Current Status of River Ganges

I. Origin

The river Ganga (Ganges) has originated from two headwaters at an altitude of about 6000 m in the Garhwal Himalaya, it flows through the Sivalik hills and entered the plains at Haridwar. Then it flows southwards, meandering over several hundred kilometers in the Indo-Gangetic plains in Uttar Pradesh, Bihar and West Bengal, ultimately to join the Bay of Bengal. Ganga is about 2,525 km long and its basin is 8,61,404 km^2, draining about one fourth area of the country. The river system covers cool upland streams and warm water stretches, including deltaic habitats. The surface water availability in the Ganga basin is about 446 million acre feet and the annual flow of freshwater in the river is estimated at 142.6 million m^3, resulting from the melting of snow in the Himalayas and monsoon rains. The tributaries to the south of the Ganga are the Yamuna and the Sone. The Yamuna flows to the west and south of the Ganga and joins it almost halfway down its course. The Sone has originated in the hills of Madhya Pradesh. To the north of the Ganga, the large tributaries are Ramganga, Gomti, Ghagra, Gandak, Kosi and Mahananda. Beyond the Mahananda the river enters its own delta, formed by its distributaries, and then merges into the combined delta of the Ganga, Brahmaputra and Meghna rivers. The Ganga carries 616 x 10^6 tons of suspended solids to the Hooghly estuary. The river holds a copious biological wealth, characterized by its rich faunistic diversity. From fisheries point of view, Ganga is regarded as the most important river of India, mainly because a substantial part of the river passes through hospitable terrains of the plains. Apart from being the original abode of the most prized carp species of the subcontinent, *viz., Catla catla, Labeo rohita, Cirrhinus mrigala* and *Labeo calbasu*, the river sustains fisheries of large catfishes, mahseers, hilsa and other miscellaneous fishes. Ganga is also the major source of riverine spawn, which meets the carp seed requirements of the culture sector to the tune of 30%. In order to get a clear picture, the river has been divided into different stretches. Upper stretch is from Deoprayag to Kanauj, middle stretch from Kanpur to Patna, lower stretch from Sultanpur to Katwa; estuarine stretch (freshwater gradient) from Nabadwip to Haldia and estuary (marine) from Kakdwip to Frazergunj. The map of the river Ganga from its origin to its merger with the Bay of Bengal is given in Fig. 1.

Fig. 1. Map of the river Ganga from its origin to its merger with the Bay of Bengal

II. Climate

Annual rainfall of the Ganga Basin ranges from 250 to 4000 mm. The summer monsoon climate is characterized by wet summers, with very little rain. Heavy monsoon showers begin in the south of India and a part of south-east Bangladesh at the beginning of June; they gradually spread inland. In approximately 10 days, the whole Lower Ganga Basin receives heavy showers. In the Middle Ganga Basin, the onset of the summer monsoon season is in the middle of June. In the Upper Ganga Basin, the heavy rains begin some 10 days later. The city of Khulna in the Lower Basin receives most of its rainfall from June to October. The plains in the Middle Basin receive 800 to 1,200 mm, and the plains in the Upper Basin get 400 to 800 mm of rain.

In the Lower Basin, three seasons are generally recognized: monsoon (June-October); winter (November-February); and summer (March-May). Although the monsoon months are remarkably wet, the winter months are suddenly very dry. Rainfall in these four months averages only about 100 mm. Winter rainfall in the Ganga Basin is due to the retreat of the southwest monsoon. This retreat is gradual in the Upper Basin, a striking contrast to the sudden burst when it arrives. By early September, the monsoon season is over in the Delhi area (Upper Ganga Basin), and by late September it is over even in Patna in the Middle Basin. While the last of the southwest (summer) monsoon still brings showers in the Lower Basin, the drier northeast (winter) monsoon winds begin to blow in the Upper Basin. By the middle of October, the Lower Basin is subjected to dry continental air and the summer monsoon rain ceases.

The Ganga-Brahmaputra delta area has a typical monsoon climate with a warm and dry season from March to May. A rainy season from June to October follows, as does a cool period from November to February. The mean annual rainfall is 2,000 mm, of which approximately 70% occurs during the monsoon season. Rainfall generally varies in a northwest to southeasterly direction, increasing from a mean annual rainfall of 1,500 mm in the northeast to 2,900 mm in the southeastern corner.

Potential evapo-transpiration rates are about 1,500 mm, exceeding the rainfall rates from November to May. The relative humidity is high, varying from 70% in March to 89% in July. The area experiences moderate to long periods of sunshine, with over 8.5 hours outside the monsoon season being common. The mean annual temperature is 26°C with peaks of over 30°C in May. Winter temperatures can fall to 10°C in January.

The southern region of the area, and in particular the southeastern coastline, is vulnerable to cyclones during the monsoon season. Storm surges can cause dramatic increases in the water level of up to 4 m above tide and seasonal levels. The southwest coastline is protected to some extent by the dampening effects of the Sunderbans.

III. Littoral states and ecosystem benefits

The Ganga river tributaries in India pass through the states of Uttarakhand, Uttar Pradesh, Rajasthan, Madhya Pradesh, Bihar, Jharkhand and West Bengal. The length of river stretch in different states is mentioned in Table 1.

Table 1. River stretch under Ganga Basin States in India

River system	Name of the main rivers	Approximate length (km)	States
Ganga	Ganga	2525	Uttar Pradesh, Bihar, Jharkhand, West Bengal
	Ramganga	569	Uttar Pradesh
	Gomti	940	Uttar Pradesh
	Ghagra	1080	Uttar Pradesh, Bihar
	Gandak	300	Bihar
	Kosi	492	Bihar
	Subarnarekha	395	Bihar, Jharkhand, West Bengal
	Yamuna	1376	Punjab, Haryana, Delhi, Uttar Pradesh
	Chambal	1080	Madhya Pradesh, Uttar Pradesh, Rajasthan
	Tons	264	Uttar Pradesh
	Sone	784	Uttar Pradesh
	Ken	360	Madhya Pradesh

Anon, 2005

The Ganga river system has combined length of 12,500 km and a catchment area of 97.6 million ha. The Ganga, Ghagra, Gomti, Ramganga, Kosi, Gandak, Yamuna, Chambal, Sone and Tons are the major rivers of this system. These rivers are spread over most of the north Indian states (except the hilly states) to extend up to West Bengal through Bihar. In the upland waters of the system commercial fisheries is virtually absent, due to inaccessible terrain and other exploitation problems. The Haridwar to Lalgola stretch of river Ganga is recognized as one of the richest sources of capture fisheries in India, comprising highly priced major carps, hilsa and catfishes. Middle of September to June is peak period for fishing. During lean period of monsoon months the fishing activities are generally confined to riverbanks.

Among the two riparian countries, the country with the larger population is India (1,032 million), followed by Bangladesh (133 million). Bangladesh has the higher population density (1,024 people/km^2), which is several times the density of India (347 people/km^2). Surprisingly, rural population density is higher than overall population density in these countries. Bangladesh is the faster growing country in the Basin, with a population growth rate of 1.74%) followed by India (1.50%). In both the countries, rural population growth rates are lower than national population growth rates, which points to a population explosion in urban areas, particularly in large metropolitan centers. The Basin countries are largely rural : the country with the lower percentage of rural population is India 72%, while Bangladesh has 74%. India has the lower numbers in the 0-14 year age bracket (33%). However, the major portion of the population falls into the working ages of 15-64 years in the countries, being higher for India (62%) and lower for Bangladesh. A higher proportion of the population in growing ages and in working and retirement ages (65 and above) in India suggests a relative slowdown in population growth rate and ageing of the population. High population growth rates and fast-growing populations in these countries remain a cause for concern in terms of food security and poverty alleviation.

Among the two Basin countries, India, by the sheer size of its population, has the largest labor force (461 million), followed by Bangladesh (71 million). During 1980-99, the labor force grew at an average annual rate of 2-2.8% in the countries, the rates being higher in Bangladesh (2.6%), and lower in India (2.0%). As noted earlier, these countries are overwhelmingly rural, with agriculture employing a large proportion of the total labor force. For example, agriculture employment accounts for 66% of total employment in India and 63% in Bangladesh. Agriculture accounts for about 50% of the male employment in Bangladesh.

The river Ganga supports fisheries resources and contributes significant economic benefits to the riparian communities and the national economy. It is utilized to support and provide benefits to the inhabitants at the basins, including hydropower, transportation, freshwater and food in the form of fish and fish products, in addition to its cultural, religious and recreational values. The on site benefits included fisheries; habitat for bio-community; recreation and tourism in the form of boating, swimming and water sports; transportation and waterways, domestic needs for bathing, washing cloths, tending cattle, dumping of sewerage and domestic waste, sand collection, *etc.* (Katiha and Marothia, 2006). The offsite benefits may be due to water abstraction and utilization of this water for agriculture, domestic use and industry. Besides, it has many indirect use benefits for ecological functions, flood control, watershed protection, nutrient cycling, pollution reduction, micro climatic functions and natural habitat biological/ ecosystem support.

IV. Ecological status

a) Sediment quality

The detailed account of soil quality of river Ganga, observed during an exploratory survey during 1995-96 by the CIFRI, based on holistic sampling at 43 centers from its origin to sea, showed that river-bed from Tehri to Patna (upper and middle stretch) is sandy with high percentage of sand (79 to 99.8%); clay being nil to 12% (Table 2). However, sand percentage decreased (34 to 79%) in the lower stretch (Sultanpur to Katwa) with corresponding increase in clay and silt load. It indicated that the stretch between Tehri and Patna suffered severely from textural deformities and sand drifting through a number of tributaries (rivers Ramganga, Yamuna, Gomti, Ghagra, Sone, Gandak, *etc*.) in this region, heavily blanketed the river bed. The run off from denuded catchments are also responsible for deformities of riverbed. Naturally, the blanketing of river-bed has prevented the contributions of soil to the aquatic productivity. Downstream of Patna, the tributaries of river Ganga are much more seasonal and Ganga passes through a predominantly clayey bed. As such, a sudden transformation in sediment texture was observed as the river flows in the lower stretch. The sediment is neutral to alkaline with relatively higher values in the estuarine stretch. Due to the dominance of silt and clay fractions in the estuarine stretch, the recorded organic carbon, total nitrogen and available phosphate content was also moderate with respect to the lower values in the upper stretches.

b) Water quality and quantity

The information provided here on water quality, biotic communities and primary productivity of the river are based on the report of the same exploratory survey of CIFRI (Sinha *et al*, 1998). The water temperature was found to fluctuate within a narrow range (19.8 - 25.5 ^{o}C). The Ganga water has a strong buffering capacity and thus, there was a little fluctuations in pH in the entire stretch (7.7-8.07). Alkalinity, conductance, dissolved solids, calcium, magnesium and hardness however, showed considerable variations. The parameters exhibited their minimum values in the upper stretch (101 mg l^{-1}, 245 mS cm^{-1}, 124 mg l^{-1}, 14.6 mg l^{-1}, 5.6 mg l^{-1} and 98.2 mg l^{-1} respectively) and showed a sudden rise in the middle stretch between Kanpur and Patna. In the lower stretch, their values again decreased. In the gradient stretch the values of alkalinity, conductance, dissolved solids, calcium, magnesium and hardness sharply increased to reach to the very high levels in the marine zone. The nutrient status of the river in respect of nitrate and phosphate was poor. The water quality of

