ECOLOGY AND FISHERIES OF BEELS IN ASSAM

Central Inland Capture Fisheries Research Institute Barrackpore

Ecology and Fisheries of Beels in Assam

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Foreword

The State of Assam is endowed with copious aquatic wealth in the form of *beels*, swamps, ponds and rivers, which bear rich potential for inland fish prodction. Nevertheless, the State still has a deficit of fish production to the tune of 1.5 lakh t per year. The floodplain wetlands (*beels)*, extending over one lakh ha, constitute the most important fishery resource of the State. The investigations carried out by the Central Inland Capture Fisheries Research Institute (CIFRI) have proved that the *beels* can produce much more fish than what they do at present. Lack of technical advice on utilization of this resource for fishery development has been one of the reasons for low yields. CIFRI has been investigating the ecological characteristics of the *beels* of Assam for the last two decades with a view to develop guidelines for their fishery management. Based on these extensive investigations, some new lights have been thrown on he ecology and fishery potential of the *beels* of Assam.

The Institute has also been able to develop some broad guidelines for the management of culture-based and capture fisheries of the *beels,* which have been presented in this bulletin. Culture-based fishery facilitates substantial increase in fish yield and production with minimal monetary inputs and environmental damage. Development of *beel* fisheries on the basis of culture-based fisheries is also significant from a socio-economic point of view. Most of them are common property resources managed under cooperative fold. Thus, benefits accrued from the increased productivity is equitably distributed among the fishers.

This belletin is the first ever attempt to provide scientific advice on fishery management of floodplain wetlands of Assam, based on scientific principles. Even though it is not possible to develop technology packages for fishery management of beels due to many reasons, the formative guidelines presented in this communication are adequate to achieve substantial increase in yield and production from *beels*. The team of CIFRI scientists under the leadership of Dr. V.V. Sugunan has done a commendable job in collecting data from the *beels* of Assam under various constraints and analyzing them to develop some very useful guidelines. I trust this bulletin, apart from being a very useful reference material for the *beel* managers, will go a long way in increasing the inland fish production in the State of Assam.

M. Sinha
Director

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INTRODUCTION

India has extensive floodplain wetlands, defined as low-lying areas bordering large rivers, which are seasonally inundated by the overspill from the main river channel. These wetlands are an integral component of the Ganga and the Brahmaputra river basins, covering an area of 0.2 million hectares. They also exist in Manipur and Tripura as well as in the foothills of Arunachal Pradesh and Meghalaya. They can be typical ox-bow lakes (*i. e.* cut off portions of river meander bends), sloughs, meander scroll depressions, back swamps, residual channels or tectonic depressions, though it is often difficult to establish their identity due to natural and man-made modifications to the environment. These water bodies are locally known as beels (Assam, West Bengal, Arunachal Pradesh, Meghalaya and Tripura) *maun, chaurs* and *dhars* (Bihar), *pats* (Manipur), *charhas* and *boars* (northern and south-eastern West Bengal respectively). Floodplain wetlands form an important fishery resource in these states and thousands of poor fishermen are dependent on these water bodies for their livelihood. The magnitude of their distribution and potential as a fishery resource in different states can be seen from Table 1.

Table 1. Distribution of floodplain wetlands in India

State	Distribution (district-wise)	River Basin	Local name	Area (ha)
Arunachal Pradesh	East Kameng, Lower Subansiri, East Siang, Dibang valley, Lohit, Changlang & Tirap	Kameng, Subansiri, Dibang, Lohit, Dihing & Tirap	Beel	2,500
Assam	Brahmaputra & Barak valley districts	Brahmaputra & Barak	Beel	1,00,000
Bihar	Saran, Champaran, Saharsa, Muzaffarpur, Darbhanga, Monghyr & Purnea	Gandak & Kosi	Maun, Chaur & Dhar	40,000
Manipur	Imphal, Thoubal & Bishnupur	Iral, Imphal & Thoubal	Pat	16,500
Meghalaya	West Khasi hills and West Garo hills	Someshwari & Jinjiram	Beel	213
Tripura	North, South & West Tripura districts	Gumti	Beel	500
West Bengal	24-Parganas North & South, Hooghly, Nadia, Murshidabad, Maldah, Cooch Behar, Burdwan, North & South Dinajpore and Midnapore	Hooghly, Ichhamati, Bhagirathi, Churni, Kalindi, Dharub, Dharala, Pagla, Jalangi, Behula, Torsa and Mahananda	Beel Charha & Baor	42,500
Total				202,213

In India, the State of Assam has the maximum number and water area under floodplain wetlands, mainly associated with the rivers Brahmaputra and Barak. Locally known as beels, they are mostly oxbow lakes, backswamps or tectonic depressions. The predominance of floodplain wetlands in Brahmaputra basin is attributed to the oft-changing course of rivers and their tributaries in the upper stretches. The river Brahmaputra passes through zones of acute seismic activity. Frequent earthquakes due to crustal instability induce local and sudden shifts in basement levels. This coupled with heavy discharge of water triggers the process of meander cutoffs leading to formation of oxbow lakes. Tectonic depressions are also formed due to earthquakes. Similarly, the Brahmaputra is prone to frequent and heavy floods, which break the levees leading to formation of back swamps and sloughs. Assam has 1,392 beels spread over more than 100,000 ha. This includes 322 on the river Barak in the districts of Hailakandi, Karimganj and Cachar with a water spread of 8,000 ha. Total area of beels associated with the river Brahmaputra and its tributaries in Assam is estimated at 92,000 ha.

Assam occupies an area of 78,438 km^2; the two important physical regions of the State are the Barak valley (6,962 $km^{2)}$ and the Brahmaputra valley (56,449 km^2). The 2,900 km long river Brahmaputra enters the state through the northeastern district of Tinsukia at an elevation of more than 600 m above MSL and passes longitudinally through the valley (150 m above MSL) before entering Bangladesh through Dhubri district. The whole northern part of the State is bordered by Himalayan hills, ranging in height between 150 and 600 m above MSL (and sometimes between 600 and 1350 m MSL). These hills give rise to many fast flowing rivulets flowing downwards and ultimately meeting Brahmaputra. Mikir and Rengma hills, located centrally at the elevation of 150 to 1350 m are the origin of many streams. North Cachar hills and Boral range (at a relatively low elevation of 150 to 600 m above MSL) is the source of Barak river system. These two river systems form a network of as many as 33 major tributaries. Altogether, there are 121 streams including distributaries (Fig. 1)

The State receives one of the highest rainfall in the world ranging between 178 and 305 cm, in some places exceeding 400 cm. Soil characteristics of the region is dominated by old alluvial types, however, areas along the bank of river Brahmaputra particularly in the lower reaches the soil is recent alluvial. Areas adjacent to Mikir hills, Rangma hills and North Cachar are characterized by either red loam or laterite soil. Forest cover of the State estimated to be approximately 26%, most of which are evergreen forests, wet grass lands and dry grass lands.

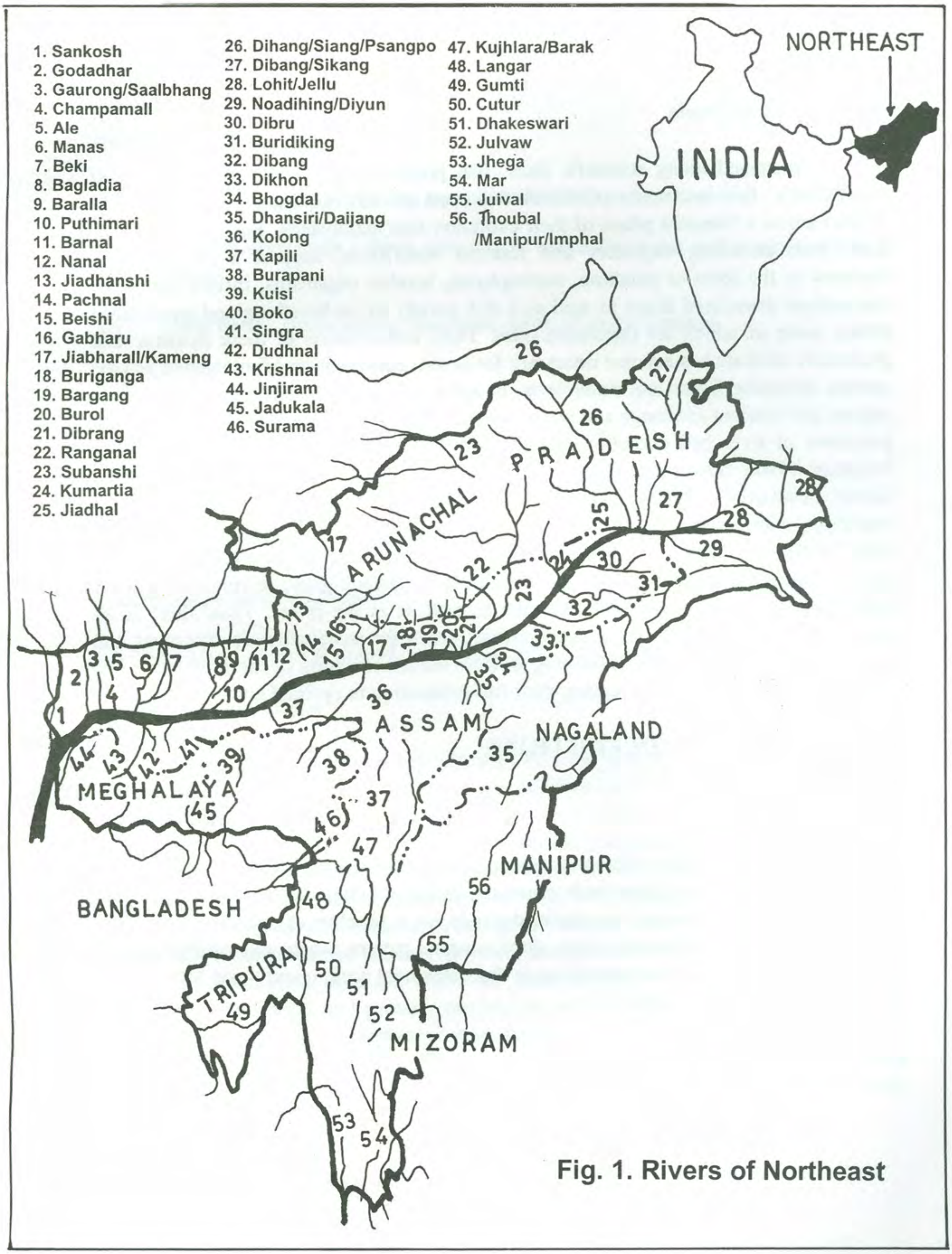


Fig. 1. Rivers of Northeast

Importance of beels

If managed along scientific lines, fish production in beels can be increased significantly. Besides, many of the closed beels (which are cut-off from the river course) are in a transient phase of their evolution into marshlands. Such water bodies, apart from attracting migratory and resident waterfowls, support a rich faunistic diversity in the form of plankton, macrophytes, benthic organisms, insects and other macrophyte associated fauna as well as a rich variety of air-breathing and small sized fishes, some of which are threatened ones. Thus, conservation of these dynamic and productive habitats has become necessary for *in situ* conservation of threatened aquatic species including fishes and waterfowls. In addition, the beels also regulate the water regime and nutrient exchange and act as natural filters. However, a combination of the processes of river bed evolution and the effects of extensive flood control and irrigation works have reduced the fish production of many beels through siltation, habitat destruction, macrophyte infestation and isolation from the seasonal floods restricting entry of riverine fish stocks. The floodplains with their associated lentic water bodies are essentially a continuum of the rivers. Indiscriminate killing of brood and juvenile fishes of commercial species during the breeding and recruitment seasons badly hampers the production in the lake as well as in the rivers. Thus, there is an urgent need to formulate sound management norms for sustainable development and optimal utilization of the beels keeping in view the conservation of the productive and dynamic ecosystem while increasing their fish production to optimal levels.

BASIC CONCEPTS/DEFINITIONS

Floodplains

The floodplains are either permanent or temporary water bodies associated with rivers that constantly shift their beds especially in the potamon regimes. The frequency with which a river changes its course depends on a number of variables like flow velocity, sediment transportation rate, slope, channel pattern, water and sediment yield, amount and duration of precipitation over the catchment area, texture and lithology of soil, tectonic status, and so on.

According to Leopold *et al* (1964), a typical floodplain will include the following:

i) The river channel

ii) Ox-bows or ox-bow lakes*: they represent the cut-off portion of meander bends of a river. These are usually serpentine or horse-shoe shaped.*

iii) Point bars*: These are loci of deposition on the convex side of curves in the channel.*

iv) Meander scrolls*: Depressions and rises on the convex sides of bends formed as the channel migrates laterally down valley by the erosion of the concave bend.*

v) Sloughs: *Area of dead water formed both in the meander scroll depressions and along the valley walls as flood flows more directly down valley scouring adjacent to the valley walls.*

vi) Natural levees*: Raised berns or crests above the floodplain surface adjacent to the channel, usually containing coarser materials deposited as floods flow over the top of the channel banks. These are most frequently found at the concave bank and are submerged annually. They may be absent or imperceptible where most of the silt load in transit is fine grained.*

vii) Back swamp deposits: *Over bank deposits of finer sediments deposited in slack water ponded between the natural levees and the wall or terrace riser. These are submerged for long periods of the year.*

viii) Sand splays : *Deposits of flood debris usually coarser sand particles in the form of splays or scattered debris :*

According to flow of water, the floodplains can be divided into two groups

a) The plain (lotic component) : Includes the river channel (s), the levee region that more or less follows the river channel course and the flats (extending from the levees to the terrace or plateau delimiting the plain. While the main channel (s) of the river usually retain water (not necessarily flowing water) throughout the year, the levee regions and the flats are seasonally inundated but remains dry for at least some parts of the year.

b) The standing water (lentic component): Receding floods leave permanent or semi-permanent standing waters in the form of sloughs, meander scroll depression, back swamps or the residual channel (ox-bow lakes). These water bodies expand or contract in area according to annual flood cycle and tend to merge into a continuous sheet or water covering the whole plain during the highest floods.

Wetlands

The Ramsar convention (1971) defined wetlands as *Areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water which is static or flowing, fresh, brackish or salt including areas of marine waters, the depth of which at low tide does not exceed nine metres.* Thus, wetland embraces a board category of water bodies, which includes riverine floodplains, swamps, marshes, estuaries, backwaters, lagoons, and so on.

The beels, or floodplain wetlands usually represent the lentic component of floodplains *viz.,* ox-bow lakes, sloughs, meander scroll depressions, residual channels and the back swamps and excludes the lotic component (the main river channels, the levee region and the flats). In addition, tectonic depressions located in river basins are also included under beels. Thus, all the wetland formations located at the floodplains can be termed as beels. They are either shallow depressions or dead riverbeds generally connected to the principal rivers and/or receive backflow water from the rivers during floods or from the huge catchment area following monsoon rains.

DESCRIPTION OF BEEL RESOURCES OF INDIA

Geomorphology

The floodplain wetlands are an integral component of the Ganga and the Brahmaputra basins. The Indo-Gangetic Plains are situated between the southern peninsula (oldest land mass in the Indian sub-continent) and the extra peninsular Himalayas in the north. The Himalayan mountains are comparatively of recent (tertiary) origin and are disturbed by earth movement, as evident from the rocks being folded, faulted, over thrust and even carried over some distance as thrust sheets. The plains occupy the depression in the earth's crust between these two elevated regions. Here, the sediments are of recent origin and largely consist of silt which can be easily eroded. The Indo-Gangetic alluvial tracts, especially in the northeast, are also geologically unstable and experience earthquakes of varying intensities from time to time. Two devastating earthquakes occurred in the northeast during 1897 and 1950.

Origin of floodplain wetlands

The lithololgy, geological structure, tectonic status, seasonal variation in river discharge and flow characteristics, largely determine the formation of the floodplain wetlands. The beels of the country owe their origin either to the often changing course of rivers in the potamonic stretches or to tectonic adjustment.

In the northern part of Bihar and West Bengal as also in Assam, the rivers emerging from the central and eastern Himalayas suddenly debouch into the plains and ultimately flow down as the river Ganga, Brahmaputra and Barak. These rivers carry heavy loads of silt and detritus from the Himalayas and overflow during the southwest monsoon season submerging huge tracts of lands every year. These rivers change their course very often creating numerous floodplain lakes and braided channels, mainly in the form of ox-bow lakes. In deltaic West Bengal, due to low gradient and high riverine discharge during the monsoon season, rechannelisation of rivers occurs at the slightest obstruction to flow, resulting in creation of beels of varied types. In the northeast (Assam, foothills of Arunachal Pradesh and Meghalaya), frequent earthquakes coupled with heavy rainfall and cutting action of river meanders have resulted in the formation of typical ox-bow lakes, lake-like beels or true tectonic depressions. The *pat*s of Manipur owe their origin mainly to the cutting action of the stream meanders.

