ECOLOGY AND PRODUCTION DYNAMICS OF RIVER BRAHMAPUTRA WITH SPECIAL EMPHASIS ON ITS TRIBUTARIES

Central Inland Capture Fisheries Research Institute

Ecology and Production Dynamics of River Brahmaputra with Special Emphasis on its Tributaries

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FOREWORD

River Brahmaputra the might river of the North East, with its 42 tributaries and three forerunners Siang, Dibang and Lohit, have diverse ecological features with tremendous fishery potential. Informations regarding the ecological status and fishery of these systems were lacking and practically nothing was known about its tributaries. To fill this gap of knowlege the Institute took up an exploratory survey of the entire stretch of river Brahmaputra including all its major tributaries to have an indepth knowledge of their ecology and fishery potential as well as, the impact of these tributaries on environment and fishery of main river Brahmaputra. I am sure that the pioneering informations collected and documented here will give an opportunity to have an indepth knowledge about the entire system hitherto unknown.

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Introduction

The mighty Brahmaputra "a fresh water moving ocean of North East" rises from the snout of Chemayungdung mountains near Tachhong (Tomchok) Khambab chhorten, about 100 km South East of Lake Mansarovar at an altitude of 5150 m (latitude 30 ^{o} 31'N and longitude 82^{o}10'E). It runs about 1250 km in a shallow valley through Tibet as river Tsangpo, almost parallel to the main Himalayan range, before taking a sharp turn South wards to enter India near Tuting in Siang district of Arunachal Pradesh. Running about 160 km in Arunachal Pradesh as river Dihang or Siang, it enters Assam on the North west of Saidiya where it meets two equally important trans-Himalayan tributaries Sikong or Dibang and Lohit. After joining with these tributaries the river assumes the name Brahmaputra. Fortified by many tributaries the river flows through the heart of the State (Assam) for about 740 km before entering Bangaladesh as river Jamuna. Flowing for its last 480 km the river joins Ganga at Goalando. Besides providing navigation facilities river Brahmaputra plays vital role in sustaining vegetated life, flora and fauna of the valley and its surroundings.

The informations regarding the ecology of River Brahmaputra are very limited. Studies made so far are localised to few stretches only and practically nothing is known about the system as a whole, including its important tributaries. (Anon 1974-79, Anon 1986-87 to 1995-96, Yadav and Sugunan 1992, Pathak and Sarkar 1997). Thus, an urgent need was felt to have a detailed knowledge of the ecology and production dynamics of the entire system and its tributaries in order to understand many unknown facts. The ecology and fishereis potential of the entire Brahmaputra system including its three fore runners Siang, Dibang and Lohit as well as all its important tributaries on both the banks were studied during the present investigation during the period 1996-98.

The river system

The Brahmaputra valley sandwitched between Eastern Himalayan and Shillong plateau covers an area of 56,339 km^{2}. The total length ofthe river is 2900 km of which about 900 km falls in India. All along its course in Assam the river is joined by many tributaries on both the banks. The major tributaries are Depi, Dekari, Simen, Gainadi, Jiadahal, Subansiri, Ranganoi, Dikrong, Buroi, Burgang, Jiabharali, Belsiri, Pasnoi, Jiadhansiri, Puthimari, Pagladia, Beki, Manas, Aie, Champamati, Gaurang, Tipkai, Gadadhar and Sankosh on the North bank and Noadihing, Dibru, Burhidihing, Disang, Diknow, Dhansiri, Kopili, Kalong, Kulsi, Singra, Dudhnoi and Krishnoi on South bank. The combined length of the river along with its 47 major tributaries is about 4000 km with a catchment area of 5,80,000 km^{2} and average water discharge of 5,10,450 mm^{3}.

The catchment area of this river system in India is 1,95,000 km^2 of which 81,424 km^2 is in Arunachal Pradesh, 70,634 km^2 in Assam, 10,803 mk^2 in Nagaland; 11,667 km^2 in Meghalaya, 7,300 mk^2 in Sikkim and 12,585 km^2 in West Bengal. The length upto confluence and catchment area of some important tributaries are given in Table 1.

The annual water discharge from the three components Siang, Dibang and Lohit are 1,85, 102 mm^3, 37,818 mm^3, and 46,946 mm^3, respectively. Theannual discharge in some important tributaries are 52,705 mm3 in Subansiri, 28,844 mm^3 in Jiabharali, 11,906 mm^3 in Burhidihing. 9023 mm^3 in Kopili-Kalong and 6785 mm^3 in Dhansiri.

Brahmaputra and its tributaries maintain most unstable courses in the plains with changing channels. These tributaries contribute substantially to the silt content in themain drainage. Characteristically the Northern tributaries aremostly hilly with very steep slope, shallow braided channels carrying high silt discharge where as Southern tributaries are deeper with meandering channels, low gradient and have comparatively less silt lead. It has been estimated that the Northern tributaries have the average silt yield in the order of 666.7 m^3 km^{-2} and the silt discharge from southern part ranges between 66.7 and 95.7 m3 km^{-2}. During the period of 50 years from 1937-87 the river bed of Brahmaputra has risen 4.5 m due to accumulation of silt. Maximum silt lead in the river has been observed during July and August months. The maximum suspended silt load at pandu (near Guwahati) is 36.600 ha/m and minimum 1487 ha/m with a general composition of 5.27% coarse, 26.05% medium and 68.68% fine.

The valley gently slopes from North-East to south west from Saidiya (134 m above mean sea level) to Guwahati (50 m above mean sea level) and then slope becomes east to west direction upto Dhubri (36 m above mean sea level). The gradient of the river bed is steep in Arunachal Pradesh and it decreases as the river flows downwards in Assam. Between different stretches the gradient is :

Kobo and Dibrugarh 1 in 3700 (*i.e.*, 0.27 m km^{-1})
Dibrugarh and Jorhat 1 in 5595 (*i.e.*, 0.178 m km^{-1})
Jorhat and Tezpur 1 in 6425 (*i.e.*, 0.155 m km^{-1})
Tezpur and Guwahati 1 in 6750 (*i.e.*, 0.148 m km^{-1})
Guwahati and Goalpara 1 in 8875 (*i.e.*, 0.113m km^{-1})
Goalpara and Dhubri 1 in 14,650 (*i.e.*, 0.068 m km^{-1})

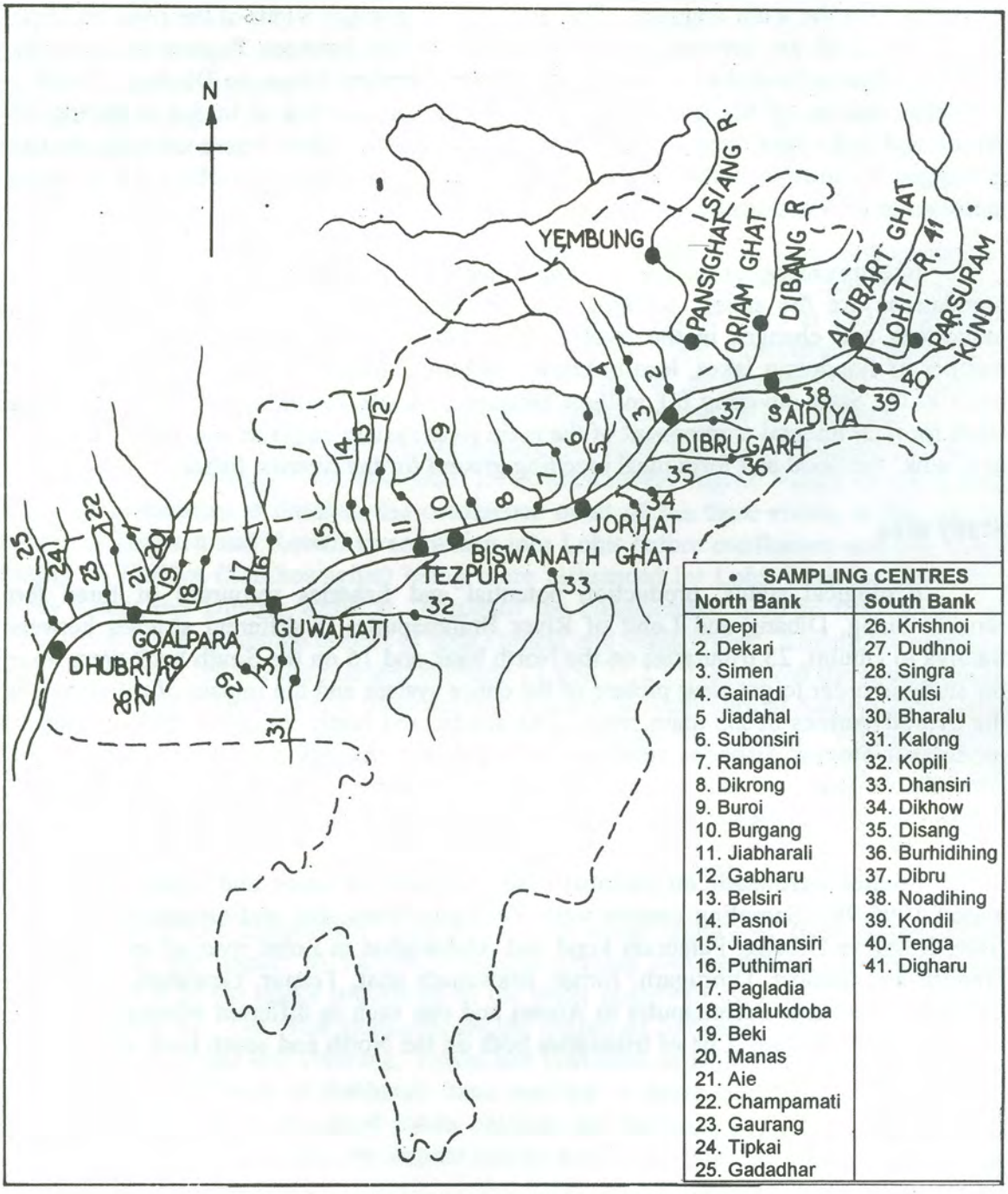
Large amount of fine silt brought during flood gives the valley its fertility. The river becomes sluggish in the lower reaches due to low gradient and many islands are formed owing to the deposition of enormous silt load carried and discharged by the tributaries into the main drainage. The approximate average width of the river in Assam is 5.46 km (5.06 km between Jorhat to Tezpur, 6.1 km between Teszpur to Guwahati, 3.78 km between Guwahati to Manas and 7.1 km between Manas to Dhubri). Depth in the upper reaches of the river (Dibrugarh) varies between 3.6 m to 5.0 m during dry season and is doubled during monsoon months. Near Guwahati where the river channel is hugged by hills on either sides the depth during dry season is about 18 m which increases to 27.4 m during high floods.

Interspreading of numerous abandoned riverine water areas and their annual inundations are the salient topographical features of Brahmaputra valley. Frequent inundtions and changes in the river courses have resulted in the formation of large number of floodplain lakes, locally known as beels. There are about 1392 numbers of beels in the State covering 0.1 million hactares of water spread area. These floodplain lakes form an integral component of the main river system and over the years have acted as a 'sink' for flood and form ideal breeding ground for the riverine fishes.

Study area

Ecological status, production potential and fisheries resources of three fore runners Siang, Dibang and Lohit of River Brahmaputtra, 8 different strtches between Saidiya to Dhubri, 25 tributaries on the North bank and 16 on the South bank were taken for study in order to get clear picture of the entire system and the impact of tributaries on the hydrodynamics of the main river. The abiotic and biotic variables, their role in the production process, fisheries structure and yield and changes over the years were also critically evaluated in the entire river system covering both the states of Arunachal Pradesh and Assam. River Brahmaputra and its various tributaries are shown in Figure 1.

Studies were made on seasonal basis (summer, monsoon and winter) during the period 1996-98. Sampling centres were Yembung, Pansighat and Oiramghat in Siang river, Roing in Dibang; Parsuram kund and Alubarighat in Lohit river all in Arunachal Pradesh and Saidiya, Dibrugarh, Jorhat, Biswanath ghat, Tezpur, Guwahati, Goal-Para and Dhubri in main Brahmaputra in Assam and one each in different tributaries both in Arunachal and Assam. List of tributaries both on the North and south bank are given in **Fig. 1**.



• SAMPLING CENTRES	
North Bank	**South Bank**
1. Depi	26. Krishnoi
2. Dekari	27. Dudhnoi
3. Simen	28. Singra
4. Gainadi	29. Kulsi
5 Jiadahal	30. Bharalu
6. Subonsiri	31. Kalong
7. Ranganoi	32. Kopili
8. Dikrong	33. Dhansiri
9. Buroi	34. Dikhow
10. Burgang	35. Disang
11. Jiabharali	36. Burhidihing
12. Gabharu	37. Dibru
13. Belsiri	38. Noadihing
14. Pasnoi	39. Kondil
15. Jiadhansiri	40. Tenga
16. Puthimari	41. Digharu
17. Pagladia	
18. Bhalukdoba	
19. Beki	
20. Manas	
21. Aie	
22. Champamati	
23. Gaurang	
24. Tipkai	
25. Gadadhar	

FIG. 1. BRAHMAPUTRA RIVER SYSTEM

River Brahmaputra at Saikhowaghat

River Brahmaputra at Tezpur

A view of river Diang

River Diang shoreline

River Lohit at Alubarighat

River Lohit near Digharu confluence

River Siang on way to Yembung

A view of river Siang

General climatic conditions of the region

River Brahmaputra is situated in the north of tropic of cancer and thus is characterised by coolness and high humidity. The most distinguishing feature of the area is copious rainfall between March and May, a time when the precipitation in other parts of the country is at its minimum. Both north east and south west monsoon are active in the region. Seasonal distinctions are based on the rainfall pattern as in most tropical and subtropical regions and they are not sharply delimited, transitions are gradual and extremely dry period do not normally occur. The hot and humid summers and prolonged monsoon give way to mild winters which last from November to February, the lowest temperature experienced in the valley is generally in January. The water level in the river fluctuates consequent to the snow melt in the Himalayan reaches and precipitation in the region.

