The Status of River Ganges in the middle stretch

1. DEMOGRAPHIC FEATURES

According to Census of India (Census of India, 2001a, 2001b) the population of India on 1st Mar 2001 stood at 1027.02 million (Male-531.28, Female-495.74). The population growth in India is fairly in tune with classical theory of demographic transition. During most of the nineteenth century, India witnessed a fluctuating but ultimately more or less a stagnant growth of population, which drifted into the twentieth century until 1921. Thereafter, the country passed through successively all the phases of demographic transition and is now widely believed to have entered the fifth phase, usually characterized by rapidly declining fertility. As per 2001 census the population density stood at 324 people per km^2. The overall literacy rate was 65.38% (Male-75.85%, Female-54.16%). The share of Uttar Pradesh and Bihar in total population was 16.17 and 8.07%, thus forming about 1/4th of the country's population. The population of districts along the river Ganga (Kanpur-Bhagalpur stretch) in U.P. and Bihar formed 20.43 and 32.36% of the respective state's population. The decadal population growth, sex ration and population density for the districts is depicted in Table 1. From the table it is obvious that population pressure is much more in the districts of Bihar as compared to U.P.

The literacy status in different districts is presented in Table 2. The literacy states was poor in Bihar as compared to Uttar Pradesh.

Table 1: Decadal population growth (%), sex ratio and population density (no./km^2)

State/ District	Decadal growth (%)		Sex ratio		Population density	
	1981-91	1991-01	1991	2001	1991	2001
UP	**25.6**	**25.8**	**876**	**898**	**548**	**689**
Kanpur Dehat	19.9	21.6	836	856	414	504
Kanpur city	22.5	27.2	832	869	1074	1366
RaeBareli	23.6	23.7	931	949	506	626
Pratapgarh	22.8	23.4	987	983	595	734
Fatehpur	21.0	21.4	882	892	457	555
Kausambhi	25.3	26.7	883	894	557	705
Allahabad	30.8	26.7	873	882	719	911
Sant Ravidas Nagar	38.2	25.5	896	918	1123	1409
Mirzapur	31.4	27.6	883	897	366	468
Varanasi	30.7	25.5	890	908	1589	1995
Chandauli	27.3	28.6	907	922	499	642
Ghazipur	24.3	26.2	957	974	716	903
Ballia	22.3	21.7	946	952	759	923

Table 1: Decadal population growth (%), sex ratio and population density (no./km^2) *Contd.*

State/ District	Decadal growth (%)		Sex ratio		Population density	
	1981-91	1991-01	1991	2001	1991	2001
Bihar	**23.4**	**28.4**	**907**	**921**	**685**	**880**
Buxar	18.6	29.0	884	901	670	864
Bhojpur	20.3	24.6	904	900	725	903
Saran	23.4	26.4	963	965	974	1231
Patna	19.8	30.2	867	873	1130	1471
Vaishali	29.1	26.4	921	921	1054	1332
Samstipur	28.6	25.6	926	927	936	1175
Begusarai	24.6	29.1	898	911	946	1222
Lakhisarai	21.1	23.9	880	923	526	652
Munger	17.8	20.3	856	878	665	800
Bhagalpur	20.7	27.2	864	878	743	946
Katihar	27.8	30.9	909	919	597	782

Table 2: Literacy rate in the districts of U.P. and Bihar along the river Ganga

State/ District	Literacy rate, 2001				Literacy rate, 2001		
	Person	Male	Female	State/Diatrict	Person	Male	Female
UP	**57.4**	**70.2**	**43.0**	**Bihar**	**47.5**	**60.3**	**33.6**
Kanpur Dehat	66.6	76.8	54.5	Buxar	57.5	72.8	40.4
Kanpur city	77.6	82.1	72.5	Bhojpur	59.7	74.8	42.8
RaeBareli	55.1	69.0	40.4	Saran	52.0	67.8	35.7
Pratapgarh	58.7	74.6	42.6	Patna	63.8	73.8	52.2
Fatehpur	59.7	73.1	44.6	Vaishali	51.6	64.0	38.1
Kausambhi	48.2	63.5	30.8	Samstipur	45.8	57.8	32.7
Allahabad	62.9	77.1	46.6	Begusarai	48.6	59.7	36.2
Sant Ravidas Nagar	59.1	78.0	38.7	Lakhisarai	48.2	61.0	34.3
Mirzapur	56.1	70.5	39.9	Munger	60.1	70.7	48.0
Varanasi	67.1	83.7	48.6	Bhagalpur	50.3	60.1	38.8
Chandauli	61.1	75.6	45.5	Katihar	35.3	45.5	24.0
Ghazipur	60.1	75.5	44.4				
Ballia	58.9	73.2	43.9				

However, in case of fishers community, the sex ratio in the entire stretch was estimated at 836 (Tyagi, 2005), which is much below the ratio for the country (933). Similary for literacy rate, the rate was much lower for fishing populations, specifically for females (U.P.: Male - 51.8%, Female – 19.0%; Bihar: Male – 47.3%, Female – 19.9%).

2. CLIMATE

The climate of Uttar Pradesh is tropical monsoon in character. It is very hot in the summers across the state but there is a slight fall in temperature from western UP towards east. Summer season persists from Apr to Aug. The daytime temperature remains very high and usually touches around 45^{o}c in western U.P. and it remains around 42^{o}c in eastern U.P. Nights are relatively cooler typical of extreme climate and the temperature comes down to as low as 28^{o}c because of the cool breeze. Winters in Uttar Pradesh are a lot cooler with day temperature pleasant around 24^{o}c and nights are chilly with temperature getting as low as 2 to 4^{o}c across the state. Earlier eastern regions were comparatively warmer but due to persistent change in the weather trends, even these areas fall under intense cold wave. Cities like Allahabad and Varanasi are continuously seeing mercury dipping to freezing point. The winter falls around mid Nov and continue till Feb end. As U.P. stretches from north India towards eastern, the rainfall varies considerably. While the south west monsoon is very moderate in western U.P., it rains very heavily in short spells as far as Awadh and eastern regions are concerned. The average annual rainfall varies from 105-110 centimeters in places like Allahabad, Varanasi to as low as 45-50 centimeters in Agra, Ghaziabad and Merrut. The western disturbance too brings fair amount of rainfall. Approximate average annual rainfall in the state is around 65-70 cm.

Bihar is mildly cold in the winter; the lowest temperatures being around 5 to 10^{o}c. Winter months are Dec and Jan. April to mid Jun are the hot months when temperature rises to 40 to 45^{o}c. The monsoon months of Jun-Sep see good rainfall. The average annual rainfall in Bihar plateau region is around 132.6 cm whereas in Bihar plains it is around 118.6 cm.

3. MORPHOLOGY

Starting west of Kanpur up to Allahabad, the river Ganga flows from northwest to southeast in an incised, straight valley cut into the older alluvium along the Ganga fault (Srivastava et. al., 1994) in an upland region. The river Ganga continues its southeast course downstream of Allahabad up to Chunar. Then the river changes its course and flows northeast up to Saidpur. From Maner to 30 km upstream of Rajmahal, the river flows in south-east-east to east-west direction and then takes a southerly turn. The river shows mainly a meandering channel from Mustafabad to Maner (Swamee *et. al.*, 2003). In the Maner-Munger reach the large tributaries like the Ghagra, Sone and Gandak join river Ganga, which shows a braided nature. This character continues up to Rajmahal.