Classification of floodplain wetlands/beels

Since the floodplain wetlands include low lying water bodies of diverse origin, size, shape, depth, inundation pattern, ecological characteristics, *etc.* many attempts have been made to classify them according to these criteria. Some of these classifications are given below :

Classification based on morphometry

i) Ox-bow lakes : These are cut of portion of river meanders. The basins are relatively narrow, long, deep and have either bent or straight shapes. They derive the name from their shape, which is usually horse-shoe shaped, crescent shaped or serpentine. They receive water from the parent river through the old channel or neighbouring catchment areas .

ii) Lake-like wetland: These are wide and shallow with irregular contours. They may be connected to the river through channels or receive water from it during floods. During the monsoon season, the entire neighboring area gets flooded, turning the beel into a vast sheet of water whereas during non-monsoon seasons the water spread area shrinks to the basin proper.

iii) True tectonic depressions : These are created by tectonic activities like earthquakes and usually resemble natural lakes with regular contours. Normally, they are not connected to rivers through connecting channels but may receive water from the latter during floods. Such tectonic wetlands are common in the northeastern region (*e. g.* Chanddubi beel in Assam)

iv) Meteorite lake: These are created by the impact of fall of a meteorite on earth. Such beels have regular, nearly oval shape and abnormally high banks on all sides, which, according to geologists, can be created when the left over portion of a large meteorite hits the earth. The morphometric features of the beels are similar to those of volcanic lakes, except for the fact that they are located in the plains and are very shallow.

Classification based on water retentivity

i) Seasonal beels: These are shallow floodplain wetlands, which periodically get inundated by monsoon rains and floods but completely dry up during summer months.

ii) Perennial beels: Deeper and permanent beels, which retain water round the year.

Classification based on depth

i) Shallow beels: Beels having maximum depth up to 5 metres.

ii) Medium deep beels : Beels, which have maximum water in the range of 5 to 10 metres.

iii) Deep beels : Beels having maximum depth of over 10 metres.

Classification based on size

i) Small beels : Effective area less than 100 hectares

ii) Medium beels : Effective area 100 to 500 hectares

iii) Large beel : Effective area more than 500 hectares.

Classification based on shape

Ox-bow shaped, crescent shaped, serpentine, oval, irregular braided channels, etc.

Ecological classification

Investigations on floodplain wetlands of West Bengal carried out by CIFRI for the last decade and a half indicate that water residence and renewal time as well as the extent of macrophyte infestation are the two most important factors affecting their ecology and fisheries. In beels that retain riverine connections, the continuous water exchange affects the nutrient input-output ratio. While this adversely affects the biological productivity of the ecosystem, it helps in delaying eutrophication process. Rapid water renewal also helps in breaking the thermal stratification, if any, in deep beel, which is beneficial for nutrient recycling and gaseous exchange. At the same time, continuous water flow does not allow the plankton species to stabilize, resulting in lower plankton density and primary production rates in such beels. Similarly, aquatic macrophytes use up large chunks of plant nutrients, thus making them unavailable for the growth of phytoplankton (Phytoplankton is a better primary producer than macrophytes in beels for efficient conversion of energy). The aquatic weeds also render operation of fishing gear difficult. Thus, the following two ecological classifications using these two characteristics are much more relevant from the ecological and fisheries point of view than the previously discussed ones and will be largely followed in this treatise.

Classification based on riverine connection

i) Open beels : These beels retain continuity with the parent rivers either for the whole year or at least during the rainy season. Such beels have continuous exchange of water as well as fish fauna with the parent river.

ii) Closed beels : These beels are completely cut-off from the nearby rivers and receive water mostly from their catchment areas following monsoon rains or during high flood. In recent years, riverine embankments constructed to prevent floods have converted many open beels into closed ones by blocking the riverine connections.

Classification based on the extent of macrophyte infestation.

i) Weed choked beels: A beel can be considered as weed choked when more than 50% of the total water spread area is covered by aquatic macrophytes.

ii) Moderately weed infested beels: A beel can be considered as moderately weed infested when less than 50% of the total water spread area is covered by aquatic macrophytes.

FISHERY RESOURCES OF ASSAM

The State has extensive freshwater resource with huge potential for fisheries development (Table 2). The floodplain lakes are a conspicuous feature of both the Brahmaputra and the Barak valleys in Assam. There are about 1392 enlisted beels in Assam (Table 3) of which 423 are registered and the remaining 969 are un-registered and under the control of both government (505) and private ownership (464). Together, these beels occupy an area of 1,00,000 ha constituting approximately 61% of the total lentic water bodies of the State. If properly managed in scientific lines, these water bodies can play a pivotal role in boosting rural economy in addition to ground water recharge and flood control.

Table 2 Fishery resources of Assam

Resource	Area
Riverine (km)	5500
Ponds (ha)	51000
Beels (ha)	100000
Reservoir (ha)	1500
Swamps and low lying areas (ha)	10000
Total (ha)	368500

Table 3. Beel fisheries resource under different categories in Assam

Category	Number	Area (ha)	Condition		
			Good	*Semi-derelict*	*Derelict*
Registered	423	40,000	10,000	15,000	35,000
Unregistered	969	60,000	Nil	10,000	30,000
Total	1,392	100,000	10,000	25,000	65,000

Three types of beels are found in Assam *viz*., *ox-bow lake type*, *lake type* and *true tectonic depressions*. Ox-bow beels are cut-off portions of river meanders or dead rivulet courses. Many of them are connected with the main rivers through channels. Ox-bow beels are relatively narrow, long and either bent or serpentine in shape. Lake-like beels are wide, shallow and irregular in contour. They are also connected to rivers through channels and receive water from them.

The beels in Brahmaputra basin are situated along the floodplains of rivers Dibru, Buridihing, Dishang, Dikhow, Jhanji, Kakodonga, Dhansiri, Sonai, Kapili, Kallong and Kulsi on the South bank and Dihang, Mora, Jiadhal, Subansiri, Kameng, Dhansiri, Pontemari, Pagladia, Manas, Aai, Champabati and Saralbhanga on the North bank. In Barak valley, the beels are situated along the rivers Barak, Sonai, Sushma, Dhaleswari and Longai. In Brahmaputra valley, 342 beels are located in Central Assam covering an area of 31,080 ha (approx.) followed by lower Assam (352) and upper Assam (376) with water spread of approximately 29,000 ha and 23,000 ha (approx.) respectively. On the other hand there are about 322 beels with water cover of 8000 ha in three districts of Barak valley (Table 4).

Table 4. Distribution of beels in the river valleys of Assam

Zones/Districts	River Basins	No. of Beels	Area(ha)
Upper Assam			
Tinsukia(s)	Lohit, Dibru, Dhala, Dangari, Buridihong, Dumduma	17	
Dibrugarh(s)	Buridihong, Dibru, Sensa	21	
Sibsagar(s)	Dimow, Dishang, Dikhow, Jhanji, Darika, Teok, Tifuk, Namdamg	54	
Jorhat(s)	Jhanji, Teok, Dishoi, Kakodonga	63	23,000
Golaghat(s)	Kakodonga, Dhanshiri, Diflu, Doiang, Lengtajan, Rengma, Digholi	68	
Dhemaji(N)	Dikbai, Simen, Jiadhal, Champara	79	
Lakhimpur (N)	Subanshiri, Kada, Ghagra, Ranga, Dikrong	74	
Central Assam			
Nagaon(S)	Kollong, Sonai, Diju, Na , Kapili	172	
Morigaon(S)	Kollong, Sonai	117	31,080
Sonitpur(N)	Kharoi, Buroi, Borgang, Burigang, Bharoli, Jiagabharu, Belshiri, Sipai	22	
Darrang(N)	Dhanshiri,Mora,Nowa,Nalapani, Baranadi	31	
Lower Assam			
Kamrup(NS)	Puthimari, Hajosuta, Baranadi, Digaru, Barapani, Kulsi, Shibang	46	
Goalpara(S)	Krishnai, Balbala, Dudhnai	45	29,000
Nalbari(N)	Pagladia,Tihu, Baralia	48	
Barpeta(N)	Moramanai, Karokhowa, Kaladiya, Bhelengi, Chaulkhowa	75	
Kokrajhar	Chanpabti, Ai, Manas, Saralbhaga, Kanamakar	26	
Dhubri	Sankhos, Tarang, Gadadhar, Diplai	112	
Barak Valley			
Cachar	Barak,Sonai,Rukni	234	
Hailakandi	Katakhal,Dholeswari	29	8,000
Karimganj	Longai	59	
		1392	

CIFRI has conducted a survey of beels in Assam during 1994 to 1998. During this period, 58 beels representing Upper Assam (25), Central Assam (12), Lower Assam (11) and Barak valley (10) were covered under the study (Table 5, Fig. 2).

Table 5. Beels Surveyed by CIFRI

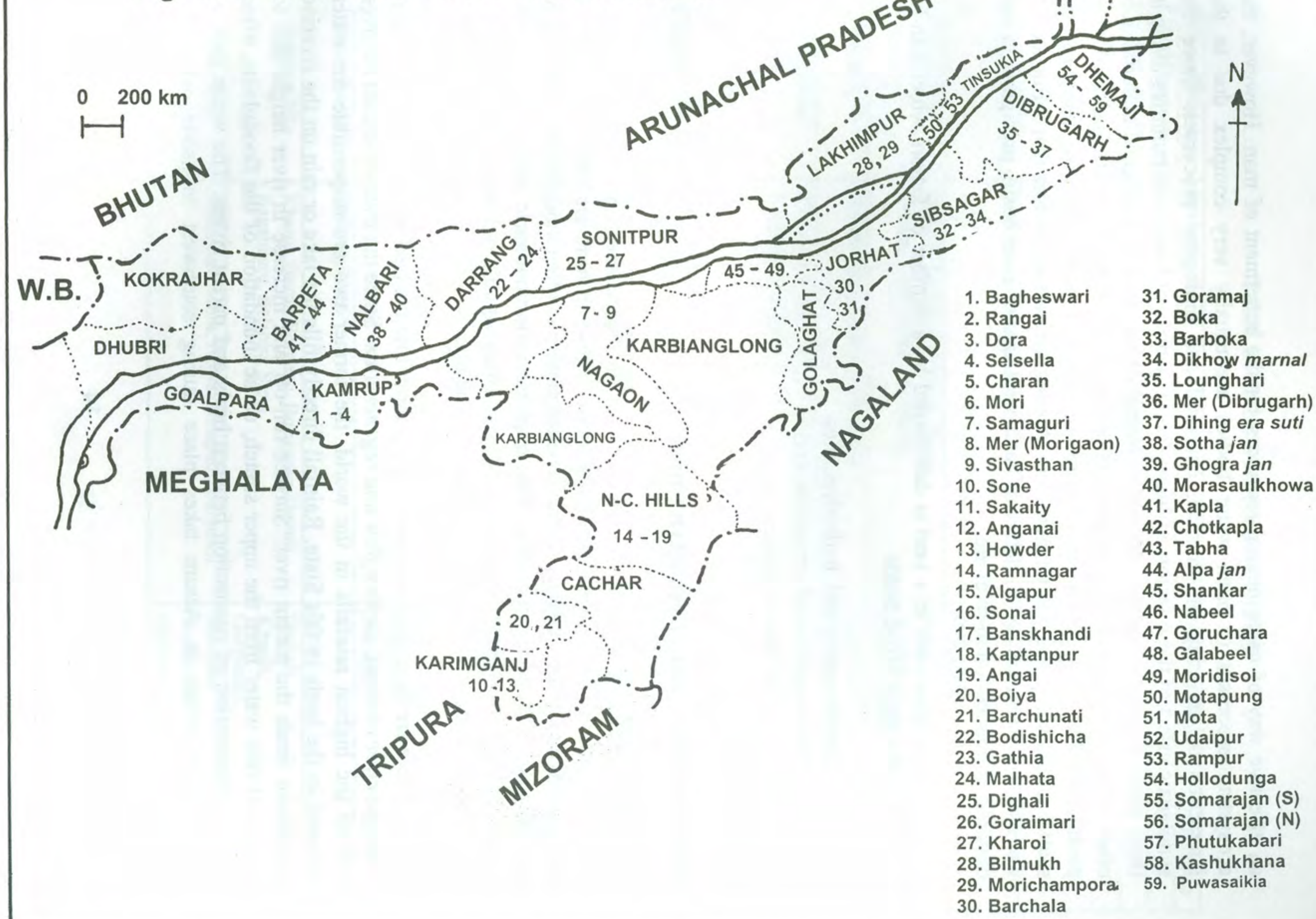
Zones/ Districts	River Basins	Name of Beels	Area(ha.)
Brahmaputra valley			
Upper Assam			
Tinsukia(s)	Lohit, Dibru, Dhala, Dangari, Buridihang, Dumduma	Motapong Mota Udaipur Rampur	100 68 4.5 13
Dibrugarh(s)	Buridihong, Dibru, Sensa	Lomghori, Mer Dihingerasuti	45 30 40
Sibsagar(s)	Dimow, Dishang, Dikhow, Jhanji, Darika, Teok, Tifuk, Namdamg	Boka, Borboka, Dikhowmornai	8 4 180
Jorhat(s)	Jhanji, Teok, Dishoi, Kakodonga	Gorormaj Borchala	70 30
Golaghat(s)	Kakodonga, Dhanshiri, Diflu, Doiang, Lengtajan, Rengma, Dighali	Sankar Nabeel Goruchara Galabeel Moridisoi	30, 10 111 65
Dhemaji(N)	Dikbai, Simen, Jiadhal, Champara	Hollodunga Somrajan(S) Somrajan(N) Phutukabari Keshukhana Puwasaikia	2 12 5 15 30 55
Lakhimpur (N)	Subanshiri,Kada, Ghagra,Ranga, Dikrong	Bilmukh, Morichampora	30 480
Central Assam			
Nagaon(S)	Kollong, Sonai, Diju, Na , Kapili	Somrajan Merr Sibasthan Samaguri	25 23 20 60
Morigaon(S)	Kollong,Sonai	Charan Mori	25 30.
Sonitpur(N)	Kharoi, Buroi, Borgang, Burigang, Bharoli, Jiagabharu, Belshiri, Sipai	Dighali Kharoi, Goroimari	40 60 18
Darrang(N)	Dhanshiri, Mora, Nowa, Nalapani, Baranadi	Mailhata Bodhisichi Gathaia	45 80 20

Table 5 contd. ……..			
Zones/ Districts	**River Basins**	**Name of Beels**	**Area(ha.)**
Lower Assam			
Kamrup(NS)	Puthimari, Hajosuta, Baranadi, Digaru, Barapani, Kulsi, Shibang	Mandira Bageswari Rangai Dora Selsela	10 160 130
Goalpara(S)	Krishnai, Balbala, Dudhnai	Tamranga	900
Nalbari(N)	Pagladia,Tihu, Baralia, Ghogra/Nond	Ghograjan Sothajan Morasaulkhowa	- 15 10
Barpeta(N)	Moramanai, Karokhowa, Kaladiya, Bhelengi, Chaulkhowa	Kapla Chotkapla Tabha Alpajan	75 10 30 750
Barak System			
Cachar	Barak, Sonai, Rukmi	Kaptanpur Banskandi Algapur Ramnagar Anganai	15 30 20 15 30
Hailakandi	Katakhal, Dholeswari	Barchumati Boiya	2 17
Karimganj	Longai	Sone Sakaity Howder	3458 15 9

ECOLOGY OF BEELS

Beel is a highly productive ecosystem which can effectively convert the solar energy into organic carbon in the presence of rich nutrients available from natural sources. Investigations carried out by CIFRI have brought to light exceptionally high rate of primary productivity through macrophyte and plankton phases from floodplain wetlands which are many time higher than those reported from other inland open water ecosystems. By manipulating the biotic communities present in the system, the high rate of organic productivity at the primary producer level can be channeled to higher trophic levels to achieve protein harvest in the form of fish flesh. Thus, growing fish in beels is

Fig. 2. Location of Beels studied in Assam



an effective way of using natural resources for the betterment of man. However, the ecosystem processes in open water bodies are usually very complex due to the interaction of an array of physical, chemical and biological processes. Since the synergistic effect of these factors influence the dynamics of biotic communities living in these water bodies and govern the rate of output of harvestable biological material, it is often difficult to link their fish production potential with any particular ecological parameters. The beel ecosystem is extraordinarily complex with wide temporal and spatial variations of many key parameters. Among the various factors that influence the wetland ecosystem are depth, nature of catchment area or river basin, precipitation and duration of connection to river etc.

Ecosystem processes in a beel is determined by a number of factors which can be brought under three broad heads

- Morphometry and hydrodynamics
- Physico-chemical properties, and
- biological characteristics

Morphometry and hydrodynamics

The main morphometric features that influence the productivity of beel ecosystem are shoreline, area, depth and slope. These, in turn, are closely linked with the hydrodynamics of wetlands. Water renewal pattern is often modified by a number of natural and man-made processes. The important morphometric and hydrodynamic characteristics of different beels scattered over Brahmaputra and Barak valley, studied by CIFRI over the last few years, are described below:

There are three main sources of water input into the beel ecosystem *viz. overspill from the river channel, surface flow and regeneration.* Since the state of Assam receives one of the highest rainfalls in the world, the former two are responsible for water renewal in the beels in this State. Rainfall directly fills the lake or rain on the riverine catchment feeds the parent river. Surface run-off and increase in river height due to inflow of rain water from the upper stretch, cause inundation of the floodplains, often causing resumption of connection between beels and parent rivers. The water gain or exchange of water in Assam takes place during southwest monsoon when the floodplains are flooded. Lake-like beels, through their connecting channels, exchange water throughout the year. Water flow into the lake and draining of excess water from the lake take place through the same channel. Permanently closed beels receive water through rainfall and surface run-off. Thus, flood is the main source of these water for the beels.

After recession of flood, water level in the river decreases snapping the beel's connection with the river. The beel gets dried up through evapo-transpiration and seepage. In some places, people practise *rabi* crop on the banks by extracting water from the beel. The water loss by various means causes shrinkage of the effective water area and lowering of depth in the lake. Consequently, the fluviatile nature of the system is transformed into a lentic and stagnant water body till next flooding. This seasonal change from a lotic condition to lentic and *vice versa* bestows the beels its unique character.

