Ganga River Basin Management Plan-2015

Volume 6: Thematic Studies – Biological Profile of Ganga River System

Centre for Ganga River Basin Management and Studies
Indian Institute of Technology Kanpur

VOLUME 6 OF 12

NATIONAL MISSION FOR CLEAN GANGA (NMCG)

NMCG is the implementation wing of National Ganga Council which was setup in October 2016 under the River Ganga Authority order 2016. Initially NMCG was registered as a society on 12th August 2011 under the Societies Registration Act 1860. It acted as implementation arm of National Ganga River Basin Authority (NGRBA) which was constituted under the provisions of the Environment (Protection) Act (EPA) 1986. NGRBA has since been dissolved with effect from the 7th October 2016, consequent to constitution of National Council for Rejuvenation, Protection and Management of River Ganga (referred to as National Ganga Council).

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cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this it is also responsible for introducing new technologies, innovations and solutions into India.

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ACKNOWLEDGEMENT

This document is a collective effort of a number of experts, institutions and organisations, in particular those who were instrumental in preparing the Ganga River Basin Management Plan which was submitted to the Government of India in 2015. Contributions to the photographs and images for this vision document by individuals are gratefully acknowledged.

SUGGESTED CITATION

GRBMP by cGanga and NMCG

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GANGA RIVER BASIN MANAGEMENT PLAN - 2015

Volume 6: Thematic Studies – Biological Profile of Ganga River System

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GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

Dr Vinod Tare
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Contents

1. Introduction

The Ganga River comprises a lotic water series, which originates at Gaumukh and flows down to Gangasagar traversing a distance of 2525 km. During its course through eleven states, the river receives numerous tributaries (with characteristic quality, pollution load and biota) including Bhilangana, Alaknanda, Ram Ganga, Kali, Yamuna, Gomti, Ghagra, Gandak, and Kosi.

A thorough review of a large number of studies available in the form of student's project reports and theses, reports produced through sponsored, consultancy, investigatory and Environment Impact Assessment studies, published papers/articles in journals/ conference/workshop/ symposia proceedings, books, news paper articles, etc. has led to collection of fragmented information on ecology and biodiversity in the Ganga Basin. The information is in different time domain and isolated stretches largely governed by the period of the study and the proximity of a river stretch/water body to the investigating institutions, organizations or individuals involved in the study. Due to lack of definitive bio-monitoring programme like river water quality monitoring programmes by the Central Pollution Control Boards, State Pollution Control Boards and National River Conservation Directorate, the analysis is based on extrapolation and interpolation of scattered, mostly qualitative data/information.

The entire stretch of the river Ganga (main stem) can be viewed into three segments:

A.	**Upper Ganga**	≈ 294 **km**	**Gaumukh to Haridwar**
B.	**Middle Ganga**	≈ 1082 **km**	**Haridwar to Varanasi**
C.	**Lower Ganga**	≈ 1134 **km**	**Varanasi to Ganga Sagar**

(The Upper Ganga Segment for all practical purposes and studies carried out, starts at Gangotri as the terrain between Gaumukh to Gangotri is essentially devoidof biota due to hostile conditions)

These three segments not only differ in their geomorphology, ecology and rheology but are different in terms of issues that need to be addressed (refer report 001_GBP_IIT_GEN_ANL_01_Ver 1_Dec 2010). Considering this, floral and faunal diversity of the main stem of Ganga is reported in a series of four reports. This report covers the Upper Ganga stretch from Gangotri to Haridwar (Up to Bhimgauda Barrage). From the point of view of aquatic ecology, the upper Ganga segment has been further divided into three sub-stretches: UG-1, UG-2 and UG-3. The floral and faunal diversity of each of these sub-stretches is described in following sections.

2. UG-1: Gangotri (Latitude: $30^o59'56.2''$N; Longitude: $78^o54'56.5''$E; Elevation: 3037 m above mean sea level) **to Gangnani** (Latitude: $30^o55'15.4''$N; Longitude: $78^o40'43.2''$ E; Elevation: 1945 m above mean sea level)

This stretch of the river Ganga is apparently insignificantly influenced by human interventions except due to road construction, small human settlements, some hotels and guest houses, and bathing and cremation at a few places. River water quality can still be characterized as essentially pristine with no fish population. Singh (2008) referred the stretch from Gaumukh to Harsil as "no fish zone". However, at Jhala downstream of Bhaironghati, Nautiyal *et al*. (2007) observed brown trout (*Salmotruttofario*). Rapids are the major habitat type followed by riffles and pools. The substrate consists of mature boulders, rocks and pebbles. The water appears clean and clear with low depths and high transparency. The water temperatures are also very low varying between 4.3-9.8°C (Nautiyal, 2010). The water velocity is high (2-3.3 m/s; Nautiyal, 2010). The only organic input to the system is through fall out of forest canopy in the form of lignocellulosic material.

The biotic components of the system are represented by periphytonic (refer Table 1) growth of diatoms (Bacillariophyceae). Sixteen taxa have been reported (Nautiyal*el al*. 2007). Singh *et al*. (1994) reported mean density of phytoplankton 149 ± 84 quanta/dm^3 with 20 taxa (refer Table 2). In the lower stretch of this sub stretch, two taxa of green algae (Chlorophyceae) have also been identified. Periphyton is the only producer factor which supports zoobenthos (benthic macroinvertebrate; refer Table 3) represented by may fly (Ephemeroptera), caddis fly (Trichoptera), stone fly (Plecoptera), beetle (Coleoptera) and two wings fly (Diptera). Typical photographs of diatoms, green algae and benthic macroinvertebrate spotted in thissub-stretch are presented in Plate 1. Dragon and damsel flies (Odonata) are conspicuous by their absence. Zooplankton has not been reported in this zone.

Table 1: Taxa of periphyton observed in the sub-stretch Gangotri to Gangnani (Nautiyal *et al*. 2007)

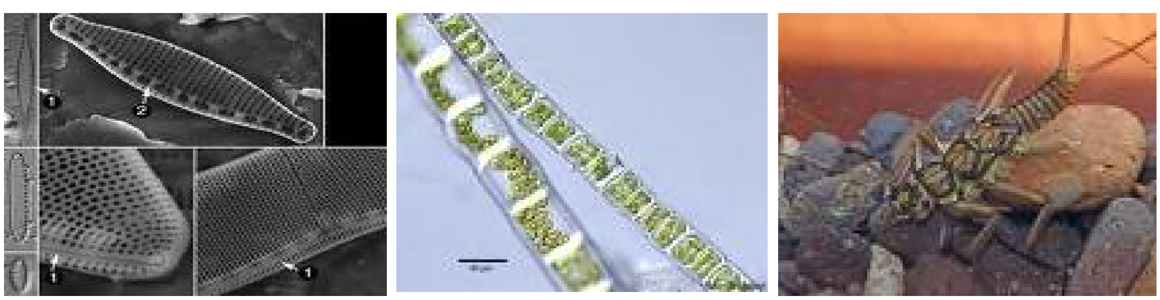
Bacillariophyceae	
Achnanthidium biasoletianum	*F.ragilaria vaucheriae*
A. minutissimum	*Frustulia rhomoids*
Amphora ovalis	*Gomphonema parvulum*
A. perpusilla	*Hippodonta* sp.
Cymbella turgida	*Nitzschia paleacea*
C. turgidula	*N. salinarum*
Diatoma hymale	*Reimeria sinuate*
Fragilaria rumpens	*Tabellaria flocculosa*

Table 2: Taxa of phytoplankton observed in the sub-stretch Gangotri to Gangnani (Singh *et al*. 1994)

Bacillariophyceae			Chlorophyceae	Xanthophyceae
Achnanthes	*Denticula*	*Nitzschia*	*Gonatozygon*	*Vaucheria*
Amphipleura	*Diatoma*	*Pinnularia*	*Ulothrix*	
Bacillaria	*Fragilaria*	*Rhoicosphenia*		
Ceratonies	*Hantzschia*	*Stephanodiscus*		
Cyclotella	*Meridion*	*Synedra*		
Cymbella	*Navicula*			

Table 3: Taxa of zoobenthos observed in the sub-stretch Gangotri to Gangnani

Taxa	Singh *et al.* (1994)	Nautiyal (2010)	Taxa	Singh *et al.* (1994)	Nautiyal (2010)
Ephemeroptera			**Diptera**		
Caenis	+		Dixidae		+
Ephemera	+		*Dixa*	+	
Baetidae		+	Tipulidae		+
Baetis	+		*Simulidae*		+
Heptageniidae		+	*Simulium*	+	
Iron	+		**Plecoptera**		
Trichoptera					
Ameletus	+		*Arcynopteryx*	+	
Hydropsyche	+		*Isoperla*	+	
Diptera			*Nemoura*	+	
Atherix	+		Chloroperlidae		+
Bibiocephala	+		Peltoperlidae		+
Megistocera	+		**Coleoptera**		
Chironomidae		+	Elmidae		+
Chironomus	+		*Promoresia*	+	
			Total	**16**	**9**



Diatom (Bacillariophyceae) **Green algae (Chlorophyceae)** **Benthic macroinvertebrate (Stone fly-Plecoptera)**

Plate 1: Typical Diatom, Green algae and benthic Macroinvertebrate spotted in the sub-stretch Gangotri to Gangnani

3. UG-2: Gangnani (Latitude: 30°55'.15.4"N; Longitude: 78°40'43.2"E; Elevation: 1945 m above mean sea level) to Devprayag (Latitude: 30°08'49.5"N; Longitude: 78°35'51.9"E; Elevation: 474 m above mean sea level)

This zone is characterized by lack of continuum of river system where connectivity has been broken by the construction of barrages and dams (Maneri Bhali I and II Projects, Tehri and Koteshwar dams). The lotic conditions of the river have been converted to lentic conditions. Riffles are major habitat type followed by rapids and pools. The substrate consists of mature cobbles, pebbles and boulders. Rocky substrate is predominant at Devprayag. River water appears clean and clear, and has high transparency at most of the places with moderate current velocity (1.0-3.3 m/s; Nautiyal, 2010). Water temperature ranges between 4.3-16.3°C (Nautiyal, 2010). However, higher water temperatures (in the range 8.5-17.2°C) have also been recorded by Agarwal *et al*. (2003) and Sharma *et al*. (2008) at Tehri.

The biota consists of periphyton, phytoplankton, zooplankton and vertebrate population essentially consisting of fish. Periphyton is represented mainly by diatoms *Achnanthidium*sp.,*Navicula*sp. and *Cymbella*sp. (refer Table 4). The phytoplankton is also dominated by diatoms (refer Table 5). The zoobenthos are dominated by may fly (Ephemeroptera) and dipterans (refer Table 6). They constitute collectors (primary consumer-food chain) from stony and soft substrate at banks of the river depth < 0.5m. Zooplankton is not conspicuous except the occasional presence of ciliates viz. *Colpidium* and *Paramecium* sp.

Table 4: Taxa of periphyton observed in the sub-stretch Gangnani to Devprayag

Taxa	Sharma *et al.* (2008)	Verma (2008)	Taxa	Sharma *et al.* (2008)	Verma (2008)
Bacillariophyceae			**Bacillariophyceae**		
Achnanthidium biasolettiana		+	*Caloneis amphisbaena*	+	
A. conspicua		+	*Ceratoneis arcus*	+	
A. exigua		+	*Cocconeis placentula*	+	
A. helvetica		+	*Cyclotella* sp.	+	
A. holistica		+	*C. meneghiniana*		+
A. marginulata		+	*Cymbella cistula*	+	
A. minutissima		+	*C. excisa*		+
A. pusilla		+	*C. metzeltinii*		+
A. sphacelata		+	*C. novazeelandiana*		+
A. subhudsonis		+	*C. tropica*		+
Adlafia miniscula		+	*C. tumida*		+
A. muscora		+	*C. turgidula*		+
Amphora inariensis		+	*C. vulgata*		+
A. montana		+	*Denticula* sp.	+	
A. ovalis	+		*Diatoma vulgaris*	+	
A. pediculus		+	*Diatomenella balfouriama*	+	

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Bacillariophyceae		
Encyonema jemtlandicum		+
E. leei		+
E. minutum		+
E. silesiacum		+
Encyonopsis leei		+
Fallacia pygmaea		+
Frustulia weinholdei		+
Gomphoneis herculeana	+	
Gomphonema sp.	+	
G. angustum		+
G. brasiliense		+
G. gracile		+
G. lagenula		+
G. lanceolatum		+
G. minutum		+
G. parvulum		+
G. pumilum		+
Gyrosigma kutzingee	+	
Hantzschia sp.	+	
Hippodonta sp.		+
H. ruthnielseniae		+
Melosira varians		+
Meridion circulare	+	
Navicula alineae		+
N. antonii		+
N. broetzii		+
N. capitatoradiata		+
N. cataracta-rheni		+
N. caterva		+
N. cryptocephala		+
N. cryptotenella		+
N. cryptotenelloides		+
N. exilis		+
N. krammerae		+
N. minima		+
N. notha		+
N. radiosa	+	
N. reichardtiana		+
N. rostellata		+
N. seminulum		+
N. tripunctata		+
N. veneta		+
N. vitabunda		+
Nitzschia sp.	+	
N. acuta		+
Bacillariophyceae		
N. amphibia		+
N. capitellata		+
N. denticula		+
N. dissipata		+
N. fonticola		+
N. frustulum		+
N. gracilis		+
N. linearis		+
N. palea		+
N. recta		+
N. tenuis		+
Opephora sp.	+	
Pinnularia sp.	+	
Planothidium lanceolatum		+
Reimeria sinuata		+
R. uniseriata		+
Sellaphora pupula		+
Starosira mutabilis		+
S. pinnata		+
S. utermohli	+	
Stauroneis anceps		+
S. phoenicenteron	+	
Surirella angusta	+	+
Synedra dorsiventralis		+
S. ulna	+	+
Tabellaria fenestrata	+	
Tetracyclus rupestris	+	
Chlorophyceae		
Chlorococcum humicola	+	
Cladophora sp.	+	
Closterium leibleinii	+	
Cosmarium granatum	+	
Desmidium sp.	+	
Hydrodictyon reticulatum	+	
Microspora sp.	+	
Oedogonium sp.	+	
Stigeoclonium sp.	+	
Ulothrix zonata	+	
Zygnema sp.	+	
Cyanophyceae		
Anabaena sp.	+	
Coccochloris stagnina	+	
Oscillatoria tenuis	+	
Phormidium sp.	+	
Total	**39**	**82**