4. SEDIMENT QUALITY AND QUANTITY

The river bed from Kanpur to Patna has been transformed into sandy soil with 80-90% sand and low percentage of silt and clay. However, in the lower stretch from Bhagalpur to Farakka the sand contribution declined considerably (54-69%) with substantial increase in silt and clay content. The study revealed that the stretch between Kanpur to Patna suffers from severe textural deformity with sediment blanketed by sand drifted through a number of tributaries, viz., Ramganga, Yamuna, Gomti, Ghagra, Gandak and Sone. In the entire river bed soil has been found to have alkaline pH (7.4-8.2) and poor in respect of available nutrients (N – 0.53 to 8.0 and P – 0.06 to 2.2 mg/100g) and organic carbon (0.014 to 0.23%). The sandy bed can naturally contribute very little to aquatic productivity as evidenced by poor nutrients and organic carbon, however, the loss is compensated by nutrient flow from the catchment.

The quantitative picture of silt load in four phases at Allahabad and Varanasi has been shown in Fig. 1. In river Ganga till 1985 silt load was of low order (Allahabad – 189.4; Varanasi – 220.46 million tones per year). Due to heavy deforestation and other developmental activities in the catchment area silt load tremendously increased to the extent of 3850.49 million tones at Allahabad and 7096.37 million tones per year at Varanasi during 1995-00. Such huge loading of silt resulted in severe hydrological degradation like decrease in water holding capacity and volume in the river. As a result many wetlands lost connection with the main channel and some of them even lost their existence due to choking. However, some improvement has been observed in subsequent years with a significant decline in silt load (Allahabad – 1738.55; Varanasi – 3432.39 million tones per year).

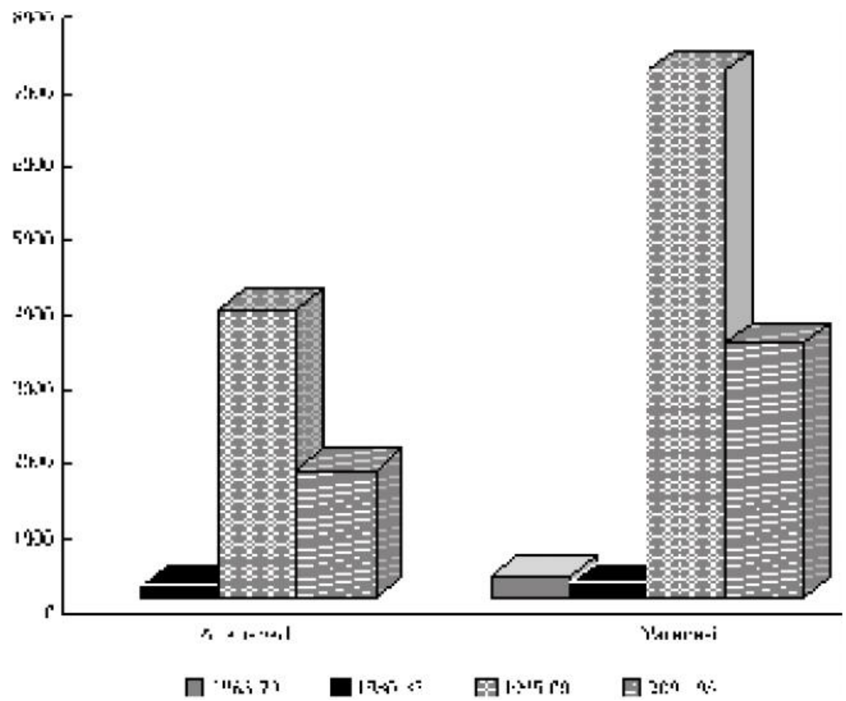

Fig. 1: Silt load in river Ganga (million tones per year)

5. WATER ABSTRACTION

From main river in Kanpur-Farakka stretch there is no major water abstraction. However, a barrage has been constructed at Kanpur (upstream) with the basic aim of diverting the river towards Kanpur city and a small canal has been digged out on south-west bank, mainly for city water supply. On north-east bank three lift canals, viz. Dalmau, Gyanpur and Deokali in the districts of RaeBareilly, Bhadoi and Ghazipur of Uttar Pradesh and one lift canal at Bhapoli on south-west bank in the district Ghazipur are functional and the water is diverted only for irrigation purpose. These abstractions are of small nature. The major water abstraction from the river is at Farakka where a barrage has been constructed to divert water to supply head waters for the Hooghly to increase and maintain better depths for navigable reach.

But, numerous dams and barrages have been constructed on almost all major tributaries feeding Ganga. In addition to Rohilkhand canal and three canals for irrigation purposes a reservoir at Kolagarh with a live capacity of 2,190 million m3 has come up in Ramganga. A number of lift canals, viz., Ghagra canal, Dohrighat, Tanda and Kuwana exists on Ghagra. A barrage has also been constructed on Ghagra near the Nepal border to feed the existing Sharda system. The Tribeni canal takes off from Gandak. Besides this there are two small canals, *viz.*, Madhuban and Lalbakhuja. A barrage with two canals taking off, one on either side has also been constructed on Gandak at Balmikinagar about 760 m below the Tribeni canal head regulator. Kosi project consists of a barrage across the main Kosi about 5 km upstream of Hanumannagar in Nepal and two canals, Eastern Kosi canal and Western Kosi canal are taking off from there (Rao, 1979).

In Yamuna, principal tributary of Ganga water is taken off by the Western and Eastern Yamuna canals at Tajewala and hardly 2.7 million cu m water is left for further exploitation, in down stream the Agra canal takes off at Delhi. Number of dama/barrages has been constructed on other important tributaries of Yamuna, specifically Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar on Chambal; Neemkhera, Berari, Rajghat, Matatila, Dhukwan, Paricha dams/barrages on Betwa along with Betwa canal; and Rangwan and Gangau dam on Ken along with Ken canal. On Sone river, Indrapuri barrage located nearly 5 km from Dehri is one of the longest barrage in India, storing a large amount of water. From it flow 2 major and several other small canals which supply the whole of western and central Bihar with water for irrigation.

6. WATER QUALITY

The important water quality parameters in three phases 1960, 1987-88 and 2001-06 in Ganga between Kanpur and Farakka has been depicted in Tab 3. The river reflected high productive character in all the stretches during sixties with fairly rich oxygen (6.9-8.4 mgl^{-1}), alkaline pH (7.9-8.2), poor free carbon dioxide (1.5-3.1 mgl^{-1}) and conductance, alkalinity, total dissolved solids, hardness and chloride ranging between 212 to 328 mmhos; 99.4 to 148.5; 107 to 170; 88 to 128 and 10 to 21 mgl^{-1}, respectively (Pahwa and Mehrotra, 1966). The nutrient status was poor both in respect of nitrate and phosphate but dissolved organic matter was quite high. Since then man induced modifications and subsequent hydrological degradations like discharge of huge quantity of domestic and industrial effluents and severe reduction in water volume, started showing impact on water quality especially at Kanpur and Varanasi, the worst hit stretches. The situation became so critical during 1987-88 that at both places dissolved oxygen showing complete absence on many occasions with tremendous rise in free carbon dioxide (up to 36 mgl^{-1}). The average value of dissolved oxygen was 1.8 mgl^{-1} at Kanpur and 2.2 mgl^{-1} at Varanasi with free CO_2 12.4 and 8.8 mgl^{-1}. The chemical parameters *viz.* alkalinity, conductance, TDS, total hardness, chloride and even dissolved organic matter showed tremendous increase from their low values in sixties (Jhingran and Pathak, 1988). The values of all parameters increased sharply from Kanpur to Varanasi, probably due to reduction in water volume and increased concentration. However, hydrological degradations were less marked from Patna and below, may be due to less variation in water volume and impact of tributaries, especially Ghagra, Sone and Gandak. Seeing the gravity of situation several steps were initiated for the protection of water quality especially diversion of effluents for agricultural uses and treatment before discharge at Kanpur or diversion of effluents in Varuna river for dilution at Varanasi. Although the control of effluents resulted in considerable improvement in water quality with DO rising up to 6.9 to 7.8 mgl^{-1} with reduction in free CO_2 but the chemical parameters still maintained their rising trend as observed during 2000-06. This may be due to further reduction in flow rate and water volume. The stretch between Patna and Farakka was found to be free from such hydrological degradations with little variation in water quality over a span of four decades (Tab. 3).

