WATER QUALITY, BIOTIC COMMUNITIES AND FISHERY OF MAJOR RIVERS OF INDIA Prepared in the backdrop of the proposal to link rivers of India

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WATER QUALITY, BIOTIC COMMUNITIES AND FISHERY OF MAJOR RIVERS OF INDIA

Prepared in the backdrop of the proposal to link rivers of India

Dr. V. R. Suresh
Ms. G. K. Vinci

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Central Inland Fisheries Research Institute
Barrackpore, Kolkata – 700 120, West Bengal

EXECUTIVE SUMMARY

Interbasin transfer of water has been a subject of debate in India for the last five decades. After the Dastur plan during the 1970s there was a long period of lull. But in the recent years the subject has again became topical. A national perspective plan has been formulated under the National Water Development Agency. Linking of rivers has always been a subject of hot controversy, mainly on account of water sharing riparian status for agriculture, power generation and flood control. An aspect, which is seldem, considered is the value of water in terms of its biological resources. Valuation of ecosystems goods and services in terms of their biodiversity and biological productivity are generally neglected all over. Often the planers never find it necessary to consider ecosystem goods and services as a factor to determine the priority in allocating water. Environmental flow requirement is still in its infancy, barring a few serious studies conducted in the South Africa and United States of America.

The possible impact of linking the Brahmaputra, the Ganga and the Peninsular Rivers is difficult to assess. There is very little background information that we can fall back upon. Information available in literature is scanty and sporadic. An attempt has been made here to collect available information on water quality and biotic communities including fish species in some of the rivers in India. This could be a very useful tool for assessing the possible impact in the event of linking rivers in the country.

Ganga

On the basis of the exploratory surveys conducted in the river during 1995-96, the pH of the water is fairly uniform in all the stretches. Temperature varies between 19.5 and 25.5 ^{o}C. Alkalinity, specific conductivity, dissolved oxygen, calcium, magnesium and total hardness of the water exhibit inter stretch variations with lower values in the upper stretch and very high values along the estuarine zone of the lower stretch. Transparency decreases along the course of the river. The nutrient status of the river in respect of nitrate and phosphate is poor. Phytoplankton constitute the bulk of plankton with Bacillariophyceae forming 83.4 %, zooplankton forming only to 16.6 % of the total count. In all, there are 18 taxa of phytoplankton and 11 taxa of zooplankton in the river. Insects dominate the benthic community of the upper stretch. The population of which, along the course of the river, give way to bivalves and they reach prominence in the middle stretch. The lower stretch however shows domination of Gastropods. Bacillariophyceae, followed by Chlorophyceae dominate the periphytic community of the river. Primary productivity varies between 28.8 and 202.5 mg C m $^{-3}$ hr $^{-1}$ in the upper stretch, 15.0 and 632.8 mg C m $^{-3}$ hr $^{-1}$in the middle stretch, 33.3 and 142.0 mg C m $^{-3}$ hr $^{-1}$ in the lower stretch and between 20.8 and 101.5 mg C m $^{-3}$ hr $^{-1}$ in the estuarine zone. From the available information, fish fauna of the river represents a total of 100 species of finfishes and 13 species of prawns. Fishery of the river shows a declining trend. At Allahabad the average landing dropped to 59.99 t from an average of 215.14 t during 1961-68. After the construction of Farakka barrage on river Ganga, the average contribution of migratory Hilsa to the total catch at Lalgola centre, about 45 km below the barrage, declined from 92.02%

(1963-76) to 16.8% (1991-2000). The fish yield from the estuarine stretch of the river fluctuated within 37,981 and 69,608 t during 1996-97 to 1999-2000.

Brahmaputra

The values of most of the water quality parameters in the entire stretch of the river Brahmaputra are fairly uniform. The upper regions of the river have maximum concentration of plankton (300 u l^{-1}), the bulk of which being phytoplankton (297.0 u l^{-1}) with Bacillariophyceae forming up to 60 %. Macrobenthic communities of the river exhibit domination of gastropods followed by bivalves. The average rate of carbon fixation along the river varies between 22.3 and 359.3 mg C m^{-3} day^{-1}. Scrutiny of the literature on fishery revealed that 129 species of finfishes have so far been recorded from the river. The fishery of most of the commercial species shows 30 % decline in their landings from 1974-77 to 1996-98.

Mahanadi

The exploratory survey in the river Mahanadi during 1995-96 showed that the water is alkaline in reaction. Values of specific conductivity, total dissolved solids, magnesium, total hardness, chloride content and level of silicate are high along the lower stretch, while the upper stretches exhibit low values. Values of other parameters are comparatively uniform in all the stretches. The nutrient spectrum of the river in respect of nitrate and phosphate reflects poor condition. A total of 107 plankton groups are recorded from the river. Phytoplankton forms 42.5 to 99.7 % of the total counts. Among phytoplankton, Myxophyceae, Bacillariophyceae and Chlorophyceae are the dominant forms in that order of magnitude. Among zooplankton copepods and rotifers dominate the upper stretch; cladocerans and rotifers in the middle stretch and again copepods in the lower stretch. Seventy nine species of macrobenthos are recorded from the river, with a domination of molluscs, followed by dipterans, nematodes and annelids. There are 46 species of periphytic forms, among which Bacillariophyceae is dominant (40.9-57.1%). The upper stretch has six species of aquatic macrophytes and the lower stretch supports 34 species. Primary productivity of the river is in the range of 327.9-575.4 mg C m^{-3} day^{-1}. The river support as many as 253 species of finfishes and 12 species of prawns. The catch per day in the upper stretch was 44.8 kg and in the middle stretch it was 15.6 kg during Aug-Sept 1996 and the annual fish catch in the freshwater zone of the lower stretch was 86.2 t while the estuarine zone landed 3,928.4 t.

Godavari

Water of the river Godavari is alkaline in reaction and most of the water quality parameters exhibit inter-stretch variations, with lowest values for total alkalinity, specific conductivity, dissolved solids, calcium, magnesium and total hardness along the upper stretch. The values of these parameters generally increase along the course of the river and maximum values are recorded along the marine of the lower stretch. Temperature, dissolved oxygen and pH are fairly uniform along the river. Nutrient concentration of the water is low. Plankton density is rather poor, with dominance of

phytoplankton. The major component of phytoplankton is Bacillariophyceae. Among zooplankton rotifers, cladocerans and copepods are the major groups. Molluscs show domination in the macrobenthic fauna, with maximum representation of gastropods. Bacillariophyceae is prominent among periphyton. The average gross productivity values for the upper, middle and lower stretches of the river are 99, 35 and 85.8 mg C m^{-3} day^{-1} respectively. Information available on fishery of the river revealed that the fish catch from the river is mainly represented by 11 species of finfishes and one species of prawn. The catch is estimated at 263.1 t during 1963-69 for a 189 km stretch of the river. The estuarine zone of the river land about 2,728 t. of fish.

Krishna

Water of the river Krishna is alkaline and no marked variations of temperature, transparency, dissolved oxygen, total alkalinity, calcium, total hardness and silicate are noted along the course of the river, according to the studies undertaken by CIFRI during 2001-2002. Conductivity and chloride content are high along the lower stretch. Nutrient status of the river is fairly good. Phytoplankton account for 88.4 to 98.8 % of the total numerical counts. Myxophyceae remain dominant in abundance (46.7%) followed by Chlorophyceae. Crustaceans and rotifers constitute the major portion of zooplankton. Molluscs are the main component of the benthic macro fauna (89.7-93.5%). Bacillariophyceae is dominant among periphyton. Six species of macrophytes are recorded from the river. Gross primary productivity of the river ranges from 28.1 to 281.3 mg C m^{-3} day^{-1}. No detailed information is available on the fisheries of the river, however recent studies indicate existence of 45 species of fishes.

Cauvery

On the basis of the exploratory surveys in river Cauvery, during 1999-2001, the pH of the water is slightly above neutral. Values of temperature and dissolved oxygen are fairly uniform through out the river. Other parameters exhibit inter stretch variations. Levels of nutrients indicate good productivity. Molluscs, with a domination of gastropods are the only benthic group showing continuous distribution along the river. Bacillariophyceae dominate periphytic communities. Three species of floating and five species of submerged macrophytes are reported from the river. Lower stretch of the river show higher primary productivity (64.9-252.1 mg C m^{-3} day^{-1}). Eighty species of finfishes and two species of prawns are recorded from the river.

Narmada

According to the information available on the ecological status and production potential of river Narmada, the water quality parameters show considerable variations within the stretches. Plankton density is comparatively poor (32 to 202 u l^{-1}). Annelids and insects dominate the benthic community of upper stretch, while the lower stretch

by molluscs. The average rate of primary productivity is 9,494 mg C m^{-3} day^{-1} (gross) and that of the net productivity is 5,873 mg C m^{-3} day^{-1}. The average fish production potential of the river is estimated at 203.4 kg ha^{-l}. Ninty species of fishes are reported from the river. Miscellaneous fishes, followed by catfishes and major carps dominate the fishery.

Tapti

Information on the water quality, biotic communities and productivity of the river is not available. From available information, a total of 52 species of finfishes are recorded from the river. During 1995-96, the monthly landing, based on seven markets, was 2,605 kg. *Tor tor* was the major contributor to the fishery. Other commercial species are carps, catfishes, murrels and miscellaneous forms.

INTRODUCTION

Interbasin transfer of water has been a subject of debate in India for the last five decades. After the Dastur plan, during the 1970s, there was a long period of lull. But in the recent years the subject has again became topical. A national perspective plan has been formulated under the National Water Development Agency. Linking of rivers has always been a subject of hot controversy, mainly on account of water sharing riparian status for agriculture, power generation and flood control. An aspect, which is seldom considered, is the value of water in terms of its biological resources. Valuation of ecosystems goods and services in terms of their biodiversity and biological productivity are generally neglected all over. Often the planers never find it necessary to consider ecosystem goods and services as a factor to determine the priority in allocating water. Environmental flow requirement is still in its infancy, barring a few serious studies conducted in the South Africa and United States of America.

The river systems in India are classified as Himalayan Rivers, the East coast rivers and the West coast rivers. The Himalayan river systems originate from the mountain ranges of Himalayas. The east coast and west coast river systems originate from different peninsular regions of India. Those discharges at the east coast in Bay of Bengal are called east coast river systems and those discharge the west coast in Arabian Sea are called west coast river systems. The Himalayan river systems comprise The Ganga, Brahmaputra and the Indus. The river Ganga, having a length of 2525 km, is one of the largest river systems in the world. It drains the southern slope of the central Himalayas. The river Brahmaputra, having a length of 2900 km, of which 900 km falls in India, drains the northern slopes of the central and eastern Himalayas. The Indus system, though massive as a whole, has only a small segment left in India *viz.* the river Beas and Sutlej. The east coast river systems comprise Mahanadi, Godavari, Krishna and Cauvery, having a combined length of about 6,437 km. These river systems drain the peninsular east of the Western Ghats and the southern parts of central India. The major west coast river systems comprise the Narmada and Tapti draining India's peninsular west. Other rivers in this system are short and many are torrential streams, originating from Western Ghats. The combined length of the rivers in west coast river system is about 3,380 km.

In the year 1980, a National Perspective for Water Resources Development, comprising Himalayan River Development and Peninsular River Development, was prepared. Under this, the linking of Ganga and Brahmaputra, Ganga with Mahanadi, inter linking of Mahanadi, Godavari, Krishna and Cauvery; west flowing rivers north of Bombay and south of Tapti; inter linking of Ken – Chambal as well as diversion of other west flowing rivers are envisaged. Government of India in September 1987 adopted the National Water Policy, which emphasized the interbasin transfer of water and states that "Water should be made available to water short areas by transfer from

other areas including transfers from one river basin to another based on National Perspective after taking into account the requirements of areas/basins". The feasibility for such mega projects is being worked out by the National Water Development Agency. While studying the feasibility of such radical projects, apart from the engineering, social and economic considerations, deliberations on the possible ecological, biological and environmental consequences of inter linking of the rivers are also important, as these rivers are not just water bodies but are ecosystems, possibly different from one another, carrying biological and fishery wealth, on which millions of people depend. The possible impact of linking the Brahmaputra, the Ganga and the Peninsular Rivers is difficult to assess. Under these circumstances it is imperative to gather knowledge on the ecology, biology and fishery of these rivers, in order to look in to the possible eco-biological consequences arising out of the linking of rivers. There is very little background information on the water quality, biology and fishery of Indian rivers that we can fall back upon. Information available in literature is scanty and sporadic. Sustained scientific studies carried out on these aspects so far are also few and far between. Nevertheless, an attempt has been made here to collect available information on water quality, biotic communities, primary productivity and fishery of the rivers Ganga, Brahmaputra, Mahanadi, Godavari, Krishna, Cauvery, Narmada and Tapti. This could be a very useful tool for assessing the possible impact in the event of linking rivers in the country.

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THE GANGA

The river Ganga is not only the lifeline of millions of people and their culture in India, but also a symbol of purity in their psyche. Originating from two headwaters, at an altitude of about 6000 m msl in Garhwal, Himalaya, and the river flows through the Sivalik hills and enter the plains at Haridwar. Then it flows southwards, meandering over several 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 of the country's total area. The river system cover 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 annual run off is about 493 m^3 and carries 616 x 10^6 tones 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 India's most important river, 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 a 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 is from Kanpur to Patna, lower stretch from Sultanpur to Katwa; estuarine stretch (freshwater gradient) from Nabdwip to Haldia and estuary (marine) from Kakdwip to Harnabad.

The information provided here on water quality, biotic communities and primary productivity of the river are based on the report of exploratory surveys conducted by CIFRI, during 1995-96 (Sinha *et al*, 1998). For information on fisheries, sources as sited in the text, are consulted.

Water quality

Among the physical parameters of water, temperature fluctuates within a narrow range (19.8-25.5 ^oC). The water has a strong buffering capacity, as a result of which there is little fluctuation in pH in the entire stretch (7.7-8.07). But alkalinity, conductance, dissolved solids, calcium, magnesium and hardness show considerable variations. These parameters are minimum in the upper stretch (101.0 mg l^{-1}, 245.8 μmhos, 124.0 mg l^{-1}, 14.6 mg l^{-1}, 5.6 mg l^{-1}, and 98.2 mg l^{-1} respectively) and show sudden rise in the middle stretch between Kanpur and Patna. In the lower stretch, their values again decrease. In the gradient stretch the values of alkalinity, conductance,

dissolved solids calcium, magnesium and hardness sharply increase to reach very high levels in the marine zone. The nutrient status of the river in respect of nitrate and phosphate is poor. The water quality of the river in respect of various parameters is shown in Table 1.

Biotic communities

Plankton

In the upper stretch, between Tehri and Kanauj, the total plankton density varies 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 is phytoplankton. Zooplankton form only to 16.6%. Bacillariophyceae being 83.4 % is 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 over all plankton density in the entire middle stretch varies 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 are encountered in the stretch between Kanpur and Allahabad.

In the lower stretch, between Sultanpur and Farakka, the plankton density range between 34 and 1204 u l^{-1}. Of this, phytoplankton formed 70.9 to 89.2 % and the rest is zooplankton. The total plankton production of the freshwater zone of Hooghly estuary varies from 26 to 935 u l^{-1}. In the marine zone of the estuary, the bulk of plankton is Bacillariophyceae (70–95%). Other phytoplankton groups observed are Chlorophyceae and Cyanophyceae.