Table 5: Taxa of phytoplankton observed in the sub-stretch Gangnani to Devprayag

Taxa	Singh *et al.* (1994)	Ayyoade *et al.* (2009)	Taxa	Singh *et al.* (1994)	Ayyoade *et al.* (2009)
Bacillariophyceae			**Bacillariophyceae**		
Achnanthes	+		*Tabellaria*	+	+
Amphipleura	+		**Chlorophyceae**		
Amphora	+	+	*Characium*		+
Bacillaria	+		*Cladophora*		+
Ceratonies	+		*Closterium*	+	+
Cocconeis	+		*Cylindrocystis*	+	
Cyclotella	+	+	*Desmidium*	+	
Cymatopleura	+		*Genicularia*	+	
Cymbella	+	+	*Gonatozygon*	+	
Denticula	+		*Hydrodictyon*		+
Diatoma	+	+	*Microspora*	+	
Epithemia	+		*Oedogonium*		+
Fragilaria	+		*Protococcus*		+
Frustulia		+	*Sphaeroplea*	+	
Gomphoneis	+		*Spirogyra*	+	+
Gomphonema	+		*Stigeoclonium*	+	
Hantzschia	+		*Ulothrix*	+	+
Melosira	+		*Zygnema*	+	
Meridion	+		**Cyanophyceae**		
Navicula	+	+	*Anabaena*	+	+
Nedium	+		*Oscillatoria*		+
Nitzschia	+	+	*Phormidium*	+	+
Pinnularia	+		*Rivularia*		+
Rhoicosphenia	+		**Xanthophyceae**		
Stauroneis	+		*Vaucheria*	+	
Stephanodiscus	+	+	**Total**	**41**	**22**
Synedra	+	+			

Table 6: Taxa of zoobenthos observed in the sub-stretch Gangnani to Devprayag

Taxa	Singh *et al.* (1994)	Agarwal *et al.* (2003)	Taxa	Singh *et al.* (1994)	Agarwal *et al.* (2003)
Ephemeroptera			**Trichoptera**		
Ameletus	+		*Leptocella*	+	
Baetis	+	+	*Limnephilids*	+	
Caenis	+	+	**Nematodes & molluscs**	+	
Cynigma	+		**Diptera**		
Ephemera	+		*Antocha*	+	
Ephemerella	+	+	*Atherix*	+	
Iron	+		*Bibiocephala*	+	
Leptophlebia		+	*Chironomus*	+	+
Trichoptera			*Dixa*	+	+
Brachycentrus	+		*Megistocera*	+	
Glossosoma	+		*Psychoda*	+	
Hydropsyche	+	+	*Simulium*	+	+

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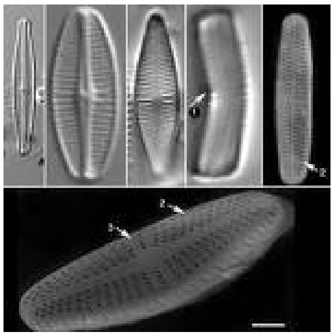
Taxa	Singh *et al.* (1994)	Agarwal *et al.* (2003)	Taxa	Singh *et al.* (1994)	Agarwal *et al.* (2003)
Coleoptera			**Odonata**		
Dytiscus	+		*Argia*	+	
Hydrophilus	+		**Water mites**	+	
Promoresia	+		**Plecoptera**		
Psephenus	+	+	*Arcynopteryx*	+	
Hemiptera			*Isoperla*	+	
Corixids	+		*Nemoura*	+	
			Total	**31**	**9**

The vertebrate population is represented by fish, mainly carps; the most typical being Trouts (*Garra* sp., *Schizothorax*sp., *Schizothoraichthys* sp.), Sissoridae (*Glyptothorax* sp., *Pseudecheneis* sp.), Balitoridae (*Nemachelius* sp.)and Mahseer (*Tor* sp.) (refer Table 7). The fish population is dependent on periphyton, plankton and zoobenthos at the level of producers and primary consumers. The fishes breed at stony substrate of 1-3 m depth during August to October and migrate towards upper reaches in search of suitable breeding environment. The migration of fish for breeding has been largely altered by the barriers and diversions (barrages, dams and tunnels).

Table 7: Taxa of fish fauna observed in the sub-stretch Gangnani to Devprayag

Taxa	Singh*et al.*(1983)	Sharma (1988)	Taxa	Singh*et al.*(1983)	Sharma (1988)
Cyprinidae			**Cyprinidae**		
Barilius barna	+	+	*Tor chilinoides*	+	
B. barila	+	+	*T. putitora*	+	+
B. bendelisis	+		*Tor tor*	+	+
B. bola	+		**Balitoridae**		
B. vagra	+	+	*Nemacheilus beavani*	+	+
Crossocheilus latius latius	+	+	*N. multifasciatus*	+	+
Garra gotyla gotyla	+	+	*N. montanus*	+	
G. lamta	+	+	*N. rupicola*	+	+
G. prashadi	+		*N. savona*	+	
Labeo dero	+	+	*N. zonatus*	+	+
L. dyocheilus	+		**Sisoridae**		
Schizothoraichthys esocinus	+		*Glyptothorax cavia*	+	+
S. progastus	+	+	*G. conirostris*	+	
Schizothorax curviforns	+		*G. madraspatanum*	+	+
S. intermedius	+		*G. pectinopterus*	+	
S. micropogan	+		*G. trilineatus*	+	
S. niger	+		*Pseudecheneis sulcatus*	+	+
S. plagiostomus	+	+	**Schilbeidae**		
S. richardsonii	+	+	*Clupisoma garua*	+	+
S. sinuatus	+	+	**Total**	**36**	**21**

Photographs of typical diatom, blue green algae and macroinvertebrate spotted in thissub-stretch are presented in Plate 2. Snow trout can be considered as the most typical and endangered species in this stretch. Typical photograph along with some characteristic features of this species are presented in Plate 3.



Diatom (Bacillariophyceae)

Blue Green algae (Cyanophyceae)

Macroinvertebrate - May Fly (Ephemeroptera)

Plate 2: Typical diatom, blue green algae and benthic macroinvertebrate spotted in the sub - stretch Gangnani to Devprayag

Name-*Schizothorax richardsonii*

Common Name- Snow trout

Size- 200-255 mm (max. 509 mm)

Characteristic features: Herbivorous: feed on algae, periphyton, bottom feeder, inferior mouth with hard cartilaginous disc adopted for scrapping

Spawning period from September – November at stony substrate with shallow water (riffles, rapids) and moderate flow. Fecundity 3190-14650 eggs /female, water temperature 8-28°C. **Adult** prefers deep pools and runs (1-3 m), while juveniles and early stages prefer shallow pools with substratum consist of cobbles with small boulders and take shelter underside of large boulders. It **migrates** to lower reaches of the stream for breeding (Shrestha and Khanna, 1976; Singh, 2008)

Plate 3: Snowtrout spotted in the sub-stretch Gangnani to Devprayag

4. UG-3: Devprayag (Latitude: 30^{o}08'49.4”N; Longitude: 78^{o}35'51.9”E; Elevation: 474 m above mean sea level) to Haridwar (Latitude: 29^{o}57'20.1”N; Longitude: 78^{o}10'56.3”E; Elevation: 290 m above mean sea level)

Devprayag is the confluence point of the rivers Bhagirathi and Alaknanda, and the river Ganga downstream descends at Rishikesh and traverses up to Haridwar in plains. Before reaching Rishikesh it is joined by another tributary Nayar, which is an established breeding ground for the most important game fish of Ganga, referred as Mahseer (*Tor* sp.). The river stretch consists of rapids, riffles and pools. The substrate consists of mature boulders, cobbles and pebbles. Sand is also present at few places in this zone.

The river water in this stretch appears clean and clear, and has high transparency with moderate depth. The current velocity ranges between 0.1-3.0 m/s (Kishor, 1998). The water temperature is also moderate and varies between 15-23°C. The flows are substantially fluctuating and the river meanders into few channels at Haridwar d/s of Rishikesh.

Periphyton, phytoplankton, zooplankton, zoobenthos and fishes constitute the biota in this stretch. Periphyton are mostly represented by diatoms. The number of taxa varies from 8 to 68 (refer Table 8). The phytoplankton comprises mostly Bacillariophyceae and Chlorophyceae, however, Cyanophyceae have also started appearing (refer Table 9). Zooplankton is scanty consisting of ciliates. A few rotifers and crustaceans are also reported. In zoobenthos, may fly (Ephemeroptera) is dominant, though odonata have started appearing (refer Table 10). Important fishes reported in this sub stretch include minor carps (e.g. *Barilius* sp., *Puntius* sp.), major carps (*Labeo* sp.), Mahseer (*Tor* sp.)and catfishes (*Bagarius bagarius*, *Rita rita*)(refer Table 11).

Table 8: Taxa of periphytonobserved in the sub-stretch Devprayagto Haridwar

Taxa	Kishor (1998)	Nautiyal*et al.* (2010)	Taxa	Kishor (1998)	Nautiyal*et al.* (2010)
Bacillariophyceae			**Bacillariophyceae**		
Achnanthidium biasolettianum		+	*E. silisiacum*		+
A. minutissimum	+	+	*Fragilaria capucina*		+
A. subhudsonis		+	*Gomphonema clevei*		+
A. suchlandti	+		*G. gracile*		+
A. trigibba	+		*G. lagenula*		+
Amphora pediculus		+	*G. lanceolatum*		+
A. veneta		+	*G. olivaceum*		+
Cocconeis placentula	+	+	*G. parvulum*		+
Cymbella affinis		+	*G. pseudospheriophorum*		+
C. australica		+	*G. pumilum*		+
C. excisa		+	*Gyrosigma scalproides*		+
C. tumida	+		*Gesslaria decusis*		+
C. turgidula		+	*Hantzschia amphioxys*		+
C. leavis	+	+	*Luticola mutica*		+
C. parva		+	*Melosira varians*		+
Diatoma hiemale		+	*Meridion circulare*		+
D. mesodon		+	*Navicula caterva*		+
D. moniliformis		+	*N. cryptofallax*		+
Diploneis ovalis		+	*N. cryptotenella*		+
Encyonema leei		+	*N. cryptotenelloides*		+
E. minutum		+	*N. exilis*		+

Table 8 continued to next page … … … …

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Taxa	Kishor (1998)	Nautiyal *et al.* (2010)	Taxa	Kishor (1998)	Nautiyal *et al.* (2010)
Bacillariophyceae			**Bacillariophyceae**		
N. lanceolata		+	*Staurosira mutabilis*		+
N. radiosafallax		+	*Surirella angusta*		+
N. rhyncocephala		+	*Synedra ulna*		+
N. schorteri		+	**Cynaophyceae**		
N. symmetrica		+	*Lyngbya* sp.		+
Nitzschia amphibian		+	*Oscillatoria* sp.		+
N. denticula		+	*O. limosa*		+
N. dissipata		+	*O. princeps*		+
N. filiformis		+	*Phormidium* sp.		+
N. linearis		+	*Spirulina* sp.		+
N. palea	+	+	**Chlorophyceae**		
N. sigmoidea		+	*Cladophora* sp.		+
N. sinuta	+		*Oedogonium* sp.		+
Planothidium lanceolata		+	*Spirogyra* sp.		+
Reimeria sinuata		+	*Stigeoclonium* sp.		+
Sellaphora pupula		+	*Ulothrix* sp.		+
			Total	**8**	**68**

Table 9: Taxa of phytoplankton observed in the sub-stretch Devprayagto Haridwar

Taxa	Singh *et al.* (1994)	Kishor (1998)	Binaxi (2006)	Nautiyal*et al.* (2010)
Bacillariophyceae				
Achnanthidium biasoletianum				+
A. minutissimum				+
*Amphipleura*sp.	+			
Amphora sp.	+		+	
*Aulacoseira*sp.			+	
Bacillaria sp.	+			
Ceratonies sp.	+			
Cocconeis sp.	+		+	
C. placentula		+		
Cyclotella sp.	+			
Cymbella affinis		+		
C. excisa				+
C. tumida				+
C. turgidula				+
C. ventricosa		+		
Denticula sp.	+			
Diatoma sp.	+		+	
D. mesodon				+
D. monoliformis				+
D.vulgare		+		
Diploneis sp.			+	
D. ovalis				+

Table 9 continued to next page … … … …

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Taxa	Singh *et al.* (1994)	Kishor (1998)	Binaxi (2006)	Nautiyal*et al.* (2010)
Bacillariophyceae				
Encyonema leei				+
E. minutum				+
Fragilaria sp.	+		+	
F. capucina		+		
Frustulia sp.			+	
Gomphoneis sp.	+			
Gomphonema sp.	+			
G. minutum				+
Gyrosigma sp.			+	
Hantzschia sp.	+			
H. amphioxyus				+
Melosira sp.	+		+	
Meridian sp.	+		+	
Navicula sp.	+	+	+	
N. caterva				+
N. cryptotenella				+
N. exilis				+
N. rhynchocephala		+		
Nedium sp.	+			
Nitzschia sp.	+			
N. dissipata				+
N. filliformis				+
Pinnularia sp.	+		+	
Planothidium lanceolata				+
Rhoicosphenia sp.	+			
Stauroneis sp.	+			
Stephanodiscus sp.	+		+	
Synedra sp.	+		+	
S. ulna		+		+
Tabellria sp.	+		+	
Chlorophyceae				
Cladophora sp.			+	
Chaetophora sp.			+	
Closterium sp.	+			
Cosmarium sp.			+	
Eudorina sp.			+	
Hydrodictyon sp.			+	
Oedogonium sp.			+	
Pandorina sp.			+	
Pediastrum sp.			+	
Scenedesmus sp.			+	
Spirogyra sp.	+		+	
Ulothrix sp.	+			
Cynophyceae				
Anabaena sp.			+	
*Chroococcus*sp.			+	
Gleocapsa sp.			+	
Lyngbya sp.			+	

Table 9 continued to next page … … … …

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Taxa	Singh *et al.* (1994)	Kishor (1998)	Binaxi (2006)	Nautiyal*et al.* (2010)
Microcystis sp.			+	
Nostoc sp.			+	
Oscillatoria sp.			+	+
Phormidium sp.	+			+
Rivularia sp.			+	
Spirulina sp.			+	
Xanthophyceae				
Vaucheria sp.	+			
Euglenophyceae				
Euglena sp.			+	
Genicularia sp.	+			
Total	**29**	**8**	**35**	**21**

Table 10: Taxa of zoobenthos observed in the sub-stretch Devprayagto Haridwar

Taxa	Kishor (1998)	Nautiyal *et al.* (2010)	Taxa	Kishor (1998)	Nautiyal *et al.* (2010)
Ephemeroptera			**Plecoptera**	+	
Baetidae	+		**Coleoptera**		
Heptageniidae	+		*Elmidae*		+
Leptophlebiidae	+		*Dytiscidae*		+
Trichoptera			*Psephenidae*	+	
Psychomyiidae	+		**Odonata**		
Hydropsychidae	+	+	*Agrionidae*		+
Diptera			*Gomphidae*		+
Helidae		+	**Molluscs**	+	
Chironomidae	+	+	**Nematoda**		+
Tabanidae		+	**Total**	**9**	**10**
Tipulidae		+			

