Riverine ecology and fisheries vis-a-vis hydrodynamic alterations : Impacts and remedial measures

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Foreword

The vast network of Indian rivers and rivulets has been source for rich fish biodiversity, lucrative fishery and provide livelihood to countless riparian fishers. The development activities during post independence era have put incredible pressure on rivers to fulfill the water demands. Series of dams/barrages constructed to meet the demands for irrigation, hydroelectric generation, domestic and industrial units. These manmade structures changed the hydrological features of rivers and resulted in loss in riverine habitat; heavy siltation and decline in water retention capacity and affected the fish production from the riverine systems. Dumping of treated and untreated waste further aggravated the situation. Furthermore, some exotic fish species are established in many rivers due to changed hydrological scenario. The depleted fish stocks have seriously affected livelihoods of fishers and forced them to search for other alternatives. Thus, conservation and restoration of riverine resources is the need of the hour. Detailed knowledge on hydrological alterations and their impact on riverine ecology and fisheries is the pre-requisite to develop fish conservation strategies for these river systems. In the present document the authors have addressed these issues in a lucid manner. They have also suggested the measures for conservation and restoration of riverine fisheries. I am sure that the document will provide an in depth knowledge on ecology and fisheries in Indian major river systems in context of changed hydrological regimes and measures for conservation and optimum utilization of our riverine fisheries resources.

A. P. Sharma
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January, 2010

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Introduction

Large rivers and their floodplains support a significant proportion of the world's biodiversity and provide important goods and ecological services to society, including fisheries. Riverine ecosystems and fisheries are subjected to intense pressure from a wide range of anthropogenic disturbances, the main ones being impacts from altered land use, modifications to river flow regimes, riparian and physical habitat loss, water pollution, exotic species invasion and intensive exploitation of fish stocks. The impact of these activities are already appearing in declining fisheries, increasing incidence of floods, lowered ground water table, *etc*. The need for high profile activities - power generation and irrigated agriculture frequently result in conflict of interest between extractive industries and the water requirement for fish and fisher community. In such conflict the interest of agriculture and power generation have invariably prevailed. One of the main reasons for this is that water requirement for power generation and agriculture is relatively well understood whereas requirement for fisheries are less clearly defined. Fisheries in large rivers and their associated floodplain wetlands provide a major source of food, employment and/or income that is crucial to sustaining the livelihoods of multitude of people, particularly the rural poor in large areas of the world.

In India, all the above anthropogenic activities have been at high profile in post independence era. The natural flow of all major rivers have been regulated for fulfilling the water demand in power and agriculture sector, without giving any attention to fisheries sector. As a result the rivers have lost their riverine character and fisheries have also suffered a serious set-back. Conservation and restoration of rivers have therefore become vital for the overall sustainable development of the country.

The present communication deals with the ecological status and fisheries of major river systems of India and measures to be undertaken for conservation and restoration of rivers.

Classification of rivers

The total length of riverine resource of India has been estimated as 45,000 km comprising of 14 major (catchment area>20,000 km^2), 44 medium (catchment area between 2,000 to 20,000 km^2) and innumerable minor rivers (catchment area<2,000 km^2). The major rivers of the country have been shown in Fig. 1.

The Indian rivers are classified as Himalayan rivers, East coast rivers and West coast rivers. Himalayan rivers originate from the mountain ranges of Himalaya, comprising of Ganga, Brahmaputra and Indus systems.

Ganga river system is one of the largest river systems in the world. The river along with its tributaries has a combined length of 12,500 km with a catchment area of 0.98 million km^2. The important rivers of this system are Yamuna, Chambal, Ken, Betwa, Tons, Son, Ramganaga, Gomti, Ghagra, Rapti, Burhi Gandak, Gandak, Kosi, *etc*. River Ganga originates from Gangotri glacier in Uttarkashi district at an elevation of 7,010 m. After traversing nearly 280 km, it descends into the plains at Haridwar. The river travels a total distance of 2525 km through the states of Uttarakhand, Uttar Pradesh, Bihar and West Bengal before joining the Bay of Bengal.

Figure 1 : Major Indian rivers

Brahmaputra river system has a combined length of 4,023 km, with a catchment area of 0.51 million km^2. The important rivers of system are Siang, Dibang, Lohit, Digharu, Subansiri, Jia-bharali, Dikrong, Jia-dahal, Beki, Manas, Kopli, Kalong, Burhi Dihing, Dhansiri, Kulsi and Krishnai. The Brahmaputra originates from Chemayungdung Mountains, about 100 km southeast of the lake Mansarovar, at an altitude of 5,150 m msl. It runs about 1,250 km through Tibet as river Tsangpo before entering into Indian territory near Tuting in Siang district of Arunachal Pradesh. After traversing nearly 160 km in Arunachal Pradesh as Siang it enters Assam on the north of Saidiya, where it meets river Dibang and Lohit. After joining these tributaries, the river assumes the name Brahmaputra. It traverses Assam for about 740 km before entering into Bangladesh as river Jamuna.

Plate 1: View of river Siang in upper stretch, Arunachal Pradesh

The Indus system comprises of the main river Indus and its major tributaries Kabul, Swat and Kurram from the west and Jhelum, Chenab, Ravi, Beas and Sutlej from the east. The Sutlej rises from lake Mansrovar at an elevation of 4,570 m. It enters into Indian Himalayas at Shipki pass, drains the Shiwalik Himalayas and enters into plains of Punjab at Ropar. The river has a length of 360 km within Indian territory. The river Ravi rises in Kulu, flows for about 370 km in India before meeting Sutlej. River Beas rises near Rohtang Pass in Kulu at an elevation of 3,960 m and flows through a gorge from Larji in Talwara and then enters Punjab plains to meet Sutlej at Harike. The total length of river is 460 km with a catchment area of 20,303 km^2.

The East coast river system comprise of Mahanadi, Godavari, Krishna and Cauvery, having a combined length of about 6,437 km with a catchment area of 1.21 million km^2.

The river Mahanadi, 857 km long, originates near Pharsiya village in Raipur district of Chhattisgarh and meets the Bay of Bengal in Orissa. The total catchment area of the river is 141,589 km^2. Its important tributaries are Seonath, Habdo, Jonk, Mand, Ib, Ong and Tel. The river Godavari is the largest of the peninsular rivers and the third largest in India. It originates near Triambakeswar in Deolali hills of the Western Ghats, Maharashtra, and flows a distance of 1,465 km before joining the Bay of Bengal in Andhra Pradesh. It has a catchment area of 312,812 km^2. The river Krishna is one of the three major perennial rivers in southern India. It originates near Mahabaleswar at an elevation of 1,360 m from a water spring. The river traverses a distance of 1,400 km before emptying in Bay of Bengal. The total drainage area of the river is 258,948 km^2. The river Cauvery originates from the Brahmagiri hills of the Western Ghats in the Coorg district of Karnataka at an elevation of 1,340 m. After flowing 800 km, it meets the Bay of Bengal at Kaveripatnam. It has a catchment area of 87,900 km^2.

The West coast river system comprises the Narmada and Tapti draining India's peninsular west. Other rivers in this system are short and many are torrential streams originating from Western ghats. The total length of rivers in West coast river system is about 3,380 km and catchment area 0.69 million km^2. The river Narmada rises near Amarkantak in Madhya Pradesh at an elevation of 900 m and has a length of 1,312 km with a catchment area of 98,796 km^2. The important tributaries of the river are Burhner, Banjar, Shar, Shekkar, Tawa and Kundi on left bank; and Hiran, Barna and Orsang on right bank. The river Tapti is one of the two important westerly flowing rivers of the peninsular India. The river rises near Multai in Betul district of Madhya Pradesh at an elevation of 730 m. The total length of the river is 724 km with a catchment area 65,145 km^2. The important tributaries joining from the left are Purna, Vaghur, Girna, Bori and Panjhra, and from the right Aner.

Ecological status of rivers

Himalayan rivers

Ganga

The water quality parameters of Ganga in different zones have been presented in Table1. Entire stretch of river was rich in oxygen (6.9-8.3 mgl^{-1}) and poor in nutrients (nitrate: 0.017-0.050 and phosphate: 0.003-0.040 mgl^{-1}). Due to strong buffering capacity of water there was practically no fluctuation in pH (8.1-8.2). Water temperature varied from 20.4 to 26.8°C and transparency was comparatively high in the upper zone (58.9 cm). On the basis of conductance, alkalinity, dissolved solids, hardness and chloride, Ganga appeared to be divided into three significant zones (upper zone: Deoprayag to Farrukhabad; middle zone: Kannauj to Varanasi; lower zone: Patna to Farakka). Upper zone showed minimum value of above parameters (206 μmhos, 78.7, 104, 74 and 14.9 mgl^{-1}, respectively), while middle zone showed maximum values (456 μmhos, 150, 227, 148 and 30.8 mgl^{-1}, respectively). As compared to sixties, water quality of Ganga has not shown any sign of deterioration with few exceptions.

Among the biotic communities, the plankton concentration was maximum in middle zone and minimum in the upper zone. In all the three zones phytoplankton was the dominant component being 96.0, 85.0 and 82.6% in upper, middle and lower zones respectively. Among different groups of phytoplankton diatoms were almost 100% in the upper zone, 56% in the middle and 50% in the lower zone. Considerable population of chlorophyceace has been observed in the middle zone (44%) and myxophyceace in lower zone (22%). Periphytic deposition was maximum at Kahalgaon in the lower zone and minimum at Deoprayag. Among periphyton no definite trend of zonal variation has been observed but diatoms (74.3 to 100%) were the dominant component in the entire river. The quantitative abundance of macrobenthic communities has been minimum in the upper zone and maximum in the middle zone. The qualitative picture showed dominance of insects in the upper zone, mollusc and insect in the middle and mollusc (85%) in the lower zone.

Ravi

Average water temperature did not show much variation (20.5-21.5) but the clarity of water was slightly higher in the upper zone. Dissolved oxygen was quite high (6.4-7.1 mgl^{-1}) and pH was in the alkaline range (7.4-7.6). Considerable difference was observed in respect of conductance, alkalinity, dissolved solids and total hardness, all being comparatively lower between Shahpur and Madhopur (178 μmhos, 83.6, 89 and 113 mgl^{-1}) but showed sudden increase between Kathlour and Sakki (332 μmhos, 151, 160 and 154 mgl^{-1}, respectively). Chloride and silicate were within the range of 12.4-16.2 and 4.2-6.8 mgl^{-1}, respectively in the entire stretch. Nutrient status of the river was poor (Table 1).