Physico-chemical properties

Water flow plays a vital role in nutrient dynamics and aquatic productivity through transport of nutrients to the organisms and removal of waste. Similarly, temperature, which effects all life processes, including growth rates, life cycles and overall productivity of the entire system is a key physical variable. The flood water and surface run-off carry huge load of silt and allochthonous organic matter which render water turbid, preventing light penetration. After the monsoons, when the system becomes lentic and stagnant, the silt starts settling making the water more transparent to facilitate light penetration. This increases effective photosynthetic zone making the system more productive. Man-made changes in the lake morphometry in the form of water abstraction, embankments and river training have created radical changes in hydrodynamics with far reaching implications on organic productivity.

The crystalization process which influences the chemical composition of beel water depends on a variety of complex factors. However, three basic mechanisms that control water chemistry of beels can be discerned *viz., precipitation, evaporation* and *nature of the basin.* The ionic composition of water is chiefly determined by the rain and the substrata over which the parent river flows. Secondary influences on the ionic composition are exerted by macrophytes and phytoplankton. In recent years, human factors related industrial, agricultural and urban activities started playing an increasingly important role in determining the chemical quality of water. The chemical and physical load brought in by rain water or surface run-off gets concentrated by evaporation and altered by chemical and biological interaction within the system, causing seasonal variations of various parameters.

Biological characteristics

The living part of the ecosystem or the biotic communities in water is governed by the variations of physical and chemical features of the water body and trophic interactions associated with it. Biotic communities of the ecosystem can be categorized broadly as (1) *autotrophs* and (2) *heterotrophs*. The autotrophs include photosynthetic pigment bearing microscopic plants, plankton and macrophytes. Heterotrophs category includes consumers and decomposers. The primary organic productivity and the fish yield potential of a water body thus depends largely on the relative abundance of various communities and their associations. Beels are generally considered as highly eutrophicated system with high rate of primary productivity. The energy produced at the primary stage *i.e.,* phytoplankton and macrophytes are transformed into higher trophic levels through food chains. It is the efficiency at which this energy is transformed into fish level that determines the effectiveness of management. In beels, two main pathways.*viz.,* the *grazing chain* and the *detritus chain* are found. In the grazing chain, primary productivity is done by phytoplankton which is grazed by zooplankton. In case of detritus chain, the macrophytes produce the primary energy. In the absence of fish feeding on macrophytes, these plants die and settle at the bottom adding to detritus. In such cases, detritivorous fish flourish and contribute to fishery.

SALIENT ECOLOGICAL FEATURES OF BEELS IN ASSAM

Soil quality

Soil is vital in maintaining the productivity of any water body. It is one of the main interfaces through which nutrient is released to the water medium. Apart from helping mineralization of the organic deposits at the bottom, soil provides shelter and food to the benthic fauna and flora, which play a significant role in maintaining the nutrient status of overlying water. Distribution of soil types in Assam is illustrated in Fig. 3. Soils of the floodplain wetlands receive additional input in terms of organic matter, inorganic minerals, silt and clay. Since most of the floodplain wetlands are heavily infested with aquatic vegetation, there is a heavy accumulation of dead plant materials at the bottom that undergoes decomposition. Consequently, the nature and properties of bottom soils of floodplain wetlands changes from year to year. Therefore, it is essential to study the soil of such water at frequent intervals in order to assess their role in actual productivity. Important physico-chemical parameters of soil of beels of Assam are presented in Table 6 .

Table 6 Soil characteristics of beels in Assam

	pH	Org.C g/kg	Av. P mg/kg	Av.-N mg/kg	$CaCO_3$ g/kg	Texture (%) Sand	Silt	Clay
Cachar								
Kaptanpur	6.1	7.0	9.6	172	48.5	80	17	3
Banskandi	5.6	4.8	7.4	155	42.5	93	4	3
Algapur	5.2	6.4	10.5	167	33.5	85	10	5
Ramnagar	5.0	10.2	8.2	197	33.5	90	5	5
Hailakandi								
Barchumaṭi	4.7	11.4	6.6	205	27.0	92	6	2
Boiya	4.9	6.9	8.4	171	4.5	84	9	7
Karimganj								
Sone	5.6	6.4	9.0	168	11.3	93	5	2
Sakaity	4.4	9.8	9.6	193	22.5	76	16	8
Howder	4.5	10.4	4.4	200	27.0	67	15	18
Anganai	5.0	10.0	16.2	195	49.5	76	14	10
Lakhimpur								
Bilmukh	5.6	14.5	21.5	230	21.0	93	4	3
Morichampora	5.6	5.7	27.0	170	27.0	93	4	3

Table 6. contd. ......

	pH	Org.C g/kg	Av. P mg/kg	Av.-N mg/kg	$CaCO_3$ g/kg	Texture (%) Sand	Silt	Clay
Dhemaji								
Hollodunga	4.5	17.8	6.6	260	10.0	90	7	3
Somrajan(S)	4.8	15.1	11.6	240	15.0	94	3	3
Somrajan(N)	4.7	17.8	13.6	272	10.0	66	25	9
Phutukabari	5.0	15.6	13.0	230	10.0	83	13	4
Keshukhana	5.7	5.0	19.8	160	5.0	85	15	4
Puwasaikia	5.5	6.2	22.6	170	10.5	92	8	2
Tinsukia								
Motapang	7.2	10.8	4.2	198	5.5	65	32	3
Motabeel	4.6	22.8	1.8	295	5.5	72	25	3
Udaipur	4.7	22.7	4.4	300	10.5	66	29	5
Rampur	6.2	6.0	18.8	175	5.5	75	23	2
Dibrugarh								
Lomghori	4.3	21.7	15.4	283	62.5	77	16	9
Mer	4.5	29.7	17.6	340	67.0	83	13	4
Dihingerasuti	4.2	12.7	7.8	215	27.0	90	7	3
Sibsagar								
Boka	4.4	27.6	14.8	330	58.0	61	21	18
Borboka	4.5	30.0	8.8	350	13.5	73	19	8
Dikhowmornai	4.3	18.7	9.0	270	38.0	81	17	2
Jorhat								
Gorormaj	4.3	29.0	12.6	332	13.5	87	12	1
Borchala	5.9	9.5	22.0	188	36.0	65	32	3
Golaghat								
Sankar	5.3	6.0	7.8	168	15.5	81	15	4
Nabeel	4.8	12.0	6.8	208	5.5	81	16	3
Goruchara	5.2	13.2	9.2	220	10.5	75	21	4
Galabeel	5.8	5.5	12.4	162	10.5	86	10	4
Moridisoi	7.4	6.0	5.0	174	5.5	90	6	4
Darang								
Bodhisicha	5.0	29.1	16.5	340	13.5	73	20	7
Mailhata	5.0	12.7	21.4	234	18.0	91	5	4
Gathaia	5.3	11.4	15.7	210	15.3	90	5	5

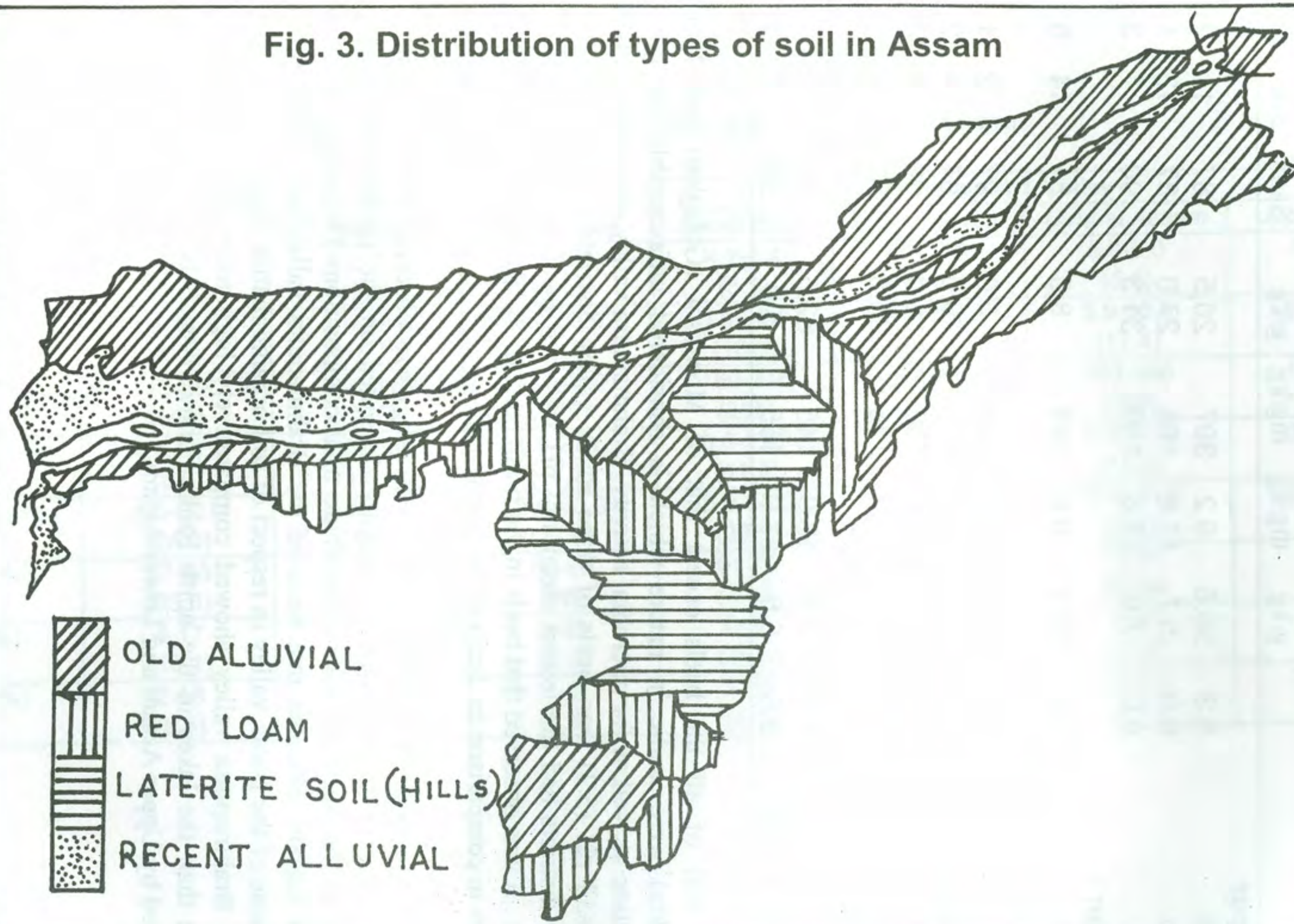
Table 6. contd. .....

	pH	Org.C g/kg	Av. P mg/kg	Av. N mg/kg	$CaCO_3$ g/kg	Texture (%) Sand	Silt	Clay
Sonitpur								
Dighali	5.3	36.6	9.2	397	20,5	87	11	2
Kharoi	6.0	5.7	17.6	165	27.0	87	12	1
Kaloi	6.0	7.6	17.6	180	31.3	90	7	3
Nagaon								
Samaguri	5.2	30.2	9.9	348	8.0	81	14	5
Barpeta								
Kapla	4.9	10.2	20.1	194	5.0	97	2	1
Chotokapla	4.7	39.0	12.0	410	20.0	94	4	2
Tabha	5.3	5.4	18.6	160	5.0	96	4	0
Alpajan	6.4	7.8	14.2	175	25.5	90	7	3
Nalbari								
Ghograjan	6.5	3.4	18.0	145	62.5	83	11	6
Morasulkhowa	5.8	5.6	13.0	165	5.0	90	6	4

Soil of all the beels except that of Moridisoi (Golaghat) and Motapang (Tinsukia) were acidic in nature which is considered unfavourable for good fish production as well as for microbial activity. Brahmaputra valley showed slightly higher mean soil pH (5.3) than beels of three Barak valley districts (5.0). Beels of Upper Assam districts had the lowest mean soil pH followed by Central Assam and Lower Assam . It was observed that beels in the north bank of the Brahmaputra had higher soil reaction in comparison to beels in the South bank.

Wide range of variation (3.4 – 39.0 g/kg) was observed in the organic carbon content of soil. This variation is mainly depended on the quantity of macrophytes present in the beels and their magnitude of decomposition. The mean values of soil organic carbon indicated that beels of the Brahmaputra valley were more productive than those of the Barak valley in respect of soil organic matter. Beels in the south bank of the Brahmaputra valley showed comparatively high mean value of soil organic carbon than the lakes in the north bank. Central Assam had higher average values followed by Upper Assam and Lower Assam.

Fig. 3. Distribution of types of soil in Assam



Available soil nitrogen status represents the easily oxidisable form of total nitrogen in the soil and its level is influenced largely by the organic matter content of the soil. Available nitrogen followed the trend of organic carbon and its values ranged from 145 to 410 mg/l. It was rather low in the beels of both the Brahmaputra valley and the Barak valley from a fisheries point of view. The low available nitrogen of soils is mainly due to reduced microbial activities and slow rate of decomposition of soil organic matter on account of the prevailing acidic reaction of the soil. Beels of the Brahmaputra valley had higher mean value of available nitrogen compared to the Barak valley. Beels of Central Assam showed highest mean value of available nitrogen, followed by Lower and Upper Assam.

Available soil phosphorus, important in influencing the aquatic productivity, was rather poor in most of the beels and the value ranged between 0.8 and 27.6 mg kg/l. Such low level of available soil phosphorus is attributable to the presence of macrophytes, especially the rooted ones which rapidly use up most of the available phosphorus. Beels of the Brahmaputra valley had higher level of available phosphorus (14.5 mg /kg) compared to the Barak valley (8.5 mg/kg). Beels of Central Assam had the highest mean value of available-P followed by Lower and Upper Assam. Calcium carbonate content ranged from 4.5 to 67.0 g/kg with the mean value of 23.0 g/kg. Beels of Barak valley had slightly higher mean value of $CaCO_3$ than beels of Brahmaputra valley while same mean value was recorded in the beels of Lower, Central and Upper Assam.

Loamy soil containing all the three fractions almost in equal proportions is considered to be conducive to productivity. However, most of the beels studied by CIFRI had poor soil texture. Beels of Karimganj district of Barak valley and Sibsagar district of Upper Assam had better soil texture compared to other districts. It is observed that the soil of the beels of Brahmaputra valley are more productive than that of Barak valley beels. Among the districts of Brahmaputra valley, beels of Central Assam are more conducive to biological productivity in respect of organic carbon and nutrient status of the soil. Soil quality in beels of different regions of Assam is depicted in Table 7.

Table 7 Important Physico-chemical properties of soil of beels of Assam

Parameters	Barak valley	Brahmaputra Valley	Beels of Brahmaputra Valley				
			North Bank	*South Bank*	*Lower Assam*	*Central Assam*	*Upper Assam*
pH	4.4-6.1 (5.0)	4.2-7.4 (5.3)	4.5-6.5 (5.5)	4.2-7.4 (5.1)	4.7-6.5 (5.8)	5.0-6.0 (5.5)	4.7-7.4 (5.2)
Org. Carbon g/kg	3.5-11.4 (8.2)	3.4-39.0 (15.2)	3.4-39.0 (12.5)	5.5-30.0 (18.0)	3.4-39.0 (11.0)	5.9-36.6 (17.4)	5.5-30.0 (17.2)
Av. Nitrogen mg/kg	145-205 (180)	144-410 (235)	144-410 (215)	160-346 (255)	144-415 (201)	163-396 (259)	160-346 (244)
Available-P mg/kg	4.4-16.2 (8.5)	0.8-27.6 (14.5)	6.6-27.6 (17.2)	0.8-22.0 (11.8)	12.0-20.1 (15.0)	9.2-21.4 (16.3)	0.8-27.0 (12.5)
$CaCO_3$ g/kg	4.5-50.0 (24.0)	5.0-67.0 (22.0)	5.0-63.0 (21.0)	5.0-67.0 (23.0)	5.0-63.0 (22.0)	13.5-31.0 (22.0)	5.0-67.0 (22.0)
Sand (%)	67-93 (83.6)	61-96 (82.9)	66-96 (88)	61-90 (77.2)	83-96 (91.2)	73-91 (85.6)	61-94 (80.3)
Silt (%)	4-17 (10.1)	3-32 (12.7)	3-25 (8.5)	6-32 (18.1)	2-11 (5.5)	5-20 (10.6)	6-32 (15.3)
Clay (%)	2-18 (6.3)	1.0-18 (4.4)	1-9 (3.5)	1-18 (4.7)	2-6 (3.3)	1.0-7.0 (3.8)	1.0-18.0 (4.4)

Water Quality

In floodplain wetlands, water quality is influenced, to a great extent, by inflow of water from the connecting rivers, local catchment area and by the metabolic processes of plants and animals living within the water body (particularly the aquatic vegetation). Water quality profile of the beels of Assam is given in Table 8.Water temperature of the beels ranged fron14 to 26 ^{0}C. Udaipur beel of Tinsukia district of Upper Assam recorded the lowest water temperature (14 ^{0}C) while Algapur beel of Cachar district recorded the maximum (26^{0}C). Secchi disc visibility varied between 11 and 103 cm and in eighteen beels light penetrated up to the bottom. Water of all the beels of Dibrugarh district of upper Assam was turbid while most of the beels of lower Assam had favourable range of transparency. It was observed that weed-choked beels had the lowest turbidity. In general, turbidity in beel water was mainly due to silt and organic debris carried by the run-off waters.

