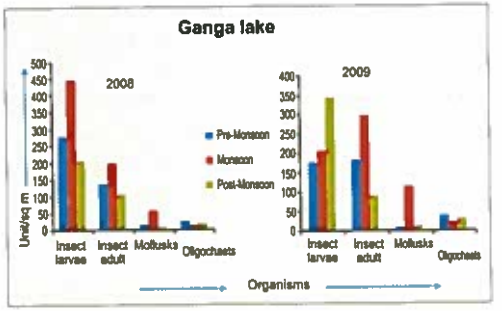


Fig. 12: Seasonal abundances (Unit/ m²) of benthos (aquatic macro-invertebrates) in Ganga Lake

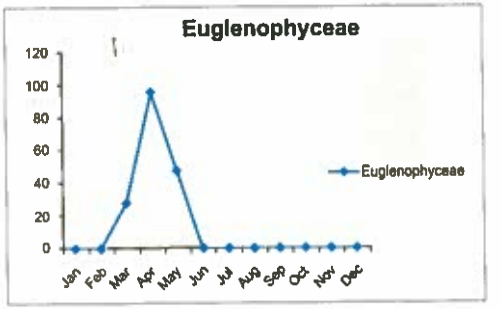


Fig. 13: Population dynamics of Euglenophyceae in Ganga Lake

3.2.2.1. Ganga lake

The planktonic population of both the lake was comprised of zooplankton and phytoplankton where phytoplankton was dominant life forms. In 2008, the mean value of zooplankton count was ranged from 4961 unit/l - 7042 unit/l on an average for summer 2008 and winter 2008 respectively. The values ranged from 5099 – 6847 unit/l in summer 2009 and winter 2009 respectively. Whereas in phytoplankton population varied between 59918-60069 unit/l respectively in winter, 2008 and summer, 2008. Again it showed the mean range of 74144 – 78066 unit/l respectively in winter, 2009 and summer, 2009. The Zooplankton population comprised of dominantly of 6 genera of *Cladocera*, 4 genera of *Copepod* and 6 genera of *Rotifera* along with various other minor population of larval forms as well as *Protozoans*. Among this Zooplankton *Daphnia* and *Moina* showed distinct population fluctuation pattern with a peak population of *Daphnia* in summer month followed by a second peak in December, January whereas *Moina* showed higher population in April, May and October – December. Interestingly the *Bosmina* depicted population peak in the winter season in both the year. On the other hand fluctuation pattern of *Copepod* groups indicated dual peak in *paracyclops* density as well as in diatomous showing abundance in January – May followed by a lag period in summer. Among the *Rotifers Braciona spp* show grdual decline from May

Melosia,Amphora,cymbella,Gyrosigma, Diatoma. However dynamics of population density showed sufficient variability in different months of the year.

The phytoplankton population of Ganga lake comprised of *Chlorophyceae* with 17 commonly available genera, *Cyanophyceae* with 9 genera and *Bacilarophyceae* with 19 genera in general. Besides members of *Euglenophyceae* were also noticed during the month of March – June only. The pattern of their population dynamics in Ganga lake are presented in Fig. 13 & Table 3.

Table 3: Mean abundances of Zooplankton and Phytoplankton (Unit/L) in Ganga lake & Mehao lake

Lake	Organisms (Unit/L)	Summer (2008)	Summer (2009)	Winter (2008)	Winter (2009)
Ganga lake, Itanagar	Zooplankton	4961	5099	7042	6847
	Phytoplankton	60069	78066	59918	74144
Mehao lake	Zoo plankton	1408	1711	1240	1274
	Phytoplankton	14979	18536	10011	12011

It is also to mention that during the study period there was some disturbance in certain points of the lake because of ongoing RCC construction works done on the bank of the lake and there were three/four sampling stations, which were totally undisturbed due to remote corner and isolated area of the lake. The variation in plankton density also may be resulted due to the differences in incident sunlight. Almost half the lake periphery is consisted of overhanging bank vegetation. The geometry of the lake is also somewhat triangular that as such has created some barrier to incident sunlight at certain sites of the lake.

Studies on the periphytic population of the Ganga lake in 2008 revealed that the post-Monsoon periphyton count ranged from 63.08 x 10^3 – 70.05 x 10^3 unit/cm^2 followed by Pre-Monsoon and Monsoon population. Similarly, the attached animalcules also showed higher concentration as the attached life form. (Table 4). Mainly diatoms and filamentous algae were found throughout the year as dominant genera as periphytic life forms.

Table 4: Abundance of periphytic communities (Unit/cm^2) in Ganga and Mehao Lake

LAKE	GANGA LAKE				MEHAO LAKE	
Year	2008		2009		2008-09	
Seasons	Algal Periphyton	Animalcules (×10^3 Unit/cm^2)	Algal Periphyton	Animalcules (×10^3Unit/cm^2)	Algal Periphyton	Animalcules (×10^3Unit/

Analysis of the macro invertebrates showed that the insect larvae were the dominant life form in Monsoon season followed by adult aquatic insects, mollusks and oligocheats respectively during 2008. However, in 2009 Post Monsoon period was dominated with insect larvae followed by adult insects in Monsoon season. The major insect larvae encountered in Ganga lake were ephemeroptera (may fly), Odonata (dragon fly), Lacoptera (stone flies and megaloptera; alder flies) and Diptera (cyronomida). Numbers of Hemipteran bugs like water bugs, water tereders, water measurers, water striders, backswimmer, water boatman and water scorpions. During Monsoon season huge population of gyrinideae (whirling beetles) are found. Among the dipterns mountain midges and dixamidges, crane flies along with mosquito and cyronomids were frequently found. Among the Mollusks members of the viviparidae family were common in addition to indoplanorbideae.

3.2.2.2. Mehao lake

The study on plankton population and diversity in the Mehao lake revealed that there are a quite diverse plankton population exist (Fig. 11 &14). The population of the zooplankton indicated that in the summer of 2008 the mean density was 1408 unit/l which declined in the winter with mean density 1240 unit/l. however in summer 2009 the population was dominated with 4 Zooplankton genera with a mean count of 1711 unit/l that again showed declining trend with mean value of 1247 unit/l in winter 2009. The major genera of the zooplankton recorded during the study were mainly *Rotifers* comprised of genera *Licane, keratella, Rotaria, Brachionus* etc. and certain species of *Cladocera* like *chydorous, Bosmina, Ceriodaphnia* etc. The Copepods are rarely found except a species of genus *Mesocyclops*. However numbers of unidentified species of *Hydrocarina* with beautiful coloration were found in association with algal mass of the submerged stone. The observation clearly revealed the poor diversity of zooplankters. However, the Protozoan population though not frequently encountered but could not be identified due to lack of sufficient literature regarding coldwater Protozoa.

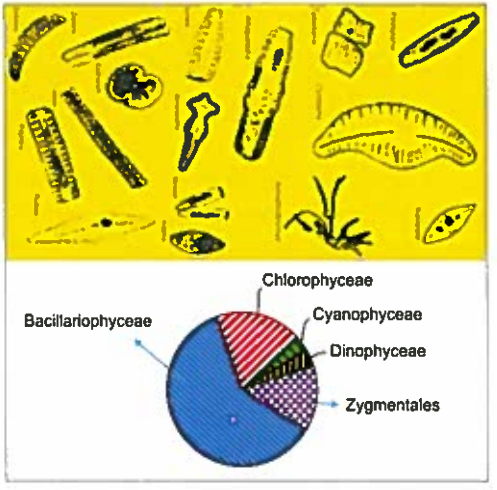


Fig. 14: Major Phytoplankters of Mehao lake

The account of phytoplankton population clearly revealed that in summer 2008 mean

Chlorophyceae with 5 genera, Zygnematales 5 genera, cyanophyceae 1 genus and dinophyceae. The observation on plankton population of Mehao Lake is presented in Fig. 14 & Table 3.

Periphytic population of Mehao lake indicated the presence of attached life forms in highest abundance during Post-Monsoon season followed by Monsoon season where animalcule population were of less abundance compared to population of the Diatom and algal mass. (Table 4).

The Benthic macro invertebrate of Mehao lake indicated Monsoon and Post-Monsoon density ranging from 605 – 662 unit/cm^2 in 2008, whereas in 2009 these ranged 588 – 676 unit/cm^2. In both the year Benthic macro invertebrate were less in Pre-Monsoon season compared to Monsoon and Post-Monsoon season. Dominant larval form of Benthic macro invertebrates were insect larvae comprising of *ephimenoptera*, *Odonata*, *Megaloptera*,*Placoptera* and *Diptera* in general.(Table 2 & Fig. 15).

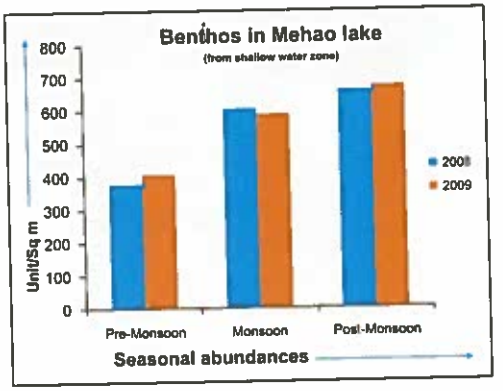


Fig. 15: Seasonal abundances (Unit/m^2) of benthos (aquatic macro-invertebrates) in Mehao lake

3.2.3. Primary productivity

However, studies on the primary productivity in the lake showed good seasonality and ascertain the fishery prospect of the lake along with other congenial parameters. The estimation of the primary productivity in Ganga lakes was done on monthly basis for both the year. However, estimation of the primary productivity in Mehao lake was done once during the period of field visit.

3.2.3.1. Ganga lake

The gross primary productivity (GPP) of Ganga lake ranged from 0.722-1.32 g C /m3/hr, net primary productivity (NPP) ranged from 0.6 – 1.18 g C /m3/hr and community respiration ranged from 0.03 – 0.111 during 2008 with maximum in July. Similarly in 2009, GPP ranged from 0.697 – 1.848 g C /m3/hr; NPP ranged 0.515 – 1.667 g C /m3/hr and NCP ranged from 0.091 –

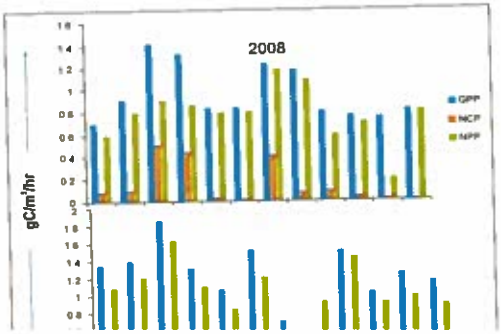


Table 5: Status of fish and fisheries in Mehao lake

Sl. No.	[a]Species Encountered	Till 2007		2008-2009		Remarks
		Number	Body weight(kg)	Numbers	Body weight(kg)	
1	*ExostomaLabiatum* (cat fish)	17 (Nov)	0.002-0.003 (July)	29		Wild species of the fish restricted in smaller part of the lake
2	*Cyprinus Carpio*(Common carp)	06 (Feb)	1.10-1.30	01	0.80	Population established
		27 (Dec)	0.60-1.56	04	0.9-1.3	
		13 (Nov)	0.25-1.00	Nil	Nil	
3	*salmo truta fario* (Brown trout)	01 (Nov)	1.65	Nil	Nil	Population declined
4	*Neolissochilus hexagonolepis* (Chocolate mahseer)	Nil	Nil	7000-8000(Dec)	0.0002-0.0005	Population established
				29 (Feb)	0.3-0.5	
				7 (Dec)	0.5-0.6	

[a]In December, 2012 Golden mahseer (*Tor Puttitora*) have been released in Mehao Lake by DCFR -RGU collaborative research team

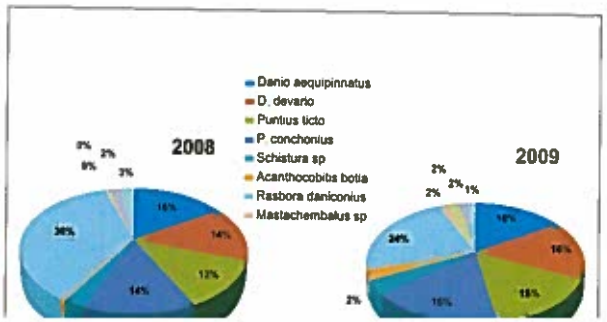
3.2.3.2. Mehao lake

Average net primary productivity (NPP) of the lake was 0.382 gC /m3/hr and gross primary productivity (GPP) was 0.614 gC /m3/hr. The average community respiration of the lake was 0.259 gC /m3/hr.

3.2.4. Fish production potential & sport fishery

3.2.4.1. Ganga lake

Survey on available fish population in Ganga Lake in 2008 and 2009 were conducted sequentially during Pre-Monsoon, Monsoon and Post-Monsoon seasons. The sampling indicated the abundance of smaller sized wild fish where dominant species were *Danio aquepinatus, Danio devario, Puntius ticto* and *Rasbora daniconius*. The seasonal abundance in both the year is



fishery department for sport purpose. Sampling indicated the presence of Indian major carps and exotic carps in the lake details of which are presented in Fig. 18.

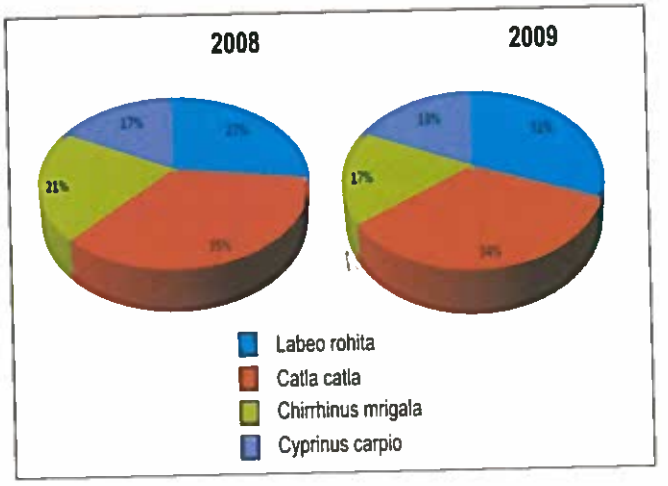


Fig. 18: Abundance and % composition of certain pre-stocked cultivable fish species in Ganga lake during 2008 & 2009

It has been estimated that the lake is conducive for the warm water fishes to thrive well. The fish species identified from this lake are many, comprised mainly of introduced cultivable species along with some naturally available wild species. The cultivable species are stocked every year by the department of fisheries Govt. of Arunachal Pradesh, however, hardly any attention has been given for development of sport fishery still.

The species composition shows a wealth and rich productivity of the lake. The fishes are growing well on the natural food composition comprising a rich density of zooplankters and phytoplankters. Besides, there found a good entry of allochthnous food items in to the lake. Some dense forest surrounds the lake periphery. The forest covers overhang the lake and the litter falls regularly into the lake producing the autochthonous food. The aquatic vegetation both floating and submerged are very rarely seen. However, the loops in the lake at some corners do contains the semi-aquatic vegetation mostly shrubs and creepers. Such loops are home for natural spawning of the fishes. The maximum storage level or the flood area during the summer submerges the peripheral grasses and thereby such items become food for the herbivorous fishes as well as breeding ground for natural breeders. The surface runoffs from the catchments are large bringing the nutrient entry into the lake. The commonly available dominant small fishes are *Danio aequipinnatus, D. devario, Puntius ticto, P. conchonius, Schistura sp, Acanthocobitis botia, Rasbora daniconius, Mastacembalus sp, Macrognathus sp. Channa punctatus, Channa sp.*, etc. The food fishes available are Indian major carps and exotic *cyprinids*, are being maintained for recreation or game purpose.

The lake can thus be considered as natural abode for some game and sport fishes like mahseer. The fishes like chocolate mahseer and putitora mahseer will be adaptable to this lake environment. The physico-chemical criteria of water and land topography support the probable

lake as a dead water body, meaning no existence of any biotic life in the lake. Information brochure of the department of tourism also did not show any importance towards the fishery types of the lake. Therefore, the present study is immense relevant in producing some pioneering outcome on the prospect of fishery and ecotourism.

The studies comprised of fish sampling during this winter period in the month of December 2008. The fishes were sampled through gill net and bamboo traps. Four gill nets of different mesh sizes were kept standing for one whole night in the lake and fishes were collected at the morning. Placing of the gill nets was found difficult because of the large size and high depth of the lake, so some banana trees were cut and a temporary boat was prepared with the help of small tree trunks; which was used for spreading of the nets in the water. In this way three consecutive nights were spent for fish sampling. The gill nets were prepared considering the high depth and large size of the lake, so the heights of each net were above 5m and lengths were nearly 100m. The bamboo traps were used in the out let channel of the lake. Five such traps were place conventionally in a row against the water flow.

So far, four species of fishes have been identified from the lake. These are viz. *Salmo trutta fario, Cyprinus carpio, Neolissochilus hexagonolepis* and *Exostoma labiatum* (Plate 5). Regarding fishery status it can be said that except brown trout other three species have established natural population in the lake. The seeds of *C. carpio* and *N. hexagonolepis* are available at the periphery of the lake in large numbers. Only a single brown trout fish was caught from the lake, which was weighed to be 1.6 kg. However other three species were comprised of varying age groups between fries to brooders. Details of the fishery status of Mehao lake are presented in Table 5 after comprehensive study conducted during the season of 2008 and 2009.

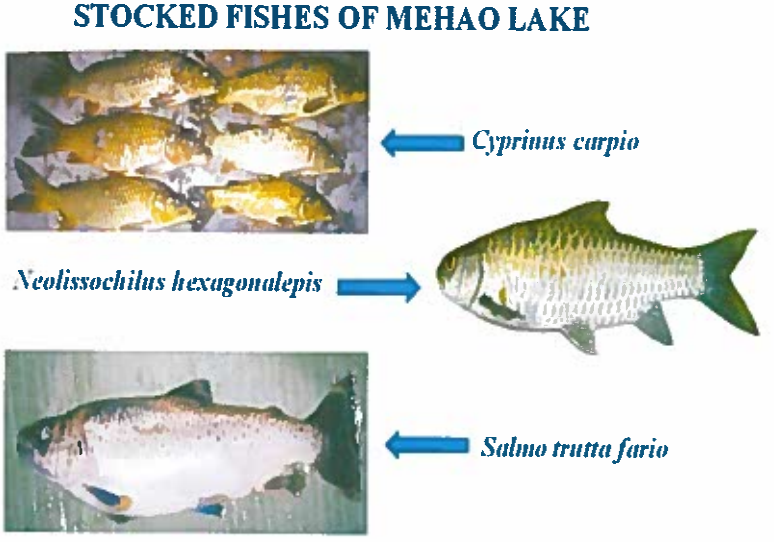


Plate 5

but the lack of infrastructure and constraints of regional insurgency might have handicapped it's the growth up to the level of expectation .The Fig. 19 indicate the state wise domestic tourist's inflow in the region where Arunachal Pradesh showed two times increase (195147 numbers of domestic visitors) in 2009 which was just 50560 in 2005. This state has no doubt enormous potential for attracting tourists from its snow clad mountain all along the northern boundary to the river sceneries of Kameng, Subansiri, Siang, the austere grandeur of Lohit valley and has lush green forests of Tirap. In these regard, fishery or lake based tourism plays alluring role either being linked with angling sports or holiday trips for enjoying wilderness in around the natural lakes like Ganga (Itanagar wild life sanctuary), Sally lake (Lower Dibang Valley District), Mehao lake (Mehao wild life sanctuary), Parasuram Kund and many other high altitude lake site (e.g, Sella and several other lakes in Tawang, East and West Kameng districts, Upper Siang) of the state. The sport fishery activities are also culturally linked with many of the tribes of Arunachal Pradesh, so special attention must be paid by the tourism sector of Govt of India to enhance such sector of ecotourism in the state like Arunachal Pradesh. The current study on Ganga and Mehao lakes also depicted its relevance in connection to development of sports fishery and conservation of wild endemic fishes of Arunachal Pradesh in- situ.