Table 2. Important soil parameters of the freshwater stretch of Ganga

Parameters	Upper stretch (Tehri - Kanauj)	Middle stretch (Kanpur - Patna)	Lower stretch (Sultanpur - Katwa)	Estuary (Fres water & gradient zone) (Nabadwip - Haldia)	Estuary (Marine zone) (Kakdwip - Frazerganj)
pH	6.8 - 8.5	7.1 - 8.4	6.5 - 8.4	7.8 - 8.6	8.2 - 8.8
Sp. cond. (µ S cm^{-1})	0.11 - 1.64	0.08 - 0.92	0.06 - 0.48	0.05 - 1.36	1.23 - 8.00
Organic carbon (%)	0.01 - 0.49	0.02 - 0.35	0.05 - 0.61	0.22 - 1.26	0.46 - 0.80
Total nitrogen (%)	0.003 - 0.02	0.011 - 0.078	0.007 - 0.048	0.019 - 0.084	0.042 - 0.067
Phosphate-P (mg $100g^{-1}$)	Tr. - 0.05	Tr. - 0.8	0.79 - 3.9	1.2 - 16.1	1.8 - 16.1
Free $CaCO_3$ (%)	0.8 - 14.5	0.25 - 8.5	4.7 - 14.0	4.0 - 17.5	5.5 - 15.5
Sand (%)	97.3 - 99.8	79.0 - 99.5	34.0 - 79.0	30.0 - 58.0	30.0 - 55.0
Silt (%)	0.2 - 1.1	0.4 - 14.0	12.0 - 60.0	31.0 - 58.0	25.0 - 54.0
Clay (%)	0.0 - 1.9	0.0 - 12.0	5.0 - 24.0	5.0 - 31.0	11.0 - 35.0

Source : Sinha, *et al.* (1998)

Table 3. Range of water quality parameters of river Ganga at different stretches

Stretches of Ganga	Water temp. (°C)	Transparency (cm)	Dissolved oxygen (mg l^{-1})	pH	Total alkalinity (mg l^{-1})	Specific conductance (µ S cm^{-1})	Dissolved solids (mg l^{-1})	Calcium (mg l^{-1})	Magnesium (mg l^{-1})	Total hardness (mg l^{-1})	Chloride (mg l^{-1})	Silicate (mg l^{-1})	Nitrate N (mg l^{-1})	Phosphate P (mg l^{-1})
Upper (Deoprayag-kanauj)	9.5-29.5 (19.8)	10.0- Clear up to bottom	7.0-11.2 (9.0)	7.6-8.6 (8.07)	48-208 (101)	120-490 (245)	62-250 (124)	8.0-25.6 (14.6)	4.4-7.6 (5.6)	(98.2)	15.1-19.9 (16.8)	Tr.- 9.4	Tr.-0.31 (0.008)	Tr.-1.66 (0.04)
Middle (Kanpur-Patna)	16.0-32.0 (23.8)	16.0-140.0 (49.2)	3.6-11.9 (6.8)	7.0-9.2 (7.9)	92-236 (179)	340-740 (521)	172-381 (262)	19.2-58.5 (38.7)	0.9-32.0 (16.8)	(172.8)	10.1-43.8 (27.2)	0.6-14.4 (6.2)	Tr.-1.05 (0.012)	Tr.-0.86 (0.042)
Lower (Sultanpur-Katwa)	18.0-31.6 (24.5)	11.0-93.0 (30.9)	4.8-9.0 (7.4)	7.3-8.8 (7.7)	68-165 (126)	100-308 (178)	52-156 (89)	8.0-26.0 (16.6)	4.9-16.8 (11.2)	(110.0)	4.0-36.0 (20.3)	5.6-8.8 (7.2)	0.045-0.13 (0.068)	0.035-0.60 (0.058)
Estuary Freshwater & gradient zone (Nabadwip - Haldia)	18.8-39.9 (25.9)	8.0-30.0 (25.4)	6.2-8.0 (6.9)	7.4-8.4 (7.9)	95-174 (128)	100-70000 (759)	50-3500 (379)	8.0-376 (52.3)	1.0-65.0 (38.0)	(282.0)	4.0-3500 (273.4)	5.4-8.8 (7.8)	0.02-0.14 (0.048)	0.04-1.82 (0.24)
Estuary Marine zone (Kakdwip-Frazergunj)	18.6-31.8 (25.5)	12.0-90.0 (26.8)	4.3-8.9 (6.8)	7.6-8.5 (8.0)	90-160 (119)	2000-31000 (14118)	1000-16000 (7054)	18.0-681.0 (266.3)	27.6-916.0 (412.8)	(782.0)	860-18000 (8677)	0.5-5.9 (3.8)	0.04-0.10 (0.066)	0.06-0.51 (0.082)

(Averages in the brackets)

the river in respect of various parameters is shown in Table 3. The physico-chemical characters of the water of river Ganga during different periods is given in Table 4. It is clear that the water quality in 1995-96 in the upper stretch (Haridwar) maintained its desired quality, revealed by high dissolved oxygen (7.6-12.5 mg l^{-1}), productive pH (7.6-8.0) and low free CO_2. The middle stretch (Kanpur) of the river showed no perceptible changes in the values of most of the parameters when compared with 1960. However, a general improvement in values in comparison to 1985-90 was observed in this stretch. Dissolved oxygen values, the most important parameter for river health, in the middle stretch of river Ganga during 1995-96 clearly indicated improvement over what it was in 1985-90. In general, dissolved oxygen values have regained healthy conditions of 1960.

c) Biological communities

i) Plankton

In the upper stretch, between Tehri and Kanauj, the total plankton density varied from 58 to 1578 u l^{-1}, 95 to 1050 u l^{-1} and 60 to 1435 u l^{-1} during summer, monsoon and winter months respectively. The bulk of it was phytoplankton. Zooplankton formed only 16.6%. Bacillariophyceae being 83.4 % was the main representative of phytoplankton. Zooplankton occupied 7.9 to 34.8 % of the total plankton in the stretch between Haridwar and Kanauj. Rotifers and protozoan made their first appearance at Anupsahar and Farukhabad respectively. The overall plankton density in the entire middle stretch varied from 24 to 782 u l^{-1}, 146 to 3649 u l^{-1} and 14 to 8049 u l^{-1} respectively during summer, monsoon and winter seasons. Maximum density is at Kanpur stretch (8049 u l^{-1}) during winter. On the whole, 18 taxa under phytoplankton and 11 taxa under zooplankton were encountered in the stretch between Kanpur and Allahabad.

In the lower stretch, between Sultanpur and Farakka, the plankton density ranged between 34 and 1204 u l^{-1}. Of this,

Table 4. Physico-chemical parameters of the water of river Ganga at various stretches during different periods

Centers	Period	Parameters						
		Water temp. (°C)	pH	Dissolved oxygen (mg l^{-1})	Free CO2 (mg l^{-1})	Phosphate (mg l^{-1})	Nitrate (mg l^{-1})	Silicate (mg l^{-1})
Haridwar	1984-85	11.25-19.75	7.6-8.0	7.6-12.5	0.75-4.65	NA	NA	NA
	1995-96	12.50-26.00	7.9-8.3	8.3-9.6	0.00-3.00	Tr.	0.01-0.24	Tr.-6.2
Kanpur	1960	16.50-30.50	7.7-8.3	5.0-10.5	0.60-4.50	0.067-0.21	0.09-0.19	8.2-20.3
	1985-90	NA	6.1-7.9	3.7-8.6	NA	0.01-2.10	0.08-1.90	NA
	1995-96	16.00-30.00	7.1-8.3	5.0-9.0	0.00	Tr.-2.5	Tr.-o.24	2.4-14.2
Allahabad	1960	17.50-31.50	7.9-8.2	6.0-10.8	1.1-3.7	0.09-2.0	0.11-0.22	6.7-17.0
	1985-90	NA	7.5-8.4	7.3-8.0	NA	0.11-0.32	0.10-0.33	NA
	1995-96	17.0-32.0	7.0-8.4	5.0-11.9	0.00	Tr.-o.8	0.06-0.24	1.6-14.2
Varanasi	1960	18.5-31.5	7.6-8.4	5.0-8.9	0.00-6.5	0.08-0.12	0.08-0.14	4.0-12.6
	1985-90	NA	7.1-8.5	2.0-9.0	NA	0.12-0.73	0.16-12.49	NA
	1995-96	20.0-31.5	7.4-8.3	4.5-10.2	0.00-2.0	Tr.-1.0	Tr.-0.28	0.6-11.2
Patna	1960	18.5-31.0	7.7-8.2	5.4-8.6	2.2-10.0	0.07-0.11	0.09-0.18	7.2-14.0
	1985-90	NA	7.8-8.0	4.7-7.9	NA	NA	NA	NA
	1995-96	19.5-31.0	7.2-8.8	5.0-10.8	0.00-1.0	Tr.-o.01	Tr.-0.86	0.8-7.1
Rajmahal (Manikchak)	1960	18.5-31.5	7.6-8.1	5.0-8.9	0.00-6.5	0.07-0.12	0.08-0.14	4.0-12.6
	1995-96	21.0-31.0	7.3-7.6	5.9-8.8	0.00-5.0	0.06-0.11	0.05-0.12	7.6-8.3

Source: Sinha, et al. (1998) NA : not available phytoplankton formed 70.9 to 89.2 % and the rest was zooplankton. The total plankton production of the freshwater zone of Hooghly estuary varied from 26 to 935 u l^{-1}. In the marine zone of the estuary, the bulk of plankton was Bacillariophyceae (70–95%). Other phytoplankton groups observed were Chlorophyceae and Cyanophyceae. A decreased density of plankton in middle and lower freshwater stretches of river Ganga was observed during 1995-96 in comparison to what was reported in these centers in early sixties. But the qualitative composition of plankton witnessed little change. The pollution indicator species *Ankistrodesmus* sp., *Coelastrum* sp., *Pediastrum* sp., *Scenedesmus* sp., *Actinastrum* sp., *Cymbella* sp., *Cyclotella* sp., *Fragillaria* sp., *Anabaena* sp., *Lyngbya* sp., *Merismopedia* sp. *and Spirulina* sp. were recorded less in number in lotic waters of Ganga during 1995-96, indicating good water quality.

ii) Macrobenthos

Macrobenthic population increased gradually from Tehri to Haridwar (189 to 628 u m^{-2}). Insects were the only component in the entire stretch. Chironomids appeared for the first time at Rishikesh. At Anupsahar, the benthos population was 644 u m^{-2}, 2108 u m^{-2}, and 811 u m^{-2} in summer, monsoon and winter respectively with 55.8 to 62.9 % annelids (Tubifex), 32.0 to 40.3 % insect larvae (Chironomids) and 3.9 to 5.1 % nymphs. The occurrence of gastropods was first observed in the stretch between Anupsahar and Kanauj, but they contributed very little. The insect population had a decreasing trend from the upper to middle stretch of the river. Bivalves formed the bulk of the benthic population in the middle stretch, represented by *Lamellidens marginalis* and *L. corrisnus*. Among gastropods *Melania striatella*, *M. plotia*, *Bellamia bengalensis* were the main forms. Insect population was represented by *Tricopteran* sp. *Chironomus* and stone fly nymph. In the freshwater zone of Hooghly the dominant forms were gastropods, followed by polychaetes, oligochaetes, decapods and bivalves. The annual production of macrobenthos in the marine zone of the estuary varied between 74 and 1472 nos. m^{-2}, mostly with a dominance of gastropods.

iii) Periphyton

The periphyton flora in the riverine and estuarine stretches depicted almost similar trend of that of phytoplankton. Over the entire Ganga, Bhagirathi and Hooghly stretches, dominance of Bacillariophyceae was observed, followed by Chlorophyceae and Cyanophyceae. The average periphyton concentration in the upper stretch was between 512 and 2338 nos. cm^{-2}, of which 87 to 94% by number, was Bacillariophyceae. In the middle stretch they formed 224 to 6080 nos. cm^{-2}, the bulk of which being Bacillariophyceae.