The pH of water which ranged from 6.0 to 8.2 (mean value of 7.1) was influenced mainly by basin soil and by aquatic vegetation. It followed more or less similar trend of variation of soil pH. Most of the beels of the Barak valley had acidic water. In the Brahmaputra valley, beels of Upper Assam recorded the low average value of water pH (7.0) compared to Lower and Central Assam recorded equal mean value of 7.6. The dissolved oxygen levels of water of most of the beels were fairly high and within the optimal range for the growth of fishes. The values ranged between 4.0 and 9.5 mg/l in the beels of the Barak valley and between 4.0 and 13.6 mg/l in the beels of the Brahmaputra valley, the mean values being 7.8 and 7.9 mg/l respectively. Free carbon dioxide levels were low in most of the beels which ranged between 1.0 and 19.6 mg/l with a mean value of 4.0 mg/l. The variations in the concentrations of dissolved oxygen and free carbon dioxide were mainly due to the rate of photosynthetic activity by aquatic vegetation and variation in the organic matter content in the basin soil.

The levels of total alkalinity, hardness and specific conductivity of water varied widely and the values ranged from 16.0 to 227.0 mg/l, 10.0 to 169.0 mg/l, and 18.0 to 354.0 μmhos/cm respectively. It was observed that the mean values of total alkalinity, hardness and specific conductivity in the beels situated at the Brahmaputra valley were twice that of Barak valley. In the Brahmaputra valley, beels of the North bank districts recorded higher mean values of total alkalinity, hardness and specific conductivity than those of the South bank districts.

Dissolved organic carbon content of all the beels were relatively high, the values ranging between 0.8 and 5.0 mg/l. The concentration of calcium and magnesium exhibited wide variations; it was relatively more in the beels of the Brahmaputra valley. The values of Ca and Mg ranged from 2.0 to 34.5 and 1.2 to 20.6 mg/l respectively. Concentrations of iron, silicate and chloride in water varied within 0.02 to 2.1, 0.8 to 9.4 and 15 to 44 mg/l respectively. Variations in the concentrations of these nutrients are mainly due to the variations in their uptake or release by macrophytes as also due to allochthonous inputs during monsoon months.

Table 8 Physico-chemical characteristics of water

	Temp. °C	Transp. (cm)	PH	DO mg/l	CO_2 mg/l	TA mg/l	Hardness mg/l	Sp. Cond. µmhos/cm
Cachar								
Kaptanpur	20	B.V.	7.2	5.2	3.8	73	86	174
Banskandi	25	62	6.8	8.0	3.8	28	48	56
Algapur	26	29	7.3	8.5	1.9	56	53	89
Ramnagar	21	B.V.	6.0	4.0	10.4	21	38	39
Hailakandi								
Barchumati	20	B.V.	6.6	8.2	2.8	36	38	76
Boiya	21	28	6.9	8.0	2.8	22	33	44
Karimganj								
Sone	25	32	7.6	8.3	2.6	41	41	66
Sakaity	20	26	6.6	9.5	3.8	21	28	49
Howder	19	16	6.4	5.2	6.7	21	32	44
Anganai	19	25	6.4	9.4	2.8	24	38	45
Lakhimpur								
Bilmukh	16	B.V.	6.7	9.5	2.4	143	142	251
Morichampora	21	B.V.	6.8	6.4	7.4	227	86	354
Dhemaji								
Holladunga	18	54	6.5	6.2	1.9	16	10	18
Somrajan(S)	19	63	7.0	7.5	2.8	16	10	18
Somrajan(N)	17	B.V.	7.0	5.0	3.8	42	59	93
Putukabari	18	B.V.	7.4	9.8	1.9	66	89	133
Keshukhana	19	35	7.6	6.4	4.7	120	25	218
Puasaikia	18	B.V.	6.7	7.0	5.7	18	30	139

Table 8. contd……

	Temp. °C	Transp. (cm)	PH	DO mg/l	CO_2 mg/l	TA mg/l	Hardness mg/l	Sp. Cond. µmhos/cm
Tinsukia								
Motapang	17	64	7.3	8.4	3.8	64	54	120
Motabeel	18	B.V.	7.0	10.4	4.7	44	50	92
Udaipur	14	B.V.	6.5	6.4	9.5	36	45	84
Rampur	21	B.V.	7.4	11	2.8	135	124	248
Dibrugarh								
Langhari	18	18	6.6	5.4	3.8	36	43	61
Mer	17	18	6.0	0.7	12.3	46	43	72
Dihingerasuti	17.5	17	7.4	6.6	3.8	89	62	229
Sibsagar								
Boka	19	46	7.1	6.4	2,8	20	22	24
Borboka	20	19	6.6	7.5	3.8	15	19	15
Dikhowmornai	21	24	6.2	1.6	19.6	55	48	89
Jorhat								
Gorormaj	19	27	6.8	-	2.8	31	19	55
Barchala	19	92	7.6	-	1.9	97	48	149
Golaghat								
Sankar	20	B.V.	7.4	8.8	2.9	58	69	131
Nabeel	19	B.V.	7.6	12.6	3.0	49	69	123
Garuchara	20	B.V.	7.6	13.6	3.0	37	50	103
Gelabeel	17	42	7.6	8.8	3.8	84	69	191
Moridesoi	16	46	8.0	7.8	1.9	164	149	335
Darang								
Bodhisicha	19	39	7.0	6.8	1.9	53	78	100
Mailhata	20	42	6.9	7.2	2.4	64	58	128
Gathia	22	B.V.	7.2	6.9	2.4	58	79	128
Sonitpur								
Dighali	20	B.V	6.5	5.6	11.4	38	35	47
Kharoi	21	28	7.5	7.6	2.7	80	100	159
Kaloi	22.5	11	7.5	8.2	3.8	86	67	169
Nagaon								
Samaguri	18.5	B.V	8.1	8.7	1.6	59	43	112
Mer	20	B.V.	7.8	8.4	1.9	44	29	81
Sibasthan	22	103	7.2	5.6	5.1	71	58	141

Table 8. contd. .....

	Temp. ^0C	Transp. (cm)	PH	DO mg/l	CO_2 mg/l	TA mg/l	Hardness mg/l	Sp. Cond. µmhos/cm
Morigaon								
Charan	20	32	8.2	9.4	1.0	73	57	97
Moribeel	21	65	8.0	9.2	3.7	86	96	165
Barpeta								
Kapla	17.5	48	7.4	6.4	7.6	79	60	141
Chotokapla	20	30	7.6	8.8	2.0	89	77	179
Tabha	16	35	7.0	4.6	3.8	133	106	247
Alpajan	19	35	6.8	3.5	7.6	164	86	200
Nalbari								
Ghograjan	19	25	7.6	6.6	2.8	98	86	203
Sothajan	19	50	7.4	6.6	5.7	111	116	258
Morasulkhowa	19	35	6.8	6.0	7.6	149	125	71
Kamrup								
Mandira	25	70	6.8	5.5	2.4	18	23	31
Dora	19	30	8.2	11.7	1.0	70	57	123
Selsella	20	36	7.4	6.6	7.4	25	29	41
Goalpara								
Tamranga	21	98	8.2	10.5	1.0	16	19	30

	TDS mg/l	Chloride mg/l	SiO_3 mg/l	Ca mg/l	Mg mg/l	Fe mg/l	PO_4 mg/l	NO_3 mg/l	Dis.Org.C mg/l
Cachar									
Kaptanpur	85	25	7.0	7.0	15	0.08	0.01	0.08	1.3
Banskandi	28	30	5.5	7.5	7.0	0.02	0.01	0.07	0.8
Algapur	44	25	6.3	6.8	8.6	0.35	0.01	0.05	2.2
Ramnagar	20	27	3.5	4.8	6.3	0.50	Tr.	0.04	2.3
Hailakandi									
Barchumati	38	29	1.6	5.8	5.8	0.16	Tr.	0.04	1.6
Boiya	28	23	4.0	3.8	5.8	1.2	Tr.	0.04	2.9

Table 8. contd. .....

	TDS mg/l	Chloride mg/l	SiO_3 mg/l	Ca mg/l	Mg mg/l	Fe mg/l	PO_4 mg/l	NO_3 mg/l	Dis.Org.C mg/l
Karimganj									
Sone	34	30	4.8	7.2	5.5	1.1	Tr.	0.03	2.0
Sakaity	45	32	3.0	4.0	4.7	1.2	Tr	0.03	2.2
Howder	22	32	2.8	5.8	6.5	1.4	Tr.	0.03	2.7
Anganai	22	29	2.0	5.8	5.8	0.16	Tr.	0.02	2.0
Lakhimpur									
Bilmukh	125	28	4.4	16	13	0.15	Tr.	0.03	2.5
Morichampora	178	34	1.8	34	1.2	0.18	Tr.	0.04	1.6
Dhemaji									
Holladunga	3.8	20	1.0	2.0	1.2	0.02	0.03	0.03	3.6
Somrajan(S)	4.7	15	1.0	2.0	1.2	0.24	0.03	0.02	2.4
Somrajan(N)	47.0	20	0.8	10	8.5	0.24	0.04	0.02	2.2
Putukabari	67.5	20	1.4	28	7.2	1.7	0.04	0.2	3.5
Keshukhana	110	20	9.0	6.0	2.4	0.6	0.03	0.02	1.9
Puasaikia	70	25	2.6	8.0	2.4	0.6	0.02	0.02	3.0
Tinsukia									
Motapang	61	20	7.0	8.0	8.5	0.4	0.01	Tr.	2.2
Motabeel	46	25	6.0	4.0	9.6	0.4	0.01	Tr.	4.9
Udaipur	43	29	1.2	6.0	7.2	0.2	0.01	Tr.	2.2
Rampur	124	29	1.0	26	14.5	0.2	0.01	Tr.	2.2
Dibrugarh									
Langhari	31	25	3.4	3.8	8.2.	0.8	0.01	0.02	2.2
Mer	30	34	4.4	3.8	8.2	1.0	Tr.	0.02	1.4
Dihingerasuti	115	44	4.4	5.8	10.5	0.31	0.01	0.02	2.2
Sibsagar									
Boka	12	32	1.5	5.8	1.8	0.23	0.01	0.02	1.6
Borboka	7.4	25	2.0	3.8	2.3	0.80	Tr.	0.02	1.8
Dikhowmornai	31	2.1	5.1	8.6	0.90	Tr.	0.02	1.8	-

Table 8. contd. .....

	TDS mg/l	Chloride mg/l	SiO_3 mg/l	Ca mg/l	Mg mg/l	Fe mg/l	PO_4 mg/l	NO_3 mg/l	Dis.Org.C mg/l
Jorhat									
Gorormaj	28	29	1.8	7.7	5.0	0.2	Tr.	0.02	1.1
Barchala	75	34	4.0	13.4	3.5	0.2	0.01	0.03	1.8
Golaghat									
Sankar	66	15	5.0	16	10	0.16	0.01	0.02	1.7
Nabeel	63	15	1.2	10	11	0.18	0.01	0.03	1.6
Garuchara	52	20	1.0	8	7	0.16	0.01	0.01	1.8
Gelabeel	98	20	5.0	14	8.5	1.2	0.01	0.01	1.6
Moridesoi	169	20	5.0	26	20.5	0.2	0.01	Tr.	2.0
Darang									
Bodhisicha	50	23	2.5	9.2	13.3	2.1	0.04	0.03	3.3
Mailhata	64	37	3.1	9.6	8.1	0.24	Tr	0.03	2.2
Gathia	64	22	3.8	11.5	12.0	1.0	0.01	0.05	3.4
Sonitpur									
Dighali	31	27	6.6	4.8	5.5	0.7	0.02	0.02	2.0
Kharoi	81	27	8.8	16	14.5	1.5	0.01	0.02	2.1
Kaloi	85	29	2.7	11	9.0	0.18	0.01	0.02	2.1
Nagaon									
Samaguri	57	25	5.0	15.4	1.2	0.15	Tr	0.01	2.1
Mer	41	29	5.0	9.6	1.2	0.10	Tr	0.02	1.1
Sibasthan	71	20	6.8	15.4	4.6	0.08	Tr	0.03	1.8
Marigaon									
Charan	49	29	4.8	11.5	11.5	0.03	Tr	0.05	1.5
Moribeel	83	39	6.6	15.4	13.8	0.03	Tr	0.08	2.9
Barpeta									
Kapla	71	25	1.3	9.6	9	0.48	Tr	0.01	3.5
Chotokapla	90	25	2.0	9.6	13	0.7	Tr	0.01	1.6
Tabha	127	29	9.4	18.4	16	0.2	0.03	0.02	1.9
Alpajan	100	29	9.0	13.4	13	0.3	0.01	0.02	2.7

Table 8. contd. .....

	TDS mg/l	Chloride mg/l	SiO_3 mg/l	Ca mg/l	Mg mg/l	Fe mg/l	PO_4 mg/l	NO_3 mg/l	Dis.Org.C mg/l
Nalbari									
Ghograjan	102	34	2.0	21	6	1.2	Tr	0.03	2.2
Sothajan	129	34	2.0	23	12	1.0	Tr	0.02	2.2
Morasulkhowa	136	25	6.0	19	19	1.2	0.01	0.02	2.4
Kamrup									
Mandira	15	27	4.0	5	3	0.2	0.01	0.08	1.9
Dora	62	39	4.8	15	5	0.04	Tr	0.03	5.0
Selsella	20	20	6.0	15	2	0.4	Tr	0.05	2.9
Goalpara									
Tamranga	15	25	5.6	3.8	2.3	0.18	Tr	0.01	2.1

All the beels under scrutiny were poor in both the major nutrients viz., nitrogen and phosphorus. The concentrations of NO_3-N ranged from traces to 0.08 mg/l and that of P_2O_5 from traces to 0.08 mg/l. Such low values of nitrogen and phosphate is common in water bodies where these nutrients are rapidly absorbed by the rich plant communities. In beels, the quick turnover of these nutrients takes place due to heavy infestation of macrophytes.

An evaluation of physico-chemical properties of water and soil indicates that in spite of some adverse conditions such as acidic nature of soil and water, beels in general are conducive for developing culture-based and capture fisheries. The water quality of the beels of the Brahmaputra valley was found to be more conducive to biological production than that of beels of the Barak valley. Among the various districts of the Brahmaputra valley, beels of north bank districts were relatively more productive. Variations in water quality of beels in different regions of Assam are given in Table 9.

Table 9 Water quality parameters of beels of Assam

Parameters	Barak valley	Brahmaputra Valley	Beels of Brahmaputra Valley				
			North Bank	*South Bank*	*Lower Assam*	*Central Assam*	*Upper Assam*
Temp(^oC)	19-26	14-25	16-22.5	14-25	16-25	18.5-22.5	14-21
Transparancy (cm)	B.v.-62	B.V.-103	B.V.-63	B.V.-103	25-98	B.V.-103	B.V.-92
pH	6.0-7.5 (6.8)	6.0-8.2 (7.4)	6.5-7.6 (7.4)	6.0-8.2 (7.4)	6.8-8.2 (7.6)	6.5-8.2 (7.6)	6.0-8.0 (7.0)
D.O. mg/l	4.0-9.5 (7.8)	4.0-13.6 (7.9)	4.0-9.8 (7.5)	4.0-13.6 (8.0)	4.0-11.9 (7.6)	5.4-9.4 (8.6)	4.0-13.6 (7.5)
CO_2 mg/l	2.6-10.4 (4.0)	1.0-19.6 (4.0)	1.9-11.4 (4.2)	1.0-19.6 (3.8)	1.0-7.6 (3.7)	1.0-11.4 (3.7)	1.9-19.6 (4.6)
T. Alkalinity mg/l	21-73 (31)	16-227 (69)	16-227 (84)	18-164 (54)	14.0-149 (68)	34.0-96.0 (65.0)	6.0-227 (72.0)
Sp Cond.μmhos/cm	39-174 (59)	18-354 (122)	18-354 (142)	18-335 (102)	30.0-258 (116)	42.0-169 (122)	8.0-354 (129)
Hardness mg/l	29-86 (37)	10-169 (60)	10-125 (70)	19-169 (50)	19.0-124 (61)	29.0-101 (61)	10.0-169 (58)
Calcium mg/l	3.8-9.6 (5.6)	2-34.5 (12)	2.0-34.5 (14.4)	3.8-25.7 (9.6)	3.8-23.0 (12.3)	4.4-16.4 (11.7)	2.0-34.5 (12.0)
Magnesium mg/l	4.7-15 (6.4)	1.2-20.6 (7.9)	1.2-18.7 (9.3)	1.2-20.6 (6.5)	2.3-18.7 (7.6)	1.2-14.5 (9.0)	1.2-20.6 (7.1)
Iron mgL^{-1}	0.08-1.4 (0.8)	0.02-2.1 (0.48)	0.02-2.1 (0.6)	0.03-1.18 (0.34)	0.02-1.2 (0.5)	0.02-2.1 (0.51)	0.02-1.7 (0.45)
Phosphate mgL^{-1}	0-0.02 (0.01)	Tr.-0.04 (0.01)	Tr.-0.04 (0.01)	Tr.-0.02 (0.01)	Tr.-0.02 (0.01)	Tr.-0.02 (0.01)	Tr.-0.04 (0.01)
Nitrate mgL^{-1}	0.02-0.08 (0.04)	Tr.-0.08 (0.03)	0.01-0.05 (0.03)	Tr.-0.08 (0.03)	0.01-0.08 (0.025)	0.01-0.08 (0.03)	Tr.-0.03 (0.02)
Dis. Org. C mgL^{-1}	0.8-2.7 (2.0)	1.1-5.0 (2.2)	1.5-3.5 (2.3)	1.1-5.0 (2.1)	0.5-5.0 (2.5)	1.5-3.4 (1.9)	1.1-4.9 (2.1)

Biotic communities

The abundance and succession of biotic communities occupying the beels are influenced mainly by the unique water renewal pattern of the ecosystem. The high fluctuations in water level and the alternating seasonal riverine connections are the inherent characters of the beel ecosystem. Thus, the organisms inhabiting this system comprise a complex mix of lotic and lentic communities. The dynamic ecological character brought in by the cyclic changes in the lake morphometry, water chemistry and sediment characteristics leads to some unique faunal and floral associations. Biotic communities of beels, thus adapt themselves to spatial and temporal fluctuation leading to a high degree of floral and faunal diversity. The major biotic communities in beels that have a bearing on fish productivity are plankton, benthos, macrophytes and fishes.