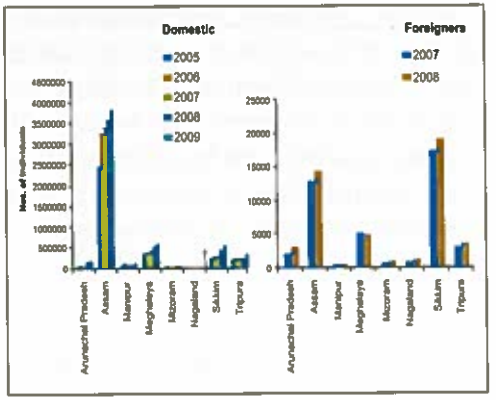


Fig. 19: Tourist inflow in Northeastern region of India (Source: Ministry of Tourism, Govt. of India)

3.2.5.1. Ganga lake

The Ganga lake holds enormous tourism based on the visitors accessibility and proximity of the lake to the state capital Itanagar. It is only about 6 to 7 km away form the capital complex, which already makes it great tourist attraction. The nature lovers visit the lake now and then for recreation and refreshment (Plate 1). People, whoever come to the Itanagar for any reason, cannot escape the attraction of the lake and definitely tries to give a visit to the lake. The visit to the lake refreshes ones mind within a moment. Its greenish water, cool air and dense tropical vegetation surrounding the lake has made it unique tourist spot. However, the tourism potential has already being managed in a planned manner to earn revenue. Appropriate boating facility; lack of facilities for game fishery, lack of tourists guiding and monitoring facility etc are certain aspects, which needs prioritization. Moreover the department

will definitely increase the tourist inflow. Even, it has been noticed that the existing watchtower is still in bad condition and non functional to the poor level of maintenance. Beautification with sporting facilities must be given prior importance to use full potential of ecotourism in Ganga lake urgently. The lake is continuously getting familiarity to the people from Northeastern states of India, as well as Employees of Government and private sectors residing at the capital complex using this lake for their weekend visit frequently. This is notably a positive sign towards its future potential generated out of these tourism activities at the lake sites. The analysis of tourism potentials and current status of tourists flow in the lake sites are presented in Fig. 19 & 20.

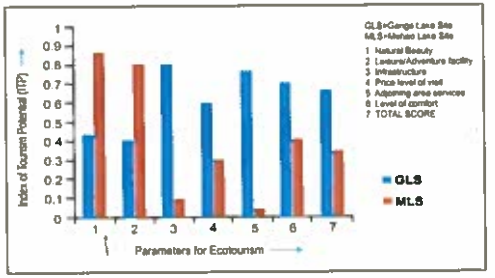


Fig. 20: Parameters of ecotourism and status of ecotourism potential in Ganga & Mehao lakes, Arunachal Pradesh

3.2.5.2. Mehao lake

The lake water is very much clear and transparent (Plate 2). During daytime the transparency of the water is visible up to chest height of an average tall man. One can easily understand the example of refraction of light from air to water because of high transparency of the water. The upper surface of the lake water is total open and there is no any floating vegetation in the lake. The wind flows from the East to West direction creates webs on the water surface and agitation of lake water is continuously visible through out the day except few hours in the morning. During the silent state of the water the lake becomes a mirror for the nearby snow covered mountain (winter season only) and surrounding jungle/ forest. The photographs of the lake taken at this time makes people confusing to distinguish the below water and above water pictures of the mountain and jungles. This gives an example of the commonly used terminology of pristine clear water. The open blue sky during daytime gives a beautiful colour to the lake water.

People visit the lake mostly during the month of November to January. The lack of organized institution concerning the tourism development in the district is the reason that the lake's beauty mostly remains unknown and under exploited. It is people participation and

VISITOR'S AT MEHAO LAKE

lake. The lake is expected to be visited by more than 600 people a year. In our two days stay in November during field trip we encountered maximum of 41 visitors in the lake (Plate 6). The major communities who visit the lake include the local Idu-Mishmi tribe, Nepalees and the non-Arunachales who are in service sectors of Government and Non Government organization within the district. The Nepalees people visit the lake for worshiping Lord Shiva (a temple is present nearby) and also enjoy some kind of picnic, while the other mostly visits the site as picnic spot only. The analysis of tourism potentials and current status of tourists flow in the lake sites are presented in Fig. 20 & 21.

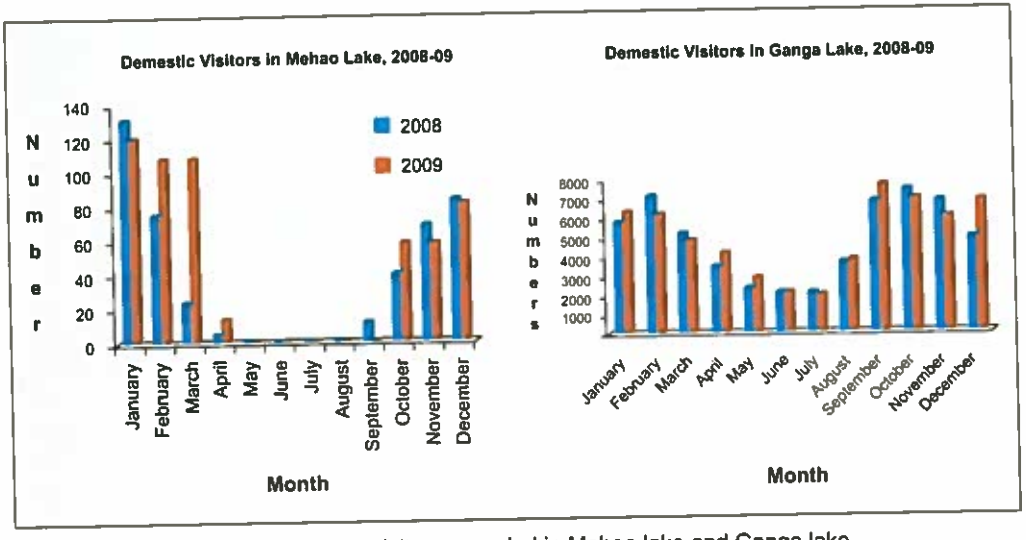


Fig. 21: Domestic visitors recorded in Mehao lake and Ganga lake by the researchers during 2008-09

4. Inferences & recommendation

Fish culture or aquaculture basically is a mode of production and is a part of larger food production system influenced by cultural and economic needs of the society. So the socioeconomic aspects and the available natural resources, both are interdependent and mutually interactive (Das, 2005). These two together, induce people's decisions and reflect their success in applying any new techniques related to developmental drive. They enjoy the social habit of open fishing and hunting from natural waters in and around. Among the tribals, caste distinction with profession of fishing and hunting activities hardly exists. All has open access in fishery

Table 6: Indicator components considered for each parameters of ecotourism assessment

PARAMETERS	INDICATOR COMPONENTS
Natural beauty	• Forests/Special floral composition • Unique Hills/mountain range/snow scapped hills • Hot springs/ springs/lakes/reservoir/river • Fauna of importance/ allurance • Landscape/Unique appearance of sunset/rise • Historical monuments/religious place
Leisure/Adventure facility	• Boating/trekking/Hunting/Shooting/kiting/rope sliding • Fishing/Angling/any other nature sports
Infrastructure	• Distance from nearest city/railway station/airport, Transport, facilities, Govt., accommodation facility, Private Hotel restaurant, Postal /telephone Service, Medical facilities, Mobile connectivity/internet, Banking Services, Electricity supply
Price level of visit	• Cost of communication, Cost of staying, Cost of essential commodity • Cost of arranging adjoining area tour
Level of comfort	• Degree of content meant, Quality of available infrastructure, Accessibility at the site of attraction/recreation/adventure, Hospitality of locals to visitors
Adjoining area services	• Market place, Outlet for traditional items/local handicrafts, Religious place Children parks, Science parks, Museum/ Zoological Garden

Simply, it can be said that, the benefits of aquaculture can create assets other than those reflected in the financial benefits. The rich natural, social and cultural capitals of the state are gradually catalyzing produced capitals through national level subsidies, bank credit and other support services as an initial investment. However, the human capital is partially skilled in fisheries and only having with traditional knowledge in general. In such a case, either exchanging of trained personnel or providing training of the people are one of the essential pre requisite for enhancing human capital further. So, it is assessed that the factors influencing the natural development of aquaculture depends on i) perceived need or desire for aquatic product, ii) suitability of available resources for supplying aquatic products and the availability of complementary factors of production, iii) knowledge of techniques possessed and iv) assured sets of property right along with peace, law and order situation in the society. The capture

system of scientific culture is to be strengthened in all the ecological zones of the state. It would be possible only when small-scale aquaculture sector is strengthened further. Fish culture in homestead pond, small ponds under individual ownership, rice fish culture, integrated farming in rural areas worldwide is almost always done in a way that combines several production components. Different from large scale monoculture, small holding produces different crops and vegetables and rears livestock. In relation to the development of small scale aqua culture the possible impacts of several socio economic factors as observed in many Southeast Asian countries (IIRR, IRDC, FAO, NACA and ICLARM, 2001). Such farming systems are beneficial to farming communities for two main reasons:

- Combining several production components decreases the risk element, if one component failed.
- The different components interact in a symbiotic and synergetic manner, enhancing overall production, optimizing resource use and then providing for the subsistence needs of the household.

On the background of the existing status, the aquaculture scenario of the state is just in its infantile stage of development. As the state is the owner of the fishery waters of diversified zonations, the aquacultural package of practices developed elsewhere in the country need to be refined for adoption in the state in accordance with the available ecological zones for proper extension (Das, 2000). Therefore, for achieving success in exploitation of aquatic resources of the state proper R&D work and extension planning is required in the following directions on priority basis. The districts like Tawang, West Kameng, Dibang Valley, Lower Subansiri, Lohit, West Siang and East Siang hold the grounds for high altitude fishery development. In these districts lie possibilities of improving trout production towards intensification of sport fishery sector from its existing level by intensifying seed production rate through establishing more hatcheries. Common carp, grass carp and silver carps can also be cultured in high altitude zones as some of the components. Besides, research and development programmes should immediately be initiated for adoption of culture technologies for snow trouts like *Schizothorax richardsonii, Schizopygae rogastus, S. esocinus*, Mahseers like *Tortor, T. putitora, A. hexagonolepis*, carps like *Labeo dero, L. pangasia, Semeplotus semiplotus, Changunius chagunio*, etc.

The flood plain fisheries of the state encompass the natural waters, beels and oxbow lakes situated in the plain areas of the state where composite carp production system may be incorporated successfully. The important accessible medium altitude lakes are Ganga, Salley, Glow, etc. (Nath & Dey, 1990) and most of the beels are distributed in East Siang (e.g.Ramro

Another important way of harnessing running water resources of the state is the adoption of cage or pen culture in the streams or rivers. The state is blessed with about 2000 km of potential riverine/stream water resources, which offer good possibilities of cage and pen culture development.

The productivity of ponds can be increased manifold by introducing modernized composite culture, integrated farming of carps and other suitable species followed by location specific management protocol for different climatic zones. The present system of culture in higher altitude and level of yield depends only on common carp and Indian major carps/exotic carps are generally used in lower/medium altitudes. Besides, introducing fresh water prawn in pond culture system may also be added if seed supply from the neighbouring seed producing state can be assured. The seed production is an important link, which should be improved first because the development of culture system is mostly dependent on this. In Arunachal, though seed production has been showing an increasing trend, it is unable to meet the demand of seed for culture ponds & tanks, rice fields as well as for ranching coldwater streams. Moreover, seed production needs skilled manpower, proper maintenance of brood fish and related other facilities, which are still not available usually in most of the state seed farms that often results uncertainty in seed production sector. The state of seed farms therefore needs to be updated and standardized for maintaining at least optimum output, which also calls for special research attention.

It is evident from the two years consecutive study that both Ganga & Mehao lakes possess sufficiently congenial environment for undertaking fish culture of fishery activities. In the context of biological parameters Ganga lake more rich with high organism diversity that may support diversified aquacultural candidates if proper protocol of management is adopted. The fishes, which thrive on phytoplankton, plankton, periphyton and aquatic insect larvae can be raised both of the lake even without supplementation of high cost feed items. Ganga lake is very rich in phyto plankton diversity, so raising of herbivorous fishes are most justified. The growth of stocked Indian major carps is a supportive proves for this assumption.

On other hand, Mehao lake being situated in the higher altitude may be ideal for raising cold water species like mahseer, trouts, common carp etc., which may be supportive for the conservation of indigenous candidate as well as development of sport fishery enhancing ecotourism potential of the location. The rich ichthyofaunal resources of AP comprised of 213 fish species belonging to 93 genera, 31 families and 10 orders. It forms about 23% of the total freshwater Indian fishes. However, all these fishes are not useful as the candidate for sport or recreational fishery development. Table 7 represent list of attractive candidate fish species those hold promising potential to promote the recreational fishery in the state. Besides, the other food fishes like

popular outdoor recreational activity, which has given boost to tourism in the Himalayas. The best categories of sport fish are *Tor putitora*, *Tor tor*, *Neolissochelius hexagonolepis* and brown, rainbow and snow trouts. AP possesses one trout breeding centre at Shergaon and a mahseer breeding centre at Roing. Seeds of these two categories of fishes can largely be produced and released in to suitable habitats in different water bodies in time and production in natural water bodies can also be enhanced. Lakes are many, rivers are networked and water is pristine clear. Fish populations are large due to less human population load. Angler tourists are increasing day by day and searches for spots of angling is centering towards hills of AP as because the region is a proud home for large numbers of nearly undisturbed pristine rivers, streams and lakes. Declining trend of fish resources in general water bodies in different other region and also the increase in pollution level in such water bodies triggering the anglers for easy fish catching in the AP. AP will give an angler to his satisfaction of catching big size fishes like Mahseer, snow trouts and exotic trouts. Besides, there are large numbers of indigenous sport fishes in the region. The number of angling sites is many and the number can be increased in many folds through systematic planning for tourism development. One of the attractions of tourist spots is scenic beauty. In hills the sites with scenic beauty are mostly related with the waterfalls, large water bodies like lakes, reservoirs and the undulating fluvial. Tourists some times enjoy the animals living underneath the water and the play is to catch the big size one. It's a competition and it's a record making. People always search for good spot where one can catch more number and big size of fish. The chocolate mahseer though successfully established in Mehao lake but the habitat of the fish is highly sensitive to an anthropogenic affect, so

Table 7: Major sport fish species in Arunachal Pradesh

Fish group	Scientific/ common names	River habitats
Mahseers	*Tor putitora, Tor tor, Neolissochilus hexagonolepis*	Rivers Kameng, Subansiri, Dikrong, Pachin, Ranga, Siang, Dibang, Lohit, Noadihing, Buridihing, Tirap, Recently stocked in Mehao lake
Exotic trout	Rainbow trout *(Oncorhynchus mykis)*	Some rivers in Mechuka, rivers in Tawang dist., Govt. farm Shergaon.
	Brown trout (*Salmotrata fario)*	Mehao lake in Lower Dibang Valley dist.
	Schizopyge esocinus *Schizopyge progastus*	Rivers Siang and Subansiri, Rivers Kameng, Subansiri, Siang, Dibang, Lohit, Tirap

conservation of fish in its natural habitat would be possible if Mehao lake ecosystem is utilized for their ranching.

Mehao Lake is unique for the tourist as it is situated in a wild life sanctuary (WLS), to reach the site one has to perform trekking of about 17 km on food through steep hills. Wild life watching may be one the alluring event along with sport fisheries. Only constraints that scoreless for this lake site to the mass tourists are the lack of tourist's infrastructure and communication problems from the contort point of view. However, this lacking may be strength to develop the spot as adventure tourism.

On other hand, Ganga lack satisfy more than 70% of the positive score where infrastructure still is not upto the mark even though it is well placed in Itanagar WLS with all the allied service sectors. Angling tourism still has not been developed towards recreational level, which needs more attention for attracting many more tourists in the spot. Special attention is required to develop warm water sport fishery by stocking warm water sport fishes in the lake even other species of mahseer viz., *Tor putittora* and *Tor tor* may be tried for this lake. Eco-tourism development is expected to achieve three major goals (3P) namely: Profits (economic), People (Social cultural benefits to communities and tourists) and Place (biodiversity conservation). The state of Arunachal Pradesh, Pasighat have a lot of places like Yingkiong, Bodak, Siom, etc., that provide good spots for Fishing and Angling. The Mahseer being a favorite among angles, getting a 20-30 kg over here is not uncommon. The colder waters 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. However, real development of mountain fishery based ecotourism will take place only when participating people shall remain conscious on the issues and definition of recreational fishery as mentioned in the **box** below:

RECREATIONAL FISHING

- Angling, recreational angling, small boats equipped with nets or longlines, hand-held lines or nets, gill nets, stationary nets on the seabed, freedivers and sportdivers with spearguns, are various forms of fishing included in the definition of recreational fishing as long no sale of fish is involved.
- Recreational fishing is fishing, which is not deemed to be commercial fishing

RECREATIONAL ANGLING

- Angling can be both commercial and non-commercial.
- Recreational angling can only be non-commercial, as recreational anglers do not sell their catch.
- Recreational anglers may return or retain the catch, or consume it within the family unit (all according to local regulations).
- Recreational angling can be pursued for many

RECREATIONAL ANGLING versus other RECREATIONALFISHING

- Recreational angling is one form of recreational fishing.
- Far the most of the socio-economic value of recreational fishing comes from recreational angling.
- Compared by their impact on fish stocks and the environment recreational angling is by far the most
- Sustainable of all the types of fishing -commercial and non-commercial- with highly selective catching gear and a low mortality rate from release of fish not to be retained.

5. Conclusion

1. Though there are several potential lakes for sport fishery development but at present the game and sport fishery in the region is mostly unorganized. Considering the natural resources available in the region concerted planning and action is needed for promoting game and sport fishery in the region. This will not only attract the tourists and generate revenue but will also create alternative sources of income for the local people. An inventory of such spots with activities is required to be prepared by the state fishery departments with assistance from NGOs, forest departments and tourism departments. Basically, the role of tourism departments is crucial and they have to come forward for the commercial benefit of the region.
2. As such a checklist of game and sport fishes is not available for the region; however, lot of work has already been done by various experts, even by some national and international anglers, which may be synthesized to prepare the checklist.
3. Action needs to be initiated on identified locations in the region for setting up of eco-tourist spots. Besides, the employment generation and revenue earning, the eco-tourism spots will also help in conservation of the fish biodiversity of that area. The minimum infrastructure requirement will be accommodation, food, transportation, rafting, boating and angling facilities. The revenue generated through eco-tourism can be utilized for undertaking conservation of fish fauna in the area.
4. It is required to promote private entrepreneurs particularly among unemployed youths to adopt eco-tourism as industry. Creation of infrastructure facilities for training is required for motivating the youth. At present there is no such facility available in the region. A suitable training programme with all aspects may be arranged by developing some infrastructure in an existing institute in the region. The training packages may be developed with the assistance from government and other agencies.