Among the biotic communities, plankton population was generally poor in the river. Phytoplankton was the dominant component mainly represented by diatoms (66-100%) and green algae (0-34%). Myxophyceace was completely absent. Periphyton deposition was also poor and mainly represented by diatoms (70-86%) and green algae (14-20%). The river sustained rich benthic population. Insect were dominant between Shahpur to Kathlour, whereas in other places mollusc was dominant. Macrophytes were also present in some stretches.

Sutlej

The water quality parameters of river between Roopnagar to Harike and below Beas confluence up to Ferozpur has been presented in Table1. Water temperature ranged from 22.0 to 24.0°C. Transparency was lower (39.5 cm) in the upper zone but comparatively higher below the confluence. Dissolved oxygen was quite rich throughout the stretch (6.5-9.6 mgl^{-1}) and water showed alkaline character with pH ranging from 7.5 to 7.8. Conductance, alkalinity, dissolved solids, hardness and chloride all were comparatively higher before Beas confluence (249 μmhos, 98.6, 150, 102 and 13.5 mgl-1, respectively) and showed decline after the confluence (204 μmhos, 87.0, 103, 95 and 8.3 mgl-1). The nutrient status of the river was poor (phosphate: 0.120-0.150 mgl^{-1}).

The plankton population was comparatively higher at Ferozpur. Phytoplankton remained the dominant component. The various groups were evenly distributed with diatoms (24.0 to 42.33%), chlorophyceace (23-43%) and myxophyceace (10.7-23.0%). Among the zooplankton, found in some stretch rotifers, copepods and cladocerons were the main component. Diatoms (31-50%), green algae (23-24%) and myxophyceace (23-35%) were the dominant group among periphyton. River was quite rich in benthic population, chironomids (15.3-100%) and gastropods (0-83.5) were the main benthic organisms.

Beas

The average water temperature was 23.3°C and transparency 29.5 cm. Dissolved oxygen was fairly rich (6.7 mgl^{-1}) and pH was near neutral (6.8). Conductance, alkalinity, dissolved solids and hardness were comparatively lower in Beas (208 μmhos, 71.5, 103 and 89 mgl^{-1}) than the main river Sutlej before confluence and as a result a decreasing trend was observed below the confluence point. This river also showed poor nutrient status (Table 1).

Table 1: Water quality parameters of Himalayan rivers

River	Zone	Water temp (°C)	Transparency (cm)	DO (mgl⁻¹)	pH	Total alkalinity (mgl⁻¹)	Conductance (μmhos)	TDS (mgl⁻¹)	Total hardness (mgl⁻¹)	Chloride (mgl⁻¹)	Silicate (mgl⁻¹)	Nitrate (mgl⁻¹)	Phosphate (mgl⁻¹)
Ganga	Upper zone (Deoprayag-Farukhabad)	20.4	58.9	8.3	8.1	78.7	206	104	74	14.9	2.0	0.017	0.003
	Middle zone (Kannauj-Varanasi)	26.8	37.2	6.9	8.2	150.2	456	227	148	30.8	3.8	0.050	0.035
	Lower zone (Patna-Farakka)	26.5	28.6	7.2	8.1	107.5	259	123	103	18.8	1.7	0.037	0.040
Ravi	Shahpur-Madhopur	20.5	43.3	7.1	7.6	83.6	178	89	113	12.4	4.2	-	0.171
	Kathlour-Saki	21.5	38.3	6.4	7.4	151.1	332	160	154	16.2	6.8		0.196
Sutlej	Roopnagar-Harike	22.0	39.5	6.5	7.5	98.6	249	150	102	13.5	1.9	-	0.120
	Below Beas confluence	24.0	69.7	9.6	7.8	87.0	204	103	95	8.3	1.4	-	0.150
Beas		23.3	29.5	6.7	6.8	71.5	208	103	89	20.7	2.0	-	0.290
Brahmaputra	Upper zone (Sadia-Jorhat)	18.2	55.9	7.4	7.6	65.5	147	74	72	22.9	5.5	0.027	0.010
	Middle zone (Biswanath ghat-Guwahati)	18.8	38.9	7.9	7.6	63.6	147	74	72	21.0	5.1	0.030	0.006
	Lower zone (Goalpara-Dhubri)	20.4	41.6	7.9	7.8	68.5	155	78	73	26.9	5.8	0.020	0.010

Plankton density in this seasonal tributary was on the average 184 $ul l^{-1}$, comprising of bacillariophyceae (36-39%), myxophyceae (27-47%) and cladocerans (14%). The periphytic community was on the average 477 $ucml^{-2}$, and benthic population 524 nml^{-2}. The presence of large proportion of coleopterans and cladocerans indicated the tributary to be polluted with organic effluents.

Brahmaputra

The water quality parameters of river between Sadia (the confluence of Siang, Dibang and Lohit rivers) to Dhubri (before entering in Bangladesh) have been depicted in Table 1. In the entire stretch water temperature did not show much variation (18.2-20.4°C) while the clarity of water was more in the upper zone. Water was fairly rich in dissolved oxygen (7.4-7.9 mgl^{-1}) and as a result of strong buffering capacity pH showed very little variation (7.6-7.8). Conductance, alkalinity, dissolved solids, hardness and chloride were within the range of 147-155 μmhos, 63.6-68.5; 74-78; 72-73 and 21.0-26.9 mgl^{-1}, respectively, with slightly higher values in the lower zone. The nutrient status both in respect of nitrate and phosphate were poor in the river.

Among the biotic communities maximum concentration of plankton was observed in the upper zone, the bulk of which being phytoplankton. Zooplankton formed only negligible proportion. Diatoms contributed 60% of the population followed by chlorophyceace and myxophyceace. Benthic population also showed maximum value in the upper zone and minimum in the middle zone. Gastropods dominated in the lower zone while both gastropods and bivalves in the upper zone.

Peninsular Rivers

Mahanadi

Important water quality parameters of the river in three zones have been presented in Table 2. The average water temperature in the river varied between 26.2 to 30.8°C while clarity of water was comparatively higher in the lower zone (101.7 cm). Dissolved oxygen was fairly high (7.4-8.0 mgl^{-1}) and pH did not show much fluctuation due to high buffering capacity. Conductance, alkalinity, dissolved solids, hardness and chloride were within the range of 164-195 μmhos, 70-89, 82-92, 68-86 and 26.5-37.0 mgl^{-1} in the upper and middle zone but except alkalinity, the values of all the other parameters showed sharp increase in lower zone. The nutrient status both in respect of nitrate and phosphate were poor.

Among biotic communities plankton population was poor and did not show any marked variation in the entire stretch. Phytoplankton (42.5-99.7%) remained the dominant component throughout the stretch with few exceptions. Myxophyceae, bacillariophyceae and chlorophyceae were the dominant groups in order of magnitude. Among zooplanktons copepods and rotifers dominated the upper zone, cladocerons and rotifers in the middle and copepods in the lower. Macrobenthos decreased from upper to lower zone. Gastropods (40-61%) and bivalves (6-21%) were dominant in the entire stretch. Zonal variation in other benthic groups was noticed with prevalence of dipterans in the upper, nematodes in the middle and annelid worms in the lower stretch. The upper zone exhibited comparatively rich epiphytes due to its hard substrate with rocks and boulders. Bacillariophyceae were dominant (40.9-57.1%) among periphytic groups. Clear water, fast current, stony and sandy bed did not allow the macro vegetation to grow in the entire river.

Godavari

Water temperature was more or less similar in all the zones (28.2-29.3°C) but clarity of water was comparatively higher in middle stretch (72.8 cm). Water was always alkaline in reaction with pH ranging from 7.6 to 8.0 and also rich in dissolved oxygen (6.9-8.9 mgl^{-1}). Conductance, alkalinity, dissolved solids and hardness all were comparatively higher in the middle stretch (482 μmhos, 160, 242 and 125 mgl^{-1}, respectively) and low in lower stretch (Table 2). Chloride was within the range of 25.6-34.8 mgl^{-1}. Both phosphate (0.007-0.009 mgl^{-1}) and nitrate (0.026-0.036 mgl^{-1}) were poor in the entire stretch.

Phtyoplankton remained the dominant component in the river except some estuarine areas. The dominant group was bacillariophyceae followed by chlorophyceae, myxophyceae and dynophyceae. Zooplankton was mainly represented by rotifers, cladocerans and copepods. The benthic fauna was maximum in the middle zone and poor in the upper zone. Benthos was mainly represented by mollusc followed by insect and nymphs of mayfly and dragonflys. Macrophytes were also recorded but confined to stagnant deep pools.

Krishna

Among the physical parameters, temperature was within the range of 27.8-30.5°C and transparency from 57 to 108 cm being comparatively higher in the lower zone. Dissolved oxygen was fairly rich in the river (6.4-8.0 mgl^{-1}) with alkaline pH (8.1-8.2). Total alkalinity and hardness were in the range of 149 to 160 and 159 to 189 mgl^{-1} in the entire stretch but conductance, dissolved solids and chloride showed sharp increase from middle zone reaching maximum in the lower zone (1039 μmhos, 520 and 254 mgl^{-1}). The nutrient status of the river both in respect of nitrate and phosphate was found to be poor (Table 2).

Among the biotic communities phytoplankton accounted 88.4 to 98.8% of the total population. Myxophyceae mainly represented by microcystis remained the dominant group (46.7%) followed by chlorophyceae (22.9-31.8%). Crustaceans and rotifers constitute the major portion of zooplankton. Among benthic communities mollusc (89.8-93.5%) was the dominant component. Other forms were insect, chironomids and worms. Among the periphytic population, bacillariophyceae dominated over others (68.1-95.6%). Some species of macrophytes were also recorded from the river.