Macrobenthos

Macrobenthic population increase gradually from Tehri to Haridwar (189 to 628 u m^{-2}). Insects are the only component in the entire stretch. Chironomids appear 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 is first observed in the stretch between Anupsahar and Kanauj, but they contribute very little. The insect population has a decreasing trend from the upper to middle stretch of the river.

Table 1. Range of water quality parameters of river Ganga at different stretches (Av. In brackets)

Stretches of Ganga	Water temperature (°C)	Transparency (cm)	Dissol-ved oxygen (mg l^{-1})	pH	Total alkalinity (mg l^{-1})	Sp. conductance (µ mhos)	Total dissolved solids (mg l^{-1})	Calcium (mg l^{-1})	Magnesium (mg l^{-1})	Total hard-ness (mg l^{-1})	Chloride (mg l^{-1})	Silicate (mg l^{-1})	Nitrate (mg l^{-1})	Phosphate (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)	48.0-208.0 (101.0)	120.0-490.0 (245.0)	62.4-250.0 (124.0)	8.0-25.6 (14.6)	4.4-7.61 (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)	92.0-236.0 (178.8)	340.0-740.0 (521.2)	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)	68.0-165.0 (126.4)	100.0-308.0 (178.0)	52.0-156.0 (89.2)	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)	95.0-174.0 (128.3)	100.0-70000.0 (758.9)	50.0-3500 (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-Harnabad)	18.6-31.8 (25.5)	12.0-90.0 (26.8)	4.3-8.9 (6.8)	7.6-8.5 (8.0)	90.0-160.0 (118.6)	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)

Bivalves form 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* are the main forms. Insect population is represented by *Tricopteran* sp. *Chironomus* and stone fly nymph. In the freshwater zone of Hooghly the dominant forms are gastropods, followed by polychaetes, oligochaetes, decapods and bivalves. The annual production of macrobenthos in the marine zone of the estuary varies between 74 and 1472 nos m^{-2}, mostly with a dominance of gastropods.

Periphyton

The periphytic flora in the riverine and estuarine stretches depict almost similar trend of that of phytoplankton. Over the entire Ganga, Bhagirathi and Hooghly stretches, a dominance of Bacillariophyceae is observed, followed by Chlorophyceae and Cyanophyceae. The average periphyton concentration in the upper stretch is 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 are the dominant forms. In the estuarine stretch the population of periphyton is found to be lower than the freshwater stretches.

Primary productivity

Gross primary production varies depending upon climatic factors, turbulence of river and water turbidity. In the upper stretch it varies between 28.8 and 202.5 mg C m^{-3} hr^{-1}. In the middle stretch the values are between 15.0 and 632.8 mg C m^{-3} hr^{-1}, while in the lower stretch the maximum gross production is 33.3 to 142.0 mg C m^{-3} hr^{-1}. In the estuarine stretch the values ranged between 20.8 and 101.5 mg C m^{-3} hr^{-1}. The gross primary productivity of the river at different stretches is depicted in Table2.

Table2. Gross primary production (mg C m^{-3} hr^{-1}) of river Ganga at different stretches (Av. in brackets**)**

Stretch	Summer	Monsoon	Winter
Upper (Tehri-Kanauj)	75-202.5 (108.6)	20.8-177.1 (87.6)	31.7-187.5 (86.9)
Middle (Kanpur-Patna)	112.5-632.8 (244.3)	86.9-171.9 (124.2)	15.0-142.5 (60.93)
Lower (Sultanpur-Katwah)	33.3-142.0 (71.4)	20.8-125.0 (68.8)	50.0-104.2 (72.9)
Estuary (Gradient, Nabadwip-Haldia)	20.8-62.5 (47.2)	20.8-93.7 (43.1)	39.1-78.1 (63.8)
Estuary (Marine, Kakdwip-Hasnabad)	50.0-104.2 (67.8)	35.0-72.9 (50.1)	46.9-137.5 (95.6)

Fishery

The headwaters of the Ganga system in the upper reaches of Himalaya have remained mostly unexplored. Menon (1962) has given a distributional list of fishes of the Himalayas. The commonly available fishes are snow trouts, catfishes, mahseers and lesser barils. The fish fauna of Himalayan and Indo-Gangetic plains is well described by Menon (1974). CIFRI undertook an exploratory survey of river Ganga during 1995-96, covering 43 centers from its origin to Sagar. On the basis of this survey, the fish fauna of different stretches is given in Table 3 (Sinha *et. al.*, 1998).

Table 3. Fish species recorded in the Ganga river system from Tehri to Sagar

Species	***Stretch 1***	***Stretch 2***	***Stretch 3***	***Stretch 4***	***Stretch 5***
Gudusia chapra	+	+	+	+	-
Tenualosa ilisha	-	+	+	+	+
T. toli	-	-	-	-	+
Anodontostoma chacunda	-	-	-	-	+
Nematolosa nasus	-	-	-	-	+
Gonialosa manmina	-	-	+	-	-
Ilisha elongata	-	-	-	-	+
Raconda russeliana	-	-	-	-	+
Colia ramcarati	-	-	-	-	+
C. reynaldi	-	-	-	-	+
Setipinna phasa	-	+	+	+	-
S. brevifilis	-	+	+	+	-
S. taty	-	-	-	-	+
Notopterus chitala	+	+	+	+	-
N. notopterus	+	+	+	+	-
Megalops cyprinoides	-	-	-	+	+
Lycodontis tile	-	-	-	+	+
Catla catla	+	+	+	+	-
Cirrhinus mrigala	+	+	+	+	-
C. reba	-	+	+	-	-
Labeo rohita	+	+	+	+	-
L. calbasu	+	+	+	+	-
L. bata	+	+	+	+	-
L. boga	-	+	+	-	-
L. gonius	-	+	+	-	-
Puntius sarana	+	+	+	+	-
P. sophore	+	+	+	-	-
P. ticto	+	+	+	+	-
P. chola	+	+	+	+	-
Tor tor	+	-	-	-	-
T. putitora	+	-	-	-	-
T. mosal	+	-	-	-	-

Chela laubuca	+	+	+	+	-
C. bacaila	-	+	+	+	-
Salmostoma phulo	-	-	+	-	-
Amblypharyngodon mola	-	+	+	+	-
Barilius bendelisis	-	+	+	-	-
B. bola	-	+	+	-	-
Schizothorax richardsonii	+	-	-	-	-
Garra gotyla	+	-	-	-	-
Crossocheilus latius latius	+	-	-	-	-
Plotosus canius	-	-	-	-	+
P. lineatus	-	-	-	-	+
Aorichthys aor	+	+	+	-	-
A. seenghala	+	+	+	-	-
Mystus cavasius	+	+	+	+	-
M. gulio	-	-	-	+	+
M. tengara	-	-	+	-	-
M. vittatus	-	+	+	+	-
M. bleekeri	-	-	+	+	-
Rita rita	+	+	+	+	-
Ompok bimaculatus	+	+	+	-	-
O. pabda	-	+	+	-	-
O. pabo	-	-	+	+	-
Wallago attu	+	+	+	+	-
Ailia coila	+	+	+	+	-
Clupisoma garua	+	+	+	+	-
Eutropiichthys vacha	+	+	+	+	-
Silonia silondia	-	-	+	-	-
Pangasius pangasius	-	-	+	+	+
Bagarius bagarius	+	+	+	+	-
Gagata gagata	-	-	+	-	-
Clarias batrachus	-	+	+	+	-
Heteropneustes fossilis	-	+	+	+	-
Aries sonar	-	-	-	-	+
A. sager	-	-	-	-	+
Osteogeneiosus militaris	-	-	-	-	+
Harpodon nehereus	-	-	-	-	+
Xenentodon cancila	+	+	+	+	-
Strongylura strongylura	-	-	-	-	+
Monopterus cuchia	-	-	+	-	-
Lates calcarifer	-	-	-	+	+
Silaginopsis panijus	-	-	-	+	+
Chanda nama	+	+	+	+	-
Pseudambassis ranga	+	+	+	+	-
Terapon jarbua	-	-	-	-	+
Johnius coitor	-	-	-	-	+

J. gangeticus	-	+	+	+	+
Otolithoides biauritus	-	-	-	-	+
Pama pama	-	-	-	+	+
Scatophagus argus	-	-	-	-	+
Nandus nandus	-	-	+	+	-
Etroplus suratensis	-	-	-	-	+
Liza parsia	-	-	-	-	+
L. tade	-	-	-	-	+
L. cephalus	-	-	-	-	+
Rhinomugil corsula	-	-	+	+	+
Sicamugil cascasia	-	+	+	-	-
Eleutheronema tetradactylum	-	-	-	-	+
Polydactylus indicus	-	-	-	-	+
Polynemus paradiseus	-	-	-	+	+
Glossogobius giuris	+	+	+	+	-
Apocryptes bato	-	-	-	+	+
Boleophthalmus dussumieri	-	-	-	+	+
Pseudapocryptes lanceolatus	-	-	-	-	+
Gobiopterus chuno	-	-	-	+	+
Eleotris fusca	-	-	-	-	+
Lepturacanthus pantului	-	-	-	-	+
Trichiurus gangetica	-	-	-	-	+
Anabas testudineus	-	+	+	+	-
Colisa fasciatus	-	-	+	+	-
Channa punctatus	-	-	+	+	-
C. marulius	-	-	+	+	-
C. striatus	-	-	+	+	-
C. orientalis	-	-	+	+	-
Macrognathus aral	-	+	+	+	-
M. pancalus	-	+	+	+	-
Mastocembelus armatus	+	+	+	+	-
Cynoglossus cynoglossus	-	-	-	-	+
C. lingua	-	-	-	-	+

Stretch 1: Tehri to Kanauj; ***Stretch 2:*** Kanpur to Patna; ***Stretch 3:*** Sultanpur to Katwah; ***Stretch 4:*** Nabadwip to Roychawk (Diamond harbour); ***Stretch 5:*** Haldia to Sagar; - Not available; + Available.

Along with the above mentioned, 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.*

In order to understand the fluctuations in the fisheries of important commercial species, data on market arrivals at eight centres were collected by CIFRI. The centres covered were Agra on Yamuna, Kanpur on Ganga and Allahabad in the upper stretch; Varanasi, Buxar and Ballia in the middle stretch; and Patna and Bhagalpur in the lower stretch of the river. Jhingran and Ghosh (1978) have discussed the trends in fluctuations in fishery at centres mentioned above and the average landings at different centres are given in Table 4.

Table 4. Average landings (t) during pre and post 1961 periods

Period	Group	Agra	Kanpur	Allahabad	Varanasi	Buxar	Ballia	Patna	Bhagalpur
1958 to 1961	MC	74.4	50.1	71.9	5.0	7.7	7.3	20.0	9.3
	CF	83.7	29.2	42.6	8.4	9.4	5.1	9.3	14.5
	H	neg	neg	15.6	15.9	27.7	14.6	8.8	4.1
	O	18.8	14.3	49.6	25.1	33.5	33.0	25.6	34.5
1961 to 1969	MC	34.7	14.6	98.9	3.0	1.7	4.0	19.9	19.4
	CF	22.0	12.7	46.9	21.3	3.1	8.7	22.2	21.2
	H	neg	neg	21.6	28.8	41.3	34.0	11.6	4.1
	O	5.2	10.9	47.7	44.5	13.7	14.7	54.5	56.9

MC- *C. mrigala, C. catla, L.rohita, L. calbasu;* **CF-** *A. aor, A. seenghala, W. attu;* **H-** *T. ilisha;*

O- *Rest of the species,* neg. – negligible.

After 1969, the studies were conducted only at five centres. Around 1974 fishery showed a sharp decline in quality and quantity, with a continuous declining pattern till 1990, and showed a constant pattern thereafter. Gupta and Tyagi (1972) discussed the catches at Allahabad, Buxar and Bhagalpur and indicated the over exploitation of major carps and selected catfishes. The status of the fishery after 1972 is presented in Tables 5 and 6.

Table 5. Fish landings (t) at Allahabad

Species	Period				
	Av. 61-68	Av. 72-78	Av. 79-87	Av. 88-92	Av. 93-01
C. mrigala	52.38	9.15	6.82	2.89	0.89
C. catla	15.33	3.47	3.53	1.96	1.73
L. rohita	16.78	2.84	2.50	2.16	1.29
L. calbasu	13.24	16.67	27.25	7.57	2.00
Major carps	**97.73**	**32.13**	**40.10**	**14.58**	**5.90**
M. aor	20.10	11.86	10.80	10.34	6.85
M. seenghala	14.59	6.88	8.74	9.67	4.25
W. attu	11.62	3.85	3.74	1.29	1.55
Selected catfishes	**46.31**	**22.59**	**23.27**	**21.30**	**12.65**
H. ilisha	22.35	2.37	1.26	0.61	1.17
Others	48.75	40.74	61.78	47.07	40.27
Total	**215.14**	**97.82**	**126.41**	**83.56**	**59.99**

Table 6. Comparison of fish landings (t) at Buxar, Patna and Bhagalpur

Period	MC	CF	Hilsa	Others	Total
Buxar					
Av. 63-71	2.10	3.37	33.48	11.13	50.08
Av. 72-86	3.03	4.82	1.86	9.28	19.00
Patna					
Av. 61-66	23.35	22.43	14.08	48.82	108.68
Av. 86-93	7.10	11.67	0.08	28.18	47.04
Bhagalpur					
Av. 61-70	18.66	31.23	4.27	59.02	113.18
Av. 73-88	8.31	25.07	0.73	50.84	84.96

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 Table 7.

Table 7. Catch composition (%) at Lalgola, pre and post Farakka period

Group	Period		
	1963-76	**1980-90**	**1991-00**
MC	0.33	4.47	9.76
CF	0.12	9.34	13.58
Hilsa	92.02	29.68	16.80
Others	7.53	56.51	59.86
Total (tonnes)	**121.43**	**57.31**	**106.35**

Jhingran (1991) has given a detailed account of fish catch from estuarine system of Ganga. Mitra *et al* (1997) reported fisheries of this estuarine system incorporating data from 1984 to 1994. Further investigations carried out by CIFRI during 1994-2000 revealed significant changes in catch and effort structure, species spectrum, catche per unit effort, and major shift in gear, particularly in the upper estuary (Mitra *et. al.*, 2001). The total estimated fish yield from the system fluctuated within 37,981 to 69,608 t during 1994-95 to 1999-2000, with an average of 32,875 t. The hike in total catch during 1996-97 was mainly due to sudden increase in catch of *T. ilisha* and unusual increase in catch of winter migratory bagnet fishery in lower

estuarine zone. Percentage contribution of different species from the Hooghly-Matlah estuarine system is depicted in Table 8.