Arunachal Pradesh has a great potential for developing fishery based tourism provided

now a day. Moreover nature being capital for tourism has another important role to play in Arunachal Pradesh. The state has little resources to support itself and around 85% of its total budgetary expenditure comes from the center in the form of Grants-in-aid (Government of Arunachal Pradesh, 1994). The situation now worse with the royalty of forest product declining due to supreme court's interim order banning all forest –based activities. These activities had contributed more than 60% of the total revenue from local sources of the state exchequer. So, alternative internal resources have to be generated within the state itself where its nature based scenic capital possesses good scope. In fact, the promotion of eco-tourism appears to be the best way of generating the revenue and it is considered the least ecologically disturbing industry in hilly regions. However, certain precautions have to be taken beforehand so that the negative effects cannot neutralize the beneficial aspects of tourism in the form of strictly defined ecotourism.

In order to promote eco tourism we need to plan in an integrated manner and it has to be inter-related with the regional economic and social development. No plan for eco tourism and its promotion can succeed unless it is integrated with the development of the indigenous people of the state, by providing employment opportunities and means of livelihood where Lake Fishery promotion may be one important option. Secondly, rapid unplanned expansion of tourist center should not be allowed to grow in the state. In fact the number of tourists should be allowed to move according to the absorbing capacity of the tourist centers. Hence, it is suggested that instead of tourists crowding in one or two such lake based tourist centers, more other such lakes should concurrently be developed in different districts of Arunachal Pradesh especially in Tawang and Upper Siang districts. Thirdly, the government should encourage tourist who select Arunachal Pradesh as their destination and are not too particular about the standard of amenities available. Such tourists aim to experience the unique culture, religion and landscape in a remote area. So, basic infrastructural facilities should be created in the state where tourists can live along with the local population. This will not only result in economic prosperity of the people but also pave the way for ecologically friendly tourism. This type of tourism does not require the construction of large and expensive facilities. However, care may be taken to control the number and type of tourists by encouraging a healthy guest-host relationship. It is to be noted that the traditional tribal society of Arunachal Pradesh is in transition. So the guest-host relationship needs to be well researched before an appropriate policy can be evolved. Unless eco tourism is found and practiced on a healthy and friendly guest-host relationship, the very purpose of the whole will be defeated.

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Namsang stream, Tirap, Arunachal Pradesh

1. The stream

The Namsang stream, also known as "Chathju" originates from Jankhrum (1211 metres msl) in Eastern part of Tirap district, Arunachal Pradesh at a longitude of 95°39′ E and latitude of 27°6′ N. The river traverses a meander course of C.50km in Tirap district of Arunachal Pradesh before it debouches into the plains near Jaipur Reserve Forest (120 metres msl) to join the river Buri Dihing in Assam. From the point of origin Namsang stream starts flowing towards east west direction. After covering a distance of about 18km, it takes a northwardly turn at a longitude of 95°30′ E to finally meet the river Buri Dihing after traversing another 32km distance.

1.1. Experimental station

The present study was conducted for a period of two years from 2007-2009. During this period, water and fish samples were collected from four different stations of the stream selected based on their altitude in four different seasons viz. premonsoon (March to May), monsoon (June to September), retreating monsoon (October and November) and winter (December and February) after Barthakur (1986).

Station 1: Station 1 is the confluence point of Namsang stream with the river Buri Dihing located at a longitude of 95°30′ E at an altitude 120 m msl.

Station 2: Station 2 is located at a distance of 10 km from station 1 (Longitude 95° 25′ E, Latitude 27° 14′ N, altitude 151 metres msl.

Station 3: Station 3 is at a distance of 5 km from station 2 located at a Longitude of 95° 28′ E, Latitude 27° 13′ N, altitude 300 metres msl.

Station 4: The station 4 was fixed at a distance of about 6 km from Station 3 at a longitude of 95°29′ E at an altitude of 333m msl.

2. Physico - chemical characteristic of the stream

2.1. Sediment quality

Physical composition of sediment reflected the dominance of sand contributing 87%. Sediment pH was found to be neutral in nature (pH 7.07). Organic carbon content, available N, P.O. and K.O were found to be low in the sediment of Namsang stream. Skeletal part was

2.2. Water quality parameters

The common features in respect of water quality of Namsang stream were slightly acidic to slightly alkaline p^H (6.0-7.7), medium alkalinity (24-60 mgl^{-1}), soft to moderately hard water (26-76 mgl^{-1}), rich DO (4.4-16.0 mgl^{-1}), high silicate (4.0-10.8 mgl^{-1}), high DOM (10-31 mgl^{-1}), high CO_2 (0.88-13.2 mgl^{-1}), moderate to rich calcium (12-34 mgl^{-1}), low specific conductivity (40-92 µmhos cm^{-2}), high values of magnesium (10-50 mgl^{-1}), TDS (35-116 mgl^{-1}), iron (0.04-15.0 mgl^{-1}) and poor values of phosphate (0.01-0.4 mgl^{-1}), nitrate (nil-0.84 mgl^{-1}) and chloride (2.0-24.0 mgl^{-1}). Physico-chemical parameters are mostly found to be in the favourable ranges for the aquatic organisms.

Table 1: Sediment quality of Namsang stream

Sl. No.	Parameters	Results
1.	p^H	7.07
2.	EC (dSm^{-1})	0.226
3.	Organic Carbon (%)	0.312
4.	Available N (Kg/ha)	103.81
5.	Available P_2O_5 (Kg/ha)	17.95
6.	Available K_2O (Kg/ha)	77.28
7.	Free $CaCO_3$ %	1.5
8.	Skeletal parts (Gravely %)	54.16
Texture		
8.	Sand (%)	87
9.	Silt (%)	3.57
10.	Clay (%)	7.14
11.	Texture class	Sandy

Variations in temperature of the rivers commensurate with changes in season. Fall in temperature and increase in p^H and dissolved oxygen during winter months are all known characteristic features of an aquatic ecosystem. During the period of study, in all the stations water was clear visible up to bottom during pre-monsoon, winter and retreating monsoon seasons while lower transparency was encountered during monsoon which may be due to mud and clay suspension in water as plankton induced turbidity was less applicable because in general plankton population in the water of the hill streams is generally low. Higher percentage of sand in the sediment of the river further supports this finding. Overall water temperature range of Namsang stream (15.0-25.0^{0}C) was favourable for aquatic habitat. Variation in p^H may be attributed to increase and decrease in biogenic activities of the system. The alkalinity range of Namsang stream ranged (24.0-60.0 mgl^{-1}). According to Unni (2003), Indian rivers with an alkalinity range of 50-100 mgl^{-1} can be considered as low or unpolluted and the present finding revealed unpolluted status of the Namsang stream. In Namsang stream, p^H values were found to be slightly acidic to alkaline and dissolved oxygen values were found to be higher, which is a common phenomenon of the rivers unaffected from anthropogenic activities. Dissolved oxygen concentration recorded in Namsang stream was much higher than those reported by other workers like Singh *et al.*(1999) in the river Ganga and its tributaries (3.56-8.76 mgl^{-1}), Laal *et al.* (1988) from river Ganga at Bhagalpur (Bihar) (4.5-6.33 mgl^{-1})

magnesium and silicate levels of Namsang stream also revealed their productive status. The hardness values of Namsang stream water imply that the water was soft to moderately hard which could sustain a good fishery.

The study of different physico-chemical parameters of Namsang stream revealed that it is a healthy hill stream, free from any pollution and the physico-chemical parameters are mostly found to be in the favourable ranges for the aquatic organisms. The stream water and sediment quality of Namsang stream also satisfies the special requirements like favourable temperature regime, high dissolved oxygen values, presence of gravels etc. indispensable for growth and propagation of hill stream fishes. Further, the ranges of different physico-chemical parameters also reflected moderate productive nature of the stream. In general, it is seen that most of the streams of Arunachal Pradesh are oligotrophic in nature. But, the present findings indicated that Namsang stream could sustain medium to high level of fish production.

2.3. Biological characteristics

2.3.1. Plankton

During the present investigation, 50 different genera of plankton were recorded from Namsang stream. Among these, 23 belonged to Bacillariophyceae (Diatoms), 11 to Chlorophyceae, 6 were Myxophyceae, 2 were Xanthophyceae and 8 Zooplankton (Fig.1).

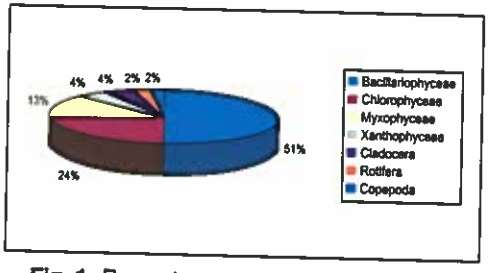


Fig. 1: Percentage contribution of different plankton groups in Namsang stream

2.3.2. Phytoplankton

Bacillariophyceae: *Amphora, Anomonies, Calonies, Ceratonies, Cocconies, Cyclotella, Cylindrotheca, Cymbella, Denticula, Diatoma, Fragilaria, Frustulia, Gomphonema, Gomphonies, Gyrosigma, Melosira, Navicula, Nitzschia, Pinnularia, Stephanodiscus, Surerrela, Synedra, Tabillaria.*

Chlorophyceae: *Ankistrodesmus, Chlorella, Chlorococcum, Cladophora, Closterium, Hormodium, Microspora, Sphaeroplea, Spirogyra, Tetradon, Ulothrix.*

Myxophyceae: *Anabaena, Lyngbya, Oscillatoria, Phromidium, Rivularia, Spirulina.*

Xanthophyceae: *Traycychloron, Goniochloris.*

2.3.3. Zooplankton

Plankton population in hill streams was greatly influenced by sandy and stony beds, fast current of water and a number of physico-chemical factors. During the present investigation plankton population was found to be low in Namsang stream. This may be attributed to the fast flowing condition of the stream water. Biswas and Boruah (2000) also reported current velocity as one of the regulating factor for the growth of plankton. Low plankton count is a characteristic feature of hill streams as periphyton takes over the function of plankton occupying the food chain (Gurumayum *et al.*2000). Seasonal fluctuation of plankton density was observed in between 8 and 67 ul^{-1} throughout different seasons. Similar observation was also made by earlier workers from this region. Pathak *et al.* (2001) reported poor values of plankton density (22 to 51 ul^{-1}) in Siang, Dibang and Lohit rivers of Arunachal Pradesh. Similarly, Gurumaym *et al.* (2000) observed a plankton density of 21 to 144 ul^{-1} in Subansiri river of Arunachal Pradesh. Daimari (2003) also reported seasonal variation of plankton population between 21 and 111 ul^{-1} from Dikrang, Subansiri, Kameng and Ranga rivers of Arunachal Pradesh. In the present investigation it was observed that winter was the peak season for growth of phytoplankton followed by retreating monsoon and pre-monsoon while the minimum density was seen during monsoon. Winter months were more productive as compared to other seasons. Boruah (1999) also reported that high current velocity and low transparency during rainy months (May- October) inhibit the growth of plankton in Brahmaputra river. This agrees with the findings of Hussainy (1967) on Govindgarh lake i.e. the trend towards an increase in plankton population during a year commences with the monsoon or immediately after that. Pathak *et al.* (2000) also reported that retreating monsoon and pre-monsoon are the favourable seasons for higher phytoplankton population. Gurumaym *et al.* (2000) reported maximum plankton density during winter and minimum during monsoon from river Subansiri in Arunachal Pradesh. Identical observation was also made by Daimari *et al.*, 2005 from the Subansiri river. Lakshminarayana (1965) studied the seasonal fluctuation of phytoplankton (net plankton) density of the river Ganga and observed least counts during the rains and maximum of 600000 per ml in December and April declining to 50% in June. Rama Rao (1979) studied plankton succession in the river Khan and reported maximum growth of plankton in summer months and minimum in monsoon months.

Phytoplankton group (consisting of Bacillariophyceae, Chlorophyceae, Myxophyceae and Xanthophyceae) as a whole dominated over zooplankton (Copepods, Cladocerans and Rotifers) throughout the different seasons. Bacillariophyceae was found to be the dominant phytoplankton group during the period of study in all the stations. The maximum abundance (85.71-96.42%) was observed during winter season when the water temperature was within the range of 15°C to 17°C. On the other hand, minimum abundance of Bacillariophyceae (20-43.75%) was during monsoon season when the water temperature ranged from 23.8°C to 25°C. This finding is

Bacillariophyceae and 10-20% Chlorophyceae with complete absence of Myxophyceae and Xanthophyceae. Diatoms dominated the population of phytoplankton in lots of tropical and temperate water bodies as observed by Kofoid (1980) in the river Illionis, Reinhard (1931) in river Mississippi followed by Baker & Baker (1979) in the same river.

Next to Bacillariophyceae, the other dominant phytoplankton group was Chlorophyceae. Maximum abundance of Chlorophyceae (16.66-30%) was observed during retreating monsoon and minimum during winter. This may be due to the fact that water temperature range of retreating monsoon season (22°C – 22.5°C) appears to be optimum for vigorous growth of Chlorophyceae. Daimari (2003) also reported maximum abundance of Chlorophyceae in retreating monsoon and minimum during winter from the rivers Dikrang, Subansiri, Kameng and Ranga of Arunachal Pradesh. The present finding is also in agreement with Butcher (1946) and Singh (1960) who opined that high atmospheric and water temperature along with bright sun shine are important factors influencing periodicity of Chlorophyceae which has been further supported by Sharma (1983).

In the present study, maximum abundance of Myxophyceae (10 to 18.75%) was seen during monsoon, which might be due to water temperature range of monsoon season (23.8 to 25°C). During the monsoon season, Myxophyceae were found to be the second dominant group of phytoplankton after Bacillariophyceae in most of the stations of the stream. Whitford and Schumachar (1968) correlated the abundance of blue green algae with hot summer months. Present observation supports their views. Daimari *et al.* (2005) also reported the same phenomenon from the river Dikrang, Subansiri, Kameng and Ranga of Arunachal Pradesh. Temperature had been found to play a key role in the periodicity of this group. This view has also been supported by Pearsall *et al.* (1946), Chakraborty *et al.* (1959), Harmer (1964), Lund (1965), Hutchinson (1967), Venkateswaralu and Bhatnagar (1969), Singh *et al.* (1979) and Biligrami & Dutta Munshi (1985). Only two genera of Xanthophyceae i.e. *Traycychloron* and *Goniochloris* have been recorded from Namsang stream during the study period. Copepods, Cladocerans and Rotifers were the three groups representing the zooplankton community of Namsang stream. Zooplankton was found to be completely absent from all the four stations during the winter season. On the other hand, zooplankton abundance was found to be maximum during the monsoon season. Byers (1960) opined that water temperature is the most important controlling factor in production of zooplankton. The present study also corroborate with that finding. Gurumayum *et al.* (2000) observed zooplankton comprising of copepods only during the winter season from the Subansiri river of Arunachal Pradesh. Daimari (2003) also reported higher abundance of zooplankton during the monsoon season in comparison to the remaining seasons from the rivers Dikrang, Subansiri, Kameng and Ranga of Arunachal Pradesh.

that the contribution of periphyton to carbon fixation and nutrient cycling can be significant, particularly in lotic systems (Wetzel 2005). Periphyton in streams and rivers are an important component of aquatic ecosystems, providing food for invertebrates, and thus fish, in local and downstream ecosystems (Finlay *et al.*, 2002).

During the present investigation, 47 different genera of periphyton were recorded from Namsang stream belonging to 8 classes: Bacillariophyceae, Chlorophyceae, Myxophyceae, Rhizopoda, Nematoda, Zooflagellate, Tardigrada and Copepoda. The study showed that Bacillariophyceae dominated the periphyton biomass of Namsang stream (45%) followed by Chlorophyceae (30%), Myxophyceae (13%) and Animal community (12%) (Fig. 2). Different groups recorded during the study are as follows-

Bacillariophyceae: *Amphora, Anomonies, Calonies, Ceratonies, Cocconies, Cymbella, Diatomella, Eucocconies, Frustulia, Gomphonema, Gomphonies, Gyrosigma, Liemorpha, Melosira, Navicula, Nitzschia, Pinnularia, Rhabdonema, Surirrela, Synedra* and *Thalosiothrix.*

Chlorophyceae: *Ankistrodesmus, Cladophora, Cosmarium, Closterium, Chlorella, Chaetophora, Coelestrum, Microspora, Mougeotia, Oedogonium, Scendesmus, Spirogyra, Ulothrix* and *Uronema.*

Myxophyceae: *Anabaena, Oscillatoria, Merismopodia, Phromidium, Rivularia* and *Lyngbya.*

Rhizopoda: *Euglypha, Arcella*

Nematoda: *Criconema octangulare*

Zooflagellate: *Oicomonas*

Tardigrada: *Hypsibus*

Copepoda: *Cyclops*

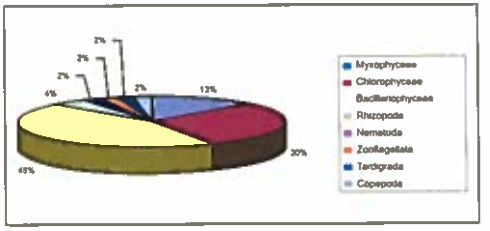


Fig. 2: Percentage contribution of different periphyton groups in Namsang stream

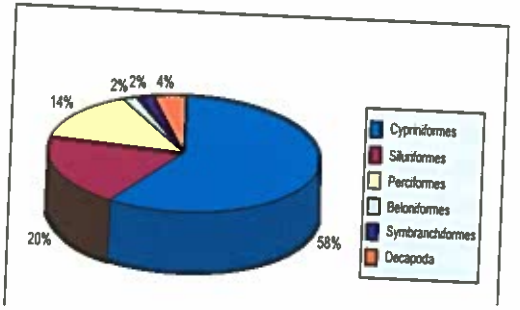
The results of the present study indicates that the periphyton population of Namsang stream is high (1400-18,100 ucm^{-2}) and showed seasonal fluctuation. Gurumayum *et al.* (2000) observed much higher value of periphyton population from the hill streams of Arunachal Pradesh (15000 to 71,001ucm^{-2}). A higher range of periphyton population (16, 520- 85,000 ucm^{-2}) was also reported by Daimari (2003) from the hill streams of Arunachal Pradesh. In the present study, it was found that retreating monsoon represents the peak season for periphyton growth. This finding is in agreement with the findings of Srivastava & Desai (1985), Kumar (1995) (periphyton of Ravisankar Sagar reservoir), Sukumaran and Kartikeyan (1999) in

Bacillariophyceae was the most dominant group of periphyton in all the seasons. Laal *et. al.* (1982), Sukumaran *et al.* (1996), Gurumayum *et al.* (2000), Daimari (2003), Liang and Li (2008) and Singh and Das (2009) also reported Bacillariophyceae dominance in periphyton count. Decreased Myxophyceae and Chlorophyceae contribution in periphyton population is a common phenomena noticed by many workers (Daimari, 2003; Singh and Das, 2009). Low nutrient value in the physico-chemical properties of the water may probably result to their low contribution.