Table 11: Taxa of fish faunaobserved in the sub-stretch Devprayagto Haridwar

Taxa	Negi &Malik (2005)	Nautiyal*et al.* (2010)	Taxa	Negi &Malik (2005)	Nautiyal*et al.* (2010)
Cyprinidae			**Cyprinidae**		
Barilius barila		+	*L. dyocheilus*	+	+
B. bendelisis	+	+	*L. gonius*	+	
B. bola	+	+	*Puntius sarana sarana*	+	
B. vagra	+		*P. sophore*	+	
Crossocheilus latius latius	+	+	*P. ticto*	+	+
Danio devario	+		*Raiamas bola*	+	
D. rerio	+		*Rasbora daniconius*	+	
Esomus danricus	+		*Salmostoma bacaila*		+
Garra gotyla gotyla	+	+	*Schizothoracthysprogastus*	+	+
Labeo angara		+	*Schizothorax plagiostomus*	+	+
L. calbasu		+	*S. sinuatus*	+	+
L. dero	+	+	*Tor putitora*	+	+

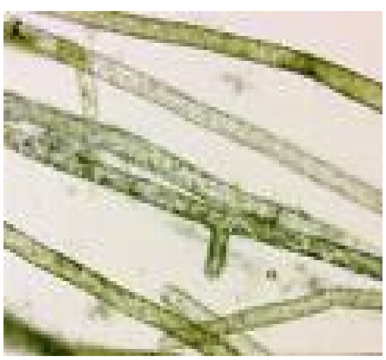
Table 11 continued to next page … … … …

… … … … Table 11 continued from previous page

Taxa	Negi & Malik (2005)	Nautiyal *et al.* (2010)	Taxa	Negi & Malik (2005)	Nautiyal *et al.* (2010)
Cyprinidae			**Belonidae**		
Tor tor	+	+	*Xenantodon cancila*	+	
Sisoridae			**Channidae**		
Bagarius bagarius	+		*Channa gauchua*	+	
Glyptothorax lineatus		+	**Mastacembelidae**		
G. pectinopterus	+		*Mastacembelus armatus*	+	
Osphronemidae			**Bagridae**		
Colisa fasciatus	+		*Mystus tengara*	+	
Balitoridae			*Rita rita*	+	
Nemacheilus beavani	+		**Clariidae**		
N. botio	+		*Clarias batrachus*		+
N. montanus	+		**Schilbeidae**		
N. savona	+		*Clupisoma garua*	+	
Cobitidae			**Mugilidae**		
Botio dario	+		*Rhinomugil corsula*		+
			Total	**35**	**19**

The most critical species is *Tor* sp., which is restricted in the upper region of Rishikesh. This species is known to migrate against water current up to the river Nayar, where it is known to spawn and rear. Mahseer is not spotted now downstream of Rishikesh barrage. This is due to lack of provision of proper fish ladder in the barrage and other obstructions.

Photographs of typical green algae (Chlorophyceae)and benthic macroinvertebrate (Diptera) spotted in this sub-stretch are presented in Plate 4. Mahseer can be considered as the most critical and endangered species in this stretch. Typical photograph along with some characteristic features of this species are presented in Plate 5.



Green algae (Chlorophyceae)

Benthic Macroinvertebrate (Diptera)

Plate 4: Typical green algae and benthic macro-invertebrate spotted in the sub-stretch Devprayag to Haridwar

Name-*Tor putitora*
Common Name-Golden Mahseer
Size- 200-260 mm (max. 450 mm). Hamilton (1822 recorded 9 feet; 271cm)
Characteristic features:- Omnivorous(Green algae, insects)

Spawning period from May to September and breed at graveled surface depth 0.5-1.0 m period. **Adult** prefers deep waters (pools and runs 1-3 m), while brooders migrate to shallow stream for breeding. Fingerlings and juveniles feed in shallow stream, grow there and return to deep waters in the main river. It **migrates** to side streams and tributaries for breeding in shallow clear water having stony substratum and moderate velocity and rich benthic life, water temperature 12-28^{o}C. (Shrestha and Khanna, 1976; Singh, 2008)

Plate 5: Golden Mahseer spotted in the sub-stretch Devprayag to Haridwar

5. Summary Remarks

The Upper Ganga segment from Gangotri to Haridwar is described in terms of three sub-stretches based on differences in aquatic biodiversity as follows:

UG-1: Gangotri to Gangani

- Biota is dominated by diatoms (Bacillariophyceae> 90%) in both phytoplankton and periphyton. Other class of algae was conspicuous by their absence since they cannot grow at such low temperature and high velocities.
- The predator, stone fly (Plecoptera) is top consumers in food chain due to absence of fish population.

UG-2: Gangani to Devprayag

- Green algae (Chlorophyceae) make their presence but diatoms (Bacillariophyceae) still continue to dominate in both plankton and periphyton communities.
- May fly (Ephemeroptera) and two wing fly (Diptera) are dominant taxa in zoobenthos community.
- Zooplanktons in the form of protozoans (Ciliates) have started to appear.
- The zone is suitable for Trout fish because of moderate water temperature and water velocity.

UG-3: Devprayag to Haridwar

- Diatoms continue to dominate in both Plankton and Periphyton community with blue green (Cyanophyceae) and green algae (Chlorophyecae) also appearing.
- Two wing fly (Diptera) are dominant and Odonata (Dragon fly and Damsel fly) have made their appearance downstream of Rishikesh.
- Mahseer is an important and typical fish of this reach followed by minor and major carps.

References

Agrawal, N.K., Rawat, U.S., Thapliyal, B.L. and Raghuvanshi, S.K. (2003).Seasonal variation in physico-chemical characteristics of the river Bhagirathi and its impact on phytoplankton and benthic entomofauna. In: Proceeding of XII National Symposium on Environment, pp. 430-437.

Ayyoade, A.A., Agrawal, N.K. and Chandola Saklani, A. (2009). Changes in physico-chemical features and plankton of two regulated high altitude rivers Garhwal Himalayas, India. *European Journal of Scientific Research*, **27(1):** 72-92.

Binaxi, (2006).Assessment of water quality of the river Ganga from Shivpuri to Haridwar segment of the Garhwal Himalaya in relation to algae.D.Phil. Thesis, HNB Garhwal University, Srinagar, Uttranchal, India.

Hamilton, F. (1822). An account of the fishes found in the river Ganges and its branches. Edinburgh & London. An account of the fishes found in the river Ganges and its branches.: i-vii + 1-405, Pls. 1-39.

Kishor, B. (1998). Foraging patterns of *Tor putitora* (Hamillton) with reference to entomofauna and its population dispersal.D.Phil. Thesis, HNB Garhwal University, Srinagar, Uttranchal, India.

Nautiyal P., Shivam, A., Verma J. and Semwal, V.P. (2007) Bhagirathi river- An endangered ecosystem. In: Proceedings of DAE-BRNS National Symposium on Limnology, pp. 164-166, Paliwal Printers, Udaipur, India.

Nautiyal, P. (2010). Food chains of Ganga River ecosystems in the Himalayas. *Aquatic Ecosystem Health & Management*, **13(4):**362-373.

Nautiyal, P., Shivam, A., Verma, J. and Dwivedi, R. (2010). Quarterly progress report (September 09) for the Living Ganga Programme with respect to environmental flow. WWF, New Delhi,India.

Negi, K.S. and Malik, D.S. (2005). Fish fauna of Ganga river at Rishikesh. *Himalayan Journal of Environmental Zoology*.**19(2):**145-148.

Sharma, R. C., Bahuguna, M. and Chauhan, P. (2008). Periphyton diversity in Bhagirathi: pre-impoundment study of Tehri dam reservoir. *Journal of Environmental Sciences & Engineering*, **50(4):** 255-262.

Sharma, R.C. (1988). Fish and fisheries of snow fed river Bhagirathi from of Garhwal Himalayas. In: Proceeding of the National Academy of Sciences, **58 (B), II**: 181-192.

Singh, H.R. (2008). Ecological parameters of the Bhagirathi, Final Technical Report, submitted to National Thermal Power Corporation (NTPC), India, pp. 1-78.

Singh, H.R., Badola, S.P. and Dobriyal, A.K. (1983).Geographical distributional list of Ichthyofauna of the Garhwal Himalaya with some new records. *Journal of Bombay Natural History Society*, **84:** 126-132.

Singh, H. R., Nautiyal, P., Dobriyal, A. K.,Pokhriyal, R. C.,Negi, M., Baduni, V., Nautiyal, R., Agrawal, N. K., andGautam, A. (1994).Water quality of the river Ganga (Garhwal Himalayas).*Acta Hydrobiologica,* **36**: 3-15.

Shrestha, T.K. and Khanna, S.S. (1976). Histology and seasonal changes in the testes of a hill-stream fish *Schizothorax plagiostomus*. *Zeitschrift fur Mikroskopisch-Anatomische ForschungLeipzig,***90(4):** 749-761.

Verma, J. (2008). Biodiversity patterns of lotic (freshwater) diatoms in mountain chains (North India). D.Phil. Thesis, University of Allahabad, U.P., India.

Floral and Faunal Diversity in Middle Ganga Segment

Haridwar – Varanasi

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin: Environment Management Plan (GRB EMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. Introduction

The Ganga river comprises a lotic water series, which originates at Gaumukh and flows down to Gangasagar traversing a distance of 2525 km. During its course through eleven states, the river receives numerous tributaries (with characteristic quality, pollution load and biota) including Bhilangana, Alaknanda, Ram Ganga, Kali, Yamuna, Gomti, Ghaghara, Gandak, and Kosi.

A thorough review of a large number of studies available in the form of student's project reports and the reports produced through sponsored, consultancy, investigatory and Environment Impact Assessment studies, published papers/articles in journals/ conference/ workshop/ symposia proceedings, books, news paper articles, etc. has led to collection of fragmented information on ecology and biodiversity in the Ganga basin. The information is in different time domain and isolated stretches largely governed by the period of the study and the proximity of a river stretch/water body to the investigating institutions, organizations or individuals involved in the study. Due to lack of definitive bio-monitoring programme like river water quality monitoring programmes by the Central Pollution Control Boards, State Pollution Control Boards and National River Conservation Directorate, the analysis is based on extrapolation and interpolation of scattered, mostly qualitative data/information.

The entire stretch of the river Ganga (main stem) can be viewed into three segments:

A.	**Upper Ganga** ≈ 294 **km**	**Gaumukh to Haridwar**
B.	**Middle Ganga** ≈ 1082 **km**	**Haridwar to Varanasi**
C.	**Lower Ganga** ≈ 1134 **km**	**Varanasi to Ganga Sagar**

(The Upper Ganga Segment for all practical purposes and studies carried out, starts at Gangotri as the terrain between Gaumukh to Gangotri is essentially devoid of biota due to hostile conditions).

These three segments not only differ in their geomorphology, ecology and rheology but are different in terms of issues that need to be addressed (refer report 001_GBP_IIT_GEN_ANL_01_Ver 1_Dec 2010). Considering this, floral and faunal diversity of the main stem of Ganga is reported in a series of four reports. This report covers the middle Ganga stretch from Haridwar (Downstream of Bhimgauda Barrage) to Varanasi. From the point of view of aquatic ecology, the middle Ganga segment has been further divided into five sub-stretches stated as follows (Figure 1).

a. <u>Haridwar to Bijnor: MG-1</u>
Distance: 77.39 km
Latitude: 29°58'33.82"N to 29°22'25.82"N
Longitude: 78°11'16.36"E to 78° 2'24.72"E
Altitude: 297-220 m

d. <u>Fatehgarh to Allahabad: MG-4</u>
Distance: 331 km
Latitude: 27°23'55.54"N to 25°25'31.79"N
Longitude: 79°37'38.13"E to 81°53'9.23"E
Altitude: 132-78 m

b. Bijnor to Narora: MG-2

Distance: 156.45 km
Latitude: 29°22'25.82"N to 28°11'44.57"N
Longitude: 78° 2'24.72"E to 78°23'30.93"E
Altitude: 220-177 m

c. Narora to Fatehgarh: MG-3

Distance: 185 km
Latitude: 28°11'44.57"N to 27°23'55.54"N
Longitude: 78°23'30.93"E to 79°37'38.13"E
Altitude: 177-132 m

e. Allahabad to Varanasi: MG-5

Distance: 144 km
Latitude: 25°25'31.79"N to 25°15'16.26"N
Longitude: 81°53'9.23"E to 83° 1'35.49"E
Altitude: 78-72 m

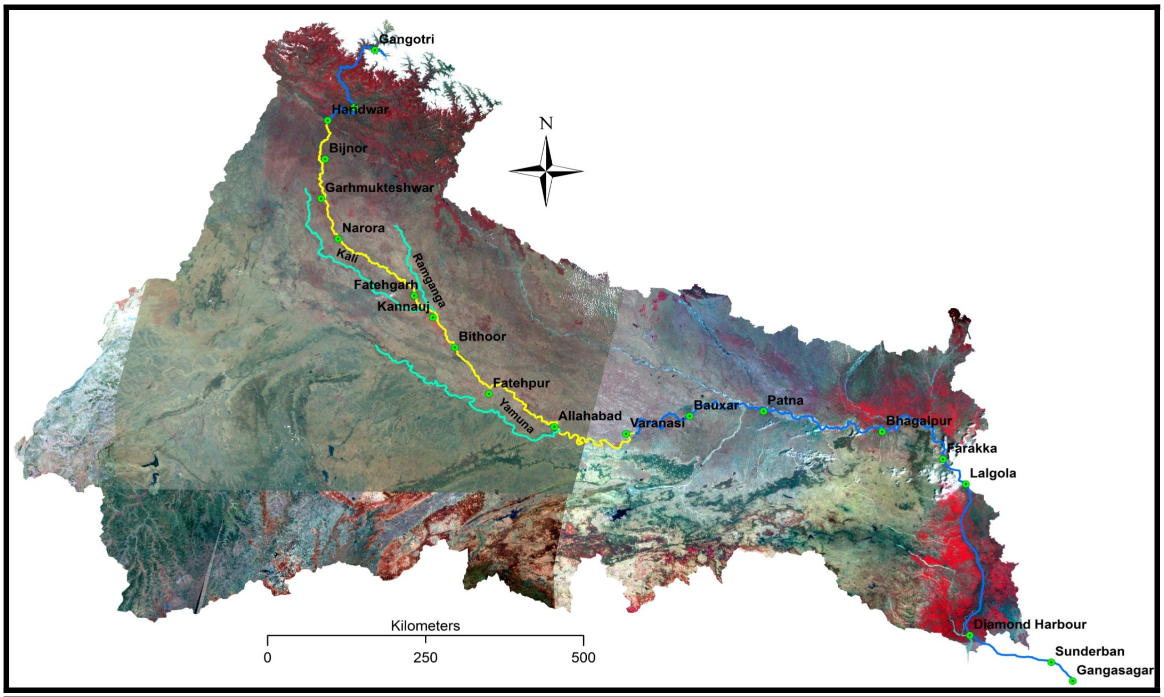


Figure 1: Ganga middle stretch and their major tributaries
(Represented from yellow and green colour, respectively)

The floral and faunal diversity of each of these sub-stretches is described in following sections.