Table 8. Average contribution (%) of different species from the Hooghly-Matlah estuarine system

Species	1984-1994	1994-2000
Tenualosa ilisha	8.14	13.15
Liza tade	<0.01	<0.01
Liza parsia	0.06	0.05
Lates calcarifer	0.10	0.24
Sillaginopsis panijus	0.11	0.10
Polynemus paradiseus	0.56	0.58
Eleutheronema tetradactylum	0.06	0.04
Polynemus indicus	0.33	0.17
Sciaena biauritus	1.14	2.85
Coilia spp.	2.39	3.25
Pama pama	11.99	11.11
Tenualosa toli	0.16	0.0
Ilisha megaloptera	1.61	1.96
Anodontostona spp. *(= Chaaetoessus* spp.*)*	0.05	0.04
Mystus gulio	0.02	0.03
Setipinna spp.	11.29	9.50
Chirocentrus dorab	0.32	0.74
Pangasius pangasius	0.04	0.05
Tachysurus jella	2.71	4.70
Osteogeniosus militaris	0.28	0.34
Plotosus canius	<0.01	<0.01
Lutjanus spp.	0.03	0.10
Trichiurus spp.	9.06	8.00
Harpodon nehereus	16.06	17.00
Pampus argenteus	2.15	2.84
Prawns	8.66	6.94
Mackerel	0.83	1.22
Miscellaneous	21.67	14.90
Freshwater species	0.18	0.10

THE BRAHMAPUTRA

The river Brahmaputra originates from Chemayungdung Mountains, about 100 km southeast of the lake Mansarovar, at an altitude of 5,150 m msl. It runs about 1,250 km through Tibet as river Tsangpo, before entering into Indian territory near Tuting in Siang district of Arunachal Pradesh. It enters Assam on the north of Saidiya, where it meets river Dibang and Lohit. After joining these tributaries, the river assumes the name Brahmaputra. It traverses Assam for about 740 km before entering into Bangladesh as river Jamuna. The river has not been explored systematically until the survey undertaken by CIFRI during 1996-98 (CIFRI, 2000a), covering ecology and production dynamics of the entire river and its tributaries.

Water quality

Water of the river is rich in oxygen (7.0 – 8.45 mg l^{-1}), alkaline in reaction with pH ranging from 7.5 to 7.9 and poor in nutrients (nitrate 0.018-0.038 mg l^{-1} and phosphate 0.003-0.016 mg l^{-1}) through its entire stretch. But considerable inter stretch variations exist in alkalinity, conductance, total dissolved solids and hardness. The water quality of the river in respect of various parameters is shown in Table 9.

Biotic communities

Plankton

In the main river Brahmaputra, the plankton density and qualitative composition show considerable zonal variations with maximum concentration in Saidiya (300 u l^{-1}) and minimum at Biswanathghat (48 u l^{-1}). Zooplankton represent only negligible fraction (0-5.4 %). Among phytoplankton, Bacillariophyceae dominates (43.5-95.8 %), followed by Chlorophyceae (3.9-50.9 %) and Myxophyceae (0-23 %). Among zooplankton, rotifers followed by copepods and cladocerans are the major groups. The qualitative and quantitative abundance of plankton in the river are shown in Table 10.

Table 9. Water quality parameters of river Brahmaputra at different stretches (Av. in brackets**)**

Stretches	Water temperature (°C)	Transparency (cm)	Dissolved oxygen (mg l^{-1})	pH	Total alkalinity (mg l^{-1})	Sp. conductance (µ mhos)	Total dissolved solids (mg l^{-1})	Calcium (mg l^{-1})	Magnesium (mg l^{-1})	Total hardness (m l^{-1})	Chloride (mg l^{-1})	Silicate (mg l^{-1})	Nitrate (mg l^{-1})	Phosphate (mg l^{-1})
Saidiya	17.8	87.2	7.32	7.5	68.0	149.0	75.3	13.6	12.4	78.0	19.6	6.00	0.02	0.02
Dibrugarh	18.7	43.5	7.00	7.63	57.5	137.1	69.5	14.7	6.9	65.6	19.6	4.70	0.04	0.01
Jorhat	18.0	36.9	7.92	7.62	71.0	155.3	78.5	19.9	5.6	72.8	29.4	4.84	0.02	0.004
Biswanath-ghat	18.0	43.0	8.45	7.63	64.6	156.7	79.0	15.4	8.5	73.6	19.6	5.30	0.03	0.004
Tezpur bridge	19.4	35.4	7.72	7.53	56.9	134.6	67.3	12.5	10.2	64.8	22.3	4.80	0.02	0.003
Tezpur forestghat	18.7	39.5	7.77	7.7	61.6	145.2	74.7	13.4	8.9	70.8	19.6	4.90	0.03	0.01
Guwahati	19.2	38.0	7.73	7.5	71.2	150.8	76.1	17.7	8.6	79.7	22.5	5.24	0.04	0.01
Goalpara	19.6	43.2	8.12	7.9	76.2	174.6	88.1	18.1	9.4	84.3	27.3	5.70	0.02	0.01
Dhubri	21.2	40.1	7.7	7.7	60.8	136.0	68.5	12.7	6.7	60.2	26.5	5.80	0.02	0.01

Table 10. Abundance of major plankton groups in river Brahmaputra.

River Stretch	Phytoplankton				Zooplankton				Total Plankton (u l^{-1})
	% Composition			Total (u l^{-1})	% Composition			Total (u l^{-1})	
	Bacill.	Chloro.	Myxo.		Rotif.	Copep.	Clado.		
Saidiya	60.0	17.0	23.0	297	1.0	-	-	3	300
Dibrugarh	4305	37.1	13.9	68	2.3	3.32	-	4	72
Jorhat	90.1	9.9	-	80	-	-	-	-	80
Biswanath ghat	88.5	7.5	4.0	48	-	-	-	-	48
Tezpur	95.8	3.9	0.3	84	-	-	-	-	84
Guwahati	46.1	50.9	-	97	1.9	-	-	3	100
Goalpara	56.3	38.2	-	86	3.2	1.2	1.1	5	91
Dhubri	44.7	45.2	-	101	1.6	1.2	1.0	4	105

Macrobenthos

Population of benthos varies considerably along different stretches of the river. The population density is maximum in Dibrugarh (365nosm^{-3}) and minimum in Biswanath ghat (32nosm^{-3}). Gastropods dominate along the lower portion, Guwahati-Dhubri, (46.4-65.9nosm^{-3}), while gastropods (32.8-58.4%) and bivalves (47.3-44.9%) are the main benthos in the upper stretch (Saidya-Dibrugarh). Chironomids dominate along Biswanathghat (75.0%) and Tezpur (71.7%). While at Jorhat, oligochaetes (57.2%) followed by gastropods (39.4%) are the main representation. The Table 11 shows the qualitative and quantitative abundance of benthic fauna.

Table 11. Abundance of benthic fauna in river Brahmaputra.

River Stretches	Percentage composition					Total abundance (Nos m^{-2})
	Molluscs		Oligochaetes	Chironomids	Insects	
	Gastropods	Bivalves				
Saidia	32.8	58.4	-	-	8.8	159
Dibrugarh	47.3	44.9	7.8	-	-	365
Jorhat	39.4	3.4	57.2	-	-	79
Biswanath ghat	-	-	25.0	75.0	-	32
Tezpur	12.3	16.0	-	71.7	-	76
Guwahati	46.5	-	18.3	35.2	-	254
Goalpara	46.4	-	12.7	35.2	-	177
Dhubri	65.9	-	25.8	-	-	157

Primary productivity

The rate of carbon fixation (mg C m^{-3} day^{-1}) by producers in eight different stretches of the river, on an average, is 22.32 in Saidiya, 271.37 in Dibrugarh, 233.2 in Jorhat, 212.7 in Biswanathghat, 213.8 in Tezpur, 323.0 in Guwahati, 331.7 in Goalpara and 359.3 in Dhubri.

Fish production

Yadava and Chandra (1994) documented 129 fish species (updated from Motwani *et. al.*, 1962) from Brahmaputra. The cyprinids constitute the dominating family in the river system.

Fish species recorded from river Brahmaputra:

Hilsa ilisha, Gudusia chapra, G. variegata, Setipinna phasa, Notopterus chitala, N. notopterus, Oxygaster bacaila, O. gora, Chela atpar, C. laubuca, Rajmas bola, Barilius barila, B. barna, B. bendelisis var. chedra, B. shacra, B. vagra, Danio aequipinnatus, D. dangila, D. devario, D. rerio, Esomus danricus, Rasbora daniconius, R. elanga, R. rasbora, Amblypharyngodon mola, Aspidoparia jaya, A. morar, Acrossocheilus hexagonolepis, Tor putitora, T. tor, T. progenies, Chagunius chagunio, Puntuis chola, P. conchonius, P. phutunio, P. sarana, P. stigma, P. sterarupagus, P. ticto ticto, Catla catla, Cirrhinus reba, C. mrigala, Labeo bata, L. calbasu, L. dero, L. dyocheilus, L. gonius, L. pangusia, L. rohita, Osteobrama cotio, Semiplotus semiplotus, Schizothorax progastus, S. plagiostomus, Crossocheilus latius latius, Psilorhyn chus balitora, P. sucatio sucatio, Balitora brucei brucei, Noemacheilus beavani, N. botia, N. corica, N. savona, N. scaturigina, N. sikmaiensis Hora, N. zonatus, Botia dario, Lepidocephalichthys berdmore, L.annandalei, L. guntea, Somileptes gongota, Ompok pabda, O. bimaculatus, Wallago attu, Batasio batasio, Mystus bleekeri, M. cavasius, M. menoda, M. montanus var. dibrugarensis, M. vittatus, M. tengra, Aorichthys aor, A.seenghala, Rita rita, Amblyceps mangois, Bagarius bagarius, Erethistes pussilus, Erethistoides montana montana, Gagata cenia, G. nangra, G. viridescens, Glyptothorax rebeiroi, G. striatus, G. telchitta, Sisor rhabdophorus, Ailia coila, Ailichthys punctatus, Clupisoma garua, Eutropiichthys vacha, E. murius, Pangasius pangasius, Pseudeutropius atherinoides, Silonia silondia, Heteropneustes fossilis, Clarias batrachus, Pisodonophis boro, Xenentodon cancila, Mugil corsula, M. cascasia, Channa gachua, C. marulius, C. punctatus, C. striatus, Amphinous cuchia, Chanda bacuits, C. nama, C. ranga, Sciaena coitor, Pama pama, Badis badis, Nandus nandus, Anabas testudineus, Colisa chuna, Colisa fasciata, C. lalius, Glossogobius giuris giuris, Mastocembelus pancalus, M. armatus armatus, Macrognathus aculiatus, Tetradon cutcutia.

The Brahmaputra survey unit of CIFRI recorded data on fish landings from different centres and the data is presented in tables 12 and 13. (Jhingran, 1991).

Table 12. Landings (t) at selected centres on river Brahmaputra (1972-80*)*

Centre	1972	1973	1974	1975	1976	1977	1978	1979	1980
Tezpur	NA	NA	79.9	59.4	35.8	25.6	NA	NA	NA
Uzan Bazar	33.5	111.1	79.0	57.4	35.5	23.7	25.5	16.3	4.0
Fancy Bazar	27.7	128.1	88.1	58.7	53.1	48.9	43.6	22.6	7.7
Dhubri	NA	NA	63.1	65.9	53.8	36.7	NA	NA	NA

Table 13. Centre-wise average fish landings (t) from river Brahmaputra (1974-76)

Species	Tezpur		Fancy Bazar		Uzan Bazar		Dhubri	
	Catch	%	Catch	%	Catch	%	Catch	%
Catfishes	15.90	27.2	13.72	20.6	12.02	21.0	14.94	24.5
Major carps	12.45	21.3	11.48	17.2	9.89	17.3	9.61	15.8
Minor carps	9.06	15.5	8.75	13.1	7.94	13.9	8.95	14.7
Hilsa	2.35	4.0	10.83	16.2	8.19	14.3	9.64	15.8
Prawns	2.24	3.8	3.01	4.5	2.29	4.0	4.46	7.3
Miscellaneous	16.36	28.0	18.87	28.3	16.96	29.6	13.36	21.9
Total	**58.36**		**66.66**		**57.29**		**60.96**	

During 1996-98, CIFRI again undertook a rapid survey of river Brahmaputra (CIFRI, 2000) and on the basis of the survey qualitative change in the fisheries of Brahmaputra is provided in Table 14.

Table 14. Qualitative change (%) in fisheries of Brahmaputra over the years

Group	Tezpur		Guwahati		Dhubri		Av. (Tezpur-Dhubri)		Change
	1974-77	1996-98	1973-79	1996-98	1974-77	1996-98	1973-79	1996-98	
Major carps	21.0	11.5	18.7	15.2	18.4	14.2	19.4	13.6	Decline by 30%
Minor carps	15.6	3.0	14.6	16.4	12.2	1.5	14.1	7.0	Decline by 50%
Catfishes	26.1	18.2	21.1	8.7	24.1	15.8	23.8	14.2	Decline by 40%
Feather backs	4.2	10.1	4.2	4.0	2.3	3.4	3.6	5.8	Increase by 61%
Hilsa	4.4	0.0	13.7	3.0	15.5	3.4	11.2	2.1	Decline by 81%
Prawn	3.9	3.2	3.7	0.7	7.4	2.3	5.0	2.1	Decline by 58%
Miscellaneous	24.9	52.4	23.0	52.0	20.0	59.4	22.9	55.2	Increase by 141%
Av. catch (kg per day)	**137.4**	**93.2**	**302.85**	**198.7**	**150.5**	**120.2**	**196.9**	**137.3**	**Decline by 30%**

THE MAHANADI

The river Mahanadi, 857 km long, originates near Pharsiya village in Raipur district of Madhya Pradesh and meets the Bay of Bengal in Orissa. It drains an area of 1,41,589 km^2 of which 53 % lies in Madhya Pradesh, 46.3 % in Orissa, 0.5 % in Bihar and 0.2 % in Maharashtra. The river course change briefly westward, then 300 km towards north to turn eastward at Khargoni to reach Mahdeopalli, 140 km away, where Hirakud dam is constructed. Immediately after the reservoir, the river flows down 150 km south to Sonepur, to take 265 km final course towards east for meeting the Bay of Bengal. The river basin offers large cultivable area of about 7,994 thousand hectares. The river has a maximum discharge rate of 44,740 cumecs and after receiving discharges from its tributaries (Seonath, Habdo, Jonk,Mand, Ib, Ong and Tel), it finally records an annual flow of 66,640 million cu m at the bay mouth. The river is divided into upper stretch (Sihawa to Tamdel), middle stretch (Durgapalli to Narsing) and lower stretch (Sasang to Patapuri).

Water quality

On the basis of the exploratory surveys conducted by CIFRI during 1995-96, the water quality of the river at different stretches, in respect of major parameters is given in Table 15. The average temperature of the entire river varies between 26.3 and 29.2 ^oC. Transparency is lowest in the lower stretches (57.1 cm) and the upper stretch exhibit higher values. Dissolved oxygen show no marked variations along the course of the river, the range being 7.2-8.0 mg l^{-1}. The water is slightly alkaline in reaction (pH 7.8-8.2). Alkalinity is lowest in the middle stretch, while specific conductance, in the order 2199 μ mhos, is highest in the lower stretch. The total dissolved solids also follow similar pattern. Calcium is fairly uniform in the entire stretch of the river (20.3-28.7 mg l^{-1}), while magnesium is significantly high in the lower stretch (53.2 mg l^{-1}). The upper and middle stretch of the river had magnesium level of 8.6 and 5.4 mg l^{-1} respectively. Total hardness and chloride content also follow similar pattern of that of magnesium. The nutrient spectrum of the river reflects poor condition (Table 15).