Cauvery

Water temperature fluctuated between 24.6 to 28.1°C and water was found to be clear up to bottom on many occasions. Dissolved oxygen was within the range of 6.6 to 7.0 mgl^{-1} in the entire river. Water was near neutral to alkaline in reaction with pH fluctuating from 6.9 to 7.9, although slightly acidic pH (6.2) has been recorded in the upper stretch. Conductance, alkalinity, dissolved solids, hardness and chloride were comparatively low in the upper zone (295 μmhos, 98, 191, 89 and 20.8 mgl^{-1}, respectively). Alkalinity and chloride were maximum in the middle zone (217 and 58.4 mgl^{-1}) while other three parameters showed maximum values in the lower zone (1215 µmhos, 655 and 412 mgl^{-1}, respectively). The nutrient status of the river was invariably low both in respect of nitrate and phosphate (Table 2).

Molluscs with a dominance of gastropods were the only benthic group showing continuous distribution along the river. Bacillariophyceae was the dominant component among periphytic communities. Floating and submerged macrophytes were available in the river.

Narmada

Water quality parameters of river at Amarkantak (origin) and Dindori to Gadarwara have been presented in Table 2. Water temperature was in the range of 24.0 to 25.7°C and transparency was higher in Amarkantak (76.0). Water was almost neutral at the origin point (6.8), while in other stretches it was in the alkaline range (pH-8.0). Dissolved oxygen was fairly rich in all the stretches (6.4-7.4 mgl^{-1}). The river showed considerable variation in respect of conductance, alkalinity, dissolved solids and hardness all being comparatively low (98 µmhos, 42, 52 and 52 mgl^{-1}) at Amarkantak, while their values were higher in the other stretches (225 µmhos, 123, 120 and 121 mgl^{-1}, respectively). The nutrient status of the river both in respect of nitrate and phosphate were poor in the entire stretch (Table 2).

Among the biotic communities plankton density was poor, dominated by phytoplankton (69.2-98.6%). Bacillariophyceae was the most important group among phytoplankton (23.1-90.6%) followed by chlorophyceae (0-40.6%). While zooplanktons was mainly represented by crustaceans and rotifers. Macrobenthos was comparatively higher in the down stretch. Annelida and insect were dominant in the upper zone while gastropods and pelecypoda in the lower zone.

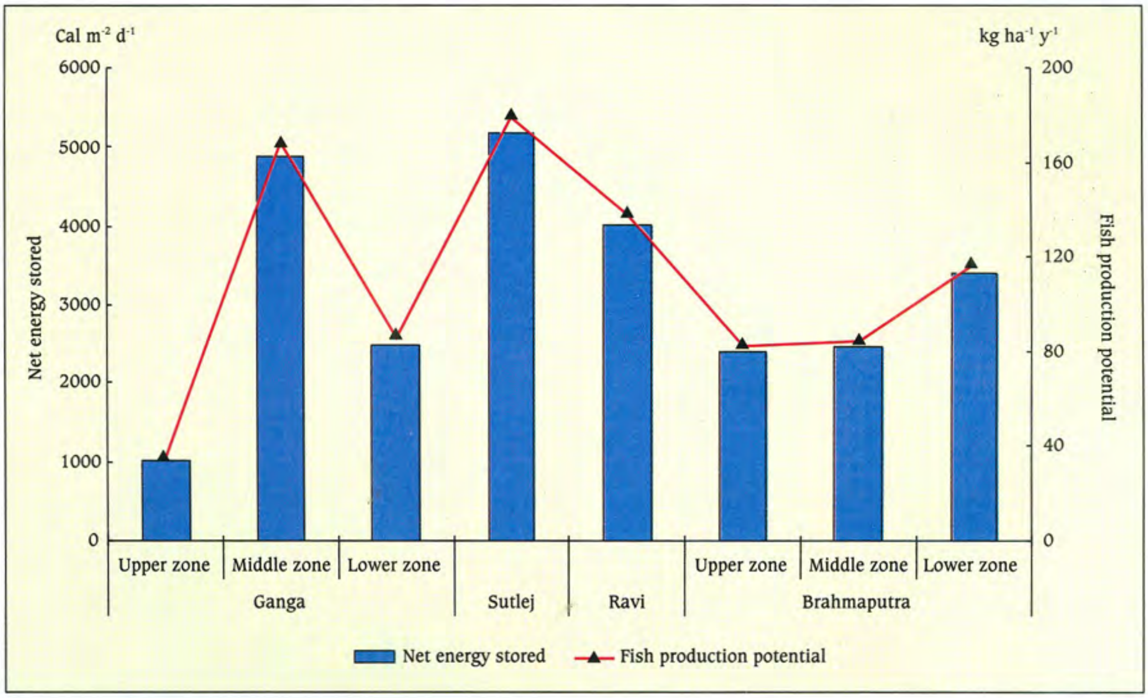
Table 2: Water quality parameters of peninsular rivers

River	Zone	Water temp (°c)	Transparency (cm)	DO (mgl^{-1})	pH	Total alkalinity (mgl^{-1})	Conductance (μmhos)	TDS (mgl^{-1})	Total hardness (mgl^{-1})	Chloride (mgl^{-1})	Silicate (mgl^{-1})	Nitrate (mgl^{-1})	Phosphate (mgl^{-1})
Mahanadi	Upper zone (Sihawa-Tamdel)	27.1	62.1	7.4	8.2	89	195	92	86	37.0	6.2	0.030	0.004
	Middle zone (Durgapalli-Narsinghpur)	26.2	89.7	8.0	7.8	70	164	82	68	26.5	7.1	0.043	0.004
	Lower zone (Sasnag-Paradip)	30.8	101.7	7.2	8.1	80	220	109	294	65.6	13.4	0.040	0.007
Godavari	Upper zone	28.2	49.7	7.3	7.6	105	378	189	110	34.8	15.3	0.036	0.009
	Middle zone	29.3	72.8	6.9	8.0	160	482	242	125	32.1	12.6	0.026	0.008
	Lower zone	28.8	64.0	8.9	8.0	106	301	151	95	25.6	10.1	0.033	0.007
Krishna	Upper zone (Wenna-Kallol)	27.8	73.0	8.0	8.1	149	406	292	159	52.5	9.1	0.140	0.098
	Middle zone (J.khandi-Bhadra)	28.9	57.0	7.3	8.2	160	689	359	185	109.7	7.50	0.370	0.038
	Lower zone (Bispalli-Penumudi)	30.5	108.0	6.4	8.1	155	1039	520	189	254.0	8.0	0.097	0.067
Cauvery	Upper zone	24.6	clear	7.0	6.9	98	295	191	89	20.8	3.7	0.020	0.023
	Middle zone (Shivsamudram-Hogenakkal)	26.7	clear	6.9	7.8	217	795	397	158	58.4	7.2	0.132	0.078
	Lower zone (Hogenkkal-confluence)	28.1	103.4	6.6	7.9	188	1215	655	412	-	4.6	0.098	0.094
Narmada	Amarkantak (origin)	24.0	76.0	6.4	6.8	42	98	52	52	-	6.0	0.180	0.070
	Dindori-Gadarwara	25.7	53.1	7.4	8.0	123	225	120	121	-	10.8	0.160	0.008

Rate of energy transformation by producers and fish production potential of rivers

The rate of net energy transformation by producers and fish production potential of both Himalayan and peninsular rivers have been shown in Fig. 2 and 3. The rate of energy transformation in Ganga was 1015 cal m^{-2} d^{-1} in the upper zone, 4877 cal m^{-2} d^{-1} in middle and 2489 cal m^{-2} d^{-1} in the lower zone with a fish production potential of 35.2, 168.9 and 86.2 kg ha^{-1} yr^{-1} respectively. Thus, in respect of potential also, Ganga was divided into three clear cut zones. The rate of energy transformation by producers in Sutlej and Ravi rivers were 5184 and 4006 cal m^{-2} d^{-1} with a fish production potential of 179.5 and 138.7 kg ha^{-1}. In Brahmaputra, the rate of energy transformation by producers was on the average 2393 cal m^{-2} d^{-1} in the upper zone, 2452 cal m^{-2} d^{-1} in middle and 3393 cal m^{-2} d^{-1} in the lower zone. The estimated fish production potential in the three zones was 82.9, 84.9 and 117.5 kg ha^{-1} yr^{-1}, respectively, being comparatively higher in the lower zone.

Figure 2: Rate of energy transformation and fish production potential of Himalayan rivers

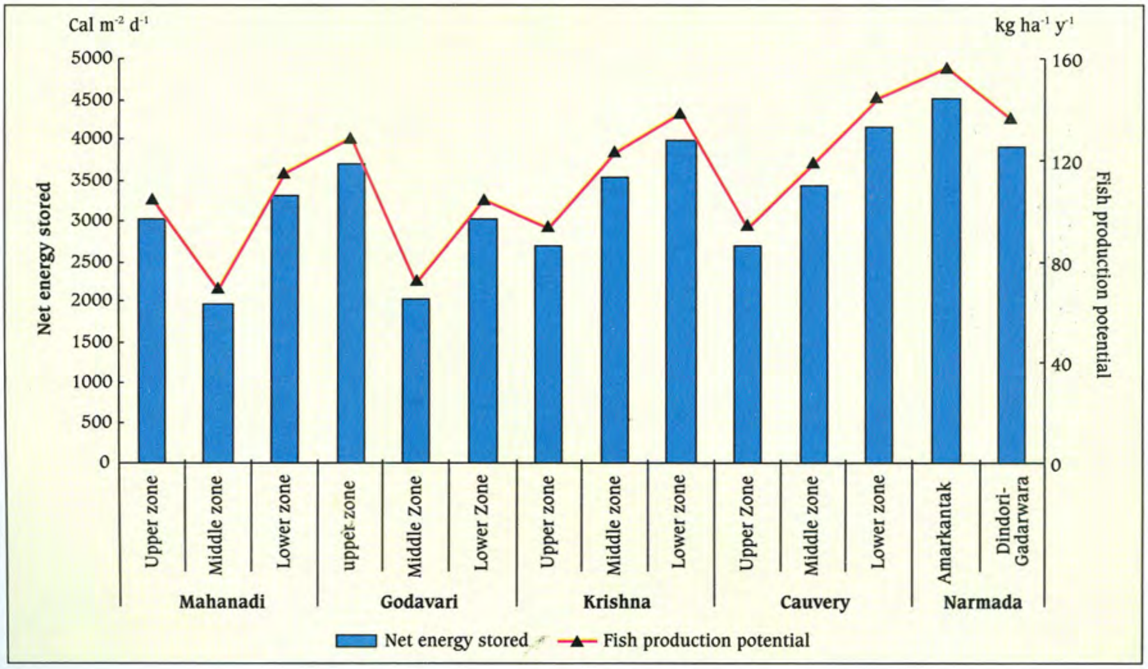


In Mahanadi the rate of energy storage was 3027, 1977 and 3312 cal m^{-2} d^{-1} in the three zones with the estimated fish production potential as 104.7, 68.3 and 114.6 kg ha^{-1}, respectively, potential was comparatively lower in the middle zone. The fish production potential in Godavari was estimated as 128.5 kg ha^{-1} in the upper zone, 70.7 kg ha^{-1} in the middle zone and 104.4 kg ha^{-1} in the lower zone with energy transformation rate as