Current influences substrate characteristics, which in turn affect site stability for attachment and growth. In addition, flow rate results in the continuous renewal of gases and nutrients, and so current speed affects diffusion rates of needed materials into the cells. McIntire and Phenny (1965) observed that diatoms especially *Synedra*, dominated under faster current. In the present study also higher altitude regions of Namsang stream with fast water current dominated by diatoms. Substrate influence periphyton population in addition to providing stability against high flows. In the present observation also, the periphyton community was found attached to the rocks surface that submerged in water. Again it has been observed that during monsoon the peripyton population was lowest which may be due to the fact that the surface destruction by monsoon rain or flood which deposited clay, sand and silt particles on the river bed. Animal community under periphyton was reported by Gurumayum *et al.* (2000) from Subansiri river of Arunachal Pradesh and Daimari (2003) from Kameng, Dikrang, Ranga and Subansiri rivers of Arunachal Pradesh. During the present investigation also, animal communities belonging to Zooflagellates, Nematoda, Copepoda, Tardigrada and Rhizopoda were observed. During the winter season (both the years), animal community found to be absent in all the stations, which may be attributed to low temperature.

3. Fish and fisheries

During the study period, 49 fish species belonging to 5 orders, 9 families and 20 genera have been recorded from the four different stations of Namsang stream (Fig.3). In addition to that, two species of prawn were also recorded from the river. The ichthyospecies of the river belong to following orders- Cypriniformes, Siluriformes, Perciformes, Beloniformes and Synbrachiformes. Out of these 49 fish species, 25 belong to family Cyprinidae follo



Badidae (1 species), Belonidae (1 species) and Mastecembelidae (1 species). Amongst the recorded species, 6 were found to be true hill stream fishes, 5 semi- torrential forms, 17 migratory forms and 21 plain water forms as per the classification of Nath and Dey (2000). The collected fish species from the four different stations are depicted in Table 2.

Table 2: Ichthyospecies of Namsang stream

Sl. No.	Order	Family	Sp. No.	Species	1	2	3	4
1	Cypriniformes	Cyprinidae	1	*Barilius tileo* (Hamilton)	+	+	-	-
			2	*B. barna* (Hamilton)	+	+	-	-
			3	*B. bendelisis (Hamilton)*	+	+	-	-
			4	*Raimas bola* (Hamilton)	+	+	-	-
			5	*B. vagra* (Hamilton)	+	+	-	-
			6	*Danio acquipinnatus* (Mc Clelland)	+	+	-	-
			7	*D. dangila* (Hamilton)	+	+	-	-
			8	*D. devario* (Hamilton)	+	+	-	-
			9	*D. rerio* (Hamilton)	+	+	-	-
			10	*Esomus danricus* (Hamilton)	+	+	+	+
			11	*Rasbora daniconius* (Hamilton)	+	+	+	+
			12	*Megarasbora elenga* (Hamilton)	+	+	+	+
			13	*R. rasbora* (Hamilton)	+	+	+	+
			14	*Puntius chola* (Hamilton)	+	+	-	-
			15	*P. conchonius* (Hamilton)	+	+	-	-
			16	*P. sarana sarana (Hamilton)*	+	+	-	-
			17	*P. sophore (Hamilton)*	+	+	-	-
			18	*P. ticto (Hamilton)*	+	+	-	-
			19	*Labeo dero* (Ham.-Buch.)	+	+	+	+
			20	*Neolissocheilus hexagonolepis (McClelland)*	+	+	+	+
			21	*Tor tor (Hamilton)*	+	+	+	+
			22	*Tor putitora (Hamilton)*	+	+	+	+
			23	*Schizothorax richardsonii* (Gray)	+	+	+	+
			24	*Garra gotyla gotyla* (Gray)	+	+	+	+
			25	*G. kempi* (Hora)	+	+	+	+
		Cobitidae	26	*Schistura rupecola rupecola*	+	+	-	-

			29	*Botia Dario* (Hamilton)	-	+	+	+
			30	*B. rostrata* (Günther)	-	+	+	+
2	Siluriformes	Bagridae	31	*Mystus bleekeri* (Day)	+	+	-	-
			32	*M. cavasius* (Hamilton)	+	+	-	-
			33	*M. vitatus* (Bloch)	+	+	-	-
		Sisoridae	34	*Glyptothorax conirostris* (Steindachner)	-	+	+	+
			35	*G. horai* (Shaw & Shebbeare)	-	+	+	+
			36	*G. cavia* (Hamilton)	-	+	+	+
			37	*Erethistes hara* (Hamilton)	-	+	+	+
			38	*E.jerdon (Day)*	-	+	+	+
			39	*Bagarius bagarius(Hamilton)*	+	+	-	-
			40	*Exostoma labiatum (McClelland)*	-	+	+	+
3	Perciformes	Channidae	41	*Channa orientalis (Bloch & Schneider)*	+	+	-	-
			42	*C. punctata (Bloch,)*	+	+	-	-
		Belontidae	43	*Colisa fasciata (Bloch & Schneider)*	+	+	+	+
		Badidae	44	*Badis badis (Hamilton)*	+	+	+	+
		Ambassidae	45	*Pseudambasis baculis* (Hamilton)	-	+	+	+
			46	*Chanda nama* (Hamilton)	+	+	+	+
			47	*Parambassis ranga* (Hamilton)	+	+	+	+
4	Beloniformes	Belonidae	48	*Xenentodon cancila* (Hamilton)	+	+	+	+
5	Synbrachi formes	Mastecem belidae	49	*Mastacembalus armatus (Lacepède)*	+	+	-	-
6	Decapoda	Palaemo nidae	50	*Machrobrachium assamense peninsulare*	+	+	-	-
			51	*M. lamerri*	+	+	-	-

An account of station wise occurrence of the fish species is presented below:

1. **Cyprinidae:** Cyprinidae represented maximum number (25 nos.) of fish species from Namsang stream. Fish species like *Esomus danricus*, *Rasbora daniconius* , *Megarasbora elenga*, *R. rasbora*, *Labeo dero* , *Neolissocheilus hexagonolepis*, *Tor tor*, *Tor putitora*, *Schizothorax richardsonii*, *Garra gotyla gotyla* and *G. kempi* were recorded from all the four stations of the river. On the other hand, species like *Pa*

reaches for food or shelter. They don't show any special adaptations for life in torrential streams and travel against the current by muscular effort. Some members of the family Cyprinidae, are large sized and they return to the lower streams to enjoy the larger water column available there during summer, at the same time they migrate upwards during monsoon for the reproduction. Lack of special adaptations and migratory nature of the cyprinids may be the reason for their presence in all the four stations of study.

2. **Cobitidae:** Five fish species belonging to this family recorded from Namsang stream. Species like *Schistura rupecola rupecola*, *Nemacheilus devdevi* and *Lepidocephalichthys arunachalensis* were recorded in Stations 1 and 2 of the river. On the other hand, two species namely *Botia dario* and *B. rostrata* were recorded from Stations 2, 3 and 4 of the river. Hora (1922) classified fish species belonging to the family Cobitidae as typical hill stream fishes. These fishes inhabit hill steams throughout their life and have special adaptations for living in high altitude areas. They generally don't migrate to the lower gradient streams for feeding, breeding etc. During the breeding season they migrate further upwards and at the time of summer they search for some perennial streams of hilly areas for survival. Fast flowing waters of hill streams harbour plenty of dissolved oxygen; hence these fishes can survive in the existing and available waters. More over, the members of this family are very small fishes with a flat or cylindrical body, small and compact fins to facilitate their living amongst pebbles and the main substrate.

3. **Bagridae:** Three species of this family namely *Mystus bleekeri*, *M. cavasius* and *M. vitatus* were observed in stations 1 and 2 of the river. These are plain water forms of species, which sometimes migrate to foothills for feeding and breeding (Nath & Dey, 2000). Their absence in stations 3 and 4 may be attributed to this fact, as these stations were located in higher altitudes.

4. **Sisoridae:** Seven fish species belonging to Sisoridae recorded from Namsang stream. Among these, 3 species namely *Glyptothorax conirostris*, *G. horai* and *G. cavia* were recorded from stations 2, 3 and 4. The modified pectoral and pelvic girdles, caudal fin and its peduncle, mouth, lips and barbells, eyes and adhesive organs help *Glyptothorax* spp. to adapt to streams with rocky substratum and fast flowing water current (Hora, 1922). Similarly, true stream water species like *Erethistes hara*, *E.jerdoni* and *Exostoma labiatum* were also observed from stations 2, 3 and 4 of the river. On the other hand, *Bagarius bagarius* was recorded from stations 1 and 2 of the river.

5. **Channidae:** Two species of this family namely *Channa orientalis* and *C. punctata* were recorded from stations 1 and 2 of the river. These are plain water forms and hence seen in

7. **Badidae:** Only one species *Badis badis* was recorded from all the stations of Namsang river. It is a migratory fish and observed in all the stations. This species is also considered as an ornamental fish (Dey, 1989).

8. **Ambassidae:** Three species of this family *Pseudambasis baculis* , *Chanda nama* and *Parambassis ranga* were recorded from Namsang stream. The first species was not observed in station 1.

9. **Belonidae:** *Xenentodon cancila* belonging to this family was observed in all the stations of the river.

10. **Mastecembelidae:** *Mastacembalus armatus* belonging to this family was observed in all the stations of the river.

Nath and Dey (2000) reported 48 fish species from the river Tirap of Tirap district. Of these 48 species, 27 were also recorded from Namsang stream, while 22 fish species were recorded for the first time from this region. The species which were seen for the first time included *B. vagra, D. devario, Esomus danricus, Rasbora daniconius, Megarasbora elenga, R. rasbora, P. conchonius, P. sarana sarana, P. sophore , G. kempi, Schistura rupecola rupecola, Nemacheilus devdevi, Mystus bleekeri , M. cavasius, M. vitatus , Glyptothorax horai , G. cavia, Erethistes hara, E.jerdoni, Exostoma labiatum, Channa punctata and Colisa fasciata . Some of the river sites of Arunachal Pradesh have been reported as type locality of 11 fish species. From these 11 species, two were collected in our study (Lepidocephalichthys arunachalensis* and *Garra kempi*).

The main fishing seasons in Namsang stream was found to be winter and early pre-monsoon seasons as during this period water level of the stream recedes. During monsoon and retreating monsoon seasons, the high water level and fast water current prevent the locals from fishing in the stream. Unlike most of the riverine states of the country, there is no regular and definite fish landing centres in Arunachal Pradesh. In Tirap district also, a similar condition was found. Fishes caught from Namsang stream sometimes brought to the local market for disposal. But in most of the cases, the catch is sold in some unorganised markets near roadside and riverbank. During winter and early pre-monsoon seasons, the catch is mainly dominated by Mahseer (*Tor putitora*), Barils (*Barilius tileo, B. bendelisis*), Minor carps (*Labeo dero)* Barbs (*Puntius ticto, P. chola,, P. conchonius, P. sarana sarana* and *P. sophore)* and Miscellaneous species (Loaches, Murrels, Catfish, Glass fish, *Gyptothorax* etc.).

3.1. Ornamental fish

1. **Barbs and Minnows:** *B. barna, B.bendelisis, B. vagra , Barilius tileo, Raimas bola, Danio acquipinnatus, D. dangila, D. devario, D. rerio, Rasbora daniconius, Rasbora daniconius, Puntius chola, P. ticto, P. conchonius* and *Esomus danricus.*
2. **Cat fishes:** *Mystus bleekeri, M. cavasius, M. vitatus, Glyptothorax conirostris, G. horai, G. cavia , Erethistes hara .*
3. **Glass fish:** *Pseudambasis baculis, Chanda nama, Parambassis ranga .*
4. **Gourami:** *Colisa fasciata*
5. **Loaches:** *Schistura rupecola rupecola, Botia dario , B. rostrata* and *Lepidocephalichthys arunachalensis .*
6. **Needle fish:** *Xenentodon cancila*
7. **Snakehead:** *Channa orientalis , C. punctata*
8. **Eel:** *Mastacembelus armatus*

4. Sport fishery

Besides capture fisheries, the drainage of Namsang stream offers tremendous scope for sport fishing. Species like *Tor putitora* (Golden mahseer or tiger of the Himalayan rivers), *Schizothorax* are acclaimed world wide as sport fishes and always attracts anglers and tourists. Some positive steps to promote this stream as a sport fishery destination like Jia bharali of Assam can boost the socioeconomic condition of the people of Tirap district.

5. Threat categories

The threats on the fish germplasm resources have caused concern. Identification, categorisation of endangered, threatened and vulnerable species and studies on their biology in order to conserve them has become inevitable (Vishwanath, 2009). Of the 49 fish species recorded from Namsang stream, 33 were assessed for threat criteria as per IUCN (CAMP, 1997). Six species were considered endangered, 13 vulnerable, 13 lower risk-near threatened and 1 lower risk-least concern (Fig.4). The list of fish

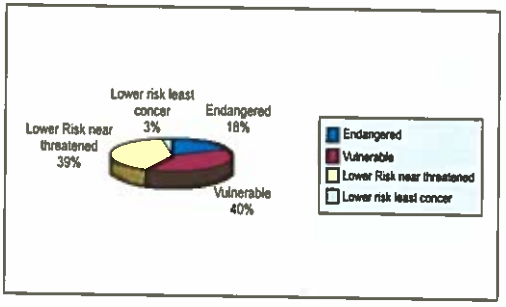


Fig. 4: Threat status of different fish species of Namsang stream as per CAMP report

Table 3: Threat category of different fish species of Namsang stream as per CAMP report

Sl. No.	Name of the species	Status of the species as per CAMP report
1	*Barilius tileo*	Lower risk near threatened
2	*B. barna*	Lower risk near threatened
3	*B. bendelisis*	Lower risk near threatened
4	*Raimas bola*	Vulnerable
5	*B. vagra*	Vulnerable
6	*Danio acquipinnatus*	Lower risk near threatened
7	*D. dangila*	Not evaluated
8	*D. devario*	Lower risk near threatened
9	*D. rerio*	Lower risk near threatened
10	*Esomus danricus*	Lower risk least concern
11	*Rasbora daniconius*	Not evaluated
12	*Megarasbora elenga*	Not evaluated
13	*R. rasbora*	Not evaluated
14	*Puntius chola*	Vulnerable
15	*P. conchonius*	Vulnerable
16	*P. sarana sarana*	Vulnerable
17	*P. sophore*	Lower risk near threatened
18	*P. ticto*	Lower risk near threatened
19	*Labeo dero*	Vulnerable
20	*Neolissocheilus hexagonolepis*	Not evaluated
21	*Tor tor*	Endangered
22	*Tor putitora*	Endangered
23	*Schizothorax richardsonii*	Vulnerable
24	*Garra gotyla gotyla*	Vulnerable
25	*G. kempi*	Vulnerable
26	*Schistura rupecola rupecola*	Lower risk near threatened
27	*Nemacheilus devdevi*	Endangered
28	*Lepidocephalichthys arunachalensis*	Endangered
29	*Botia dario*	Not evaluated
30	*B. rostrata*	Not evaluated
31	*Mystus bleekeri*	Vulnerable

36	*G. cavia*	Endangered
37	*Erethistes hara*	Endangered
38	*E.jerdoni*	Not evaluated
39	*Bagarius bagarius*	Vulnerable
40	*Exostoma labiatum*	Not evaluated
41	*Channa orientalis*	Vulnerable
42	*C. punctata*	Lower risk near threatened
43	*Colisa fasciata*	Lower risk near threatened
44	*Xenentodon cancila*	Lower risk near threatened
45	*Mastacembalus armatus*	Not evaluated
46	*Badis badis*	Not evaluated
47	*Pseudambasis baculis*	Not evaluated
48	*Chanda nama*	Not evaluated
49	*Parambassis ranga*	Not evaluated
50	*Machrobrachium assamense peninsulare*	Not evaluated
51	*M. lamerri*	Not evaluated

6. Fishing methods

Common fishing gears are generally used for catching fishes from Namsang stream. Generally tribal people fond of fishing and every household possess one or two fishing gears. They generally catch fish for daily consumption. The common fishing gears operated in Namsang stream are cast nets, gill nets, scoop nets, Chinese dip nets, impaling gears and different types of traps.

6.1. Bheta fishing

Apart from these gears, the Nocte tribe of Tirap district practice a unique method of fishing at Namsang stream. **Locally this method is known as 'BHETA' literally means obstruction in the river.** This method is generally practiced during winter season, when the water level of the river recedes. The fisher folks in a group of 8-10 construct an obstruction at a suitable location of the river. Generally those locations where the width of the river gets reduced and water current is less are selected for construction of a 'Bheta'. For construction of a 'Bheta' the width of the stream at that location should be 20-25 m. Materials like bamboo, tree trunks, boulders are used for construction of a 'Bheta'. Generally it requires 10-15 days for making a 'Bheta' completely ready for use. After the construction is complete, the fisher

season (winter months) the maximum catch recorded from a Bheta was 12 kg/day. The catch mainly comprised of Mahseers (*Tor putitora*) (70-75 %), Barils (15-20%) and others (Barbs, Loaches, Murrels, Ctafish etc.) (5-15%). But occasionally, Barils (*Barilius tileo*) dominated the catch of some 'Bheta's' contributing 80-85 % of catch. The catch is generally shared among the members of the group of fisher folks and sometimes sold on the spot. Generally a 'Bheta' is used for 1 to 2 months with minimum maintenance. During winter months 15-20 nos. of 'Bheta' can be seen in the entire course of the river.

6.2. Threats

Apart from the above mentioned methods, the local people in recent times started using portable generators, agriculture pesticides, chemicals etc. for catching fishes. These fishing practices are causing a great threat to the fish diversity of the stream as they kill both target and non target species along with their eggs and young ones.

In addition to this, extraction of boulders from Namsang stream is also altering the habitat of the hill stream fishes. As a result of this, the occurrence of many hill stream fishes has become rare as reported by the local fisher folks of Namsang stream.

7. Conclusion

The fisher folk community of Namsang stream has not been able to harness the fishery potential of this stream in true sense till date. Among the four stations studied, station 2 was found to be the richest in terms of fish species diversity as this station possess the characteristics of both hill stream and foot hills. This station is located near Deomali sub-division of Tirap district and well connected by road. This station can be effectively utilized for harnessing the fishery potential and conservation of precious ichthyofaunal resources of Namsang stream. As the station is located in foothills and the temperature regime of this area is favourable, the concept of a fish breeding centre/live gene bank of endemic fishes having food value and ornamental value can be mulled in this area. Most of the ornamental fish species recorded from Namsang stream are having great demand in the international market. Trading of these ornamental fish species can be encouraged after standardising their breeding and propagation techniques. This station can also be promoted as a sport fishing destination as it is well connected by road.

Fishing in hill stream is a difficult task. Most of the fishing gears operated in Namsang stream is inefficient to utilise the fishery resources of the stream. However, the indigenous fishing practice of local 'Nocte' tribe of Namsang stream, 'BHETA' is a very effective fishing

and non-target species along with their eggs and young ones. In addition to this, some of the anthropogenic activities like extraction of boulders from Namsang stream, sediment are also altering the specialised habitat of hill stream fishes of the stream. As a cumulative impact of all these activities, the occurrence of many hill stream fishes have become rare as reported by the local fisher folks.

The threats on the fish germplasm resources have caused concern. Identification, categorisation of endangered, threatened and vulnerable species and studies on their biology in order to conserve them has become inevitable (Vishwanath, 2009). Of the 49 fish species recorded from Namsang stream, 34 were assessed for threat criteria as per IUCN (CAMP, 1997). Six species were considered endangered, 13 vulnerable, 13 lower risk-near threatened and 1 lower risk-least concern.