Table 15. Water quality parameters of different stretches of river Mahanadi (in brackets average**)**

Stretch	Temp. (°C)	Transparency (cm)	Dissolved oxygen (mg l^{-1})	pH	Total alkalinity (mg l^{-1})	Sp.cond. tivity (μ mhos)	Total dissolved solids (mg l^{-1})	Ca (mg l^{-1})	Mg (mg l^{-1})	Total hardness (mg l^{-1})	Chloride (mg l^{-1})	Silicate (mg l^{-1})	Nitrate (mg l^{-1})	Phosphate (mg l^{-1})
Upper (Sihawa to Tamdel	24.6-30.2 (27.1)	Clear-158.0 (62.1)	6.44-8.45 (7.4)	8.05-8.40 (8.2)	66.8-129.0 (89.1)	121.2-201.3 (144.8)	59.8-101.0 (71.9)	13.4-33.8 (20.3)	6.20-10.7 (8.6)	60.7-128.1 (86.3)	32.7-42.5 (37.0)	5.70-7.30 (6.20)	0.02-0.05 (0.03)	0.002-0.009 (0.004)
Middle (Durga-palli to Narsingh)	25.3-28.2 (26.2)	63.5-122.7 (89.7)	7.20-9.60 (8.0)	7.60-8.00 (7.8)	63.0-77.0 (69.9)	148.0-177.5 (164.5)	73.8-88.3 (82.4)	14.1-21.6 (18.0)	3.80-6.70 (5.4)	59.2-78.7 (67.6)	23.6-30.6 (26.5)	5.70-8.10 (7.10)	0.022-0.078 (0.043)	0.003-0.005 (0.004)
Lower (Sasang to Patapuri	28.4-30.8 (29.2)	34.0-101.7 (57.1)	3.90-8.20 (7.20)	7.0-8.3 (8.1)	71.6-93.2 (80.3)	169.3-21994 (2199)	84.0-10909 (1088)	16.5-151.8 (28.7)	4.50-557.5 (53.2)	60.1-2666 (294)	4.00-8298 (656)	8.00-16.6 (13.4)	Tr. – 0.11 (0.04)	0.001-0.05 (0.007)

Biotic communities

Plankton

Among 137 members of the plankton community recorded from the Mahanadi river system, 93 occurre in the upper stretch (origin to Hirakud), 57 in the middle stretch (Hirakud to Narsinghpur, and 94 in the lower stretch (below Narsinghpur to sea mouth). The numbers of representative plankter in different sectors of the lower stretch are not uniform

Among phytoplankton *Aphanocapsa* sp and *Chroococcus* sp of Myxophyceae; *Genicularia* sp, *Staurastrum* sp and *Triploceras* sp of Desmidiaceae; *Gomphonema* sp., *Mastogloia* sp, *Rhopalodia* sp and *Surirella* sp of Bacillariophyceae; *Peridinium* sp of Dinophyceae; *Botryococcus* sp of doubtful Xanthophyceae; and *Binuclearia* sp, *Kirchneriella* sp. *Tetraspora* sp and *Tribonema* sp occurre exclusively in the upper stretch of the river. Such exclusive phytoplankton is missing in the middle stretch of the river. *Protococcus* sp. and *Golenkinia* sp. are occurring mainly at the lower stretch of Mahanadi. Similarly, *Ankistodesmus* sp., being basically a contributor for upper stretch, appeared at the lower stretch also. *Ulothrix* sp. and *Zygnema* sp. are found only in the freshwater stretch between river origin and Cuttack, when *Microspora* sp was encountered in the upper and middle stretches. Phytoplankton dominate over zooplankton in the entire river system in all seasons, contributing more or less 42.5-81.7% at the upper stretch upto Hirakud, 48.8-100% at the middle stretch below Hirakud to Narsinghpur, and 49.1-99.7% at the lower stretch .When Myxophyceae, Bacillariophyceae, Chlorophyceae or Desmidiaceae contribute considerably, the shares of Euglenophyta and Dinophyceae are quite insignificant. Euglenophyta is not recorded from upstream stretch *i.e.*, above Hirakud. However, during pre-monsoon this group occurre at Sambalpur, Baunsuni, Baudh and in the zone from Kamaldihi to Narsinghpur.

Among zooplankton *Diaptomus* sp and *Cyclops* sp are found to occurre at all the stretches. But *Alona* sp, *Alonella* sp, *Diaphanosoma* sp and *Leydigia* sp among *Cladocera*; *Ascomorpha* sp, *Chromogaster* sp, *Conocheilus* sp, *Diplois* sp, *Gastropus* sp, *Horaella* sp, *Lophocharis* sp, *Mytilina* sp, *Polyarthra* sp and *Rotaria* sp among Rotifera; and *Blepharisma* sp, *Bullinularia* sp, *Colpoda* sp, *Oxytricha* sp, and *Trinema* sp among Protozoa were recorded only from the upper stretch.

Among zooplankton, Copepoda and Rotifera dominate the entire upper stretch (origin to Hirakud) in all seasons. The upper and lower parts of the middle stretch (Durgapalli to Binka and Harbhanga to Narsinghpur) in all seasons and the central part of the middle stretch (Jharpara to Baudh) during pre-monsoon season has dominance of Cladocera along with Rotifera and Copepoda. While the entire lower stretch below Narsinghpur to sea-mouth inclusive of distributaries, estuarine loops, *etc*. exhibit dominance of copepoda and rotifera in all seasons.
Among planktonic insect larvae dipterans are distributed in the middle and the lower stretches of Mahanadi. When *Pempholyx* sp, a rotiferan is encountered only from the middle stretch. Other rotifers *viz., Testudinella* sp and *Lecane* sp belonging mainly to

the same stretch also appeared at the lower stretch of the Mahanadi system. The total plankton occurrence at various stretch of the river is shown in Table 16.

Table 16. The range (and in brackets average for the stretch) of plankton densities at various stretches of the river Mahanadi (u l^{-1})

Stretch of the river	Post-monsoon	Pre-monsoon	Monsoon
Upper (origin to Hirakud)	60-512 **(137)**	44 - 284 **(12**5)	16-160 **(57)**
Middle (Hirakud to Narsinghpur)	78 - 598 **(228)**	32 –288 **(104)**	2 – 57 **(15)**
Lower (Narsinghpur to sea-mouth)	88 – 312 **(201)**	56m – 202 **(128)**	32 – 136 **(79**)
Lower estuary (Kujang to Paradip)	105 – 320 **(212)**	117 – 331 **(244)**	59 – 217 **(138)**

Against pooled averages of plankton density (68-196 u l^{-1}) for the entire Mahanadi system, the upper stretch (origin to Hirakud), the middle stretch (Hirakud to Narsinghpur) and the lower stretch (below Narsinghpur to sea-mouth) has densities of plankton varying from 57 to 137, 15 to 228 and 117 to 206 u l^{-1} respectively, exhibiting not much differences in their concentrations from the average.

Macrobenthos

More than 79 species of macrobenthic fauna were recorded from the Mahanadi system. Among these, upper, middle and lower stretches support 24, 33 and 66 species respectively. *Gyraulus* sp, *Lymnaea* sp, *Viviparus* sp, *Corbicula* sp, *Lamellidens* sp and *Perreysia* sp among molluscs; *Chironomus* sp, *Limnephilus* sp, *Argia* sp, *Isogenus* sp and *Elophila* sp among entomological fauna; and *Chaetogaster* sp and *Lumbriculus* sp among annelids are present in all the stretches of the river system. Exclusive distribution of single molluscan species, three insect fauna and two kinds of oligochaete worm are recorded at the upper stretch from Sihawa to Tamdei. Similar exclusive fauna for the middle stretch between Durgapalli and Narsinghpur included five species of molluscs and three species of insect larvae and nymphs and

for the lower stretch between Sasang and Paradip comprised 16 molluscan species, six species of crustaceans, three species of insect larvae, single species of nymph, two species of aquatic bugs, three species of beetles and two species of polychaetes. Molluscs dominate among the bottom biota of the entire river stretch. This is followed by dipterans in the upper stretch, nematodes in the middle stretch and annelid worms in the lower stretch of the river. The distribution of benthos in the river is as follows in the Table 17.

Table 17. The contribution of different macrobenthos at various stretches of the river Mahanadi

Macrobenthic groups	Percentage contribution								
	Upper stretch			Middle stretch			Lower stretch		
	Post M	Pre M	M	Post M	Pre M	M	Post M	Pre M	M
Mollusca									
Gastropoda	28.2	33.1	54.2	25.0	59.7	91.4	74.5	65.1	58.3
Pelecypoda	19.5	19.8	25.2	7.6	9.0	2.9	10.4	11.0	17.2
Crustacea									
Copepoda	-	-	-	-	-	-	-	2.0	0.65
Ostracoda	-	-	-	-	0.01	-	-	0.18	0.05
Amphipoda	-	-	-	-	-	-	-	0.6	0.12
Cladocera	-	-	-	-	-	-	-	0.082	0.01
Decapoda	-	-	-	-	-	-	-	0.03	0.22
Insecta									
Diptera	32.5	27.7	19.8	-	3.1	-	1.9	8.7	10.8
Trichoptera	9.3	6.6	-	-	0.1	-	-	0.06	0.019
Odonata	0.9	9.5	0.8	4.4	4.3	4.3	-	2.37	3.3
Plecoptera	0.3	-	-	-	-	-	-	0.01	0.001
Lepidoptera	0.6	-	-	-	0.02	-	-	0.003	0.03
Hemiptera	-	-	-	-	-	-	0.5	1.1	0.7
Ephimeroptera	-	-	-	-	0.7	-	-	0.06	0.025
Coleoptera	-	-	-	-	-	-	-	0.04	0.17

Neuroptera	-	-	-	-	0.03	-	-	-	0.005
Annelida									
Oligochaeta	8.7	3.3	-	14.1	6.1	1.4	10.9	6.965	7.8

Post M:Post monsoon; Pre M: Premonsoon; M: Monsoon.

Periphyton

The upper stretch (origin to Hirakud) has the richest periphyton population, due to the presence of hard substrates like rocks and boulders. As many as 46 periphytic flora are recorded from the region. Of these, 10 species *viz., Navicula* sp, *Fragilaria* sp., *Synedra* sp, *Nitzschia* sp and *Gyrosigma* sp among Bacillariphyceae, *Gonatozygon* sp, *Genicularia* sp and *Closteriun* sp among Desmidiaceae; *Spirogyra* sp among Chlorophyceae; and *Spirulina* sp among Myxophyceae are available in the entire stretch throughout the year. Regarding the remaining 36 species of periphytic forms, it may be mentioned that their distribution during various seasons and at different sampling zones are not uniform. Bacillariophyceae dominate among periphyton (40.9-57.1 %) followed by Chlorophyceae (14.3-35.5 %), Desmidiaceae (13.3-25 %) and Myxophyceae (3.6-6.9 %). As many as 13 species of periphytic diatoms *viz., Navicula* sp, *Fragillaria* sp, *Synedra* sp, *Gyrosigma* sp, *Diatoma* sp, *Nitzschia* sp, *Cymbella* sp, *Tabellaria* sp, *Pinnularia* sp *Frustulia* sp, *Stauroneis* sp, *Melosira* sp, *Surirella* sp; were encountered from the entire stretch of the river Mahanadi.

Aquatic macrophytes

Macrophytes are available throughout the river except during monsoon months when the availability of such weeds becomes restricted to certain areas. Six species of hydrophytes *viz., Hydrilla verticillata, Vallisneria spiralis, Ceratophyllum demersum, Najas indica, Potamogeton crispus,* and *Chara* sp are encountered from the upper stretch. Other aquatic plants like, *Marsilea qudrifoliata* invaded Chapajhor/Surajgarh area and *Cyperus articulatus* and *Polygonum glabrum* invaded Chandrapur, Mahadeopalli and Surajgarh stretches where representation of some of the above cited six major weeds are also there. The down stretches of the Mahanadi

and its distributaries have 34 species of macrophytes belonging to 21 families, either as aquatic weeds or marginal plants. While very few of them are local resident flora, most of the species are washed down the river course or from the adjoining nullahs, fields and tributaries during monsoon floods.

Primary productivity

Overall gross primary productivity (327.97-575.37 mg C m^{-3} day^{-1}) of the Mahanadi river system is quite normal and the net primary productivity of the system is 60-73% of the gross values.

Average gross primary productivity value for the entire stretch of the river is 443.98 mg C m^{-3} day^{-1} against a net productivity of 285.91 mg Cm^{-3} day^{-1} and a respiration rate of 156.35 mg C m^{-3} day^{-1} (*i.e.,* nearly 35% of the gross). The average value for the post-monsoon months (428.61 mg C m^{-3} day^{-1}) is lower than that for the pre-monsoon season (575.37 mg C m^{-3} day^{-1}) and higher than that for the monsoon months (327.97 mg C m^{-3} day^{-1}). The productivity of different stretches of the river is shown in Table 18.

Table 18. Primary productivity of the water in river Mahanadi at different stretches over different seasons.

Stretches, Seasons	Gross primary productivity (mg C m^{-3} day^{-1})	Net primary productivity (mg C m^{-3} day^{-1})	Respiration (mg C m^{-3} day^{-1})
Upper stretch			
Post-monsoon	740.20	490.29	299.89
Pre-monsoon	943.17	356.54	703.95
Monsoon	790.87	513.48	332.86
Middle stretch			
Post-monsoon	309.27	209.73	119.45
Pre-monsoon	320.33	197.81	149.28
Monsoon	314.99	196.76	141.88
Lower stretch			
Post-monsoon	352.70	294.20	70.20
Pre-monsoon	575.63	464.38	133.50
Monsoon	83.75	25.50	69.90

Average (for entire river)			
Post-monsoon	428.61	311.34	140.72
Pre-monsoon	575.37	348.39	272.38
Monsoon	327.97	198.01	55.95
Annual Average	443.98	285.91	156.35

Fishery

A total of 253 species of fish belonging to 73 families have been recorded from the river (Hora, 1940; Chauhan, 1947; Menon, 1951; David, 1953; Job *et. al.*, 1955 and Chakraborty, 1999).