2. Biological Profile

The data of biota in the middle Ganga is very fragmentary. All components have not been reported in all stretches, MG-1 to MG-5. A compilation of the species presented has been prepared on the basis of the information available in different stretches and time domain.

2.1. Phytoplankton

Phytoplanktons are tiny free floating living organisms which drift with the water. They constitute the main autotrophic component of Ganga ecosystem being chief primary producers forming the base of food chain.

Phytoplankton of river Ganga from Haridwar to Varanasi were studied in detail by various workers. An account of phytoplankton profile in middle stretches based on the studies conducted at various centres has been reported by Khan *et al*. (1998b), Khanna and Bhutiani (2003) and Dubey and Boswal (2009). According to the data phytoplankton belonging to seven families, Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dianophyceae, Euglenophyceae, Xanthophyceae and Chrysophyceae were identified. In zone MG-1, MG-3, MG-4 and MG-5 the members of Bacillariophyceae were dominant, followed by members of Chlorophyceae and Cyanophyceae while in MG-2 Chlorophyceae were dominant over Bacillariophyceae and Cyanophyceae. Euglenophyceae were rare from MG-1 to MG-4. Few genera of Dianophyceae were found in MG-4 and MG-5 stretch. The most abundant genera of Bacillariophyceae recorded are *Cyclotella*, *Cymbella*, *Fragillaria*, *Gomphonema, Nitzschia*, *Navicula* and *Synedra.* Common genera of Chlorophyceae were *Cosmarium, Spirogyra, Scenedesmus* and *Pediastrum. Anabena, Oscillatoria, Phormidium* and *Spirulina* are the common genera of Cyanophyceae.

Presence of some algae had been reported by Khanna *et al.* in 1998 from Ganga canal at Haridwar. According to them the population of diatoms were most abundant (87.85%), followed by green algae (10.36%) and by blue-green algae (6.69%). Sinha *et al.* (1997) reported that phytoplankton is dominated by diatoms (*Cyclotella* sp., *Tabellaria* sp., *Synedra* sp. and *Nitzschia* sp.), some seasonal blue green algae (*Microcystis* sp., *Oscillatoria* sp. and *Spirulina* sp.), green algae (*Hormidium* sp. and *Pediastrum* sp.) and yellow green algae (*Tribonema* sp.) at Kanpur.

Total 42 genera and 166 species of Bacillariophyceae, 47 genera and 113 species of Chlorophyceae and 15 genera and 56 species of Cyanophyceae are reported in the middle stretch from Haridwar to Varanasi. While 3 genera and 9 species of Euglenophyceae, 3 genera and 9 species of Dinophyceae were present in MG-4 and MG-5 region. Members of Xanthophyceae and Chrysophyceae were very rare and were represented by a single genus with a single species. Distributions of families with their taxa are represented in Figure 2 and Appendix-1(a).

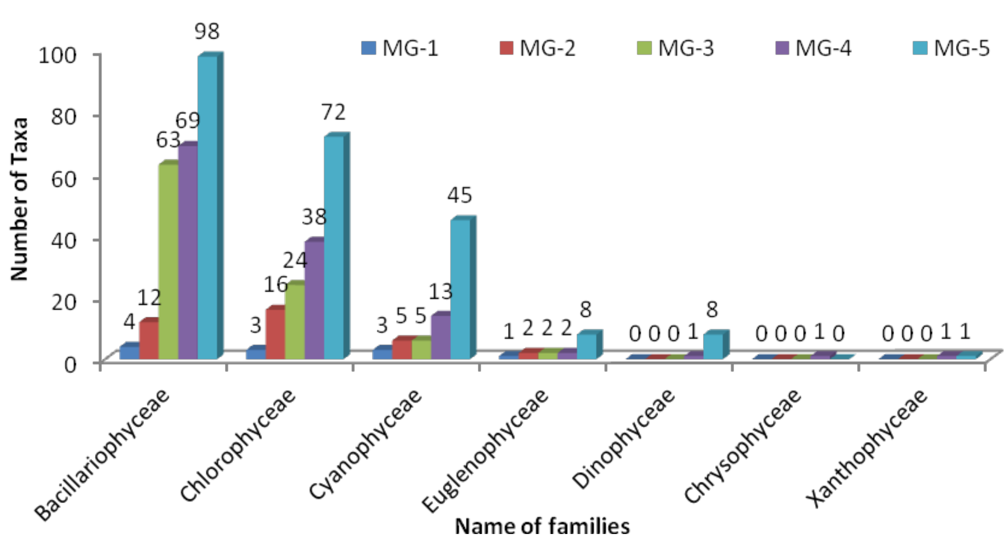


Figure 2: Graphical presentation of phytoplankton from MG-1 to MG-5

2.2. Periphyton

Periphyton is complex of algae, Cyanobacteria, heterotrophic microbes and detritus those are attached to submerged surface in most aquatic system. They are important food source of higher forms in the food chain and also are the indicators of water quality. Diverse group of algae including Bacillariophyceae, Chlorophyceae and Cyanophyceae comprise the periphyton. Total 58 genera and 114 species were reported from MG-1, MG-3 and MG-4. Bacillariophyceae were dominant in every stretch followed by Chlorophyceae and Cyanophyceae. Most common genera were *Achnanthes, Cyclotella, Cymbella, Navicula, Nitzschia, Oscillatoria, Pediastrum, Synedra* and *Merismopedia.* A list of species reported is given in Appendix-1(b).

The periphytonic community depicted almost opposite trend of phytoplankton due to the absence of hard substratum and the low current velocity of river that helps to the growth of planktonic forms in the river (Khanna, 1989; Khan *et al*. 1998a; Khan *et al*. 1998b; Nautiyal *et al.* 2004). The distribution of periphyton is shown in Figure 3.

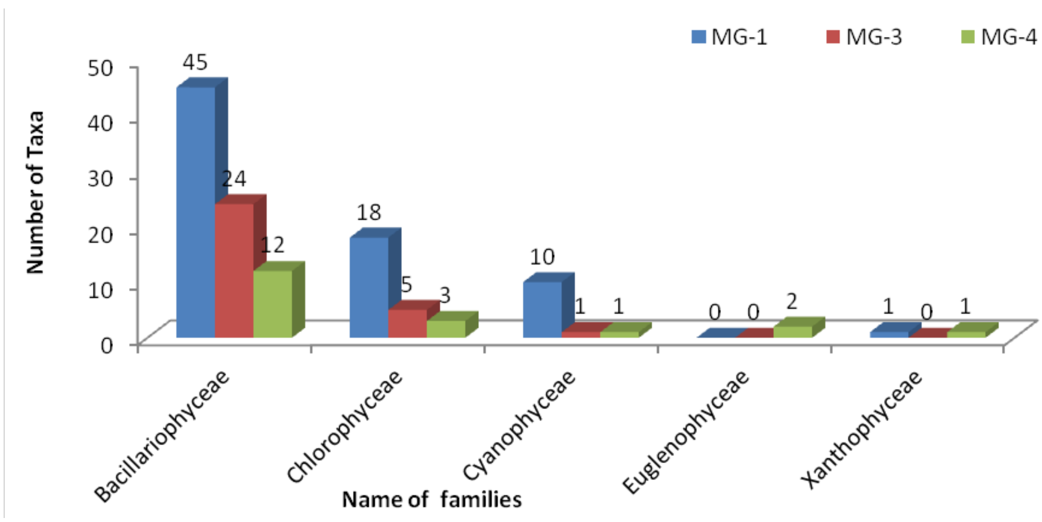


Figure 3: Distribution of periphyton from MG-1 to MG-5

**** The data of MG-2 and MG-5 was not available***

2.3. Zooplankton

Zooplankton is an assemblage of free floating microscopic animal forms including Protozoa, Rotifers, small Crustaceans, Copepods, Cladocerans, larvae and pupae of Insects. Zooplankton's main sustenance depends on bacteria and phytoplankton, making them the second link in the food chain. In the middle stretch of Ganga river, zooplankton were represented by Protozoans, Rotifers, Copepods and Cladocerans. Maximum population of Rotifers was reported at MG-2 followed by MG-4, MG-3 and MG-1. The distribution of zooplankton from MG-1 to MG-4 is represented by 10 genera and 11 species of Protozoa, 14 genera and 28 species of Rotifers, 11 genera and 17 species of Cladocera, 2 genera and 2 species of Copepods and 4 miscellaneous.

Total number of genera and species recorded were 38 and 59, respectively. No data of Zooplankton was however, available from MG-5. Distribution of zooplankton is shown in Figure 4 and list in Appendix-1(c). Zafar and Sultana (2005) also reported the zooplankton fauna belong to different groups (Protozoans, Rotifers, Cladocerans and Copepods) in the Ganga river at Kanpur. The dominant genera at Kanpur were *Paramecium*, *Brachionus*, *Filinia* and *Keratella*. Untoo *et al.* (2003) studied 236 km stretch of Ganga river between Narora to Kannauj and reported the abundance and composition of zooplankton. The order of abundance of various zooplankton groups was found to be Rotifers > Cladocera > Copepoda > Eggs and Nauplii. Sinha *et al.* (1997) reported that the zooplankton is dominated by Rotifers (*Brachionus* sp., *Keratella* sp. and *Anura* sp.) with relatively few Cladocera (*Moina* sp.) and Copepods (*Cyclops* sp. and *Diaptomus* sp.) at Kanpur.

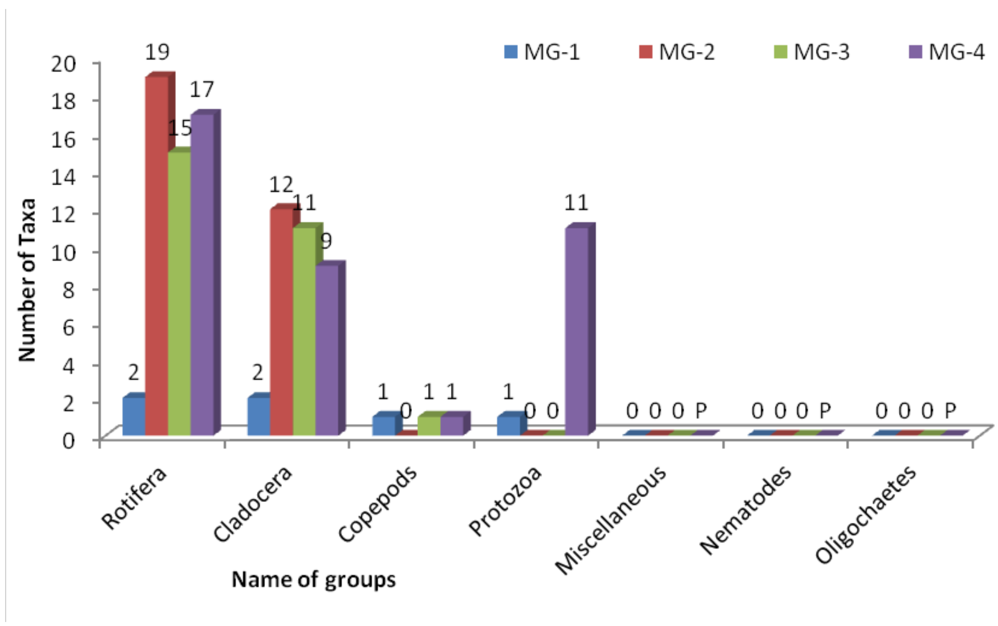


Figure 4: Distribution of zooplankton from MG-1 to MG-4

**** The data of MG-5 was not available***

2.4. Zoobenthos

Zoobenthos represents the community of organisms which live on, in or near the water bed also known as benthos. Many organisms which adapt to deep water pressure are not able to survive in the upper part of the water column. Zoobenthos in the middle Ganga region was represented by 8 orders of Insecta, Annelida and Molluscs. The zoobenthic community was represented by 51 families of Insects, 8 families of Molluscs and assorted group of Annelids. The data about the zoobenthos at MG-2 and MG-5 was not available. Among the various group of organisms, the Insecta population was dominant in the entire middle stretch and represented by Diptera and Trichoptera. Annelids were mainly represented by Oligochaetes and Polychaete. There was a decrease in marcobenthic population from Haridwar to Varanasi which may be due to the absence of hard substratum. Trichoptera, Diptera, Coleoptera and Ephemeroptera have been reported in that order, a few Odonata, Hemiptera and Plecoptera were also observed however the populations change at MG-3 and MG-4. Dipterans were conspicuously followed by Ephemeroptera/ Trichoptera at MG-4 and Gastropods, Pelecypoda and others at MG-3. The shift from insects to molluscs was due to soft substratum (Zafar and Sultana, 2005; Shivam, 2006). Sinha (1997) reported the seasonal occurrence of benthic fauna at Kanpur were *Chironomus* larvae, Oligochaetes and Rhizopods.

The distribution of zoobenthos is shown in Figure 5 and Appendix-1(d).

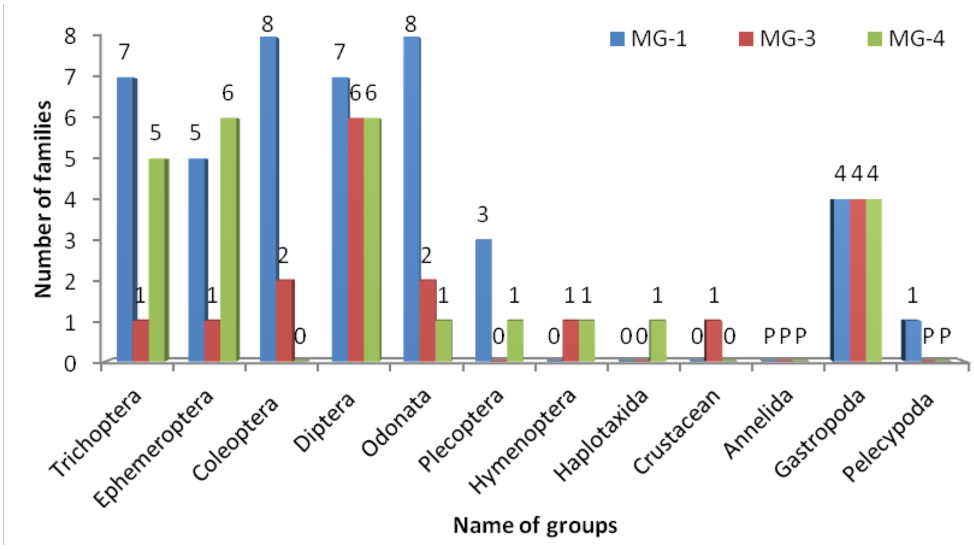


Figure 5: Distribution of zoobenthos from MG-1, MG-3 and MG-4

**** The data of MG2 and MG5 was not available;***

P symbolized the presence of the members of following order

On the basis of data of phytoplaktons, periphytons, zooplanktons and zoobenthos, the characteristics taxa and the ecological preferences of organisms reported above in the middle stretch of river Ganga are given in Table 1.