Plankton

Plankton comprises microscopic organisms (both plants and animals) with very limited or no power of locomotion. They move about and drift in water purely at the mercy of water movements. Phytoplankton bearing photosynthetic pigments make use of the rich inorganic nutrients available in the beel ecosystem and synthesize organic matter (autotrophs). Thus, they form the base of ecological pyramid. Zooplankton, on the other hand live on the huge reserve of organic matter of plants or animal origin, both in live and dead form (detritus). Thus, zoolplankton is the secondary producer linking the phytoplankton with the communities occupying higher trophic levels. Zooplankton in beels play a vital role in making efficient use of dead and living organic matter. Both zoo and phytoplankton form direct food and thereby sustain a substantial portion of planktiphagus fishery of beel resources.

Most of the beels studied were found to be infested with weed at varying levels, some of them being completely choked. Floating weeds have deleterious impact on the abundance of the plankton. As a result, average numerical abundance of the phytoplankton is found to be low except in Bagheswari beel in Mandira complex of Kamrup district. Out of three zones *viz.* upper, central and lower Assam in Brahmaputra valley, beels in the later two zones exhibited better abundance of plankton as compared to upper zone. Density of plankton in the beel of upper zone varied between nil to 84 u/l. Phytoplankton group was generally represented by *Chlorophyceae, Bacillariophyceae* and *Myxophyceae*.

Zooplankters were represented by *Ostracoda, Copepoda, Cladocera* and *Rotifera*. Generic representation under various groups also found to be very poor. The Ostracods were found only in Mota beel under Tinsukia district as a unique occurrence. Domination of one group over the other cannot be generalised, however, in many cases phytoplankton dominated over zooplankton. In some stray cases, poor representation of phytoplankton community was observed indicating low productivity. The possible reasons are low temperature causing poor nutrient load as indicated by poor conductivity and nitrate nitrogen and phosphate in water phase.

Beels in the central Assam zone showed higher plankton count. Phytoplankton density in this zone varied between nil to 948 u/l. Phytoplankton groups were well represented by good number of genera under *Chlorophyceae, Bacillariophyceae, Myxophyceae, Dinophyceae* and *Euglenophyceae*. The striking feature of this zone is the appearance of *Euglenophyceae* which was not found in the beels of upper Assam zone. Zoo plankters were represented by *Rotifera, Copepoda, Cladocera* and *Protozoa*. In the central zone phytoplankters dominated over zooplankters as general trend. Plankton density was relatively richer in the beels of lower Assam zone too, the density ranging between nil to 8180 u/l. Generic representation was found to be similar to that of central Assam beels. Beels in the Barak valley, with low productive water and soil quality, had plankton in moderate numbers, ranging between 9 and 406 u/l.

In general, productivity in terms of phytoplankton density was poor in all the beels of Assam. Although low pH, transparency and conductivity are attributable to this, low plankton concentration, the predominant factor is the competition with macrophytes in garnering sunlight and nutrients. Moderate to high level of infestation of various categories (emergent, submerged, floating, *etc.*) of macrovegetation were always associated with low plankton count. The relatively high plankton count in Central and lower Assam beels is attributable to the low altitude with sloppy gradient of the Brahmaputra. In these regions, riverine flow slows down leading to the settling of nutrients. Relatively high temperature also favoured production of plankton. Distribution of plankton in different beels of Assam is presented in Table 10.

Table 10 Plankton in different beels of Assam

District Beel	Plankton density (u/l)	Phytoplankton group	Zooplankton group
Cachar			
Ramnagar	233	**Chlorophyceae:** *Ankistrodesmus, Mougeotia, Closterium* **Bacillariophyceae:** *Nitzschia, Pinnularia, Melosira, Navicula*	**Copepoda;** Nauplii
Kaptanpur	20	Nil	**Rotifera:** Filinia
Banskandi	76	**Chlorophyceae:** *Botryococcus*	**Copepoda;** Nauplii
Algapur	126	**Bacillariophyceae:** *Melosira, Surirella*	**Rotifera:** *Brachionus* *Copepoda: Mesocyclops*
Hailakandi			
Barchumati	44	**Bacillariophyceae:** *Pinnularia, Surirella*	Nil
Boiya	27	**Myxophyceae :***Nostoc*	Nil
Karimganj			
Sone	163	**Myxophyceae:** *Nostoc* **Chlorophyceae:** *Spirogyra* **Bacillariophyceae:** *Surirella*	**Copepoda:** *Mesocyclops*
Sakaity	83	**Bacillariophyceae:** *Diaptoma* **Chlorophyceae:***Micrasterium*	**Copepoda:** Nauplii, *Mesocyclops*
Howder	9	**Bacillariophyceae:** *Pinularia*	Nil
Anganai	406	**Chlorophyceae:** *Microspora, Pleodorina, Cosmarium* *Dinophyceae: Ceratium*	**Copepoda:** Nauplii, *Neodiaptomus* **Cladocera:** *Ceriodaphnia* **Rotifera:***Trichocera*
Darrang			
Mailhata	Nil	Nil	Nil
Gathia	35	**Chlorophyceae:** *Microspora* **Bacillariophyceae:** *Synedra*	**Copepoda:** Nauplii
Bodischia	538	**Chlorophyceae:** *Microspora, Eudorina, Pleodorina, Volvox, Zygnema, Pandorina,*	**Copepoda:** Nauplii **Cladocera:** *Eurycerus* **Rotifera:** *Keratella*

		Spirogyra, Cosmarium	
Sonitpur Digholi	49	**Bacillariophyceae:** *Nitzschia* **Chlorophyceae:** *Microspora*	Nil
Kharoi	188	**Chlorophyceae:** *Surirella, Gyrosigma*	**Copepoda:** Nauplii, *Mesocyclops*
Kaloi	498	**Myxophyceae:** *Spirulina* **Chlorophyceae:** *Surirella,Gyrosigma*	**Rotifera:** *Filinia, Trichocera* **Copepoda:** Nauplii
Lakhimpur Bilmukh	84	**Chlorophyceae** :*Eudorina, Pleodorina* **Bacillariophyceae:** *Pinnularia*	**Copepoda:** Nauplii, *Mesocyclops*
Mori-chompora	34	**Chlorophyceae:** *Spirogyra*	**Copepoda:** Nauplii
Jorhat Gorormaj	16	**Myxophyceae**:*Oscillatoria*	**Copepoda:** *Eucyclops*
Borchala	Nil	Nil	Nil
Sibsagar Boka	34	**Chlorophyceae:** *Botryococcus*	**Cladocera:** *Bosmina*
Barboka	41	Nil	**Cladocera:** *Moina* **Copepoda:** Nauplii, *Mesocyclops, Eucyclops*
Dikhow-mornai	15	**Bacillariophyceae:** *Nitzschia*	**Copepoda:** Nauplii, *Neodiaptomus*

Table 10. contd. **Dibrugarh** Lomhori	49	**Bacillariophyceae:** *Cyclotella*	**Copepoda:** *Neodiaptomus* **Cladocera:** *Moina*
Mer	18	Nil	**Copepoda:** *Eucyclops* **Rotifera:** Euclinis
Dihing era-suti	26	Nil	**Copepoda:** *Mesocyclops*
Barpeta Kapla	10	**Chlorophyceae:** *Spirogyra*	Nil
Chotkapla	20	**Chlorophyceae:** *Mougeotia, Spirogyra*	Nil
Tabha	118	**Bacillariophyceae:** *Nitzschia* **Myxophyceae:***Anabaena*	**Copepoda:**Nauplii, *Neodiaptomus*
Alpajan	24	**Myxophyceae:***Anabaena*	Nil
Nalbari Sothajan	Nil	Nil	Nil
Morasaul-khowa	11	**Chlorophyceae:** *Pandorina*	Nil
Ghograjan	Nil	Nil	Nil

Table 10. contd			
Bongaigaon			
Tamranga	332	**Chlorophyceae:** *Mougeotia, Triploceras,Staurastrum, Eudorina,Closterium, Ankistrodesmus* **Bacillariophyceae:** *Fragillaria, Pinnularia,Tabelaria, Surirella,Synedra, Asterionella* Dinophyceae: *Ceratium,Glenodinium*	**Copepoda:** Nauplii, *Cyclops* **Rotifera:** *Polyarthra, Keratella* **Cladocera:** *Bosmina*
Dhemaji			
Hollodunga	84	**Bacillariophyceae:** *Stephanodiscus* **Chlorophyceae:** *Pachycladon* **Myxophyceae:** *Oscillatoria*	**Cladocera:** *Bosmina*
Somrajan(s)	22	**Myxophyceae:** *Nodularia*	**Copepoda**: Nauplii
Somrajan(N)	12	Nil	**Cladocera:***Moina*
Phutukabari	28	**Bacillariophyceae:** *Melosira*	Nil
Keshukhana	Nil	Nil	Nil
Puwasaikia	Nil	Nil	Nil
Golaghat			
Sankar	42	**Myxophyceae:** *Oscillatoria* **Chlorophyceae**: *Mougeotia* **Bacillariophyceae**: *Fragillaria*	Nil
Na beel	10	**Bacillariophyceae:** Melosira	Nil
Goruchara	36	**Chlorophyceae:** *Mougeotia*	**Copepoda:** Nauplii
Galabeel	11	**Chlorophyceae:** *Pediastrum*	Nil
Moridisoi	22	**Chlorophyceae:** *Ulothrix*	**Cladocera:** *Bosmina*

Table 10. contd **Tinsukia** Motapung	Nil	Nil	Nil
Mota	13	Nil	**Ostracoda:** *Cyclocypris*
Udaipur	20	**Chlorophyceae:** *Spirogyra, Cosmarium*	Nil
Rampur	11	Nil	**Copepoda**:*Mesocyclops*
Nagaon Mer	35	**Dinophyceae:** *Ceratium*	**Rotifera:** *Keratella, Brachionus* **Copepoda:** Nauplii
Sibasthan	948	**Bacillariophyceae:** *Melosira, Navicula,Synedra* **Dinophyceae:** *Ceratium* **Chlorophyceae:***Staurastrum, Ankistrodesmus, Pediastrum*	**Rotifera:** *Keratella* **Copepoda:** Nauplii
Samaguri	103	**Myxophyceae:** *Anabaena, Microcystis, Gloeotrichia, Rivularia* **Chlorophyceae:** *Spirogyra, Uronema, Eudorina,Volvox, Clostarium, Actinastrum* **Bacillariophyceae:** *Melosira, Pinularia, Tabelaria, Navicula, Synedra, Cyclotella* **Euglenophyta:** *Euglena, Phacus* **Dinophyceae:** *Ceratium*	**Protozoa:** *Centropyxis* *Copepoda: Cyclops,* Nauplii **Rotifera:** *Brachionus, Asplancha*

Table 10. contd **Morigaon** Mori	17	**Bacillariophyceae:** *Asterionella, Melosira, Tabelaria, Synedra*	**Rotifera:** *Filinia*
Kamrup Dara	354	**Dinophyceae:** *Peridinium,* **Euglenophyta:** *Euglena, Trachelomonas, Phacus* **Chrysophyceae:** *Dinobryon*	**Rotifera:***Polyarthra* **Copepoda:** Nauplii
Salsala	639	**Chlorophyceae:** *Xanthidium, Pediastrum, Kirchneriella* **Euglenophyta:** *Euglena, Phacus*	**Rotifera:** *Polyarthra, Keratella* **Copepoda:** Nauplii,*Cyclops* **Cladocera:***Bosmina*
Bagheswari (Mandira complex)	8180	**Chlorophyceae:** *Botryococcus, Microspora, Pediastrum, Coelastrum, Kirchneriella, Pandorina Closterium* **Myxophyceae:** *Microcystis Microspora, Pleodorina, Ankistrodesmus,Staurastrum, Tetraedron, Kirchneriella* **Myxophyceae:** *Microcystis* **Bacillariophyceae:** *Melosira* **Chrysophyceae:** *Dinobryon*	**Rotifera:***Brachionus, Trichocera,Filinia,Lecane* **Copepoda:** Nauplii, *Mesocyclops* **Cladocera:** *Bosmina*

Chlorophyceae is a dominant component of phytoplankton in the beels of Assam. A total of 24 species of *Chlorophyceae*, 14 species of *Bacillariophyceae,* 9 species of *Myxophyceae,* 3 species each of *Dinophyceae* and *Euglenophyceae* and 1 species of *Chrysophyceae* represent the phytoplankton community. In beels of upper Assam zone phytoplankters represent 4 classes in the order of *Chlorophyceae* > *Bacillariophyceae* > *Myxophyceae* > *Dinophyceae*. In the beels of the central Assam zone, phytoplankters were represented by 5 classes including *Euglenophyceae.* The class Dinophyceae, which was present only in upper Assam zone, occupied second most dominant position after *Chlorophyceae* in the central Assam zone. The order of domination of various classes of phytoplankters in central Assam zone is as follows : *Chlorophyceae* > *Dinophyceae* > *Bacillariophyceae* > *Myxophyceae* > *Euglenophyceae.*

Phytoplankton diversity in the lower Assam zone of the Brahmaputra valley was richer. A total of 6 classes represent the phytoplankton group including *Chrysophyceae.* After *Chlorophyceae, Myxophyceae* was the most dominant group in the lower Assam zone. Low altitude, higher temperature and gradual slopes provided conducive conditions for richer plankton growth. Greater amount of nutrient availability favoured the blooming of the blue green algae (*Myxophyceae*). The order of domination of phytoplankton in lower Assam beels was as follows: *Chlorophyceae* > *Myxophyceae* > *Dinophyceae* > *Euglenophyceae* > *Bacillariophyceae* > *Chrysophyceae.* Another notable feature in the beels in lower Assam was the high rate abundance of Euglenophyceae.

Phytoplankters in the beels of Barak valley represented by the same four classes as was observed in the upper Assam beels. The order of domination was *Chlorophyceae* > *Bacillariophyceae* > *Myxophyceae*> *Dinophyceae.*

Five groups of zooplankters were present in the beels of Assam *viz. Rotifera, Copepoda, Cladocera, Ostracoda* and *Protozoa.* There were 8 genera of *Rotifera,* 4 genera of *Copepoda,* 3 genera of *Cladocera* and 1 each of *Ostracoda* and *Protozoa.* Generally, *Copepoda* dominated the zooplankton communities in the beels surveyed, followed by either *Cladocera* or *Rotifera.* Members of *Ostracoda* were recorded only from the beels of upper Assam.

Benthos

Benthic communities varied widely in the *beels* in the range of 0 to 1763 organisms/m^2 (Table 11). Of the three b*eels* of Tinsukia district, Mota and Rampur beels are devoid of any benthic community. Motapang in the same district has a thin population of 32 units/m^2. Most of the beels of Barak valley districts were poor in benthic community while beels of Marigaon and Kamrup districts were rich in bottom macrofauna. Beels of Golaghat, Nagaon, Darrang and Sonitpur had moderate population of benthos. The beels of Tinsukia, Dibrugarh and Sibsagar had scanty or nil population of benthos. Gastropods dominated the benthic organisms followed by bivalves, oligochaetes and insects. The beels of Golaghat district are uniformly rich in bottom macrofauna (128-864 organisms/m^2). In Dhemaji, except Keshukhana with an exceptionally high density (960 organisms/m^2), all others have scanty or nil population of benthos. Gastropods dominated the benthic organisms followed by bivalves, oligochaetes and insects.

Table 11 Benthic communities in the beels of Assam

District	Name of beels	Average benthos (nos./m^2)	Gastro-pods	Bival-ves	Chirono-mids	Oligo-chaete	Insec-ts
Tinsukia	Motapung	32	100				
	Mota	Nil					
	Udaipur						
	Rampur	Nil					
Dibrugarh							
	Lomhori	Nil					
	Mer	Nil					
	Dihing era suti						
Sibsagar:	Boka	Nil					
	Barboka	32	100				
	Dikhow-mornai	Nil					
Jorhat:	Gorormaj	64				100	
	Borchala	224	57				43
Golaghat:	Sankar	256	25			75	
	Na beel	192	67	16		17	
	Goruchara	128	100				
	Galabeel	224	57	43			
	Moridisoi	864	93	7			
Dhemaji	Hollodunga	Nil					
	Somrajan(s)	Nil					
	Somrajan(N)	32	100				
	Phutukabari	Nil					
	Keshukhana	960	87	10			3
	Puwasaikia	Nil					

Table 10 contd..