3715, 2045 and 3017 cal $m^{-2} d^{-1}$, respectively. In Krishna, the rate of energy storage by producers was 2675, 3535 and 3987 cal $m^{-2} d^{-1}$ in the three zones respectively. The fish production potential was estimated as 92.5 kg ha^{-1} in the upper zone, 122.4 kg ha^{-1} in middle zone and 138.0 kg ha^{-1} in the lower zone showing considerable increase from upper to lower zone. In Cauvery also both rate of energy transformation and fish production potential showed a gradual increase from 2681 cal $m^{-2} d^{-1}$ and 92.8 kg ha^{-1} in the upper zone to 4164 cal $m^{-2} d^{-1}$ and 144.2 kg ha^{-1} in the lower zone.

In Narmada both rate of energy transformation and fish production potential were comparatively higher at Amarkantak (4507 cal $m^{-2} d^{-1}$ and 156.0 kg ha^{-1}). In the stretch between Dindori-Gadarwara values were 3907 cal $m^{-2} d^{-1}$ and 135.3 kg ha^{-1} being comparatively lower than Amarkantak.

Figure 3: Rate of energy transformation and fish production potential of peninsular rivers



Rich dissolved oxygen, alkaline pH, moderate to high alkalinity, conductance, dissolved solids and rich biota of both Himalayan and peninsular rivers confirm their healthy condition. The rate of energy transformation by producers and fish production potential of rivers are of higher order and as such there is no sign of much deterioration. The only negative feature is poor nutrients which in a fluviatile system are well compensated by catchment flow.

Fish fauna

Himalayan rivers

The endemic and exotic species of fish occurring in natural waters of Himalayas has been reported as 218. However, from Indus river system the main fishery is composed of 32 species belonging to 10 families. The headwaters of the Ganga system in the upper reaches of Himalaya have remained mostly unexplored. The commonly available fishes are snow trouts, catfishes, mahseers and lesser barils. The fish fauna of Himalayan and Indo-Gangetic plains is well described and the total number of species has been recorded as 265. In recent studies 95 species belonging to 28 families have been recorded. The Brahmaputra river system has been reported to be inhabited by 221 species belonging to 36 families. But studies conducted in 1996-98 by CIFRI revealed the presence of 123 species belonging to 30 families. The list of species available on the basis of recent studies is presented in Table 3.

Table 3: Fish fauna of Himalayan rivers

Order	Family	Species	Indus river system	Ganga	Brahmaputra
Anguilliformes	Anguillidae	*Anguilla bengalensis bengalensis*	Y	Y	Y
	Ophichthidae	*Pisodonophis boro*			Y
Beloniformes	Belonidae	*Xenentodon cancila*	Y	Y	Y
Clupeiformes	Clupeidae	*Gonialosa manimina*		Y	
		Gudusia chapra		Y	Y
		Gudusia variegata			Y
		Tenualosa ilisha		Y	Y
	Engraulididae	*Setipinna phasa*		Y	Y
	Pristigasteridae	*Ilisha megaloptera*		Y	
Cypriniformes	Balitoridae	*Aborichthys elongatus*		Y	
		Acanthocobitis botia		Y	Y
		Balitora brucei brucei			Y
		Schistura rupicola	Y		
		Nemacheilus sikmaiensis			Y
		Schistura beavani			Y
		Schistura corica			Y
		Schistura savona			Y
		Schistura scaturigina			Y
		Triplophysa kashmirensis	Y		
		Triplophysa marmorata	Y		
	Cobitidae	*Botia birdi*	Y		
		Botia dario		Y	Y
		Botia dayi		Y	

Table 3: Fish fauna of Himalayan rivers (contd.)

Order	Family	Species	Indus river system	Ganga	Brahmaputra
		Botia lohachatta		Y	
		Lepidocephalus annandalei			Y
		Lepidocephalus berdmorei			Y
		Somileptus gongota		Y	Y
		Lepidocephalichthys guntea		Y	Y
	Cyprinidae	*Acrossocheilus hexagonolepis*			Y
		Amblypharyngodon mola		Y	Y
		Aristichthys nobilis		Y	
		Aspidoparia jaya		Y	Y
		Aspidoparia morar		Y	Y
		Barilius barila			Y
		Barilius barna		Y	Y
		Barilius shacra			Y
		Barilius vagra			Y
		Catla catla		Y	Y
		Chagunius chagunio		Y	Y
		Chela cachius		Y	Y
		Chela fasciata		Y	
		Chela laubuca		Y	Y
		Cirrhinus mrigala	Y	Y	Y
		Cirrhinus reba	Y	Y	Y
		Crossocheilus latius latius	Y	Y	Y
		Ctenopharyngodon idella		Y	
		Cyprinion semiplotum			Y
		Cyprinus carpio carpio	Y	Y	
		Danio dangila			Y
		Danio rerio			Y
		Devario aequipinnatus			Y
		Devario devario			Y
		Esomus danricus		Y	Y
		Garra gotyla gotyla		Y	
		Garra lissorhynchus		Y	
		Hypophthalmichthys molitrix		Y	
		Labeo bata	Y	Y	Y
		Labeo boga		Y	
		Labeo boggut		Y	
		Labeo calbasu	Y	Y	Y

Table 3: Fish fauna of Himalayan rivers (contd.)

Order	Family	Species	Indus river system	Ganga	Brahmaputra
		Labeo dero	Y	Y	Y
		Labeo dyocheilus	Y		Y
		Labeo fimbriatus		Y	
		Labeo gonius	Y	Y	Y
		Labeo kontius			
		Labeo pangusia		Y	Y
		Labeo rohita	Y	Y	Y
		Osteobrama cotio cotio		Y	Y
		Puntius chola		Y	Y
		Puntius conchonius	Y	Y	Y
		Puntius phutunio			Y
		Puntius sarana	Y	Y	Y
		Puntius sophore		Y	Y
		Puntius ticto		Y	Y
		Raiamas bola			Y
		Rasbora daniconius		Y	Y
		Rasbora elanga			Y
		Rasbora rasbora			Y
		Salmostoma bacaila		Y	Y
		Schizopyge curvifron	Y		
		Schizopyge esocinus	Y		
		Schizothorax plagiostomus			Y
		Schizopyge niger	Y		
		Schizothorax progastus			Y
		Schizothorax richardsonii	Y	Y	
		Securicula gora		Y	Y
		Tor progeneius			Y
		Tor putitora	Y	Y	Y
		Tor tor		Y	Y
	Psilorhynchidae	*Psilorhynchus balitora*			Y
Osteoglossiformes	Notopteridae	*Notopterus chitala*		Y	Y
		Notopterus notopterus	Y	Y	Y
Perciformes	Ambassidae	*Chanda nama*		Y	Y
		Parambassis ranga		Y	Y
	Anabantidae	*Anabas testudineus*		Y	Y
	Belontiidae	*Colisa lalia*			Y
		Colisa fasciata			Y

Table 3: Fish fauna of Himalayan rivers (contd.)

Order	Family	Species	Indus river system	Ganga	Brahmaputra
	Channidae	*Channa gachua*			Y
		Channa marulius	Y	Y	Y
		Channa punctatus			Y
		Channa striatus	Y	Y	Y
	Cichlidae	*Oreochromis mossambicus*		Y	
	Gobiidae	*Glossogobius giuris*		Y	Y
	Mastacembelidae	*Mastacembelus armatus*		Y	Y
		Macrognathus aculeatus			Y
		Macrognathus pancalus		Y	Y
	Mugilidae	*Rhinomugil corsula*		Y	Y
		Sicamugil cascasia		Y	Y
	Nandidae	*Badis badis*			Y
		Nandus nandus		Y	Y
	Osphronemidae	*Trichogaster chuna*		Y	Y
	Sciaenidae	*Johnius coitor*			Y
		Johnius gangeticus		Y	
		Pama pama		Y	Y
Siluriformes	Amblycipitidae	*Amblyceps mangois*			Y
	Bagridae	*Aorichthys aor*	Y	Y	Y
		Aorichthys seenghala	Y	Y	Y
		Batasio batasio			Y
		Mystus bleekeri		Y	Y
		Mystus cavasius		Y	
		Mystus gulio			Y
		Mystus menoda			Y
		Mystus montanus			Y
		Mystus tengara			Y
		Mystus vittatus		Y	Y
		Rita rita	Y	Y	Y
	Clariidae	*Clarias batrachus*		Y	Y
	Heteropneustidae	*Heteropneustes fossilis*		Y	Y
	Pangasiidae	*Pangasius pangasius*		Y	Y
	Schilbeidae	*Ailia coila*		Y	Y
		Ailia punctata			Y
		Clupisoma garua		Y	Y
		Eutropiichthys murius		Y	Y
		Eutropiichthys vacha		Y	Y

Table 3: Fish fauna of Himalayan rivers (contd.)