Abiotic variables

(i) Three forerunners of Brahmaputra

The sediment and water quality of Siang, Dibang and Lohit rivers, which make Brahmaputra after their confluence, have been presented in table 2 & 3. The physical features of the sediment in the three rivers reflect te dominance of sand contributing 97 to 99.5%, the silt and clay representing only 0.5 to 0.75 and 0.0 to 2.25% respectively. Chemically the sediment is alkaline in reaction with pH ranging from 7.01 to 7.52, specific conductance 127.0 to 226.0 μmhos and free calcium carbonate 2.0 to 2.87%. Organic carbon is quite high in the sediment from Siang river (1.635%) but in other two its percentage ranges between 0.125 and 0.235 only. The nutrient status however is poor in respect of both available nitrogen (9.84 to 12.88 mg/100 g) and phosphorus (0.48 to 0.72 mg/100 g). In general the sediment quality is almost similar in the three rivers with few exceptions.

The common features in respect of water quality of the three rivers are low water temperature (10.0 to 12.8°C) high transparency (120.0 to 164.0 cm), rich oxygen (9.02 to 10.3 mgl^{-1}), alkaline pH (7.5 to 7.7), high dissolved organic matter (1.45 to 2.04 mgl^{-1}) and poor nutrient status (nitrate (0.015 to 0.025 mgl^{-1}) and phosphate 0.005 to 0.05 mgl^{-1}). But considerable differences have been observed in respect of chemical parameters like alkalinity, conductance, dissolved solids, calcium and hardness, all being maximum in Siang rive (av. 62.67 mgl^{-1}, 141.3 μmhos, 71.3 mgl^{-1}, 14.72 mgl^{-1} and 60.8 mgl^{-1} respectively) and minimum in Dibang river (35.72 mgl^{-1}, 99.8 umhos, 50.6 mgl^{-1}, 7.68 mgl^{-1} and 38.4 mgl^{-1} respectively). It is interesting to see that all the above parameters

Table 1 : Length and catchment area of some of the important tributaries

NORTH BANK TRIBUTARIES			SOUTH BANK TRIBUTARIES		
Tributaries	**Length upto confluence (km)**	**Catchment area (km^2)**	**Tributaries**	**Length upto confluence (km)**	**Catchment area (km^2)**
Jiadahal	99	1346	Noadihing	-	-
Subansiri	375	28200	Burhidihing	360	8730
Ranganoi	150	2941	Disang	230	3950
Dikrang	145	1528	Dikhow	236	4022
Buroi	63	791	Jangi	108	1349
Burgang	42	550	Bhagdoi	160	920
Brahmagon	28	92	Kopili	261	20068
Jiabharali	-	14738	Kalong		
Dipota	-	296	Bharalu	40	469
Gabharu	-	296	Kulsi	220	3770
Belsiri	-	751	Deosila		
Jiadhansiri	76	956	Dudhanoi	103	1615
Puthimari	112	1787	Krishnoi		
Pagladia	197	1674	Jinari	60	594
Aie	30		Jingra	-	3467
Manas	114	41350	Dhansiri	352	10305
Beki	84				
Champamati	-	1038			
Gaurang	-	1023			
Tipkai	-	1744			
Gadadhar	-	610			
Sankosh	321	10345			

Table 2 : Sediment quality in three components of River Brahmaputra

	Parameters	River Siang	River Dibang	River Lohit
Physical features	Sand (%)	97.0	99.5	98.0
	Silt (%)	0.75	0.5	0.75
	Clay (%)	2.25	0.0	1.25
	pH	7.01	7.28	7.52
	Sp. Conductance (µmhos)	148	127	226
	Free $CaCO_3$ (%)	2.87	2.0	2.25
Chemical features	Av. Phosphorus (mg/100 g)	0.72	0.48	0.58
	Av. Nitrogen (mg/100 g)	12.88	9.84	10.12
	Organic carbon (%)	1.635	0.125	0.235

Table 3 : Water quality of three components of River Brahmaputra

Parameters	River Siang				River Dibang	River Lohit		
	Yem-buny	Pansi -ghat	Oiram -ghat	Av. for stretch		Parsu-ram kund	Central Lohit	Av.
Water temp. (°C)	10.0	11.0	11.0	10.7	12.5	11.5	12.8	12.15
Transparency (cm)	125.0	140.0	120.0	128.0	164.0	162.4	130.0	146.2
DO (mgl^{-1})	10.3	9.75	9.94	10.0	9.02	10.2	9.27	9.73
pH	7.6	7.5	7.6	7.57	7.6	7.6	7.7	7.65
Free CO_2 (mgl^{-1})	0.96	0.96	0.96	0.96	1.92	0.96	1.42	1.19
Total alkalinity (mgl^{-1})	62.98	61.10	63.92	62.67	35.72	38.4	57.35	47.87
Sp. Conductance (μmhos)	145.6	142.2	136.2	141.3	99.8	102.4	132.5	117.45
Total dissolved solids (mgl^{-1})	73.6	71.6	68.8	71.3	50.6	50.8	66.85	58.82
Calcium Ca^{++} (mgl^{-1})	15.36	13.44	15.36	14.72	7.68	7.68	18.24	12.96
Magnesium Mg^{++} (mgl^{-1})	7.30	7.03	3.51	5.95	4.68	4.68	5.22	4.95
Total hardness (mgl^{-1})	67.2	62.4	52.8	60.8	38.4	38.4	62.2	50.3
Chloride (mgl^{-1})	29.4	29.4	24.8	27.77	24.5	29.4	29.5	29.45
Silicate (mgl^{-1})	3.4	4.0	3.2	3.5	3.6	5.0	5.0	5.0
Iron Fe^{+++} (mgl^{-1})	0.14	0.08	0.08	0.10	0.12	0.62	0.265	0.442
Dissolved organic matter (mgl^{-1})	2.04	1.496	1.45	1.662	1.904	1.712	1.49	1.601
Nitrate (mgl^{-1})	0.025	0.025	0.025	0.025	0.015	0.02	0.022	0.021
Phosphate (mgl^{-})	0.005	0.05	0.016	0.024	0.005	0.005	0.006	0.055

have been found to be almost similar in the entire stretch of Siang river between Yembung and Oiramghat but in Lohit river their values are much lower at Parsuramkund (38.4 mgl^{-1}, 102.4 μmhos, 50.8 mgl^{-1}, 7.68 mgl^{-1} and 38.4 mgl^{-1} respectively) and have shown remarkable increase at Central Lohit near Alubarighat (57.35 mgl^{-1}, 132.5 μmhos, 66.85 mgl^{-1}, 18.24 mgl^{-1}, and 62.2 mgl^{-1} respectively). The increase in the values of above chemical parameters may be attributed to the impact of highly alkaline waters of Digharu river which join Lohit near Alubarighat. The impact has been experienced even upto Saidiya.

(ii) Important tributaries of Brahmaputra

a) <u>*Sediment quality*</u> *:*

The sediment quality of both north and south bank tributaries have been presented in tables 4 & 5. Physical composition of sediments of tributaries on the north bank shows complete dominance of sand (81.75 to 99.5%) with silt and clay representing only 0.0 to 10.75% and 0.0 to 12.25% respectively. Higher precentage of silt has been observed in Champamati and Gaurang while clay has been comparatively higher in Manas and Pagladiya. Sediment is neutral to slightly alkaline in reaction in the downstretch tributaries from Pasnoi to Gadadhar (pH 7.06 to 7.43), the only exception being Champamati (pH 6.66) while in the upper stretch tributaries it is acidic in reaction with pH ranging from 5.66 to 6.94, except Depi (pH 7.28) and Gainadi (pH 7.13). specific conductance has been found to be minimum in Burgang (47.5 μmhos) and maximum in Gainadi (295 μmhos). The values of free calcium carbonate are low to medium in most of the tributaries (0.88 to 3.12%) ecept Manas and to some extent Aie where the values have been comparatively much higher (7.5% and 6.25% respectively). This clearly shown the impact of catchment quality and is a clear example that the tributaries must be flowing through rich calcium belt (Lime stone). Organic carbon is in general poor in almost all the tributaries (0.091 to 0.628%). the nutrient status of the sediment in respect of both nitrogen and phosphorus is also poor in all the tributaries except slightly higher values in Champamati and Gaurang (Table 4).

The sediment quality of south bank tributaries is also dominated by sand (78.5 to 98.5%) with silt and clay ranging from 0.5 to 16.5% and 1.0 to 18.5% respectively. Comparatively higher percentage of silt has been found in Bharalu and Kalong while clay is higher in Disang. Except Noadihing (pH 7.2) and Burhidihing (pH 7.0). the sediment from all the tributaries is slightly acidic in reaction with pH ranging from 5.97 to 6.97. specific conductance and free calcium carbonate are in the range of 50 to 290 μmhos and

0.75 to 2.0% respectively. Organjic carbon (0.12 to 0.557%), available nitrogen (6.04 to 22.84 mg/100 g) and phosphorus (0.28 to 1.97 mg/100 g) all are generally poor in the sediment.

(b) *Water quality* :

The water quality parameters of both north and south bank tributaries have been presented in Table 6 & 7. The north bank tributaries have shown consideable variations in respect of chemical parameters like alkalinity, conductance, dissolved salts, calcium, magnesium and hardness all being exceptionally high in Manas river 2.07.67 mgl^{-1}, 345.5 mmhos, 173.84 mgl^{-1}, 25.7 mgl^{-1}, 22.02 mgl^{-1} and 155.8 mgl^{-1} respectively) and extremely low in Ranganoi (23.5 mgl^{-1}, 52.6 µmhos, 26.6 mgl^{-1}, 6.4 mgl^{-1}, 3.0 mgl^{-1}, and 32.1 mgl^{-1}, respectively), the values of these parameters in all the other tributaries ranged between the two extremes. The south bank tributaries also have shown considerable variations in respect of the alkalinity. Conductance, dissolved salts and hardness all being maximum in Digharu (131.6 mgl^{-1}, 299.0 µmhos, 150 mgl^{-1}, and 86.4 mgl^{-1}, respectively) and minimum in Bharalu, head waters (22.0 mgl^{-1}, 46.0 µmhos, 23.2 mgl^{-1}, and 25.8 mgl^{-1}). It is interesting to see that none of the two tributaries are similar in respect of the above chemical parameters specially those in the north bank and the qualitative difference in the water clearly reflect the impact of their catchment. The common features of the tributaries on both the banks are rich oxygen, high values of dissolved organic matter, neutral to alkaline pH and low nutrient status (Table 6 & 7). Among the physical parameters water temperature is comparatively lower in some o fthe tributaries like Subansiri (14.2°C) Ranganoi (14.1 °C), Dikrong (16.3 °C), and Jiabharali (16.5 °C) in the north bank and Digharu (14.0 °C), Tenga (15.0 °C), and Kondil (16.0 °C), on the south bank. Subansiri and Jiabharali, (north bank tributaries) have shjown high degree of light penetration while in many tributaries water is transparent upto bottom specially those having low depth.

The diverse hydrological set up of various tributaries have great bearing on the water quality of the main river specially those in the north bank.

(iii) *River Brahmaputra*

The sediment and water quality of river Brahmaputra between Saidiya and Dhubri have been presented in Table 8 & 9. The physical composition of the sediment is dominated by sand (83.75 to 98.5%) with silt and clay ranging from 0.5 to 10.25% and 1.0 to 6.5% respectively. Higher percentage of silt is found in Jorhat and Biswanathghat while clay is comparatively more in Biswanathghat. Sediment is slightly alkaline in

reaction with pH ranging between 7.33 to 7.67 throughout the stretch with specific conductance ranging from 95.0 umhos (Dhubri) to 249.5 μmhos (Biswanathghat). Free calcium carbonate is medium to low in the sediment from Saidiya to Dhubri, the values ranging from 1.0 to 2.12%. organic carbon is slightly better in Guwahati (0.567%), Jorhat (0.453%) and Biswanathghat (0.339%) while in other places its value ranges between 0.105 to 0.259%. Both the available nutrients nitrogen (10.04 to 21.44 mg/100 g) and phosphorus (0.53 to 1.90 mg/100 g) are of low order. The sediment quality of the river between Jorhat and Biswanathghat is slightly different from other stretches, specially in respect of its physical composition.

In respect of water quality river Brahmaputra is found to be quite rich in oxygen (7.0 to 8.45 mgl^{-1}), alkaline in reaction with pH ranging from 7.5 to 7.9, rich in dissolved organic matter (1.39 to 1.84 mgl^{-1}) and poor in nutrients (Nitrate 0.018 to 0.038 mgl^{-1} and phosphate 0.003 to 0.016 mgl^{-1}) throughout the stretch. But considerable interstretch variations have been observed in respect of chemical parameters like alkalinity, conductance, dissolved solids, and hardness, all being maximum at Goalpara (76.23 mgl^{-1}, 174.6 μmhos, 88.06 mgl^{-1} and minimum in Tezpur below the bridge (56.9 mgl^{-1} 134.0 mmhos, 67.3 mgl^{-1} and 64.8 mgl^{-1}). Comparatively higher values of the above chemical parameters at Saidiya, the confluence point of the three rivers, is due to the impact of Digharu and Kondil rivers which join Lohit before confluence and the water quality of Saidiya (Saikhowaghat) being more influenced by Lohit than the other two rivers Siang and Dibang while at Dibrugarh the considerable drop in their values is mainly due to the combined impact of both Dibang and Siang rivers. Among the physical parameters water temperature ranged between 17.8 to 21.2°C throughout the stretch being slightly higher at Dhubri while transparency of water is maximum at Saidiya (87.2 cm) and varied between 35.4 to 43.5 cm between Dibrugarh and Dhubri. Comparatively lower values of transparency below Saidiya down upto Dhubri is mainly due to high silt load brought by the tributaries, joining between these stretches.