Table 3 : Water quality parameters in different stretches of river Ganga

Stretches	Period	DO	pH	CO_2	Total alkalinity	Conductance	TDS	Hardness	Chloride	NO_3	PO_4	DOM
		mgl^{-1}		mgl^{-1}	mgl^{-1}	mmhos	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}
Kanpur	1960	7.8	7.9	2.2	148.5	328	170	128	10	0.14	0.14	1.12
	1987-88	1.8	7.2	12.4	198	565	278	176	28	0.28	0.18	3.86
	2001-06	6.9	8.2	3.2	200	568	285	182	32	0.18	0.14	2.2
Allahabad	1960	8.4	8.1	1.5	142	285	148	122	12.1	0.17	0.15	1.26
	1987-88	8	8	4.6	171	412	206	152	24	0.19	0.18	1.84
	2001-06	7.8	8.2	1.8	198	505	253	164	35	0.18	0.12	1.48
Varanasi	1960	7	8	3.1	127.5	257	130	110	21	0.1	0.04	0.98
	1987-88	2.2	7.4	8.8	178.6	436	216	154	25	0.22	0.17	3.12
	2001-06	7.4	8.1	2.4	192	468	234	162	33	0.11	0.1	1.68
Patna	1960	7	7.9	4	141.7	300	148	120	10.7	0.14	0.1	1.12
	1987-88	7.8	8	2	139.6	283	138	118	20.2	0.22	0.18	1.84
	2001-06	7.8	8.1	2.6	168	308	155	148	22.3	0.16	0.12	1.24
Bhagalpur	1960	6.9	8.2	2.3	131.4	268	134	112	11.2	0.14	0.09	0.94
	1987-88	7.2	8.1	2.5	142.2	310	158	120	18.4	0.18	0.12	1.32
	2001-06	7.6	8.2	2.2	146	326	164	124	24.6	0.16	0.1	1.28
Rajmahal	1960	7.6	7.9	2.4	99.4	212	107	88	10.8	0.16	0.16	0.98
	1987-88	na	na	na	na	na	na	na	na	na	na	na
	2001-06	7.8	8	2.2	128	246	124	112	14.8	0.16	0.14	1.21
Farakka	1960	na	na	na	na	na	na	na	na	na	na	na
	1987-88	na	na	na	na	na	na	na	na	na	na	na
	2001-06	7.4	8.1	2.6	126	242	121	108	14.2	0.14	0.12	1.18

6.1 Water quantity

Average annual flow in Ganga and its important tributaries during seventies has been presented in Tab 4 (Rao, 1979). The annual discharge of Ganga after Yamuna confluence was 152,000 million cu m.

Table.4: Average annual flow in Ganga and its important tributaries

Sr. no.	Sub-basin	Annual flow (million cu m)
1	Ganga at Allahabad	58,980
	Ramganga	(15258)
2	Yamuna at Allahabad	93,020
	Chambal	(30,050)
3	Ganga at Allahabad after Yamuna confluence	152,000
4	Ganga at Patna	364,000
	Gomti	(7,390)
	Ghagra	(94,400)
	Gandak	(52,200)
	Tons	(5,910)
	Sone	(31,800)
5	Ganga at Farakka	459,040
	Buri Gandak	(7,100)
	Kosi	(61,560)

The analysis of discharge data collected from Central Water Commission, New Delhi revealed that the annual discharge at Allahabad come down to 108,775 million cu m in 1980-85. During 2000-03 the annual discharge showed sharp decline and tumbled down to merely 74,944 million cu m, showing an overall decline of 77,004 million cu m within a spell of four decades. The discharge data for other centres could not be obtained but it is presumed that other centres might have followed the similar pattern as observed in Allahabad.

7. PRODUCTION FUNCTIONS

7.1 Plankton structure and dynamics

Information on plankton communities and their dynamics is meager, fragmented and in piecemeal. Hydrobiological features of selected centres along Ganga (Kanpur – Bhagalpur stretch) have been studied by many workers *viz,* Ray *et. al.* (1966), Pahwa and Mehrotra (1966), Anon (1979), Sinha *et. al.* (1979), Khan *et. al.* (1996), Bilgrami and Dutta Munshi (1979), *etc.* The Riverine Division of CIFRI, Barrackpore has been collecting information on plankton density and their population structure along with micro invertebrates from various centers on Ganga with a view to assess the eco health of the river in general and to assess the environmental stress causing deleterious effect on fish and fisheries in particular.

Recent studies on Ganga has shown that major groups contributing to phytoplankton were Bacillariophyceae (*Amphora, Asterionella, Cyclotella, Cymbella, Diatoma, Fragilaria, Gomphonema, Gyrosigma, Navicula, Nitzschia, Pleurosigma, Pinnularia, Synedra);* Chlorophyceae (*Actinastrum, Ankistrodesmus, Chlorella, Closterium, Denticula, Desmidium, Eudorina, Hydrodictyon, Mougeotia, Pediastrum, Scenedesmus, Spirogyra*), Cynanophyceae (*Anabaena, Lyngbya, Merismopoedia, Microcystis, Nostoc, Oscillatoria, Phormidium)*. Among zooplankton, copepods, cladocerans, rotifers and protozoans were the major groups. The maximum abundance of plankton in terms of quality and quantity was observed in the stretch between Kanpur and Allahabad. The overall plankton density in the entire middle stretch varied from 24 to 782 ul^{-1}; 146 to 3,649 ul^{-1} and 14 to 8049 ul-1 during summer, monsoon and winter season. Maximum density was observed in Kanpur stretch (8,049 ul^{-1}) during winter season. Of this the contribution of phytoplankton and zooplankton was 7,953 ul^{-1} and 96 ul^{-1}, respectively. Among phytoplankton, dominant group was Bacillariophyceae followed by Chlorophyceae and Cyanophyceae. 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 Barauni and Farakka the plankton density ranged between 34 and 1204 ul^{-1}. The total plankton density varied in this stretch was from 100 to 1204 ul^{-1}, 34 to 259 ul^{-1} and 98 to 396 ul^{-1} during summer, monsoon and winter seasons respectively. Plankton population was maximum during summer and abundance was as: Sultanpur (315 ul^{-1}), Barauni (1204 ul^{-1}), Munger (1160 ul^{-1}), Bhagalpur (936 ul^{-1}), Kahalgaon (278 ul^{-1}), Manikchakghat (652 ul^{-1}) and Farakka (544 ul^{-1}). The bulk of population was constituted by phytoplankton. In total plankton population, 70.98 to 89.22% and 10.78 to 29.02% by numbers were contributed by phyto and zooplankton respectively. Thus, a sharp dominance of phytoplankton was observed over the entire stretch with highest percentage of Bacillariophyceae, Chlorophyceae and Cynophyceae, in order of abundance. At Kahalgaon, Munger and Barauni the maximum percentage of zooplankton ranging from 26.92 to 29.02% was observed. On the basis studies it could be concluded that although plankton density has considerably decreased around middle and lower stretches of Ganga as compared to sixties but the composition of plankton organisms has not changed much.