Order	Family	Species	Indus river system	Ganga	Brahmaputra
		Pseudeutropius atherinoides		Y	Y
		Silonia silondia		Y	Y
	Siluridae	*Ompok bimaculatus*		Y	Y
		Ompok pabda		Y	Y
		Wallago attu	Y	Y	Y
	Sisoridae	*Erethistes pusillus*			Y
		Erethistoides montana			Y
		Pseudolaguvia rebeiroi			Y
		Bagarius bagarius	Y	Y	Y
		Erethistes hara		Y	
		Gagata cenia			Y
		Glyptothorax kashmirensis	Y		
		Glyptothorax telchitta			Y
		Gogangra viridescens		Y	Y
		Nangra nangra			Y
		Sisor rahabdophorus		Y	Y
Synbranchiformes	Synbranchidae	*Monopterus cuchia*		Y	Y
Tetraodontiformes	Tetraodontidae	*Tetraodon cutcutia*		Y	Y

Plate 2: Fish catch from river Ganga and Yamuna at Allahabad

Peninsular rivers

The rivers Mahanadi, Godavari, Krishna and Cauvery of the East coast river system used to support a very rich fish fauna prior to the construction of numerous dams, barrages and anicuts. From river Mahanadi, 253 species of fish belonging to 73 families have been recorded. But recent studies revealed the presence of 117 species belonging to 29 families. For Krishna, Godavari and Cauvery no detailed information is available, but the commercial catches comprised of 41 species (19 families), 27 species (13 famillies) and 60 species (17 families), respectively. The list has been provided in Table 4.

On the basis of CIFRI studies the fish fauna of rivers Narmada and Tapti is represented by 83 and 51 species belonging to 23 and 15 families, respectively (Table 4).

Table 4: Fish fauna of Peninsular rivers

Order	Family	Species	Mahanadi	Krishna	Godavari	Cauvery	Narmada	Tapti
Anguilliformes	Anguillidae	*Anguilla bengalensis bengalensis*	Y	Y	Y	Y	Y	
		Anguilla bicolor bicolor				Y		
Beloniformes	Belonidae	*Xenentodon cancila*	Y	Y			Y	Y
Clupeiformes	Clupeidae	*Gonialosa manimina*	Y					
		Gudusia chapra	Y					
		Tenualosa ilisha		Y	Y		Y	Y
Clupeiformes	Engraulididae	*Setipinna phasa*	Y					
Clupeiformes	Pristigasteridae	*Ilisha megaloptera*	Y					
Cypriniformes	Balitoridae	*Acanthocobitis botia*	Y				Y	
		Indoreonectes evezardi						Y
		Nemacheilus botia aureus	Y					
		Schistura dayi					Y	
	Cobitidae	*Botia dayi*						Y
		Lepidocephalichthys guntea	Y				Y	Y
	Cyprinidae	*Salmostoma clupeoides*	Y				Y	Y
		Acrossocheilus hexagonolepis				Y		
		Amblypharyngodon mola	Y			Y	Y	Y
		Aristichthys nobilis	Y					
		Aspidoparia morar	Y					
		Barilius barila	Y				Y	Y
		Barilius barna	Y					
		Barilius bendelisis					Y	Y
		Barilius evezardi					Y	Y
		Barilius radiolatus					Y	

Table 4: Fish fauna of Peninsular rivers (contd.)

Order	Family	Species	Mahanadi	Krishna	Godavari	Cauvery	Narmada	Tapti
		Barilius vagra	Y					
		Brachydanio rario	Y					
		Catla catla	Y	Y	Y	Y	Y	Y
		Chela dadiburjori	Y					
		Chela fasciata	Y					
		Chela laubuca	Y			Y	Y	Y
		Cirrhinus cirrhosus				Y		
		Cirrhinus mrigala	Y	Y	Y	Y	Y	Y
		Cirrhinus reba	Y	Y		Y	Y	Y
		Crossocheilus latius latius	Y				Y	Y
		Cyprinus carpio carpio	Y	Y		Y		
		Danio rerio					Y	Y
		Devario aequipinnatus	Y			Y	Y	Y
		Devario devario	Y				Y	
		Devario malabaricus	Y					
		Esomus danricus	Y			Y	Y	Y
		Garra gotyla gotyla	Y				Y	
		Garra lamta					Y	
		Garra mcclellandi				Y		
		Garra mullya	Y			Y	Y	Y
		Hypselobarbus kolus			Y			
		Labeo ariza	Y			Y		
		Labeo bata	Y			Y	Y	Y
		Labeo boga	Y	Y				
		Labeo boggut	Y			Y	Y	Y
		Labeo calbasu	Y	Y	Y	Y	Y	Y
		Labeo dero	Y					
		Labeo dyocheilus	Y				Y	Y
		Labeo fimbriatus	Y	Y	Y	Y	Y	Y
		Labeo gonius	Y	Y			Y	Y
		Labeo kontius	Y			Y		
		Labeo rohita	Y	Y	Y	Y	Y	Y
		Oreichthys cosuatis	Y				Y	
		Osteobrama cotio cotio	Y		Y		Y	Y
		Osteobrama cotio cunma	Y	Y				
		Osteobrama vigorsii	Y					

Table 4: Fish fauna of Peninsular rivers (contd.)

Order	Family	Species	Mahanadi	Krishna	Godavari	Cauvery	Narmada	Tapti
		Osteochilichthys brevidorsalis				Y		
		Osteochilus nashi				Y		
		Puntius ambassis					Y	
		Puntius amphibius	Y				Y	
		Puntius carnaticus				Y		
		Puntius chola	Y			Y	Y	
		Puntius chrysopoma					Y	
		Puntius conchonius	Y				Y	
		Puntius curmuca				Y		
		Puntius dorsalis	Y			Y	Y	
		Puntius dubius				Y		
		Puntius filamentosus				Y		
		Puntius gelius	Y					
		Puntius guganio	Y				Y	
		Puntius jerdoni		Y				
		Puntius kolus		Y				
		Puntius lithopidos		Y				
		Puntius phutunio	Y				Y	
		Puntius sarana	Y	Y	Y	Y		Y
		Puntius sophore	Y				Y	Y
		Puntius ticto	Y	Y		Y	Y	Y
		Rasbora caverri				Y		
		Rasbora daniconius	Y		Y	Y	Y	Y
		Salmostoma bacaila	Y		Y		Y	
		Salmostoma boopis	Y					
		Salmostoma horai			Y			
		Salmostoma phulo	Y					Y
		Salmostoma untrachi	Y					
		Schismatorhynchos nukta nukta		Y				
		Securicula gora	Y					
		Tor khudree	Y				Y	
		Tor putitora	Y			Y	Y	
		Tor tor	Y				Y	Y
	Parapsilorhynchidae	*Parapsilorhynchus tentaculatus*					Y	

Table 4: Fish fauna of Peninsular rivers (contd.)

Order	Family	Species	Mahanadi	Krishna	Godavari	Cauvery	Narmada	Tapti
Cyprinodontiformes	Poeciliidae	*Poecilia reticulata*					Y	
	Aplocheilidae	*Aplocheilus panchax*	Y					
Gonorynchiformes	Channidae	*Chanos chanos*		Y				
Osteoglossiformes	Notopteridae	*Notopterus chitala*	Y				Y	
		Notopterus notopterus	Y	Y	Y	Y	Y	Y
Perciformes	Acanthuridae	*Acanthurus lineatus*		Y				
	Ambassidae	*Chanda nama*	Y				Y	Y
		Parambassis ranga	Y				Y	Y
	Anabantidae	*Anabas testudineus*	Y	Y		Y	Y	
	Belontiidae	*Colisa lalia*	Y					
		Colisa fasciata	Y				Y	
	Centropomidae	*Lates calcarifer*		Y				
	Channidae	*Channa gachua*			Y		Y	Y
		Channa marulius	Y	Y	Y	Y	Y	Y
		Channa orientalis	Y			Y		
		Channa punctatus	Y			Y	Y	Y
		Channa striatus	Y			Y		
	Cichlidae	*Etroplus suratensis*		Y	Y	Y		
		Oreochromis mossambicus	Y			Y		
	Gobiidae	*Awaous guamensis*	Y					
		Glossogobius giuris	Y	Y		Y	Y	Y
		Odontamblyopus rubicondus	Y					
	Leiognathidae	*Leiognathus splendens*		Y				
	Mastacembelidae	*Mastacembelus armatus*	Y		Y	Y	Y	Y
		Macrognathus aculeatus	Y	Y				
		Macrognathus pancalus	Y				Y	Y
	Mugilidae	*Rhinomugil corsula*	Y			Y	Y	
	Nandidae	*Badis badis*	Y				Y	
		Nandus nandus	Y				Y	
	Osphronemidae	*Osphronemus goramy*				Y		
	Sciaenidae	*Johnius coitor*	Y					
		Johnius dussumieri	Y					
Siluriformes	Amblycipitidae	*Amblyceps mangois*	Y				Y	
	Bagridae	*Aorichthys aor*		Y	Y	Y	Y	Y
		Aorichthys seenghala	Y	Y	Y	Y	Y	Y
		Batasio tengana	Y					

Table 4: Fish fauna of Peninsular rivers (contd.)

Order	Family	Species	Mahanadi	Krishna	Godavari	Cauvery	Narmada	Tapti
		Hemibagrus maydelli		Y				
		Mystus armatus		Y		Y		
		Mystus bleekeri	Y			Y	Y	Y
		Mystus cavasius	Y			Y	Y	Y
		Mystus gulio	Y					
		Mystus malabaricus				Y		
		Mystus tengara	Y				Y	
		Mystus vittatus	Y			Y	Y	
		Rita chrysea	Y	Y				
		Rita pavimentatus		Y			Y	
		Rita rita		Y			Y	
	Clariidae	*Clarias batrachus*	Y			Y	Y	
	Heteropneustidae	*Heteropneustes fossilis*	Y		Y	Y		
	Pangasiidae	*Pangasius pangasius*	Y	Y	Y	Y		
	Schilbeidae	*Ailia coila*	Y					
		Clupisoma garua	Y				Y	Y
		Eutropiichthys vacha	Y				Y	
		Proeutropiichthys taakree taakree			Y			
		Pseudeutropius atherinoides	Y					
		Silonia childreni	Y	Y	Y			
		Silonia silondia	Y			Y		
	Siluridae	*Ompok bimaculatus*	Y	Y	Y	Y	Y	Y
		Ompok pabda	Y					
		Ompok pabo	Y					
		Wallago attu	Y	Y	Y	Y	Y	Y
	Sisoridae	*Gagata itchkeea*					Y	Y
		Bagarius bagarius	Y	Y	Y			
		Erethistes hara	Y					
		Gagata gagata	Y					
		Glyptothorax lonah	Y					
		Glyptothorax madraspatanum				Y		
		Glyptothorax striatus					Y	
		Glyptothorax telchitta					Y	
		Gogangra viridescens	Y				Y	
Synbranchiformes	Synbranchidae	*Monopterus cuchia*	Y					
		Microphis cuncalus						Y

Fishery

The riverine fisheries system on the whole is very complex and it is very difficult to collect information on the catch. Fisheries being the State subject, the information about the catch should be collected by the states but unfortunately none of the state collects such information. Whatever information is available that is based on the studies conducted by Central Inland Fisheries Research Institute (CIFRI) in selected stretches of some important rivers.