List of fish species recorded from the river Mahanadi

Notopterus chitala,	*N. notopterus*	*Gudusia chapra*
Gonialosa manmina	*Catla catla*	*Cirrhinus mrigala*
C. reba	*Labeo bata*	*L. calbasu*
L. dyocheilus	*L. fimbriatus*	*L. gonius*
L. rohita	*L. boga*	*L. dero*
L. boggut	*L. ariza*	*L. pangusia*
Cyprinus carpio	*Chanda nama*	*Pseudambansis ranga*
Osteobrama vigorsii	*O. cotio*	*O. cotio cunma*
Puntius amphibius	*P. gelius*	*P. sarana*
P. sophore	*P. ticto*	*P. chola*
P. conchonius	*P. stigma*	*P. tetrarupegus*
P. guganio	*P. phutunio*	*P. dorsalis*
Tor mosalmahandicus	*T. khudree*	*T. tor*
T. putitora	*Salmostma phulo*	*S. bacaila*
Chela laubuca	*C. gora*	*C. dadidurjori*
C. untrahi	*C. clupeoides*	*C. boopis*
C. fasciatus	*C. chela*	*Pangasius pangasius*
Amblypharyngodon mola	*Aspidoparia morar*	*Barilius barila*
B. barna	*B. bendelisis*	*B. vagra*
Brachydanio rerio	*Danio devario*	*D. aequipinnatus*
D. malabarica	*Securicula gora*	*Rasbora daniconius*
D. crysops	*Esomus danricus*	*Perluciosoma daniconius*
Oreichthys cosuatus	*Crossocheilus latius*	*Garra mullya*
G. gotyla	*Nemacheilus botia*	*N. botia aureus*
N. denisoni	*Lepidocephalichthys guntea*	*Aorichthys aor*
A. seenghala	*Mystus bleekeri*	*M. cavasius*
M. tengra	*M. vittatus*	*M. gulio*
Rita crysea	*Batasio tegona*	*Ompok bimaculatus*
O. pabo	*O. pabda*	*Bagarius bagarius*

Wallago attu *Ailia coilia* *Clupisoma garua*
Eutropiichthys vacha *Silonia silondia* *S. childreni*
Pseudoeutropius atherinoides
Gagata gagata *G. cenia* *G. basio*
Glyptothorax lonah *Hara hara* *Clarias batrachus*
Heteropneustes fossili *Amblyceps mangois*
Rhinomugil corsula *Ambassis baculis* *A. commersoni*
Johnius dussimieri *J. coitor* *J. sina*
Nandus nandus *Setipinna phasa* *S. taty*
Badis badis *Glossogobius giuris* *Awaous stamineus*
Ophiocephalus gachua *Channa punctatus*
C. striatus *C. marulius* *Mastocembelus armatus*
M. pancalus *Macrognathus aculeatus* *Anguilla bengalensis*
Nagra viridescens *Aplocheilus panchax*
Monopterus (Amphipnuous) cuchia *Johnius coitor*
Oreochromis mossambicus *Xenentodon cancila* *Chanda nama*
Anabus testudineus *Colisa lalia* *C. fasciatus*
Ilisha motius *Ilisha elongata* *I. filigera*
Tennualosa ilisha *T. toli* *Anadontostoma chakunda*
Epinephalus diacanthus *E. malabaricus* *Therapon jarbua*
Sillago sihama *Sillaginopsis panijus* *Echeneis naucrates*
Caranx sexfasciatus *C. gallus* *C. para*
Scomberoides commersonius *S. lysan* *C. malabaricus*
Mene maculata *Leiognathus equala* *L. fasciatus*
L. brivirostris *Secutor insidiator* *Lutjanus johni*
Gerres filamentosus *G. abbreviata* *G. lucidus*
Gerremorpha setifer *Datnoides quadrifasciatus* *Lobotes surinamensis*
Mylio (Sparus) berda *Apocryptus lanceolatus* *Gobius personatus*
Drepane punctata *Platax pinnatus* *Scatophagus argus*
Sphyraena acutipinnis *S. lewini* *S. jella*
S. obtusa *Polydactylus sextaris* *P. indicus*
Polynemus paradiseus *P. heptadactylus* *Kurtus indicus*
Elutheronema teradactylum *Odontamblyopus rubicondus* *Trichiurus savala*
Brachyamblyopus brachysoma *Nematolosa nasus*
Pampus argentus *P. chinensis* *Parastromateus niger*
Pseudorhambus arsius *Cynoglossus lingua* *Boleopthalmus boddaerti*
Pseudotriacanthus strigilifer *Triacnathus brevirostris* *Tetraodon cutcutia*
Solea ovata *Syneptura orientalis* *Plagusia marmorata*
Cybium guttatum *Elops saurus* *Orizias melastigma*
Syngnathus cyanospilus *Pomadasys hasta* *Gaterin cinctus*
Toxotes chatareus *Trypauchen vagina* *Scoliodon sorrakowah*
Chiloscylliam griseum *Trygon zugei* *Rhinobatos obtusus*
Lates calcarifer *Platycephalus indicus* *Hemiramphus limbatus*
H. cantori *H. marginatus* *Harpodon nehereus*
Muraena punctata *M. meleagris* *Moringua raitaborua*

Megalops cyprinoides	*Chirocentrus dorab*	*Plotosus canius*
Ophichthys microcephalus	*Monopterus (=Amphipnuous) cuchia*	
Chanos chanos	*Herangula punctata*	*Tachysurus jella*
T. sona	*T. dussumieri*	*T. subrastratus*
T. crossocheilus	*T. macronotacanthus*	*T. venosus*
Osteogeneiosus militaris	*Etroplus suratensis*	*Anchoviella(Stolephorus) tri*
Coilia ramcarati	*C. borneensis*	*C. dussumieri*
C. reynaldi	*Thryssocles mystax*	*T. kammalensis*
T. hamiltoni	*T. purava*	*T. rambhae*
Strongylura strongylura	*Tylosurus leiurus*	*Liza parsia*
L. carinata	*L. macrolepis*	*L. tade*
Osteomugil cunnesius	*Mugil cephalus*	*M. jordoni*
M. belanak	*Sciaena glaucus*	*S. cuja*
Pseudosciaena soldado	*Sciaenoides brunneus*	*Otolithoides biauritus*

Besides the above species, the following prawns were also recorded from sectors of the downstream stretch of the river Mahanadi:

Macrobrachium rosenbergii, M. malcolmsoni, M. dyanum, M. lamarrei, M. rude, Metapenaeus monoceros, M. brevicornis, Leander styliferus, Penaeus indicus, P. mondon, P. carinatus, Acetes indicus.

During 1995-96, an exploratory survey of river Mahanadi was carried out by CIFRI. In the upper stretch fish landings were observed at Dhamtari, Rajim, Mahasamund, Aurang, Seorinarayan, Chandrapur, Raigarh, surajgarh and Mahadeopalli fish markets. The landing pattern at these fish markets is shown in Table 19 .

Table 19. Contribution (%) of various groups in landings, upper stretch of Mahanadi

Group	Post-monsoon (Nov-Dec, 1995)	Pre-monsoon (May-Jun, 1996)	Monsoon (Aug-Sep, 1996)
Catfishes	40.5%	36.7%	42.4%
Minnows	34.2%	35.4%	19.4%
Major carps	15.2%	8.5%	19.1%
Miscellaneous	10.1%	19.4%	19.1%
Average (kg day^{-1} market)	**56.4**	**29.4**	**44.8**

In the middle stretch (below Hirakud reservoir to Narsinghpur), the fish markets, Burla (Durgapalli), Sambalpur, Binka, Sonepur, Baunsuni, Bandh, Charichak (Harbhanga), Angul (Tikarpara) and Narsinghpur (Kakpuria) were studied for landing pattern. The pattern for different seasons is depicted in Table 20.

Table 20. Landing pattern of different groups, middle stretch of river Mahanadi

Group	Post-monsoon (Nov-Dec, 1995)	Pre-monsoon (May-Jun, 1996)	Monsoon (Aug-Sep, 1996)
Carps	63.1%	26.6%	14.0%
Catfishes	12.4%	23.3%	68.3%
Other commercially important species	5.6%	7.1%	9.6%
Miscellaneous	9.6%	28.6%	-
Prawns	9.3%	14.4%	8.0%
Average (kg/day/market)	**106.7**	**17.2**	**15.6**

On the basis of recent survey the assessed landings from the Mahanadi complex in the downstream stretch is given in Table21.

Table 21. Landings from lower stretch of Mahanadi complex

Stretch	Centre	Average landings (kg day^{-1})			Approx. Annual catch (t)	
		Post monsoon	Pre monsoon	Monsoon	For centre	For stretch
Freshwater stretch	Sasang	30	5	15	5.1	**86.2**
	Baideswar	80	20	40	14.4	
	Bankigarh	25	5	10	4.2	
	Subarnapur	200	20	50	29.4	
	Chowdwar	70	20	30	12.6	
	Jobra	15	5	10	3.0	
	Jholasahi	100	10	30	15.0	
	Alipingla	2	0	5	0.8	
	Balikuda	3	1	10	1.7	
Estuarine	Tirtal	8	2.5	15	3.1	**3928.4**
	Taladanda	2	-	5	0.8	
	Kujanj	75	10	5	10.8	
	Kujanj	75	10	5	10.8	
	Paradip	25000	5000	1000	3660	
	Basupur	5	-	15	2.0	
	Narayanpur	30	5	100	13.2	
	Marsaghai	50	300	5	42.5	
	Barapal	200	500	30	86.7	
	Ostar	80	200	10	34.5	
	Teragaon	30	70	5	12.4	
	Gajarajpur	120	35	20	19.8	
	Machgaon	250	80	50	42.6	
Patamundai stretch of Brahmani river	Patamundai (Freshwater - Brackishwater landings)	100	50	20	19.2	**19.2**

Besides, the landings cited above, more than 500 trawlers fish in the continental shelf near Mahanadi mouth and land coastal fishes at Paradip. These trawlers operate for about 100 days in a year with a catch about 10 t per month per trawler, comprising 70% fishes and 30% prawns. Thus, the total landing from the downstream comes to about 20,000 t per year.

THE GODAVARI

The river Godavari is the largest of the peninsular rivers and the third largest in India. It originates near Triambakeswar in Deolali hills of the Western Ghats, Maharashtra, from altitudes of 1219 to 1524 m msl. In its course, the river flows across the Decan Plateau from Western to Eastern Ghats through Maharashtra and Andhra Pradesh before joining the Bay of Bengal. The river has a total catchment area of about 8,12,812 km^2. More than 90% of the annual runoff occurs between May and October under the impact of southwest monsoon. The annual flood discharge of Godavari varies from a maximum of 80,137 cumecs to a minimum of 42 cumecs. The river course is divided into upper stretch (Maharashtra from head water at Nasik to Nanded), Middle stretch (Andhra border, where the river Manjira joins Godavari, down to Eturunagaram) and the lower stretch (extends from Parnasala to Yanam and Narsapur).

The information on water quality, biotic communities and primary productivity of the river, compiled here are based on the studies conducted by CIFRI, (CIFRI, 2000b). For information on fisheries, other sources, as sited in the text are also consulted.

Water quality

Temperature of the water varies from 20.0 to 31.5 ^oC, 26.0 to 31.5 ^oC, and 24.5 to 32.9 ^oC respectively in the upper, middle and lower stretches. The mean annual temperature fluctuate over 27.0 to 30.0 ^oC in the entire river course. Transparency is

low in the upper stretch (16-40 cm), higher in the middle stretch (10-200 cm) and the lower stretch has 6 to 152 cm. Dissolved oxygen is high in the upper stretches (6.8-8.0 mg l^{-1}) and the lower stretch has 8.1 to 9.8 mg l^{-1}. The pH is in the alkaline range through out the river (7.4-8.2). Total alkalinity is 99-119 mg l^{-1} (upper), 137-191 mg l^{-1} (middle) and 96-125 mg l^{-1} in the lower stretches. Specific conductivity and total hardness show similar trends as that of alkalinity. Calcium and magnesium (mg l^{-1}) ranges between 18.4 and 34.7 and 6.8 and 18.0 respectively in the upper stretch, while the middle stretch recorded higher values. At the lower stretch Ca was 119-374 mg l^{-1} and Mg was 331.7 – 450.0 mg l^{-1}. Nitrate values range between 21.0 and 54.5 μg l^{-1} for the entire river, while the range of phosphate is 60-180 μg l^{-1}. Upper stretch recorded higher silicate levels followed by the middle and lower stretch. The water quality and nutrient parameters for different stretches of the river is shown in Table 22.

Biotic communities

Plankton

Phytoplankton show overwhelming presence in the river, except in its estuarine areas. The constituents of phytoplankton are Chlorophyceae, Bacillariophyceae, Cyanophyceae and Dinophyceae. Chlorophyceae dominated the upper stretch. The most common Chlorophyceae are *Spirogyra singularis* and *Zygnema melonosporum*. The common diatoms are *Asterionella* and *Tabellaria*. *Microcystis* and *Oscillatoria* are the dominant Myxphyceans, while Dinophyceae is represented by *Ceratium hirudinella*.

Zooplankton concentration is higher in the estuarine zone. Rotifera, Cladocera and Copepoda are the major groups. The plankton abundance in the river Godavari is presented in Table 23.

Table 22. Water quality parameters of the river Godavari at various stretches (Av. in brackets**)**

Stretch of river	Water temperature (°C)	Transparency (cm)	Dissolved oxygen (mg l^{-1})	pH	Total alkalinity (mg l^{-1})	Sp. conductance (µ mhos)	Total dissolved solids (mg l^{-1})	Calcium (mg l^{-1})	Magnesium (mg l^{-1})	Total hardness (mgl^{-1})	Chloride (mg l^{-1})	Silicate (mg l^{-1})	Nitrate (mg l^{-1})	Phosphate (mg l^{-1})
Upper	27.2-29.2 (28.2)	16.0-180.0 (49.7)	6.8-8.0 (7.32)	7.4-8.0 (7.6)	99-119 (105.4)	415-525 (478)	270-342 (311.0)	22.4-28.0 (26.0)	6.8-12.2 (11.0)	98-118 (110.0)	22.9-69.6 (34.8)	13.1-17.8 (15.3)	0.026-0.054 (0.036)	0.068-0.100 (0.09)
Middle	28.6-30.0 (29.3)	10.0-200.0 (72.8)	6.4-7.6 (6.9)	7.7-8.2 (8.0)	125.0-191 (159.6)	373-605 (482.0)	243-379 (311.3)	27.0-34.7 (29.5)	9.3-18.3 (13.13)	120-145 (125)	29.3-38.0 (32.1)	11.1-14.2 (12.6)	0.021-0.036 (0.026)	0.06-0.11 (0.08)
Lower	27.0-30.0 (28.8)	8.0-152.0 (64.0)	8.1-9.1 (8.9)	7.8-8.2 (8.02)	96-123 (108.2)	277-347 (300.6)	180-226 (195)	18.4-23.4 (21.96)	7.1-11.0 (9.03)	84.0-105.0 (95.2)	17.0-36.0 (25.6)	8.8-11.2 (10.1)	0.03-0.037 (0.033)	0.058-0.12 (0.08)
Estuary	27.8-28.0 (27.9)	10.0-120.0 (57.5)	8.5-8.9 (8.7)	(7.8)	104-125 (114.5)	21413-36643 (29028)	13918-23818 (18868)	119.0-374.0 (246.5)	331.7-450.0 (390.8)	1724-2788 (2256)	6837-10188 (8512)	1.8-7.9 (4.85)	0.031-0.033 (0.032)	0.062-0.065 (0.063)

Table 23. Plankton abundance in the river Godavari (Av. in brackets**)**

Stretches	Phytoplankton (u l^{-1})					Zooplankton (u l^{-1})			
	Myxo.	Chloro.	Bacillar.	Dinoph.	Phyto. (%)	Rotifer.	Cladocer	Copep.	Zoopl.(%)
Upper(Nasik-Nanded)	1-21 (6.4)	4-570 (127.4)	1-126 (30.4)	0-1 (0.5)	80-100 (95.9)	0-5.0 (2.0)	0-1(0.2)	0-5(2.5)	0-200 (6.9)
Middle(Kandkurti-Eturunagaram)	0-775 (130.8)	5-565 (108.3)	0-5488 (514.3)	0-3 (0.8)	23.1 (69.9)	1.0-4.0 (1.8)	0-4 (2.0)	0-10 (5.3)	16-79.9 (27.7)
Lower(Parnashala-Kotipalli)	0-16 (2.9)	0-76 (24.8)	1-33 (12.6)	--	77-100 (94.1)	0-1.0 (0.5)	--	1-4 (1.5)	0-22.2 (6.2)
Estuarine(Yanam-Narsapur)	0-1 (0.5)	0-9 (4.5)	9-10 (7.8)	1-2 (1.5)	18-47 (32.5)	0-13(6.5)	0-2 (1.0)	23-38 (30.5)	54-82 (67.5)

Macrobenthos

The benthic macro invertebrate fauna varies from 261 to 782 organisms m^2 in the upper stretch, 252-2631 in the middle stretch and 26 to 2465 organisms m^2 in the lower stretch. Molluscs dominate the river course, of this gastropods are the major portion. Common molluscs encountered are *Bellamya bengalensis, Thiara tuberculata, Brotia coastula, Pila globosa, P. virens, Lymnaea acuminata* among gastropods and *Corbicula striatella, Lamellidens scutum* and *L marginalis* among bivalves. Common insect forms are *Corixa, Belostoma, Ranatra*, stonefly nymph and nymphs of mayfly and dragon flys.