District	Name of beels	Average benthos (nos./m²)	Gastro-pods	Bival-ves	Chirono-mids	Oligo-chaete	In-sects
Lakhimpur	Bilmukh						
	Mori chompora						
Nagaon	Mer	344	50	-	50		
	Sibasthan	129	-	-	100		
	Samaguri	492	100	-	-		
Morigaon	Mori	1763	85.4		14.6		
	Charan	1505	74.3		25.7		
Sonitpur	Digholi	15				100	
	Kharoi						
	Kaloi	159	86	14			
Darrang	Mailhata						
	Gathia	212	4			96	
	Bodischia	76	20			80	
Kamrup	Dara	817	5.3		94.7		
	Salsala	1591			100		
	Bagheswari	8				100	
	Mandira	501	20		80		
	Arikata	545	21		71	8	
	Bidhanjika	272	5		84	11	
	Rangai	173	58		42		
Nalbari	Sothajan						
	Morasaul-khowa						
Bongaigaon	Tamranga	301	85.7		14.3		
	Ghograjan						
Barpeta	Kapla						
	Chotkapla						
	Tabha						
	Alpajan						

Table 10 contd.. **District**	**Name of beels**	**Average benthos (nos./m²)**	**Gastro-pods**	**Bival-ves**	**Chirono-mids**	**Oligo-chaete**	**In-sects**
Cachar	Ramnagar	Nil					
	Banskandi	Nil					
	Algapur	151				100	
	Kaptanpur	8				100	
Hailakandi	Barchumati	38				100	
	Boiya	8	100				
Karimganj	Sone	99	77	15		8	
	Sakaity	8				100	
	Howder	Nil					
	Anganai	8				100	

Macrophytes

A unique feature of the floodplain wetlands of Brahmaputra basin is the rich growth of marginal and submerged vegetation due to the allochthonous and autochthonous nutrient loading. These macrophytes often tend to replace the plankton community. Progressive replacement of plankton community with macrophytes as the main primary producer hastens the pace of eutrophication. This also leads to higher rate of evapo-transpiration and swampification of the lake. However this process can be reversed through effective management.

Open beels, which generally harboured less macrophytes, were favourably disposed for energy transformation through phytoplankton. Closed beels were mostly choked with floating (water hyacinth), submerged (*Najas*, *Vallisneria*, *Hydrilla* and *Chara*) and marginal (*Typha*) vegetation affecting productivity. This was confirmed by the low rate of net primary productivity (0 to 281 $mgC/m^3/day$) recorded in *beel*s like Dikhowmornai and Ramnagar in Districts of Sibsagar and Cachar respectively. Dense mat formation by marginal and floating macrophytes was observed in a few beels like Motabeel (Tinsukia). Udaipur beel in the same district is choked with water hyacinth. Open beels like Galabeel (Golaghat district) were almost free from weed infestation.

However, Samrajan north in the district of Dhemaji has a good standing crop of macrophytes despite being an open beel. Weed infestation rate by districts is given in Table 12.

Table 12. Infestation rate and dominant macrophytes in beels by district

District	Infestation of macrophytes *(%)*
Golaghat	20-70 *H, Cp, Wh*
Jorhat	70-80 *H, Wh*
Sibsagar	60-90 *Wh, V*
Tinsukia	70-90 *T, Wh*
Dibrugarh	50-80 *N, V*
Dhemaji	Cl-90 Wh, H, Nj

Cl- clear, Wh- *Eicchornia crassipes*, V- *Vallisneria*, T- *Typha*, H- *Hydrilla*, N- *Nymphaea*, C- *Chara* Nj- *Najas*

By virtue of their high nutrient status, warmer water regime and the rich sunshine, beels of Assam are considered to be highly productive ecosystem. In fact, many of them are passing through transient phases of europhication leading to weed choking. These water bodies are extremely rich in nutrients as reflected by rich organic carbon and high levels of available nitrogen and phosphorus in the soil. But, generally, the nutrients are locked up in the form of large aquatic plants, especially water hyacinth, which are not readily available as food for fishes. Decaying weeds are the main source of organic detritus at the bottom which normally support a good bottom macrofauna, comprising mainly molluscs. However, sometimes, excessive deposition of organic matter leads to anaerobic conditions. Similarly, due to the acidic nature of the soil-water interface, release of nutrients from the soil to water is hampered.

PRIMARY PRODUCTIVITY AND FISH YIELD POTENTIAL

Primary productivity

Solar energy is fixed by both plankton and macrophyte community in beels. In case of Assam beels, carbon fixation takes place predominantly through the macrphytic chain. In the Upper Assam, net primary productivity through macrophytes ranged from 742 mg C/m^2/day (in Gala beel) to 4,618 mg C/m^2/day as against 250 mg C/m^2/day to

1,750 mg C/m^2/day through the phytpoplankton route. Rate of net carbon production in Central Assam was higher in the range of 667 mg C/m^2/day to 3377 mg C/m^2/day through macrophytes and 110 mg C/m^2/day to 2,062 mg C/m^2/day through phytoplankton. In Lower Assam, macrophytes fixed carbon at the rate of 1,824 mg C/m^2/day to 4,613 mg C/m^2/day through macrophytes and 212 mg C/m^2/day to 1,209 mg C/m^2/day through phytoplankton. Three beels surveyed in Barak valley recorded net primary production through macrophytes as 1,700 mg C/m^2/day to 3,011 mg C/m^2/day while primary production through phytoplankton in this region was 584 mg C/m^2/day to 988 mg C/m^2/day (Table 13).

Table 13. Primary production (mg C/m^2/day) of phytoplankton and macrophytes in selected beels of Assam

Name of beels	*Net Primary Production*	
	Macrophyte	*Phytoplankton*
BRAHAMAPYTRA VALLEY		
Upper Assam		
Motapung	1080.4	250.0
Boka	2521	1717.3
Nabeel	3012	562.5
Galabeel	742	562.5
Somrajan(s)	3024	500.0
Somrajan(N)	4618	1750.0
Puwasaikia	1169	187.5
Bilmukh	3175	1057.5
Central Assam		
Mer	3377.2	110.3
Sibasthan	2063.2	412.6
Samaguri	1169	1100.4
Mori	989.5	1286.4
Charan	1042.1	1126.8
Digholi	1082	1286.1
Kharoi	1700	2062.5
Bodischia	667	712.5
Lower Assam		
Dara	1824.2	412.6
Mandira	3876.4	465.6
Arikata	2041.6	288.2
Bidhanjika	4612.8	562.4
Rangai	2948.2	364.4
Tamranga	2676.1	212.5
Kapla	3377	1209.3
BARAK VALLEY		
Ramnagar	1700	988.2
Boiya	1711.6	982.4
Sone	3011	584.6

A beel thicky infested with water hyacinth

Since weeds re-grow after clearance, it is necessary to continue with clearance operations every year

Gill net is a common fishing gear in beel

Marginal areas of beels are converted into paddy fields causing conflicts of interests among agriculturists

Fish yield potential

Fish yield potential is estimated as a function of the rate of primary productivity. The phenomenal rate of energy fixation recorded from the beels clearly suggests the high fish yield potential. The total quantum of carbon produced by macrophytes and phytoplankton in the beels of Assam is enormous. Even at a very modest rate of 1% of primary carbon, this can account for a huge fish yield of 981 to 1,313 kg/ha in Barak valley, 817 to 1,889 kg/ha in Lower Assam , 791 to 1,399 kg/ha in Central Assam and 476 to 2324 kg/ha in Upper Assam (Table 14).

Beels of Upper Assam had the highest average yield potential (1245 kg/ha/year) followed by the Lower (1221 kg/ha/year)and Central Assam (1060 kg/ha/year). Barak valley beels with yield potential of 1093 kg/ha was poor compared to upper and lower Assam areas of Brahmaputra valley. Phytoplankton chain contributed to the yield potential to a substantial extent (35%) in the central Assam. In all the other regions, macrophytes accounted for 71 to 86 % of the fish yield potential.

Table 14. Estimation of production potential of some beel of Assam

Name of beels	Type	Area infested with Macrophyte(%)	Production potential (kg/ha/yr)		Total (kg/ha/y)
			Macrophyte chain	Plankton chain	
Upper Assam					
Motapung	closed	30	394	91	485
Boka	open	70	920	627	1547
Nabeel	closed	50	1099	205	1304
Galabeel	closed	clear	271	205	476
Somrajan(s)	closed	50% swampy 10%weed	1104	183	1287
Somrajan(N)	open	75	1685	639	2324
Puwasaikia	open	50% swampy 50% weed	427	68	495
Bilmukh	open	65	1159	886	2045
Average			*883 (71%)*	*362*	*1245*
Central Assam					
Mer	closed	85	1282	40	1322
Sibasthan	closed	70	753	151	904
Samaguri	closed	40	428	402	830
Mori	open	clear	361	469	830
Charan	open	20	380	411	791
Digholi	closed	85	930	469	1399
Kharoi	open	40	620	750	1370
Bodischia	closed	95	772	260	1032
Average			*692 (65%)*	*368*	*1060*
Lower Assam					
Dara			666	151	817
Mandira	closed	50	979	75	1054
Arikata	closed	70	745	105	850
Bidhanjika	closed	70	1684	205	1889
Rangai	closed	80	1076	133	1209
Tamranga	open	80	977	78	1055
Kapla	closed	90	1232	441	1673
Average			*1051 (86%)*	*170*	*1221*
Barak valley					
Ramnagar	closed	70	620	361	981
Boiya	closed	40	625	358	983
Sone	open	55	1099	214	1313
Average			782	311	1093

FISH AND FISHERIES

Fish fauna

Many of the beels were managed on capture fishery norms by exploiting the natural fish stock. In the absence of any species management, these beels were dominated by small fishes (*Puntius* spp., *Colisa* spp., *Chanda* spp., *Mystus vittatus, Ambassis* sp., *Amblypharyngodon mola, Nandus nandus, Mastacembelus pancalus,* small prawns, *Botia* sp.,), carnivorous catfishes (*Wallago attu, Ailia coila, Ompok bimaculatus)* and air breathers *(H. fossilis, Channa punctatus, A. testudineus* and *N. notopterus)* and others (Table 15

Fishery status of the floodplain wetlands of Assam

Most of the beels were managed on capture fishery norms by exploiting the natural fish stock, leading to low yield rates in the range of 66.67 to 638 kg/ha/year. In the absence of any sound species management,.these beels are dominated by small fishes, carnivorous catfishes, and air and others (Table 15). Boiya (Hailakandi district) and Kapla (Barpeta district) beels were the only exceptions where culture-based fishery was followed.

Table 15. Fish and fisheries of the beels surveyed in Assam

District	Area (ha)	Depth (m)	Dominant fish	Fishing methods
Cachar	18-30	1.0-4.0	*Puntius* spp., *Mystus vittatus, Ambassis* sp., *A. mola, N. nandus, M. pancalus,* small prawns, *Botia* sp., *Wallago attu, Ailia coila, Ompok bimaculatus, H. fossilis, Channa punctatus, A. testudineus* and *N. notopterus, Gudusia chapra,* IMC, *L. calbasu, Tenualosa ilisha*	Drag net, Surrounding net, Trap (*dori*), *Katal*
Hailakandi	17	0.5-2.5	*Puntius* spp., *Mystus vittatus, Ambassis* sp., *A. mola, N. nandus, M. pancalus,* small prawns, *H. fossilis, C. punctatus, G. chapra,* Cultured species (*IMC*), *Wallago attu*	Drag net, Surrounding net, Cast net
Karimganj	9-2815	0.5-5.0	*Puntius* spp., *Mystus vittatus, Ambassis* sp., *A. mola, N. nandus, M. pancalus,* small prawns, *Botia* sp., *M. cavasius, G. giuris, H. fossilis, Channa punctatus, A. testudineus* and *N. notopterus, Clupisoma garua* IMC, *G. chapra*	Surrounding net (*Ghoran jal*), Traps
Darrang	20-80	0-4.0	*Puntius* spp., *Colisa* spp., *Botia* sp., *M. pancalus, H. fossilis, C. punctatus, C. striatus, Clarias batrachus, N. notopterus, Wallago attu*	Dewatering, Gill net, Long line, Cast net
Sonitpur	18-60	0.5-4.5	*Puntius* spp., *Danio spp., Colisa* spp., *Botia* sp.; *M. pancalus, H. fossilis, C. punctatus, C. striatus,C. marulius; Clarias batrachus, N. notopterus, Wallago attu*	Cast net, Drag net, *Jeng/Katal*
Lakhimpur	20-450	0.5-7.0	*Puntius* spp., *Danio* spp., *Colisa* spp., *Botia* sp., *M. pancalus, L. bata, L. gonius,C. reba, IMC , O. pabda, N. notopterus, N. chitala, Wallgo attu*	Gill net, Cast net, Surrounding net, Dip net, Drag net (*Bor jal*)
Jorhat	30-89	0.9-4.5	*Puntius* spp., *Danio* spp., *Colisa* spp., *Botia sp., M. pancalus, Chanda spp., L. gonius, Wallgo attu, A. mola*	Gill net, Cast net, Surrounding net, *Jeng fishing*
Sibsagar	4-180	0.8-3.0	*Puntius* spp., *Danio spp., Colisa* spp., *Botia* sp., *M. pancalus, M. vittatus,* Small prawns, *L. gonius, Wallgo attu*	Drag net, Surrounding net, *Jeng fishing*
Dhemaji	10-65	1.0-3.0	*Puntius* spp., *Danio spp., Colisa* spp., *Botia* sp., *M. pancalus, M. vittatus,* Small prawns, *L. gonius, Wallgo attu*	Drag net, Gill nets, Surrounding net, cast net

Table 15........

District	Area (ha)	Depth (m)	Dominant fish	Fishing methods
Tinsukia	30-70	1.5-7.0	*Puntius* spp., *Danio* spp., *Colisa* spp., *Botia sp., M. pancalus, Chanda spp., L. gonius,L. calbasu, Wallgo attu, A. mola,* small prawns	Gill net, surrounding net, Drag net, Traps
Dibrugarh	20-45	1.0-6.0	*Puntius* spp., *Danio* spp., *Colisa* spp., *Botia* sp., *M. pancalus, M. vittatus,* Small prawns, *Channa punctatus, H. fossilis, A. testudineus, L. gonius, Catla catla, Wallgo attu*	Long line, Gill net, *Jeng fishing*
Golaghat	10-50	1.0-5.0	*Puntius* spp., *Danio spp., Colisa* spp., *Botia* sp., *M. pancalus, M. vittatus,* small prawns, *L. gonius, W. attu*	drag net, gill net, surrounding net, cast net
Nalbari	7-	0.3-4.0	*Puntius* spp., *Colisa* spp., *Botia sp., M. pancalus, H. fossilis, C. punctatus, C. striatus, Clarias batrachus, N. notopterus, Wallago attu, M. seenghala*	Dewatering, Gill net, Long line, Cast net, *Jeng fishing*
Barpeta	10-	0.3-5.0	*Puntius* spp., *Colisa* spp., *Botia* spp., *Nandus nandus, M. pancalus, H. fossilis, C. punctatus, C. striatus, Clarias batrachus, N. notopterus, A. testudineus, Wallago attu,* IMC, Common carp	Long line, Surrounding net (*Ber jel*), Traps (*Bana* and *Dingori*), *Jeng*

IMC - *Catla catla, Cirrhinus mrigala, Labeo rohita*

Fish yield

The floodplain wetlands (*beels*) associated with the Brahmaputra and Barak river systems contribute to the major chunk of fishery resources of Assam. Beels of Assam generally posseses high potential for *in situ* fish production. A number of them also provide a "collection sink' for fish produced in the surrounding flooded catchments. Estimation of fish yield from beels of Assam is very difficult task due to the unorganized marketing activities and dissipation of catch. On the basis of enquiries made at the beel sites an effort was made by CIFRI to assess the yield. But the results are far from accurate. Fish yield of the beels surveyed are in the range of 14 - 488 kg/ha/year. Average fish yield of 17 beels in the Brahmaputra valley was estimated at 134 kg/ha, compared to 285 kg/ha for 6 beels in Barak valley. The average yield of Assam on the basis of enquiries made in 23 beels in the State was 173 kg/ha (Table 16).

Table 16 Fish production from different beels of Assam

	Name of beel	Average fish production (kg/ha/yr)
Brahmaputra Valley	Dora	116
	Selsella	243
	Dighali	36
	Kapla	126
	Dipar	21
	Siligurijan	418
	Rangai	31
	Hagal	70
	Ghorajan	14
	Hasilakumari	14
	Potakallong	15
	Samaguri	96
	Mer	71
	Charan	49
	Barmanaha	258
	Dhir	377
	Sareswar	330
Average production (Brahmaputra valley)	-	***133.8***
Barak valley	Sone	97
	Boiya	211
	Barchumati	488
	Banskandi	400
	Algapur	300
	Ramnagar	215
Average production (Barak valley)	-	***283.5***
Average production (Assam)	-	**172.9**

Fishing activities in different types of beels

Open beels

In open beels, new recruits come to the fishery mainly from the adjoining rivers. They provide breeding grounds and /nursery pastures for commercially important fishes during southwest monsoon months. Migration (spawning/feeding) of Indian major carps (mainly *C. catla, L. rohita, L. calbasu* and *L. gonius* is significant from the point of view of recruitment/autostocking in these *beels*. Fishes like *E. vacha* and *G. chapra* migrate in large numbers during monsoon and form a considerable post-monsoon fishery. In addition, occurrence of juveniles (32-80 mm) and adults (up to 534 mm) of Hilsa has been observed in Dhir, Dora and Sona (all open) beels. Most recruits enter the fishable stock in their 1st year (6-8 months). Eventhough the stocks are continuously exploited, stock is replenished through fresh recruitment the next year. However, small mesh size of fishing nets used and intense fishing in winter/summer may deplete the stocks below the minimum reproducible stocks needed to renew the stocks. In addition, in many open beels, the connecting channel with the adjoining river is blocked with split bamboo screens (*bana*) to prevent back migration of fishes into the feeder river. Since the open floodplain wetlands are a continuum of the parent river, such hindrance/in free to-and-fro migration is likely to affect the fishery of the river and thereby that of the beel itself in subsequent years.