Table 1: The characteristic taxa of middle Ganga

Characteristic Taxa	Dwelling Habits & Habitat	Feeding/Habits & Habitats	Breeding Ground	Zones
Diatoms (Bacillariophyceae)	Pools, Riffles, runs	Producers grow in open water and on stony substrate, sand and plant debris	Deep pools with sandy substratum	MG-1 to MG-5
Green Algae (Chlorophyceae)	Riffles, Runs, Pools, sand & Plant debris	Producers grow in open water and on stony substrate, sand and plant debris	Deep pools with sandy substratum	MG-1 to MG-5
Rotifers	Pools, Runs, Riffles	Consumers feed on phytoplanktons and	Pools, Runs, Riffles	MG-1 to MG-4

		protozoans on dead or decomposing organic materials		
Cladocera	Pools, Runs, Riffles	Pools, Runs, Riffles; Feed on planktonic algae and bacteria, and on detritus	Pools, Runs, Riffles	MG-1 to MG-4
Euglenoids	Runs, Riffles	Mainly feeds on bacteria and debris, also photosynthetic	Runs, Riffles	MG-4
Two Wing Fly (Diptera)	Sand/Silt substratum	Collectors, feeds on FPOM*	Sandy substratum, Breeding season pre-monsoon (May-June)	MG-1, MG-3, MG-4
Caddis Fly (Trichoptera), Beetle (Coleoptera)	Stony substratum	Shedders/Collectors feeds on CPOM* and FPOM	Stony substratum, Breeding season pre-monsoon (May-June)	MG-1

**FPOM is Fine particulate organic matter; *CPOM is Course particulate organic matter*

2.5. Fishes

The middle stretch is very productive in fish resources and is represented by 126 species belonging to 28 families. Three important commercial fish landing centres, Kanpur, Allahabad and Varanasi are located in the middle reach which account for nearly 2000 tons of catch every year. Almost all commercially important fishes viz. Major Carps, other Carps, large and other Catfishes along with a variety of low economical species abound. Hilsa which used to be an important catch at Allahabad and Varanasi has almost disappeared. The distribution of fishes along the entire stretch is shown in Table 2 and Figure 6. Photographs of Major Carps and Cat fishes reported in this stretch are given in Plate 1.

Table 2: Distribution of fish families (MG-1 to MG-5)

Families	MG-1	MG-2	MG-3	MG-4	MG-5
Ambyceptidae	-	-	-	1	-
Ambassidae	-	-	2	2	2
Anabantidae	-	-	1	-	1
Badidae	-	-	1	-	-
Bagridae	3	7	7	9	7
Balitoridae	4	-	8	1	1
Belonidae	1	-	1	1	-
Chacidae	-	-	1	-	-
Channidae	4	3	5	5	4
Clariidae	-	1	1	1	1
Clupeidae	-	1	1	2	4
Cobitidae	4	-	2	1	3
Cyprinidae	37	17	30	21	29
Engraulidae	-	-	-	1	1
Gobiidae	1	-	1	1	1
Heteropneustidae	1	1	1	1	1
Mastacembelidae	2	2	2	1	3

Mugilidae	1	1	-	1	2
Nandidae	1	-	1	1	1
Notopteridae	2	2	2	2	1
Osphronemidae	1	-	2	1	2
Pangasiidae	-	1	1	2	-
Pristigasteridae	-	-	-	-	1
Schilbeidae	2	2	3	5	4
Sciaenidae	-	-	-	1	1
Siluridae	-	1	4	4	-
Sisoridae	4	1	2	3	5
Tetraodontidae	1	-	-	-	-
Total	**69**	**40**	**79**	**68**	**75**

(- not reported)

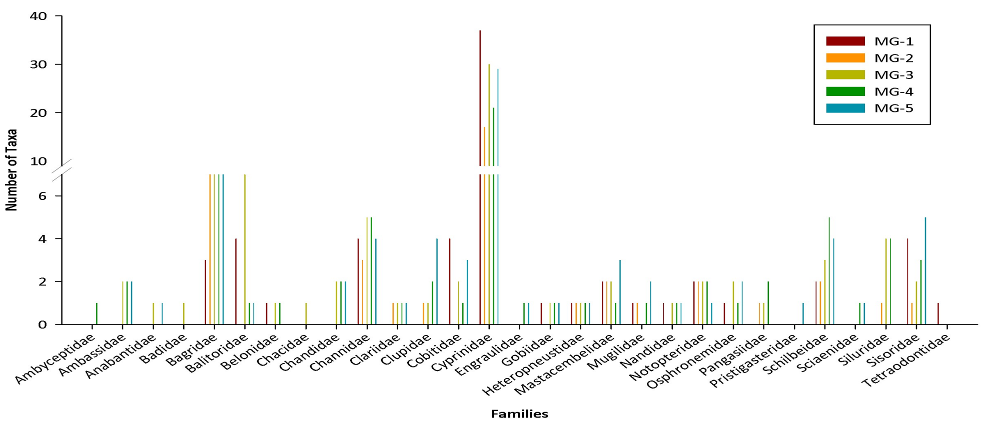
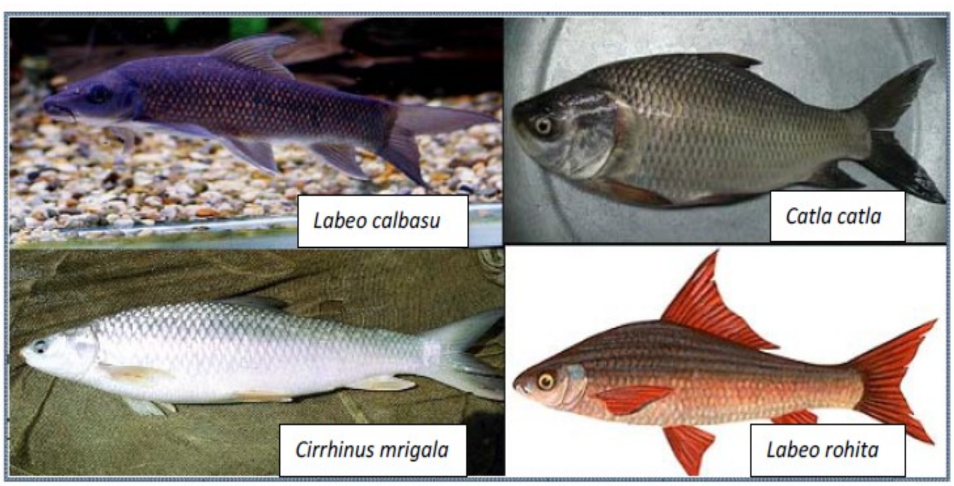


Figure 6: Distribution of fishes from MG-1 to MG-5

Major Carps



Cat Fishes

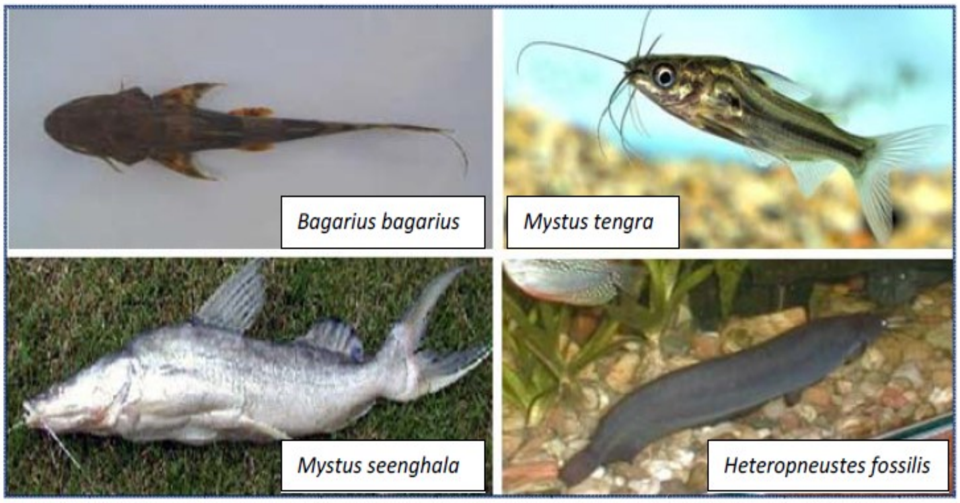


Plate 1: Typical Major Carps and Cat fishes spotted in the stretch Haridwar - Varanasi ***(* all the images were downloaded from internet)***

The important contributing families are Cyprinidae, Sissoridae, Cobitidae, Siluridae, Bagridae, Channidae, Clupeidae, Notopteridae and Mestcembalidae. Cyprinidae alone account for 55% of the fish species and also the catch in the middle Ganga river. The preponderance of the fish species is due to habitat diversity coupled with abundant fish food organism. Since the stretch is rich in nutrients, supports the growth of algae, which in term is consumed by Carps. The important fishes of the stretch are *Labeo rohita, L. calbasu, Cirrhinus mrigala, Catla catla, Sperata seenghala, Sperata aor, Wallago attu, Bagarius bagarius, Eutropiichthys vacha, Notopterus notopterus, Notopterus chitala, Mystus tengara* and *Channa marulius.* Sahgal (1973) reported four Major Carps, *viz. Labeo rohita*, *L. calbasu*, *C. mrigala* and *Catla catla* and 2 large Cat fishes, *M. seenghala* and *W. attu* at Aligarh. Of these *L. rohita* and *W. attu* are most predominant and constitute about 80% of the total fish landing. Payne *et al.* (2004) reported fish yield from Allahabad varied between 5.1-10.6 kg ha^{-1}.

Some fishes of the upper Ganga such as *Schizothorax, Tor and Glyptothorax* found in UG-2, UG-3 have also been recorded at MG-1 and MG-2. Characteristics species of middle Ganga are given in Table 3. A few exotic species viz. *Cyprinus carpio* and *Hypophthalmicthys molitrix* have been recorded downstream of Allahabad (Varanasi). *Cyprinus carpio* has been reported to grow like IMC (*Labeo rohita, L. calbasu* and *Catla catla*), with which it competes for food and growth. A detailed report on fish and fisheries in the Ganga river is contained in fishery report entitled "Status of Fish and Fisheries of River Ganga" of GRB EMP. A compilation of all the fishes recorded stretch wise is given at the end in Appendix-1(e).

Table 3 Characteristic species of middle Ganga

Characteristic Taxa	Dwelling Habitat	Feeding Habits	Breeding Ground	Stretch
Indian Major Carps *Labeo rohita,* *L. calbasu,* *Cirrhinus mrigala,* *Catla catla*	Inhabits fast flowing streams and rivers 1.0-3.0 m deeps water pools, velocities 20- 30 cm/sec. Temp. 15- 25°C	Herbivorous, plankton feeders	Migrate to shallow waters 0.5- 1.0m depth for spawning, period July-August	MG-1 to MG-5

	feed selectively in upper, column, rank and bottom areas.			
Minor Carps *Labeo bata, Salmophasia bacaila, Aspidoparia morar, Puntius* sp.	Column of side waters/ ditches and banks of small streams 0.5- 1.5 m pools shallow waters	Omnivorous small insects, plankton	Breed in shallow waters Feb-Nov	MG-1 to MG-5
Cat Fishes *Sperata aor, Sperata seenghala, Wallago attu, Bagarius bagarius*	Sandy beds with deep waters >1.0 m and slow currents	Carnivorous small insects, zoobenthos, bottom dwellers	Some build nests where eggs hatch and young ones get shelter breeding (Mar-June)	MG-2 to MG-5

2.6. Other Higher Vertebrates

The zoological survey of India (ZSI, 1991) has documented 27 species of reptiles in Ganga river besides an endangered mammal Ganga river dolphin (*Platanista gangetica*). Menon (1963), Jhingran (1974), Jhingran and Ghosh (1978) have given account on the presence of fishes, amphibians and reptiles in Ganga river system. Among the important higher vertebrates reported in middle Ganga are Gangetic dolphin, gharyal, soft and hard shell turtles.

Gangetic dolphin has been reported to be present in the middle stretch MG-2 to MG-5. Dolphin has not been sighted in the stretch Haridwar to Bijnor. In between Ganga barrage at Bijnor and Narora dolphins are reported to be present in large numbers. W.W.F. survey report has put in number around 56. Downstream of Narora upto Kanpur dolphin are spotted rarely and the number between Allahabad and Buxar (downstream of MG-5) in a stretch of 425 km, 172 dolphins have been reported (Sinha *et al*. 2010).

The Gharyals (*Gavialis gangeticus*) was once common in the Ganga system (Whitaker and Basu, 1983; Hussain, 1999). Of late their numbers have greatly reduced attributable to change in land use pattern, reduction in flows, modifications in river morphology and increased mortality in fishing nets. In a survey conducted by Rao (1995), three Gharyals were reported downstream of Narora barrage. A number of Gharyal hatchlings have been introduced from Hastinapur hatchery.

A total of 12 sp. of fresh water turtles have been identified in middle Ganga. Hard shell *Kachuga* include five species (*K. smithii, K. tecta, K. tentoria, K. dhongoka and K. kachuga*) and two species of soft shell turtles (*Aspideretes gangeticus* and *A. hurum*) and one each of *Chitra indica, Lissemys punctata, Hardella thurji, Geoclemys hamiltoni* and *Melanochelys trijuga*.

The turtles are common at Allahabad but have been found in Gangdaspur in Bijnor. The turtles have been reported from Haridwar also (Rao, 1995; Smith, 1933; Das, 1985; Moll, 1987). A comprehensive account of status of higher vertebrates in Ganga river is reported in GRB EMP report entitled "Status of Higher Aquatic Vertebrates in the Ganga River, India".

The characteristic taxa and the ecological preferences of some important vertebrates from Haridwar-Varanasi are given in Table 4.

3. Summary Remarks

The middle Ganga is biologically very productive due to the presence of higher concentration of nutrients, warm water and meandering river, flood plains and reduced flow velocities. It supports 355 species of phytoplankton, 114 species of periphyton, 58 species of zooplankton, 51 families of Insects, 8 families of Molluscs, assorted group of Annelids as zoobenthos and 126 species of fishes. The characteristic species of the stretch is the Indian Major Carps. Higher vertebrates are also common. Dolphin is also a characteristic and indicator species of the middle Ganga.

The ratio of diatoms (Bacillariophyceae) to green algae (Chlorophyceae) to blue green algae (Cyanophyceae) in the middle Ganga substretches are depicted as MG_1-MG_3 (100:36:15) and MG_4-MG_5 (100:67:36) compared to the ratio of 100:39:18 in the upper Ganga. The Indian Major Carps constitutes about 55% of the fish population and the catch in the middle reach.