The present study clearly shows high ichthyofaunal diversity of Namsang stream. Many of these fish species are endemic only to this hilly stream. The hydro biological parameters of this study also showed that by and large, Namsang stream is a productive ecosystem congenial for hill stream fishes. On the other hand, the CAMP report is indicating the extent of threat to these valuable fish species. The threat may be much more higher during recent times since the report represents a picture of late nineties and no serious effort for conservation of these resources have been made so far. It is therefore need of the hour to take some scientific measures to protect and conserve the diverse endemic fish faunal diversity of Namsang stream.

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Bheta fishing and fishes seen trapped in Bheta

Deopani stream, Dibang valley, Arunachal Pradesh

1. Deopani stream

Deopani stream of Lower Dibang valley district of Arunachal Pradesh is located at a longitude of 95°51′12.96″ E and latitude of 28°09′31.58″ N. The stream originates at the confluence point of two small streams Eze and Eme at a longitude 95°51′16.00″ E and latitude of 28°09′34.60″N at an altitude of 475m msl. This perennial stream with rocky substratum traverses a course of 12 km before it debouches into the Dibang river at a longitude of 95°44′ 14.83″ E and latitude of 28°10′26.60″N at an altitude of 217m msl.

The study was conducted during 2008 and 2009. During this period fish and water samples were collected from the stream at an interval of two months viz. October'08, November'08, January'09, April'09, June'09 and September'09. These samples were collected from four different stations of the stream selected based on their altitude. Station 1 is the point of origin of Deopani stream, the confluence point of two small streams Eze (Ezengo in local language) and Eme located at a longitude of 95°51′16.00″ E and latitude of 28°09′34.60″N at an altitude of 475m msl. Station 2 is located near the Rowing (district headquarter of Lower Dibang valley district) and Anini (district headquarter of Dibang valley district) connecting bridge at a distance of about 1.14 km from station 1 at a longitude of 95°50′34.27″ E and latitude of 28°09′35.50″N at an altitude of 431m msl. Station 3 is about 600m distances from station 2 at a longitude of 95°50′12.35″ E and latitude of 28°09′42.98″N at an altitude of 413m msl. The station 4 was fixed at a distance of about 1.6km from Station 3 at a longitude of 95°49′24.93 ″ E and latitude of 28°09′49.08″N at an altitude of 379m msl.

2. Physico-chemical parameters

The river substratum is mainly composed of stones, rock girders and large boulders. Gravelly sand is deposited where the water flows serenely in sheltered bays in the rocks and corner reaches of the river. Riverbed is marked by the conspicuous absence of many-rooted plants.

Water temperature fluctuated between 17.0-24.0°C, minimum during winter and maximum in the monsoon in all the stations. River current ranged between 0.53-5.88 m/sec. In all the stations higher velocity was recorded during monsoon (June to September) and retreating monsoon (October- November) seasons whereas lower values were recorded during winter season (December- February). The pH of the river water was neutral in nature (7.0-7.5). Alkalinity value was observed to be in the range of 20-65 mg/l. Dissolved oxygen values

Table1: Seasonal variation of different physico-chemical parameters at Station 1

Sl. No.	Parameters	First Sampling (Oct'08)	Second Sampling (Nov'08)	Third Sampling (Jan'09)	Fourth Sampling (Apr'09)	Fifth Sampling (Jun'09)	Sixth Sampling (Sep'09)
1.	Air Temperature (°C)	34	28	27	28	30	28
2.	Water Temperature (°C)	24	19	17	20.5	21	21.5
3.	Water pH	7.0	7.0	7.0	7.0	7.0	7.5
4.	Water velocity (m/sec)	5.88	0.97	0.68	1.79	0.96	2.33
5.	Dissolved oxygen (mg/l)	9.89	6.4	9.6	9.2	6.8	12.4
6.	Total Alkalinity (mg/l)	30	60	44	50	40	20
7.	CO_2 (mg/l)	3.52	4	4	8	12	5

Table 2: Seasonal variation of different physico-chemical parameters at Station 2

Sl. No.	Parameters	First Sampling (Oct'08)	Second Sampling (Nov'08)	Third Sampling (Jan'09)	Fourth Sampling (Apr'09)	Fifth Sampling (Jun'09)	Sixth Sampling (Sep'09)
1.	Air Temperature (°C)	34	27.5	27	27	30	31.5
2.	Water Temperature (°C)	24	19.5	17	19	21	22
3.	Water pH	7.0	7.0	7.0	7.0	7.0	8.0
4.	Water velocity (m/sec)	5.66	0.89	0.60	1.49	0.81	1.17
5.	Dissolved oxygen (mg/l)	9.66	6.8	9.4	10.8	5.2	6.8
6.	Total Alkalinity (mg/l)	30	65	46	55	30	20
7.	CO_2 (mg/l)	2.64	3	4	7	9	4

Table 3: Seasonal variation of different physico-chemical parameters at Station 3

Sl. No.	Parameters	First Sampling (Oct' 08)	Second Sampling (Nov' 08)	Third Sampling (Jan' 09)	Fourth Sampling (Apr' 09)	Fifth Sampling (Jun' 09)	Sixth Sampling (Sep' 09)
1.	Air Temperature (°C)	34	27.5	28	31	32	32.5
2.	Water Temperature (°C)	24	19	17	20	22	22.5
3.	Water pH	7.0	7.0	7.0	7.0	7.0	7.5
4.	Water velocity (m/sec)	4.28	0.83	0.56			

Table 4: Seasonal variation of different physico-chemical parameters at Station 4

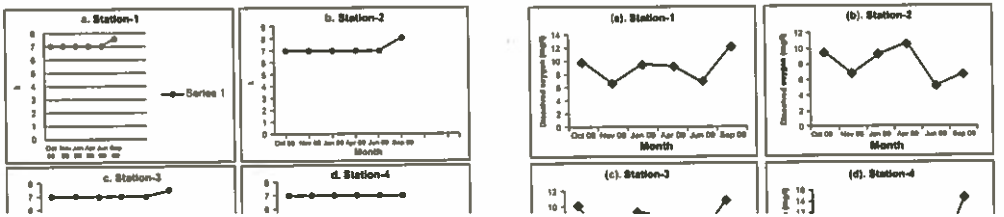
Sl. No.	Parameters	First Sampling (Oct'08)	Second Sampling (Nov'08)	Third Sampling (Jan'09)	Fourth Sampling (Apr'09)	Fifth Sampling (Jun'09)	Sixth Sampling (Sep'09)
1.	Air Temperature (°C)	34	27.5	28	29	32	31
2.	Water Temperature (°C)	24	19.5	17.5	20	22	22.5
3.	Water pH	7.0	7.0	7.0	7.0	7.0	7.0
4.	Water velocity (m/sec)	3.75	0.78	0.53	0.82	0.64	2.04
5.	Dissolved oxygen (mg/l)	10.35	6.8	10.2	8.4	3.2	14.8
6.	Total Alkalinity (mg/l)	32	60	46	60	50	30
7.	CO_2 (mg/l)	4.401	3	3	8	6	6

3. Biological parameters

The major fish groups recorded during the study were Glyptothorax, Mahseers (*Tor putitora*, *Neolissocheilus hexagonolepis*) and Barils (*Barilius bendelensis*, *B. teleo*). Among all these fish species, *Glyptothorax* sp. were to found to be the most common species recorded in all the seasons. The rocky substratum of the river favours the occurrence of this species. The details of the different fish species recorded during the study period are presented in table 5.

Table 5: Fish Species recorded during the First sampling

Sl. No.	Fish Species	Length (cm)	Weight (gm)
1.	*Tor putitora*	10	12
2.	*Barilius* sp.	8	2
3.	*Barilius teleo*	9	4
4.	*Ompok pabda*	19	10
5.	*Neolissocheilus hexagonolepis*	12	22
6.	*Parluciosoma daniconius*	4	2
7.	*Glyptothorax* sp.	7	4



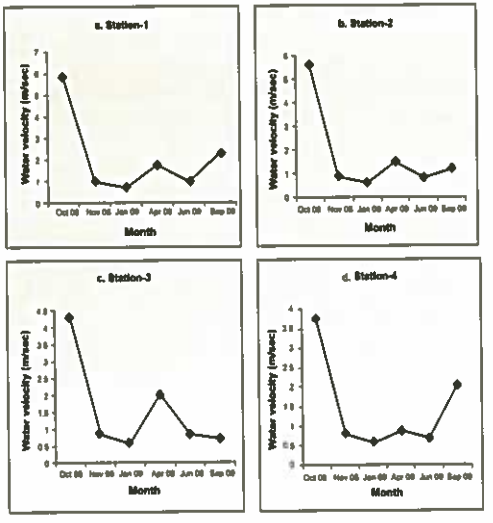


Fig. (a-d). Monthly variations in water velocity at all Stations

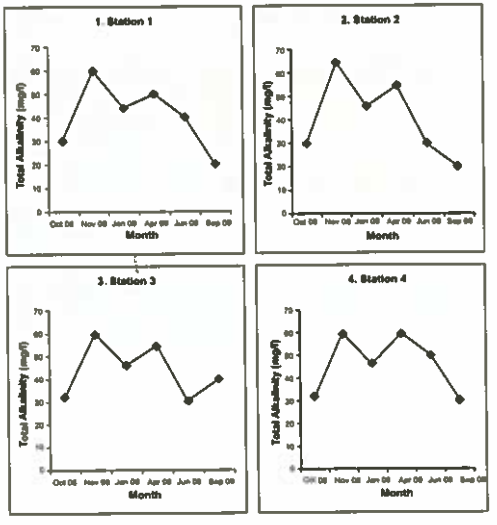


Fig.(a-d) Monthly variations in Total alkalinity at all stations

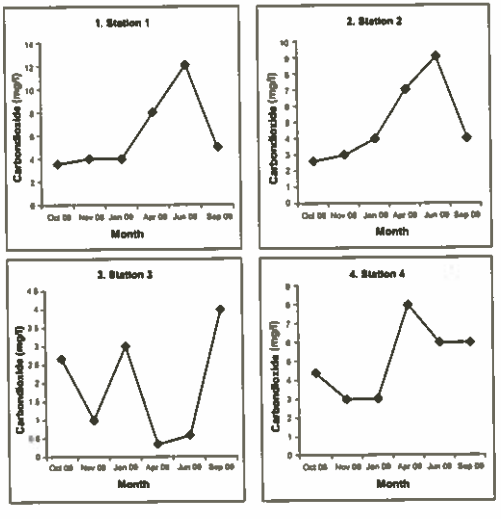


Fig. (a-d) Monthly variations of free

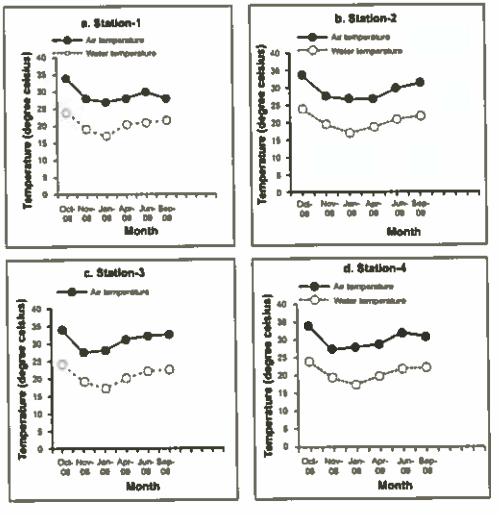


Fig. (a-d). Monthly variations in air and water

4. Satellite images of Deopani

...hese rivers are tributaries of the river
...ict and joins the river Brahmaputra

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Dirang river, West...

1. The West Kameng

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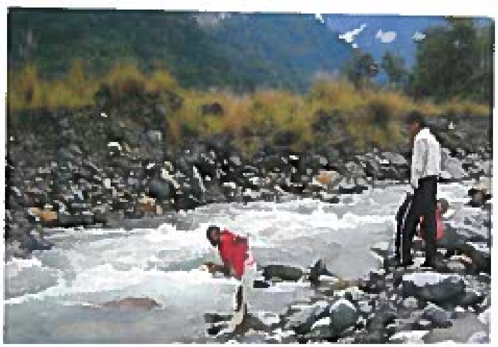
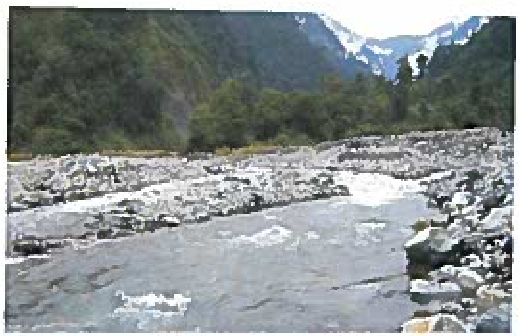




Dirang river, West Kameng, Arunachal Pradesh

1. The West Kameng

Arunachal Pradesh – the Land of the Rising Sun – with an area of 83,743 sq. km. is the largest state in the Northeastern region sharing international boundaries with Bhutan in the west, China in the north and Myanmar in the east. The states of Assam and Nagaland flank its Southern and Southeastern borders. The State is administratively divided into 16 districts. The state capital is at Itanagar at an altitude of 530 m above MSL. It is named after the brick fort built by Ahom King of Assam in the 14th Century. The population of Arunachal Pradesh is 10, 91,117 (2001 census). The average population density is 13 persons per sq. km. The people are of Mongoloid stock with heritage of arts and crafts, enchanting folk songs with their own distinct and diverse culture, dialects and lifestyles. There are 20 major tribes in the State namely Adi, Nyishi, Apatani, Bugun, Galo, Hrusso, Koro, Meyor, Monpa, Tagin, Mishmi, Sajolang, Sartang, Tai Khamti, Yobin, Singpho, Sherduken, Khamba, Tangshang and Memba. The State has a literacy rate of 54.74% (2001 census). Forest covers about 82% area of the State and numerous turbulent streams, roaring rivers, deep gorges, lofty mountains, snow clad peaks and rich diversity of flora and fauna characterize the landscape. The climate varies from sub-tropical in the south to temperate and alpine in the north with large areas experiencing snowfalls during winter. The heights of the mountain peaks vary, the highest peak being Kangte (7090 above MSL) in West Kameng District. The state is divided into five river valleys; the Kameng, the Subansiri, the Siang, the Lohit and the Tirap. All these are fed by snow from the Himalayas and countless rivers and rivulets.

The West Kameng district is located in the western part of Arunachal Pradesh covering an area of 7422 km^2 accounts for 8.86% of the total area of the state. Its main land extends between 91°30" to 92°40"E longitudes and 26°54" to 28°01"N latitudes. The district is surrounded by East Kameng district in the east. Its northern boundary passes through the high peaks of the Himalayas that form the boundary between India and China (Tibet). The western boundary of the district demarcates Bhutan from India. Tawang district lies in the north-west of the district while the southern boundary extends to Sonitpur district of Assam. The name of the district is derived from Kameng river, a tributary of the Brahmaputra, that flows through the district. The topography of the district is mostly mountainous. A greater part of it falls within the higher mountain zone, consisting a mass of tangled peaks and valleys. In West Kameng there are three principal mountain chains - part of Sela range, Bomdila range and

Chu are the main rivers flowing through the district. All these rivers are tributaries of the river Kameng which flows through Bhalukpong circle of the district and joins the river Brahmaputra in plains of Assam.

1.1. Dirang valley

The Dirang river valley resembles typical V-shaped valley of Himalayan terrain surrounded by denudation hills. Developments of terraces (Fig. 1) were observed at few locations along present river course on both sides of the river with an average elevation of about 5-15 m from the riverbed. In general both the banks of the river are mostly covered with slope wash deposits with occasional bedrock outcrops. Major Geodynamic features observed along the left bank of the river are dormant slide zones with slope wash deposits and potential rock fall zones (Fig. 2). Main crops in the region are Paddy, wheat, millets and maize. The inhabitant of the valley comprises mainly of Monpa (Dirang, Boot, Lish, and Kalaktang monpa), Miji (Sajalong), Sherdukpen, Aka, Bugun (Khawa), tribes of other districts and Government service holders from other states. The Monpas belong to the Tibeto-Mongoloid stock and are the largest tribe of the district, inhabiting mainly in Dirang and Kalaktang circles. By and large the Monpas are Buddhists though Akas, Khawas and Mijis believe in indigenous religion and follow partly Buddhist and Hindu practices. Peoples are employed in tourism industry, constructions, government jobs, agriculture and household activities.

As a part of the study, field studies have been conducted for a period of one year in 2010 to analyze water quality, aquatic ecology and fish diversity. The existing data on water quality has been collected to evaluate river water quality on upstream and downstream of the river Dirang Chu (Fig. 3). As a part of aquatic ecology, phytoplanktons, zooplanktons, periphyton, benthic invertebrates, primary productivity has been monitored. Fish diversity and availability in the river was recorded by sample collection from various sites and investigation with local people.

2. Hydrology of Dirang chu (river)

The river Dirang originates in the upper Himalayan ranges at an elevation of about 4600m bordering Bhutan near Bangajang and Luguthang extending from 92° 18" to 92°52"E longitudes and 27°18" to 27°22" N longitudes. Dirang Chu ('Chu' means 'River' in local dialect) which runs parallel to the main highway all the way upto & beyond Dirang (Fig. 4). The old name of Dirang chu was "Mewa ri" and is also known as "Gong ri" (Big water body). The topography of the basin is hilly with steep slopes in upper regions and moderately plain areas in lower regions. The river in its upper reaches generally flows in north-south direction, taking almost

remains snow bound throughout the year and keeps contributing to the river flow during the lean months in the form of glacial melt. The remaining catchment area of about 80% is rain fed. The valley receives varying amounts of rainfall, ranging from a minimum of 1000 mm in the upper reaches to about 5000 mm in the extreme foothills annually and the average rainfall is fairly high. The catchment is covered by thick forest, which gives the advantage of maximum runoff of the rainwater into the river and also ensures minimum inflow of silt. The area has a number of species of flora and fauna and abundant aquatic life in the river. The hilly regions are low in fertility due to rock out-crops, boulders and gravels. There are no major sources of organic pollution loading in the Dirang valley. The river valley has low population density with low cropping intensity. The low cropping intensity coupled with low agro-chemical dosing also means that the pollution load due to agro-chemicals is quite low. The absence of industries implies that there is no pollution load from this source as well.

2.1. Meteorology and climate

The Dirang valley falls under Alpine/Mountain climatic region as per climatic classification of India, which is an indicator of low temperature conditions. The climatic conditions in West Kameng vary greatly with change in altitudes. Four seasons are distinctly observed in the valley viz., **(i) Pre Monsoon** (March-May): Temperature generally ranges between 7-22°C. Humidity varies from 81-87% **(ii) Monsoon** (June- September): the area receives maximum rainfall under the influence of southwest monsoons during this season. The average annual rainfall in the region is 997 mm (1998-2006). The temperature generally ranges from 10-24°C and humidity varies from 90-84%, **(iii) Post Monsoon** (October-November): in this season, there are occasional showers. **(IV) Winter Season** (December to February): The minimum and maximum temperature in this season varies from 1° C and 14°C. The wind direction is southward to North in the monsoon and northward to South in the winter season. No snowfall data is available in the valley.