(iv) Impact of tributaries on the water quality of the main river

Considerable interstretch variations in the water quality of river Brahmaputra clearly reflect the impact of various tributaries joining between these stretches. The impact of some of the major tributaries on the water quality of the main river have been shown in table 10. The clear examples are the impact of Jiabharali at Tezpur, Manas at Goalpara (Jogighopa) and Gaurang, Tipkai and Gadadhar at Dhubri. As shown in table the low alkaline waters of Jiabharali have resulted in sharp decline in the values of alkalinity, conductance, dissolved solids, calcium and hardness of river Brahmaputra at Tezpur (near the bridge) and the impact can be seen even upto forest ghat. In fact the

Table 4 : Sediment quality of North Bank Tributaries

Tributaries	Physical Features			Chemical Features					
	Sand (%)	*Silt (%)*	*Clay %)*	*pH*	*Sp.con-ductance (μmhos)*	*Free $CaCO_3$*	*Organic Carbon (%)*	*Av. Phos-phorus (mg/100 g)*	*Av. nitrogen (mg/100 g)*
Depi	98.5	0.5	1.0	7.28	111.0	1.25	0.091	0.82	16.12
Dekari	99.5	0.5	0.0	5.66	250.0	1.0	0.191	0.68	12.42
Simen	97.5	2.5	0.0	6.24	242.0	1.0	0.091	0.72	13.12
Gainadi	99.0	1.0	0.0	7.13	295.0	1.75	0.104	0.84	16.88
Jiadahal	99.0	1.0	0.0	6.94	164.0	1.5	0.09	0.52	9.84
Subansiri	98.0	1.0	1.0	6.64	224.0	2.37	0.257	0.51	10.15
Ranganoi	96.5	1.75	1.75	6.76	135.5	1.38	0.184	0.51	9.38
Dikrong	98.5	0.5	1.0	6.84	137.0	0.88	0.104	0.44	8.7
Buroi	98.25	0.75	1.0	6.41	67.0	1.0	0.117	0.55	11.51
Burgang	98.0	0.75	1.25	6.52	47.5	1.37	0.230	1.78	19.27
Jiabharali	98.5	0.0	1.5	6.96	128.0	1.12	0.119	0.61	11.49
Gabharu	94.0	2.0	4.0	6.65	94.0	2.0	0.278	0.89	14.32
Belsiri	92.0	5.75	2.25	6.47	75.0	1.5	0.391	1.42	18.6
Pasnoi	98.5	0.25	1.25	7.3	53.5	1.87	0.136	0.53	10.89
Jiadhansiri	97.75	0.5	1.75	7.45	90.5	1.13	0.188	0.49	9.73
Bhalukdoba	94.0	3.5	2.5	7.23	128.5	2.0	0.382	0.69	10.85
Puthimari	93.75	4.5	1.75	7.19	176.0	2.5	0.38	0.51	11.27
Pagladia	81.75	6.0	12.75	7.06	148.0	2.12	0.39	1.21	17.47
Beki	96.75	1.5	1.75	7.33	209.5	3.12	0.166	1.31	17.57
Manas	87.5	2.25	10.25	7.25	282.0	7.5	0.457	0.33	6.21
Aie	97.0	0.5	2.5	7.40	172.0	6.25	0.628	0.30	6.84
Champamati	87.25	10.75	2.0	6.66	107.0	1.38	0.186	2.61	30.49
Gaurang	86.75	10.0	3.25	7.1	109.0	1.13	0.131	2.54	30.79
Tipkai	93.75	4.0	2.25	7.43	155.0	2.88	0.380	0.380	7.2
Gadadhar	97.5	0.5	2.0	7.38	94.0	1.75	0.429	0.26	4.12

Table 5 : Sediment quality of South bank tributaries

Tributaries	Physical Features			Chemical Features					
	Sand (%)	*Silt (%)*	*Clay %)*	*pH*	*Sp.con-ductance (μmhos)*	*Free $CaCO_3$*	*Organic Carbon (%)*	*Av. nitrogen (mg/100 g)*	*Av. Phosphorus (mg/100 g)*
Noadihing	98.0	0.75	1.25	7.2	108.5	1.75	0.12	21.02	1.95
Dibru	95.75	2.0	2.25	6.75	73.0	1.13	0.217	6.39	0.37
Burhidihing	95.25	2.0	2.75	7.0	122.5	1.87	0.163	6.48	0.4
Disang	78.5	3.0	18.5	6.32	290.0	1.0	0.50	6.84	0.36
Dikhow	96.5	2.0	1.5	6.64	210.0	2.0	0.326	7.12	0.44
Dhansiri	86.75	5.5	7.75	5.97	172.0	1.5	0.475	6.52	0.48
Kopili	90.5	6.0	3.5	6.73	76.5	1.37	0.223	6.04	0.28
Kalong	79.25	10.5	10.25	6.77	169.5	2.0	0.557	22.84	1.12
Bharalu	81.0	16.0	3.0	6.57	179.5	0.87	0.434	9.12	0.48
Kulsi	96.0	1.5	2.5	6.63	83.5	1.375	0.247	21.12	1.12
Singra	96.5	1.0	2.5	6.77	50.0	0.75	0.169	17.42	1.12
Dudhnoi	94.75	3.25	2.0	6.65	59.0	1.0	0.277	9.84	0.48
Krisnoi	98.5	0.5	1.0	6.97	78.0	1.75	0.188	9.84	0.52

Table 6 : Water quality of North Bank Tributaries of River Brahmaputra

Tributaries	Water temp. (° c)	Transp (cm)	DO (mgl^{-1})	pH	Free CO_2 (mgl^{-1})	Tot. alk. (mgl^{-1})	Sp. Cond. (μmhos)	Tot. Diss. solid (mgl^{-1})	Calcium Ca++ (mgl^{-1})	Mg (mgl^{-1})	Tot. Hardness (mgl^{-1})	Chloride (mgl^{-1})	Silicate (mgl^{-1})	Diss. Organic matter (mgl^{-1})	Nitrate (mgl^{-1})	Phosphate (mgl^{-1})
Depi	17.0	Upto bottom	9.38	7.6	1.92	75.2	194.2	97.6	11.52	9.37	67.2	19.6	4.6	1.428	0.02	0.014
Dekari	17.3	-do-	8.83	7.6	1.92	69.56	175.0	88.0	11.52	9.37	67.2	24.5	4.2	1.428	0.02	0.060
Simen	17.0	-do-	9.94	7.6	1.92	84.6	190.2	96.2	15.36	9.37	76.8	24.5	3.0	1.020	0.01	0.004
Gai	20.0	-do-	8.28	7.6	0.96	103.6	272.0	136.0	28.8	7.03	100.8	24.5	4.0	1.088	0.02	0.008
Jiadahal	20.5	31.0	7.04	7.55	0.95	61.07	185.9	93.7	12.48	7.55	62.4	20.85	4.4	1.51	0.02	0.0045
Subansiri	14.2	86.4	8.49	7.55	0.96	48.8	123.3	61.9	11.6	8.49	60.7	21.2	4.3	1.704	0.025	0.004
Ranganoi	14.1	-do-	8.33	7.2	1.89	23.5	52.6	26.6	6.4	3.0	32.1	21.2	6.2	1.77	0.026	0.007
Dikrong	16.3	63.5	8.45	7.15	1.27	25.81	62.2	31.4	4.48	6.18	36.8	21.2	5.9	1.84	0.016	0.007
Buroi	20.0	-do-	7.56	7.08	3.2	36.88	82.3	44.6	6.91	7.24	47.36	21.2	5.1	1.704	0.016	0.0075
Burgang	19.5	-do-	8.09	7.2	2.22	39.65	84.73	42.8	8.32	7.28	49.6	22.9	5.2	1.55	0.023	0.005
Jiabharali	16.5	91.7	8.63	7.25	1.68	34.33	76.22	38.4	9.97	3.70	40.3	23.5	5.14	1.71	0.025	0.004
Gabharu	19.7	22.0	7.56	7.15	1.91	44.85	90.03	45.6	4.76	5.39	36.8	21.2	7.5	1.80	0.017	0.010
Belsiri	19.7	20.7	7.5	6.85	2.2	31.07	64.9	32.8	5.76	4.26	32.2	24.7	8.0	1.824	0.02	0.009
Pasnoi	21.3	-do-	7.56	6.9	1.91	32.32	68.4	34.7	7.04	3.09	33.4	24.6	7.7	2.08	0.018	0.013

Tributaries	Water temp. (° c)	Transp (cm)	DO (mgl^{-1})	pH	Free CO_2 (mgl^{-1})	Tot. alk. (mgl^{-1})	Sp. Cond. (μmhos)	Tot. Diss. solid (mgl^{-1})	Calcium Ca++ (mgl^{-1})	Mg (mgl^{-1})	Tot. Hardness (mgl^{-1})	Chloride (mgl^{-1})	Silicate (mgl^{-1})	Diss. Organic matter (mgl^{-1})	Nitrate (mgl^{-1})	Phosphate (mgl^{-1})
Jiadhansiri	19.0	17.4	7.58	7.2	1.60	44.27	106.1	53.8	10.25	5.22	47.5	26.2	7.13	1.97	0.015	0.010
Bhalukdoba	20.3	35.4	8.02	7.45	2.22	67.68	143.4	72.3	16.31	10.04	82.2	21.23	6.0	1.738	0.015	0.007
Puthimari	21.04	23.4	8.12	7.65	1.42	93.15	181.0	91.3	17.89	15.48	109.4	25.5	5.7	1.61	0.016	0.007
Pagladia	21.45	27.8	8.04	7.7	1.43	95.67	186.2	93.1	20.03	12.13	100.35	21.5	6.5	1.80	0.021	0.022
Beki	17.0	49.0	8.80	7.52	1.87	50.58	120.68	60.7	13.53	9.83	74.8	23.1	5.28	1.67	0.014	0.004
Manas	21.5	29.6	7.69	7.87	1.67	207.67	345.5	173.84	25.7	22.02	155.8	27.18	5.96	1.727	0.016	0.010
Aie	21.6	44.2	8.0	7.6	1.50	137.2	249.52	125.2	23.60	17.42	132.08	26.7	6.0	1.545	0.023	0.0046
Champamati	20.7	28.2	7.38	7.4	1.66	48.4	101.3	51.12	8.4	7.64	52.8	23.8	6.45	1.95	0.022	0.008
Gaurang	20.7	43.0	7.37	7.35	2.26	36.03	78.34	39.50	6.54	6.22	41.72	25.14	6.4	1.904	0.018	0.0034
Tipkai	21.7	35.1	7.14	7.2	2.06	46.54	91.32	46.12	7.10	7.04	47.16	21.56	6.52	2.112	0.02	0.021
Gadadhar	20.5	23.35	6.96	7.3	2.36	37.05	72.63	36.85	4.31	7.27	41.35	22.55	9.2	2.42	0.032	0.015

Table 7 : Water quality of South Bank Tributaries

Tributaries	Water temp. (° c)	Transp (cm)	DO (mgl^{-1})	pH	Free CO_2 (mgl^{-1})	Tot. alk. (mgl^{-1})	Sp. Cond. (μmhos)	Tot. Diss. solid (mgl^{-1})	Calcium Ca++ (mgl^{-1})	Mg (mgl^{-1})	Tot. Hardness (mgl^{-1})	Chloride (mgl^{-1})	Silicate (mgl^{-1})	Diss. Organic matter (mgl^{-1})	Nitrate (mgl^{-1})	Phosphate (mgl^{-1})
Digharu	14.0	Upto bottom	8.10	8.10	Nil	131.6	299.0	150.0	30.72	2.34	86.4	19.6	5.2	1.360	0.015	0.002
Kondil	16.0	Upto bottom	7.91	7.8	0.96	98.7	192.4	98.1	9.6	14.05	81.6	24.5	4.0	1.425	0.015	0.014
Tenga	15.0	Upto bottom	8.24	8,2	nil	58.24	166.7	85.0	17.28	10.37	86.4	24.5	8.0	0.98	0.012	0.002
Noadihing	19.7	33.0	7.58	7.5	1.27	43.5	117.9	59.6	8.32	7.03	52.8	22.86	4.5	1.611	0.03	0.003
Dibru	19.7	38.0	6.94	7.1	3.87	50.19	111.3	56.3	7.68	9.66	55.86	22.7	8.3	1.886	0.038	0.006
Burhidihing	22.3	38.3	8.59	7.9	nil	70.42	159.3	80.7	8.96	11.2	68.8	27.8	5.87	1.059	0.029	0.005
Disang	21.3	Upto bottom	6.73	7.23	2.22	53.62	153.9	77.4	8.32	9.27	59.2	26.13	6.5	1.93	0.066	0.005
Dikhow	21.3	Upto bottom	5.61	7.15	2.85	54.83	154.9	77.3	13.44	6.42	57.6	24.5	3.7	1.776	0.03	0.006
Dhansiri	21.7	32.0	7.44	7.45	2.13	67.08	158.3	79.7	10.08	8.67	61.2	23.3	6.2	1.97	0.020	0.011
Kopili	22.7	29.0	6.95	7.07	2.22	36.82	87.1	43.9	7.68	4.26	36.8	16.33	6.1	1.97	0.023	0.005
Kalong	18.5	29.0	7.3	7.3	2.36	45.1	88.9	44.5	7.68	6.64	46.8	25.72	4.95	1.822	0.046	0.025
Bharalu	16.5	Upto bottom	8.52	7.25	2.10	22.0	46.0	23.2	5.28	3.86	25.18	26.96	7.45	1.63	0.019	0.003
Kulsi	19.0	36.0	6.99	6.95	1.89	24.35	49.35	24.9	4.8	3.18	25.35	22.05	6.8	1.78	0.023	0.007

Tributaries	Water temp. (° c)	Transp (cm)	DO (mgl^{-1})	pH	Free CO_2 (mgl^{-1})	Tot. alk. (mgl^{-1})	Sp. Cond. (μmhos)	Tot. Diss. solid (mgl^{-1})	Calcium Ca++ (mgl^{-1})	Mg (mgl^{-1})	Tot. Hardness (mgl^{-1})	Chloride (mgl^{-1})	Silicate (mgl^{-1})	Diss. Organic matter (mgl^{-1})	Nitrate (mgl^{-1})	Phosphate (mgl^{-1})
Singra	19.5	28.0	7.37	7.05	2.36	28.76	52.2	26.1	4.8	4.04	28.8	24.5	7.15	1.97	0.019	0.013
Dudhnoi	19.9	27.5	7.92	7.2	1.66	28.6	55.4	28.0	5.28	4.92	33.5	23.3	6.05	1.608	0.023	0.006
Krishnoi	19.25	41.9	7.8	7.0	2.33	29.76	53.9	27.2	4.8	4.04	28.8	24.5	6.8	1.63	0.023	0.007