In the lower stretch also, Bacillariophyceae followed by Cyanophyceae and Chlorophyceae were the dominant forms. In the estuarine stretch the population of periphyton was lower than the freshwater stretches.

The list of plankton and macro benthic fauna in Ganga River is given in Table 5.

d) Primary production

Gross primary production varies depending upon climatic factors, turbulence of river and water turbidity. In the upper stretch it varied between 20.8 and 202.5 mg C m^{-3} h^{-1}. In the middle stretch the values were between 15.0 and 632.8 mg C m^{-3} h^{-1}, while in the lower stretch the maximum gross production was 33.3 to 142.0 mg C m^{-3} h^{-1}. In the estuarine stretch the values ranged between 20.8 and 137.5 mg C m^{-3} h^{-1}. The gross primary productivity of the river at different stretches is depicted in Table 6.

Table 5. List of plankton and macro benthic fauna in river Ganga

Phytoplankton	**Bacillariophyceae** *Amphora* sp. *Asterionella* sp. *Biddulphia* sp. *Chaetoceros* sp. *Cosinodiscus* sp. *Cyclotella* sp. *Cymbella* sp. *Diatoma* sp. *Fragilaria* sp. *Gomphonema* sp. *Gyrosigma* sp. *Melosira* sp. *Navicula* sp. *Nitzschia* sp. *Pinnularia* sp. *Pleurosigma* sp. *Stephanodiscus* sp. *Surirella* sp. *Synedra* sp. *Tabellaria* sp., *etc.*	**Chlorophyceae** *Actinastrum* sp. *Chlorella* sp. *Closterium* sp. *Coelastrum* sp. *Conococcus* sp. *Cosmerium* sp. *Desmidium* sp. *Eudorina* sp. *Gonium* sp. *Hormidium* sp. *Microspora* sp. *Pandorina* sp. *Pediastrum* sp. *Spirogyra* sp. *Tetraspor* sp. *Ulothrix* sp. *Zygnema* sp. *etc.*	**Cyanophyceae** *Anabaena* sp. *Anabaenopsis* sp. *Calothrix* sp. *Lyngbya* sp. *Merismopedia* sp. *Microcustis* sp. *Nostoc* sp. *Oscillatoria* sp. *Phormidium* sp. *Rivularia* sp. *Schizothrix* sp. *Spirulina* sp. , *etc.*	**Xanthophyceae** *Bumillaria* sp. *Chlorobotrys* sp. *Tribonema* sp., *etc.*	**Euglenophyceae** *Astasis* sp. *Euglena* sp. *Peronia* sp. *Phacus* sp. *Trachelomonas* sp. ,*etc.*
Zooplankton	**Protozoa** *Arcella* sp. *Chilodonella* sp. *Difflugia* sp. *Globigerina* sp. *Holophrya* sp. *Noctiluca* sp. *Paramaceum* sp. *Spathidium* sp. *Sphenoderia* sp. *Tintinnopsis* sp. *Vorticella* sp., *etc.*	**Rotifera** *Anura* sp. *Asplanchna* sp. *Brachionus* sp. *Filinia* sp. *Horaella* sp. *Keratella* sp. *Lecane* sp. *Notholca* sp. *Notholca* sp. *Rotaria* sp. *Testudinella sp.,etc.*	**Copepoda** *Cyclops* sp., *Diaptomus* sp. Nauplii,*etc.*	**Cladocera** *Bosmina* sp. *Ceriodaphnia,* sp. *Cydorus* sp. *Daphnia* sp. *Diphanosoma* sp. *Moina* sp. *Simocephalus* sp.,*etc.*	**Ostrachoda** *Cypris* sp. *Gastrocypris* sp., *etc.*
Macrobenthos	**Gastropoda** *Bellamya* sp. *Gabbia* sp. *Lymnaea* sp. *Thiaria* sp., *etc.*	**Annelids** Oligochaetes, Polychaetes, *etc.*	**Insects** *Argia sp.* *Caenis sp.* *Cloeon sp.,* *Enallagma sp.,*		

Table 6. Gross primary production (mg C m^{-3} h^{-1}) of river Ganga at different stretches

Stretch	Summer	Monsoon	Winter
Upper Stretch (Tehri-Kanauj)	37.5-202.5 (108.6)	20.8-177.1 (87.6)	31.7-187.5 (86.9)
Middle Stretch (Kanpur-Patna)	112.5-632.8 (244.3)	86.9-171.9 (124.2)	15.0-142.5 (60.93)
Lower Stretch (Sultanpur-Katwah)	33.3-142.0 (71.4)	20.8-125.0 (68.8)	50.0-104.2 (72.9)
Estuary: (Gradient zone, Nabadwip-Haldia)	20.8-62.5 (47.2)	20.8-93.7 (43.1)	39.1-78.1 (63.8)
Estuary: (Marine zone Kakdwip-Frazergunj)	50.0-104.2 (67.8)	35.0-72.9 (50.1)	46.9-137.5 (95.6)

(Averages in brackets)

V. *Fish and fisheries*

a) Species dynamics

The river is home for more than 140 fish species, of which many are commercially important. The fisheries in the upper stretch of the river comprise only fresh water species whereas the lower stretch comprises both freshwater and estuarine species. The list of commercially important species available in various stretches is given in Table 7 (Sinha, *et al.* 1998).

Table 7. Commercially important species available in Ganga river system

Species	Stretch 1	Stretch 2	Stretch 3	Stretch 4	Stretch 5
Ailia coila	+	+	+	+	-
Amblypharyngodon mola	-	+	+	+	-
Anabas testudineus	-	+	+	+	-
Anodontostoma chacunda	-	-	-	-	+
Aorichthys aor	+	+	+	-	-
A. seenghala	+	+	+	-	-
Apocryptes bato	-	-	-	+	+
Aries sonar	-	-	-	-	+
A. sager	-	-	-	-	+
Bagarius bagarius	+	+	+	+	-
Barilius bendelisis	-	+	+	-	-
B. bola	-	+	+	-	-
Boleophthalmus dussumieri	-	-	-	+	+
Catla catla	+	+	+	+	-
Chanda nama	+	+	+	+	-
Channa punctatus	-	-	+	+	-
C. marulius	-	-	+	+	-
C. orientalis	-	-	+	+	-
C. striatus	-	-	+	+	-
Chela laubuca	+	+	+	+	-
C. bacaila	-	+	+	+	-
Cirrhinus mrigala	+	+	+	+	-
C. reba	-	+	+	-	-
Clarias batrachus	-	+	+	+	-
Clupisoma garua	+	+	+	+	-
Colia ramcarati	-	-	-	-	+
C. reynaldi	-	-	-	-	+
Colisa fasciatus	-	-	+	+	-

Species	Stretch 1	Stretch 2	Stretch 3	Stretch 4	Stretch 5
Crossocheilus latius latius	+	-	-	-	-
Cynoglossus cynoglossus	-	-	-	-	+
C. lingua	-	-	-	-	+
Eleotris fusca	-	-	-	-	+
Eleutheronema tetradactylum	-	-	-	-	+
Etroplus suratensis	-	-	-	-	+
Eutropiichthys vacha	+	+	+	+	-
Gagata gagata	-	-	+	-	-
Garra gotyla	+	-	-	-	-
Glossogobius giuris	+	+	+	+	-
Gobiopterus chuno	-	-	-	+	+
Gonialosa manmina	-	-	+	-	-
Gudusia chapra	+	+	+	+	-
Harpodon nehereus	-	-	-	-	+
Heteropneustes fossilis	-	+	+	+	-
Ilisha elongata	-	-	-	-	+
Johnius coitor	-	-	-	-	+
J. gangeticus	-	+	+	+	+
Labeo rohita	+	+	+	+	-
L. bata	+	+	+	+	-
L. boga	-	+	+	-	-
L. calbasu	+	+	+	+	-
L. gonius	-	+	+	-	-
Lates calcarifer	-	-	-	+	+
Lepturacanthus pantului	-	-	-	-	+
Liza parsia	-	-	-	-	+
L. cephalus	-	-	-	-	+
L. tade	-	-	-	-	+
Lycodontis tile	-	-	-	+	+
Macrognathus aral	-	+	+	+	-
M. pancalus	-	+	+	+	-
Mastocembelus armatus	+	+	+	+	-
Megalops cyprinoides	-	-	-	+	+
Monopterus cuchia	-	-	+	-	-
Mystus cavasius	+	+	+	+	-
M. bleekeri	-	-	+	+	-
M. gulio	-	-	-	+	+
M. tengara	-	-	+	-	-
M. vittatus	-	+	+	+	-
Nandus nandus	-	-	+	+	-
Nematolosa nasus	-	-	-	-	+
Notopterus chitala	+	+	+	+	-
N. notopterus	+	+	+	+	-
Ompok bimaculatus	+	+	+	-	-
O. pabda	-	+	+	-	-
O. pabo	-	-	+	+	-
Osteogeneiosus militaris	-	-	-	-	+
Otolithoides biauritus	-	-	-	-	+
Pama pama	-	-	-	+	+
Pangasius pangasius	-	-	+	+	+
Plotosus canius	-	-	-	-	+
P. lineatus	-	-	-	-	+

Species	Stretch 1	Stretch 2	Stretch 3	Stretch 4	Stretch 5
Polydactylus indicus	-	-	-	-	+
Polynemus paradiseus	-	-	-	+	+
Pseudambassis ranga	+	+	+	+	-
Pseudapocryptes lanceolatus	-	-	-	-	+
Puntius sarana	+	+	+	+	-
P. chola	+	+	+	+	-
P. sophore	+	+	+	-	-
P. ticto	+	+	+	+	-
Raconda russeliana	-	-	-	-	+
Rhinomugil corsula	-	-	+	+	+
Rita rita	+	+	+	+	-
Salmostoma phulo	-	-	+	-	-
Scatophagus argus	-	-	-	-	+
Schizothorax richardsonii	+	-	-	-	-
Setipinna phasa	-	+	+	+	-
S. brevifilis	-	+	+	+	-
S. taty	-	-	-	-	+
Sicamugil cascasia	-	+	+	-	-
Silaginopsis panijus	-	-	-	+	+
Silonia silondia	-	-	+	-	-
Strongylura strongylura	-	-	-	-	+
Tenualosa ilisha	-	+	+	+	+
T. toli	-	-	-	-	+
Terapon jarbua	-	-	-	-	+
Tor tor	+	-	-	-	-
T. mosal	+	-	-	-	-
T. putitora	+	-	-	-	-
Trichiurus gangetica	-	-	-	-	+
Wallago attu	+	+	+	+	-
Xenentodon cancila	+	+	+	+	-
Total Fish species available	34	47	63	56	45

Stretch 1 : Tehri to Kanauj; Stretch 2: Kanpur to Patna; Stretch 3: Sultanpur to Katwa; Stretch 4: Nabadwip to Roychawk (Diamond harbour); Stretch 5: Haldia to Sagar. '-'= Not available; '+'= A vailable.