Himalayan rivers

The Indus river system

Commercial fisheries of part of river Jhelum, flowing through Jammu and Kashmir in India for Jul 1980 to Jun 1982 has been reported by the CIFRI. The bulk of catches was formed by *Schizothorax* spp., *L. dero, L. dyocheilus, C. latius* and *P. conchonius* among Cyprinids, *G. kashmirensis* and *G. reticulatum* among Sisoridae and *B. birdi, N. kashmirensis, N. rupicola* and *N. marmoratus* among Cobitidae. The exotic fish *C. carpio* (*var. specularis* and *var. communis*) was reported to contribute substantially to commercial catches of river Jhelum. Systematic data regarding total catch is not available for this river.

Based on CIFRI studies from a 280 km stretch of river Sutlej, the fish landings at five centres, *viz*., Roopnagar, Ludhiana, Sultanpur, Harike and Ferozpur were 37.47 t per month. Major carps and minor carps contributed 31.0 and 22.0%. Among major carps *L. rohita* was dominant followed by *C. mrigala*. *T. putitora* was available only at Roopnagar (0.11%). Among large sized catfishes *A. seenghala* and *W. attu* were the main contributor, however, *A. aor* share was small (0.06%). Among exotics only *C. carpio* was observed and contributed significantly (14.4%). Smaller species contribution was almost 1/4th of the total.

Subsistence fishery exists all along the course of Ravi with maximum at Ranjit Sagar dam. Commercial fishery in Ravi is restricted to certain stretches only as it forms international border in many segments. During 2006-07, the average catch per month at Pathankot, Kathlour, Derababa and Amritsar were estimated as 2.68, 1.33, 0.92 and 1.10 t, respectively. The contribution (%) of important groups is presented in Table 5.

Table 5: Fish landings from Ravi and contribution (%) of major groups

Centre	Landing (per month) in tonnes	Major carps	Minor carps	*Tor* sp.	*C. carpio*	*S. richardsonii*	Catfish	Others
Pathankot	2.68	3.7	58.6	6.3	9.3	1.9	1.9	18.3
Kathlour	1.33	2.2	79.7	0.8	0.0	0.0	0.0	17.3
Derababa	0.92	2.6	48.9	0.0	3.3	0.0	1.1	39.1
Amritsar	1.10	0.0	47.3	0.0	0.0	0.0	7.3	45.4

Fish landings at Talwara, Mukerian, Pathankot and Amritsar covering about 165 km stretch of river Beas were recorded as 1.20, 2.19, 2.75 and 5.31 t per month. The contribution of various groups is shown in Table 6.

Table 6: Fish landings from Beas and contribution (%) of major groups

Centre	Landing (per month) in tonnes	Major carps	Minor carps	*Tor* sp.	*C. carpio*	*S. richardsonii*	Catfish	Others
Talwara	1.20	0.8	25.0	0.03	66.7	0.0	1.7	5.8
Mukerian	2.19	50.2	18.7	1.4	5.0	0.0	11.0	13.7
Pathankot	2.75	0.0	86.9	2.2	0.7	3.6	1.1	5.4
Amritsar	5.31	30.6	2.4	0.0	39.1	0.0	11.1	16.8

Ganga

From fisheries point of view Ganga is the most important river and source of livelihood for countless fishers inhabiting on its bank. Upper reaches (origin to Haridwar) is practically a non-fishing zone, however, species available in the stretch are *S. richardsonii*, *Tor* spp., *L. dero*, *L. pangusia*, *G. gotyla*, *C. latius*, *M. armatus*. The commercial fishing actually starts from district Bulandshahar (U.P.). The fishery in the potamon zone of the river is mainly represented by the species belonging to Cyprinidae and Siluridae families.

The fishery from the river has shown serious structural changes and decline over the years. During 1958-61 the yield rate in different stretches of river varied from 480.4 to 2339.5 kg km^{-1}, being maximum at Kanpur and minimum at Bhagalpur. In the middle stretches the major carps contribution was around 50% followed by large sized catfishes, but in Varanasi - Bhagalpur stretch the fishery was dominated by smaller species and

Plate 3 : Dip net in Ganga at Mirzapur

hilsa. During 1961-69 the yield rate dropped slightly (929.8 kg km^{-1}) with maximum at Patna (1811.3 kg km^{-1}) and minimum at Ballia (876.0 kg km^{-1}) with no significant change in fisheries structure.

From 1972 onwards fishery from river started declining with sharp changes in stock structure. At Allahabad the yield rate came down from 935.39 kg km^{-1} of sixties to 368.01 kg km^{-1} for the present with a drastic decline in catches of major carps and large sized catfishes (*A. aor, A. seenghala, W. attu*). On the contrary, the catches of smaller species showed a marginal increase (211.96 kg km^{-1} to 223.41 kg km^{-1}) with slight changes in catch composition. The yield rate at Allahabad for different periods is presented in Table 7.

Table 7: Fish yield rate (kg km^{-1}) in different periods at Allahabad

Period	Major carps	Large cat fishes	Hilsa	Exotics	Others	Total
1961-68	424.91	201.35	97.17	-	211.96	935.39
1972-80	135.17	98.55	9.66	-	197.86	441.25
1981-90	155.73	99.40	4.31	-	247.59	507.03
1991-00	28.91	62.74	4.51	-	178.20	274.36
2001-06	38.58	40.56	1.20	64.27	223.41	368.01

It is obvious from the table that all economic species followed a constant declining trend from 1972 onwards. However, the major carps fishery showed some improvement during 1981-90, which was due to good catches of *L. calbasu*, but during 1991-00 contribution of calbasu declined drastically and major carps share slipped to merely 28.91 kg km^{-1}. During 2001-06, the fishery showed a general improvement, mainly due to invasion of exotic species, specifically *C. carpio* which is constantly increasing over the years.

A comparative account of fish yield at Buxar, Patna and Bhagalpur has been depicted in Table 8. During sixties hilsa fishery was the mainstay at Buxar contributing 744 kg km^{-1} in 1112.89 kg km^{-1} of the total. Again after 1972 the hilsa fishery suffered a serious set-back and came down to only 22.37 kg km^{-1} in 1981-86. However, due to shift in fishing effort the fishery of rest of the species showed some improvement.

Plate 4: Catch of common carp and tilapia from river Ganga, Varanasi

At Patna the yield came down to 783.94 kg km^{-1} in 1986-93 from 1811.30 kg km^{-1} during sixties. The decline was reflected for all the species but hilsa was the worst sufferer.

Fishery at Bhagalpur also showed a declining pattern over the years. The main decline was observed in catches of major carps and hilsa.

Table 8: Comparison of fish yield (kg km^{-1}) from Ganga at Buxar, Patna and Bhagalpur

Period	Major carps	Large catfishes	Hilsa	Others	Total
Buxar					
1963-71	46.67	74.89	744.00	247.33	1112.89
1972-80	64.12	89.95	53.90	138.35	346.32
1981-86	72.26	132.96	22.37	308.26	535.85
Patna					
1961-66	389.20	373.8	234.70	813.70	1811.30
1986-93	118.40	194.48	1.38	469.69	783.94
Bhagalpur					
1961-70	143.54	240.23	32.85	454.00	870.62
1972-80	90.50	189.74	5.22	372.66	658.12
1981-88	46.03	205.73	7.12	403.98	662.86

With the construction of Farakka barrage on river Ganga, the fishery scenario at Lalgola centre about 45 km below Farakka barrage, showed a major change in stock structure. Prior to Farakka, the hilsa used to be the main fishery (92.02%). With the commissioning of the barrage, hilsa contribution came down to merely 16.8% and the niche was replaced by other species. The details are depicted in Tab. 9.

Table 9: Catch composition (%) at Lalgola, pre and post Farakka period

Group	Period		
	1963-76	1980-90	1991-00
Major carps	0.33	4.47	9.76
Large catfishes	0.12	9.34	13.58
Hilsa	92.02	29.68	16.80
Others	7.53	56.51	59.86
Total (t)	121.43	57.31	106.35

Brahmaputra

Investigations carried out in the entire Brahamputra stretch both in Arunachal Pradesh and Assam during 1996-98 showed that the fishery of main river Siang and its other two components Lohit and Dibang was dominated by mahaseer (*T. putitora* and *N. hexagonolepis*), snow trouts (*S. richardsonii*) and other cold water species (*L. dero, L. dyochilus*). At the confluence of three rivers (Sadiya), the above species contributed around 60% and the rest was catfishes and other smaller species. From Dibrugarh the fishery shifted to major carps, minor carps, catfishes, hilsa and others. Based on CIFRI studies during the years 1973-79, the average fish catch at Tezpur, Guwahati and Dhubri was as 50.15, 110.54, 54.93 t per year. In the entire stretch the contribution of major carps, minor carps, large catfishes, featherbacks, hilsa and others were 19.2, 14.2, 23.2, 3.7, 12.0 and 27.9%, respectively, the inter stretch variation was of smaller magnitude. However, the contribution of hilsa at Tezpur was small (4.2%) as compared to Guwahati and Dhubri (13.7-15.5%). The fish landings at different centres are shown in Tab 10.

The studies made in 1996-98 showed considerable decline in fisheries from the river with a significant qualitative change. The total landings declined from 215.62 t to 150.42 t. Major carps, minor carps and catfishes contribution reduced to almost half and hilsa fishery touched a very low level. However, the fishery of smaller species showed an improvement and increased by 41%.