7.2 Benthic population and dynamics

The available data on bottom fauna studied during 1958-59 at different centres showed 3476 um^{-2} at Kanpur, 1121 um^{-2} at Allahabad, 880 um^{-2} at Varanasi, 71 um^{-2} at Ballia, 1593 um^{-2} at Patna, 218 um^{-2} at Bhagalpur and 502 um^{-2} at Rajmahal. Insects were observed to be maximum at Kanpur (98.0%) and minimum at Patna (0.6%) while molluscs were dominant group at Patna (99.4%) and minimum at Kanpur. Among inset population dipteran larvae contributed maximum at Kanpur and Allahabad while at Varanasi trichoptera dominated the benthic population. At Bhagalpur the insect population mainly consisted of hemipterans while at Rajmahal mayflies dominated the population. Among molluscs, the gastropods were dominant group at Patna (94.3%) mainly represented by *Melanoides lineatus*. At Bhagalpur *Pila globosa* formed the bulk of gastropod population. At Rajmahal two species of gastropods *viz. V. bengaleasis* and *I. exustus* were observed. The population of bivalves was maximum at Varanasi (155 um^{-2}) and minimum at Ballia (27 um^{-2}). Among annelids polychaetes were dominant at Varanasi, Rajmahal, Bhagalpur and Allahabad but absent at Kanpur, Ballia and Patna. Pahwa (1979) reported macro invertebrates of Ganga between Kanpur and Rajmahal during 1960 and recorded an average density of benthic population of

3476 um^{-2} at Kanpur, 1121 um^{-2} at Allahabad, 880 um^{-2} at Varanasi, 1,593 um^{-2} at Ballia, 218 um^{-2} at Patna, 218 um^{-2} at Bhagalpur and 508 um^{-2} at Rajmahal. Insect population belonging to the order *Diptera*, *Ephemeroptera*, *Odonata, Hemiptera, Trichoptera* and *Coleoptera* were dominant at Kanpur. Interestingly the contribution of *Ephemeroptera* (2.4%) and *Trichoptera* (11.52%) and absence of annelids (oligochaete) indicated that the Ganga at Kanpur during sixties was relatively pollution free. Khan *et. al*. (1999) while investigating macro-benthos of middle and lower stretch of Ganga reported macro-benthos density as 500-3,636 um^{-2} at Kanpur, 220-800 um^{-2} at Allahabad and 204-2,432 at Varanasi and concluded that the stretch was moderate to heavily polluted. The results of exploratory survey revealed considerable decline in the macro-benthic density in middle and lower reaches of Ganga. Sinha and Prasad (1988) recorded 728 and 277 um^{-2} benthic population during 1980 at Buxar and Patna. During 1982-95 these workers further observed an increase in the number of species and density of benthic macro invertebrates. At Buxar the production of benthic macro-invertebrates increased from 728 um^{-2} in 1985-87 to 4,514 um^{-2} in 1995 while at Farakka it increased from 1,669 in 1991 to 12,825 in 1995. Recent studies on macro-benthic communities showed an average of 1,065 um^{-2} between Kanpur to Varanasi stretches and 607 um^{-2} in Patna to Farakka stretch of Ganga, indicating a decline in the benthic population over the years. As regard various groups of organisms, the molluscs population dominated the entire middle and lower stretch of the river pre-dominance of gastropods followed by bivalves, insect being represented by *diptera* and *odonata* while annelids mainly represented by oligochaetes and polychaete. *V. bengalensis, V. Melania tuberculata, Gyrulus, L. accuminata, Bratia astula, indoplanorbis* were the dominant group of gastropods while bivalves were mainly represented by *Lamelidens marginalis*, *L. lorriantus*, and *Navaculina gangetia*. Among annelids *Tubifex*, *Naris* and *Lumbriculu* were most dominant while insect were mainly represented by dipteran larvae and odonates (dragonfly nymphs and mayfly nymphs)

7.3 Flow of energy in river Ganga

The pattern of utilization by fishes feeding at various trophic levels in Ganga has shown remarkable variations with the passage of time (Tab. 15). At Allahabad the energy harvest was 56,136 k cal ha^{-1}, mainly contributed by primary, secondary and detritus consumers (55.8%). Among the three consumers, the share of detritus feeders was maximum (30%). Tertiary consumers and miscellaneous species contributed 21.5 and 22.7%, respectively. Over a span of four decades the pattern of utilization changed completely with primary, secondary and detritus consumers going down to 10.8% and tertiary consumer to 11%, however, miscellaneous species increased sharply to 60.7% during 2000-06. Recently the exotic species have emerged in the system and their contribution is quite significant (17.5%). The shift in the pattern of energy utilization has resulted in sharp decline in the energy harvest (22,080 k cal ha^{-1}). At Buxar the total energy harvest was 133,560 k cal ha-1, mainly contributed by primary, secondary and detritus consumers (71%). Among the three the major contributor was hilsa (66.9%). Tertiary consumers and miscellaneous species contributed 6.7% and 22.3%. During 1981-86 the contribution of primary, secondary and detritus consumers dropped to 17.7%, however, tertiary consumers increased to 24.8% and miscellaneous species by 57.5%. The variation in energy utilization resulted in decline of energy harvest to 64,320 k cal ha^{-1}

At Patna the energy harvest during sixties was 86,940 k cal ha^{-1}, the contribution of primary, secondary and detritus consumers being 34.4%. Tertiary consumers and miscellaneous species contributed 20.6 and 45.0% respectively. In the years 1986-93, the contribution of primary, secondary and detritus consumers

Table 5 : Pattern of energy utilization (k cal ha^{-1}) by fishes in Ganga

River stretch	Period	Primary	Secondary	Tertiary	Miscellaneous	Detritus	Total
Allahabad	1961-68	10,212	3,996	12,084	12,720	17,124	56,136
	2000-06	612	780	2,436	13,404	996	22,080
Buxar	1963-71	91,176	1,872	8,988	29,676	1,848	133,560
	1981-86	4,464	1,212	15,960	36,996	5,688	64,320
Patna	1961-66	17,844	3,420	17,946	39,060	8,676	86,940
	1986-93	1,836	2,376	9,336	22,548	1,548	37,644
Bhagalpur	1961-70	4,008	3,780	14,412	27,240	2,796	52,236
	1981-88	1,104	1,308	12,348	24,240	792	39,792

dropped to 15.3% but tertiary consumer and miscellaneous species increased by 24.8 and 59.9%. The shift in the energy utilization pattern resulted in decline in energy harvest to 37,644 k cal ha-1. The energy harvest in Bhagalpur stretch during 1961-70 was 52,236 k cal ha^{-1} which dropped to 39,792 k cal ha^{-1} during 1981-88. The contribution of primary, secondary and detritus consumers reduced from 20.3 to 8%. However, tertiary consumers increased from 27.6% to 31%, and miscellaneous species from 52.1 to 61%.

7.4 Energy transfer

The rate of energy transformation by producers and estimated fish production potential in three different phases 1960, 1987-88 and 2000-06 has been presented in Tab 5. During sixties the rate of energy transformation and potential energy resource was high at all the places with maximum at Kanpur (4,678 cal m^{-2} d^{-1}, 194,000 k cal ha^{-1} y^{-1}) and minimum at Rajmahal (3,078 cal m^{-2} d^{-1}, 127,800 k cal ha^{-1} y^{-1}) reflecting good productive character of the river. Due to hydrological degradation considerable decline in energy transformation rate and potential energy was observed during 1987-88 at Kanpur (1,008 cal m^{-2} d^{-1}, 41,880 k cal ha^{-1} y^{-1}) and Varanasi (1,987 cal m^{-2} d^{-1}, 82,538 k cal ha^{-1} y^{-1}). At Allahabad the magnitude of decline was however much lower. As observed in respect of water quality, the rate of energy transformation and fish production potential did not show any declining trend in the stretches below Patna. Control in the discharge of effluents have resulted in tremendous increase in rate of energy transformation and potential energy during 2000-06 at both at Kanpur (4,897 cal m^{-2} d^{-1}, 203,520 k cal ha^{-1} y^{-1}) and Varanasi (3,842 cal m^{-2} d^{-1}, 159,627 k cal ha^{-1} y^{-1}). In the stretch below Patna to Rajmahal the energy transformation and potential remained almost similar during a span of four decades, thereby showing no sign of environmental degradation.