Periphyton

Among periphytic communities Bacillariophyceae is the predominant group. Chlorophyceae and Dinophyceae are encountered predominantly in the middle and lower stretches. In all a total of 31 genera are recorded in periphytic communities.

Aquatic macrophytes

Macrophytes are confined to stagnant pools and around islets. Common of these are *Hydrilla verticellata, Potamogeton, Vallisneria, Ceratophyllum, Typha, Najas, Eichhornia, Pistia and Spirodella.*

Primary productivity

The average gross productivity values for the upper, middle and lower stretches of the river are 99, 35 and 85.8 mg C m^{-3} day^{-1} respectively indicating that the middle stretch is less productive. The higher production in the upper stretch is attributed to water stagnation due to barrages and weirs.

Fisheries

CIFRI made observations on fish catch from a 189 km long stretch of river Godavari during 1963-69 (Jhingran, 1991). The stretch was divided into three zones. Zone I comprised a 33.6 km stretch between Dowleswarm and Pattiseema; Zone II, a 59.2 km stretch between Polavaram and Jidiguppa and Zone III, a 96.2 km long stretch between Kunavaram and Dummagudam. In three zones, 11 centres were selected for investigations. Zone I consisted 4 centres (Rajamundry, Dowlaiswaram, Bobbarlanka and Kovvur), Zone II 4 centres (Polavaram, Divipatham, Kondamodalu and Jidiguppa), Zone III 3 centres (Kunavaram, Bhadrachalam and Dummagudam). Table 24 shows average fish landings from different zones for the period 1963-69.

Table 24. Landings (t) from 189 km stretch of river Godavari (av. of 1963-69*)*

Species	**Zone 1**	**Zone 2**	**Zone 3**
C. mrigal	7.84	7.79	0.90
L. fimbriatus	9.24	5.01	7.47
C. catla	1.44	1.10	0.30
L. rohita	0.19	0.04	0.04
C. horai	1.41	0.30	0.31
A. seenghala	5.83	1.80	2.71
W. attu	1.80	0.53	0.91
S. childreni	1.56	0.83	0.51
P. pangasius	1.23	0.17	0.26
H. ilisha	25.94	0.23	0.10
L. calbasu	0.87	2.63	3.44
Bagarius	0.27	0.57	1.69
Prawns	76.14	2.76	5.97
Miscellaneous	57.06	8.80	15.10
Total	**190.82**	**32.56**	**39.71**

The total yield from the entire 189 km stretch fluctuated between 218 t in 1969 to 330.1 t in 1963 depicting a declining trend. Fish yield kg ha^{-1} from these waters were estimated to be: 9.36 in 1963, 9.11 in 1964, 6.97 in 1965, 6.56 in 1966, 7.44 in 1967, 6.6 in 1968 and 6.19 in 1969.

The principal fish groups, which support the fishery of river Godavari are:

Carps: *Labeo fimbriatus, Cirrhinus mrigala, Labeo calbasu* and *Catla catla*.

Catfishes: *Aorichthys seenghala, A. aor, Silonia childreni, Wallago attu, Pangasius pangasius, Bagarius bagarius*.

Hilsa ilisha, *prawns* (mainly constituted by the species *Macrobrachium malcolmsonii*) and miscellaneous group (comprising less than 0.5% individually, in the total catch at any time).

From estuarine zone of the river (from one branch of the estuary) the fish landings during 1963-64 was estimated at 2299 t (Rajyalakshmi and De, 1979). Prawns and crabs contributed 57.8%, sharks and rays were the next largest contributors followed by pomfrets, *Stromateus* sp, mackerals, mullets, clupeids, ribbon fish and perches. The second branch of the estuary, smaller in extent, landed 1617 t. Here, sharks and rays were more dominant (35%) followed by clupeids, mackerals, catfishes, perches, sciaenids and ribbonfish. The prawn and crab landings were very low. The second year's (1964-65) total from both the branches was 3156 t with prawns and shrimp contributing 29% only.

On the basis of recent studies conducted by CIFRI (CIFRI, 2000) fishery is very poor in the upper stretch of Godavari (origin to Nanded), consisting mainly miscellaneous fishes. The annual catch from 134 km stretch of river in Nanded district is reported to be about 100 t consisting of carps (*C. catla, L. rohita, C. mrigala* and *L. fimbriatus*), catfishes (*A. aor* and *A. seenghala*) and miscellaneous fishes. Nanded centre used to be an important fishing ground before the construction of Sriramsagar dam at Pochampad. In the isolated pools of the river, *Gambusia affinis* and *Poecila* (*Lebistes*) *reticulata* are also recorded.

In the middle stretch (Nanded down to Eturunagaram) among carps *L. fimbriatus* is the dominant species followed by *L. rohita* and *L. calbasu* in the post monsoon months. Catfishes *Aorichthys aor* and *A. seenghala, S. childreni* and *W. attu* also contribute significantly. Prawns (*M. malcolmsonii*) are caught at Eturunagaram and Manthani centres. The deep pool Lanjanmadugu is productive but it has been declared a crocodile sanctuary. Sriramsagar reservoir has so far remained undeveloped and any development of fisheries in this reservoir will have a positive impact on the upstream and downstream fisheries of the river.

In the freshwater zone of lower stretch (Eturunagaram down to Narsapur), the stretch between Dummagudam and Dhawaleswaram is the most productive part of the river. Fishing activity is intensive between Dhawaleswaram and Polavaram. After Polavaram fishing intensity is very low due to deep gorges and poor accessibility. Activity again picks up after Papi hills and is centered around Jidiguppa, Kunavaram, Bhadrachalam, Dummagudam, Parnasala and Chelra. At Dhawaleswaram and Rajamundry fishing is done throughout the year. During monsoon the target species is hilsa. Hilsa catches were not observed beyond Rajamundry. From January to June, fishing is mainly for prawns and fish occurs only as a by-catch. Besides miscellaneous species, juveniles of *A. seenghala, S. childreni* and *L. fimbriatus* are caught in considerable number.

In the estuarine zone of lower stretch at Narsapur and Yanam, penaeid prawns, mullets, hilsa, perches, sciaenids and catfishes accounted for the commercial catch. At Kotipalli (above Yanam) major carps are also available. Among prawns the important species available are *Penaeus indicus, P. monodon* and *Metapenaeus* spp.

In the riverine zone of lower stretch, major carps *L. rohita, C. catla, C. mrigala* and *L. fimbriatus* occurre in their order of abundance. Catfishes are represented by *A. seenghala, A. aor, S. childreni, P. pangasius, P. taakree* and *W. attu*. Miscellaneous group included *Oxygaster* spp, *Osteobrama* spp, *N. notopterus, C. reba*, *Puntius* spp. and others. In the estuarine zone *Mugil parsia, M. cephalus, Lates calcarifer, Thryssa* spp, *Pseudosciena coibor*, *Arius* spp., *Gerres* spp. are the common fishes.

THE KRISHNA

The river Krishna is one of the three major perennial rivers in southern India with a drainage of 1,58,948 km^2. Originating from Mahabaleswar Hills of Western Ghats in Maharashtra, the river traverses 1280 km, covering Maharashtra, Karnataka and Andhra Pradesh before emptying into the Bay of Bengal. The main course of the river has many dams such as Dhom,Almati,Narayanpur,Srisailam and Nagarjunsagar in its course. The river is divided into three stretches. The upper stretch (Wenna-Kallol), the middle stretch (J.Khandi-T.Bhadrd) and the lower stretch covering Bispalli to Penumudi.

Water quality

On the basis of the studies conducted by CIFRI, in the year 2001-2002, water temperature of the river is higher during premonsoon (27.0-35.2 ^oC), followed by monsoon (27.0-31.5 ^oC) and postmonsoon period (24.8-31.3 ^oC) for the entire river course. Dissolved oxygen is generally high along the upper stretch (8.02 and lowest along the lower stretch (6.42 ml l^{-1}). The water reaction is alkaline through out the course of the river with a pH range of 8.1 to 8.18. Alkalinity is found to be higher in the middle stretch (160.0 mg l^{-1}), however the variation along the entire river is not very high. Specific conductivity is lower along the lower stretch and increased along down the river to attain highest values in the lower stretch of the river. Dissolved

solids also followed the same pattern in its concentration. Calcium levels range between 31.6 and 44.5 mg l^{-1} for the entire river with highest values along the lower stretch. Total hardness is fairly low along the upper stretch (159 mg l^{-1}) and highest at lower stretch (188.8 mg l^{-1}). Chloride also exhibits similar pattern in its concentration. Although the level of nitrite fluctuation was in the tune of 3-1095 μ g l^{-1} in the river, the average fluctuation in the entire river varied between 97.3 μ g l^{-1} (lower stretch) and 374 μ g l^{-1} (middle stretch). Silicate is maximum along the upper stretch (9.1 μ g l^{-1}) and lowest along the middle stretch (7.46 μ g l^{-1}). Phosphate variation along the entire course of the river is 38.0 to 98 μ g l^{-1}. The levels of major water quality parameters along the river are shown in Table 25.

Biotic communities

Plankton

Phytoplankton population account for 88.4 to 89.8 % of the total plankton. Myxophyceae remain dominant in abundance (46.7 to 1.5 %). The most prevalent Myxophycean is *Microcystis* sp. Second important group is Chlorophyceae accounting for 22.9 to 31.8 %. Crustaceans and Rotifers constitute zooplankton population. Major forms are *cyclops* and *branchionus*. Upper stretches of the river are comparatively richer in plankton than the lower stretches. Seasonally, plankton dominance is higher in monsoon.

Macrobenthos

Molluscs dominate the macrobenthic communities of the river (89.8 to 93.5%). Other forms are chironomids, insect larvae and worms. Higher benthic production is observed during pre-monsoon period and species diversity is high in Maharashtra and Karnataka stretches of the river.

Periphyton

Among periphytic population Bacillariophyceae dominated (68.1-95.6%). Other groups are Myxophyceae (2.5-21.2%) and Chlorophyceae (1.8-10.8%). Major periphytic forms encountered are *Merismopedia* sp., *Synedra ulna, S.rumbens, Navicula cuspidate, N.exigua,Gomphonema montanum etc.*

ज्ंइसम 25ण् ॅजमत ुनंसपजल वि तपअमत ज्ञतपीदं ंज अंतपवने ेजतमजबीमे ; ।अण् पद इतंबामजेद्ध

Stretches	Water temperature (°C)	Transparency (cm)	Dissolved oxygen (mgl^{-1})	pH	Total alkalinity (mgl^{-1})	Sp. conductance (µmhos)	Total dissolved solids (mgl^{-1})	Calcium (mgl^{-1})	Total hardness (mgl-1)	Chloride (mgl^{-1})	Silicate (mgl^{-1})	Nitrate (μgl^{-1})	Phosphate (μgl^{-1})
Upper (Wenna T.-Kallol)	26.4-28.77 (27.8)	0.38-1.07 (0.73)	6.17-9.03 (8.02)	7.93-8.63 (8.10)	95.0-209 (149.4)	209-960 (406.9)	104.5-480 (292.3)	17.6-60.7 (33.3)	81.0-275 (159)	19.9-146.7 (52.5)	7.30-13.56 (9.1)	12.0-594.0 (141.3)	42.0-680 (98.8)
Middle (J.Khandi-T bhadra)	28.3-30.5 (28.9)	0.21-0.75 (0.57)	6.6-8.2 (7.34)	8.11-8.33 (8.18)	109-235 (160)	340-1095 (688)	170-548 (359)	17.4-38.3 (31.6)	110-267 (185)	54.9-179.8 (109.7)	5.67-9.1 (7.46)	14.0-1590 (374)	28.0-51.0 (38.0)
Lower (Bispalli-Penumudi)	28.8-31.8 (30.5)	0.77-1.67 (1.08)	4.67-7.43 (6.42)	8.02-8.34 (8.12)	123-231 (154.9)	380-6510 (1039)	190-3255 (1723)	21.2-232 (44.5)	118-812 (189)	49.2-2319 (254)	6.46-11.3 (8.0)	50.0-379 (97.3)	32.0-126 (67.9)
Average for the river	29.1	0.79	7.26	8.13	154.8	711.1	791.4	36.5	177.5	138.7	8.19	204.2	68.2

Aquatic macrophytes

Upper stretches of the river are generally devoid of macrovegetation. In Karnataka and Andhra Pradesh stretches, patches of vegetation were observed. The major forms of these are *Potamogeton crispus, P.indicus, Hydrilla verticellata, Vallisneria spiralis, Ceratophyllum demersum* and *Ipomoea aquatica* in their order of abundance.

Primary productivity

The gross primary productivity increase progressively from the upper stretch towards the lower stretch. The over all range of gross production is 28.1 to 281.3 mg Cm^{-3} h^{-1}. Productivity is generally higher where water stagnated due to anicuts and pools. Net production mostly attains 50% of the gross production in most of the regions of the river, irrespective of seasons.

Fishery

No information is available about fish and fisheries of Krishna River. However, on the basis of recent survey conducted by CIFRI, the important species observed in commercial catches are as follows:
C. catla, L. calbasu, L. rohita, C. mrigala, C. reba, L. boga, L. gonius, C. carpio, P. sarana, P. kolus, P. ticto, L. fimbriatus, P. jerdoni, A. aor, A. seenghala, M. krishnensis, W. attu, M. armatus, Mystus spp., *R. rita, R. pavimentata, N. notopterus, R. corsula, O. bimaculatus, B. bagarius, P. pangasius, S. childernii, E. suratensis, S. nukta, N. notopterus, Lates calcarifer, G. giuris, Osteobrama cotio, X. cancila, C. marulius, P. lithopidos, A. lineatus, A. testiduneus, Macrognathus* sp., mullets, *T. ilisha, H. lymbatus, C. chanos, L. splendens* and perches.

THE CAUVERY

The river Cauvery originates from the Brahmagiri hills of the Western Ghats in the Coorg district of Karnataka. It traverses about 850 km., draining 89,600 km^2 area enroute before joining the Bay of Bengal. The river course is broadly divided into upper stretch (Mountainous zone) from the origin and up to Sivasamudram, the middle stretch (Plateau zone from Sivasamudram to Hogenakkal) and the lower stretch (Plain zone from Hogenakkal to its confluence with the Bay of Bengal). The upper and middle stretch lies in Karnataka and the lower stretch lies in Tamilnadu.

Investigations on ecology, biology and production functions in the river, undertaken by CIFRI during 1999-2001, are the main source of our knowledge of the environment and fishery of river Cauvery.