Table 4: Characteristic vertebrate taxa of middle Ganga

Characteristic Taxa	Dwelling Habitat	Feeding Habits	Breeding Ground	Zones
Turtles, Kachuga and *Aspideretes* sp.	Shallow waters on sandy banks	Adult turtles feed mainly on insect larvae and decomposing organic materials (Scavengers)	Breed on sand beds Nesting in Dec- Feb hatching in May	MG-1 to MG-5
Gharyals *Gavialis gangeticus*	Less interrupted basking sites, prefer clayey islands from sand of banks	Juveniles feed on small crustaceans insects, frogs. Adults feed on small fish	Nesting in dry season preferred riverine sand banks	MG-1 to MG-3
Dolphins *Platanista gangetica gangetica*	Mid channel depth approx 2- 4.5 m with bank depth greater than 1.5 m. Rocky and muddy substrates velocity 25-30 cm/sec.	Catfish, Small carps, Prawns molluscs and turtles preferred food small fish.	No specific birth period move in pairs and give birth from Oct- March on sand bars	MG-2 to MG-5

Appendix-I

Distribution of all aquatic organisms in the middle stretch of Ganga river from Haridwar to Varanasi.

I (a). Distribution of phytoplankton in the middle stretch of Ganga from Haridwar to Varanasi.

	MG-1	MG-2	MG-3	MG-4	MG-5
Bacillariophyceae					
Achnanthes affinis					+
A. clevei					+
A. crenulata				+	
A. exigua					+
A. lanceolata					+
A. linearis					+
A. microcephala					+
A. minutissima			+	+	+
A. subhudsonis			+		
Achnanthidium biasolettianum			+	+	
Amphora sp.			+		
A. montana		+	+	+	
A. ovalis					+
A. pediculus			+		
A. veneta			+		+
Anomoeoneis spheriophora					+
Asterionella sp.		+	+	+	
A. formosa				+	
Aulacoseira granulata			+		
Bacillaria paradoxa			+	+	
Caloneis amphisbaena					+
C. bacillum				+	
C. bacillaris				+	
C. silicula					+
Ceratoneis arcus			+	+	
Cocconeis placentula			+	+	+
Craticula cuspidata				+	+
C. halophila					+
C. molestiformis				+	
Cyclotella sp.		+	+		
C. antigua					+
C. comta					+
C. glomerata			+	+	+
C. kutezingiana			+		+
C. meneghiniana			+	+	
C. operculata				+	+
C. stelligera				+	
Cymbella sp.				+	

	MG-1	MG-2	MG-3	MG-4	MG-5
C. affinis				+	+
C. cymbiformis					+
C. excisa			+		
C. kolbei			+		
C. lancetuliformis			+		
C. leavis			+	+	
C. parva			+		
C. prostrata					+
C. tumida				+	+
C. turgida					+
C. turgidula			+		
C. ventricosa					+
Cymbopleura sp.			+		
Diatoma sp.	+	+	+	+	
D. elongatum					+
D. mesodon			+	+	
D. moniliformis			+		
D. vulgaris					+
Diploneis intermedia					+
Encyonema minutum			+	+	
E. silisiacum			+		
Epithemia sp.				+	
E. gibba				+	
Fallacia pygmaea				+	+
Fragilaria sp.				+	
F. brevistriata					+
F. capucina					+
F. construens					+
F. crotonensis				+	+
F. intermedia					+
F. virescens				+	
Frustulia sp.		+	+		
Gesslaria decussis			+	+	
Gomphonema angustatum					+
G. augur					+
G. clevei					+
G. constrictum				+	+
G. gracile					+
G. lagenula			+		
G. macropuctatum					+
G. minutum			+	+	
G. olivaceum					+
G. parvulum			+	+	+
G. subclavatum					+

	MG-1	MG-2	MG-3	MG-4	MG-5
Gyrosigma sp.			+	+	
G. accuminatum		+	+	+	+
G. kutzingii					+
G. scalproides			+	+	
Hantzschia amphioxys				+	
Luticola mutica				+	+
Mastogloia danseii				+	
Melosira sp.		+	+	+	
M. ambigua		+			+
M. distans					+
M. exigua					+
M. granulata				+	+
M. variance			+		+
Meridian sp.				+	
Navicula sp.	+		+	+	
N. capitata				+	
N. cari		+	+		
N. caterva				+	
N. cincta					+
N. cocconiformis					+
N. cryptocephala					+
N. cryptofallax			+	+	
N. cryptotenella			+		
N. cryptotenelloides			+		
N. exigua					+
N. gracilis					+
N. gregaria					+
N. krarkei					+
N. microcephala					+
N. minima					+
N. minisculus					+
N. radiosafallax			+	+	
N. rhyncocephala			+	+	
N. rostelata			+		+
N. salinarum					+
N. sculpta				+	
N. seminulum					+
N. simplex					+
Nitzschia sp.			+	+	
N. acicularis		+		+	+
N. amphibia			+		+
N. capitelata				+	
N. communis			+		+
N. commutata					+

	MG-1	MG-2	MG-3	MG-4	MG-5
N. filiformis					+
N. fonticola			+	+	
N. frustulum			+	+	+
N. gracilis					+
N. hungarica			+		+
N. kittonii					+
N. linearis			+	+	+
N. microcephala				+	
N. obtusa			+	+	
N. palea			+	+	+
N. paleaceae					+
N. punctata					+
N. recta			+		+
N. sigma					+
N. subtilis					+
N. sublinearis					+
N. thermalis					+
N. trybonella					+
Pinnularia gibba				+	+
P. maior					+
P. viridis					+
Placoneis elegans			+	+	
Planothidium lanceolatum			+		
Reimeria sinuata			+		
Rhopalodia gibba					+
Sellaphora pupula			+	+	+
Stauroneis sp.				+	
S. anceps					+
Stephanodiscus sp.		+	+		
Surirella elegans					+
Synedra sp.	+	+	+	+	
S. acus				+	+
S. amphirhynchus				+	
S. fasciculata					+
S. minuscula					+
S. rumpens					+
S. ulna			+	+	+
Tabellaria sp.	+			+	
T. fenestrata				+	
T. flocculosa					+
Chlorophyceae					
Actinastrum sp.		+	+	+	
A. hantzschii					+
Ankistrodesmus sp.		+	+		

	MG-1	MG-2	MG-3	MG-4	MG-5
A. acicularis					+
A. angustus					+
A. falcatus				+	+
Botryococcus sp.		+	+		
Bumillaria exilis				+	
Celastrum sp.			+		
Chlamydomonas derenbenji					+
C. laginula					+
C. mirabilis					+
C. truncata					+
Chlorella subsala					+
C. vulgaris				+	+
Chlorobottrys sp.				+	
Chlorococcum humicola				+	
C. infusionum					+
Chlorogonium elongatum				+	
Cladophora sp.		+	+		
C. glomerata					+
Coelastrum sp.			+	+	
Closterium calosporum		+			+
C. cambricum					+
C. incurvatum					+
C. maxima					+
C. microporum					+
C. nitzsch				+	
C. parvulum					+
C. peracerosum					+
C. reticulum					+
C. rostratum					+
C. sphaericum					+
Cosmarium sp.			+		
C. anceps					+
C. denatum					+
C. dentiferum					+
C. granatum					+
C. undulatum					+
Crucigenia sp.		+	+		
C. apiculata					+
C. lanterbornei				+	
C. rectangularis					+
C. tetrapeda					+
C. truncata					+
Desmidium sp.			+		
D. aptogonum					+

	MG-1	MG-2	MG-3	MG-4	MG-5
Dictyosphaerium pulchellum					+
Diaspora cuneiformis					+
Eudorina sp.				+	
Eudorina elegans				+	+
Gonatozygon sp.			+		
G. kinahani				+	
Hormidium sp.				+	
H. suletile				+	
Hydrodictyon sp.		+	+	+	
H. reticulatum				+	+
Kirchneriella contorta					+
K. obesa					+
Micractinium radiatum					+
Microspora sp.	+	+	+		
M. amoena				+	
Mougeotia sp.			+	+	+
Netrium sp.			+		
Oedogonium sp.			+	+	
Oocystis crassa					+
O. marsoni					+
O. parva					+
O. solataria					+
Palmella sp.				+	
Pandorina sp.				+	
P. morum					+
Pediastrum sp.		+	+		
P. boryanum					+
P. clathratum					+
P. constrium					+
P. duplex				+	+
P. simplex			+	+	+
P. tetras				+	+
Pleurodermus sp.				+	
Protococcus sp.		+	+	+	
Scenedesmus sp.			+	+	
S. acuminatus		+			+
S. arcuatus					+
S. bicaudatus					+
S. bijugatus					+
S. denticulatus					+
S. diamorplus					+
S. falcatus					+
S. longus					+
S. quadricauda				+	+

	MG-1	MG-2	MG-3	MG-4	MG-5
Selenastrum sp.		+		+	
S. gracile					+
Sphaerocystis schroeteri				+	
Spirogyra sp.	+	+	+	+	
S. affinis					+
S. decimina					+
S. spingularis					+
S. subsala					+
Staurastrum sp.			+		
Stigeoclonium sp.				+	
Tetrahedron bifidum					+
T. constrictum					+
T. minimum					+
T. muticum					+
Tetraspora sp.		+	+		
Treubaria varia				+	
Tribonema sp.				+	
Ulothrix sp.	+	+	+	+	
U. subtellisma					+
U. zonata					+
Volvox globator				+	
Zygnema sp.		+	+	+	+
Cyanophyceae					
Agmenellum sp.		+	+		
Anabaena sp.	+	+	+	+	
A. circularis					+
A. cylindrica					+
A. laxa					+
A. sphaerica					+
A. torulosa					+
A. variabilis					+
Anacystis sp.		+	+		
Aphanocapsa pulchra					+
Chroococcus dispersus					+
C. turgidus					+
Cylindrospermum sp.				+	
Lyngbya gracilis					+
L. heironymusii					+
L. limnetica					+
L. manifica					+
Merismopedia sp.				+	
M. convulata					+
M. glauca					+
M. marsinii					+

	MG-1	MG-2	MG-3	MG-4	MG-5
M. minima					+
M. punctata					+
Microcystis sp.				+	
M. aeruginosa				+	+
M. flos-aquae					+
M. protocystis					+
Nostoc sp.				+	
N. calcicola					+
Oscillatoria sp.	+		+	+	
O. agardhii		+			+
O. amphibia					+
O. formosa					+
O. irrigua					+
O. limnetica					+
O. limosa				+	+
O. planktonica					+
O. princeps				+	+
O. raciboraki					+
O. subbrevis					+
O. subsalsa					+
O. tenuis				+	+
Phormidium sp.		+	+	+	
P. calcicola					+
P. inundatum					+
P. mucicola					+
Raphidiopsis curvata					+
R. indica					+
R. mediterranea					+
Rivularia sp.	+				
Spirulina sp.				+	
S. laxissima					+
S. maior					+
S. princeps				+	+
S. subsalsa					+
S. subtillisma					+
Euglenophyceae					
Euglena sp.	+	+	+		
E. acus				+	+
E. gracilis					+
E. proxima					+
E. viridis				+	+
Phacus accuminatus		+	+		+
P. pusillus					+
Trachelomonas granulata					+

	MG-1	MG-2	MG-3	MG-4	MG-5
T. planktonica					+
Dianophyceae					
Ceratium sp.				+	
C. digitatum					+
C. evareuatum					+
C. falcatum					+
Peridiriium brevipes					+
P. brochii					+
P. cinatum					+
Gymnodinium album					+
G. variabile					+
Chrysophyceae					
Botryococcus sp.				+	
Xanthophyceae					
Tribonema bombycinum				+	+

I (b). Distribution of periphyton in the middle stretch of Ganga river from Haridwar to Varanasi.

	MG-1	MG-3	MG-4
Bacillariophyceae			
Achnanthes sp.	+		
A. brevipes	+		
A. microcephala	+		
Achnanthidium biasolettianum	+		
A. minutissimum	+		
Amphora sp.	+		
A. montana	+		
A. ovalis	+		
Anomoeoneis serians	+		
Asterionella formosa	+		
Aulcoseira granulata	+		
Caloneis silicula	+		
Cocconeis sp.	+		
C. placentula	+		
Cyclotella sp.		+	
C. glomerata	+		
C. kuetzingiana	+		
C. meneghiniana	+	+	
C. stelligera			+

	MG-1	MG-3	MG-4
Cymbella sp.	+	+	
C. austriaca			+
C. delicatula			+
C. kolbei		+	
C. leavis	+		
C. parva		+	
C. perpusilla		+	
C. prostrata	+		
C. turgidula	+		
Diatoma sp.			+
D. mesodon		+	
D. vulgare	+		
D. vulgaris	+		
Encyonema minutum		+	
Fragilaria sp.	+		
F. crotonensis		+	
F. inflata		+	
Frustulia sp.	+		
Gomphonema sp.		+	+
G. helvaticum			+
G. minutum		+	
Gyrosigma sp.	+		
G. acuminatum		+	
G. distortum	+		
G. scalproides	+		+
Mastogloia danseii	+		
Melosira granulata	+		
Navicula sp.	+	+	
N. constans		+	
N. cryptotenella			+
N. hustedtii	+		
N. lancettula		+	
N. mutica		+	
N. radiosa	+		
N. rostellata			+
N. rynchocephala	+		
N. stagnorum	+		
Nitzschia sp.	+		
N. communis	+		
N. gracilis			+
N. hungarica		+	
N. ignorata	+		
Pinnularia sp.	+		
P. gibba	+		

	MG-1	MG-3	MG-4
P. subcapitata	+		
Placoneis elegans			+
Planothidium lanceolata		+	
Pleurosigma sp.	+		
Stauroneis sp.	+		
Surirella sp.		+	
S. apiculata		+	
S. delicatissima		+	
Synedra sp.	+		
S. ulna	+	+	
Tabellaria sp.			+
T. fenestrata		+	
Chlorophyceae			
Chlorella sp.	+		
Chlorogonium sp.			+
Cladophora sp.	+		
Closterium sp.	+		
Cosmarium sp.	+	+	
Dictyosphaerium ehrenbergianum	+		
Draparnaldia sp.	+		
Hydrodictyon sp.	+		
Kirchneriella sp.	+		
Oedogonium sp.	+	+	
Oocystis elliptica	+		
Pandorina morum	+		
Pediastrum sp.	+		
P. clathratum	+		
P. duplex			+
P. simplex	+		
Scenedesmus sp.	+		
S. dimorphus		+	
S. quadricauda			+
Schizogonium sp.	+		
Spirogyra sp.	+	+	
Ulothrix sp.	+		
Zygnema sp.		+	
Cyanophyceae			
Anabaena sp.	+		
Coelosphaerium naegelianum	+		
Lyngbya sp.	+		
Merismopedia glauca		+	
M. minima	+		
M. tenuissima	+		
Microcystis aeruginosa	+		

	MG-1	MG-3	MG-4
Nostoc sp.	+		
Oscillatoria sp.	+		
O. limosa			+
Phormidium sp.	+		
Rivularia sp.	+		
Euglenophyceae			
Euglena acus			+
E. viridis			+
Xanthophyceae			
Tribonema bombycinum			+
Vaucheria sp.	+		

I(c). Distribution of zooplanktons in the middle stretch of Ganga river from Haridwar to Varanasi.