Along with the above mentioned species, the following species of prawns were also recorded: *Macrobrachium lamarrei, M. birmanicum choprai, M. malcolmsonii, Parapenaeopsis sculptilis, P. stylifera, Metapenaeus brevicornis, M. monoceros, Penaeus mondon, P. indicus, P. semisulcatus, Expalaemon stylifera, E. tenuipes* and *Leptocarpus fluminicola.*

b) Catch trends and production

The catch from the river Ganga is declining day by day. The average catch per kilometer of stretch worked out from the data collected at Allahabad centre depict that in 1950's the catch was as high as 1344 kg whereas the catch declined to 362 kg during 2000s (Table 8 and Fig. 2).

Table 8. Average catch from Ganga river system at Allahabad in different decades

Decade	Catch/km (kg)
1950s	1343.64
1960s	1168.03
1970s	529.70
1980s	664.88
1990s	332.57
2000s	361.51

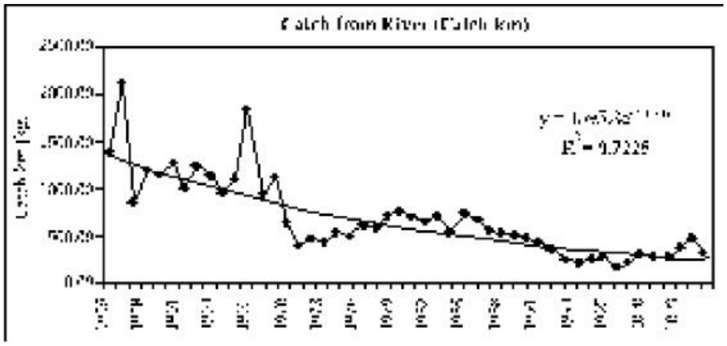


Fig. 2. Average catch from Ganga river system at Allahabad in different decades

rivers and estuaries subject to strong current and tidal movements, sturdier plank built boats are used. The boats operated in river Ganga are generally made of wood or tin (CIFRI, 2006). The fishers of river stretch in the state of Bihar generally had small wooden boat, while in the middle stretch from Kanpur to Ghazipur they had small to large boats made of either tin or wood.

c) Potential and actual production

The production potential of Ganga, in its lower reaches, is estimated at 198.3 kg/ha/year, whereas the actual fish yield is 30 kg/ha/year. Thus, only 15.2% of the potential is harvested (Sinha, 1999).

d) Fishing gear

Various types of fishing gears are in operation in the riverine and estuarine stretches. They are designed to suit the local conditions such as, depth of water, prevalent water current, desired fishes to be captured, *etc.* Some of them are selective for a particular species, but mostly a gear takes multispecies catch. The list of most prevalent gears in freshwater zone of Ganga is given in Table 9.

Hook and line was found to be the main gear in the uppermost stretch where no organised fishery was observed. In the middle stretch, gill nets and drag nets are widely operated, besides hook and line, cast net and traps. In the lower stretch of Ganga, various types of gill nets (*chandijal, phansijal*), drag net, seine net (*kochal, konajal, berjal, chatberjal*) dip or lift net (*gara basal; nauka basal*), purse net (*sangla jal*) are the main gears. Other gears *viz.,* falling net (cast net), scoop net, hook and line and traps are also used in this stretch.

e) Fishing crafts

The fishing boats used throughout the river are mostly indigenous, non-mechanized and locally built, except for mechanized boat in few stretches. They have been designed to suit local conditions. The simplest and most primitive types of boat used for fishing in the river are the rafts and *dongas*, operated in calm waters. In the larger rivers and estuaries subject to strong current and tidal movements, sturdier plank built boats are used.

rivers and estuaries subject to strong current and tidal movements, sturdier plank built boats are used.

The information on boat(s) per fisherman in different stretches of Ganga revealed that in comparison to 1960s the availability of boats had increased (CIFRI, 2006). It was due to change in fishing practices and demographic pattern towards nuclear families. The percentage of fishers having own boat varied from 38% in upper stretch to 89% in middle stretch.

Another study in different stretches of Ganga river systems (Sinha and Katiha, 2001) under various fisheries management regimes (Table 10) revealed that most prevalent gear under all the regimes were gill nets followed by hook and lines in case of open access and co-operatives. For private regime it was the drag net due to fishing operations by hired professional parties, which generally use this type of net. The highest percentage of crafts was owned under open access followed by private and co-operatives. The area of operation was limited for co-operative and private regimes, while it was not so for open access. To avail this facility of fishing anywhere, the fishers preferred to have their own fisheries requisites. It increased their degree of freedom for fishing, which influenced their returns. In case of co-operatives, the member fishers have limited area of operation and have greater association, thus preferred to share the requisites, particularly the boats. In case of private regime, the remuneration is low, so, fishers did not want to share their catch with anyone, which would reduce their income; it led them to prefer their own boats and gears. Further, the contractors also provided them finance to purchase the inputs. In case of co-operatives and open access, credit support from any institution was very rare.

Table 9. Fishing gear prevalent in Ganga river system with period of operation and probable catch

Type of gear	Local name	Period of operation	River conditions	Probable catch
Drag net				
With pocket	*Chanta*	After monsoon months	Mild current, turbid water, receding flood phase	Medium sized carps, *Aorichthys* spp., *Wallago attu*, *Rita rita*, *Channa* spp.
Without pocket	*Mahajal*	Round the year, except monsoon months	Clear water with clean sandy bottom	Large sized carps, *Aorichthys* spp. *N. chitala*, *B. bagarius*, other misc. catch
	Chaundhi	Winter months till river receives freshets	Clean sandy bottom without sludge, clear water	*C. mrigala*, *Aorichthys* spp., *Wallago attu*, *Rita rita*, *B. bagarius*
	Ghanali	Pre-and post-monsoon months	Turbid water with mild current, even sandy bottom	Medium sized misc. fishes *G. chapra*; *S. phasa*; *Chela* spp.; minor carps, *etc.*
	Dodandi	Mostly summer months	Feeble current, clear water	Medium sized misc. fishes *G. chapra*; *S. phasa*; *Chela* spp.; minor carps, *A. morar*, *E. vacha*; *C. garua*, *Mugil* spp. *etc.*
Gill net	*Gochail*	Monsoon months, except in heavy floods	Fast current , turbid water	Large sized fishes, major carps, *Aorichthys* spp. *W.attu*, *B. bagarius*; *etc.*
	Ranga	Round the year except in monsoon, mostly in pre-monsoon months	Mild current with clean sandy river bottom	Mostly *Aorichthys* spp.
	Phasla	Round the year except in monsoon	Slow current, clear stagnant water	Medium to large sized major carps, minor carps, *E. vacha*; *C. garua*, *Aorichthys* spp.
Purse net	*Kamel*	Pre-monsoon and early winter months	Fast current, clear water	Medium and large sized major carps, minor carps, *Hilsa ilisha*, *Aorichthys* spp. and *Rita rita*
Hook & Line	*Jor*	Round the year, mainly in monsoon	Fast current with turbid water	*Aorichthys* spp. *E. vacha*; *C. garua*, *W.attu*, *R.rita*
Cast net	*Bhanwar jal*	Round the year		Small sized mixed catch, occasionally large sized fishes
Scoop net	*Jali*	Post monsoon and winter months	Clear to turbid water with mild current	Juveniles of carps and catfishes, small sized misc. fishes, shrimp
Trap	*Kuriar*	Post monsoon and winter	Clear water and sandy bottom	Large sized carps, *Aorichthys* spp.; *B. bagarius*
	Gopal Jal	Summer months	Clear water and sandy bottom	Exclusively used for *Aorichthys seenghala* and *Aorichthys aor*
	Sirki	Summer months	Clear waters at river turnings	Shrimp, small miscellaneous fishes

Seth and Katiha, 2003

Table 10. Percentage of different gears used in Ganga river system

Sl. no.	Input profile	System		
		Common property	Private	Cooperative
		Ganga, Kanpur to Farakka	Yamuna, Yamuna Nagar to Panipath	Ghagra, Ghagra Barrage to Faizabad
1.	Per cent of fishers with type of gears			
	Gill net	67.06	56.27	57.14
	Drag net	18.14	32.23	17.14
	Cast net	7.78	5.02	2.86
	Hook and line	24.37	21.73	34.20
	Others	6.59	5.62	20.00
2.	Per cent of fishers with own boat	79.64	62.13	25.00

VI. *Fishers and their status*

The socio-economic status of the fishers of river Ganga (CIFRI, 2006) revealed following observations.

a) Demography

The age distribution and sex composition expresses that the minor adult proportion and extent of gender equity prevailing in a society. The age distribution of the fisher community (Fig. 3.) showed comparatively higher proportion of minors (55%) than adults (45%).

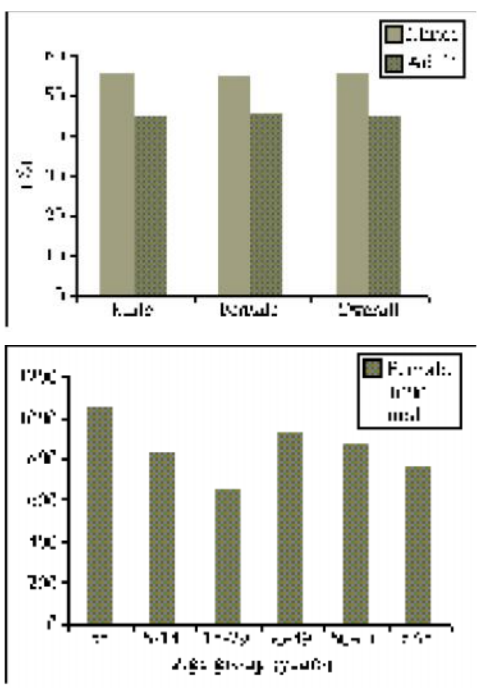


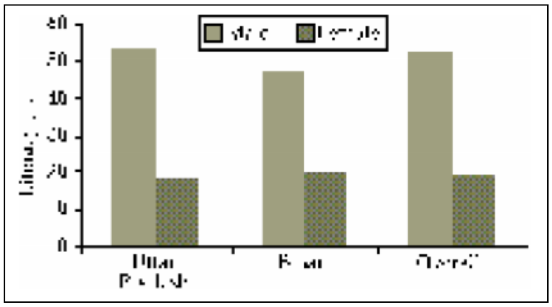
Fig. 3. Age and sex-wise distribution of fisher community of river Ganga

The sex ratio across the age groups varied from 656 to 1053 females per 1000 males in the age groups 15-29 and <5 years, respectively. The sex ratio was above one only in <5 year age group and it was less than one for all the other age groups. The lower ratio was primarily due to gender bias, poor health care and social attention for the females.

b) Literacy

Literacy rates were low with a significant difference between male (52%) and female (19%) indicating females were far behind the males (Fig. 4.). The percentage of literate males in Uttar Pradesh was more than Bihar, while it was vice versa for females, although, the difference in literacy rate was small.