3. Aquatic ecology and water quality

3.1. Temperature

Water temperature has direct and indirect effects on nearly all aspects of stream ecology. For example, the amount of oxygen that can be dissolved in water is partly governed by temperature. As cold water can hold more oxygen than warm water, certain species of aquatic invertebrates and fish with high oxygen demands (including popular sport fish such as trout and mahseer) are found only in these waters. Temperature also influences the rate of photosynthesis by algae and aquatic plants. A

3.2. Dissolved oxygen

Dissolved oxygen concentrations increase wherever the water flow becomes turbulent, such as in a riffle area, waterfall, or a dam. Oxygen concentrations are much higher in air, which is about 21 percent oxygen, than in water, which is a tiny fraction of 1 percent oxygen. Where the air and water meet, this tremendous difference in concentration causes oxygen molecules in the air to dissolve into the water until saturation is reached. More oxygen dissolves into water when turbulence caused by rocky bottoms or steep gradients brings more water into contact with the surface. The oxygen content in the Dirang river was found to be above the optimum requirement of the fishes.

3.3. Other water quality parameters

River water at all the sites investigated was relatively alkaline. The pH values ranged from 7.2 to 7.6. The total hardness in various water samples ranged from 32-40 mg/l, 40-47 mg/l and 34.1-39.5 mg/l in post-monsoon, winter and summer seasons respectively. The low

Table 1: Estimation of water quality parameters of Dirang river in different seasons

Water quality parameters	Unit	Pre-monsoon (March-May)		Monsoon (June-September)		Post-monsoon (October-November)		Winter (December-February)	
		Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
pH	-	7.2-7.4	7.1-7.3	7.2-7.5	7.2-7.5	7.3-7.6	7.2-7.5	7.5-7.6	7.4-7.8
Temp.	°C	7.9-16.7	6.7-14.0	7.2-19.3	8.2-18.8	6.8-16.4	6.3-15.0	6.1-7.2	6.2-7.2
Dissolved Oxygen	mg/l	8.5-8.7	8.9-8.8	8.4-9.0	8.4-10.3	8.5-11.0	8.3-10.8	8.6-11.2	8.4-11.0
Electrical conductivity (EC)	ìS/cm	70-115	75-112	75-78	74-112	67-110	66-122	78-120	77-115
Total Dis solved Solids (TDS)	mg/l	48-51	45-48	44-50	45-52	45-51	47-53	50-52	48-51
Alkalinity	mg/l	34-44	26-35	22-34	23-36	47-52	43-55	52-57	47-52
Hardness	mg/l	35-37	33-37	37-40	34-41	32-42	37-43	40-47	39-44
Calcium hardness	mg/l	15.1-15.3	14.1-15.0	15.0-15.2	15.1-15.3	15.2-15.4	15.0-15.3	15.1-15.4	15.1-15.3
Magnesium hardness	mg/l	3.0-3.1	3.0-3.1	3.1-3.3	3.0-3.2	3.0-3.2	3.0-3.3	3.1-3.3	3.0-3.1
Fluorides	mg/l	0.1	0.1	0.1	0.1	0.1	0.10.1	0.1	
Nitrate	mg/l	4.9-5.8	4.6-5.5	4.2-6.0	4.1-5.8	4.3-6.1	4.2-6.2	5.6-6.5	4.2-5.5
Phosphate	mg/l	ND	ND	ND	ND	ND	NDND	ND	
BOD	mg/l	1.4-1.5	1.2-1.4	1.1-1.2	1.2-1.6	1.2-1.4	1.2-2.0	1.5-2.1	1.2-1.8

calcium and magnesium levels are responsible for soft nature of water. The carbonate hardness (for water with alkalinity level as observed in the study area) is equal to the alkalinity level. The non-carbonate hardness accounts for the balance hardness. Normally non-carbonate hardness can be removed by boiling. However, hardness levels in the area do not warrant any treatment. The low EC and TDS values indicate the lower concentration of cations and anions. This is also reflected by the fact that the concentration of most of the cations and anions are well within the permissible limit. The fluorides level was lower than the permissible limit (1 mg/l) for drinking purposes. The BOD and COD values are well within the permissible limit, which indicates the absence of organic pollution loading. This is mainly due to the low population density and absence of industries in the area. The marginal quantity of pollution load which enters river Dirang gets diluted. In fact, even for the minimum flow, there is more than adequate water available for dilution. The total coliform and faecal coliform are also low. The concentration of various heavy metals was below the permissible limit specified for domestic use. Thus, it can be concluded that water quality was observed to be quite good (Table 1), as various parameters are well below the permissible limit specified for meeting domestic requirements, irrigation, agriculture, fisheries and livestock.

3.4. Phytoplankton

Phytoplankton is the autotrophic component of the plankton community and plays an important role in the primary production process in the stream ecosystems. They serve as a base of the aquatic food web, providing essential ecological function for all aquatic life. In terms of numbers, the important groups of phytoplankton comprise of diatoms, dinoflagellates, cyanobacteria, and other groups of unicellular algae. The species composition of two conditions viz. lake conditions and river conditions will be different. Density and diversity of phytoplankton in the river water was studied for a period of six months viz., April, May, June, July, August and September 2010 by collecting samples from various sampling locations. A total of 15 numbers of phytoplankton were found in the Dirang valley area viz. Myxophyceae-3, Chlorophyceae-5, and Bacillariophyceae-7. Phytoplankton density ranged from 3-40 individuals/l at various sampling sites, which was dominated by the members of Bacillariophyceae.

3.5. Zooplankton

Zooplankton is the heterotrophic component of the plankton community, and is a broad categorization spanning a range of organism sizes that includes both small protozoan and large metazoan. Through their consumption and processing of phytoplankton (and other food

from various sites of Dirang Chu. The density and diversity of zooplankton species was highest in all the sites in April and it showed decreasing trend in the months of May, June, July, August and September. Zooplankton community in Dirang river was dominated by members of *Rotiferans* and *Cladocerans* which mostly feed on fish waste, dead bacteria, algae and small particles of food suspended in water generated from falling leaf litter from the riparian forest areas. The dominant genera were *Difflugia*, *Colurella*, *Testudinella*, *Keratella* and *Polyarthra*, although their dominance varied across sites and seasons in the river. Zooplankton density ranged from 3-27 individuals/l at various sampling sites monitored for the study. It indicates the poor diversity of zooplankton in the Dirang river.

3.6. Periphyton

Periphyton is a complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most riverine ecosystems. It serves as an important food source for invertebrates, tadpoles, and some fish. It can also absorb contaminants; removing them from the water column and limiting their movement through the environment. The periphyton is also an important indicator of water quality; responses of this community to pollutants can be measured at a variety of scales representing physiological to community-level changes. The periphytic algal components were sampled in the selected sites for 6 months viz. March, April, May, July, August and September 2010. Samples of periphytic algae were collected by scraping 1 cm^2 area of the substratum on which they were growing. The scraped algae were then put in a small container and brought to the laboratory for identification. Density of the periphytic algae was expressed in terms of cm^2. Periphyton communities were prominent in the months of April, May and June in the shallow, rocky and gravelly bottoms in all the sites of Dirang Chu. However, their population became insignificant in the months of July, August and September, which could be attributed to frequent flooding, and turbidity of the river water during these months. The common periphyton genera found in the samling sites were *Nitzchia, Cymbella cistula, Hormidium, Cosmerium, Spirotaena, Gloeocapsa, Nitzchia* and *Chlorella.* Overall, 8 taxa of periphytic algae were recorded from all the sites in the Dirang river. Periphyton density ranged from 60-120 individuals/cm^2 at various sampling sites monitored for the study.

3.7. Benthic invertebrate

Benthic invertebrates are organisms that live on the bottom of a water body (or in the sediment) and have no backbone. Their size spans 6-7 orders of magnitude and they range from microscopic (*e.g.* micro invertebrates, <10 microns) to a few tens of centimeters or more in length (*e.g.* macro invertebrates, >50 cm). Benthic invertebrates live either on the surface of bedforms (*e.g.* rock, coral or sediment - epibenthos) or within sedimentary deposits (infauna).

invertebrates with overall 29 taxa of invertebrates belonging to 8 orders were recorded from all the sampling sites. Members of Ephemeroptera, Trichoptera, Plecoptera and Diptera dominated the invertebrate group. Other orders included Coleoptera, Hemiptera, Megaloptera and Odonata. The families of macroinvertebrates included Baetidae, Chironomidae, Corixidae, Corydalidae, Dytiscidae, Ecdyonuridae, Elmidae, Ephemerellidae, Gomphidae, Gyrinidae, Heptageniidae, Hydropsychidae, Leptoceridae, Leptophlebiidae, Limoniidae, Molannidae, Nemouridae, Peltoperlidae, Perlidae, Perlodideae, Philopotamidae, Polycentropidae, Psychomyiidae, Rhagionidae, Rhyacophilidae, Simulidae, Tabanidae, Taeniopterygidae and Tipulidae. The diversity and abundance of macro invertebrates was higher in the months of March, April and May while it decreased in the rainy months of July, August and September. The density and abundance of macro invertebrates in the later months decreased due to increased water flow regime, which washed off the macro invertebrates and their habitats. Benthic invertebrates density ranged from 5-61 individuals/m^2 at various sampling sites monitored for the study.

3.8. Primary productivity

Phytoplankton is autotrophic, prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis. Among the more important groups are the diatoms, cyanobacteria, dinoflagellates and coccolithophores. Phytoplankton accounts for half of all photosynthetic activity on Earth and contribute significantly to primary production process in aquatic ecosystems. Phytoplankton primary productivity is defined as the rate of organic matter production by the growth of planktonic plants. The details of primary productivity for the months of April, May, June, July, August and September 2010 in different sampling sites are summarized in Table 2. Gross primary production (GPP) and net primary production (NPP) show an increase in the months of April and May, and then decreases in the months of July, August and September in all the sites. Net Primary Productivity (NPP) ranged from 7.5 – 33.3 mgC/m^2/day at various sampling sites monitored for the study.

The diatom species, which were abundant in both benthic as well as planktonic forms were *Achnanthidium minutissima, Achnanthidium microcephala, Achnanthidium exilis* and *Achnanthidium linearis* followed by *Hannaea arcus, Synedra ulna* var. *oxyrhynchus,* and *Fragilaria construens.*

Table 2: Primary productivity of Dirang river

	Month wise estimation of primary productivity
	April

4. Diversity of fish fauna

Works done on fish diversity in the state is fragmentary and limited by the following studies viz., McClelland (1839), Chaudhuri (1913), Hora (1921), Jayaram and Majumder (1964), Srivastava (1966), Choudhury and Sen (1977), Ghosh (1979), Dutta and Barman (1984, 1995), and Nath and Dey (2000). These studies mainly dealt with systematics including new records from India viz., *Amblyceps apangi* and *Amblyceps arunachalensis* (Nath and Dey 1989). Recently, Bagra *et al.* (2009) prepared a checklist of 213 species of fishes for Arunachal Pradesh of which 138 species were first hand collections from 35 rivers in the state. About 5 species are endemic to this region viz., *Amblyceps apangi*, *Amblyceps arunachalensis*, *Labeo devdevi*, *Osteacheilus neilli* and *Calisa labiosus*. The distribution of fishes in Arunachal Pradesh can be mainly attributed to altitude and topography. The higher elevations have cold water forms such as *Schizothorax* spp., *Glyptothorax* spp. etc. The foot hills and mid-elevations comprises of Mahseers such as *Acrossocheilus hexagonolepis*, *Tor tor*, *Tor putitora* which are economically important. Other species include *Labeo dero*, *Labeo pangusia*, *Clarius spp.*, *Wallago attu*, *Aborichthys aor*, *Pabda spp.*, *Notopterus notopterus*, *Belone cancila* etc. The state also has a large number of ornamental fishes such as: Barbs and minnows (*G. chapra*, *A. mola*, *P. ticto*, *A. morar*, *S. bacaila*), Cat fishes (*Ailia coila*, *B. tengana*, *H. hara*, *G. horal*, *M. vittatus*, *M. montanus*), Eels (*M. aculeatus*, *M. armatus*, *P. indica*), Glass fish (*C. baculis*, *C. nama*, *C. ranga*), Gourami (*C. fasciata*, *C. labiosus*), Loaches (*A. elongatus*, *A. kempi*, *N. devdevi*, *B. dario*, *B. rostrata*), Needle fish (*X. cancila*), Perches (*B. badis*, *N. nandus*), Snakeheads (*C. marulius*, *C. striatus*, *C. orientalis*), Puffer fish (*T. cutcutia*), Knife fish (*N. notopterus*).

4.1. Fisheries of West Kameng district

The district West Kameng is one of the largest in terms of geographical, topography as well as river drainage. It harbors many rivers, streams and streamlets, which supports diverse fish species of which many are endemic to the region. Fish species like the *Botia dario*, *B. bendelisis*, *B. bola*, *Punitus chola*, *Tor tor*, *Tor putitora*, *Danio spp.*, *Garra spp.*, *Gotyla gotyla*, *Anguilla* are found in the rivers of West Kameng district. Several spawning grounds of the coldwater species were also identified in the river valley.

4.2. Assessment of fish diversity

The commercial fisheries are non-existent in the river Dirang. Fishing by individuals is only practiced during the lean season in the river valley by the anglers and the traditional fishers. The inaccessible terrain is also one of the reasons that the fishermen are not able to operate their fishnets very effectively. The sampling of fish species was done for a year during 2010-11. Random sampling in selected areas of the river was carried out using a cast net, hook

Snow trout comprises *Schizothorax richardsonii* and *Schizothoraichthys progastus* and are endemic to Himalaya (Plate VII). These fish are herbivores, column feeders and feed on benthic algae with powerful muscular streamlined body. Snow trouts account for major and important part of the capture fishery in the region. *Schizothorax richardsonii* is considered as 'vulnerable' species (CAMP-BCPP, 1997).

Salmo trutta fario (Brown trout) and *Onchorhynchus mykiss* (Rainbow trout) (Plate VIII) are exotic fish species, introduced in certain stretches of Dirang chu from a hatchery established by State Fishery Department at Nuranang and Shergaon. Fry of trout are directly stocked in Dirang Chu, however, a self-sustainable population of brown and rainbow trout could not be established in the river so far. They come rarely in the fish catch.

Botia berdmorei (Blyth's loach) and *B. rostrata* (Gangetic loach) are bottom dweller fish and are carnivorous. They get shelter among the pebbles and shingles in shallow waters. They are not of any commercial fishery interest due to their small size but are considered as aquarium fish. *Botia berdmorei* is designated as 'endangered' species. Generally, these species do not come in the catch, particularly by the caste net and hooks.

Catfish group comprises *Mystus vittatus* and *Amblyceps mangois,* which belong to families Bagridae and Amblycipitidae, respectively. *Mystus vittatus* prefers to inhabit muddy bottom, therefore, very rarely comes in the catch. *Amblyceps mangois* is a bentho-pelagic freshwater species, which clings to the stones/pebbles in the rapid water current. Both species are not of any commercial fishery interest.

Sisorid group of fish comprises *Erethistoides montana*, *Euchiloglanis hodgarti*, *Exostoma berdmorei*, *Gagata cenia* and *Pseudechneis sulcatus*. None of these species is of commercial interest and all are rheophilic and bottom feeders. *Erethistoides montana* has been categorized as 'critically endangered' fish, whereas *Euchiloglanis hodgarti* and *Pseudecheneis sulcatus* are designated as 'vulnerable'.

Average catch per unit effort (CPUE) was recorded to be 0.03 kg/per day and 0.05 kg/day in winter and pre-monsoon seasons, respectively. Hook and line methods, cast nets were mostly used to land the fish. Bamboo woven traps and gill nets were also seen in certain stretches of the river. The capture fishery depends mainly on the snow trout (*Schizothorax richardsonii* and *Schizothoraicthys progastus*) (Plate IX). The low CPUE and scanty population indicated by the low density of fish in the upper reaches which may be due to passage of river through deep and narrow gorges, and presence of cold glacier and snow-melt water, which is not conducive for much fish diversity at these altitudes.

5. Fisheries development plan

species, iv) diversification of fish species for aquaculture practices for livelihood, iv) promotion of eco-tourism and angling for income generation, v) ban of usage of fish poisons and dynamites, vi) provision of fisheries manpower in furlong areas of hilly terrains.

Fig.1: Terraces along the sides of Dirang Chu at Lish village

Fig. 2: Rock fall zone

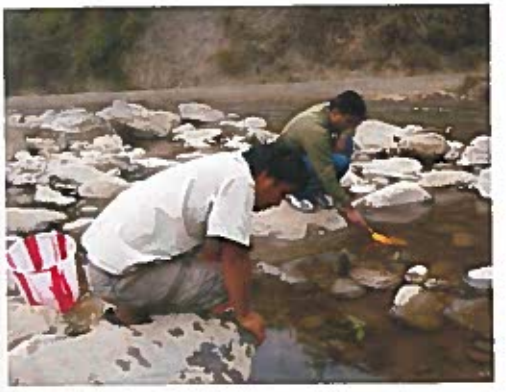


Fig. 3: Study of aquatic ecology

Fig. 4: The Dirang valley

Rivers of Arunachal Pradesh at a glance

1. Water and soil quality of important rivers (2005-06)

1.1. Physico-chemical parameters

(i) Temperature

Air and water temperature of the selected rivers of Arunachal Pradesh ranged between (13.5-27.0) °C and (7.0-22.0) °C. During winter, water temperature fluctuated between (7.0-20.0) °C and in pre-monsoon between (14.0-22.0) °C. The water of river Noa-Dihing (17.0-22.0) °C was hotter and Siang (9.0-14.5) °C was colder.

(ii) Transparency

Waters of all the rivers were transparent in all the seasons.

(iii) pH

pH ranged between 6.8 (Lohit) and 8.1 (Subansiri). Except these two extreme observations, most of the values were within the range of (7.2-7.6) which indicate neutral to slightly alkaline nature of water. No distinct seasonal fluctuation could be observed.

(iv) Free Carbon Dioxide

Free carbon dioxide fluctuated between 0.9-3.8 mg/L. It was minimum (0.95-1.9) mg/L in Tirap river and maximum 2.9-3.8 mg/L in Dikrong river. Post-monsoon (3.8) mg/L and winter (3.6) mg/L recorded high values of carbon dioxide in the river Ranganadi.

(v) Dissolved Oxygen

Dissolved oxygen was rich in the rivers under study, which fluctuated between (7.6-15.2) mg/L. Winter season recorded the higher values of oxygen in all the rivers (10.7-15.2) mg/L. Siang (9.2-14.5) mg/L and Kameng (8.6-15.0) mg/L and Subansiri (9.2-15.2) mg/L were comparatively rich among the other rivers.

(vi) Total Alkalinity

Total alkalinity was found to be medium in the rivers (16.4-98.7) mg/L.

(vii) Specific Conductivity

Specific conductivity was also found to be medium, which varied between (45.0-198.3) ì mhos cm^{-2}. Higher specific conductivity could be observed in the rivers Tirap (155.4-174.8) ì mhos cm-2, Siang (51.3-198.3) ì mhos cm^{-2}, Subansiri (136.9-172.4) ì mhos cm^{-2}, Dibang (97.0-184.0) ì mhos cm^{-2} and Noa-Dihing (95.5-124.2) ì mhos cm^{-2}.