Table 6 : Energy transformation in different stretches of river Ganga

Stretch	Period	Rate of energy transformation by producers	Fish production potential	Potential energy resource
		cal m^{-2} day^{-1}	kg ha^{-1} yr^{-1}	(k cal ha^{-1} yr^{-1})
Kanpur	1960	4678	162	194000
	1987-88	1008	34.9	41880
	2000-2006	4897	169.6	203520

Table 6 : Energy transformation in different stretches of river Ganga *(Contd.)*

Stretch	Period	Rate of energy transformation by producers	Fish production potential	Potential energy resource
		cal m^{-2} day^{-1}	kg ha^{-1} yr^{-1}	(k cal ha^{-1} yr^{-1})
Allahabad	1960	4545	157.3	188822
	1987-88	3085	106.8	128160
	2000-2006	4368	151.2	181440
Varanasi	1960	4248	147	176500
	1987-88	1987	68.8	82538
	2000-2006	3842	133	159627
Patna	1960	3770	130.5	156600
	1987-88	3639	126	151200
	2000-2006	3533	122.3	146760
Bhagalpur	1960	3462	119.8	143820
	1987-88	3278	113.5	136200
	2000-2006	3024	104.7	125640
Rajmahal	1960	3078	106.5	127800
	1987-88	2897	100.3	120360
	2000-2006	2730	94.5	113424
Farakka	1960	na	na	na
	1987-88	na	na	na
	2000-2006	2849	98.6	118320

8. FISH & FISHERIES

8.1 Fish structure

From fisheries point of view Ganga is the most important river and source of livelihood for countless fishers inhabiting on its bank. The fishery in the potamon zone of the river is mainly represented by the species belonging to Cyprinidae and Siluridae families. Recent studies revealed the presence of 79 fish species of seven order and 25 families from Kanpur – Farakka stretch of the river (Tab. 7).

Tab 7: Fish fauna of river Ganga in Kanpur-Farakka stretch

Order	Family	Species
1	2	3
Beloniformes	Belonidae	*Xenentodon cancila*
Clupeiformes	Clupeidae	*Gonialosa manimina*
		Gudusia chapra
		Tenualosa ilisha
	Engraulididae	*Setipinna phasa*
	Pristigasteridae	*Ilisha megaloptera*

Tab 7: Fish fauna of river Ganga in Kanpur-Farakka stretch *(Contd.)*

Order	Family	Species
1	**2**	**3**
Cypriniformes	Cobitidae	*Botia dario*
		Botia dayi
		Botia lohachatta
		Lepidocephalichthys guntea
	Cyprinidae	*Amblypharyngodon mola*
		Aspidoparia jaya
		Aspidoparia morar
		Catla catla
		Chagunius chagunio
		Cirrhinus mrigala
		Cirrhinus reba
		Crossocheilus latius latius
		Cyprinus carpio carpio
		Esomus danricus
		Garra gotyla gotyla
		Garra lissorhynchus
		Labeo bata
		Labeo boga
		Labeo boggut
		Labeo calbasu
		Labeo dero
		Labeo fimbriatus
		Labeo gonius
		Labeo pangusia
		Labeo rohita
		Osteobrama cotio cotio
		Puntius chola
		Puntius conchonius
		Puntius sarana
		Puntius sophore
		Puntius ticto
		Rasbora daniconius
		Salmostoma bacaila
		Securicula gora
Osteoglossiformes	Notopteridae	*Chitala chitala*
		Notopterus notopterus

Tab 7: Fish fauna of river Ganga in Kanpur-Farakka stretch *(Contd.)*

Order	Family	Species
1	2	3
Perciformes	Ambassidae	*Chanda nama*
		Parambassis ranga
	Anabantidae	*Anabas testudineus*
	Channidae	*Channa marulius*
		Channa striatus
	Cichlidae	*Oreochromis niloticus*
	Gobiidae	*Glossogobius giuris*
	Mastacembelidae	*Mastacembelus armatus*
		Macrognathus pancalus
	Mugilidae	*Rhinomugil corsula*
		Sicamugil cascasia
	Nandidae	*Nandus nandus*
	Osphronemidae	*Trichogaster chuna*
	Sciaenidae	*Johnius gangeticus*
		Pama pama
Siluriformes	Bagridae	*Aorichthys aor*
		Aorichthys seenghala
		Mystus bleekeri
		Mystus cavasius
		Mystus vittatus
		Rita rita
	Clariidae	*Clarias batrachus*
	Heteropneustidae	*Heteropneustes fossilis*
	Pangasiidae	*Pangasius pangasius*
	Schilbeidae	*Ailia coila*
		Clupisoma garua
		Eutropiichthys murius
		Eutropiichthys vacha
		Pseudeutropius atherinoides
		Silonia silondia
	Siluridae	*Ompok bimaculatus*
		Ompok pabda
		Wallago attu
	Sisoridae	*Bagarius bagarius*
		Gogangra viridescens
		Sisor rahabdophorus
Tetraodontiformes	Tetraodontidae	*Tetraodon cutcutia*

Table 8 : Fish landinss (t) at different centres on Ganga

Year	*C. mrigala*	*C. catla*	*L. rohita*	*L. calbasu*	Major carps	*A. aor*	*A. seenghala*	*W. attu*	CF	*T. ilisha*	Exotic	Others	Total
Allahabad													
19 61-68	52.38	15.33	16.78	13.24	97.73	20.10	14.59	11.62	46.31	22.35		48.75	215.14
1972-80	8.50	3.32	2.59	16.68	31.09	11.85	7.22	3.59	22.67	2.22		45.51	101.49
1981-90	5.96	3.26	2.76	23.84	35.82	10.40	9.18	3.29	22.86	0.99		56.95	116.62
1991-00	1.08	1.67	1.19	2.71	6.65	7.58	5.37	1.48	14.43	1.04		40.99	63.10
19 01-06	2.17	2.99	2.06	1.66	8.87	5.56	2.66	1.11	9.33	0.28	14.78	51.38	84.64
Buxar													
1963-71	0.57	0.70	0.71	0.12	2.10	2.02	0.79	0.56	3.37	33.48		11.13	50.08
1972-80	0.40	1.02	1.18	0.30	2.89	2.15	1.36	0.54	4.05	2.43		6.23	15.58
1981-86	0.54	0.46	0.67	1.59	3.25	2.38	1.55	2.06	5.98	1.01		13.87	24.11
Patna													
1961-66	10.02	4.28	8.22	0.83	23.35	10.61	**	11.82	22.43	14.08		48.82	108.68
1986-93	0.83	2.98	2.20	1.10	7.10	4.80	4.55	2.32	11.67	0.08		28.18	47.04
Bhagalpur													
1961-70	5.38	8.19	4.41	0.68	18.66	4.95	5.95	20.33	31.23	4.27		59.02	113.18
1972-80	2.70	5.87	2.55	0.65	11.76	4.44	4.36	15.87	24.67	0.68		48.45	85.56
1981-88	1.35	2.83	1.45	0.36	5.98	6.48	3.65	16.61	26.75	0.93		52.52	86.17

In Ganga commercial fishery commences from Anupshahar (Jhingran and Ghosh, 1978) and middle stretches of Ganga are considered rich source of fishery. The fish landings at major commercial fish landing centres in different stretches of river Ganga are presented in Tab 8. It is obvious from the table that at all the centres fishery showed a constant declining pattern. The worst sufferer was major carps and hilsa. At Allahabad, the landings of major carps came down to merely 8.87 t from 97.73 t of sixties. Large catfish catches also reduced to almost 1/5th and hilsa fishery reached to negligible. In the present the fishery showed some improvement due to emergence of exotic species, specifically *C. carpio* and *O. niloticus* which are showing a constant increasing trend.