The figure also revealed very poor literacy level of fisher community. Most of them were literate up to primary level and to the maximum of higher secondary. The literacy level also followed the similar trend across the sex groups of both the states. The overall scenario may be attributed to poverty, involvement of female children in domestic and household economic activities from childhood, ignorance of parents about girl's education, *etc.*



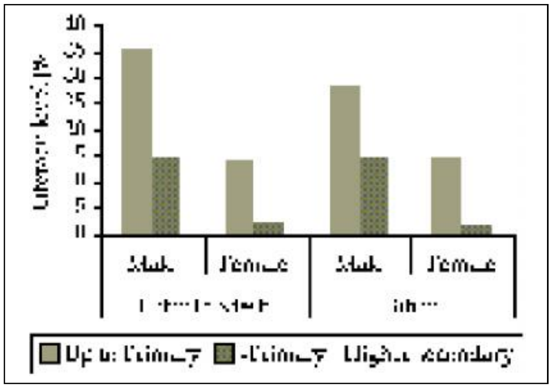


Fig. 4. Literacy rate and level of fisher community of river Ganges

c) Living standard

Housing characteristics are the one of the major indicators of standard of living. Most of the fishing community lived in hut and *kachha* tiled houses (Table 11). The situation in Bihar was comparatively better than Uttar Pradesh with higher percent having *pucca* houses. Floor type in both the states was earthen followed by cemented and with bricks.

Table 11. The type of fisher community houses and number of persons per room (%)

Particulars	Uttar Pradesh	Bihar
Structure type		
Hut and *kachha* tiled	69.0	56.3
Semi *Pucca*	9.4	11.4
Pucca	21.6	32.2
Number of persons		
<3	15.9	16.0
3-4	36.7	34.1
5-6	22.6	25.6
>7	24.8	24.3

The estimates for number of persons per room indicated that mostly 3-6 persons had to adjust in a room. Such crowded housing conditions affected their health and quality of life. In one fourth of the households, more than seven persons lived in a room. The scenario was more or less same for both of the states.

Most of the fishers were land less and some of them had own or shared land and few utilised unclaimed land for domestic and productive purpose. Proportion of fishing group households having own land was less than 25% for both states and the holding size was also small. Greater proportion of Bihar households had shared community land as compared to Uttar Pradesh, while it was vice versa for unclaimed land utilised by fisher community.

The Standard of living refers to the quality and quantity of goods and services available to the people and the way these goods and services are distributed within a population. This composite index was calculated by scoring for house type, toilet facility, source of lighting, main fuel for cooking, source of drinking water, ownership of land, livestock, durable goods, *etc.* It is therefore, concluded that the standard of living of fishers is very poor for over 75% of their community.

d) Employment

The estimates of Worker Population Ratios (WPRs) computed as number of persons employed per 1000 persons indicated higher values for males (673) than females (431) for river Ganga. The average ratio for male ranged between 666 for Uttar Pradesh and 696 for Bihar in comparison to females at 455 and 351, respectively. This may be due to participation of females in allied activities and agricultural harvesting in Uttar Pradesh.

The principal activity among fisher males was fishing in rivers (48-57%) followed by general and fishing labour. In case of females allied activity (65%) was the principal activity in Uttar Pradesh, while in Bihar business (62%) was reported as the principal activity followed by fish retailing.

Migration was common phenomenon among the fishers. Female migration was generally for short duration and related to unskilled activities. Male migration was very common for all the activities including higher percentage for unskilled labour.

e) Expenditure pattern

The ranges for per capita monthly expenditure on food and non-food items are depicted in Table 12. On an average, fishers spent 66% on food and 34% on non-food items. The major food item of the expenditure was cereals (37%) followed by vegetables (7%). Among non-food items highest expenses were on medical (9%) followed by intoxicants (8%).

f) Market and pricing

The riverine fish marketing operations were conducted either by fishers or other concerned people after completion of fishing or fish production process. In India, most of the riverine catch is consumed in the fresh form. A negligible quantity of it is either dried and processed by traditional methods or used for non-edible purposes. The marketing of Ganga fish catch includes operations: Disposal of fish catch by fishers; transportation of catch to landing centre/ wholesale or retail market, wholesaling, packaging and retailing.

The pricing of fish catch was primarily through auctioning of the riverine catch. The auctioning process starts when the catch is ready for display to the buyers e.g. retailers, vendors or bulk consumers. There are two systems of auctioning: i) auction by lots without weighing and ii) auction by lots after weighing. In the former system, whole of the segregated lot of fish is auctioned by bidding either for whole lot or on per unit basis, *i.e.* per kg. In case of bid for whole lot, the highest bid price will be paid by the bidder, but, for per unit bid price, the lot is to be weighed after bid. The amount payable by bidder is calculated as the product of weight of lot and highest bid price. In the second system, the process for auction and calculation of payable amount by the highest bidder is same as without weighing. The only difference is that the lot of fish to be auctioned is weighed before beginning of auction process.

The declining proportion of riverine catch in total market arrivals emphasized the need to collect the data on total landings (including catch from other water bodies). So, these observations were analysed for the first time. This may provide a base for detailed investigations on changing role of

Table 12. Range of per capita monthly expenditure on food and non-food items for fisher community of river Ganges

Item	Range of per capita monthly expenditure (Rs.)
Cereals and substitutes	87.61-131.47
Pulses and products	9.43-17.74
Milk and milk products	1.82-7.99
Edible oil	11.57-19.62
Vegetables	16.16-29.58
Fruits	0.00-3.96
Meat egg and fish	7.22-24.67
Other food items	11.30-16.61
Total food	**163.16-249.10**
Fuel and light	13.50-31.39
Education	1.63-10.56
Medical	16.87-43.73
Toilet articles	5.24-8.16
Clothing	12.87-20.46
Pan, tobacco and intoxicants	13.55-32.03
Other items	0.00-1.37
Total	**251.68-382.65**

rivers in fish production. The data on fish market arrivals from river Ganga and its tributaries and waters other than river was collected. Out of total fish landings, 29.8% was the riverine catch and remaining 70.2% from other fishery waters. About 97% of carps were from other water bodies leaving only 3% from rivers. In case of catfishes, rivers contributed over 80%, while for remaining fish species about 49% was from the rivers. The size-wise catch composition of riverine catch indicated dominance of small sized fishes (76%), while for other water bodies medium sized fish contributed the maximum (65%). The observation on size-wise catch composition from rivers and other water bodies reveals the nature and small mesh size of the gears prevalent in the riverine system, and the priority of the fish farmers to culture fish for table purpose. The marketing channels observed for fish marketing in Ganga river system are given in Table 13.

drainage use, *etc.* The river being a fluvial resource, the interests of users with domestic and drainage purposes, may be safeguarded in a sustainable manner, in the stretches with sufficient width and depth. But the crux lies with the commercial users or the individuals who depend on rivers for their livelihood, like members of fishing community, agriculture (cutting water for irrigation), sand industry, water transporters, *etc.* To diffuse this situation, the property regimes must clarify the perceptions of collective use of scarce and valuable or worth protecting resources. It would restrict all the users to exploit the resource in tolerable limits, in order to avoid any encroachment in the interests of other users with same or different purposes. The fish stock of river Ganga, a scarce and valuable natural resource had followed declining trend over past few decades due to human invasion in interests of fishers through water abstraction, dam

Table 13. Different fish marketing channels in riverine fisheries

1	Fisherman Þ Wholesaler cum commission agent Þ Retailer Þ Consumer
2	Fisherman Þ Retailer Þ Consumer
3.	Fisherman Þ Local dealer/ Local dealer cum commission agent Þ Consumer
4.	Fisherman Þ Local dealer Þ Wholesaler cum commission agent Þ Retailer Þ Consumer
5.	Fisherman Þ Local dealer cum retailer Þ Consumer
6.	Fisherman Þ Contractor/ Contractor cum wholesaler Þ Retailer Þ Consumer
7.	Fisherman Þ Co-operative society Þ Contractor / Contractor cum wholesaler Þ Retailer Þ Consumer
8.	Fisherman Þ Co-operative society Þ Wholesaler cum commission agent Þ Retailer Þ Consumer
9.	Fisherman Þ Co-operative society Þ Consumer
10.	Fisherman Þ Consumer

g) Implications of different property and management regimes in Ganga river system

Traditionally, the rivers are managed as common property resource and Ganga river system is in no way an exception. It also has multiple uses for riparian area population, which have the customary ownership of local river stretch as social units with definite membership. The key concept to assure stakeholders' interests is characterizing their relationships for purpose of domestic, commercial and construction, river training, sedimentation, *etc.* It emphasized the need to discuss fish exploitation in context of all the other multiple water use rights. But, it would be a very cumbersome exercise. For simplicity, Ganga river fishing alone is discussed under different property rights and management systems.

h) Ownership, fishing rights and management regime

The constituent rivers of Ganga system are the state property and various river stretches within or between the states belong to departments of fisheries, revenue, forestry, village panchayats, *etc.* These departments adopted varied policies for fishing in these stretches. The rivers being fluvial and fish being migratory renewable resource, it is difficult to apportion the fish biomass in territorial limits. From fisheries viewpoint most of the river stretches are in open access, with some exceptions where these are leased to co-operatives or private parties. A comparative account of fishery activities under these management regimes has been made selecting one stretch in each of these management regimes, *i.e.* open access, private and co-operatives (Table 14). These include stretches of river Ganga (Kanpur to Farakka) under open access and its tributaries river Yamuna (Yamuna Nagar to Panipat) under private (contractor) and river Ghagra (Ghagra Barrage to Faizabad) under co-operatives.

To have a wishful comparison the institutional framework and terms of rights and duties under different regimes and stretches are summarized in Table 14.

i) The fishing rights under different regimes

In open access, as the name indicates, the fish biomass has a free access to any one. There was free entry to fishing enterprise, which allowed anyone to fish anywhere, anytime. Although, there were regulations under Indian Fisheries Act for responsible fisheries and responsibility of conservation of fish stock was with the state governments, but due to vast magnitude of the river, institutional arrangements and authority systems inevitably ceased in this regime. Under co-operative management regime, state government leased out the stretch to fisheries co-operative societies, and conferred all the rights and powers of decision-making regarding fisheries in the stretches to co-operatives. Generally, the stretches were leased for one year, but it was likely to be renewed every year, unless there was some serious complaint about fisheries management by the co-operative. The members of society had the right to fish and exclude non-members from fishing. The non-members had the duty to abide by this exclusion.