Water quality

The water temperature fluctuate between 24.6 and 28.1 ^{o}C through the entire stretch of the river, with maximum value reaching up to 28.1 ^{o}C in the lower stretches. Transparency is lowest along the upper stretch (22 cm), while in the lower stretch it is 103.4cm Dissolved oxygen is found to be fairly high with 6.6 to 6.95 ml l^{-1} for the entire stretch of the river. The average pH of the river is slightly above neutral (7.55). Nevertheless, in the upper stretches the reaction is slightly acidic (6.92). Total alkalinity range between 98.0 and 188.7 mg l^{-1} in the entire stretch of the river. Specific conductivity on an average for the entire river is 768.2 μ mhos with a range of 294.9-1215.3 μ mhos. Dissolved solids are maximum along the lower stretch of the river (655.6 mg l^{-1}) compared to the upper and middle stretches. Calcium shows an increasing trend from the upper to the lower stretch (85.5 mg l^{-1}). The trend of magnesium and total hardness are similar to that of Calcium. The level of silicate, nitrate and phosphate favoured good productivity. The major water quality parameters are depicted in Table 26.

Biotic communities

Plankton

Major phytoplankton forms encountered are *Spirogyra singularis, S.submaxima, Hormidium* sp., *Ulothrix* sp., *Pediastrum tetras, P duplex, Anabaena ambigua, Ocillatoria* tenuis, Synedra ulna, Navicula cuspidate, N. exigua, *Gomphonema sphaerophorum,etc*. Among zooplankton *Cyclops, Diaptomus, Branchionus,Moina* sp.*etc* are the major forms.

Macrobenthos

The abundance of benthic community is in the tune of 14854-18788 nos m^{-2} in the river. Centers with rich bottom fauna are T.Narasipur (3524 nos m^{-2}) in the upper stretch and Mettur (7283 nos. m^{-2}), Bhavani (2370 nos m^{-2}), Kumbakonam (5635 nos m^{-2}) and Kollidam (12146 nos m^{-2}) in the lower stretch. Molluscs are the only group occurring through out the stretch of the river. Of this gastropods form a major component. Common molluscs occurred are *Thiara scabra, T. tuberculata, Brotia coastula, Lymnaea, Corbicula, Striatella, Parreysia coeeugata etc*.

Table 26. Water quality parameters of the river Cauvery, (Av. in brackets**)**

Stretches	Water temperature (°C)	Transparency (cm)	Dissol-ved oxygen (mg l^{-1})	pH	Total alkalinity (mg l^{-1})	Sp. conductance (µ mhos)	Total dissolved solids (mg l^{-1})	Calcium (mg l^{-1})	Magnesium (mg l^{-1})	Total hard-ness (mgl^{-1})	Chloride (mg l^{-1})	Silicate (mg l^{-1})	Nitrate (mg l^{-1})	Phosphate (mg l^{-1})
Upper (Wenna T.-Kallol)	22.2-26.0 (24.6)	22.0-up to bottom	6.2-7.2 (6.95)	6.2-7.3 (6.92)	23.0-151 (98.0)	59.0-453 (294.9)	38.0-294 (191.7)	2.9-24.4 (14.82)	1.7-14.7 (9.2)	15.0-119 (89.0)	12.6-30.9 (20.8)	1.69-5.9 (3.7)	Tr-0.02	0.001-0.08 (0.023)
Middle (Sivasamudram-Hogenakkal	25.0-30.0 (26.7)	90- up to bottom	6.3-8.7 (6.85)	7.5-8.2 (7.81)	90.0-264 (217)	550-1470 (795)	124-956 (497)	16.0-51.3 (28.6)	4.8-43.2 (20.1)	60-228 (158)	25.6-138 (58.4)	5.0-9.5 (7.2)	Tr-0.272	0.001-0.29 (0.078)
Lower (Hogenakkal-Confluence)	27.1-29.5 (28.1)	60.0-240.0 (103.4)	5.0-7.8 (6.6)	7.2-8.2 (7.9)	152-247 (188)	588-2170 (1215)	382-1085 (655)	21.8-492.6 (85.5)	13.9-437 (77.8)	120-1765 (412)	----	1.72-7.34 (4.57)	0.045-0.105 (0.098)	0.048-0.124 (0.094)
Average for the river	26.5	---	6.8	7.55	167.9	768.2	448.1	42.9	35.7	219.9	--	5.2	0.07	0.068

Periphyton

Premonsoon period show maximum deposition of periphyton (49325 nos m^{-2}) followed by monsoon (25500 nos m^{-2}). Bacillariophyceae remains the dominant group.

Aquatic macrophytes

The dominant floating forms are *Azolla pinnata, Lemna minor ,Eichhornia crassipes*; submerged forms were *Hydrilla verticellata, Potamogeton crispus, P. indicus, Ceratophyllum demersum* and *Ipomea aquatica.*

Primary productivity

The upper stretch of the river registered a primary production range of 25.0-62.5 mg C m^{-3} hr^{-1} and the lower stretch recorded 64.85 to 252.1 mg C m^{-3} hr^{-1}. The production is higher in stagnated pools of the river. The mean annual range of variation in net production is 31.3-34.4 mg C m^{-3} hr^{-1} for the upper stretch and29.9-148.4 mg C m^{-3} hr^{-1} for the lower stretch. The P/R ratio, a predictor for organic pollution, exhibited low amplitude of temporal variation. The annual mean range in P/R ratio is 1.6 (Ramanathapuram) to 7.4(Kollidam) for the entire stretch of the river.

Fishery

Eighty species of fish have been reported by Chacko *et. al.* (1954) from river Cauvery. Among carps, the species forming a special feature of the Cauvery fish fauna are: *Acrossocheilus hexagonolepis, Tor putitora, Barbus carnaticus, Labeo kontius, L. ariza, Cirrhinus cirrhosa, Osteochilus brevidorsalis* and *O. nashi*. The important catfishes were *Glyptothorax madraspatanus, A. aor, A. seenghala, Pangasius pangasius, Wallago attu* and *Silonia silondia*. Murrels and feather-backs were represented by *Channa marulius* and *Notopterus notopterus*. Gangetic carps such as *Catla catla, Labeo rohita, Cirrhinus mrigala* and the exotic species *Cyprinus carpio* and *Osphronemus goramy* have been transplanted in the Cauvery river system.

No information is available on the fisheries for Cauvery. On the basis of recent exploratory survey of river Cauvery by CIFRI, in the stretch below Mettur dam, the catch per unit effort is estimated at 1-6 kg day^{-1} during full water level. It ranged from 10 to 100 kg day^{-1} when releasing of water from Mettur is stopped. A sizeable catch (50 to 300 kg day^{-1}) was caught with a minimum labour of 2-3 fishermen through trapping of jumping fishes at the sluice gates in the regulators and anicuts. The following species are recorded in the Tamilnadu stretch of the river:

Anguilla bengalensis, A. bicolor, N. notopterus, Chela laubuca, Danio aequipinnatus, Rasbora daniconius, R. caverri, Amblypharyngodon mola, Cyprinus carpio, Puntius carnaticus, P. chola, P. curmuca, P. dorsalis, P. dubius, P. filamentosus, P. sarana, P. ticto, Labeo bata, L. boggut, L. calbasu, L. fimbriatus, L. kontius, L. rohita,

Cirrhinus reba, C. mrigala, Catla catla, Garra mclellandi, G. mullya, Nemacheilus iatus, Mystus armatus, M. bleekeri, M. cavasius, M. malabaricus, M. vittatus, Aorichthys aor, A. seenghala, Wallago attu, H. fossilis, C. batrachus, Channa marulius, C. striatus, C. punctatus, C. orientalis, Etroplus suratensis, Oreochromis

mossambicus, Liza parsia, R. corsula, Glossogobius giuris, Anabas testudineus and *Mastocembelus armatus.*

Among prawns only two species *viz. Macrobrachium malcomsonii* and *M. rosenbergii* were observed.

THE NARMADA

The river Narmada originates as an underground spring from the highlands of Vindhya range at an altitude of 900 m msl and opens in the Kundh inside Narmada temples. It flows down as a narrow strip. The river is then joined by a small nullah and takes a coarse through mountain valleys inside deep forests and again emerges at Dindori. In its path from Amarkantak and up to Gadarwara, the river is joined by a number of streams. The ecology and fisheries of River Narmada was studied during 1967 and 1996, in some stretches. Apart from this, no detailed information is available on the ecological status and production dynamics of river Narmada in different stretches. In order to fill up this knowledge gap, an exploratory survey was taken up by CIFRI on the ecology and fisheries of the river from origin up to Sink (Dwivedi *et al*. (2003). Studies conducted on the fisheries of the river are also few and far between.

Water quality

The water quality parameters of the river in different stretches have are in Table 27. Among the physical parameters, water temperature is in the range of 23.5 to 29.3^{0}C and transparency 22.3 to 79.0 cm. Water is slightly acidic in Amarkantak (pH 6.8) but in the other stretches, it is alkaline (pH 7.8 to 8.17). Dissolved oxygen is optimum in the entire stretch (6.05 to 8.15 mg l^{-l}) with low carbon dioxide (0.87 to 3.7 mg l^{-l}). Despite some common feature the river showed considerable variations in respect of chemical parameters like alkalinity, conductance, dissolved solids, calcium, magnesium and hardness between the stretches, all being comparatively much lower in Amarkantak (42.5 mg l^{-l}, 97.6 μ mhos, 51.9 mg l^{-l}, 15.9 mg l^{-l}, 9.04 mg l^{-l} and 54.16

mg l^{-1}, respectively) and shows sharp increase in the next station Dindori (115.54 mg l^{-1}, 224.8 μ mhos, 102.4 mg l^{-1}, 22.7 mg l^{-1}, 16.34 mg l^{-1} and 118.76 mg l^{-1}, respectively). The inter stretch variations in the chemical parameters between Amarkantak and Gadarwara may be due to variations in the catchments as well as the impact of various streams draining in between. The nutrient status of the river in respect of both nitrate and phosphate being 0.15 to 0.18 mgl^{-1} and 0.003 to 0.03 mgl^{-1} respectively, organic matter is quite high ranging from 0.74 to 1.57 mg l^{-1}. In general, rich dissolved oxygen, distinct alkaline pH (except Amarkantak) high values of alkalinity, conductance, dissolved solids, calcium hardness and organic matter reflect good productive nature of the river, the only negative point being low nutrient status.

Table27. Water Quality of river Narmada in different stretches

Parameters	Amar-kantak	Dindori	Mandala	Jabal-pur	Narsingh-pur	Karaili	Gadarwala
Water temperature (^{0}C)	24.0	23.5	26.7	25.9	24.4	29.4	24.4
Transparency (cm)	76.0	22.3	53.6	41.5	69.0	53.3	79.0
Dissolved oxygen (mgl^{-1})	6.43	6.05	6.58	7.72	7.24	8.35	8.15
pH	6.8	8.0	7.84	7.82	8.02	7.97	8.17
Free Carbon dioxide (mgl^{-1})	3.7	0.7	1.44	1.27	1.85	2.12	0.87
Total Alkalinity (mgl^{-1})	42.5	115.54	123.12	99.69	127.2	132.6	138.6
Sp. conductance (μ mhos)	97.6	224.8	224.8	193.4	221.5	236.7	249.5
Total dissolved solids (mgl^{-1})	51.9	102.4	118.6	104.3	124.0	132.3	138.3
Calcium (mgl^{-1})	15.9	22.7	23.66	22.33	26.9	28.4	26. 0
Magnesium (mgl^{-1})	9.04	16.34	14.0	14.07	15.4	12.5	17.0
Total hardness (mgl^{-1})	54.16	118.76	114.5	102.56	127.5	130.8	134.6
Silicate (mgl^{-1})	6.0	13.26	11.2	10.5	9.42	10.0	10.82
Dissolved organic matter (mgl^{-1})	1.57	1.13	1.15	0.94	0.74	0.83	0.88
Nitrate (mgl^{-1})	0.18	0.165	0.164	0.174	0.15	0.15	0.176
Phosphate (mgl^{-1})	0.03	0.018	0.02	0.0046	0.002	0.003	0.0033

Biotic communities

Plankton

The numerical abundance of plankton in different stretches range between 32 u l^{-1} (Dindori) and 202 µ l^{-1} (Amarkantak) mainly comprising phytoplankton (69.2 to 98.6%). Bacillariophyceae is the most important group among phytoplankton (23.1 to 90.6%) followed by Chlorophyceae (0 to 40.6%), Myxophyceae (0 to 9.3%) and desmids (0 to 8.7%) while zooplankton is mainly represented by crustaceans (0 to 30.4%) and rotifers (0.6 to 9.4%). Considerable zonal variations are observed, both in the qualitative and quantitative appearance of various planktonic groups. Except Amarkantak and Mandala, where Chlorophyceae remained the most dominant group (36.2 to 40.6%) other stretches are dominated by diatoms.. The dominant forms encountered in the various stretches are *Fragilaria, Synedra, Cymbella, Diatoma, Gomphonema, Navicula radiosa, Melosira, Asterionella, Tabellaria, Surirella and Gyrosigma* among Bacillariophyceae; *Protococcus, Pediastrum, Kirchneriella, Gloebotrys, Ulothrix* and *Spirogyra* among Chlorophyceae. Among zooplankton the dominant species are *Bosmina, Nauplius* larvae, *Cyclops, Diaptomus, Limnocalanus, Ceriodaphnia* and *Leptodora sp.*

Macrobenthos

Qualitative and quantitative abundance of benthic communities are shown in Table-28. The population ranged from 259 µ m^{-2} (Mandala) to 642 µ m^{-2} (Jabalpur) being comparatively higher in the down stretch between Jabalpur and Gadarwara. The qualitative picture indicate dominance of Annelida and Insecta in the upper stretch upto Jabalpur (hilly and forest area of the river) while in plains between Narsinghpur and Gadarwara, the dominant groups are Gastropods and Pelecypoda. The Gastropods are mainly comprised *Thiara, Plotia scabra, Bellamya bengalensis, Thiara sp, Gyraulus sp, Lymnaea accuminata, Tuberculata* while Pelecypoda by *Corbicula striatella*, *Lamellidens marginalis, L. corrinus and Sphaerium sp.* The Oligochaeta (Annelida) is represented by tubifex and Insecta by chironomid larvae (Diptera) dragon fly and damsel fly nymphs (Odonata), mayfly (Ephemeroptera) and whirling beetles (Coleoptera).

Table28. Qualitative and Quantitative abundance of biotic communities in different stretches (u l^{-1})

Parameters	Amar-kantak	Dindori	Mandala	Jaba-lpur	Narsingh-pur	Karaili	Gadarwala
Total plankton	202	32	78	151	101	78	131
Phytoplankton	86.6	90.6	69.2	90.7	96.0	98.6	91.0
Myxophyceae	2.9	-	5.6	9.3	1.1	1.7	8.9
Chlorophyceae	36.4	-	40.6	21.9	25.7	17.9	20.4
Bacillariophyceae	36.2	90.6	23.1	58.6	69.2	79.0	61.0
Desmids	8.7	-	-	0.9	-	-	-

Dinophyceae	2.4	-	-	-	-	-	-
Zooplankton	13.4	9.4	30.8	9.3	4.0	2.6	9.0
Rotifers	7.5	9.4	0.4	3.5	2.6	0.6	6.6
Protozoans	1.5	-	-	-	-	-	-
Crustaceans	4.4	-	30.4	6.8	1.4	0.8	2.4
Annelids	51.2	30.5	7.5	20.8	-	-	0.7
Insecta	47.5	69.5	50.0	41.8	5.5	8.4	31.9
Pelecypoda	-	-	6.7	4.1	17.3	44.3	31.9
Gastropoda	1.3	-	35.8	33.3	77.2	47.3	35.5

Primary productivity

The status of primary productivity, community metabolism and fish production potential of the river in its different stretches are shown in Table 29.