	MG-1	MG-2	MG-3	MG-4
Protozoa				
Actinophrys sp.				+
Actinosphaerium sp.				+
Amoeba sp.				+
Arcella sp.				+
Colpedium sp.				+
Difflugia sp.				+
Euglena sp.				+
E. viridis				+
Euplotes sp.	+			+
Paramecium sp.				+
Vorticella sp.				+
Rotifera				
Asplanchna sp.		+	+	
A. priodonta				+
Brachionus sp.				+
B. angularis		+	+	
B. calyciflorus		+	+	+
B. caudatus				+
B. forficula		+	+	+
B. quadridentatus		+	+	+
B. rubens		+		+
Euchlanis dilatata		+	+	
Filinia sp.				+
F. longiseta		+		+
F. terminalis		+		
Gastropus sp.		+	+	
Hexarthra sp.				+

	MG-1	MG-2	MG-3	MG-4
Keratella sp.	+			+
K. cochlearis				+
K. procurva		+	+	
K. quadrata				+
K. tropica		+	+	+
K. valga		+	+	
Lecane sp.		+	+	+
Notholca sp.	+	+	+	+
Philodina sp.			+	
Platyias quadricornis		+		
Polyarthra sp.		+	+	+
Rotaria sp.		+		
Testudinella sp.		+	+	
Cladocera				
Anura fissa				+
Bosmina sp.	+	+	+	
B. longirostris				+
Ceriodaphnia sp.		+	+	
C. carinata				+
Daphnia sp.	+	+		
D. carinata		+	+	
Diaphanosoma sp.		+	+	+
Diaptomus sp.		+	+	+
Leydigia sp.		+	+	
Mesocyclops sp.				+
M. hyalinus		+	+	
M. leuckarti		+	+	
Moina sp.		+	+	
M. micrura				+
Moinodaphnia sp.				+
Nauplius larvae		+	+	+
Simocephalus sp.		+	+	
Copepods				
Cletocamptus sp.			+	
Cyclops sp.	+			+
Miscellaneous				
Chironomus larva				+
Mosquito larvae				+
Nematodes				+
Oligochaetes				+

I(d). Distribution of zoobenthos in the middle stretch of Ganga river from Haridwar to Varanasi.

	Taxa	MG-1	MG-3	MG-4
Trichoptera				
Brachycentridae				+
Glossosomatidae		+		+
Helicopsychidae	*Helicopsyche* sp.	+		
Hydropsychidae		+	+	+
Hydroptilidae				+
Limnephilidae	*Hesperophylax* sp.	+		
	Limnephilus sp.	+		
Leptoceridae	*Mystacides* sp.	+		
	Leptocella sp.	+		
	Triaenodes sp.	+		
Polycentropodidae	*Cyrnellus* sp.	+		
Rhyacophilidae				+
Other Trichoptera		+		+
Ephemeroptera				
Baetidae		+	+	+
Caenidae		+		+
Ephemerellidae		+		+
Heptageniidae		+		+
	Epeorus sp.	+		
	Rhithrogena sp.	+		
Leptophlebiidae				+
Neoephemeridae				+
Siphlonuridae		+		
Other Ephemeroptera				+
Coleoptera				
Amphizoidae	*Amphizoa* sp.	+		
Chrysomelidae	*Donacia* sp.	+		
Dytiscidae			+	
	Cybister sp.	+		
	Dytiscus sp.	+		
Elmidae	*Stenelmis* sp.		+	
Gyrinidae	*Dineutus* sp.	+		
Hydrochidae	*Hydrochus* sp.	+		
Hydrophilidae	*Hydrophilus* sp.	+		
Noteridae	*Hydrocanthus* sp.	+		
Psephenidae	*Psephenus* sp.	+		
Other Coleoptera				+
Diptera		+		
Athericidae	*Atherix* sp.	+		
Chironomidae		+	+	+
Culicidae			+	+

	Taxa	MG-1	MG-3	MG-4
	Culex sp.	+		
Dixidae	*Dixa* sp.	+		
Heleidae			+	+
Limoniidae	*Antocha* sp.	+		
Muscidae	*Limnophora* sp.			+
Simuliidae	*Simulium* sp.	+	+	
Syrphidae	*Eristalis* sp.			+
Tabanidae	*Tabanus* sp.	+	+	+
Tipulidae	*Megistocera* sp.		+	
Other Diptera		+		
Odonata				
Aeshnidae	*Aeshna* sp.	+		
Corduliidae	*Epicordulia* sp.	+		
	Helocordulia sp.	+		
	Macromia sp.	+		
Gomphidae			+	+
	Hagenius sp.	+		
Lestidae	*Lestes* sp.	+		
Hemiptera			**+**	
Belostomatidae	*Belostoma* sp.	+		
Corixidae	*Sigara* sp.	+		
Nepidae	*Ranatra* sp.	+		
Notonectidae	*Notonecta* sp.	+		
Plecoptera				
Chloroperlidae	*Alloperla* sp.	+		
Perlidae				+
	Neoperla sp.	+		
Perlodidae	*Isoperla* sp.	+		
Hymenoptera				
Agaonidae			+	+
Crustacean				+
Cyprididae	*Cypris* sp.		+	
	Heterocypris sp.		+	
Annelida		+	+	+
Hirudinea		+	+	+
Haplotaxida				
Glossoscolecidae				+
Unidentified			+	
Mollusca				
Gastropoda		+	+	
Bithyniidae	*Bithynia* sp.	+	+	
Lymnaeidae	*Lymnaea* sp.	+		+
	L. accuminata	+		
Pleuroceridae	*Goniobasis* sp.	+		

	Taxa	MG-1	MG-3	MG-4
Planorbidae	*Gyraulus* sp.	+		
	G. convexiculus	+		
	Indoplanorbis sp.		+	
Subulinidae	*Subulina* sp.		+	
Thiaridae				+
Viviparidae	*Bellamya bengalensis*			+
	Vivipara crassa			+
	V. bengalensis		+	+
Pelecypoda			+	+
Corbiculidae	*Corbicula* sp.	+		

I(e). Distribution of fishes in the middle stretch of Ganga river from Haridwar to Varanasi.

Species	Families	MG-1	MG-2	MG-3	MG-4	MG-5
Ailia coila	Schilbeidae			+	+	+
Amblyceps mangois	Ambyceptidae	+				
Amblypharyngodon melettinus	Cyprinidae			+		
A. mola	Cyprinidae		+	+	+	+
Anabas testudineus	Anabantidae			+		+
Aspidoparia jaya	Cyprinidae				+	
A. morar	Cyprinidae	+			+	+
Badis badis	Badidae			+		
Bagarius bagarius	Sisoridae	+	+	+	+	+
Barilius barila	Cyprinidae	+	+	+		+
B. bendelensis	Cyprinidae	+				+
B. bola	Cyprinidae	+	+	+	+	+
B. dimophicus	Cyprinidae	+				
B. vagra	Cyprinidae	+	+	+		
Botia almorhae	Cobitidae	+				
B. dario	Cobitidae	+		+	+	+
B. dayi	Cobitidae					+
B. lohachata	Cobitidae	+				
Catla catla	Cyprinidae	+	+	+	+	
Chaca chaca	Chacidae			+		
Chagunius chagunio	Cyprinidae	+				+
Chanda nama	Ambassidae			+	+	+
C. ranga	Ambassidae			+	+	+
Channa gachua	Channidae	+		+	+	+
C. marulias	Channidae	+	+	+	+	+
C. punctatus	Channidae		+	+	+	+
C. stewartii	Channidae			+	+	
C. striatus	Channidae	+	+	+	+	+
Chela laubuca	Cyprinidae			+		+
Cirrhinus mrigala	Cyprinidae	+	+	+	+	+
C. reba	Cyprinidae	+	+	+	+	+
Clarias batrachus	Clariidae		+	+	+	+
Clupisoma garua	Schilbeidae	+	+	+	+	+
C. montana	Schilbeidae	+				
Colisa fasciaotus	Osphronemidae	+		+	+	+
C. lalia	Osphronemidae			+		
Crossocheilus latius latius	Cyprinidae	+		+		+
Cyprinus carpio	Cyprinidae					+
Danio devario	Cyprinidae	+		+		+
D. rerio	Cyprinidae	+		+		+
Esomus danricus	Cyprinidae	+	+		+	+
Eutropiichthys murius	Schilbeidae				+	+

Species	Families	MG-1	MG-2	MG-3	MG-4	MG-5
E. vacha	Schilbeidae		+	+	+	+
Gagata cenia	Sisoridae				+	+
Garra gotyla gotyla	Cyprinidae	+		+	+	+
G. prashadi	Cyprinidae			+		
Glossogobius giuris	Gobiidae	+		+	+	+
Glyptothorax dakpathri	Sisoridae	+				
G. indicus	Sisoridae	+				
G. pectinopterus	Sisoridae	+				
Goniolosa manmina	Clupeidae					+
Gudusia chapra	Clupeidae		+	+	+	+
Heteropneustes fossilis	Heteropneustidae	+	+	+	+	+
Hypophthalmichthys molitrix	Cyprinidae					+
Ilisha motius	Pristigasteridae					+
Johnius coitor	Sciaenidae				+	+
Labeo bata	Cyprinidae	+	+		+	+
L. boga	Cyprinidae	+		+		
L. calbasu	Cyprinidae	+	+	+	+	+
L. dero	Cyprinidae	+				
L. dyocheilus	Cyprinidae	+	+			
L. gonius	Cyprinidae	+	+	+	+	+
L. pangusia	Cyprinidae	+		+		+
L. rohita	Cyprinidae	+	+	+	+	+
Laubuca atper	Cyprinidae			+		
Lepidocephalus guntea	Cobitidae	+		+		+
Macrognathus aculeatus	Mastacembelidae		+			+
M. pancalus	Mastacembelidae	+		+		+
Mastacembelus armatus	Mastacembelidae	+	+	+	+	+
Mystus bleekeri	Bagridae		+	+	+	+
M. cavasius	Bagridae		+	+	+	+
M. menoda	Bagridae				+	
M. tengara	Bagridae	+	+	+	+	+
M. vittatus	Bagridae		+	+	+	+
Nandus nandus	Nandidae	+		+	+	+
Nangra nangra	Sisoridae			+		
N. punctata	Sisoridae					+
Nemacheilus bevasni	Balitoridae			+		
N. botia	Balitoridae	+		+	+	+
N. corica	Balitoridae	+		+		
N. montanus	Balitoridae	+		+		
N. multifasciatus	Balitoridae			+		
N. rupecola	Balitoridae	+				
N. savena	Balitoridae			+		
N. scaturingina	Balitoridae			+		
N. zonatus	Balitoridae			+		

Species	Families	MG-1	MG-2	MG-3	MG-4	MG-5
Notopterus chitala	Notopteridae	+	+	+	+	+
N. notopterus	Notopteridae	+	+	+	+	
Ompok bimaculatus	Siluridae			+	+	
O. boopis	Siluridae			+		
O. pabda	Siluridae			+	+	
O. pavole	Siluridae				+	
Ophiocephalus punctatus	Channidae	+				
Osteobrama cotio	Cyprinidae			+	+	+
Oxygaster bacaila	Cyprinidae		+	+	+	
O. gora	Cyprinidae		+			
Pangasius pangasius	Pangasiidae			+	+	
Pseudotropius atherinoides	Schilbeidae				+	
Puntius chagunio	Cyprinidae		+		+	
P. chola	Cyprinidae	+		+		
P. conchonius	Cyprinidae	+				
P. sarana sarana	Cyprinidae	+		+	+	
P. sophore	Cyprinidae	+		+	+	+
P. ticto	Cyprinidae	+		+	+	
Raiamas bola	Cyprinidae	+				+
Rasbora daniconius	Cyprinidae	+		+		
Rhinomugil corsula	Mugilidae	+			+	+
Rita rita	Bagridae	+	+	+	+	+
Salmostoma bacaila	Cyprinidae	+				+
Schizothoracthys progastus	Cyprinidae	+				
Schizothorax plagiostomus	Cyprinidae	+				
S. richardsonii	Cyprinidae	+				
S. sinuatus	Cyprinidae	+				
Sciamugil cascasia	Cyprinidae					+
Securicula gora	Cyprinidae					+
Setipinna phasa	Engraulidae				+	+
Silonia silondia	Schilbeidae		+		+	
Sisor rabdophorus	Sisoridae				+	
Sperata aor	Bagridae		+	+	+	+
S.seenghala	Bagridae	+	+	+	+	+
Tenulosa ilisha	Clupeidae				+	+
Tetraodon cutcutia	Tetraodontidae	+				
Tor putitora	Cyprinidae	+	+	+		
T. tor	Cyprinidae	+		+	+	
Wallago attu	Siluridae		+	+	+	
Xenentodon cancila	Belonidae	+		+	+	

Besides the above list few taxas were reported for which no confirmation was available. The list of the same is given below:

Species	Families	MG-1	MG-2	MG-3	MG-4	MG-5
Amblypharyngodon microlepis	Cyprinidae				+	
Barilius tileo	Cyprinidae					+
Barilus modestus	Cyprinidae			+		
Colisa chuna	Belontidae					+
Glyptothorax telchita	Sisoridae					+
Leiocassis rama	Bagridae				+	
Mugil corsula	Mugilidae		+			
Nangra viridescens	Sisoridae					+
Puntius spp.	Cyprinidae				+	
Rasbora elanga	Cyprinidae			+		

References

Das, I. (1985). Indian turtles: A field guide. WWF, India. (Eastern Region), Eureka Pub. Serv. Calcutta, India.

Dubey, S. and Boswal, M.V. (2009). Diatoms tolerating industrial waters of south Kanpur. *Indian Botanical Society*, **88(3 & 4):** 103-107.

Jhingran, A.G. and Ghosh, K.K. (1978). The fisheries of the Ganga river system in the context of Indian aquaculture. *Aquaculture*. **14:** 141-162.

Jhingran, A.G. and Pathak, V. (1988). Impact on man-induced environmental modifications on productivity potential and energy dynamics of river Ganga. *Journal of Inland Fisheries Society of India*. **20(2)**: 43-53.

Jhingran, V.G. (1974). Fish and fisheries of India. Hindustan Publishing Corporation, Delhi, India, pp. 136-139.

Jhingran, V.G. (1991). Fish and Fisheries of India. Revised and enlarged third edition. Hindustan Publishing Corp., New Delhi, India, pp. 727.

Hussain, S.A. (1999). Reproductive success, hatchling survival and growth of a managed population of Ganges gharial. *Biological Conservation*, **87:** 261-268.

Khan, A.A, Alam, A. and Gaur, R.K. (1998a). Seasonal variation in the abundance and composition of phytoplankton in the river Ganga at Narora, *U.P. Journal Inland Fishery Society*, **30(1):** 79-86.