The only difference between cooperative and private management regime was that fishing rights and power to transfer fishing rights and decision making rested with the individual to whom the stretch was leased out in the later case. The stretch was leased out for a period of one year based on open auction. As there was an open auction, so, the lease may continue with same person or may be transferred to others, with higher bid. The lessee or contractor transferred the fishing rights to the fishers on terms and conditions best suited to him. In all the regimes fishing rights rested with fishers, but they had to perform the fishing activities within socially acceptable limits, and allow the non-fishing people to use water to meet their day to day requirements.

The studied stretch of river Ganga with open access was rich in fish biomass, and fishing activities were also intense as compared to other stretches under private and co-operative management regimes.

The ownership of different portions of the stretch was with various departments *e.g.* fisheries, revenue, forestry, village panchayat, *etc.* Some of these portions were disputed as more than one department stated their claim on same stretch. Furthermore, since, the districts on both banks of the river may also be different, so the conflict on ownership was also be within same department operating in different districts. In some stretches the same stretch was leased out by two offices to different parties, which led to great tension in the area. This duplicity of fishing rights and claim of ownership by more than one department led to overall degradation of fishery resources of the river stretch, due to improper monitoring and exploitation of fish stock. All the river stretches have multiple water uses *i.e.*, for fishing, bathing, washing clothes, drinking water, *etc.*

Table 14. Fisheries institutional arrangements in Ganga river system

Item	Regime		
	Common property	Private	Co-operative
River stretch	Ganga, Kanpur to Farakka	Yamuna, Yamuna Nagar to Panipat	Ghagra, Ghagra Barrage to Faizabad
Property right regime	State departments of Revenue/Forestry, Village Panchayat	State departments of Revenue/ Forestry, Village Panchayat	State departments of Revenue/Forestry, Village Panchayat
Management system	Individual fisher/ fisher group	Contractor	Fishermen Co-operative
Whether in multiple uses, if yes in			
i) Fishing	Yes	Yes	Yes
ii) Bathing	Yes	Yes	Yes
iii) Washing clothes	Yes	Yes	Yes
iv) Drinking water	Yes	Yes	Yes
Duration of lease	–	One year	One year
Harvesting period	Round the year with lean period in monsoon	Round the year with lean period in monsoon	October to January and March to June
Arrangements for fisheries requisites	Individual/Shared	Self + Contractor	Co-operative
Time and mode of payment	In cash on the day of disposal of catch	Daily/Weekly/ Monthly, in cash	Daily/Weekly in cash
Remuneration for the fish catch	Within the group based on pre-decided percentage share	Based on prefixed labour charges/ royalty per kg of catch	Based on fixed/% of market price per kg of catch
Distribution of profits	Only as remuneration	Solely of contractor	Among members

(Modified from Sinha and Katiha, 2001)

j) The exploitation under different regimes

Regarding the management regimes, under open access, individual fisherman or group of fishermen can fish any where in the river till mid seventies, but due to declining fish catch, local fishers started prohibiting the migrating fishers to fish in their area. It largely depended upon the mutual relationship between the fishers of different stretches. In case of co-operatives the member fishers mostly fished in their own stretch. The length of stretches leased to society varied to a great extent. Accordingly, the fishing area and time spent by fishermen fluctuated for these co-operatives. For private management regimes, the contractors (mostly fish traders), generally engaged local fishermen or the professional parties for fishing. Regarding the level of exploitation and follow up of conservation measures, the open access and cooperatives adopted mild fishing practices and try to follow the mesh and fish size regulations, as they have to continue fishing over the years, but for contractor under private regime, as the lease period is one year, and there is no certainty for future, the fishing gears used are comparatively less mild. The parties engaged for fish harvesting generally, use smaller mesh dragnets, to have the maximum catch. The fishing period under all the management regimes extended almost round the year with lean period or closed season during monsoon months. The only exception was the co-operative stretch. The water level of the river observed high fluctuations over the year, due to opening of barrage gates so, it reduced the fishing period over the year, as it is difficult and uneconomic to fish under very high water levels. The fishing in the stretch was limited to March to June and October to January.

k) The input-output profile under different regimes

Pattern of inputs used, fishing efforts, cost structure and net returns under different regimes are depicted in Table 15. Most prevalent gears under all the regimes were gill nets followed by hook and lines in case of open access and co-operatives. For private regime it was the drag net due to fishing operations by hired professional parties, which generally use this type of net. The highest percentage of crafts was owned under open access followed by private and co-operatives. The area of operation was limited for co-operative and private regimes, while it was not so for open access. To avail this facility of fishing anywhere, the fishers preferred to have their own fisheries requisites. It increased their degree of freedom for fishing, which influenced their returns. In case of co-operatives, the member fishers had limited area of operation and had greater association, thus preferred to share the requisites, particularly the boats. In case of private regime, the remuneration was low, so, fishers did not want to share their catch with anyone, which would reduce their income. It led them to prefer their own boats and gears. Further, the contractor also provided them finance to purchase the inputs. In case of co-operatives and open access systems, credit support from any institution was very rare.

Table 15. Input-output profile under different management regimes

Item	Regime		
	Common property	Private	Co-operative
Input profile			
Per cent of fishers with type of gears			
Gill net	67.06	56.27	57.14
Drag net	18.14	32.23	17.14
Cast net	7.78	5.02	2.86
Hook and line	24.37	21.73	34.20
Other	6.59	5.62	20.00
Per cent of fishers with own boat	79.64	62.13	25.00
Hired labour (Mandays/Year)	–	96.28	–
Annual fishing effort (Mandays/Year)	281.82	293.24	147.63
Output			
Catch per family (kg/year)	1431.67	780.02	376.46
Catch per day (kg)	5.08	2.66	2.55
Costs and benefits			
Costs			
Fixed cost (per year)	2907.31	3017.17	1451.48
Variable cost (per year)	1712.21	1737.39	285.43
Total cost	4619.52	4754.56	1736.91
Benefits			
Price received (kg)	24.09	18.79	34.82
Gross returns (per year)	34488.93	14656.58	13108.34
Net returns (per year)	29869.41	9902.02	11371.43
Net returns (Rs/per kg)	20.86	12.69	30.21
Input output ratio	7.49	2.90	7.55

(Modified from Sinha and Katiha, 2001)

The annual fishing effort was highest for private regime followed by open access and co-operative; while annual and per day catch was the maximum for open access. The cost structure was almost similar for open access and private regimes, while very low for co-operatives. These observations may be attributed to intensity of fishing or the fishing effort put in by the fishers under different regimes. Fluctuations and height of water level and the fish stock present in the river affected these over year. The lower cost in case of co-operative might be due to lower fishing effort and sharing of inputs.

The remuneration for catch and distribution of profits were the best in case of open access. These were on the basis of contribution in effort and fisheries requisites. The fishermen having the boat and nets got higher share than the other fishermen sharing these requisites. For private and co-operatives the remuneration and payments largely depended upon the pattern of disposal of catch and mode adopted for payments under respective regimes. It may be daily, weekly or monthly. The contractors generally remunerated the catch of local fishers at some fixed rate/ royalty per kg. But, in case of hired fishing party it may be on share basis. Contractor being the fish trader himself did not share the profits with the fishers. In case of co-operatives the remuneration was in term of per cent of market price, after deduction of commission by the society, for rendering the services. The profits are distributed among the member fishers according to their share capital. It revealed that the marketing benefits were passed on to the fishers in case of open access and co-operatives, while under private regime they were deprived of these benefits.

The price per kg received by the fishers may be recognised as the indicator of impact of these management regimes and fishing rights on the fishers' income. These estimates favoured co-operative regime the most followed by open access. The lowest values for these estimates were under the private regime. The co-operatives directly disposed the catch in local market or at nearby town. The members of the society themselves performed the marketing functions, eliminating all the market intermediaries, so received much better prices. In open access, the catches were auctioned in the wholesale markets and fishermen received the auction price after deduction of wholesaler's commission. In private regime, the contractor remunerated the fishers' catch in term of fixed rate/ loyalty per kg, so, they got the minimum remuneration and deprived of the benefits of market price.

The gross and net annual and per day returns were maximum for open access regime followed by co-operative and private, but the net income per kg of catch favoured co-operatives the most followed by open access, and the least for the private regime. The input output ratios also indicated the superiority of co-operatives and open access regimes over the private as their value for these ratios were more than 2.5 times of the estimated ratio for private regime. It depicted the working efficiency and extent of remuneration of fish catch for different management regimes and revealed that privatization of the fishing rights in riverine fisheries would accelerate the process of social disequilibrium to broaden the income inequalities. It would push the downtrodden more down to uplift the economically fluent fish traders, who are already well off.

VII. *Valuation, conservation and sustainable fisheries*

a) Valuation

In the recent past riverine eco-systems in India have been destroyed or altered, as growing human population exploited the benefits provided by these natural systems beyond their carrying capacity. Extensive aquatic resources have either been lost or are undergoing drastic changes in major river basins of India. These losses are occurring either as a direct result of intensive agriculture, aquaculture and domestic and industrial waste disposal through slow degradation process associated with hydrological parameters, biotic and abiotic pressures, *etc.*

Aquatic ecosystems are valuable environmental assets with high preservation and conservation values. Despite this, large number of aquatic eco-system within and outside the river basin network is not managed in economically and socially optimal way. Aquatic eco-system users have inadequate understanding about the social cost associated with utilization of these resources. The misutilization of aquatic eco-systems has largely been the result of market and policy failures. Social inefficiency in aquatic eco-system use is related to the fact that these resources are multifunctional and have multiple use conflicts with different functions. The multiple use pressure is inevitable, particularly because of spatial location of majority of aquatic systems (along rivers, coast and terrain). These can be treated as natural use conflict. However, conflicting social objectives and inefficient government policies can result in created use conflict and as a result most of the time these eco-systems operate at sub-optimal levels.

Conservation and preservation values of the aquatic eco-systems generally do not have any readily available market expression, unlike a number of possible eco-system development values, *e.g.* value of agriculture output, residential and industrial complex, *etc.* Economically inefficient habitat modification of eco-systems has been encouraged as natural and semi-natural eco-systems have been completely or partially converted to other land uses. As a result social benefits have been sacrificed for smaller monetary benefits in many parts of India (Marothia 1995).For example complete infilling of urban water bodies in some parts of India for housing and commercial complexes may represent irreversible policy decisions (Marothia 1997, 2003).