Table 8 : Sediment quality in different stretches of Brahmaputra

Stretches	Physical features				Chemical features				
	Sand (%)	Silt (%)	Clay (%)	pH	Sp.cond. (μmhos)	Free $CaCO_3$ (%)	Organic C (%)	Av. Phosphorus (mg/100 g)	Av. Nitrogen (mg/100 g)
Saidiya	98.0	0.75	1.25	7.76	130.6	1.87	0.105	0.53	10.04
Dibrugarh	92.75	6.25	1.0	7.52	207.0	1.37	0.170	0.55	10.81
Jorhat	87.75	10.25	2.0	7.63	170.5	1.0	0.453	1.84	21.64
Biswanathghat	83.75	9.75	6.5	7.43	249.5	2.12	0.339	1.49	17.32
Tezpur	98.5	0.5	1.0	7.42	107.0	1.45	0.123	1.90	21.44
Guwahati	92.0	5.0	3.0	7.33	164.5	1.25	0.567	1.18	13.44
Goalpara	97.75	1.0	1.25	7.67	130.0	1.25	0.172	1.20	15.34
Dhubri	98.0	0.75	1.25	7.38	95.0	1.62	0.143	1.62	19.7
Av. for the stretch	93.5	4.3	2.2	7.52	156.75	1.49	0.259	1.29	16.22

Table 9 : Water quality of River Brahmaputra in different stretches

Stretches	Water temp. (° c)	Transp (cm)	DO (mgl^{-1})	pH	Free CO_2 (mgl^{-1})	Tot. alk. (mgl^{-1})	Sp. Cond. (μmhos)	Tot. Diss. solid (mgl^{-1})	Calcium Ca++ (mgl^{-1})	Mg (mgl^{-1})	Tot. Hardness (mgl^{-1})	Chloride (mgl^{-1})	Silicate (mgl^{-1})	Diss. Organic matter (mgl^{-1})	Nitrate (mgl^{-1})	Phosphate (mgl^{-1})
Saidiya	17.8	87.2	7.32	7.5	2.22	68.02	149.0	75.3	13.61	12.36	78.0	19.6	6.0	1.59	0.022	0.016
Dibrugarh	18.7	43.5	7.00	7.63	1.58	57.51	137.1	69.5	14.72	6.96	65.6	19.6	4.7	1.41	0.038	0.005
Jorhat	18.0	36.9	7.92	7.62	1.14	71.0	155.3	78.5	19.95	5.61	72.8	29.4	4.84	1.682	0.018	0.004
Biswanathghat	18.0	43.0	8.45	7.63	1.27	64.6	156.7	79.0	15.44	8.48	73.6	19.6	5.3	1.84	0.03	0.004
Tezpur (below bridge)	19.4	35.4	7.72	7.53	1.73	56.9	134.6	67.3	12.48	10.17	64.8	22.3	4.8	1.743	0.022	0.004
Tezpur (forest ghat)	18.7	39.5	7.77	7.7	1.65	61.56	145.22	74.7	13.44	8.97	70.82	19.6	4.9	1.752	0.025	0.003
Guwahati	19.2	38.0	7.73	7.5	1.52	71.2	150.78	76.1	17.66	8.57	79.68	22.54	5.24	1.39	0.036	0.0072
Goalpara	19.6	43.2	8.12	7.9	1.20	76.23	174.6	88.06	18.05	9.40	84.34	27.3	5.7	1.54	0.024	0.005
Dhubri	21.2	40.1	7.7	7.7	0.93	60.75	136.0	68.5	12.67	6.72	60.24	26.46	5.8	1.494	0.019	0.0052

Table 10 : Impact of tributaries on water quality of river Brahmaputra

	Stretches	Water temp. (° c)	pH	DO (mgl^{-1})	Free CO_2 (mgl^{-1})	Carbo-nate (mgl^{-1})	Bicarbo-nate (mgl^{-1})	Sp. Cond. (μmhos)	Tot. Diss. solid (mgl^{-1})	Calcium Ca++ (mgl^{-1})	Mg (mgl^{-1})	Tot. Hard-ness (mgl^{-1})
Impact of Jia Bharali on Brahmaputra at Tezpur	Brahmaputra	18.0	7.6	8.2	1.89	nil	70.44	160.4	80.8	18.62	11.52	88.4
	Jiabharali	14.0	7.1	8.02	1.89	nil	38.29	82.4	41.5	11.52	5.76	52.8
	At confluence (OF)	15.0	7.2	8.12	1.89	nil	40.4	84.8	42.4	12.82	5.6	58.8
	Below confluence (BOF-I)	16.0	7.4	8.08	1.89	nil	52.12	98.4	49.8	14.12	7.26	60.4
	Below confluence (BOF-II)	18.0	7.5	8.12	1.89	nil	64.61	147.2	74.4	15.36	10.8	80.8
Impact of Manas on Brahmaputra at Goalpara	Brahmaputra	18.0	7.8	9.8	1.89	nil	76.44	176.3	88.0	24.96	11.52	110.4
	Manas	21.0	8.1	7.6	Nil	1.85	218.7	381.0	192.0	33.04	20.80	177.6
	At confluence (OF)	20.0	8.1	7.4	nil	0.95	172.90	338.0	171.0	32.56	20.34	172.0
	Below confluence (BOF-I)	19.2	8.0	8.0	0.95	nil	122.80	282.0	144.0	26.12	14.28	136.8
	Below confluence (BOF-II)	18.0	7.8	8.6	0.95	nil	101.92	207.0	104.0	26.25	12.67	114.6

water quality of Brahmaputra in the stretch at Tezpur reflect more of the tributary than its own. Similarly at Goalpara (Jogghopa) the highly alkaline Manas water results in sharp increase in the values of alkalinity, conductance, dissolved solids, calcium and hardness at the confluence point and the impact has been seen much below the confluence. In fact vast sheet of Brahmaputra water at Goalpara reflects characteristics of Manas river than its own. A sudden decline in the values of above chemical parameters at Dhubri from comparatively much higher values at Goalpara again reflects the influence of low alkaline waters of Gaurang, Tipkai and Gadadhar which join Brahmaputra between Goalpara and Dhubri. Even some of the south bank tributaries have considerable impact on the water quality of main river although with lesser magnitude. It can thus be concluded that in maintenance of annual water quality cycle of river Brahmaputra tributaries play key role.

Biotic variables

(i) Plankton

The numerical abundance of plankton and percentage composition of different groups in Siang, Dibang and Lohit, the three forerunners of Brahmaputra and 8 different stretches of the river have been presented in Table 11. In the three rivers the abundance of plankton is generally poor ranging from 22 to 51 ul^{-1}, the higher concentration being in Lohit. The qualitative picture has shown complete dominance of phytoplankton, the main representation being of Bacillariophyceae (80 to 90%) and Chlorophyceae (10 to 20%) with complete absence of Myxophyceae. Hormidium and Mougeotia among chlorophyceae and Navicula and Tabelaria among Bacillariophyceae were the main species encountered in these rivers.

In the main river Brahmaputra the plankton density and qualitative composition have shown consideable zonal variations with maximum concentration in Saidiya (300 ul^{-1}) and minimum in Biswanathghat (48 ul^{-1}). Zooplankton represent only negligible fraction of the total population (0 to 5.4%) being almost absent in many stretches. Among the various groups of phytoplankton Bacillariophyceae has shown dominance over others (43.5 to 95.8%) followed by Chlorophyceae (3.9 to 50.9%) and Myxophyceae (0 to 23%) the last one showing appearance only in Saidiya, Dibrugarh and Biswanathghat. Higher concentration of plankton and presence of group Myxophyceae at Saidiya (the meeting point of three components) and large expansion of water mass reflect some what stagnant conditions of the river in this stretch. Considerable qualitative shift has been observed between Saidiya to Dibrugarh with group Chlorophyceae increasing upto 37.1% resulting in consideable decline inDiatom population. The stretch between Jorhat and Tezpur is again completely dominated by diatoms (88.5 to 95.8%).

The downstretch between Guwahati to Dhubri however, has shown shift towards Chlorophyceae (38.2 to 50.9%). The qualitative shift in the planktonic structure in various stretches have shown direct reflection of the changes in the water quality of theriver. In general the population has shown a declining trend between Saidiya to Biswanathghat and improvement between Tezpur to Dhubri. The group Myxophyceae was mainly represented by a single species Oscillatoria while chlorophyceae was represented by Spirogyra, Hydrodictiyon, Zygnema, Microspora and Oedogonium and Bacillariophyceae by Fragilaria, Navicula, Tabellaria and Cyclotella.

Tributaries

The numerical abundance and qualitative composition of plankton in 25 north bank tributaries are shown in Table 12. Among the various tributaries maximum concentration of plankton is observed in Burgang (753 u^{-1}) and minimum in Dekari (48 ul^{-1}). The qualitative picture has shown considerable variations between the tributaries. Some of them like Subansiri, Manas, Aie, Burgang, Gainadi and pagladia had comparatively higher percentage of Chlorophyceae (25.4 to 78.2%) while Ranganoi, Belsiri, Pasnoi and Beki had only representation of Bacillariophyceae (100%). In geneal Bacillariophyceae was the dominant component among phytoplankton followed by Chlorophyceae while Myxophyceae was present only in Depi and Simen. It may be mentioned that the tributaries differ considerably in respect of their water quality and qualitative variations in the planktonic composition may be the reflections of the same. Zooplankton had negligible contribution in the total plankton population.

The plankton abundance and qualitative composition in the south bank tributaries hasbeen shown in Table 13. Among the 13 tributaries maximum population is observed in Dibru (370 ul^{-1}) while minimum in Singra 20 ul^{-1}). Except Dibru and Burhidihing, which have shown zooplankton representation upto 6.2 to 7.4%, phytoplankton remained the dominant component. The qualitative picture showed considerable variations. The tributaries Burhidihing, Disang, Singra and Krishnoi showing comparatively higher precentage of Chlorophyceae (25 to 66.2%), Dhansiri having higher concentration of Myxophyceae (32.1%) while others showing complete dominance of Bacillariophyceae (Table 13). Like north bank tributaries the south bank tributaries have also shown consideable variations in water quality and the qualitative shift in the plankton populations may be attributed to the hydrological differences.

Various species encounteredc in the tributaries on both the banks are Oscillatoria (a single species) among Myxophyceae Spirogyra, Microspora among Chlorophyceae and Fragillaria, Synedra and Surirella among diatoms.

(ii) Benthos

Qualitative and quantitative abundance of benthos in the three forerunners, 8 stretches and tributaries on both the banks has been presented in Table 14. In the three rivers Siang, Dibang and Lohit the numerical abundance of benthos ranged between 162 to 290 nos m^{-2} mainly represented by chironomids (68 to 78%) and insect (22 to 32%). The rich abundance of chironomids in these rivers clearly reflect rich detritus load in the system. As the rivers are flowing through dense forest falling of plant leaves contribute richness of the detritus pool. However, the same was not reflected in organic carbon content of the sediment of Dibang and Lohit. It may be mentioned that the sediment contained 98 to 99% of sand and although the sediment was being constantly loaded by organic detritus the same was not retained due to very high sand content. However, the benthic organisms do get enough organic detritus for their growth.

In the river Brahmaputra considerable qualitative variations have been observed in the stretches between Saidiya to Dhubri, the population being maximum in Dibrugarh (365 nos m^{-2}) and minimum at Biswanathghat (32 nos m^{-2}). The down stretch of the river between Guwahati and Dhubri represented higher population of Gastropods (46.4 to 65.9%), in upper stretch Saidiya and Dibrugarh both Gastropods and bivalves were main benthos (32.8% and 58.4% and 47.3% and 44.9% respectively) while chironomids dominate over others in Biswanathghat (75.0%) and and Tezpur (71.7%). the stretch at Jorhat represent maximum concentration of oligochaetes (57.2%) followed by Gastropods (39.4%).

The north bank tributaries also differ considerably in respect of numerical abundance of benthic communities, the population being maximum in Jiabharali (1412 nos m^{-2}) and minimum in Jiadahal (37 nos m^{-2}). The qualitative picture shows the dominance of molluscan population in Dekari (71.2%), Ranganoi (68.2%), Dikrong (72%), Belsiri (95.1%), Bhalukdoba (64.2%), Beki (59.4%), Manas (81.7%) and Aie (100%). Oligochaetes are higher in Simen (72.8%), Buroi (49%) and Burgang (48%) while Jiadahal (90.8%), Subansiri (60.0%), Jiabharali (58.6%), Pasnoi (66.7%), Jiadhansiri (47%), Pagladia (75%) and Tipkai (49.7%) are comparatively rich in chironomids. Insects are comparatively higher in Champamati (69.1%) and Gadadhar (89.6%). High concentration of benthos in Jiabharali and Subansiri are mainly due to rich population of chironomids.