Diverse fish populations present in the beels support a multi-species fishery, which is more complex to understand but is more resilient. However, though most open beels have multi-species fishery, only a few species predominate the landings.

Closed beels

A majority of beels remain cut-off from the rivers due to natural causes or construction of riverine embankments. In the absence of significant recruitments from rivers, these are inhabited by fishes that can spawn in stagnant waters like murrels, *W. attu*, *N. notopterus*, barbs, rasboras, loaches, *etc*. Indian major and medium carps, large riverine catfishes (*Bagarirus bagarius, Pungasius pangasius*), *N. chitala*, *Ompok* spp., *Aspidoparia morar*, *etc*. are likely to be absent there. In general, the natural fishery of closed beels is overwhelmingly (50 to 90%) dominated by miscellaneous fishes (*Puntius* spp., *Rasbora* spp., *Colisa* spp., *Mystus* spp., *N. notopterus*, etc.). Weed-choked beels are dominated by insectivorous and air-breathers like *Channa* spp., *Anabas* sp., *N. notopterus, C. batrachus, H. fossilis*, etc. Stocking of IMC seed is done in some closed and seasonally open beels like Samaguri and Kapla beel.

Fish species composition

About 54 species belonging to 18 families were recorded from Dighali beel (Kamrup district).

The common species contributing to commercial landings belong to eight groups as follows:

i) Carps (Indian major and medium carps like *L. bata, C. reba*)
ii) Catfishes (*A. seenghala, W. attu, A. aor)*
iii) Murrels (*Channa* spp.)
iv) Featherbacks (*N. chitala, N. notopterus*)
v) Air-breathing fishes (*Colisa* spp., *C. batrachus, H. fossilis*)
vi) Hilsa (*T. ilisha*)
vii) Prawns (*Macrobrachium* spp.)
viii) Miscellaneous fishes (*Puntius* spp., *G. chapra, Rasbora* spp., *Mystus* spp.)

Percent contribution of the major fishes is reported to have declined from 50% to about 25% in most beels during recent years. The share of miscellaneous (minor) fishes increased by 15 to more than 50% over the years. This is an unhealthy trend indicating reduced autostocking from rivers, siltation, macrophyte infestation and/or selective overexploitation of stocks. Many exotic fishes such as common carp, silver carp, grass carp and the African catfish (*C. gariepinus*) have been recorded from beels. They are either washed down from culture ponds by flood or stocked deliberately. In either case, their presence in beels may have far-reaching negative implications on our indigenous ichthyofauna.

A wide variety of fishing methods is employed in the beels of Assam. Five main groups of fishing methods used are:

i) **Passive gear**: Set barrier (banas), dip nets and traps. They capture fish as they migrate to or return from the beels.

ii) **Active gear**: Drag nets, seine nets, gill nets, frame nets, trawls and scoop nets. These are used mainly during the dry season (October to April).

iii) **Fish aggregating devices (FADs)** *Katal/jeng* fishing. This is an indigenous method of erecting circular patches of weeds to attract fish. *Katals* are erected during August-September and harvested from December onwards. While harvesting, the *katal* area is encircled by *banas*/nets. After gradually reducing the encircled area, fishes are caught by using cast and drag nets.

iv)**Falling gear** (Polo, cast net), hook & line, wounding and grappling, catching with hands, *etc.* are of minor importantance.

v) **Dewatering,** which is a destructive fishing practice, has also become an important method in many small, closed beels (eg., Mailhata, Sotha jan, etc.) in recent years.

PEN CULTURE

A series of pen culture experiments were carried out by CIFRI at different locations in Assam. The experiments were conducted in Peetkathi (1990-91, 1991-92), Bageswari (1996-97, 1997-98) and Samaguri (1998-99) beels. Split bamboo screen with inner lining by nylon net was used as pen material. Water area covered by pen enclosure under different experiments varied from 0.005 to 0.1 ha. After the erection of pen enclosure macrovegetation were removed manually and the area was cleared off undesirable fishes by repeated netting. The pH of soil and water in beels are acidic. Lime was applied to correct the pH within enclosed area.

In most of the experiments, fingerlings/ advanced fingerlings of Indian major carps were used as stocking material. Stocking densities varying from 6000 to 60000/ha were tried. In some cases like in Samaguri beel during 1998-99, only silver carp was stocked and in Peetkati, *Puntius javanicus* was stocked along with Indian major carp. Duration of experiments varied between 90- 180 days. Fishes were fed, in all cases, with a conventional mixture of rice bran and mustard oil cake (1:1) at the rate of 2 - 5% of the body weight per day over the period of experiments.

In all the experiments growth rate of catla observed to be faster compared to other two carp species followed by rohu and mrigal. The highest growth (2325%) of Catla was recorded in Peetkati beel over a rearing period of 180 days. In the same experiment, growth rate of rohu and mrigal recorded to be 1085% and 800%, respectively (Table 17). Improved growth performance was associated with longer period of rearing and low stocking density. Higher stocking density and shorter duration did not favour encouraging growth rate. These experiments were conducted during October - December months after the recession of flood water, when temperature of the region starts falling. This has affected the growth. From the pen culture experiments conducted so far no technologies were developed. However, the following conclusions could be drawn:

1. Liming in split doses at regular intervals is needed to correct the low pH. Rock lime which dissolves slowly is very useful for prolonging the effects of liming.
2. Intermittently, phosphate fertilizer may be used to favour plankton growth as PO_4^- concentration in Assam water is very low.
3. Detritivorous fishes like *Labeo calbasu L. dero, Puntius sarana* and exotic species like silver carp and *Cyprinus carpio* can be stocked in largr numbers to get better growth rate.
4. To obtain faster growth in shorter duration one year old stunted (hatchery stunt) fingerling can be used for stocking.
5. To avoid slow growth due to low temperature, fishes can be stocked in the middle of January and rear them till end of April.
6. Feed should be done by using hanging bag.

Table 17 Details of the pen culture experiments conducted by CIFRI in Assam

Name of Beel	Year	Area enclosed (ha.)	Fishes stocked	Stocking density (no/ha.)	Weight gain (%)	Duration of stocking (days)	Management Measures	
							Liming (kg./ha.)	Feeding
Peetkati	1990-91	0.1	Catla Rohu Mrigal	2000 2000 2000	2325 1085 800	180	-	Rice bran:Mustard oil cake(1:1)
Peetkati	1991-92	0.1	Catla Rohu Mrigal P. java-nicus	7030 6160 3370 500	620 800 - 430	120	-	-
Bagheswari	1996-97	0.1	Catla Rohu Mrigal	4550 4550 3900	280 155 150	90	Liming done	Ricebran: Mustard oil cake(1:1) @ 5% b.wt.
Bagheswari	1997-98	0.1	Catla Rohu Mrigal	3300 3850 3850	75 55 36	130	200	Ricebran: Mustard oil cake(1:1) @ 2% b.wt.
Samaguri	1998-99	0.005	Silver carp	60000	40	100	1000	Ricebran: Mustard oil cake(1:1) @ 5% b.wt.

GUIDELINES FOR FISHERY MANAGEMENT OF BEELS OF ASSAM

Biological productivity of a water body depends primarily on the capacity of the system to trap solar energy and store them in the form of chemical energy. The energy conversion efficiency at trophic levels of consumers differs considerably from one water body to another, depending on the qualitative and quantitative variations in the biotic communities. Any conversion rate above 1% can be considered as good. The studies conducted in Assam has proved beyond doubt that beels in this State can yield fish at substantially higher levels compared to other states and other inland aquatic ecosystems.

In an ideal situation, the commercial species share the ecological niches in such a way that trophic resources are utilized to the optimum. At the same time, the fishes should belong to short food chain in order to allow maximum efficiency in converting the primary food resources into harvestable materials. Thus, the basic parameters that abet primary productivity (soil and water quality) and affect composition of community and their efficiency to transfer energy from one trophic level to the other are the primary considerations in selecting management option. These factors are again dependent on the water renewal cycle and the species spectrum of the parent rivers and the beels. Ecosystem-oriented management implies increasing productivity by utilizing the natural ecosystem processes to the maximum extent. This will be more cost effective and to do minimum damage to ecosystem and biodiversity.

There is an increasing trend of dichotomy between intensive aquaculture and the more eco-friendly option such as fishery enhancement. While the protagonists of intensive aquaculture advocate for high input culture systems to produce maximum biomass from a unit area of water, there is an equally strong view point in favour of settling for environment friendly sustainable system of production, even if it means a lower yield rate. This debate throws open the whole gamut of options available in managing our aquatic ecosystems.

One of the useful criteria for demarcating the culture and capture fisheries is the extent of human intervention in the management process. In a typical capture fishery, the wild untended stock of organisms is harvested with little intervention on either habitat variables or the biotic communities. On the other hand in a culture fishery, the whole operation is based on captive stock with a high degree of effective human control over the physico-chemical water quality, and other habitat variables. The marine fisheries is the example of capture fisheries and the intensive aquaculture of fish and prawn in small ponds is the typical culture fishery.

Fishery management purely on capture fishery lines, as understood in case of marine fisheries seldom operates in the inland waters of India, with the possible exception of rivers and estuaries. Catch from rivers are actually falling drastically in the world over, due to negative impact of human activities on the aquatic environment. Most of the open waters which contribute substantially to fish production such as reservoirs, beels, boars, chaurs, etc, are managed on the basis of culture-based fishery or various forms of enhancement, which are intermediate to culture and capture fishery norms. However, these norms lacks conceptual clarity due to absence of clear cut definitions. Since semantic confusion regarding definition of water bodies and management norms are very much evident in the literature, an attempt is made here to define and explain some of them

Culture based fisheries and enhancement

When the fish harvest in an open water system depend solely or mainly on artificial recruitment (stocking), it is referred to as a culture-based fishery. Many of the small reservoirs, closed beels, and number community water bodies in India fall under this system. The main focus of management here is stocking and recapture. The size at stocking, grow out period, and the size at capture are the important criteria in culture-based fishery management.

Fisheries enhancement is the process by which qualitative and quantitative improvement is achieved from water bodies through exercising specific management options. This can be in the form of improving stock, changing the exploitation norm, changing craft and gear, introducing new forms of access and so on. Apart from improving the production of absolute biomass from water bodies, it can also be in the form of interventions on access to the fishery or improvement in their monetary and aesthetic value. The common norms of enhancement which are relevant to inland water bodies of India are :

Fishing operations in beel

- ***Stock enhancement*** (increasing the stock) : augmenting the stock of fish has been the most common management measure followed in the beels. Augmentation of the stock is necessary to prevent unwanted fish to utilize available food niches and flourish at the cost of economically important species. Stocking of floodplain wetlands with fingerlings of economically important fast growing species to colonize all the diverse niches of the biotope is one of the necessary prerequisites in management. The main aspects of stock enhancement are the selection of species for stocking, determination of stocking rate and the size at stocking.

- ***Species enhancement*** : is planting of economically important, fast growing fish from outside with a view to colonizing all the diverse niches of the biotope for harvesting maximum sustainable crop from them. It can be just stocking of new species or new introduction.

- ***Environmental enhancement*** : is improvement of nutrient status of water by the selective input of fertilizers. Although this is common management option adopted in intensive aquaculture, a careful consideration of the possible impact on the environment is needed before this option is resorted to in the floodplain wetlands.

There are other forms of enhancements such as management enhancement when new management options are exercised. For example a water body can be thrown open for sport fishing to attract fishers or a community management approach can be adopted. The new culture systems such as cage and pen culture can be resorted to to augment yield and increase revenue.

The beels of Assam are heterogeneous groups of fresh water wetlands which are diverse in origin, water renewal pattern, soil and water qualities and biotic communities. Since management options to be adopted for obtaining higher yields depend upon an number of biotic and abiotic parameters, it is impossible to suggest a uniform set of guidelines for all types of beels. Thus it is imperative to give stress on ecosystem oriented management.

Community metabolism

Community metabolism or the transfer of energy from one trophic level to the other can be the major criterion for selecting management options especially the species selection in culture-based fisheries. In an ecosystem, the biological output or the production of harvestable organisms can be at various trophic levels. Under a grazing chain, a *phytoplankton > zooplankton > minnows > catfishes* system or a *phytoplankton > zooplankton > fish* system prevails. Since no grazing chain of *macrophytes> fish* exists in beel, macrophytes are invariably channeled through detritus chain. There are different detritus chains such as *macrophytes >detritus> detritivore* system, *phytoplankton > detritus > benthos > bottom feeders* system and *macrophytes > associated fauna > air breathing fish* system.

Two typical systems generally found in the closed and open beels of Assam are depicted in Fig 4 and 5. In both the cases, the birds are at the apex of the food chain. In an open beel, most of the energy are transferred through *phytoplankton > zooplankton > planktophagus > predatory* fish chain. This is more or less the case with most of the open beels. In sharp contrast, closed beel has a macrophytes base food chain with dominance of fish feeding on weed associated fauna or detritus. The management norms in both cases should aimed at correcting the fish species spectrum with the above food chain in view.

Since it is very difficult to prescribe management norms for all possible situations, a few management options are described below.

Culture-based fisheries of the closed beels

Management of completely closed beels or those with a very brief period of connection with the river is more like small reservoirs. The basic strategy here will be stocking and recapture. Beels are the ideal water bodies for practising culture-based fisheries for many reasons. Firstly, they are very rich in nutrients and fish food organisms which enable the stocked fishes to grow faster to support a fishery. Thus, the growth is achieved at a faster rate compared to reservoirs. Secondly, the beels allow higher stocking density by virtue of their better growth performance and the per hectare yield is quite high. Thirdly, there are no irrigation canals and spillways as in the case of

Fig. 4. Pathways of energy flow in (Macrophyte-Detritus chain)

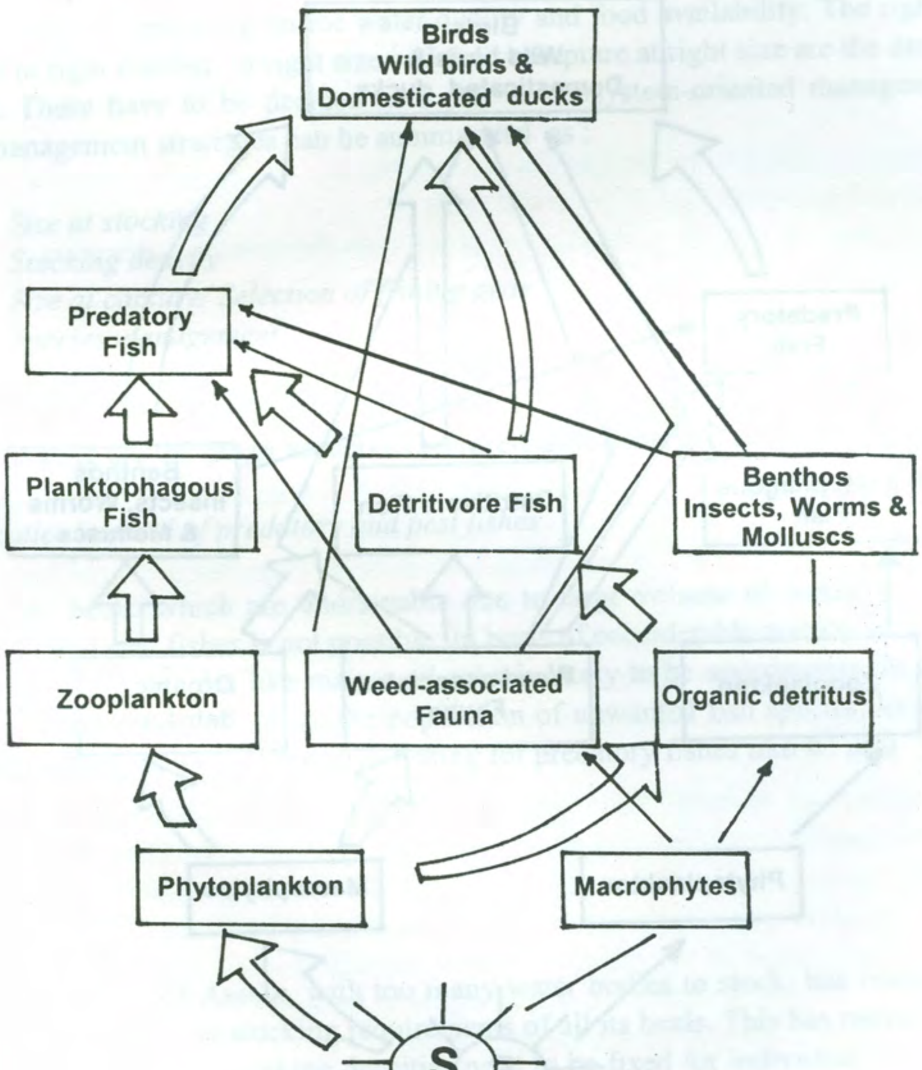
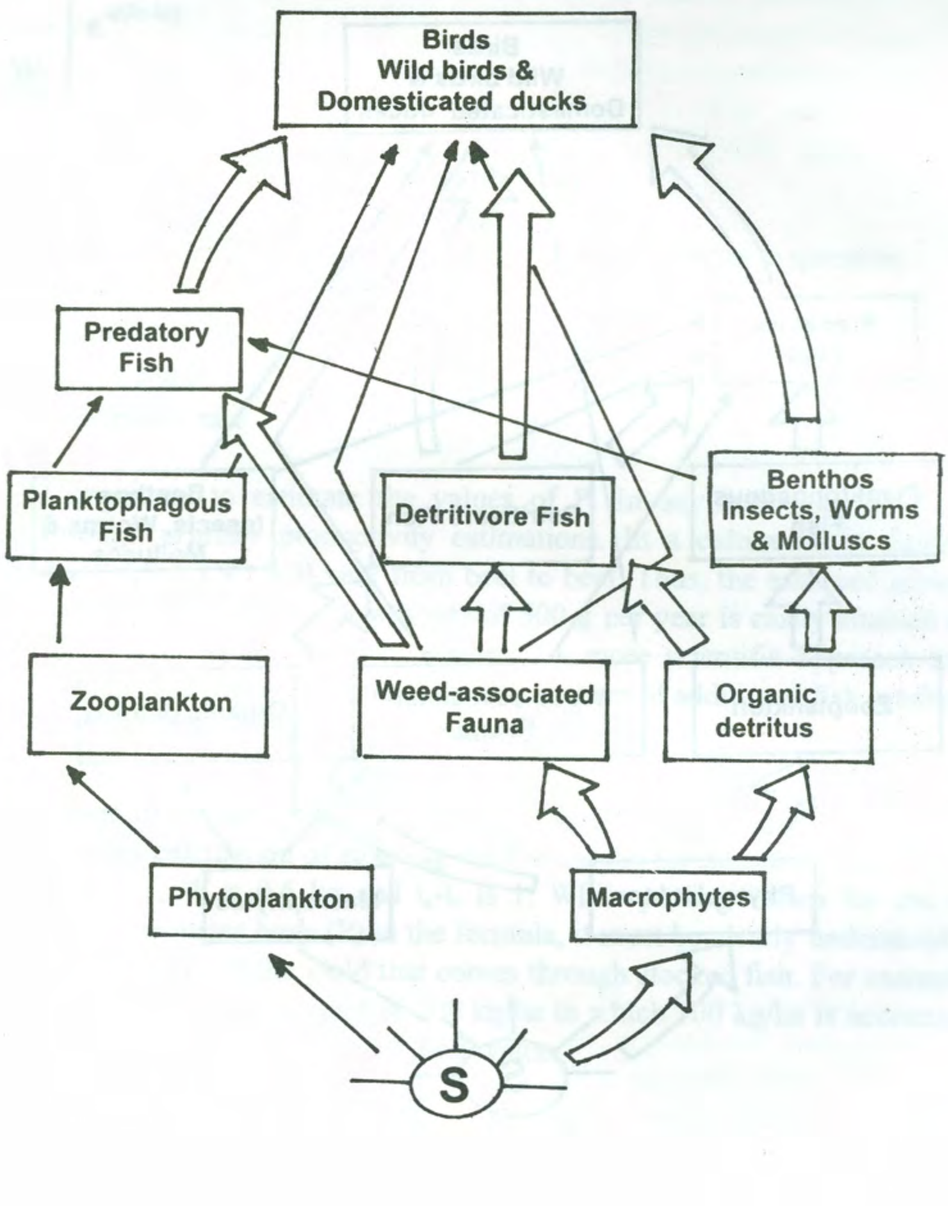