Aquatic ecosystem, generally, provide tangible benefits in form of plants, animals, fish, soil and water function services in terms of life supporting services, pollution assimilative capacity, cycling of nutrients and maintenance of the balance of gases in the atmosphere. Many ecosystems often extend beyond the boundaries of ecosystem itself in the broad framework of river basin. Benefits of aquatic eco-system should be, in principle, based on a full appreciation of total economic value. To this end, we now discuss conceptual framework of total economic valuation.

b) Conservation and restoration

There has been gradual to sharp decline in fish landing from Ganga. The rate of abstraction of water from almost all rivers of Ganga river system is very intensive. The total length of canal network in Ganga basin is over 15,000 km. Resultant to continued increased abstraction of water, the volume of water available in this river system is on a continuous decline. Based on the daily water-level data of the Central Water Commission, it has been estimated that mean water level of river Ganga at Allahabad during July to September (the period of maximum water availability) had declined by about 4 m during 1975 to 1995. The environmental health indicates a general improvement in water quality of river Ganga, observed during 1995-96, than what it was during 1985-90. Studies carried out during 1995-96 by the CIFRI did not indicate any serious pollution, which could affect fish and fish food organisms. The comparatively better water quality during this period appears to be due to effects of Ganga Action Plan: Phase I, which was implemented post 1985. Contrary to normal expectation, a gradual decline in fish production, both quantitatively and qualitatively, along with that of other biotic communities (planktons and benthos), is clearly evident in freshwater zone of river above Farakka barrage. Environmental aberrations in the form of high rate of sedimentation (616 million tones annually), increased water abstraction and river course modifications, coupled with irrational fishing, appear to be the likely cause for this. High rate of sedimentation, caused due to deforestation in catchments, has resulted in ‘desertification’ of river bed in major part of the freshwater zone (origin to Patna), blanketing of soil-water interface and, thus, loss in productivity of the system.

In view of this, it can be said that the present available productivity of the river water in this stretch is the result of nutrients being drained from allochthonous sources. Sedimentation and water abstraction has drastically decreased the flows, which has resulted in habitat loss for several biotic communities inhabiting the system. The breeding process of several fishes has also been affected due to non inundation of original breeding grounds. River course modifications have affected migratory species (hilsa and freshwater prawns). Sharp decline in fishery of hilsa above Farakka barrage, immediately after its commissioning, is a glaring example of river-course modification affecting fishery of migratory species.

Fish production in the rivers depends on the recruitment. Natarajan (1989) and CIFRI Annual Reports 1994 to 2004 indicated that the spawn availability index of Ganga declined from 2984ml during the 1960s to 27ml during 1994 to 2004. The failure of recruitment of young ones to the system was because of failure in breeding of the IMC. Majority of the fishes of the Ganga river system breed during the monsoon months. Decrease in precipitation over the years in the catchments of river Ganga, which is more in the plains, resulted in decreased runoff. As a consequence the required flow and turbidity of the water essential for breeding of IMC is now not available (Das, 2007).

A number of fish species which were predominantly only available in the lower and middle Ganga in 1950s as reported by Menon (1954) are now recorded being from the upper cold-water stretch upto Tehri (Das, 2007). Among them *Mastacembalus armatus* is available between Tehri and Rishikesh and *Glossogobius giuris* is available in the Haridwar stretch (Sinha *et al.*, 1998). There is shift in distribution of the fish species in Ganga. This may be due to rise in maximum temperature in the upper Himalayan stretches of the river Ganga making it a conducive habitat for the warm water fishes of the lower stretch. The cool upper stretch with the earlier maximum temperature conditions of 17.5 °C were not suitable for these fishes but with the increase of the maximum temperature in this stretch to 25.5 °C (Das, 2007), it has become conducive to the warm water fishes. Maximum water temperature has increased by 6°C during 1975 to 2005 (Das, 2007).

c) Sustainable fisheries

Open water bodies like rivers, especially the mighty river like Ganga, which is associated with human habitations, civilization and industrial development, serving livelihood, suffers from unregulated fishing, environment degradation, water abstraction and encroachment. Increased fishing pressure by the ever increasing fisher population and demand for fish, followed by development of fishing crafts and gear suitable for mass fishing increased the fishing effort which gradually led to drop the catch per unit effort. With reduction in catch and non availability of alternate source of livelihoods, the situation encouraged indiscriminate fishing, leading to over exploitation. Growth and recruitment over fishing led to imbalances in recruitment process. With the decreasing natural stocks the fishers had to increase fishing effort for whatever the species or size of fish available to support their livelihoods. Interventions like regulations/wise use or awareness generation may not yield desired results to reverse the trend as livelihoods are affected. Without alternate livelihoods, any form of management plans will be wedging on peoples' existence, which a civilized society cannot afford to allow. Although the ecology, fish species composition and landing trends are studied in Ganga, there is also acute paucity of sound empirical information on the fish population, exploitation levels and sustainable yields from the river to implement effective resource management plans.

VIII. *Environmental status*

a) Pollution scenario

Along the banks of Ganga, over 29 cities, 70 towns and thousands of villages are situated. Nearly all of their sewage - over 1.3 billion liters per day - goes directly into the river, along with thousands of animal carcasses, mainly cattle. Another 260 million liters of industrial waste are added to this by hundreds of factories along the river banks. Municipal sewage constitutes 80 per cent by volume of the total waste dumped into the Ganga, and industries contribute about 15 percent. The majority of the pollution of Ganga is organic waste, sewage, trash, food, and human and animal remains. Over the past century, city populations along the Ganga have grown at a tremendous rate, while waste-control infrastructure has remained relatively unchanged (http:/www.gits4u.com/water/ganga.htm).

The industrial pollutants also contaminate the Ganga to a great extent. The major polluting industries are the leather industries, especially near Kanpur, which use large amounts of chromium and other toxic chemical and much of it finds its way into the meager flow of the Ganga. From the plains to the sea, pharmaceutical companies, electronics plants, textile and paper industries, tanneries, fertilizer manufacturers and oil refineries discharge effluent into the river. This hazardous waste includes hydrochloric acid, heavy metals, bleaches and dyes and pesticides.

b) Pesticide residues

Studies indicate that the residues of organochlorine pesticides including HCH, DDT, endosulfan and their metabolites are commonly occurring substances in water of the river and its estuary. Unusual content of the pesticides was reported by Nayak *et al*. (1995) in the middle stretch (Varanasi) of the river (Table 16). Moderate content of HCH compounds were recorded in the studies of Kumari and Sinha (2001). DDT and its analogues was noticed moderate by Ray (1992) and Halder *et al*. (1989). Ray (1992) also reported moderate content of endosulfan compounds. Although the observed residue levels are sometimes high or very high, the tropical climate of the country is protecting the water phase from the worst state of pollution even after a huge consumption of these compounds in the past. Comparison of the data with the US EPA permissible limits for aquatic organisms or their consumers clearly indicates that the river water is contaminated with the residues of organochlorine pesticides, the content of which often cross thousands of times over the permissible limits (Samanta, 2007).

Only limited studies are made with the sediment phase of the river and the reported levels are also found low. Senthilkumar *et al*. (1999) reported HCH <0.1 – 8.1, DDT 0.1 – 36 and chlordane <0.1 – 49 ppb in the river while Joshi (1986a, b) observed DDT 17 – 89 ppb in the estuary.

In the fishes of river Ganga, significant accumulation of DDT (60 – 3700 ppb) was noticed by Senthilkumar *et al*. (1999). In the

Table 16. Organochlorine pesticide residues (ng l^{-1} or ppt) in water of river Ganga

Water resource	HCH	DDT	Aldrin	Endosulfan	Hepta-chlor	Chlor-dane	Reference
Ganga River	1–971	0–1240		0–2890			Ray, (1992)
Ganga River		0–5808					Singh, (1992)
Ganga River	0–1119	0–832	0–120	0–232	0–412		Agnihotri, (1993)
Ganga River	105–99517	69–143226		83–66516			Nayak *et al.*, (1995)
Ganga River	189–2597	19–1663	0–800	0–862			Kumari & Sinha, (2001)
Hooghly Estuary	1– 400	2–560					Thakar, (1986)
Hooghly Estuary		6–4000		0–97			Halder *et al*, (1989)
Hooghly Estuary (Kolkata)	1.5	6.2				0.180	Anbu, (2002)

studies of Kumari *et al*. (2001) observed pesticide levels in fishes were HCH (55 – 1207 ppb) and DDT (14 – 1666 ppb). Aldrin and endosulfan were relatively low of 0 – 225 and 0 – 175 ppb, respectively. In the estuary, the reported levels were relatively low (Joshi, 1986 a & b and Samanta, 2006).

Thus, it may be concluded that the Ganga river fishes sometimes cross the limits for HCH and endosulfan (Kumari *et al.*, 2001). Although in majority of the cases, the observed residues of DDT in fish samples were much more than that of HCH or endosulfan, the permissible limit is not exceeded. Probably the dilution effect in the estuarine zone is protecting the fishes from accumulating these persistent compounds. observed by Prasad *et al.*, (1989), Joshi (1991) and Ghosh *et al.*, (1983).

Metal content in sediment of river Ganga has been studied by many workers (Table 19). In the upper stretch, as per expectations, the metal contents were found low. Since the area is free from human activities, the metal contents were attributed to the geochemical sources. In the middle stretch (Rishikesh to Ramghat near Bulandshahr), highest content of the metals was recorded in the Ghaziabad stretch receiving industrial discharges. Although the Kanpur stretch of the river is reported to be heavily polluted, these are not reflected in the sediment metal content due to huge sediment load of the river and fresh deposition is protecting the system from high accumulation of the same.

Table 17. Organochlorine pesticide residues (ng g^{-1} or ppb) in fish and mollusks of river Ganga

Items	HCH	DDT	Aldrin	Dieldrin	Endosulfan	Reference
Fish	77	160	2.7	2.9		Kannan *et al.*, (1993)
Fish	28 – 110	60 – 3700				Senthilkumar *et al.*, (1999)
Fish	55 – 1207	14 – 1666	0 – 225		0 – 175	Kumari *et al.*, (2001)
Hooghly estuary fish		31 – 460				Joshi, (1986) a & b
mollusks		66 – 953				
Hooghly estuary fish	0.1 – 9.0	1.4 – 73.4	0 – 0.7		0 – 4.2	Samanta, (2006)
Safe limits for human						
US FDA		5000	300	300		FAO, (1983)
FAO	100 lindane	5000	200	200	100	
Thailand	500 lindane	5000	100	300		

c) Heavy metals

A number of research works has been conducted to determine the metal content in water of river Ganga (Table 18). The upper most stretch is relatively free from different metals. The middle stretch, receiving different effluents, is found heavily polluted with the metals. Although a significant stretch of the estuarine zone is densely industrialized and receive effluents regularly, due to greater dilution the metal contents were found lower than that of the middle stretch. In majority of the cases the reported levels are found much higher than the US EPA permissible limits for the aquatic organisms. All the effluents were found contaminated with metals and sometimes it goes to unusually high values as was As a whole, the river is found moderately polluted with respect to the US EPA permissible limits.

Joshi (1991) studied metal content in fish in the Rishikesh to Kolkata stretch of river Ganga. The highest values are given in the Table 20. Like sediment, the content of Cr, Cu, Pb and Zn was found high in the fish samples collected from middle stretch of the river while Hg was high in the estuarine samples. Kaviraj (1989) reported relatively high content of Zn (135.6 μg g^{-1}) in *Penaeus indicus*. Among the studied fishes, *Mastacembelus pancalus* accumulated more amount of Zn (108.2 μg g^{-1}). As per the US FDA limit for human consumption, the Pb and Cr are found to cross the limits in some occasions. As a whole, the numbers of studies are limited.