Table 11 : Qualitative and quantitative abundance of plankton in River Brahmaputra

Components of Brahmaputra	Rivers/ stretch	Total plankton (ul^{-1})	Phytoplankton				Others	Zooplankton				
			Total abundance (ul^{-1})	% composition				Total abundance (ul^{-1})	% composition			
				Myxophyceae	Chlorophyceae	Bacillariophyceae			Rotifers	Copepods	Cladocerans	Protozoans
	Siang	22	22	-	20.0	80.2	-	-	-	-	-	-
	Dibang	34	34	-	15.8	84.2	-	-	-	-	-	-
	Lohit	51	51	-	10.0	90.0	-	-	-	-	-	-
	Saidiya	300	297	23.1	17.0	58.9	-	3	1.0	-	-	-
	Dibrugarh	72	68	13.9	37.1	43.5	-	4	2.3	3.2	-	-
	Jorhat	80	80	-	9.9	90.1	-	-	-	-	-	-
	Biswanathghat	48	48	4.0	7.5	88.5	-	-	-	-	-	-
Stretches of Brahmaputra	Tezpur	84	84	0.3	3.9	95.8	-	-	-	-	-	-
	Guwahati	100	97	-	50.9	46.1	-	3	1.9	-	-	-
	Goalpara	91	86	-	38.2	56.3	-	5	3.2	1.2	1.1	-
	Dhubri	105	101	-	45.2	44.7	6.3	4	1.6	1.2	1.0	-

Table 12 : Qualitative and quantitative abundance of plankton in North bank tributaries

Tributaries	Total plankton (ul^{-1})	Phytoplankton				Others	Zooplankton				
		Total abundance (ul^{-1})	% composition				Total abundance (ul^{-1})	% composition			
			Myxophyceae	Chlorophyceae	Bacillariophyceae			Rotifers	Copepods	Cladocerans	Protozoans
Depi	54	50	5.8	22.4	64.4	-	4	4.4	1.0	2.0	-
Dekari	48	48	-	24.2	75.8	-	-	-	-	-	-
Simen	75	68	7.6	19.8	63.3	-	7	-	3.9	5.4	-
Gainadi	115	106	-	26.7	65.5	-	9	1.0	2.0	4.8	-
Jiadahal	32	32	-	21.8	78.2	-	-	-	-	-	-
Subansiri	65	61	-	78.2	15.7	-	4	4.0	2.1	-	-
Ranganoi	34	34	-	-	100.0	-	-	-	-	-	-
Dikrong	109	106	-	18.0	79.2	-	3	2.8	-	-	-
Buroi	184	180	-	20.1	77.7	-	4	2.2	-	-	-
Burgang	753	733	-	34.7	62.6	-	20	-	2.7	-	-
Jiabharali	140	140	-	4.3	95.7	-	-	-	-	-	-
Gabharu	114	114	-	10.2	89.8	-	-	-	-	-	-
Belsiri	50	50	-	-	100.0	-	-	-	-	-	-
Pasnoi	45	45	-	-	100.0	-	-	-	-	-	-
Jiadhansiri	115	109	-	5.0	89.8	-	6	-	2.0	3.2	-
Bhalukdoba	108	102	-	22.4	72.1	-	6	3.3	-	2.2	-
Puthimari	213	213	-	10.8	89.2	-	-	-	-	-	-

Tributaries	Total plankton (ul^{-1})	Phytoplankton				Others	Zooplankton				
		Total abundance (ul^{-1})	% composition				Total abundance (ul^{-1})	% composition			
			Myxophyceae	Chlorophyceae	Bacillariophyceae			Rotifers	Copepods	Cladocerans	Protozoans
Manas	177	166	-	41.8	52.0	-	11	-	4.2	-	-
Aie	182	182	-	35.4	61.3	3.3	-	2.0-	-	-	-
Champamati	232	220	-	18.2	76.7	-	12	1.9	-	3.2	-
Gaurang	530	530	-	15.3	84.7	-	-	-	-	-	-
Tipkai	124	118	-	3.6	91.6	-	6	3.8	1.0	-	-
Gadadhar	73	73	-	10.96	89.03	-	-	-	-	-	-

Table 13 : Qualitative and quantitative abundance of plankton in South bank tributaries

Tributaries	Total plankton (ul^{-1})	Phytoplankton				Others	Zooplankton				
		Total abundance (ul^{-1})	% composition				Total abundance (ul^{-1})	% composition			
			Myxophyceae	Chlorophyceae	Bacillariophyceae			Rotifers	Copepods	Cladocerans	Protozoans
Noadihing	55	55	-	12.5	87.5	-	-	-	-	-	-
Dibru	370	347	7.1	16.7	70.0	-	23	1.4	3.0	1.8	-
Burhidihing	148	137	2.4	43.5	46.7	-	11	3.2	-	4.2	-
Disang	98	98	-	30.8	69.2	-	-	-	-	-	-
Dikhow	100	100	-	10.4	89.6	-	-	-	-	-	-
Dhansiri	144	141	32.1	6.9	59.0	-	3	2.0	-	-	-
Kopili	93	93	-	4.0	96.0	-	-	-	-	-	-
Kalong	65	65	-	5.5	94.5	-	-	-	-	-	-
Bharalu	33	33	2.6	11.9	85.5		-	-	-	-	-
Kulsi	49	49	1.7	10.0	88.3	-	-	-	-	-	-
Singra	20	20	-	25.0	75.0	-	-	-	-	-	-
Dudhnoi	35	35	0.4	3.6	96.0	-	-	-	-	-	-
Krishnoi	51	51	-	66.2	38.8	-	-	-	-	-	-

Table 14 : Qualitative and quantitative abundance of benthic communities

Rivers/ Stretches/ Tributaries	Total abundance (nos.m^{-2})	Percentage composition					
		Molluscs					
		Gastropods	*Bivalves*	*Oligochaetes*	*Chironomids*	*Insect*	*Others*
Component of Brahmaputra							
Siang	290	-	-	-	78.0	22.0	-
Dibang	162	-	-	-	68.0	32.0	-
Lohit	223	-	-	-	73.0	27.0	-
Stretches of Brahmaputra							
Saidia	159	32.8	58.4	-	-	8.8	-
Dibrugarh	365	47.3	44.9	7.8	-	-	-
Jorhat	79	39.4	3.4	57.2	-	-	-
Biswanath-ghat	32	-	-	25.0	75.0	-	-
Tezpur	76	12.3	16.0	-	71.7	-	-
Guwahati	254	46.5	-	18.3	35.2	-	-
Goalpra	177	46.4	-	12.7	35.2	-	-
Dhubri	157	65.9	-	25.8	-	8.3	-
North bank tributaries							
Depi	32	-	-	100.0	-	-	-
Dekari	222	71.3	14.4	-	14.4	-	-
Simen	127	-	-	72.8	17.2	-	-
Gainadi	82	28.2	-	38.8	-	33.0	-
Jiadahal	37	9.2	-	-	90.8	-	-
Subansiri	590	11.2	-	30.8	60.0	-	-
Ranganoi	182	68.2	20.2	11.6	-	-	-
Dikrong	174	72.0	10.8	-	17.2	-	-
Buroi	48	20.6	-	49.0	30.4	-	-
Burgang	342	32.4	-	48.0	-	19.6	-
Jiabharali	1412	-	-	20.7	58.6	20.7	-
Gabharu	184	42.8	-	20.4	36.8	-	-
North Bank Tributaries							
Belsiri	115	95.1	-	-	-	4.9	-
Pasnoi	96	33.3	-	-	66.7	-	-
Jiadhansiri	172	42.8	10.2	-	47.0	-	-
Bhalukdoba	287	64.2	18.4	17.4	-	-	-
Puthimari	155	3.7	33.3	33.3	29.7	-	-
Pagladia	54	-	-	-	75.0	25.0	-
Beki	50	59.4	-	-	40.6	-	-
Manas	365	81.7	-	-	-	19.3	-
Aie	141	100.0	-	-	-	-	-

Rivers/ Stretches/ Tributaries	Total abundance (nos.m^{-2})	Percentage composition					
		Molluscs					
		Gastropods	*Bivalves*	*Oligochaetes*	*Chironomids*	*Insect*	*Others*
Champamati	54.0	30.9	-	-	-	69.1	-
Gaurang	151	100.0	-	-	-	-	-
Tipkai	926	17.0	-	33.5	49.7	-	-
Gadadhar	108	10.4	-	-	-	89.6	-
Noadihing	32	-	-	-	100.0	-	-
Dibru	108	10.4	-	-	-	60.9	-
South bank tributaries							
Burhidihing		706	-	9.5	-	-	90.5
Disang	175	39.1	-	-	-	-	-
Dikhow	274	70.0	-	-	30.0	50.0	-
Dhansiri	45	33.3	-	66.7	-	-	-
Kopili	110	8.4	33.4	8.2	-	39.2	-
Kalong	98	61.1	38.9	-	-	-	-
Bharalu	364	60.8	-	-	-	-	-
Kulsi	160	49.8	50.2	-	-	-	-
Singra	128	49.8	50.2	-	-	-	-
Dudhnoi	86	97.4	-	2.6	-		-
Krishnoi	95.0	94.1	5.9	-	-		-

The benthic population in south bank tributaries is maximum in Burhidihing (706 nos m^{-2}) and minimum in Noadihing (32 nos m^{-2}). The qualitatuive picture has shown dominance of Gastropods in Dikhow (70%), Kalong (61.1%), Bharalu (60.8%), Singra (100%), Dudhnoi (97.4%) and Krishnoi (94.1%), both Gastropods and bivalves in Kulsi, while oligochaetes are dominant in Dhansiri (66.7%). Chironomids dominate in Noadihing and insects in Dibru (89.6%), Burhidihing (90.5%), Disang (60.9%) and Kopili (50%).

The qualitative difference in the benthic communities in various tributaries and different stretches of the main river clearly reflect differences in their bottom deposites.

Energy transformation through primary production and production potential

The range and average rate of carbon production energy transformation by producers, photosynthetic efficiencies and fish production potential in three forerunners of Brahmaputra, Siang, Dibang and Lohit. 8 different stretches of Brahmaputra between Saidiya and Dhubri and some important tributaries are presented in Table 15.

(i) Siang, Dibang and Lohit

The net carbon production (mg Cm^{-2} day^{-1}) and rate of energy transformation from light to chemical (Cal m^{-2} day^{-1}) are on average 148.67 and 1460 in Siang, 174.37 and 1712 in Dibang and 197.5 and 1939 in Lohit respectively. The rates are comparatively higher in Lohit among the three rivers. The incident light energy penetrating the water surface range between 17,85,000 Cal m^{-2} day^{-1} in Siang and 17,98,000 Cal m^{-2} day^{-1} in Lohit and thus only 0.082% of solar energy available on the water surface is transformed into chemical energy and stored by producers in Siang, 0.096% in Dibang and 0.108% in Lohit rivers. Based on the rate of energy transformation and taking 0.5% of net energy fixed by produces as energy at fish level the production potential of Siang, Dibang and Lohit rivers have been estimated as 50.5 kg ha^{-1} yr^{-1}, 59.3 kg ha^{-1} yr^{-1} and 67.3 kg ha^{-1} yr^{-1} respectively **(Fig. 2).**

(ii) Brahmaputra

The rate of carbon production (mg cm^{-1} day^{-1}) and energy transformation by producers (Cal m^{-2} day^{-1}) in 8 different stretches of Brahmaputra are on average 227.32 & 2232 in Saidiya; 271.37 & 2665 in Dibrugarh, 233.2 & 2290 in Jorhat, 212.56 & 2087 in Biswanathghat, 213.80 & 2099 in Tezpur, 323.0 & 3172 in Guwahati, 331.73 & 3258 in Goalpara and 359.32 & 3528 in Dhubri. The production rates show a gradual increasing

trend in the down stretch from Biswanathghat (where it is minimum) to Dhubri. Incident light energy penetrating the water surface is in the range of 18,05,000 cal m^{-2} day^{-1} in Saidiya to 18,54,200 cal m^{-2} day^{-1} in Dhubri and thus 0.113 to 0.190% of solar energy is transformed to chemical energy and stored by producers in the entire stretch. Between Saidiya to Dhubri the average rate of energy transformation comes to 2666 cal m^{-2} day^{-1} while average rate of solar energy available on the water surface is 18,36,825 cal m^{-2} day^{-1}. Thus on average 0.145% of available light energy is fixed by producers in the entire stretch of Brahmaputra. Although the rate of energy fixation and photosynthetic efficiency in Brahmaputra appears to be comparatively lower than many stagnent and flowing waters but considering the highly fluavitile conditions of the system a net production efficiency of 0.145% is sufficient to sustain the whole trophic chaing of the system. Based on the energy flow studies the fish production potential of the river ranged between 72.3 to 122.2 kg ha^{-1} yr^{-1} being maximum in Dhubri and minimum in Biswanath ghat. The average potential of the entire stretch of the river comes to 92.32 kg ha^{-1} yr^{-1} **(Fig. 2).**

(iii) Tributaries

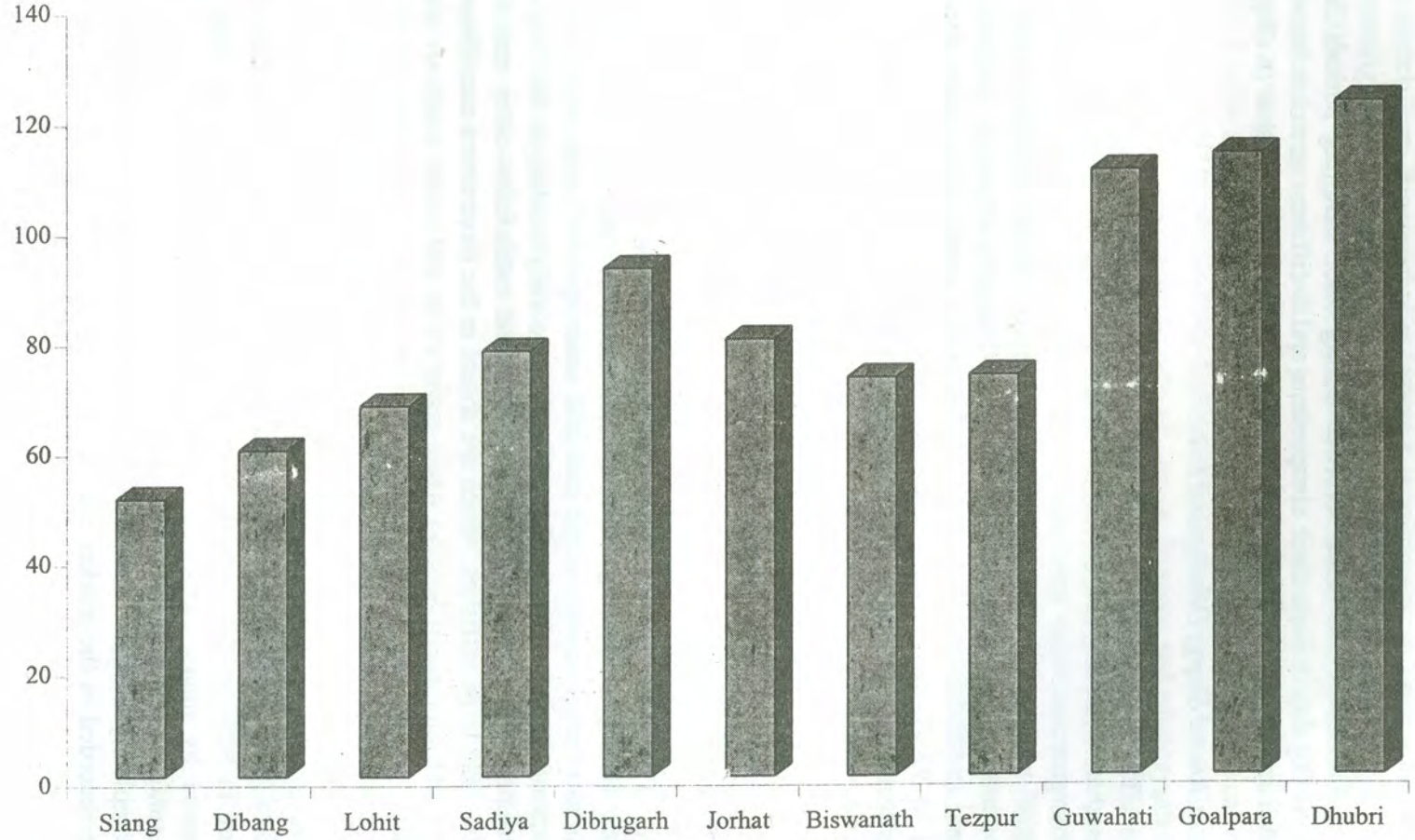
The rate of carbon production ($mgCm^{-2}day^{-1}$) and rate of energy transformation (cal $m^{-2}day^{-1}$) has also been studied in some of the important tributaries. The average rates are 193.5 & 1900 in Subansiri, 178.4 & 1752 in Jiabharali, 314.4 & 3087 in Manas, 392.1 & 3850 in Burhidihing and 197.6 & 1940 in Kalong. The photosynthetic efficiency is maximum in Burhidihing (0.212%) and minimum in Kalong (0.105%). The fish production potential of these tributaries estimated from energy flow studies are 65.79 kg ha^{-1} in Subansiri, 60.66 kg ha^{-1} in Jiabharali, 106.9 kg ha^{-1} in Manas, 133.21 kg ha^{-1} in Burhidihing and 67.18 kg ha^{-1} in Kalong. Studies made in the above tributaries clearly show that they have tremendous fisheries potential, some of them even have potential more than the main river.