At Buxar hilsa was the main fishery and with the commissioning of Farraka barrage the fishery declined sharply in 1972-80, some how the fishery improved during 1981-86 due to improvement in landings of other species. Patna centre also showed drastic decline in major carps landings and as compared to sixties it was almost half during 1986-93. Decline at Bhagalpur was not as severe as at other centres. Gupta and Tyagi (1991) have discussed the fishery of Ganga with an analytical approach and showed that the fishery is harvested at a level higher than the optimum fishing level and efforts should be made to reduce the fishing pressure to obtain a sustainable fishery from the system.

8.2 Catch trends and production

During 1961-68 the fishery from river Ganga in Kanpur to Bhagalpur stretch was of higher order with annual fish yield rate as 1169 kg km^{-1} (Tab 9). The yield rate was maximum at Patna (1803.3 kg km^{-1}) and minimum at Bhagalpur (781.5 kg km^{-1}). Fishery showed considerable structural variation in difeerent stretches with major carps domination in Kanpur to Allahabad stretch and others in Varanasi, Patna and Bhagalpur stretches of river. At Ballia and Buxar hilsa was the main fishery. The fishery during the period has been discussed in detail by Jhingran and Ghosh (1978).

Table 9 : Yield rate (kg km^{-1}) in different stretches of river Ganga, 1961-68

Centre	Major carps	Large catfishes	Hilsa	Others	Total
Kanpur	365.0	317.5	0.0	272.5	955.0
Allahabad	430.0	203.9	93.9	207.4	935.2
Varanasi	46.2	327.7	443.1	684.6	1501.5
Buxar	37.8	68.9	917.8	304.4	1328.9
Ballia	57.1	124.3	485.7	210.0	877.1
Patna	331.7	370.0	193.3	908.3	1803.3
Bhagalpur	149.2	163.1	31.5	437.7	781.5

From 1972 onwards fishery from river started declining with sharp changes in stock structure. At Allahabad the yield rate came down from 935.2 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 (207.4 to 223.41 kg km^{-1}) with slight changes in catch composition. The yield rate at Allahabad for different periods is presented in Tab 10.

Table.10 : Fish yield rate (kg km^{-1}) in different periods at Allahabad

Period	Major carps	Large cat fishes	Hilsa	Exotics	Others	Total
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	-	178.2	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.

At Buxar the fishery showed serious decline from 1972 onwards mainly due to decline in hilsa fishery. During sixties the fish yield at Buxar was 1112.9 kg km^{-1}, out of which 744 kg km^{-1} was contributed by hilsa. After 1972 the hilsa fishery suffered a serious set-back and came down to only 22.37 kg km^{-1} in 1981-86. Although as compared to 1963-71, the yield rate was almost half, but due to shift in fishing effort the fishery of major carps and large catfishes showed some improvement. The yield of major carps increased from 46.7 to 72.3 kg km^{-1}. Large catfishes showed the maximum increase and were almost double of sixties (74.9 kg km^{-1}), however, improvement in smaller species was little.

In the past the yield rate was maximum at Patna (1811.30 kg km^{-1}) but during 1986-93 the rate came down to only 783.94 kg km^{-1}. As an exception the fishery of smaller species suffered badly in this stretch and their yield rate slipped to 469.7 from 813.7 kg km^{-1}. The contribution of major carps reduced to one third, whereas large catfishes reduced to half. Again the worst sufferer was hilsa whose contribution reached to almost negligible (1.4 kg km^{-1}).

As compared to 1961-70, the fishery from Bhagalpur stretch also showed a decline but not as severe as in other stretches. The yield rate came down to 662.9 in 1981-88 from 870.6 kg km-1 of the past. The large catfishes and smaller species registered a smaller decline but major carps and hilsa fishery suffered badly. The contribution of major carps came down to 46.0 from 143.5 kg km^{-1} of the past, whereas contribution of hilsa was only 7.1 kg km^{-1}.

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.11.

Table 11 : 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

8.3 Fishing crafts

A techno-socio-economic survey of fishing families along the banks of river Ganga was conducted during 2000-03 (Tyagi, 2005). The data revealed that fishing boats were available with 57.7% households whereas gears in 77.7% families. The proportion of families possessing both boat and gears was 56.7%.

For fishing purpose mainly small or medium sized boats was used. Stretch-wise distribution of boats is presented in Tab 12. More than half of the boats irrespective of size were from middle stretch of river. Small wooden boats were mainly available in Bihar.

Table 12: Percent distribution of boats by type in different stretches

Stretch No.	Districts	Small wooden (<5.5 m)	Small tin & wooden (<5.5 m)	Medium 5.5-9 m	Large size >9 m
1	Kanpur	2.4	10.3	0.0	0.0
2	Fatehpur, Kaushmbi	0.0	7.4	1.2	4.6
3	RaeBareli, Pratapgarh, Allahabad, Mirzapur north, Sant Ravidas nagar	0.0	16.3	16.3	18.2
4	Allahabd, Mirzapur, Varanasi south bank	2.4	23.7	24.5	13.6
5	Varanasi north, Ghazipur north	2.4	12.9	13.8	31.8
6	Chandauli, Ghazipur south	2.4	5.1	6.8	4.6
7	Ballia	2.4	2.5	5.5	9.1
8	Buxar, Bhojpur	19.5	3.2	8.0	4.6
9	Patna, Munger, Bhagalpur	36.6	8.1	16.3	9.1
10	Saran, Vaishali, Samstipur, Begusarai	24.4	2.3	7.7	4.6

As compared to sixties the availability of boats per fishermen showed an increase, this may be due to change in fishing pattern. As in past mainly dragnets were used for fishing involving only two boats and more than 10 fishers in a fishing unit. With the passage of time dragnets have lost their place and fishers have switched over to gill nets involving maximum 2-3 persons and a boat. In the districts Chandauli, Ghazipur (south bank) and Ballia the boat availability index decreased as compared to sixties. This may be ascribed to decline in fishing activity in these stretches due to sharp changes in river course. In these stretches fishing activity was mainly carried out by migratory fishers and about them no information could be collected.

8.4 Gears

Availability of gears per fishermen is presented in Tab.13. For dragnets and gill nets; the area of the gears was taken as unit due to variation in dimensions. In case of hook and lines only availability was considered, as information on number of hooks seems to be vague. Gill nets availability was highest in stretch 9 and lower in stretches 1, 2 and 7. Dragnets were divided in two categories, small (less than 300 m) and large (>300 m). It is obvious from Tab. 13 that availability of dragnets was low in almost all stretches. In number of stretches large dragnets were not present at all. Use of hook and lines were mainly in the upper and middle stretches, whereas traps were more in district Ballia and Bihar stretches. Small scoop nets were available in the entire stretch but large size was available only in lower stretches. Dip nets were observed in Allahabd and Mirzapur districts only in small number.