Table 18. Heavy metal content in water (µg l^{-1}) of river Ganga

River	Cd	Cr	Cu	Mn	Ni	Pb	Zn	Reference
Ganga (upstream)	2 - 11		8 - 17	27 -116	12 - 50		75 - 157	Saikia *et al.*, (1988)
Ganga (upstream)	0	0	7			0	72	Joshi, (1991)
Ganga (midstream)	0	57	28	93	2	6		Mohammed *et al.*, (1987)
Ganga (midstream)	0 - 1	5 - 32	3 - 49	35 - 211	1 - 10	1 - 6	61 - 311	Israili, (1991)
Ganga (midstream)		2 - 3					18 - 41	Singh *et al.*, (1993b)
Ganga (midstream)	0 - 2		0 - 7			0 - 4	1 - 6	Singh *et al.*, (1993a)
Ganga (midstream)	5 - 7		20 - 170			80 - 680	30 - 230	Vass *et al.*, (1998)
Ganga (midstream)	28	3 - 119	17 - 106					Gupta and Raghubanshi, (2002)
Ganga (midstream)	5 - 8		62 - 140			102 - 166	7 - 23	Untoo *et al.*, (2002)
Hooghly Estuary	0 - 10	0 - 10	6 - 38			0 - 6	37 - 248	Joshi, (1994)
Hooghly Estuary	8 - 70		10 - 70			40 - 300	20 - 80	Vass *et al.*, (1998)
Hooghly Estuary	20		79 - 90			69 - 129	64 - 92	Ghosh *et al.*, (2000)
Hooghly Estuary	20 - 60	10 - 60	0 - 50	0 - 40		30 - 160	10 - 50	Nath *et al.*, (2003)
Hooghly Estuary	2 - 14		5 - 19	8 - 88		17 - 41	22 - 37	Samanta *et al.*, (2005)
Ganga (midstream) Effluent water	63 - 115	13 - 106	177 - 228	380 - 9242	344 - 1035	2 - 5	202 - 613	Prasad *et al.*, (1989)
Ganga (midstream) Effluent water	14	200	179			26	285	Joshi, (1991)
Hooghly Estuary Effluent water		0 - 28500	0 - 500			0	0 - 8500	Ghosh *et al.*.,(1983)
US EPA limit for aquatic organisms								
Fresh water	0.25	11 / 74	9.0		52	2.5	120	
Saline water	8.8	50	3.1		8.2	8.1	81	

Table 19. Heavy metals in sediment ($\mu g\ g^{-1}$) of river Ganga

River	Cd	Cr	Cu	Mn	Ni	Pb	Zn	Reference
Ganga (upstream)	0.8 - 29.4		4.1 - 17.9	107.3 - 226.1	4.9 – 11.8		26.3 - 48.3	Saikia *et al.*, (1988)
Ganga (midstream)	0.0 - 1.2	3.0 – 51.0	2.5 - 45.0	70.9 - 511.0	4.5 – 49.0	1.2 - 16.0	125.0 - 259.0	Israili, (1991)
Ganga (midstream)		8.4 – 13.0					60.0 – 84.0	Singh and Mahaver, (1997)
Ganga (midstream)	2.1 – 9.9		10.2 – 128.1			30.5 – 47.1	50 - 249	Vass *et al.*, (1998)
Ganga (midstream)	0.4 – 1.0	12.8 – 20.9				1.9 - 22.0		Khan *et al.*, (2003)
Ganga	3.5	83.2	95.0	470.0	28.8	21.8		Mohammad *et al.*, (1987)
Hooghly Estuary			4.0 - 53.0	250.0 – 800.0		12.0 – 115.0	12.0 – 611.0	Subramanian, (1985)
Hooghly Estuary Mouth			7.9 – 32.2	53.6 – 286.0	9.1 – 39.0	3.0 - 27.4	21.1 - 147.7	Mitra *et al.*, (1996)
Hooghly Estuary	2.5 – 7.7		35.5 – 52.5			24.0 – 36.4	145.8 – 165.6	Vass *et al.*, (1998)
Hooghly Estuary Mouth	0.4 (0.1 - 0.7)	61.5 (24.9 – 96.6)			37.5 (16.9 – 58.3)	10.5 (6.8 - 14.2)	64.4 (27.2 - 95.2)	Ramesh *et al.*, (1999)
Hooghly & Haldi	2.0 (0.4 – 4.4)		26.0 (3.9 – 80.4)	298.5 (34.4– 539.6)		36.0 (0.5 – 79.4)	77.0 (25.0– 363.4)	Samanta *et al.*, (2007)
US EPA limit								
Not polluted	-	< 25	< 25	-	< 20	< 40	< 90	
Moderate pollution	-	25 – 75	25 – 50	-	20 – 50	40 – 60	90 – 200	
Heavy pollution	> 6	> 75	> 50	-	> 50	> 60	> 200	

Table 20. Heavy metal content in fishes and prawns (µg g^{-1}) of river Ganga

Fish	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Zn	Reference
Rita rita (Dry weight)		1.75	11.8	0.485			14.5	80.9	Joshi, (1991)
Miscellaneous fish (Dry weight)			31.2	0.53				189.6	Joshi, (1991)
Rita rita from midstream (Dry weight)	0.35 – 0.49	3.9 – 11.2					0.0 - 6.0		Khan *et al.*, (2003)
Hooghly estuary									Kaviraj, (1989)
Fish	0.14 – 0.50	3.4 – 17.4	3.3 – 47.7					4.4 – 108.2	
Prawn	1.92	1.4	19.8					135.6	
Hooghly estuary Fish			0 – 340		0 – 20	0 – 20		0 – 340	Bhattacharya *et al.*, (1994)
US FDA limit*				(methyl mercury)					US FDA (2001)
Crustacea	3	12				70	1.5		
Molluscan bivalve	4	13		1		80	1.7		

**US FDA limit for human consumption on wet weight basis*

d) Environmental restoration: **The Ganga Action Plan**

The Ganga runs through 29 cities with population over 1,00,000 (class-I), 23 cities with population between 50,000 and 1,00,000 (class-II), and about 48 towns. It is a river with which the people of India are attached spiritually and emotionally. In December, 1984 the Department of Environment, Government of India prepared an action plan for immediate reduction of pollution load of the river Ganga to the bathing requirements (DO not < 5 ppm; BOD not > 3 ppm, coliform not > 10000 per 100 ml). The Cabinet approved the GAP (Ganga Action Plan) in April 1985 as a 100% centrally sponsored scheme (http:/www.cag.gov.in/reports/scientific/2000_book2gangaactionplan.htm).

To oversee the implementation of the GAP and to lay down policies and programmes, Government of India constituted the CGA (Central Ganga Authority) in February 1985, renamed as the NRCA (National River Conservation Authority) in September 1995. The Government also established the GPD (Ganga Project Directorate) in June 1985 as a wing of Department of Environment, to execute the projects under the guidance and supervision of the CGA. The Government renamed the GPD as the NRCD (National River Conservation Directorate) in June 1994.

The GAP-I envisaged to intercept, divert and treat 882 mld (Million liters per day) out of 1340 mld of wastewater, generated in 25 class-I towns in three States *viz.*, Uttar Pradesh, Bihar and West Bengal. The NRCD had scheduled the GAP-I for completion by March 1990, but extended it progressively up to March 2000. While the GAP-I was still in progress, the CGA decided in February 1991 to take up the GAP-II, covering the following pollution abatement works: (a) on the tributaries of river Ganga, *viz*. Yamuna, Damodar and Gomati (b) in 25 class-I towns left out in Phase-I (c) in the other polluting towns along the river.

The CCEA (Cabinet Committee on Economic Affairs) approved the GAP-II in various stages during April 1993 to October 1996. The States of Uttar Pradesh, Bihar, West Bengal, Delhi and Haryana were to implement the GAP-II by treating 1912 mld of sewage. GAP-II was scheduled for completion by December 2001.

The GAP aimed to tackle 2794 mld of sewage; 882 mld under the GAP-I and 1912 mld under the GAP-II. The NRCD records put the estimates of total sewage generation in towns along river Ganga and its tributaries as 5044 mld. Delhi alone accounts for 2270 mld. The GAP-II was to tackle only 20 mld in Delhi, and Delhi Government was to handle the balance 2250 mld separately from augmentation of its own available installed capacity.

To achieve the objective of pollution abatement, the GAP took up core and non-core schemes. The core sector schemes consist of interception & diversion schemes and STPs (Sewage Treatment Plants), designed to tackle point pollution, i.e. pollution that is from measurable sources such as drains, sewage pumping stations and sewage systems. Non-core schemes comprise low cost sanitation schemes, river front development schemes, electric and improved wood crematoria; and, tackle non-point, non-measurable pollution, such as dumping of solid waste and open defecation, dumping of un-burnt / half-burnt dead bodies, *etc.*

Approved outlays for the GAP-I and the GAP-II were Rs. 462.04 crore and Rs. 1276.25 crore respectively. The Central Government was to bear the entire expenditure on schemes under the GAP-I, and to share it equally with the States in the GAP-II. The Government of India decided in November 1998 to bear the entire expenditure on schemes from April 1997, as the States found it difficult to provide their matching share. After delay of over 10 years, the GAP-I is not fully complete. Audit found that the GAP-II is also far behind its schedule.

December 2001 was its time of completion, yet it has reportedly created only a part of the targeted sewage treatment capacity so far.

There are differences in opinion regarding the water quality of river Ganga after implementation of Ganga Action Plan. The water quality data of NRCD shows that the Ganga has deteriorated over the period 1993-1999. During 1999 BOD exceeded the permissible limit at 10 out of 27 sampling stations, as against only at 1 sampling station, viz. Kanpur down stream in 1993. The coliform levels exceeded in 17 out of 60 stations sampled during 1999 (http:/www.cag.gov.in/reports/scientific/2000_book2/gangaactionplan.htm). The studies of the Zonal Office of Central Pollution Control Board during 2006 indicated that the water quality in the Haridwar to Allahabad stretch was class B of Designated Best Use criteria, which implies that water quality conforms for uses like bathing, swimming, water contact sports. However, in summer season, the river stretch does not confirm the water quality under class -B and found exceeding the BOD limit. The high BOD (5 ppm) at Sangam in Allahabad and Dashashwamegh ghat (Varanasi) rendered the water unfit for bathing in winter season. During 2002 – 2006, the river Ganga is showing a decreasing trend of BOD (CPCB 2006).

The GAP schemes did not provide for control of bacterial load earlier. It exceeded the permissible limits at all the studied sampling stations. In order to find a techno-economically viable technology, the NRCD sanctioned 4 research projects during December 1993 to December 1995 using ultra-violet radiation, gamma radiation, chlorination and biological means. The technologies developed were found either cost intensive and economically unviable or these required a large land area for construction of stabilization ponds, which was not available in large towns. The waste stabilization pond technology was the only cost effective technology capable of making the levels of microbial pollution in treated water safe for bathing. It was also recommended that all conventional technologies needed to be supplemented by maturation ponds for control of bacterial load. The NRCD, however, did not take any steps for inclusion of maturation ponds and the objective of reducing the bacterial load to the desired levels remained to be achieved.

The conclusions of GAP are: after launching in 1985, with the objective of bringing water quality of river Ganga and its tributaries to bathing levels, it may not have achieved its objectives fully, but the river is protected from farther deterioration.

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