(viii) Total Dissolved Solids

Total dissolved solids were medium in the rivers of Arunachal Pradesh, which ranged from (20.2-100.6) mg/L. Among those rivers Siang (35.6-100.6) mg/L, Subansiri (57.3-82.6) mg/L, Tirap (61.2-88.2) mg/L contained more dissolved solids.

(ix) Dissolved Organic Matter

Dissolved organic matter ranged between (0.52-1.73) mg/L. Pre-monsoon recorded maximum value (1.07-1.73) mg/L. It followed almost similar pattern in all the rivers.

(x) Chloride

Chloride was medium (9.6-32.2) mg/L, Noa-Dihing (18.4-24.5) mg/L, Tirap (14.7-32.2) mg/L; Dibong (19.7-27.6) mg/L was comparatively rich in chloride content. Tai river had the minimum concentration of chloride (9.6) mg/L.

(xi) Total Hardness

Total hardness was (5.0-90.0) mg/L in the selected rivers. However, Tirap (76.3-90.0) mg/L, Siang (30.0-81.8) mg/L and Lohit (38.2-60.1) mg/L reflect more availability among these rivers. No definite trend of seasonal change could be observed.

(xii) Calcium

Calcium was medium (4.1-49.5) mg/L. Except these two extreme values in the river Subansiri, calcium in the selected rivers fluctuated between (10.0-39.6) mg/L.

(xiii) Magnesium

Magnesium content was found to be high ranging between (0.13-49.5) mg/L, Lohit (6.1-49.5) mg/L, Noa-Dihing (2.1-39.6) mg/L, Dibong (5.3-24.1) mg/L,Kameng (6.1-24.7) mg/L, Siang (3.97-24.1) mg/L were the rivers having more magnesium content.

(xiv) Silicate

(xv) Total Iron

Total iron was high in the rivers of Arunachal Pradesh. It ranged between (0.09- 4.7) mg/L, Noa-Dihing (0.12-4.7) mg/L, Ranganadi (0.12-1.1) mg/L were the rivers having more iron content.

(xvi) Nitrate Nitrogen

Nitrate nitrogen was low in the rivers of Arunachal Pradesh. It fluctuated between (trace 0.85) mg/L. It was observed that during pre-monsoon, its content was more than that of post monsoon or winter. Dikrong (0.003-0.85) mg/L, Siang (0.01-0.35) mg/L, Lohit (0.007-0.5) mg/L had more nitrate content.

(xvii) Phosphate Phosphorus

The phosphate content was low (0.001-0.40) mg/L, Tirap (0.006-0.40) mg/L, Lohit (0.003-0.40) mg/L were the major contributors.

1.2. Primary Productivity

Gross primary production fluctuated between (281.0-2125.0) mg C m3 d^{-1}. Winter recorded higher productivity (625.0-2125.0) mg C m3 d^{-1}. Siang (563.0-1874.0) mg C m3 d^{-1} and Tirap (375.0-1000.0) mg C m3 d^{-1}, Noa-Dihing (469.0-1250.0) mg C m3 d^{-1} and Tirap (375.0-1000.0) mg C m3 d^{-1} recorded higher GPP. Net primary productivity fluctuated within the range (94.0-1800.0) mg C m3 d^{-1}, Siang (375.0-1800.0) mg C m3 d^{-1}, Dibong (300.0-1750.0) mg C m3 d^{-1} were the notable contributors. Respiration was within (12.5-900.0) mg C m3 d^{-1}. Respiration was maximum in Noa-Dihing (900.0) mg Cm3d^{-1} followed by Ranganadi (750.0) mg C m3 d^{-1}, Subansiri (600.0) mg C m3 d^{-1} and Tirap (600.0) mg C m3 d^{-1}.

1.3. Soil Quality

Soil pH showed variations in most of the rivers. pH ranged (6.0-7.3) in Kameng, (4.8-6.7) in Ranganadi, (6.9-7.4) in Dibong, (5.3-7.2) in Subansiri, (6.8-7.7) in Noa-Dihing, (5.9-6.3) in Tirap, (4.7-5.5) in Dikrong, (7.0-7.1) in Siang and (7.0-7.2) in Lohit. On an average pH value indicated acidic soil. The soil is almost sandy in texture.

1.4. Biotic Communities

(i) Plankton

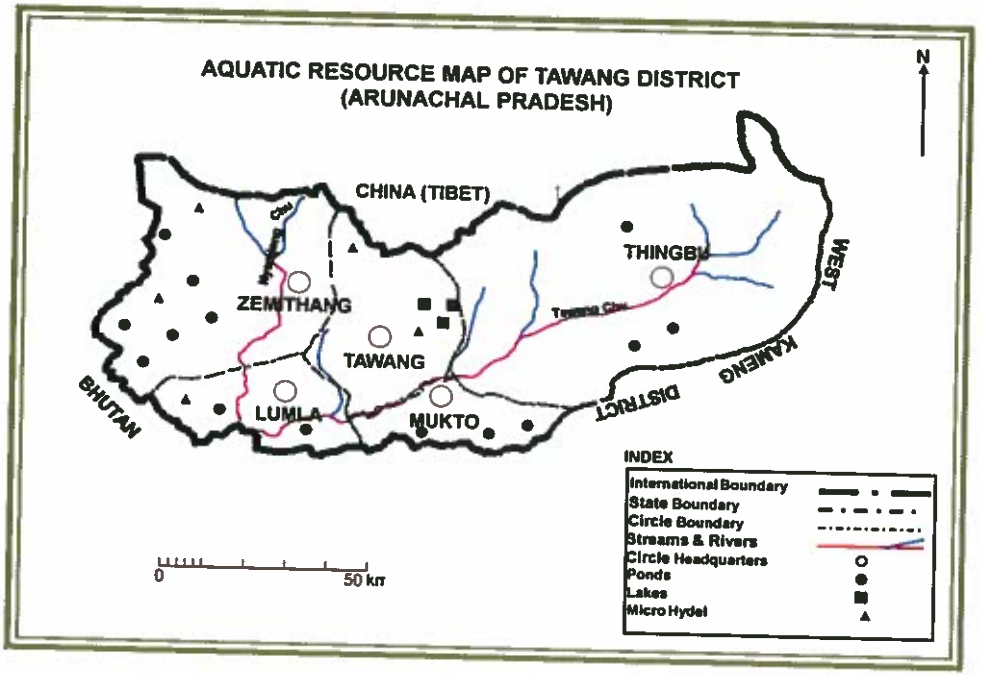
The average plankton density in the rivers of Arunachal Pradesh is maximum in Ranganadi

(4.76-41.82%) and Myxophyceae (Nil – 6.6%). Xanthophyceae (1.35 %) though available, are quite negligible. Bacillariophyceae was represented 22 species out of which *Amphora*, *Cocconeis*, *Cymbella*, *Fragillaria*, *Frustualia*, *Navicula*, *Surirella* and *Synedra* dominated. Chlorophyceae was represented by 18 species *Cladosphora*, *Spirogvra* and *Ulothrix* were present in all the rivers. *Ankistrodesmus*, *Phormodium*, *Mougeotia*, *Closterium*, *Chlorococcum*, *Microspora*, *Sphaeropleae*, *Chlorella*, *Tetradon* and *Rhapdonema* were also present. Myxophyceae was represented by 5 species Oscillatoria, Rivularia, Anabaena, Spirulina among Myxophyceae were present in those riverse. Xanthophyçeae was represented by two species viz. *Traychyloron* and *Goniochlories*. Presence of *Rizopods*, *Zooflagellates*, *Rotifers*, *Ostracods*, *Cladocerans*, *Copepods*, *Dipterans*, *Plecopterans* of Zooplankton are occasional and very meager in numbers.

(ii) Periphyton

Rivers of Arunachal Pradesh are rich in periphyton abundance. It ranged from (12974 – 80369) μ cm^{-2}. Concentration of periphyton was maximum in river Dibong and minimum in Dikrong. Winter was the peak season for its higher concentration and minimum in Dikrong. Winter was the peak season for its higher concentration. Major contributors of periphyton are Lohit (80085) μ cm^{-2}, Noa-Dihing (70949) μ cm^{-2}, Siang (74384) μ cm^{-2}, Kameng (47425) μ cm^{-2}, Tirap (43204) μ cm^{-2}. Bacillariophyceae (55.20-97.69) % contributed the maximum followed by Chlorophyceae (0.36-29.04) % and Myxophyceae (1.15-15.75)%. The contribution of Bacillariophyceae was maximum in Siang river (97.69%) and minimum in Tirap river (55.25%). Bacillariophyceae was represented by 28 species followed by Chlorophyceae (17) and Myxophyceae (6). Animal forms ranged between (0-21375) μ cm^{-2} with the absence in Ranganadi and Lohit. Tirap (21375) μ cm^{-2} and Subansiri (2209) μ cm^{-2} was dominated by the animal community.

1. Map


AQUATIC RESOURCE MAP OF TAWANG DISTRICT
(ARUNACHAL PRADESH)
N
CHINA (TIBET)
THINGBU
ZEMITHANG
TAWANG
LUMLA
MUKTO
BHUTAN
WEST KAMENG DISTRICT
0
50 km
INDEX
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State Boundary
Circle Boundary
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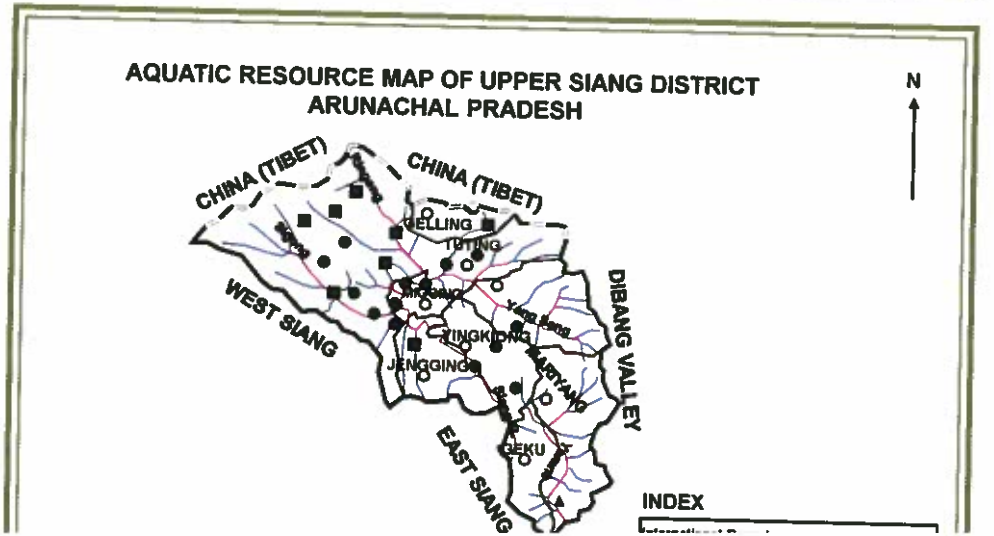
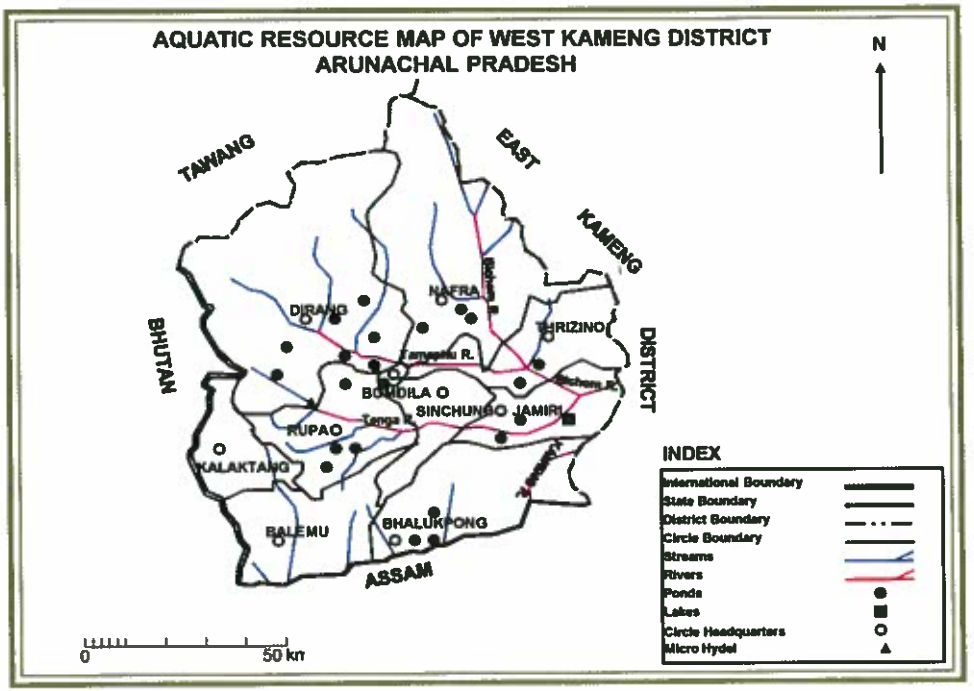
Circle Headquarters
Ponds
Lakes
Micro Hydel


AQUATIC RESOURCE MAP OF UPPER SIANG DISTRICT
ARUNACHAL PRADESH
N
CHINA (TIBET)
CHINA (TIBET)
GELLING
TUTING
YINGKIONG
JENGGING
WEST SIANG
DIBANG VALLEY
EAST SIANG
INDEX


AQUATIC RESOURCE MAP OF WEST KAMENG DISTRICT
ARUNACHAL PRADESH
N
TAWANG
EAST
KAMENG
DISTRICT
BHUTAN
DIRANG
HAFRA
THRIZINO
Tenga R.
BOMDILA
SINCHUNGO
JAMIRI
RUPAO
Tenga R.
KALAKTANG
BALEMU
BHALUKPONG
ASSAM
0
50 km
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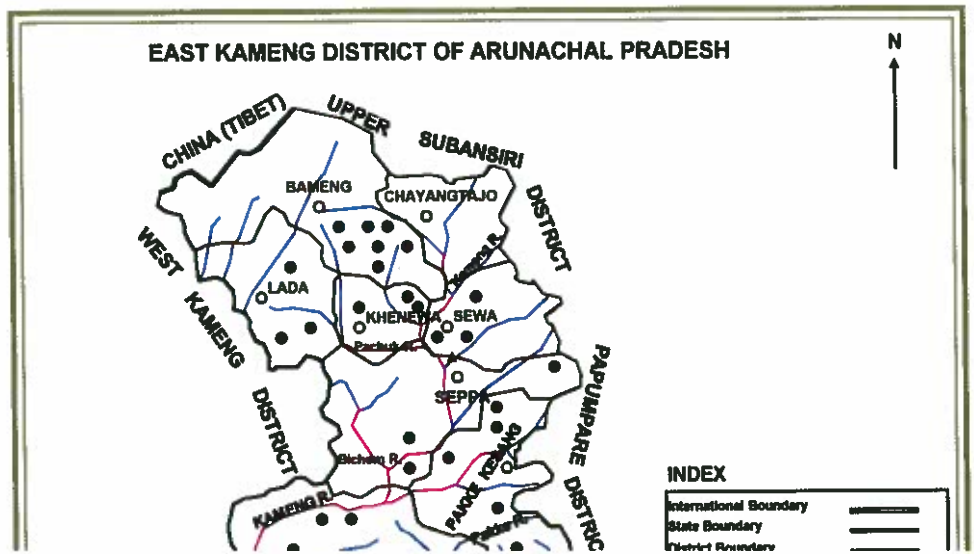
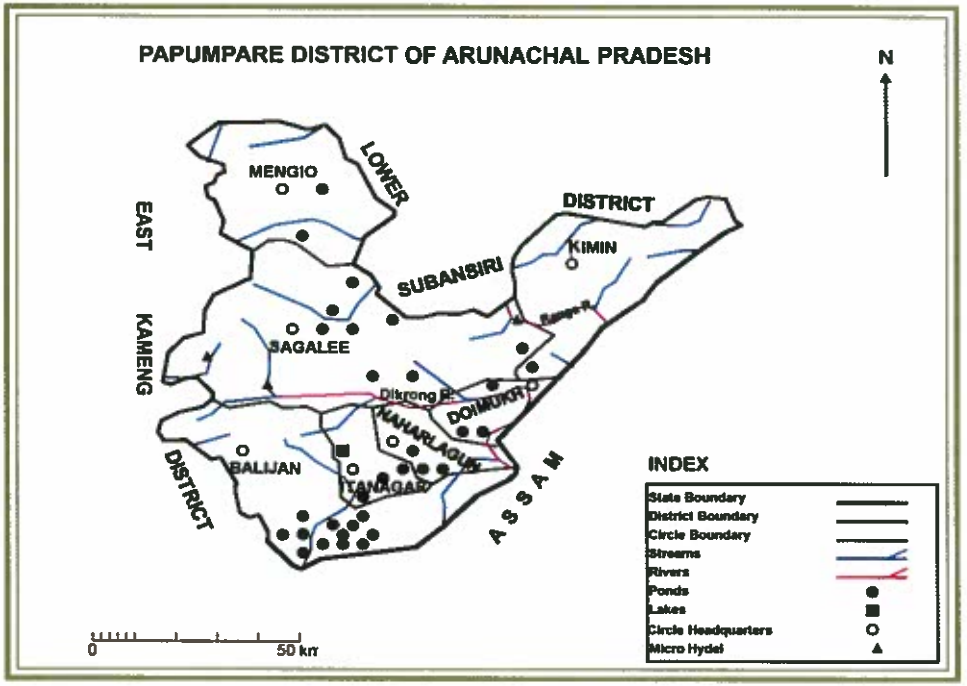
Circle Headquarters
Micro Hydel


EAST KAMENG DISTRICT OF ARUNACHAL PRADESH
N
CHINA (TIBET)
UPPER
SUBANSIRI
DISTRICT
BAMENG
CHAYANGTAJO
WEST
KAMENG
DISTRICT
LADA
KHENEWA
SEWA
SEPPA
PAPUMPARE
DISTRICT
Bichom R.
KAMENG R.
INDEX
International Boundary
State Boundary