Table 13: Availability of gears per fishermen

Stretch No	Stretch	Gill net area (sq. m)	Dragnet area		Hook & Line unit	Trap
			Small	Large		
1	Kanpur	182.3	24.7	0.0	0.44	0.03
2	Fatehpur, Kaushambi	245.0	115.4	20.7	0.36	0.04
3	RaeBareli, Pratapgarh, Sant Ravidas Nagar, Allahabad and Mirzapur north	450.6	100.3	0.0	0.37	0.13
4	Allahabad, Mirzapur and Varanasi south	972.9	361.5	5.1	0.26	0.05
5	Varanasi and Ghazipur north	461.1	293.5	0.0	0.19	0.16
6	Ghazipur south, Chandauli	695.3	43.7	0.0	0.26	0.04
7	Ballia	337.2	111.2	32.1	0.07	0.49
8	Buxar, Bhojpur	492.8	58.9	0.0	0.05	0.50
9	Patna, Munger, Bhagalpur	1671.5	320.9	279.2	0.31	0.55
10	Saran, Vaishali, Samstipur, Begusarai	879.8	464.0	137.3	0.16	0.43

Distribution of gill nets according to mesh size is given in Tab 13. It is obvious from the table that about two third of gill nets in use were of smaller mesh size. The proportion of lower mesh size gears was slightly more in U.P. Though no earlier information is available about the distribution of gill nets according to mesh size but with the interaction of fishers it could be inferred that in past the use of small meshed gears was little. Saxena (1966) has described the fishing gears of Ganga and has reported that mesh size of gill nets varied from 18 to 26 cm and for most of the dragnets more than 2 cm.

Mesh size of around 75% of dragnets was up to 1.5 cm in Bihar (Tab. 14). In fact in Bihar and Varanasi, Ghazipur and Ballia districts of U.P. use of large dragnets of mosquito net clothing is common. These gears are highly destructive as water gets filtered and due to dragging the river bed is completely cleaned leaving only sand and thus developing ecological desert. In a village of Ballia district dragging activity of such a gear was observed and output was hardly a few kg of smaller sized species and quintals of algal material.

Table 14 : Distribution (%) of gill nets and dragnets by mesh size

Mesh size (cm)	Gill net		Dragnet	
	U.P.	Bihar	U.P.	Bihar
up to 1	17.4	12.5	43.5	62.4
1.1-1.5	11.2	8.5	4.0	13.5
1.6-2	16.5	18.3	20.5	3.9
2.1-3	10.7	10.1	9.6	5.6
3.1-4	8.0	11.1	7.8	5.6
4.1-5	4.5	5.2	3.7	2.8
5.1-10	22.3	19.7	9.3	3.4
10.1-20	9.4	14.5	1.6	2.8

Tab. 15 presents availability of dragnets and gill nets per fishermen. It is obvious from the table that use of dragnets has declined sharply as compared to sixties. However, availability of gill nets had increased manifold in all stretches. The use of traps and hook and lines had also declined considerably in the entire stretch of Ganga. In the past from Allahabad to Dhulian (W.B) purse nets, specifically *kamel* and *bandal* a trap was used in large numbers, mainly for hilsa fishery. Due to Farakka barrage, hilsa fishery has almost collapsed in these stretches and during the course of survey hardly a few *kamel* and *bandal* were reported.

Table 15 : Availability of dragnets and gill nets per fishermen

Strech no.	Stretch	Drag net large		Drag net small		Gill net	
		Present	1960's	Present	1960's	Present	1960's
1	Kanpur	0.00	0.39	0.08	0.00	1.00	0.02
2	Fatehpur, Kaushambi	0.02	n.a	0.37	n.a.	1.89	n.a
3	RaeBareli, Pratapgarh, Sant Ravidas Nagar, Allahabad and Mirzapur north	0.00	1.68	0.16	0.09	1.36	0.22
4	Allahabad, Mirzapur and Varanasi south	0.01	10.40	0.19	0.05	1.31	0.07
5	Varanasi and Ghazipur north	0.00	9.18	0.14	0.00	1.16	0.05

Table 15 : Availability of dragnets and gill nets per fishermen *(Contd.)*

Strech no.	Stretch	Drag net large		Drag net small		Gill net	
		Present	1960's	Present	1960's	Present	1960's
6	Ghazipur south, Chandauli	0.00	14.83	0.12	0.00	0.86	0.00
7	Ballia	0.02	15.49	0.11	0.00	0.85	0.61
8	Buxar, Bhojpur	0.00	n.a	0.14	n.a	1.03	n.a
9	Patna, Munger, Bhagalpur	0.03	3.64	0.34	0.44	1.17	0.17
10	Saran, Vaishali, Samstipur, Begusarai	0.02	n.a	0.36	n.a	0.76	n.a

n.a. – information not available

9. ENVIRONMENTAL STRESS

9.1 Impact of dams and barrages

About 60% of the world's river flow is regulated. There are more than 40,000 large dams and barrages and more than 100 dams with heights>150 m (MacAllister *et. al., 2001).* Dams and their associated reservoirs impact freshwater biodiversity by blocking movement of migratory species up and down rivers, causing extirpation or extinction of genetically distinct stocks or species. Creation of dams/barrages changes turbidity/sediment levels to which species/ecosystems are adapted in the rivers. Due to blockade in water passage the woody debris which provides habitat and sustain food chain are filtered. Rivers loose their fluviatile character, running waters become still, silt is deposited and the hydrological conditions are altered. Dam management that diminishes or stops normal river flooding of flood plain wetlands will impact diversity and fisheries. Further, due to regulated flow the timing, extent and duration of floods is altered. The changed hydrological scenario badly hampers the breeding and recruitment process in rivers.

In case of Ganga due to blocking of water passage at Farakka, the migration of anadromous hilsa has been badly affected and its fishery in the upper reaches has reached to almost negligible. This has put a serious jolt to livelihood of fishers dependent on hilsa fishery for their livelihood. Even in downstream, the fishery of hilsa has gone down appreciably. Other migratory species such as *P. pangasius*, *P. pama,* large prawns, *etc.* have also lost their place in fishery of upstream stretches. Over the years, the creation of numerous dams/barrages on feeding tributaries as well as main river, severe hydrological degradations have taken place in Ganga basin. As a result the flow has been regulated, water volume has declined, silt load has tremendously increased, many floodplain wetlands have lost their connection and breeding and nursery grounds have been lost. The cumulative effect of hydrological degradations has resulted in severe declining fishery from river Ganga and its tributaries.

9.2 Organic pollution

It has been observed that out of the total pollution load runoff reaching the river 95% is from point source, including 79% load from municipal sewage and 16% from industries. The remaining 5% is contributed by non point source such as agricultural runoff, livestock, rural households, *etc.* There are 223 cities/towns generating significant amount of sewage in the Ganga basin. These cities/towns generate about 8250 mld (million litres per day) of wastewater, out of which nearly 2460 mld is directly discharged in Ganga and the remaining 4570 mld is discharged into its various tributaries. Out of 8250 mld waste the treatment facilities are available only for 3500 mld. Jhingran (1989) observed that the sewage effluent received by Ganga at Haridwar, Farrukhabad, Mirzapur and Bhagalpur was 16 mld while Allahabad and Varanasi received 100 mld. The load increased to 150 mld at Patna and 275 mld at Kanpur. The total BOD load in Ganga basin from urban areas was estimated at 2504 million kg d-1, of which the share of domestic sewage was 1,338 million kg d-1. Uttar Pradesh contributed the largest share (31%) of the BOD load in Ganga.

Studies made by CIFRI have shown that the organic pollution was very low during sixties but with the discharge of huge quantity of effluents directly in Ganga the BOD load showed sharp increase at Kanpur and Varanasi in subsequent years. At Kanpur discharge of both industrial and sewage effluents resulted in severe increase in BOD load, touching 200 mgl^{-1} on some occasions during 1987-88 (Jhingran and Pathak, 1988). Similar was the situation at Varanasi where the BOD load ranged from 90 to 100 mgl^{-1}. Dissolved organic matter, which is an indicator of organic pollution and COD load also showed high values ranging from 4 to 7 mgl^{-1} in the above stretches. However, in other stretches the organic load was comparatively low. After regulation in the discharge the situation has improved considerably in Kanpur and Varanasi stretch in recent years.