If the production potential of the tributaries and the main river are taken together the system has very high potential energy resource as fish. The average fish production potential for the three forerunners main Brahmaputra and five studied tributaries were estimated at 59, 92.3 and 86.8 kg ha^{-1} yr^{-1} respectively. Thus if managed and exploited scientifically, it will be a real boon for both Assam and Arunachal Pradesh so far as fish production is concerned.

Table 15 : Energy transformation through primary production in Brahmaputra and some of its tributaries

Rivers/stretches	Latitude	Incident visible solar radiation (Cal m^{-2} day^{-1})	Net production		Photosynthetic efficiency (%)	Fish production potential (kg ha^{-1} yr^{-1})
			(MgC m^{-2} day^{-1})	(Cal m^{-2} day^{-1})		
Stretches of Brahmaputra component of Brahmaputra						
Siang	28°42'	17,85,000	148.67	1460	0.082	50.5
Dibang	28°30'	17,90,000	174.37	1712	0.096	59.3
Lohit	28°12'	17,98,000	197.5	1939	0.108	67.3
Saidiya	27°56'	18,05,000	227.32	2232	0.124	77.3
Dibrugarh	27°32'	18,18,000	271.37	2665	0.147	92.2
Jorhat	26°50'	18,52,500	233.20	2290	0.125	79.3
Biswanathghat	26°40'	18,40,800	212.56	2087	0.113	72.3
Tezpur	26°34'	18,40,800	213.80	2099	0.114	72.7
Guwahati	26°14'	18,49,100	323.0	3172	0.172	109.8
Goalpara	26°5'	18,54,200	331.73	3258	0.176	112.8
Dhubri	26°0'	18,54,200	359.32	3528	0.190	122.2
Av. Brahmaputra stretch	-	-	271.54	2666	0.145	92.32
Tributaries						
Subansiri	27°40'	18,10,00	193.5	1900	0.105	65.79
Jiabharali	27°34'	18,40,000	178.4	1752	0.095	60.66
Manas	27°5'	18,54,200	314.4	3087	0.166	106.90
Burhidihing	27°32'	18,18,000	392.1	3850	0.212	133.31
Kalong	26°14'	18,49,100	197.6	1940	0.105	67.18

Production potential, River Brahmaputra ($kgha^{-1}yr^{-1}$)



Fish production

Estimated fish catch recorded during brief sampling periods in three different seasons (kg day^{-1}) from three components and 8 different stretches between Saidiya and Dhubri and their qualitative composition has been shown in Table 16 **(Fig. 3).**

(i) Rivers Siang, Dibang and Lohit

The average daily fish landing recorded from various landing centres *eg.* Pansighat, Yembung and Oiramghat in Siang, Roing and Shantipur market in Dibang and Alubarighat and some local markets in Lohit are 91.0 kg day^{-1}, 102.2 kg day^{-1} and 62.5 kg day^{-1} respectively. Fishery in the three rivers is almost similar mainly represented by *Tor putitora, Neolisocheilus hexagonolepis* among Mahseer, *Scizothorax richardsoni* among snowtrout and *L.dero* and *L.dyocheilus* among cold water species contributing 80.2 to 92.4% of the total landings. Miscellaneous and trace fishes also contribute significantly in the total catch (7.6 to 19.8%) while major carps, minor carps and catfishes are completely absent.

(ii) Stretches of Brahmaputra

(a) Saidiya

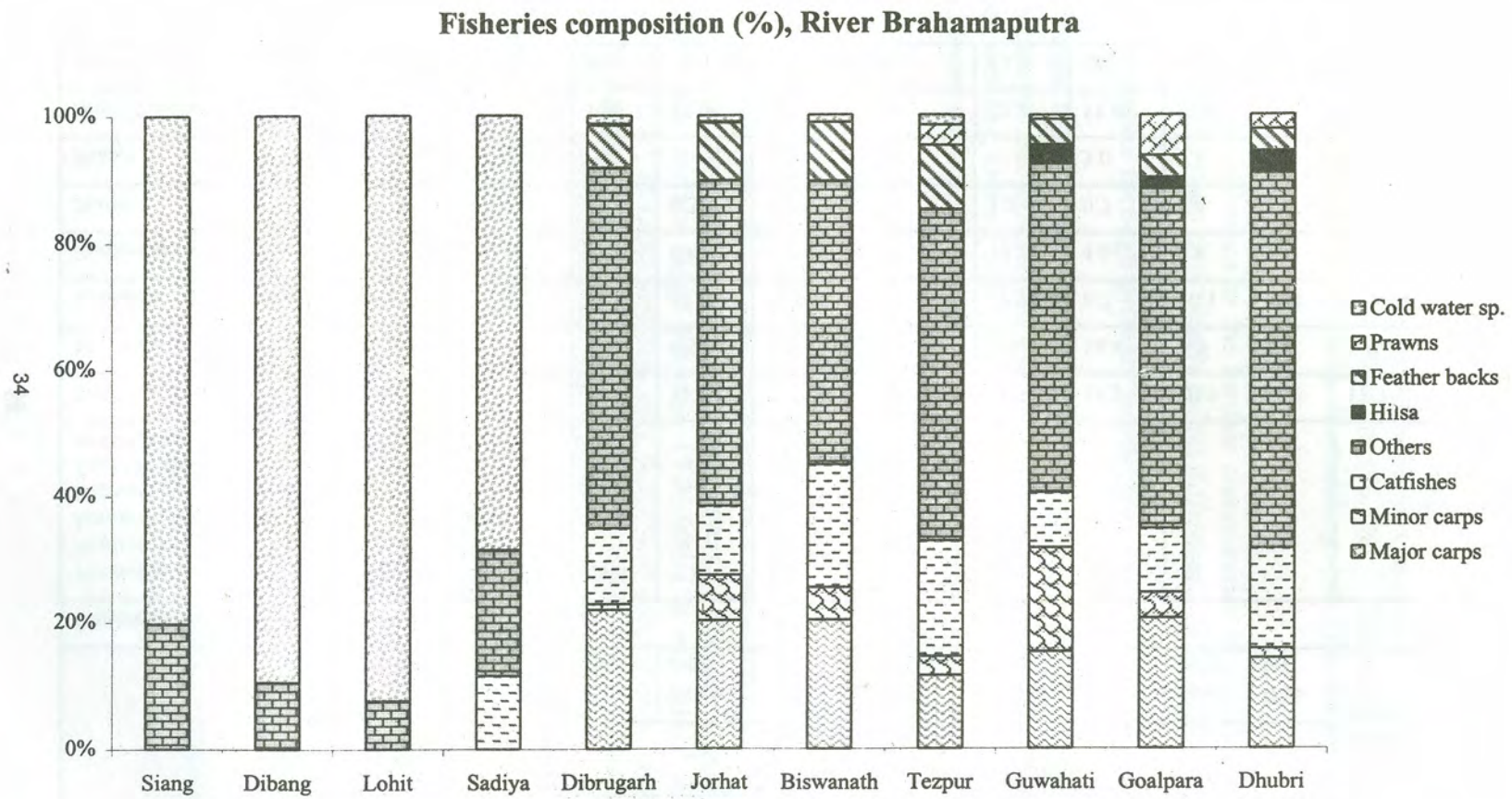
The fishery of river Brahmaputra at Saidiya, the meeting point of three rivers, Siang, Dibang and Lohit is also dominated by Mahseer species Tor putitora and Neiolissocheilus hexagonolepis and cold water species L.dero and L.dyocheilus the main fishery of the three rivers. Out of an average daily landing of 69.7 kg day-1 the above mentioned species contribute 68.6% of the total catch followed by miscellaneous species 19.8%. the large catfishes, which are absent in the three rivers contributed almost 11.6% of the total landing of Saidiya while major carps and minor carps are also absent in this stretch.

(b) Dibrugarh

The average daily fishlanding in Dibrugarh market recorded during sampling period is 90.0 kg day^{-1} mainly dominated by miscellaneous and trace fishes (57.0%), followed by major carps (21.9%) catfishes (12.0%) and feather backs (6.6%). the percentage contribution of minor carps (0.9%) and prawn (0.3%) are very low while hilsa is completely absent. The above mentioned mahseer and coldwater species have also been recorded in the market but their contribution is only 1.3% of the total catch. It is

Table 16 : Qualitative and quantitative shift in fisheires between the stretches

Groups	% composition of various groups in total landings											*Av. Brahmaputra stretch (Dibrugarh to Dhubri)*
	Components of Brahmaputra			Stretches of Brahmaputra								
	Siang	*Diba-ng*	*Lohit*	*Sai-diya*	*Dibru-garh*	*Jorhat*	*Biswa-nathghat*	*Tezpur*	*Guwa-hati*	*Goal-para*	*Dhu-bri*	
Coldwater species												
Tor putitora, Neolisochilus hexagonolopis, L.dero, L.dyocheilus, Scizothorax richardsoni	80.2	89.4	92.4	68.6	1.3	1.0	1.2	1.6	-	-	-	-
Major carps	-	-	-	-	21.9	20.2	20.3	11.5	15.2	20.5	14.2	17.7
Minor carps	-	-	-	-	0.9	7.2	5.1	3.0	16.4	4.0	1.5	5.4
Catfishes	-	-	-	11.6	12.0	10.9	19.4	18.2	8.7	10.1	15.8	13.6
Featherbacks	-	-	-	-	6.6	9.0	9.2	10.1	4.0	3.4	3.4	6.5
Prawn	-	-	-	-	0.3	0.2	-	3.2	0.7	6.4	2.3	1.9
Hilsa	-	-	-	-	-	-	-	-	3.0	1.8	3.4	1.2
Misc. & others	19.8	10.6	7.6	19.8	57.0	51.5	44.8	52.4	52.0	53.8	59.4	53.7
Total catch (kg day^{-1})	91.0	102.2	62.5	69.7	90.0	123.0	103.0	93.2	198.7	67.0	120.2	113.7


Fisheries composition (%), River Brahamaputra
100%
80%
60%
40%
20%
0%
Siang
Dibang
Lohit
Sadiya
Dibrugarh
Jorhat
Biswanath
Tezpur
Guwahati
Goalpara
Dhubri
Cold water sp.
Prawns
Feather backs
Hilsa
Others
Catfishes
Minor carps
Major carps

A view of river Brahmaputra

Miscellaneous fish species from river Brahmaputra

Captured mahseer from river Brahmaputra

surprising that the catch structure of Brahmaputra at Saidiya which is dominated by the species like *Tor putitotra, Neolisocheilus hexagonolepis* and *L.dero* has shown a complete qualitative shift in the stretch at Dibrugarh where these species disappeared and in the stretch at Dibrugarh where these species disappeared and replaced by normal fishery of major carps, minor carps, catfishes and feather backs. The fish landings at Dibrugarh market also include substantial contribution from river Burhidihing, one of the most productive tributary of south bank *L.rohita* is the dominant species among major carps in this stretch while the catfish is dominated by M.seenghala and W.attu.

(c) *Jorhat*

The average daily landing at Jorhat centre (including both Neematighat and market) is 123 kg day^{-1} mainly represented by miscellaneous species (51.5%) followed by major carps (20.2%) catfishes (10.9%), featherbacks (9.0%). a few mahseer species have also been recorded on some occasions but their contribution in the total catch is only 1%. *Catla catla* is the dominant major carp species in this stretch while catfish is dominated by *M.aor.*

(d) *Biswanathghat*

The fish landing from river at Biswanath-Chariali market is on average 103.7 kg day^{-1} represented mainly by miscellaneous species (44.8%) followed by major carps (20.3%), catfishes (19.4%), featherbacks (9.2%) and minor carps (5.1%). *C.catla* and *L.rohita* are the dominant major carps species while catfish is represented by *M.seenghala* and *M.aor.* a few species of cold water have also been recorded from the market (1.2% in the total catch) may be from the nearby tributary Jiabharali.

(e) *Tezpur*

The average daily fish landing from Brahmaputra at Tezpur is 93.2 kg day^{-1} mainly dominated by miscellaneous species (52.4%) followed by catfishes (18.2%), major carps (11.5%), featherbacks (10.1%). prawn (3.2%) and minor carps (3%), *M.aor* and *W.attu* are the dominant catfishes in this stretch while major carps is mainly represented by *L.calbasu* and *C.catla*. Some cold water and mahseer species have also been recorded in the market probably from R.Jiabharali but their contribution in the total catch is only 1.6%.