Fig. 5. Pathways of energy flow in (Grazing chain)



small reservoirs which cause the stock loss and the lack of effective river connection prevents entry of unwanted stock. The beels also allow stocking of detritivores as the energy transfer takes place through the detritus chain.

In a culture-based fishery, the growth is dependent on stocking density and survival is dependent on size of the stocked fish. The growth varies from one water body to another depending on the water quality and food availability. The right species stocked in right number, in right size and their recapture at right size are the determining factors. These have to be decided as a part of ecosystem-oriented management. The basic management strategies can be summarized as :

i) *Size at stocking*
ii) *Stocking density*
iii) *Size at capture/ Selection of fishing gear*
iv) *Species management*
v) *Selection species*

The following are the major aspects of culture-based fishery in closed beels:

Eradication/control of predatory and pest fishes

In beels, which are undrainable due to large volume of water, eradication of predatory and pest fishes is not possible. In beels of considerable size (more than 10 ha), application of piscicides like mahua oil cake is likely to be uneconomic. In such cases, the aim should be to minimize the population of unwanted fish species, by the way of repeated netting as well as selective fishing for predatory fishes like *W. attu*.

Stocking density

The State of Assam, with too many water bodies to stock, has inadequate state machinery to meet the stocking requirements of all its beels. This has resulted in under-stocking of the beels. Stocking densities need to be fixed for individual water bodies or a group of them sharing common characteristics such as size, presence of natural fish populations, predation pressure, fishing effort, minimum marketable size, amenability to fertilizing and multiplicity of water use. The main considerations in determining the stocking rate are growth rate of individual species stocked, the mortality rate, size at stocking and the growing time. The following formula can be used for calculating stocking density in beels:

$$S = \left[\frac{q.P}{W}\right] e^{-z(tc-to)}$$

S	Number of fish to be stocked (in number/ha)
P-	Annual potential yield of the water body
q	The proportion of the yield that can come from the species in question
W	Mean weight at capture
t_c	Age at capture
t_o	Age at stocking
-z	Total mortality rate

It is important to estimate the values of P. In an ideal situation it can be calculated through primary productivity estimations. In a culture-based fishery, the growth of stocked fish (W) will vary from beel to beel. Thus, the assumed growth rate can not be uniform. However, a growth rate of 500 g per year is easily attained in case of Indian major carps in the beels of Assam. A more scientific approach to stock enhancement of the beels is needed since the larger share of additional fish production is expected to come from this management measure alone.

The range of mortality rates can be found out from the estimated survival rate. Table 18 illustrates calculation of stocking rates using the formula given above, when P = 200 kg/ha, q = 1, W = 0.5 kg and t_c-t_0 is 1. While putting values for *the annual potential yield of the water body* (P) in the formula, it must be clearly understood that it should cover only a part of the yield that comes through stocked fish. For example, if a beel is expected to give a total yield of 500 kg/ha in which 100 kg/ha is accountable to natural populations, then 400 should be the P value.

The model assumes insignificant breeding by stocked population and therefore applies mainly to total cropping situations *i.e.,* those in which fish are caught below their minimum size for maturity, those whose natural reproduction does not take place and those where water body is not permanent. It shows that stocking density, which depends on the natural conditions of productivity, growth and mortality, are very sensitive to Z. Because of the very large numbers of fry needed, this formula may have very limited utility in large reservoirs.

Table 18. Calculated stocking density at different levels of mortality (adopted from Welcomme, 1976)

Annaul per cent survival	-z	Estimated number of fish to be stocked (number/ha)
50	0.7	805
37	1.0	1,087
22	1.5	1,792
13	2.0	2,955

Despite the lack of any policy and sound scientific advice, the stocking efforts made in Assam beels have been very effective in improving the yield. This is because of the fact that success in management of beels depends more on recapturing the stocked fish rather than on their building up a breeding population. The smaller water bodies have the advantage of easy recapture and stock monitoring. The smaller the reservoirs, the better are the chances of success in the stock and recapture process. Instances where stocking of Indian major carps became ineffective in beels are very rare. The basic tenets of stocking policy are:

- Selection of the right species, depending on the fish food resources available in the system.
- Determination of a stocking density on the basis of production potential, growth and mortality rates.

- Proper stocking and harvesting schedule including staggered stocking and harvesting, allowing maximum grow out period, taking into account the critical water levels.

- In case of small irrigation reservoirs with open sluices the season of overflow and the possibilities of water level falling too low or completely drying up, are also to be taken into consideration.

Stocking size

Since mortality of fish is size-dependent, it is vital to stock fish at a proper size. to ensure a good survival/ recovery of stocked fingerlings. In the undrainable beels having large carnivorous population like *W.attu, C. marulius, N. chitala etc.* (more than 10% of catch) the minimum size of the stocking should be at least 10 cm in length. In beels having moderate (less than equal to 5 % of total fish catch) carnivore population , this minimum stocking size may be reduced to 8 cm. At present, it will be difficult, if not impossible, to get a steady supply of large sized fingerlings in adequate number and at the right time to stock the beels. It is also difficult task to transport large number of advanced fingerlings (>10 cm in size) to the beel sites, which have remote location and poor road connections. Buying the seed for stocking will be an expensive and difficult proposition, which in all likelihood will not be complied with. It may be noted that contrary to the claims, it is the lapse in stocking (in the right size, in adequate number and in time) that is mainly responsible for low yield obtained from culture-based fisheries in reservoirs and beels of India. *Construction of rearing ponds or pen enclosures should be provided in each beel for* in situ *rearing of carp fingerlings.*

Stocking combination and ratio

The combination of three Indian major carps and three exotic carps is expected to give much higher yield than IMC alone. However, in recent years, fish farmers are gradually shifting from 6 species composite carp culture to polyculture of 3 species IMC, because the exotic carps have less consumer preference, low shelf life and the resultant lower price. Since the beels have very high detritus energy, one is tempted to suggest a higher proportion (30 rohu:30 catla:40 mrigal) but experience with pen culture experiment have shown that *mrigal* either does not thrive well in beel bottom due to anoxic condition or are difficult to harvest.

Size at harvest

Size at harvest of stocked fish should be at least 500g (in case of staggered stocking and multiple harvesting) to 750 g (in case of single stocking and terminal harvesting). This may vary depending upon the period of water retention (8-10 months) in the closed beels. In case of staggered stocking, it is important to allow the stocked fish to grow for an adequate period so as to achieve optimum growth. Thus, the stocking and harvesting schedule need to be worked out for each beel, depending on its water renewal pattern. In case staggered stocking is adopted, parameters like stocking interval, minimum size at capture are to be determined and spelt out.

Macrophyte control

Keeping the macrophytes under control is the most important measure to be followed in the closed beels. As explained in earlier chapters, clearance of macrophytes creates congenial atmosphere for rich plankton growth. Since plankton is easily/directly converted into terminal (fish) production, yield rates of beels will go up significantly from macrophyte control alone. Normally, stocking of exotic fish is not encouraged due to the possibility of these fishes entering natural waters through flooding. However, in totally closed beels with little chance of getting flooded, grass carp fingerlings @ 10% of the total stocking density may be released to beel to control submerged macrophytes like *Hydrilla, Najas etc.*

Liming

Since the beels are plagued by the condition of low pH of soil and water, liming is expected to augment release of essential plant nutrients from the soil phase and thereby increasing fish production. Liming during post-monsoon or winter season will also help prevent occurrence of Epizootic Ulcerative Syndrome (EUS), a common cause of loss of fish stocks and associated monetary loss in many beels of the state. However, this measure may not be cost effective in beels larger than 20 ha.

Fertlisation / Bottom raking

Since the beels receive a lot of allochthonous inputs from their catchment areas, and usually have larger organic matter reserve, external fertilisation is unwarranted. Further, external fertilization is not sustainable ecologically since it is likely to hasten the natural eutrophication process of the beel. Instead of external fertilization, macrophyte clearance and bottom raking resulted in rich plankton growth and the highest ever production.

Capture fisheries of the open beels

Some beels retain their riverine connection for a reasonably long time, which are relatively free from weed infestations. These beels are typical continuum of rivers where the management strategy is essentially akin to riverine fisheries. Thus, basic approach is to allow recruitment by conserving and protecting the brooders and juveniles. These measures have the dual advantage of conserving the natural habitat of the beels along with extending the benefits of conservation to the lotic ecosystem of the parent stream. In capture fishery management, the natural fish stock is managed. Therefore, a thorough insight of population dynamics including recruitment, growth and mortality is very much essential. In order to ensure recruitment, the following parameters are taken into consideration.

i) *Identification and protection of breeding grounds*
ii) *Allow free migration of brooders and juveniles from beel to river and vice versa.*
iii) *Protection of brood stock and juveniles by conservation measures.*

The growth over-fishing is prevented by taking appropriate measures for gear selection. Adjustments in quality and quantity of fishing gear is an essential component of capture fishery management. Common strategies followed are summarized as:

i) *Increase the minimum mesh size.*
ii) *Increase or decrease the fishing effort.*
iii) *Observe the closed season to protect the brooders.*

iv) *Strict adherence of the restriction on the minimum size at capture.*
v) *Diversity of the gear.*
vi) *Selective augmentation of stock, only if unavoidable.*

Culture and capture systems

There are systems which combine the norms of capture and culture fisheries. The marginal areas of beels are cordoned off for culture systems either as ponds or as pens and the central portion is left for capture fisheries (Fig. 6). This has been tried in many places of the country with certain degree of success.

Fishery options

i) *Fishery based on Indian major carps*

The beel, especially the closed ones can be developed as big ponds has their fishery solely depends on stocking with IMC. Although not done in a scientific way the beels are being stocked regularly. In the absence of natural recruitment, stocking with economically important species form the best management option.

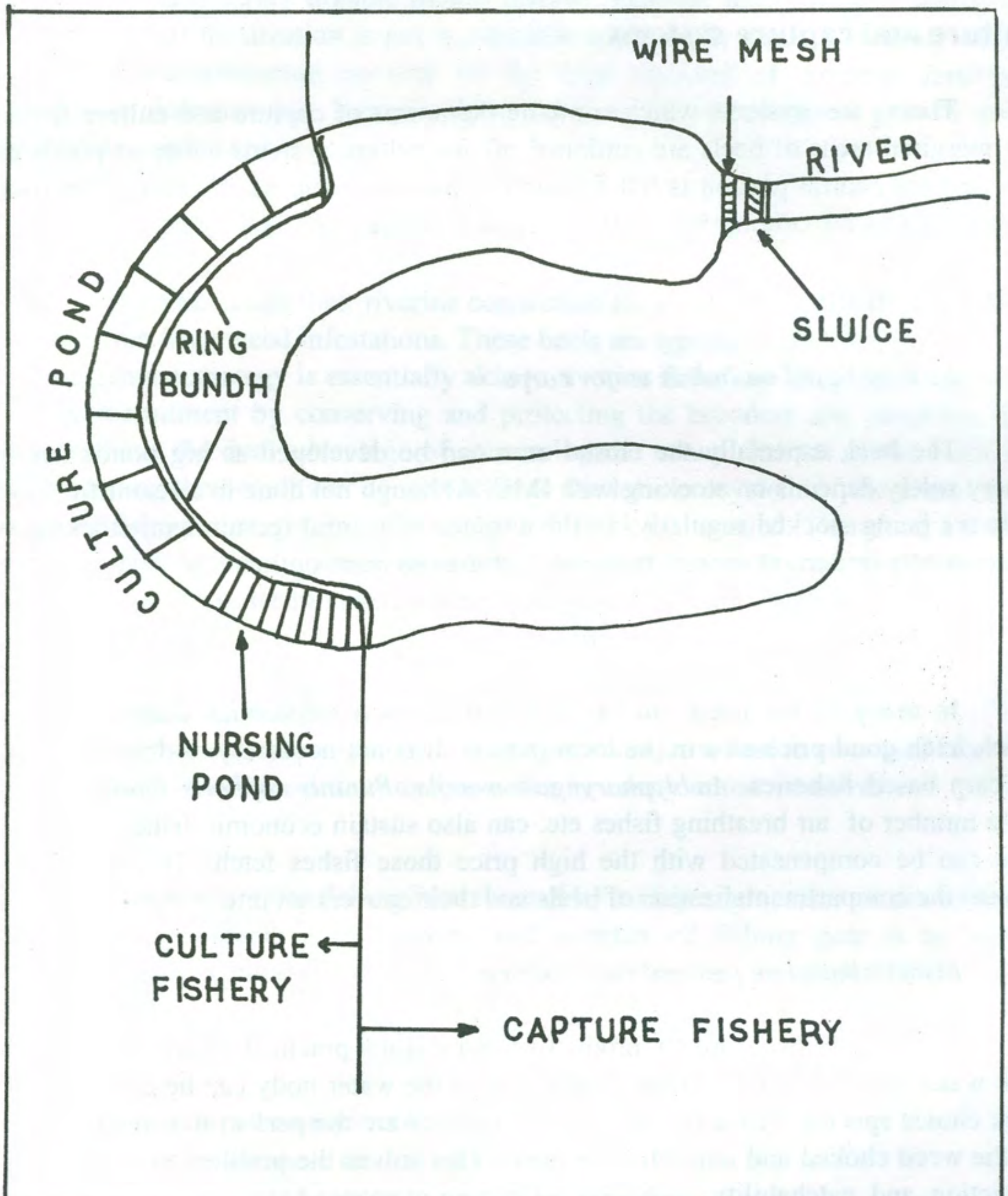
ii) *Fishery based on indigenous fishes*

In many of the beels indigenous fish forms a substantial share of the catch which fetch good price also in the local market. It is not necessary to develop all beels as carp based fisheries. *Amblypharyngodon mola, Puntius sophore, Gudusia chapra* and a number of air breathing fishes etc. can also sustain economic fishery. Low yield rates can be compensated with the high price those fishes fetch. This practice will prevent the compartmentalization of beels and their conversion into ponds.

iii) *Fishery based on pen and cage culture*

Many of the beels are not productive and it is not practical to fertilize the whole open water area. Therefore a manageable part of the water body can be cordoned off to stock choice species. Pen and cage culture practices are the perfect management option for the weed choked and unproductive beels. This solves the problem created by gear restriction and catchability.

Fig. 6. Diagrammatic representation of culture and capture fisheries development in Assam



Beels also can be part of an integrated system including navigation, bird sanctuary, post harvest, aquaculture and open water fisheries. A scheme for an beel (Fig. 7) has been shown as an example. This plan is a part of holistic development of the wetland, which can benefit the local people and help retaining the biodiversity of the beel and its environment. It is proposed that the deep northern part of the lake can be retained in its natural state to conserve aquatic communities and fish population. This will act as a reservoir for irrigation and capture fisheries. The periphery of the swampy southern sector of the beel could be converted into aquaculture ponds/pens leaving the middle portion of this sector as bird sanctuary.

Fig 7.. Integrated Development of Beel