Table29. Primary productivity (mg C m^{-3} day^{-1}) of different stretches of Narmada River and its fish production potential

Stretches	**Gross production**		**Net production**		**Respiration**		**Fish production potential ($kgha^{-1}yr^{-1}$)**
	Range of variation	**Average**	**Range of variation**	**Average**	**Range of variation**	**Average**	
Amarkantak	7365-13269	10311	4913-8838	6628	3653-4419	3683	229.5
Dindori	4419-14376	7902	2946-7718	4517	1768-6599	3385	156.4
Mandala	5155-14730	8684	3682-7365	5339	1768-4419	3345	185.0
Jabalpur	5523-22,213	10,760	2934-14,730	7249	1591-7365	3511	251.0
Kherpani (Narsinghpur)	2209-20,292	9,546	1473-14,730	6628	884-5538	2918	229.5
Kareily	2946-	9984	2209-	5436	884-6304	4548	188.5
Gadarwara	4419-16,792	9,263	2946-11,195	5316	1768-5008	3947	184.0
Av. for the whole stretch	-	**9493**	-	**5873**	-	**3619**	**203.4**

After Dwivedi *et al,* 2002.

Fishery

The fish fauna of Narmada river was first reported by Hora and Nair (1941) covering district Hoshangabad only and enlisting 40 species. Later Karamchandani *et al* (1967) during their extensive survey of 48 km stretch of river around Hoshangabad documented the fish fauna raising the list to 77 species. Subsequently, the Madya

Pradesh State Fisheries Department (Anon, 1976) compiled the list of 45 species from the entire stretch of the river in the state. Rao *et. al.* (1991) brought out a list of 85 species based on their 150 km survey of western part of the river from Punasa to Barwani. The fish fauna based on above studies is as follows

Hilsa ilisha	*Gonialosa manmina*	*Notopterus notopterus*
N. chitala	*Oxygaster laubuca*	*O. clupeoides*
O. bacaila	*Glossogobius giuris*	*Colisa fasciatus*
Barilius barila	*B. bendelisis* var. *chedra*	*B. evezardi*
B. radiolatus	*Danio aequipinnatus*	*Nandus nandus*
D. devario	*D. (Brachydanio) rerio*	*Esomus danricus*
Rasbora daniconius	*Amblypharyngodon mola*	*Tor khudree*
T. putitora	*T. tor*	*Puntius ambassis*
P. amphibius	*P. chrysopoma*	*P. conchonius*
P. dorsalis	*P. guganio*	*P. pinnauratus*
P. sarana	*P. sophore*	*P. ticto*
P. titius	*Oreichthys cosuatis*	*Catla catla*
Cirrhinus mrigala	*C. reba*	*Garra gotyla*
G. lamta	*G. mullya*	*Labeo bata*
L. boggut	*L. calbasu*	*L. dyocheilus*
L. fimbriatus	*L. gonius*	*L. rohita*
Osteobrama cotio	*Crossocheilus latius*	*Rhinomugil corsula*
Parapsilorhynchus tentaculatus		*Anabas testudineus*
Noemacheilus dayi	*N. botia*	*N. evezardi*
Eutropiichthys vacha	*Lepidocephalichthys guntea*	*Ompok bimaculatus*
Wallago attu	*Mystus bleekri*	*M. cavasius*
M. vittatus	*M. aor*	*M. seenghala*
M. tengra	*Rita pavimentata*	*R. rita*
Amblyceps mangois	*Gagata itchkeea*	*Amblyceps mangois*
Lebistes reticulatus	*Glyptothorax lonah*	*G. vibeiroi*
Laguvia ribeiroi	*Clupisoma garua*	*Heteropneustes fossilis*
Clarias batrachus	*Anguilla bengalensis*	*Xenentodon cancila*
Channa gachua	*C. marulius*	*C. punctatus*
Chanda nama	*C. ranga*	*Badis badis*
Glossogobius giuris giuris	*Mastocembelus armatus*	*M. pancalus*

In order to obtain the estimate of total fish production of Narmada River in Madhya Pradesh, important fish markets were covered in the 720 km stretch of river (Mandla to Barwani) during Nov 1960-Mar 1961 by Narmada-Tapti unit of CIFRI. For eastern zone (Mandla to Gadarwara, 240 km), the fish catch for three months was estimated at 36.9 t. The catch for five months from central zone (Gadarwara to Harda, 240 km)

was estimated at 52.5 t. For western zone (Harda to Barwani, 240 km), the landings were estimated at 33.85 t for a period of four months.

Karmchandani *et al* (1967) have given the catch statistics for the period 1958-66 from a 48 km stretch of river Narmada, based on two fish landing centres (Hoshangabad and Shahganj). During the period of eight years the annual landings ranged between 32.3 and 57.2 t, the average being 41.5 t. The commercial catches were represented by about 23 species of fish. The av. catch of major carps was 16.36 t, catfishes 9.27 t and *Channa* spp., *Mastocembelus* spp. And *N. notopterus* contributed 1.49 t. The Department of fisheries, M.P. (Anon, 1971) estimated fish landings at Maheshwar, Mandleshwar, Hoshangabad and Shahganj, while Rao *et. al.* (1991) have collected data from Punasa, Omkareswar, Mandleshwar, Maheshwar and Barwani during 1989-90. A comparative statement of the above referred studies is given in Table 30.

Table 30. Contribution (%) of various fish species of Narmada River

Species	Karamchandani *et al* (1967)	Anon (1971)			Rao et. al. (1991)
		East. Zone	Cent. Zone	West. zone	
Tor tor	28.0	25.3	30.1	28.1	25.9
Labeo fimbriatus	19.7	21.5	24.4	22.1	18.5
Labeo calbasu	4.1	3.7	0.0	5.0	5.4
Cirrhinus mrigala	2.5	1.2	1.8	2.7	2.7
Labeo bata	1.7	1.4	2.9	1.3	1.4
Labeo rohita	0.0	0.0	0.0	0.0	0.4
Labeo dyocheilus	1.6	0.0	0.0	1.2	1.3
Puntius sarana	1.4	3.6	3.5	4.6	0.0
Puntius spp.	0.0	0.0	0.0	0.0	2.2
Catla catla	0.6	0.6	0.0	0.5	0.8
Cirrhinus reba	0.5	0.0	0.0	0.0	0.5
Labeo gonius	0.3	1.1	0.0	0.0	0.5
Rita pavimentata	10.2	6.4	3.0	4.7	-
Rita spp.	0.0	0.0	0.0	0.0	12.6
Mystus seenghala	9.0	8.2	10.3	5.6	8.2
Mystus aor	4.7	6.5	9.1	6.8	4.8
Wallago attu	7.7	10.6	4.4	3.9	7.7
Clupisoma garua	1.8	0.0	0.8	0.0	0.0
Ompok bimaculatus	0.4	0.0	0.0	0.8	1.6

Mystus cavasius	0.3	0.0	0.0	0.0	0.7
Mystus tengara	0.0	0.0	0.0	0.0	0.4
Channa spp.	3.7	4.2	2.0	2.6	1.9
Mastocembelus spp.	1.3	1.9	0.0	3.1	1.6
Notopeterus notopeterus	0.5	0.0	0.0	0.0	0.7
Other small species	Not reported	4.1	7.7	7.1	0.3

Nath and Srivastava (1999) estimated the fish landings during summer (Mar-Jun), post monsoon (Sep-Nov) and winter (Dec-Feb) seasons in the years 1996-99 from 280 km stretch of river between Sandia and Mola. The annual fish catch was estimated at 129.2 t. Fish catch composition during different seasons is depicted in table 31.On the basis of recent survey conducted by CIFRI, Dwivedi *et. al.* (2003) have discussed fish catch from the Mandla-Gadarwara stretch of river Narmada. The estimates are based on information collected from fish markets.

Table 31. Fish catch composition (%) in Mandla-Gadarwara stretch of river Narmada

Centre	Major carps	Catfishes	Miscellaneous
Mandla	35.7	15.0	49.3
Jabalpur	18.0	58.9	23.1
Narsinghpur	25.9	7.7	66.4
Kareli	24.4	36.9	38.7
Gadarwara	17.0	40.4	42.6

The Narmada-Tapti system on the west coast of India can be considered as a small type estuary. Information on catch from estuarine zone of Narmada is scanty. On the basis of studies conducted by CIFRI during 1991-98, fish catch composition at three centres is given in Table 32.

Table 32. Fish catch composition (%) from Narmada estuarine zone (1991-98)

Group	Rajpipala	Dandia Bazar	Katupura
Major carps	27.8-48.2	3.7-16.9	1.6-6.3
Minor carps	15.8-27.2	0.2-2.3	0.3-2.6
Mahaseer	2.5-7.4	0.0-0.1	0.0-0.1
Catfishes	12.0-19.6	1.6-12.4	2.3-12.1
Featherbacks	0.6-2.4	0.0-0.1	0.2-0.5
Hilsa	0.0-3.5	32.9-69.4	20.4-66.7
Murrels	3.7-6.2	0.0-1.0	0.0-0.4
Mullets	0.0-0.2	2.0-11.4	2.8-18.4
Shell fishes	1.6-5.7	9.5-32.6	17.4-39.9
Miscellaneous	3.3-9.7	6.5-19.2	6.2-24.4

The fish production potential of river Narmada in different stretches ranged between 156.4 to 251 kg $ha^{-1}yr^{-1}$, being maximum in Jabalpur and minimum in Dindori. The average fish production of the river in the entire stretch was 203.4 kg $ha^{-1}yr^{-1}$. The potential observed in river Narmada is higher than many Indian rivers. On the basis of energy conversions the river has got an average capacity of giving an energy harvest of 2,44,080 k cal ha^{-1} as fish.

The fish landing and composition of various groups in the total catch are presented in Table 33. The catch data clearly show the dominance of miscellaneous species (47.3%) followed by major carps (28.8%) and catfishes (23.9%). Among the different stretches Mandala shows maximum production (1094.46kg). The better catch in this stretch may be due to upward migration of fishes during monsoon months from Bergidam the stretch below Mandala. Among carps C. *catla* contributed maximum (36.2%) followed by *C. mrigala* (25.7%), *L. rohita* (13.3%), *L. calbasu* (13.1%), Tor tor (7.8%) and *L. fimbriatus* (3.91%).

Table 33. Species composition of fishes in different stretches of Narmada

Stretches	**Major carps**		**Catfishes**		**Miscellaneous fishes**		**Total landing**
	Weight (kg)	**(%)**	**Weight (kg)**	**(%)**	**Weight (kg)**	**(%)**	**(kg ha^{-1} yr^{-1})**
Mandla	130.3	35.7	54.9	15.0	180.0	49.3	365.2
Jabalpur	9.8	18.0	32.3	58.9	12.7	23.1	54.8
Narsinghpur	27.7	25.9	8.2	7.7	70.8	66.4	106. 7
Kareli	28.3	24.4	43.1	36.9	45.4	38.7	116.8
Gadarwara	16.2	17.0	38.4	40.4	40.4	42.6	95.0
Total landing for the whole stretch	212.3	28.8	176.9	23.9	349.3	47.3	738.5

THE TAPTI

The river Tapti is one of the two important westerly flowing rivers of the peninsular India. Rising from the Vindhya Mountain of the Satpura range at an elevation of 670 to 1000 m MSL, flows westward through Madhya Pradesh, Maharashtra and Gujarat states before joining the Arabian Sea at Dumas near Surat in Gujarat. The total catchment area of Tapti River is about 48,000 km^2. With a view to utilize huge quantities of rain water for developing the regions of the lower Tapti valley and also to control floods in Surat district a weir has been constructed at Kakrapar in Mandvi taluka of Surat district. Ukai, a big multipurpose dam, has been constructed above the Kakarpara weir, just on the border of Maharashtra and Gujarat state. An anicut has been constructed in the district Jalgaon, Maharashtra; near Adejabad. Information on the water quality, biotic communities and productivity of the river is not available. However there is some information on the fish and fishery of the river.

Fishery

Karamchandani and Pisolkar (1967) reported the presence of 52 fish species from river Tapti.

Fish fauna of river Tapti

Hilsa ilisha	*Notopterus notopterus*	*Chela laubuca*
Oxygaster clupeoides	*O. phulo*	*Barilius barila*
B. bendelisis ord. chedra	*B. evezardi*	*Doryichthys cunculus*
Danio (Danio) aequipinnatus		
D. (Brachydanio) rerio	*Esomus danricus*	*Rasbora daniconius*
Amblypharyngodon mola	*Tor tor*	*Puntius sarana*
P. sophore	*P. ticto*	*Catla catla*
Cirrhinus mrigala	*C. reba*	*Garra mullya*
Labeo bata	*L. boggut*	*L. calbasu*
L. dyocheilus	*L. fimbriatus*	*L. gonius*
L. rohita	*Osteobrama cotio*	*Crossocheilus latius*
Noemacheilus dayi	*N. botia*	*N. evezardi*
Lepidocephalichthys guntea	*Ompok bimaculatus*	*Wallago attu*
Mystus bleekeri	*M. cavasius*	*M. aor*
M. seenghala	*Gagata itchkeea*	*Clupisoma garua*
Xenentodon cancila	*Channa gachua*	*C. marulius*
C. punctatus	*Ambassis nama*	*A. ranga*

Glossogobius giuris *Mastocembelus armatus* *M. pancalus*

Karamchandani and Pisolkar (1967)

There is not much information about fish catches from river Tapti. Pisolkar (1994) has given the landing data for 7 centres, based on Karamchandani and Pisolkar (1967) and Jhingran (1991). Table 34 should catch composition of selected centers of the river Taoti.

Table 34. Catch composition (%) at selected centres of river Tapti (1959-60)

Species	**Madhya Pradesh**			**Maharashtra**		**Gujarat**	
	Tedtalai	Raitalai	Burhanpur	Bhusawal	Adelabad	Mandvi	Kathor
T. tor	40.5	13.8	60.7	44.5	57.0	34.6	59.7
L. fimbriatus	8.8	-	3.8	11.0	-	-	27.8
C. mrigala	-	-	-	-	6.7	-	2.0
L. calbasu	-	9.6	-	-	-	-	2.8
P. boggut	14.2	21.4	-	-	8.4	-	-
P. sarana	-	8.5	3.8	-	-	-	-
C. reba	3.5	-	-	-	-	-	-
Mystus sp.	14.2	-	19.0	44.5	7.5	-	2.0
W. attu	4.2	-	-	-	-	-	4.3
C. garua	-	12.8	-	-	-	-	0.7
Channa sp.	-	-	7.6	-	-	-	0.7
M. armatus	-	-	5.1	-	-	-	-
Miscell.	15.2	33.9	-	-	20.4	-	-
Total landing (kg month^{-1})	**800**	**115**	**215**	**250**	**175**	**250**	**800**

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