(f) Guwahati

The fish landing from Uzain Bazar landing centre at Guwahati is on average 198.7 kg day^{-1} mainly represented by miscellaneous sp. (52%) followed by minor carps (16.4%) major carps (15.2%), catfishes (8.7%), featherbacks (4%) and prawn (0.7%). hilsa which is completely absent between Saidiya upto Tezpur has shown its presence in this stretch of the river with a contribution of 3% in the total catch. The dominant species present in this centre are *L.rohita, C.catla, L.calbasu, C.reba* and *W.attu.*

(g) Goalpara

The average fish landing in the Goalpara market is 53.8 kg day^{-1} mainly comprised of miscellaneous species (53.8%) followed by major carps (20.5%) catfishes (10.1%) prawn (6.4%), minor carps (4%), featherbacks (3.4%) and hilsa (1.8%). *L.rohita* and *C.catla* are the dominant carps in this stretch while catfishes are represented by *M.aor* and *W.attu.*

(h) Dhubri

The average daily fish landings recorded in this landing centre, the lowest stretch of the river, is 120.2 kg day^{-1} which is mainly contributed by miscellaneous species (59.4%) followed by catfishes (15.8%), major carps (14.2%), featherbacks (3.4%), hilsa (3.4%), prawn (2.3%) and minor carps (1.5%), catfishes are mainly dominated by *M.aor* and *M.seenghala* while major carps by *L.rohita* and *C.catla.*

(i) Qualitative variations in the fisheries

It is apparent from the fish landing patterns at various landing centres that river Brahmaputra shows considerable interstretch variations both in respect of quality and quantity. The main river Siang and its other two components Dibang and Lohit throughout their stretch in Arunachal Pradesh are dominated by Mahseer *species Tor putitora* and *Neolisocheilus hexagonolepis* trout *Schizothorax richardsoni* and other cold water species *L.dero* and *L.dyocheilus* and the average catch of these species is around 57.7 to 91.4 kg day^{-1} from the three rivers. At the confluence point of the three rivers near Saidiya although the percentage contribution of these species has gone down to 68.6% they still represent the main fishery of the stretch. Miscellaneous species formed 19.8% of the catches while catfish which ar completely absent in the three rivers, have been recorded in this region with a contribution of 11.6% in the total catch. Below Saidiya in the stretch at Dibrugarh the above mentioned cold water and Mahseer species

have disappeared completely and they are replaced by major carps, catfishes, featherbacks and minor carps. The miscellaneous and trace fishes, which contributed 19.8% of the catches at Saidiya have increased to 57.0% at Dibrugarh. A few specimen of mahseer and coldwater fishes have been recorded between Dibrugarh to Tezpur but their contribution is almost negligible in the total catch (1.0 to 1.6%). although the qualitative picture of fishes is similar in the stretches between Dibrugarh down upto Dhubri, with an overall domination of miscellaneous species in the commercial catches, but the percentage contribution of various groups in different stretches have shown considerable variations. Even the contribution of miscellaneous and trace fishes, which are dominant through out the stretch, have shown consideable variation being minimum in Biswanathghat (44.8%) and maximum in Dhubri (59.4%). The contribution of major carps is almost similar at Dibrugarh, Jorhat, Biswanathghat and Goalpara (20.2 to 21.9%) but they have shown decline at Tezpur (11.5%), Guwahati (15.2%) and Dhubri (14.2%). Minor carps are dominant only in Guwahati (16.4%) while in other places their contribution is comparatively much lower. The percentage contribution of catfishes are maximum in the stretch betwee Biswanathghat and Tezpur (18.2 to 19.4%) while in other stretches they are in the range of 8.7 to 15.8% being minimum in Guwahati (8.7%). featherbacks are comparatively similar in Jorhat to Tezpur (9.0 to 10.1%) while in other places their contribution is much lower. Hilsa which is completely absent in the upper stretches between Saidiya to Tezpur has appeared in Guwahati and continued upto Dhubri, although the contribution in total catch is only 1.8 to 3.4%.

A part from qualitative variations between the stretches the fish yield has also shown considerable quantitative distribution being minimum in Goalpara and maximum in Guwahati (67.0 kg ha^{-1} and 198.7 kg day^{-1} respectively).

Fisheries of important tributaries of River Brahmaputra

Fishery in some of the major tributaries in the North bank like Jiabharali, Subansiri, Manas etc. have shown very interesting features. These tributaries are famous for mahseer angling and are good attraction for tourists. In fact 80 to 90% of the total catches from the upper stretches of these tributaries are represented by species *like Tor putitora, Neolisochilus hexagonolepis, L.dero* and *L.dyocheilus*. but interestingly the fish landing from the down stretches of the above tributaries towards their confluence with Brahmaputra have not shown any contribution by the above mentioned species and almost entire catch is mainly comprised of catfishes major carps, minor carps, miscellaneous species and prawn.

North bank tributaries

(i) Subansiri

One of the most important tributary of North bank R.Subansiri supports a rich fish fauna. The average fish landings from upper stretch of the river in Gogamukh, Dhemaji and N. Lakhimpur markets are 40 to 60 kg day^{-1}. Fishes are mainly represented by *Tor putitora, L.dero, L.dyocheilus* and *Barilius* sp. Peak fishing season is October to December extended even upto February. The fish landing from the down stretch at Jorhat centre is on average 50 to 200 kg day^{-1} mainly comprised of *L.calbasu, M.seenghala, W.attu, M.aor, P.sarana, L.gonius* and prawn. The fishes dominant in the upper stretch have not been recorded in the down stretch good amount of miscellaneous species like *Aspidoparia* sp., *Botia* sp. have also been recorded in the total catch.

(ii) Jiabharali

It is one of the most important cold water stream of the state known for its annual angling competition in the Balipara forest range. Important cold water fishes recorded are *Neolisochilus hexagonolepis, Tor putitora, Tor tor, L.dero, Barilius* sp. The average fish landing at Tezpur and Biswanath Chariali markets is 30 to 50 kg day^{-1}. The catch is maximum during winter when cold water fishes migrate down stream from Arunachal Pradesh (October-December). These fishes have not been encountered in the down stretch towards meeting point of R.Brahmaputra.

(iii) River Burgang

A tributary with swift current and sandy belt is a good source of coldwater fishes *Tor tor, L.dero* and *Barilius* sp. Other species encountered in the down stretch of the river towards meeting point are *W.attu, L.bata* and *Aspidoparia* sp. Peak fishing season is post monsoon and earlier winter (September-November).

(iv) Buroi

It is large and deeper than Burgang and supports rich fishery. Important species available in the commercial catches are *Labeo dero* (av.catch size 1-3 kg). *Tor tor, Tor putitora* and *Barilius* sp. A good quantity of catfishes *W.attu* and *M.seenghala* featherback *N.chitala* and miscellaneou sp. *Aspidoparia* are also caught fish yield is more during winter months (November-February) when cold water fishes migrate down stream.

(v) Dikrong and Ranganoi

These rivers are shallow with fast current and are characterised with low water temperature. They support poor fishery of cold water species. The fish catch is more during winter months.

(vi) Manas

The fishery of river Manas has been reported to be rich in the upper stretch having main representation of Mahseer species. Earlier records show that when angling was done in the upper stretches almost 100 kg of mahseer mainly *Tor putitora* and *Neolisochilus hexagonolepis* were caught. Although a few big specimen of Mahseer are often caught but the main fishery in the lower stretch are major carps, catfishes and miscellaneous species.

South bank tributaries

(i) Noadihing

It is the larger portion of Dihing river, shallow wide having fast current. October to December are the peak fishing seasons in the river and the main nets used are incircling dip nets etc. Important commercial species available in the total catch are cold water fishes *L.dyocheilus, L.dero, Tor tor, Barilius* sp. Other species encountered are *L.gonius, L.rohita, C.mrigala* and small catfish *M.cavasius* although the contribution of these species in the total catch is of less order.

(ii) Burhidihing

The river was once deep with large volume of water and fast current but after division into two parts old (Burhi) and new (Noa) a few years back the river has become comparatively shallower with lesser flow rate. It supports good fishery and large portion of the fish landing in Dibrugarh market is contributed by fishes from this river. The dominant species in the catches are *L.rohita* and *C.mrigala* among carps, *M.seenghala* and *W.attu* among catfishes, *N.chitala* among feather backs and some miscellaneous and trace fishes. October to December is the peak fishing months.

(iii) Dikhow (near Dikhowmukh)

The main fishery of the river are *W.attu, M.seenghala, B.bagarius, Rita rita* (the last two being available near the confluence point with Brahmaputra*), C.catla, L.rohita, C.mrigala* among carps, *L.bata* among minor carp, *N.chitala* among featherbacks and *Aspidoparia* sp., *A.mola* etc. among miscellaneous species. During peak fishing season upto 150 to 200 kg day^{-1} are caught using large encircling nets, small hand operated push nets, etc.

(iv) River Disang

This river is comparatively less productive than Dikhow. The fish landing from the river mainly comprised of small miscellaneous species *Puntius* and *Aspidoparia* sp. The major carps *L.rohita* and *C.mrigala* and catfishes *M.seenghala* and *M.aor* and featherback *N.chitala* are also caught but their contribution is not much in the total catches.

(v) River Kulsi

Fish production from this river is of low order peak fishing seasons are from October to December and nets in operation are largely castnets, chinese dipnets and small mesh size gill nets all in the marginal areas. The fishes caught are mainly minor carps and miscellaneous species *C.reba, Puntius ticto, Colisa faciatus, A.mola* etc.

(vi) Singra

It may be considered to be a tributary of R.Kulsi as the two rivers join few km downstretch from Singra Bazar. Nets in operation are similar to that of Kulsi and the fishes generally caught *are Puntius ticto, P.sophor, Channa punctatus, A.mola, Anabas testudineus, C.reba* etc. Biger fishes like *W.attu, Channa striatus* (snake head) are also caught during September to November when wate rlevel and flow receeds.

(vii) Dudhnoi

The river joins R.Krishnoi some 15 km down stretch from Dudhnoi market. The fish production from Dudhnoi is very poor mainly comprised of miscellaneous trace fishes.

(viii) Krishnoi

The river is comparatively rich in fisheries and the atch is mainly represented by *Puntius* sp. *Channa punctatus, W.attu, L.rohita* and some miscellaneous species.

Two types of fishery in some tributaries

Fisheries in some of the tributaries specially in the North bank *eg.* Subansiri Jiabharali, Manas, etc. have shown very interesting pattern, the upper stretch being represented by Mahseer species *Tor putitora* and *Neolisocheilus hexagonolepis* and cold water species *L.dero* and *L.dyocheilus* where as the down stretch towards the confluence of Brahmaputra is represented by major carps, minor carps, catfishes, prawn and miscellaneous species. The existence of two type of fishery in the same ecosystem clearly indicate the presence of some kind of natural barrier which is preventing one set of fishes in migrating from one stretch to other. There are probably two type of possibilities (i) the water tempeature of these tributaries are comparatively much lower in the upper stretches than the down stretch as well as the main river. The difference in the water temperature may be working as a thermal barrier and not allowing the cold water fishes to enter the higher temperature zone (ii) the water quality parameters of tributaries like alkalinity, conductance dissolved solids, hardness etc. are totally different from river Brahmaputra e.g. Jiabharali has comparatively much lower values of the above parameters than the main river similarly Manas has much higher values than Brahmaputra. The drastic difference in the water quality parameters in the two systems may be aeting as a density barrier in preventing one set of fishes to migrate and cross the natural barrier.

Brahmaputra "Past & Present"

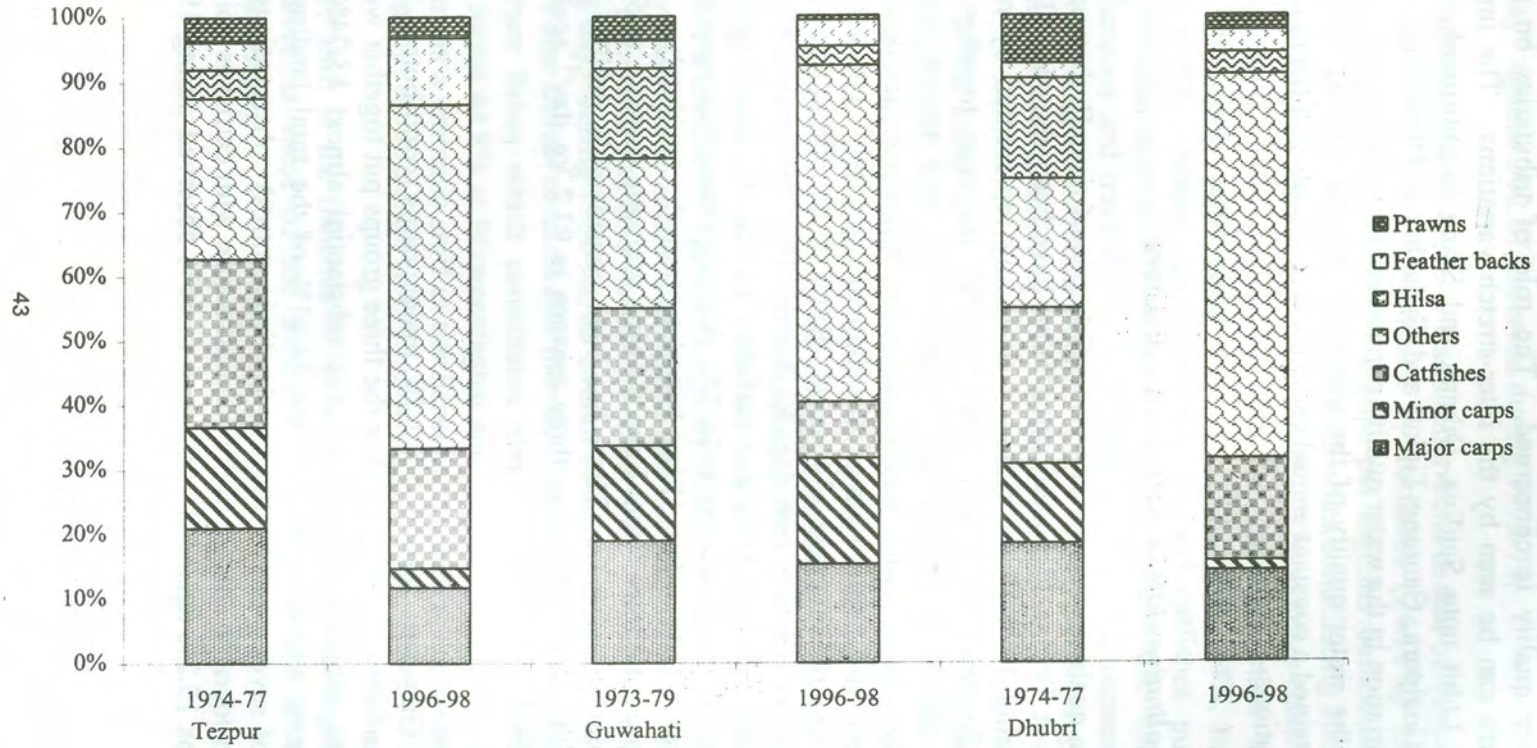
(i) Water quality

The water quality parameters in respect of pH, dissolved oxygen, total alkalinity, sp.conductance, dissolved solids, calcium, hardness and nutrients have not shown any significant variation over the years. However, a declining trend has been observed in respect of clarity of water over the years the water transparency which was as high as 150 cm during 1974-77 (Anon 1974 to 1979) has been reduced to 30-40 cm during 1997-98. The reduction in transparency is a clear example of increasing silt load in the system. It needs to be mentioned that tributaries play key role in maintaining the annual water quality cycle of the main river and increase in turbidity over the gears is obvious as huge quantity of silt is discharged into Brahmaputra by these tributaries year after year. No