9.3 Inorganic pollution

The discharged effluents induce both direct and indirect impact on aquatic environment. The indirect impacts are deoxygenation, abrupt increase in free CO_2 and other chemical parameters, such as alkalinity, conductance, dissolved solids, chloride, hardness and nutrients. The observations in Ganga during 1987-88 at Kanpur and Varanasi has shown complete deoxygenation on many occasions with sudden increase in the level of free CO_2 and other chemical parameters due to the impact of discharged effluents. However, with the control in flow of effluents, the situation improved considerably during subsequent years. The direct impact of effluents is rise in the level of heavy metals and pesticides. These chemicals have been put under the category of poisons because of their tendency to accumulate and concentrate in the trophic chain. Studies made in Ganga between Kanpur and Varanasi under an ICAR Scheme has shown varying levels of these chemicals in sediment and water phase. The level of heavy metals – Cu, Cr, Cd, Pb, and Zn in the sediment ranged between 6.42-211.42; 8.92-13.86; 1.2-1.38; 20.4-28.2; and 38.4-52.8 mg g^{-1}, respectively. Copper and zinc were found to be higher at Allahabad while chromium at Kanpur. In the water phase the level of above heavy metals were 0.028-0.054; 0.003-0.034; 0.009-0.022; 0.054-0.056; and 0.128-0.276 ppm, respectively. The accumulation of pesticides in the sediment from Ganga (Kanpur-Varanasi) stretch was in the range of 40.5 to 58.6 $^{n}g\ g^{-1}$. HCH and DDT were the main component at all the places. Allahabad stretch showed comparatively higher accumulation of pesticides.

9.4 Contamination and toxicity

The synthetic compounds like organochlorine pesticides and heavy metals are long lasting and there is enough opportunity for them to accumulate in the food chain and rich concentration factor of several thousands after reaching the end of trophic chain. The elevation level of organochlorine in a fish with higher fat content poses a problem for the predators including human beings. Information about hazardous heavy metals and pesticides in fishes from Ganga are inadequate. The accumulation of pesticides (DDT and g-HCH) and heavy metals Cu, Cr, Cd, Zn and Hg in fish and molluscan samples collected from different stretches of Ganga has been reported by Jhingran (1989). Detailed studies made in Kanpur – Varanasi stretch of Ganga under an ICAR Scheme have shown the level of accumulation of Cu, Cd, Pb and Zn as 0.414-0.471; 0.035-0.157; 2.586-2.995; and 3.888-7.840 ppm in *Catla catla*, while in *Cyprinus carpio* the level ranged between 0.341-0.421; 0.034-0.044; 3.315-4.604; and 6.779-11.022 ppm, respectively. The level of lead and zinc were comparatively higher in *C. carpio*. Chromium was detected only in fish samples collected from Kanpur (nd – 0.498 ppm). The total organochlorine pesticides in *C. catla* ranged from 3.604 to 5.774 ppb and in case of common carp the values ranged from 3.634 to 5.875 ppb. There was practically no difference in the level of pesticides in both species. HCH and DDT were the main component in total organochlorines. When compared with the standard limits, the level of heavy metals and pesticides were very low and there is no threat at present in fishes collected from these stretches of river.

9.5 Impact of stress

In addition to sub lethal chronic effects on the environment, industrial effluents cause direct fish kill, destruction of habitat for benthic and plankton communities. Tannery, textile and other mixed organic wastes caused depletion of oxygen and high BOD load at Kanpur. Plankton and benthic fauna disappeared up to a good distance from outfall. Similarly the major adverse impacts of sewage pollution are deoxygenation, high BOD load, rapid eutrophication and accumulation of heavy metals in the environment. Sharp fall in dissolved oxygen in water put the biotic communities under severe stress. While some species can tolerate a wide range of dissolved oxygen, many communities are highly sensitive to this parameter. For example, complete absence of zooplankton during Jan to Aug and its reappearance in Sep represented by *Keratella* sp. have been observed in the downstream of sewage effluent outfall on the Ganga. The oil bearing wastes at Barauni affected the major and minor carp populations and caused periodic mortalities.

The damage caused by the pesticides is the most lethal and interminable to the environment. The organochlorine pesticides are lipophilic, extremely toxic and non-biodegradable and all of them have been found to be toxic to fish food organisms and fish populations. Sublethal concentrations of DDT and BHC adversely affect the fish at tissue level. Damage of liver cells, besides decline in growth, RBC count, Hb, PVC level has been noticed in *Oreochromis mossambicus*. Similar effects have been noticed in *Labeo rohita* and *Cirrhinus mrigala*.

Instances of heavy metal accumulation have been reported from different stretches of river Ganga and its tributaries. Accumulation of Zn in gonad at a high level (148.8 ppm) was found to be detrimental to fish health affecting its reproductive potential in the long run. Fish food organisms such as *Cyclops* and *Daphnia* are more sensitive to metals like Zn. Presence of such persistent pollutants in the water course not only creates unfavourable environment for fish, but also causes paucity of fish food organisms.

The impact of sewage and industrial effluent was discernible on rate of energy transformation and potential energy resource at Kanpur and Varanasi during 1987-88. During sixties the rate of energy transformation rate and potential energy were 4678 cal m^{-2} d^{-1} and 194,000 k cal ha^{-1} at Kanpur, while at Varanasi the parameters were 4248 cal m^{-2} d^{-1} and 176,500 k cal ha^{-1}. In 1987-88 the values declined to 1008 and 41,880 at Kanpur, and 1,987 and 82,538 at Varanasi due to impact of discharged effluents. However, no case of fish mortality was observed during the period.

10. CONSERVATION AND ENHANCEMENT

At present there seems to be no chance of changing the hydraulic scenario and the conservation measures may be centered around

1. Maintenance of minimum flow required for the sustainable fishery from the river. Studies have shown that if the river is to be maintained close to its pristine state, as much as 60 to 80% of the total annual natural flow is required which is at present around 15 to 20% in the middle stretches of the river.

2. 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. Studies in Ganga river system have pinpointed relationship between decline of fishery and choking of wetlands. Improvement in wetlands will enhance the breeding and recruitment process. Although it needs great political will to change the land use back to that in the past.

3. To check the sediment flow, extensive plantation of native trees, shrubs, reeds, *etc.* on the river banks and nearby catchment area should be undertaken. Studies in U.P. has shown that the area under miscellaneous tree crops declined considerably from 1950-51 to 1989-90. during the period it reduced to half, which is undesirable (Singh *et. al.*, 2001).

4. To control increased fishing pressure, an important cause of declining fishery, mass awareness programs should be undertaken to educate the fishers about the ill effects of indiscriminate killing of brooders and juveniles and non judicious exploitation of fish stocks.

5. Steps should be taken to improve the fish pass ways in existing dams/barrages so that the fishes may negotiate the upstream areas for their natural requirements. The impact assessment studies for future dams/barrage projects should be mandatory and recommendations of such studies should be strictly followed.

6. Studies have shown that some of the exotic species, specifically *C. carpio* and *O. niloticus* have already invaded the Ganga river system and in some stretches their contribution has become quite significant. Although there seems to be no way out for eradicating these species from the system but stringent measures should be taken to avoid invasion by other exotic species so that the condition is not further worsened.

7. Works under various schemes of Govt. of India and State Govt. for improving water quality of river may be geared up further, so that the water quality is improved to desired level. Such improvement will give a chance to rebuild the fish stocks in the affected areas.

8. Rivers as a fishery resource are almost neglected by State Govt. They should give proper attention to these natural renewable resources, so that rivers may regain their original character.

In order to enhance the fishery from river Ganga, the above conservation measures are need of the hour. In the present all factors responsible for declining fishery are uncontrolled and if proper measures are not taken we may reach to a point of no return.

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