PAPUMPARE DISTRICT OF ARUNACHAL PRADESH
N
MENGIO
LOWER
SUBANSIRI
DISTRICT
KIMIN
EAST
KAMENG
SAGALEE
Dikrong R.
DOIMUKH
NAHARLAGUN
BALIJAN
ITANAGAR
DISTRICT
ASSAM
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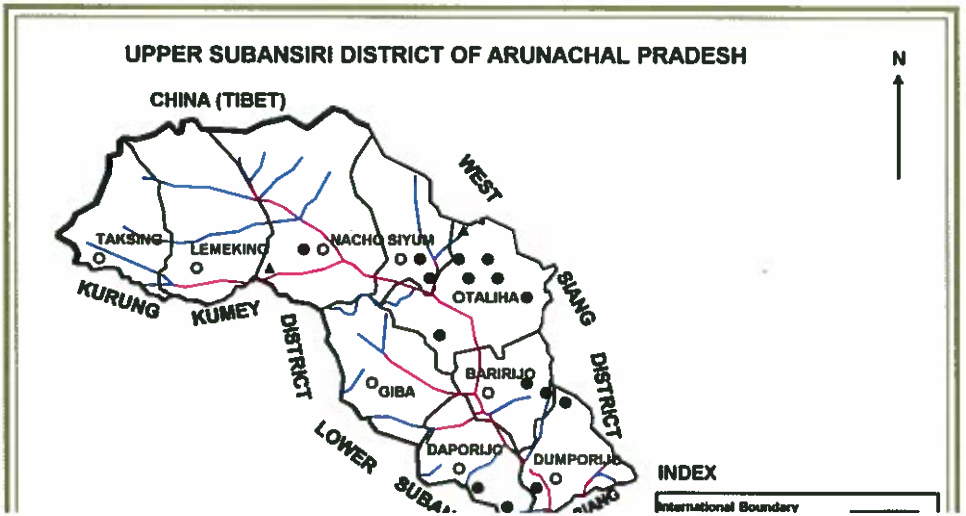
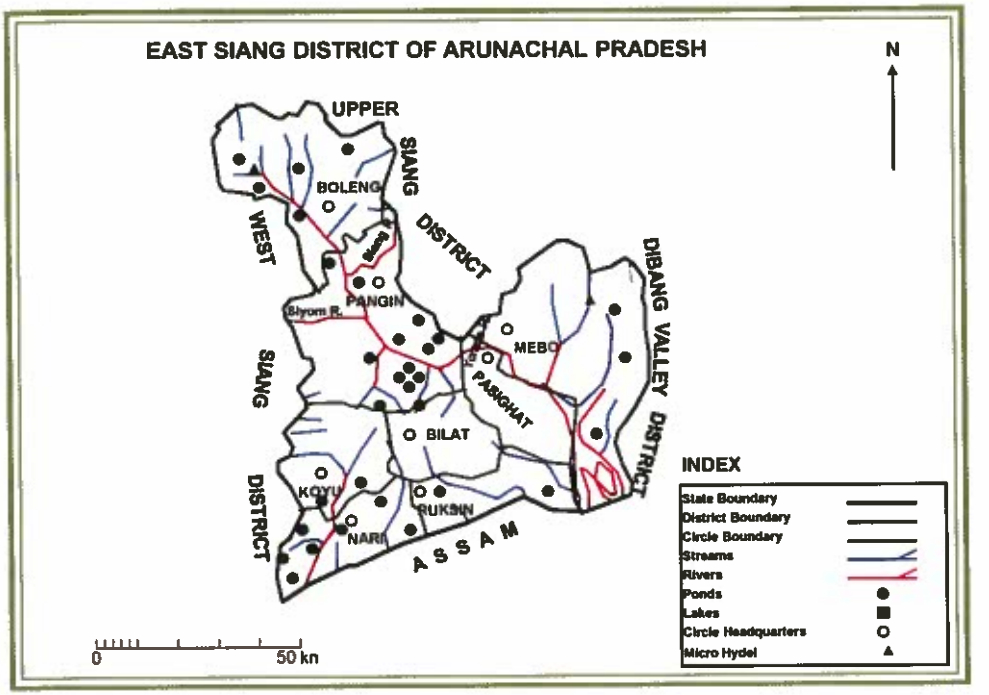
Lakes
Circle Headquarters
Micro Hydel
0
50 km


UPPER SUBANSIRI DISTRICT OF ARUNACHAL PRADESH
N
CHINA (TIBET)
WEST
TAKSING
LEMEKING
NACHO SIYUM
KURUNG
KUMEY
DISTRICT
OTALIHA
SIANG
DISTRICT
BARIRIJO
GIBA
LOWER
DAPORIJO
DUMPORIJO
INDEX
International Boundary


EAST SIANG DISTRICT OF ARUNACHAL PRADESH
N
UPPER
SIANG
DISTRICT
WEST
SIANG
DISTRICT
DIBANG VALLEY
DISTRICT
BOLENG
PANGIN
Siyom R.
MEBO
PASIGHAT
BILAT
KOYU
RUKSIN
NARI
ASSAM
0
50 kn
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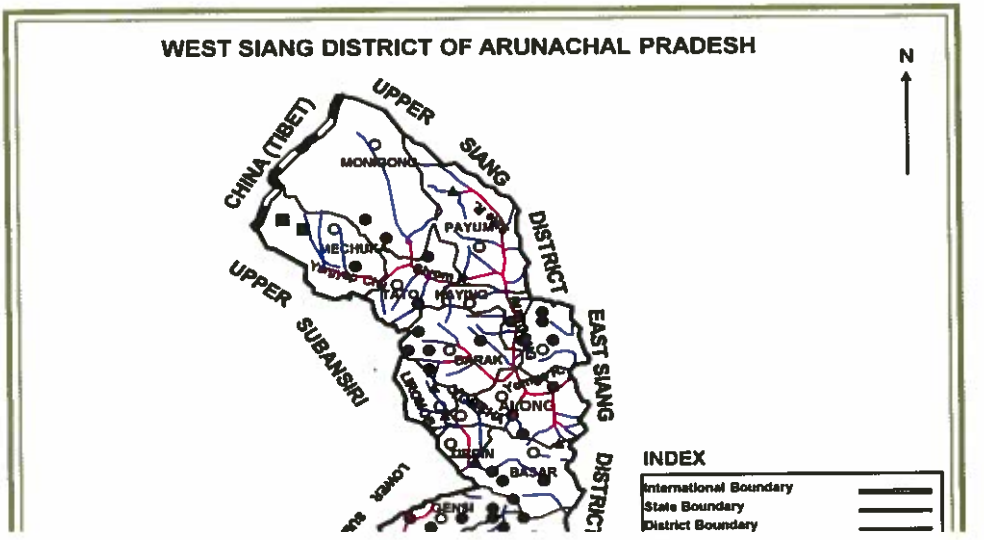
Circle Headquarters
Micro Hydel


WEST SIANG DISTRICT OF ARUNACHAL PRADESH
N
CHINA (TIBET)
UPPER
SIANG
DISTRICT
MONIGONG
PAYUM
MECHUKA
HAYING
UPPER
SUBANSIRI
EAST SIANG
DISTRICT
BASAR
INDEX
International Boundary
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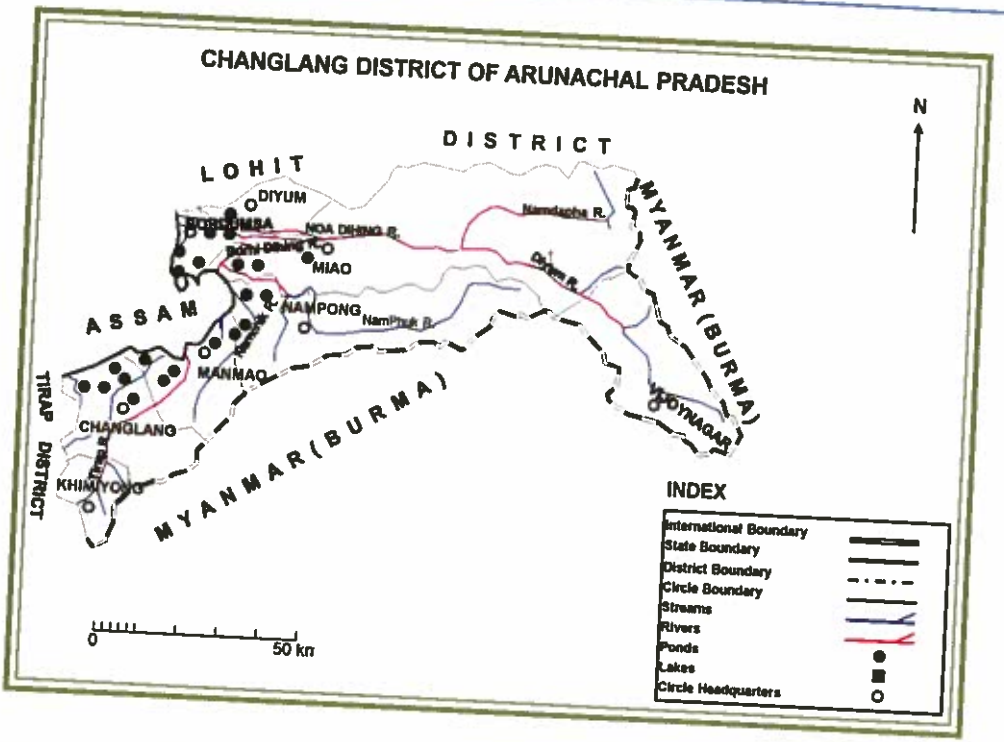
CHANGLANG DISTRICT OF ARUNACHAL PRADESH
N
LOHIT
DISTRICT
DIYUM
NOA DIHING R.
MIAO
Namdapha R.
Dihing R.
MYANMAR (BURMA)
ASSAM
NAMPONG
NamPhuk R.
MANMAO
TIRAP DISTRICT
CHANGLANG
KHIMIYONG
MYANMAR (BURMA)
0
50 km
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Rivers
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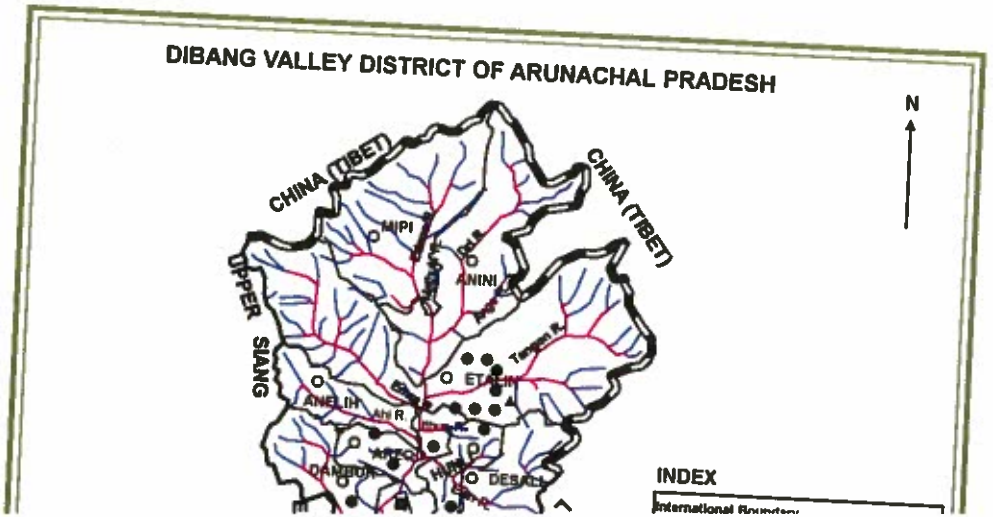
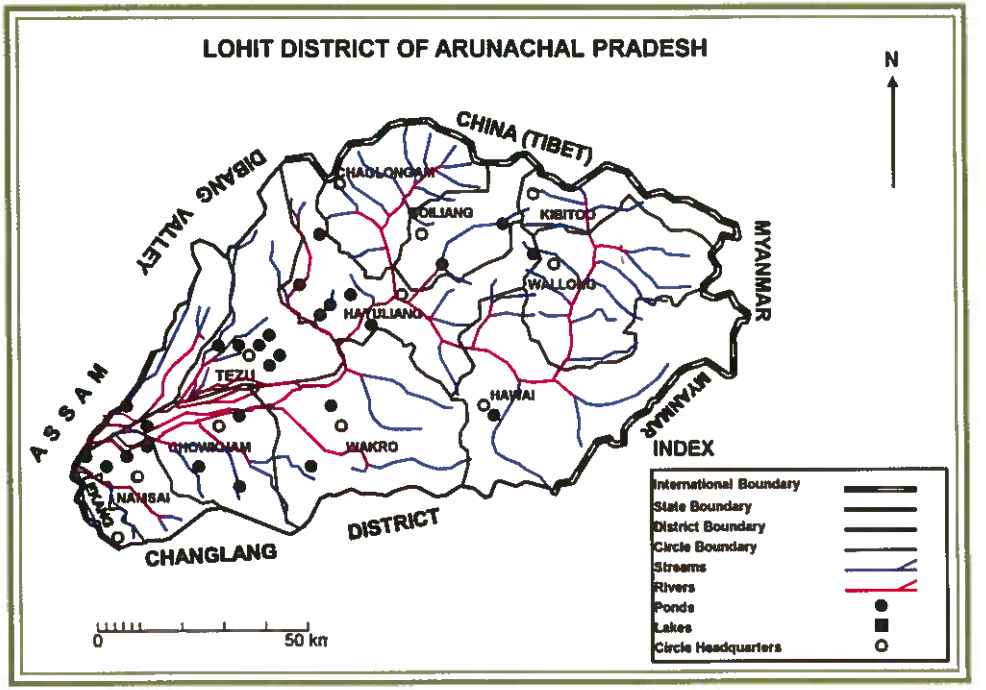

DIBANG VALLEY DISTRICT OF ARUNACHAL PRADESH
N
CHINA (TIBET)
CHINA (TIBET)
MIPI
ANINI
UPPER SIANG
ANELIH
DAMBUK
DESALI
INDEX


LOHIT DISTRICT OF ARUNACHAL PRADESH
N
CHINA (TIBET)
DIBANG VALLEY
MYANMAR
ASSAM
CHAGLAGAM
KIBITOO
WALLONG
HAYULIANG
TEZU
HAWAI
CHOWKHAM
WAKRO
NAMSAI
CHANGLANG
DISTRICT
0
50 km
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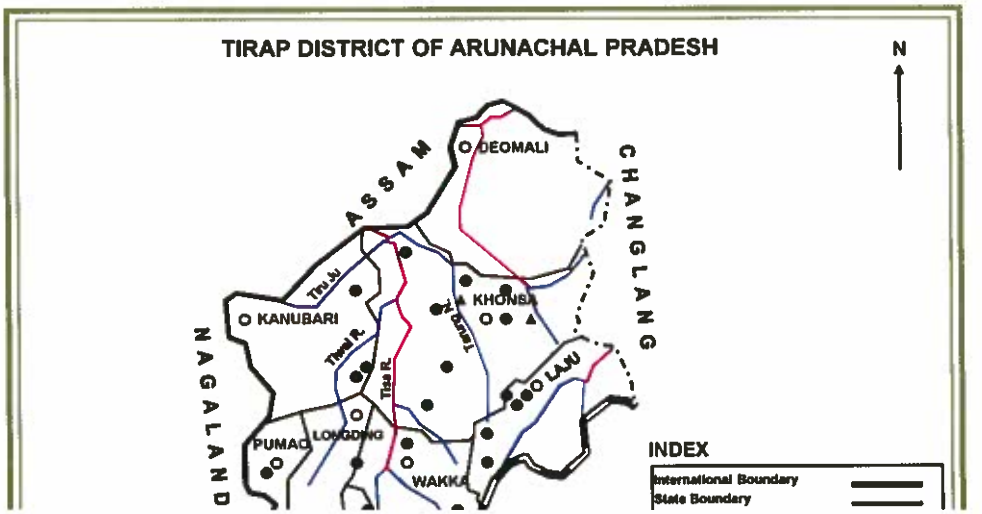
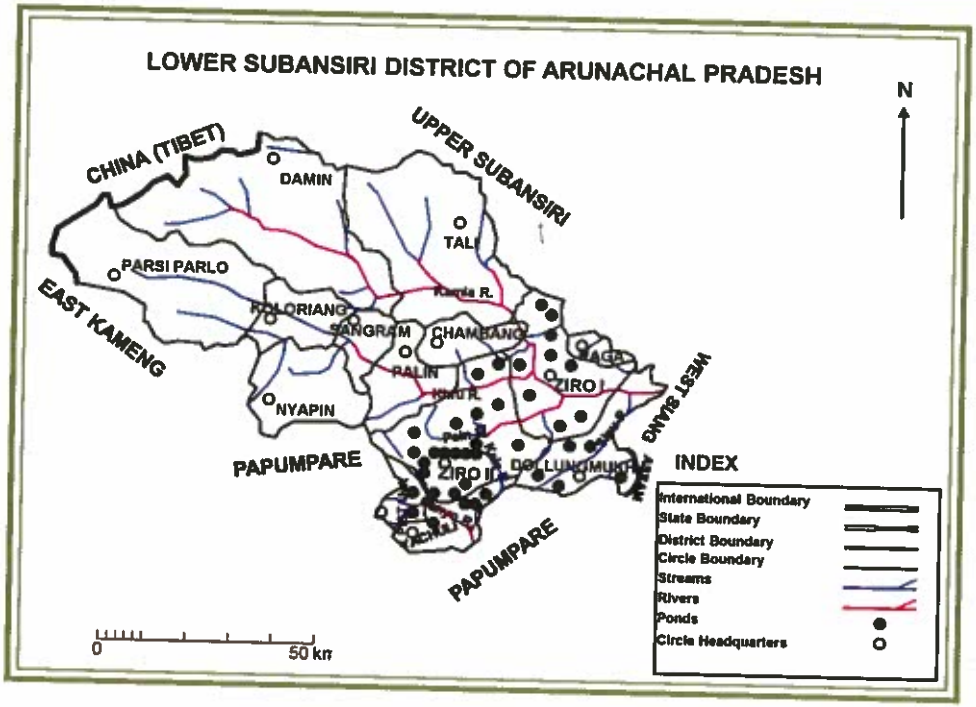

TIRAP DISTRICT OF ARUNACHAL PRADESH
N
ASSAM
DEOMALI
CHANGLANG
KANUBARI
KHONSA
LAJU
NAGALAND
PUMAO
LONGDING
WAKKA
INDEX
International Boundary
State Boundary


LOWER SUBANSIRI DISTRICT OF ARUNACHAL PRADESH
N
CHINA (TIBET)
UPPER SUBANSIRI
DAMIN
TALI
PARSI PARLO
EAST KAMENG
POLORIANG
SANGRAM
CHAMBANG
RALIN
ZIRO I
NYAPIN
WEST SIANG
PAPUMPARE
ZIRO II
DOLUNGMUKH
PAPUMPARE
0
50 km
INDEX
International Boundary
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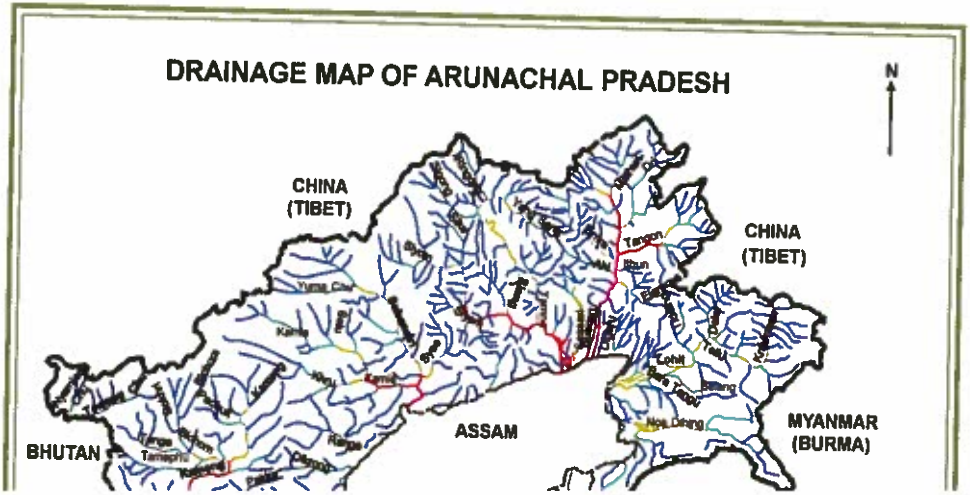
Circle Headquarters


DRAINAGE MAP OF ARUNACHAL PRADESH
N
CHINA (TIBET)
CHINA (TIBET)
BHUTAN
ASSAM
MYANMAR (BURMA)

Directorate of Coldwater Fisheries Research