Table 17 : Qualitative shift in the fisheries of river Brahmaputra over the years

Groups	Tezpur		Guwahati		Dhubri		Av. For the stretch (Tezpur-Dhubri)		Trends of variation
	1974-77	1996-98	1973-79	1996-98	1974-77	1996-98	1973-79	1996-98	
Major carps (%)	21.03	11.5	18.66	15.2	18.41	14.2	19.4	13.6	Decline by 30%
Minor carps (%)	15.65	3.0	14.56	16.4	12.23	1.5	14.1	7.0	Decline by 50%
Catfishes (%)	26.08	18.2	21.09	8.7	24.11	15.8	23.76	14.2	Decline by 40%
Featherbacks (%)	4.18	10.1	4.2	4.0	2.32	3.4	3.6	5.8	Increase by 61%
Hilsa (%)	4.42	0.0	13.74	3.0	15.51	3.4	11.2	2.1	Decline by 81%
Prawn (%)	3.86	3.2	3.74	0.7	7.4	2.3	5.0	2.1	Decline by 58%
Misc. & others	24.87	52.4	23.01	52.0	20.02	59.4	22.9	55.2	Increase by 141%
Av. Catch (kg day^{-1})	137.45	93.2	302.85	198.7	150.48	120.2	196.93	137.34	Decline by 30%

Fisheries (%) of river Brahmaputra



signifiant variation in wate quality parameters over the years clearly indicate that there has been practically no qualitative degradation in the tributaries or the river as a whole so far as water quality is concerned. The role of tributaries on the water quality of Brahmaputra can be seen by the inter-stretch variations. The impact of Digharu and Kondil on Lohit upto Saidiya, Dibang and Siang in Dibrugarh, Jiabharali in Tezpur, Manas in Goalpara, Gaurang Tipkai and Gadadhar in Dhubri are clear examples. The trend of variation in the water quality parameters in the above stretches are repeated every year. As the water quality of the tributaries joining various stretches of Brahmaputra have maintained a constant annual cycle the water quality of the main river has not shown much variations.

(ii) Qualitative shift in the fisheries structure

The qualitative variations in the fisheries of river Brahmaputra over the years in the stretch at Tezpur, Guwahati and Dhubri have been shown in Table 17 **(Fig. 4).** At Tezpur during 1974-77 the fishery was mainly represented by major carps (21.03%) catfishes (26.08%) and minor carps (15.65%), the three together contributing almost 62.7% of the total population. Featherbacks and prawn were 4.18 and 3.86% respectively. Hilsa, which was absent in the upper stretches contributed 4.42% of the total fishery. The contribution of miscellaneous species was only 24.87 of the total catch of 137.45 kg day^{-1} (average of 4 years). But with the passes of time the complexion has changed and after nearly two decades during 1996-98 the major carps have declined to 11.5%, minor carps to 3.0% and catfishes 18.2%, the three together contribution only 32.7% against 62.7% during 1974-77. Although there has been some improvement in featherback (10.01%) but Hilsa has disappeared completely. On the other hand miscellaneous and trace fishes have shown a dramatic increase to 52.4% against 24.78% observed during 1974-77. There has been considerable decline in the fish yield and average yield observed during three seasons is 93.2 kg day^{-1} against 137.45 kg day^{-1} during 1974-77.

In Guwahati during 1973-79 major carps contributed 18.66% minor carps 14.56%, catfishes 21.09% and thus the three groups put together were 54.3% of the total catch. The contribution of hilsa was substantial almost 13.74% of the catch while miscellaneous and trace fishes were 24.01% of the total landing of 302.85 kg day^{-1} (average of seven years in the two landing centres) observations during 1996-98 has shown considerable change in the catch structure with catfishes going down to 8.7% and major carps 15.2% against 18.66% and 14.56% observed during 1973-79. Hilsa fishery

which represented 13.74% has gone down to 3.0% but miscellaneous and trace fishes have shown a dramatic increase to 52.0% of the total catch. The total fish lanidng has also show considerable decline over the years and the averge landing recorded during 1996-98 is 198.7 kg day^{-1} against 302.87 observed during 1973-79.

The stretch Dhubri has shown more or less similar trend to that of Tezpur. During 1974-77 the catches at Dhubri were dominated by catfishes (24.11%) major carps (18.41%) and minor carps (12.23%), the three groups put together contributing almost 54.75% of the total catch. Hilsa fishery was also of high order contributing 15.51% while the contribution of miscellaneous species was only 20.02%. The average catch during the years was 150.48 kg day^{-1}. But during 1996-98 the catch structure has shown considerable change with minor carps going down to 1.5%, hilsa 3.4%, major carps 14.2% and catfishes 15.8%. major carps, minor carps and catfishes put together contributed 31.5% of the total against 54.75% observed two decades back. Like in other stretches the miscellaneous and trace fishes have shown a dramatic increase forming 59.4% of the total. The average yield in the stretch has also shown a declining trend over the years 150.48 during 1974-77 to 120.2 kg day^{-1} during 1996-98.

A comparison of the entire stretch between Tezpur and Dhubri has shown some interesting pattern. During 1973-79 the contribution of major carps, minor carps and catfishes in the total catch were 19.4%, 14.1% and 23.70% respectively, the three put together contributing 57.26%. The average yield of hilsa was 11.2% and miscellaneous species 22.9%. With passes of time their percentage contribution has shown drastic change, the major carps going down to 13.6% minor carps 7%, catfishes 14.2% and hilsa 2.1% on the contrary the miscellaneous and trace fishes have increased to 55.2%. thus major carps have shown a decline 30%, minor carps by 50%, catfishes by 40% and hilsa by 81%. Surprisingly miscellaneous and trace fishes have shown an over all increase by 141%. The average fish yield has also shown a decline from 196.93 kg day-1 during 1973-79 to 137.34 kg day^{-1} during 1996-98, an overall reduction by 30%. Observations in other stretches have also shown considerable increase in the percentage contribution of miscellaneous and trace fishes which contributed almost 57% of the total catch at Dibrugarh, 51.5% at Jorhat 44.8% at Biswanathghat and 53.8% at Goalpara. It can thus be concluded that there is a dramatic shift in the fisheries towards miscellaneous species and trace fishes throughout the stretch of river Brahmaputra over the years.

The qualitative shift in the fisheries is bound to have great bearing on the fish production of the river as most of the available potential energy is utilised by miscellaneous and trace fishes.

Anthropogenic impact on environment and fisheries

(i) Deforestation and soil erosion in the catchment

Large scale deforestation in the region has passed severe threat to the environment. Except Arunachal Pradesh, where atleast 61% of the geographical area is still under forest cover, the existing coverage in Nagaland (17.34%), Meghalaya (37%) and Assam (25.4%) portrays a dismal picture. Mass destruction of forest cover for timber and five coupled with shifting or Jhoom cultivation not only disturb the delicate balance of forest ecosystem but also leads to erosion of the top soil bringing high silt load in the river basin. Observation in Assam hills indicate that atleast 10 cm of the soil is washed away, even from moderate slope, in each Jhoom cycle. The problem of soil erosion is very acute in the North bank due to heavy deforestation in Arunachal Pradesh and Bhutan foot hills and general topography of the land being 3 to 5% slope towards the Brahmaputra valley. As a result of man made degradation in the environment these tributaries carry and discharge vast amount of silt in the main river. Observations have shown that the average annual silt discharge by North bank tributaries into Brahmaputra is of the order of 666.7 m^3 km^{-2} and that from south bank tributaries range between 66.7 to 95.7 m^3 km^{-2}. Due to accumulation of huge amount of silt the Brahmaputra bed is rising alarmingly. Siltation in tributaries and the main river has become such a serious problem that many of the tributaries often change their path.

Heavy siltation, drastic reduction in the water volume and loss of breeding grounds are some of the major factors responsible for decline in fisheries of River Brahmaputra as well as its tributaries.

(ii) Habitat destruction in floodplain lakes

The problems and potentialities of river Brahmaputr can be viewed in totality only with the inclusion of floodplain lakes, locally known as beels. Almost 80% of the total lentic waters of the Assam state is represented by beels. Being an integral part of the river system during inundation these beels serve a vital spawning ground for major carps as their easily accessible shallow area provide optimum breeding conditions. There are about 1392 beels in the state covering an area of 0.1 million hactares and fish harvest from these beels have been considered as a renewable natural resource available for fish exploitation. Of-late the developmental activities in the river basin specially in relation to irrigation and flood control measures, indiscriminate and unscientific construction of sluice gates as well as excessive siltation of connecting channels have led to severing of links with the mainstream. As a result of these activities the natural breeding ground is lost.

(iii) Mass destruction of juveniles

Heavy exploitation of spawners (Ujaimara fishing) during breeding season and subsequent fishing of juveniles does the maximum damage to the natural recruitment process. The landing pattern have shown maximum fish catch from the river during September-October (almost 60% of the annual catch). Maximum catch recorded during these months is due to large scale fishing of carp juveniles (70 to 80%). Mass destruction of juveniles results in failure of natural recruitment of the quality fishes which ultimately leads to decline in the overall fishery of the river.

Conclusion

Tributaries of River Brahmaputra posses distinct ecological status and play key role in maintaining the annual water quality and production potential of the main river. Practically no change in water quality parameters ove rthe years, clearly reflected the healthy condition of the tributaries and the system as a whole. Brahmaputra along with its tributaries has a very high production potential but man made environmental modifications, like destruction of forest cover in the catchment and subsequent influx of silt load, large scale killing of fishes in using explosive materials, mass destruction of juveniles and habitat destruction in floodplains etc have done great damage to the fishery of the system. There is thus an urgent need to protect the environment before it goes beyond repair.

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EXECUTIVE SUMMARY

1. Ecological status, production potential and fishery resources of forerunners. Siang, Dibang and Lohit of Brahmaputra, 8 different stretches of main river Brahmaputra between Saidiya and Dhubri, 25 tributaries on the North bank and 16 on the South bank were studied.

2. Sediment from the entire system was dominated by sand (78.5 to 99.5%) having poor organic carbon and available nutrient and near neutral to slightly acidic pH with few exceptions.

3. Remarkable variation was observed in respect of water quality parameters *viz.*, alkalinity, conductance, dissolved solids, calcium, magnesium and hardness among the tributaries of the North bank, all being exceptionaly low in Ranganoi (23.5 mgl^{-1} 52.6 mmhos, 26.6 mgl^{-1}, 6.4 mgl^{-1} and 3.0 mgl^{-1} respectively) and exceptionaly high in Manas (207.77 mgl^{-1}, 345.5 µmhos, 173.8 mgl-$^{-1}$, 25.7 mgl^{-1}, 22.01 mgl^{-1} and 155.8 mgl^{-1}, respectively).

4. The South bank tributaries as well as the three forerunners of Brahmaputra also showed considerable variations in alkalinity conductance, dissolved solids and hardness.

5. The diverse hydrological set-up of various tributaries have great bearing on the water quality of the main Brahmaputra, which also showed considerable variations between the stretches. The impact was more evidenced at Tezpur and Goalpara (Jogighopa) where the tributaries JiaBharali and Manas have completely changed the water quality of Brahmaputra and the impact could be seen upto a long distance.

6. Though the water quality of Brahmaputra has not shown much variations due to healthy conditions of its tributaries, the clarity of water has reduced sharply over the years. Thereby showing constant increase of silt load in the river.

7. The biotic set-up of the system showed considerable variations both in respect of quality and quantity. While many of the tributaries have shown dominance of diatoms among phytoplankters, some of them showed higher concentration of chlorphyceae. Even in the main Branmaputra, the upper stretches including the forerunners Siang, Dibang and Lohit were dominated by diatoms, the down stretch showed dominance of chlorophyceae. In respect of benthic organisms, mollusc remained the dominant component ub nabt tributaries as well as the main Brahmaputra, while Siang, Dibang, Lohit, Subansiri and Jia Bharali showed dominance of chironomids. Insect dominated in Noadihing, Dibru and Burhidihing.

8. The efficiency of energy transformation by producers was on average 0.095% of light in Siang, Dibang and Lohit, 0.145% in the main Brahmaputra and 0.137% in the five tributaries where the studies could be made.

9. The fish production potential of the three forerunners, river Brahmaputra and five tributaries were estimated at 59.0, 92.32 and 86.8 kg ha^{-1}, respectively. Showing high potential energy resource of the system as a whole.

10. The fishery of Siang, Dibang and Lohit as well as some of the tributaries like Subansiri, Jia Bharali etc. were dominated by Mahseer *species Tor putitora, Neolisocheilus hexagonolepis*, snow trout *Schizothorax richardsoni* and coldwater species *L.dero* and *L.dyocheilus,* while these species were completely absent in the main Brahmaputra except at Saidiya the confluence point of the forerunners.

11. The fishery of the main river was dominated by miscellaneous species (53.7%) followed by major carps (17.7%) catfishes (13.6%), featherbacks (6.9%) and minor carps (5.4%). The average catch in the entire stretch being 113.7 kg day^{-1}.

12. There has been considerable variations in the catch composition over the years. Major carps, minor carps and catfishes showed considerable decline with marked increase in miscellaneous species. The change in the fishery structure has also affected the fish yield from the river.

13. There has been considerable decline in the actual fish yield from the river during last two decades.

14. The probable reasons for the decline in fish production may be attributed to heavy siltation, loss of breeding and nursery grounds due to changing course of tributaries, failure of recruitment, habitat destruction in floodplains, mass destruction of juveniles besides natural change in catch structure.

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