Table 10: Fish catch (t) from Brahmaputra and contribution (%) of various groups

Group	Period	Major carps	Minor carps	Catfishes	Feather backs	Hilsa	Others	Av. annual catch (t)
Tezpur	1974-77	10.48	7.82	13.09	2.11	2.21	14.44	50.15
	1996-98	3.91	1.02	6.40	3.44	0.00	19.25	34.02
Guwahati	1973-79	20.67	16.14	23.32	4.64	15.14	30.62	110.54
	1996-98	11.02	11.89	6.31	2.90	2.18	38.22	72.53
Dhubri	1974-77	10.16	6.70	13.24	1.26	8.51	15.05	54.93
	1996-98	6.23	0.66	6.93	1.49	1.49	27.07	43.87
Total	1973-79	41.32	30.66	49.65	8.01	25.87	60.11	215.62
	1996-98	21.17	13.57	19.64	7.83	3.67	84.54	150.42
Change in two phases (%)		-48.8	-55.7	-60.5	-2.3	-85.8	40.6	-30.2

Peninsular rivers

Mahanadi

As far as fishery is concerned not much information is available from Mahanadi. During 1995-96, an exploratory survey of river Mahanadi was carried out by CIFRI and for the purpose of information river was divided into three stretches. In the upper stretch fish landings were observed at Dhamtari, Rajim, Mahasamund, Aurang, Seorinarayan, Chandrapur, Raigarh, Surajgarh and Mahadeopalli fish markets. The total fish catch from these centres was estimated as 143.28 t, comprising of major carps (15.0%), large catfishes (40.3%) and other smaller species (44.7%). Among others about 2/3rd was contributed by minnows.

In the middle stretch (below Hirakud reservoir to Narsinghpur), the fish markets, *viz.* Burla, Sambalpur, Binka, Sonepur, Baunsuni, Baudh, Charichak, Angul and Narsinghpur) were studied for landing pattern. The total catch from these centres was estimated as 153.16 t. As compared to upper stretch the proportion of catfishes reduced to half but the contribution of major carps increased and reached to 34.9%. However, the share of others remained almost similar but with a change in structure. In this stretch the prawn fishery was important and both smaller and large species formed about 10% of the total fishery.

In lower stretch (freshwater zone) below Narsingpur (Sasang to Balikuda) the fish catch was poor (86.2 t).

In all the stretches bulk of the landings was during post monsoon months, however, in the upper stretch monsoon months also contributed significantly.

Godavari

CIFRI made observations on fish catch from a 189 km long stretch of river Godavari during 1963-69. The stretch was divided into three zones. Zone I comprised a 33.6 km stretch between Dowleswarm and Pattiseema; Zone II, a 59.2 km stretch between Polavaram and Jidiguppa and Zone III, a 96.2 km long stretch between Kunavaram and Dummagudam. In three zones, 11 centres were selected for investigations. Zone I consisted 4 centres (Rajamundry, Dowlaiswaram, Bobbarlanka and Kovvur), Zone II 4 centres (Polavaram, Divipatham, Kondamodalu and Jidiguppa), Zone III 3 centres (Kunavaram, Bhadrachalam and Dummagudam). Total catch from the entire stretch was estimated as 263.1 t per year, the contribution of three zones being 190.82, 32.56, 39.71 t, respectively. Prawn was the major fishery in Zone I with a share of 39.9% in total. In Zone II and Zone III, major carps and *L. fimbriatus* were the main component and formed 30.6 to 50.9% of the total landings. Hilsa fishery was mainly from Zone I (13.6%), in rest zones its contribution was insignificant. The others group were almost same (32%) in Zone I and Zone II, but shared about half in Zone III. The total yield from the entire 189 km stretch fluctuated between 218.0 t in 1969 to 330.1 t in 1963 depicting a declining trend.

On the basis of recent studies conducted by CIFRI, fishery was very poor in the upper stretch of Godavari (origin to Nanded), consisting mainly smaller species. The annual catch from 134 km stretch of river in Nanded district was about 100 t consisting of carps (*C. catla, L. rohita, C. mrigala* and *L. fimbriatus*), catfishes (*A. aor* and *A. seenghala*) and miscellaneous fishes. Nanded centre used to be an important fishing ground before the construction of Sriramsagar dam at Pochampad. In the isolated pools of the river, *G. affinis* and *P. reticulata* were also recorded. In the middle stretch (Nanded down to Eturunagaram) among carps *L. fimbriatus* was the dominant species followed by *L. rohita* and *L. calbasu* in the post monsoon months. Catfishes *A. aor* and *A. seenghala, S. childreni* and *W. attu* also contributed significantly. Prawn fishery was observed at Eturunagaram and Manthani centres. Hilsa catches were not observed beyond Rajamundry. From January to June, fishing is mainly for prawns and fish occurs only as a by-catch. In lower stretch, major carps *L. rohita, C. catla, C. mrigala* and *L. fimbriatus* occurred in their order of abundance. Catfishes were represented by *A: seenghala, A. aor, S. childreni, P. pangasius, P. taakree* and *W. attu*. The fishery of others group was significant.

Krishna and Cauvery

There is limited information available about fish and fisheries of Krishna and Cauvery rivers. However, during recent survey conducted by CIFRI, the important species available were recorded and has already been described. In the stretch below Mettur dam in Cauvery, the catch per unit effort was estimated at 1-6 kg d^{-1} during full water level. It ranged from 10 to 100 kg d^{-1} when releasing of water from Mettur was stopped. A sizeable catch (50 to 300 kg d^{-1}) was caught with a minimum labour of 2-3 fishermen through trapping of fishes at the sluice gates in the regulators and anicuts.

Narmada

In order to obtain the estimate of total fish production of Narmada in Madhya Pradesh, important fish markets were surveyed in the 720 km stretch of river (Mandla to Barwani) during November 1960-March 1961 by Narmada-Tapti unit of CIFRI. For Eastern zone (Mandla to Gadarwara, 240 km), the fish catch for three months was estimated at 36.9 t. The catch for five months from central zone (Gadarwara to Harda, 240 km) was estimated at 52.5 t. For Western zone (Harda to Barwani, 240 km), the landings were estimated at 33.85 t for a period of four months.

On the basis of CIFRI studies the fish catch for the period 1958-66 from a 48 km stretch of river Narmada, based on two fish landing centres (Hoshangabad and Shahganj) ranged between 32.3 and 57.2 t, the average being 41.5 t. *T. tor* and *L. fimbriaus* were the important constituents and formed 28.0 and 19.7% of the total landings. The contribution of major carps, large catfishes and others were 7.2, 21.4 and 23.7%, respectively.

The Department of fisheries, M.P. estimated fish landings at Maheshwar, Mandleshwar, Hoshangabad and Shahganj around 1970, while Rao has collected data from Punasa, Omkareswar, Mandleshwar, Maheshwar and Barwani during 1989-90. These studies did not reflect significant qualitative change in catch as compared to CIFRI studies during 1958-66.

On the basis of CIFRI studies during 1996-99 for a 280 km stretch of river between Sandia and Mola the annual fish catch was estimated at 129.22 t, comprising of *Tor* spp. (15.9%), *L. fimbriatus* (10.2%), major carps (5.2%), catfishes (43.3%), minnows (12.4%) and others (13.2%).

For Mandla-Gadarwara stretch of river Narmada, the total catch at five centrec, *viz.*, Mandla, Jabalpur, Narsinghpur, Kareli and Gadarwara was estimated as 269.55 t. The catch data clearly showed the dominance of miscellaneous species (47.3%) followed by major carps (28.8%) and catfishes (23.9%). Among the different stretches Mandla showed maximum production. The better catch in this stretch may be due to upward migration of fishes during monsoon months from Bargi dam. Among carps *C. catla* contributed maximum (36.2%) followed by *C. mrigala* (25.7%), *L. rohita* (13.3%), *L. calbasu* (13.1%), *T. tor* (7.8%) and *L. fimbriatus* (3.9%).

Tapti

There is not much information available about fish catch from river Tapti. Based on CIFRI studies during 1959-60 in a 728 km long stretch of the river from Burhanpur (Madhya Pradesh) to Kathor (Gujrat) on seven landing centres, the total fish catch was estimated as 31.20 t per year. From fishery point of view Tedtalai and Kathor were the important centres with a share of almost half in total landings. Carps (*T. tor* and *L. fimbriatus*) were the main constituent of catches. At Bhusawal the catfishes contribution was significantly high (44.5%), whereas the proportion of others was maximum (55.2%) at Raitalai. The catch structure at different centres is presented in Table 11.

Table 11: Contribution (%) of important species and different groups from Tapti

Species	Madhya Pradesh			Maharashtra		Gujarat	
	Burhanpur	Raitalai	Tedtalai	Bhusawal	Adelabad	Mandvi	Kathor
T. tor	60.7	13.8	40.5	44.5	57	34.6	59.7
L. fimbriatus	3.8	0	8.6	11.0	0	22.4	27.8
C. mrigala	0	0	0	0	6.7	0	2.0
L. calbasu	0	9.6	0	0	0	6.9	2.8
P. boggut	0	21.4	14.2	0	8.4	0	0
Large catfishes	19.0	0	18.3	44.5	7.5	13.7	6.3
Others	16.5	55.2	18.5	0	20.4	22.4	1.4
Total (t)	2.58	1.38	9.60	3.00	2.10	3.00	9.60

Factors influencing fish production from rivers

Fish production from rivers is influenced by a number of factors, out of which hydrological regimes, environmental degradation and fishing pressure are most important.

Hydrological regimes: Flood waters are important for most species of fish because the flooding of lateral plains increase the habitat rich in food, shelter from predators and provides ideal site for fish to develop and grow. The annual hydrological cycle influences the migration of many species between floodplain and main channel. The abundance and biomass of floodplain dependent species and the related fish catch fluctuate from year to year depending on the strength of flooding. Correlation between catches in a particular year and the intensity of flooding in the same or preceding year has been found in a number of rivers. Some authors have found correlation between catch and the amount of water persisting during lean seasons. Flood component of the hydrological regime is the most important factor affecting fish production although the dry season component can not be ignored. The effect of declining water level on fish production and catch has been illustrated when flooding fail over number of successive years.

There has been drastic change in hydrological regime of Indian rivers over the years. Due to erratic monsoon precipitation and controlled flow, the flooding pattern of rivers has changed and do not coincide with the demand by fish for favorable breeding conditions. In several cases absorption in fishes has been observed in Ganga. This has badly hampered the breeding and recruitment processes in rivers, resulting in decline in catches, especially for rheophilic and floodplain spawning species like Indian major carps that like swift flowing water.

Environmental degradation: Most of the rivers have one or more dams/barrage for utilization of river water for irrigation, water supply, power generation and other developmental activities. The larger dams/barrages are the major cause for degradation of the aquatic environment and disruption of the livelihood of communities dependent on fishery along the river valley. Dams have a major effect on fisheries downstream. They act as a barrier to upstream and downstream migration. They also regulate water flow so as to change the amount and timing of discharge and can prevent the regular inundation of down river floodplains. The loss of floodplains below major dams has been observed in many cases and even the failure of flooding has been observed. The creation of dams decreases the river flow and also the timing, extent and duration of floods is altered. Decreased river flow has tremendously affected the flushing property of rivers and aggravated the sedimentation effect. This results in sharp decrease in fish populations due to loss of breeding and nursery grounds ultimately affecting the recruitment process. The reduction in the catch is usually accompanied by change in species composition whereby flow loving and floodplain spawning rheophilic species are replaced by lentic species that favour still water and those breed in main channel. This change also often results in local loss of species. The effects become more marked in systems already stressed by water level. This may be important reason for the establishment of common carp and tilapia fishery in Ganga and Yamuna, the fishery of these exotic species could not develop in Ganga below Varanasi due to increase in flow and fast current.

In addition to discharge regulation and heavy siltation due to deforestation in the catchment area, dumping of untreated domestic and industrial effluents and agricultural fields washings in the rivers aggravates the situation further. Due to heavy siltation the river beds rise and this result in decline in water retention capacity of the rivers, thus, a loss to habitat. Studies in Ganga have shown tremendous increase in silt load over the years. The situation became worst during 1995-00, with silt load increasing up to twenty times at Allahabad and thirty times at Varanasi over the years 1980-85. Incidentally, this coincided with the worst period for fishery from the system. In Brahmaputra the river bed has risen by 4.5 m due to accumulation of silt during a period of fifty years from 1937 to 1987. This has resulted in choking of many wetlands and loosing their connection with main river. In Ganga the heavy silt load has resulted in significant decline in water volume and during lean seasons very low quantum of water remains in the river between Farrukhabad and Allahabad which used to be important fishery resource. How, the water volume affects fishery can be well illustrated by the example of Hooghly estuary, where the quantum jump in water volume after the commissioning of Farakka barrage resulted in sharp increase in estuarine fishery from 9482 t (1966-75, pre Farakka period) to 62,000 t (1999-00).

A critical analysis of data from Ganga and Brahmaputra for last four decades have shown considerable decline in fisheries along with change in species composition. The fish yield from Ganga system at Allahabad was as high as 935.4 kg km^{-1} during sixties but it has reduced to 368 kg km^{-1} in recent years. The contribution of major carps reduced from 46% to hardly 10% and large catfishes reduced to almost $1/5^{th}$, however, other smaller species showed marginal increase. Hilsa which used to be important fishery in the middle and lower stretches of Ganga and Yamuna has almost collapsed with the commissioning of Farakka barrage. Similar situation was observed in other stretches also. In Brahmaputra, the landings at studied centres declined by 30% over a span of two decades. The contribution of major carps, minor carps and large catfishes reduced to almost half, whereas hilsa fishery declined to a very low level. However, smaller species showed an increase of 41%. The major cause for decline in fishery may be due to loss of wetlands which used to be ideal breeding and nursery grounds. Although no detailed information is available on other rivers, but information collected during exploratory survey depicted more or less similar picture as in case of Ganga and Brahmaputra.

Fishing pressure: In rivers a large number of fish species are exploited by using a range of fishing gears, each adapted to particular species life stages and habitat. Use of gear varies from season to season in such a way that nearly all life stages of the species are vulnerable to capture.

Recent studies in Ganga have shown a sharp change in gear pattern. During sixties dragnets used to be the principal gear and gill nets use was little. With the passage of time dragnets were replaced by gill nets. Being low energy gear and cheaper in cost, this increased fishing pressure in river considerably. In some stretches very large dragnets made up of mosquito netting cloth are in use, which filters all stages of fish from river. Earlier generally the fishing was undertaken by traditional fishermen but the growing population and increasing shortage of land means and lack of other livelihood avenues many people from other communities have forced to fishing. The pressure on riverine fish resources have tended to increase over the last three decades. Increase in fishing effort put a serious pressure on fish stocks and eliminates the larger individuals and species from multi species communities and replaces them with smaller species and individuals. The intensive fishing pressure in rivers is now wide spread and the impact has been clearly reflected on their fisheries.

The Second International Symposium on The Management of Large Rivers for Fisheries concluded that there are no proven causes of a river fishery as a whole have been collapsed from fishing pressure alone. Where collapse has occurred, they have always been linked to degradation in the environmental quality because of altered hydrological regimes caused by dams and barrages, *etc*.

The studies in different river systems have shown that the water quality parameters are by and large in the productive range. In Ganga four decades investigation have shown many ups and downs in respect of water quality in some stretches. During eighties the discharge of huge quantity of domestic and industrial effluents resulted in serious degradation in water quality at Kanpur and Varanasi with dissolved oxygen declining to

Plate 5: Drag netting in river Yamuna near Kairana (U.P.)

almost zero level and other chemical parameters including BOD and COD load increasing sharply. But after regulation in discharge, there was tremendous improvement in water quality. In Yamuna an important tributary of Ganga the condition is still pathetic due to heavy discharge of effluents specifically in Yamunanagar to Agra stretch. The situation has become more critical due to heavy abstraction and regulation in water discharge. In other river systems, the impact of pollutants, if any, were confined around the outfall region only and no serious degradation in water quality has been observed. Similarly, in respect of biotic set up, barring some quantitative and qualitative variation, not much change has been observed. The rivers have shown good potential energy resource and this has not shown any declining tendency, except for discharge point areas. In spite of favorable conditions maintained by the rivers, the fishery has shown a constant declining trend as observed in almost al the rivers.

The key factors identified for such decline are erratic flood pattern, regulation in flow, reduction in water volume, heavy siltation, and increased fishing pressure and indiscriminate fishing. Creation of dams, barrages, embankments, and subsequent regulation of river flow appears to be main reason for degradation of riverine environment. Numerous hydraulic structures have come up on Indian rivers without looking in to their impact on ecosystem itself. The minimum, adequate environmental flow for sustainable fishery is being debated worldwide and methods are being developed to estimate these requirements under diverse conditions.

Looking into dismal state of this natural fishery resource, serious effort should be made to save rivers from further disaster and to bring them to their original healthy status. If steps are not taken for mitigating the situation then in coming years, rivers may loose their identity and source of original fish germplasm will be lost. Conservation of fish germplasm is essential for sustenance of freshwater aquaculture where genetic deterioration due to inbreeding is already evident. Further, the riverine fishery is the main source of livelihood for countless fishers and thus loss to riverine fishery will create a socio-economic problem.

Conservation measures

In order to conserve the fishery resources and for optimum utilization of potential energy resource the following should be taken into consideration.

1. At present there seems to be no chance of changing the hydraulic scenario, therefore effort should be made to estimate the minimum flow required for the maintenance of healthy ecosystem, for the restoration of lost breeding grounds and to restore the failed recruitment process. Studies have shown that if the river is to be maintained close to its pristine state, as much as 60-80% of the total annual natural flow may be required. In highly developed river basins, where water reallocation is difficult, the environmental flow component may be as low as 15-20%. This may be achieved by negotiation with all stakeholders so that the required flow and depth of the river is maintained round the year.

2. The restoration of wetlands should be point of focus. It is encouraging that the importance of flood plains as integral part of riverine ecosystem has been realized in recent years. These floodplains, many of which have already lost their connection with the main channel due to heavy siltation, play an important role in storing huge quantity of water during peak flow and storm run off in rainy season and subsequently release them during lean months. In addition they serve as breeding and nursery grounds especially for major carps, and ultimately help in their recruitment process. Studies in Ganga and Brahmaputra river systems have pinpointed relationship between decline of fisheries and choking of wetlands. Under prevailing situation the restoration of flood pain wetlands becomes primary requirement although it needs great political will to change the land use back to that in the past.

3. Heavy siltation being real culprit for reducing the water holding capacity, decline in water volume and choking of wetlands, efforts should be made to check the sediment flow by extensive plantation of native trees, shrubs, reeds, *etc.* on the river bank and nearby catchment area.

4. In order to control increased fishing pressure, an important cause of decline in fishery, mass awareness programs should be undertaken to educate the fishing communities about the ill effects of indiscriminate killing of brooders and juveniles and non judicious exploitation of fishing stocks. In addition schemes should be provided for alternative livelihood resources for the fishers keeping in view their strength and capabilities.

5. Severe reduction in flow rate, decline in water volume and stagnant water conditions with feeble current have led to the emergence of exotic species especially common carp and tilapia in Indian rivers. Since these fishes got ideal condition for breeding and recruitment, they have established in the system and their contribution in the total fish yield is becoming significantly high. The exotic species in our riverine system is a serious thing as they may hamper the possible recovery of endemic species, specifically Indian major carps. The studies in Ganga have shown that the

exotic species have not been found below Varanasi, may be due to improved hydrological regime with fast current and increased water volume. There seems to be no way out of the elimination of these exotics from the system, but immediate steps should be taken to check the invasion of other exotic species so that the conditions are not further worsened. Proper flow and increase in water volume may help in natural elimination of exotics from the riverine systems; on other side improved hydrological conditions may help in augmenting the breeding and recruitment process of Indian major carps.

6. The fishery of migratory species has been badly affected due to construction of dams and barrages on rivers since provided fish passes failed in their purpose. A clear example is hilsa fishery in Ganga, which used to form a good share in catches in stretches below Allahabad has almost disappeared after inception of Farraka barrage although fish ladders were provided. Steps should be taken to improve the fish pass ways so that the fishes may negotiate upstream areas.

7. Rivers being state subject, state governments should give proper attention to these natural resources, so that they may regain their original character.

8. National River Conservation Directorate, Central and States Pollution Control Boards have launched number of schemes for improvement in water quality of rivers, but results could not be achieved up to targeted levels. The work under formulated schemes may be geared further, so that water quality may be improved to desired level. The improvement in water quality will give a chance to rebuild the fish stocks in the affected zones.