Khan, M.A., Panwar, R.S., Mathur, A. and Jetly, R. (1998b). Studies on plankton communities and primary production in middle stretch of river Ganga in context of cultural eutrophication. . *Journal Inland Fishery Society*, India, **30(1):** 47-68.

Khanna, D.R. (1989). Limnological study of the river Ganga at Haridwar. D.Phil Thesis, HNB Garhwal University, India.

Khanna, D.R., Malik, D.S. and Rana, D.S. (1998). Phytoplanktonic communities in relation to certain physico-chemical parameters of Ganga canal at Hardwar. *Himalayan Journal of Environment and Zoology.* **12:** 193-197.

Khanna, D.R. and Bhutiani, R. (2003). Limnological characteristics of the river Ganga at Hardwar (Uttaranchal). *Uttar Pradesh. Journal of Zoology*, **23(3):** 179-183.

Menon, A.G.K. (1963). A distribution list of fishes of Himalayas. *Journal of Zoological Society*, India, **14**: 23-32.

Moll, E.O. (1987). Survey of freshwater turtles of India Part II: The Genus *Kachuga*. *Journal of the Bombay Natural History Society*, **84 (1):** 7-25.

Nautiyal, P., Nautiyal, R., Kala, K. and Verma, J. (2004). Taxonomic richness in the diatom flora of Himalayan streams (Garhwal, India). *Diatom*, **20**: 123-132.

Payne, A.I., Sinha R., Singh H.R. and Huq, S. (2004). A review of the Ganges Basin: Its fish and fisheries. Welcomme, R.L. and Petr, T. (Eds.), In: Proceedings of the Second International Symposium of Management of Large Rivers for Fisheries, Vol. 1. Bangkok, Thailand: RAP Publication, FAO Regional Office for Asia and the Pacific, pp. 229-252.

Rao, R.J. (1995). Studies on biological restoration of Ganga river in Uttar Pradesh: An indicator species approach. School of Studies in Zoology, Jiwaji University, Gwalior, India.

Sahgal, J.K. (1973). Fish and fisheries of Aligarh with notes on the fish catches. *Journal of Inland Fisheries Society of India*, **5**: 23-30.

Sinha, M., Laal, A.K., Singh, B., Tyagi, R.K., Pathak, V., and Katiha P.K. (1997). Likely impact on Aquatic ecology in the context of barrage construction across the river Ganga at Kanpur. CIFRI Report, Barrackpore, West Bengal, India.

Sinha, R.K., Behera, S. and Choudhary, B.C. (2010). The conservation action plan for the Ganges river dolphin 2010-2020. National Ganga River Basin Authority Ministry of Environment and Forests, Government of India.

Shivam, A. (2006). Longitudinal distribution of benthic macroinvertebrate communities in the fluvial systems of Vindhyan Hills, D. Phil. Thesis, University of Allahabad, India.

Smith M.A. (1933). The fauna of British India, including Ceylon and Burma. Reptila and Amphibia. Vol I, Loricata, Testudines. Today and Tomorrow's Printers and Publishers, New Delhi.

Untoo, S.A., Khan, A.A. and Parveen, S. (2003). Studies on the distribution and abundance of zooplankton in Ganga river. In: River Pollution in India and its Management. APH Publishing Corporation, New Delhi, India, pp. 147-167.

Whitaker, R. and Basu, D. (1983). The Gharial (*Gavialis gangeticus*): A review. *Journal of the Bombay Natural History Society*, **79(3):** 531-548.

Zafar, A. and Sultana, N. (2005). Zooplankton and microinvertebrates of river Ganga at Kanpur. *Uttar Pradesh Journal of Zoology*. **25(1)**: 63-66.

Zoological Survey of India. (1991). Faunal resources of Ganga. Part I. Zoological Survey of India. Calcutta, India, pp. 145.

Floral and Faunal Diversity in Lower Ganga

Varanasi to Farakka

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Environment Management Plan (GRB EMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

The river Ganga comprises a lotic water series, which originates at Gaumukh and flows down to Gangasagar traversing a distance of 2525 km. During its course through eleven states, the river receives numerous tributaries (with characteristic quality, pollution load and biota) including Bhilangana, Alaknanda, Ram Ganga, Kali, Yamuna, Gomti, Ghagra, Gandak, and Kosi.

A thorough review of a large number of studies available in the form of student's project reports and theses, reports produced through sponsored, consultancy, investigatory and Environment Impact Assessment studies, published papers/articles in journals/ conference/ workshop/ symposia proceedings, books, news paper articles, etc. has led to collection of fragmented information on ecology and biodiversity in the Ganga Basin. The information is in different time domain and isolated stretches largely governed by the period of the study and the proximity of a river stretch/water body to the investigating institutions, organizations or individuals involved in the study. Due to lack of definitive bio-monitoring programme like river water quality monitoring programmes by the Central Pollution Control Boards, State Pollution Control Boards and National River Conservation Directorate, the analysis is based on extrapolation and interpolation of scattered, mostly qualitative data/information.

The entire stretch of the river Ganga (main stem) can be viewed into three segments:

A.	*Upper Ganga*	*≈* ***294*** *km*	*Gaumukh to Haridwar*
B.	*Middle Ganga*	*≈* ***1082*** *km*	*Haridwar to Varanasi*
C.	*Lower Ganga*	*≈* ***1134*** *km*	*Varanasi to Ganga Sagar*

(The Upper Ganga Segment for all practical purposes and studies carried out, starts at Gangotri as the terrain between Gaumukh to Gangotri is essentially devoid of biota due to hostile conditions)

These three segments not only differ in their geomorphology, ecology and rheology but are different in terms of issues that need to be addressed (refer report 001_GBP_IIT_GEN_ANL_01_Ver 1_Dec 2010). Considering this, floral and faunal diversity of the main stem of Ganga is reported in a series of four reports. This report covers the fresh water zone of lower Ganga stretch from Varanasi to Farakka (LG-A). The lower Ganga comprises of a fresh water zone (Varanasi to Farakka) 701 km (LG-A) and estuarine zone (Farakka to Gangasagar) 286 km (LG-B). The LG-A zone spreads through three states *viz.* Uttar Pradesh, Bihar, West Bengal and includes five important towns, Varanasi, Buxar, Patna, Bhagalpur and Farakka (Figure 1).

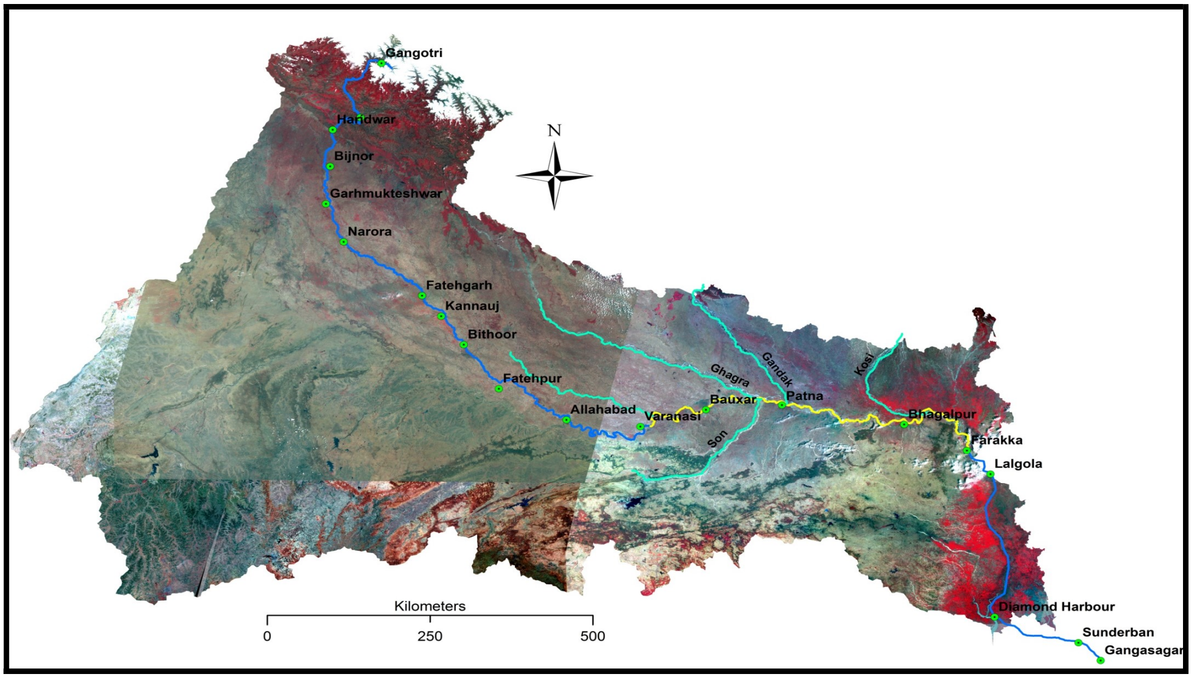

Figure 1: Ganga in lower fresh water zone (LG-A) and their major tributaries

(* The LG-A zone represented from yellow and green colour, respectively)

This stretch is characterized by the presence of number of tributaries. Downstream of Varanasi, the Varuna joins the Ganga on the left bank at Khalispur. The river then flows to Ghazipur, where it joins the united stream of two major tributaries, the Sai and the Gomti. Further downstream, the Ganga receives the Basu Nadi on the left and the Karamnasa on the right bank at Narbatpur. Before reaching Buxar, Ganga is joined by the Thora on the right bank. It then enters Bihar passing through Ballia. At the Uttar Pradesh-Bihar border the Ghagra which is formed by the confluence of Sarda, Sarju, Gori and Kali joins the Ganga on the left bank.

In Bihar the Ganga receives the Sone, Gandak and Punpun. The Gandak, which originates from Nepal is formed by seven holy Gandakis and join the Ganga on the left bank at Hazipur. After passing through Patna it receives water from the Patna canal and the combined stream of the Punpun, Morhan, and Dordhan at Fatuha and moves to Munger. The united stream of the Harohar, Dhanayan, Mohani, and Dharhara river joins on the right bank and the Barhi Gandak on the left bank. Then on its way to Bhagalpur, the Ganga receives the Man and Jumania river on the right bank. Downstream of Bhagalpur, the Kosi joins Ganga at Kursela on the right bank and then the river enters West Bengal (Mathur, 1991).

The river bed of this region is sandy in nature with 80-90% sand and low percentage of silt and clay. But from Bhagalpur to Farakka, the sand contribution declines considerably with 54-69% sand and substantial increase in silt content. Sand bed is indicator of low aquatic productivity. This is compensated by the nutrient flow from the basin. Due to the confluence of number of tributaries water velocity in this stretch is high. The slope of the river Ganga is appreciably reduced from Varanasi to Farakka due to silting. In this region sediment load is very high and the substrate is silt over sand (Mathur, 1991).

Like middle Ganga this stretch of lower Ganga also supports good growth of biological communities due to the presence of nutrients, higher temperature and clean water with high velocity. Good solar radiation also supports the primary productivity. The biodiversity in this stretch is very similar to middle Ganga and that it does not vary significantly at different stretches. Thus the fresh water zone of lower Ganga has been considered a single stretch (LG-A) from Varanasi to Farakka.

2. Biological Profile

The data of biological communities has been taken from biological profile of the Ganga and ecological imbalance of the Ganga river system and consists of phytoplankton, zooplankton, zoobenthos including macro-invertebrates, fish and higher vertebrates specially Gangetic dolphin (Sreenivasaprasad, 1991; Bilgrami, 1991; Ray, 1998; Nesemann *et al*. 2011).

2.1. Phytoplankton

Phytoplankton constitutes the main autotrophic component of Ganga river. They are microscopic, free floating and belong to ten classes of algae of which Cyanophyceae, Bacillariophyceae, and Chlorophyceae, comprises 93% of the taxa. The other seven classes are Euglenophyceae, Chrysophyceae, Dinophyceae, Xanthophyceae, Cryptophyceae, Rhodophyceae and Synurophyceae. The most productive stretches of the river Ganga are middle and lower. A representation of taxa and percent composition of various classes of algae reported from fresh water zone (LG-A) of the Ganga river are shown in Figure 2 and 3, respectively.

The diatoms constitute the major group in upper Ganga, while diatoms, green algae and blue green algae in that order represent the dominant group in the middle Ganga and green algae, diatoms and blue green algae predominate in the lower Ganga. In addition, the lower Ganga also includes the other seven classes as well. The species richness of total taxa could be represented as:

Chlorophyceae (91) > **Bacillariophyceae (81)** > **Cyanophyceae (78)** > **Euglenophyceae (8)** > **Chrysophyceae, Xanthophyceae (3)** > **Dinophyceae, Rhodophyceae (2)** > **Cryptophyceae, Synurophyceae (1)**

****(The number in parenthesis represents number of taxa)***

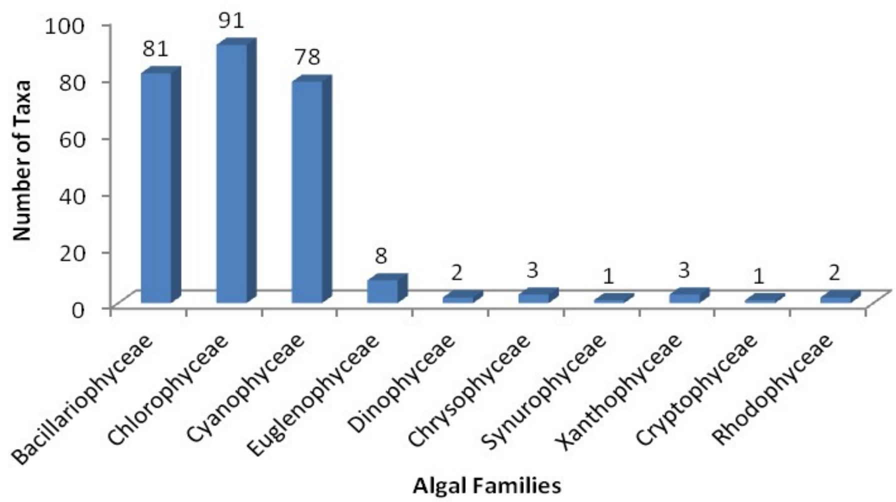

Figure 2: Changing pattern of algal dominance in lower Ganga (LG-A)

A compendium of algae reported in different stretches is given in the Appendix I.

The most common genera of Bacillariophyceae are *Amphora, Cymbella, Fragillaria, Gomphonema, Melosera, Navicula, Pinnularia, Surirella, Synedra*; Cyanophyceae are *Anabaena, Aphanocapsa, Chroococcus, Lyngbya, Merismopedia, Microcystis, Oscillatoria, Phormidium, Spirulina*; Chlorophyceae are *Chlamydomonas, Closterium, Crucigenia, Cosmerium, Pediastrum, Scendesmus, Ulothrix, Spirogyra*, Euglenophyceae are *Euglena, Phacus*; Chrysophyceae is *Dinobryon*; Synurophyceae is *Synura* and Dinophyceae are *Ciratium* and *Peridinium*.

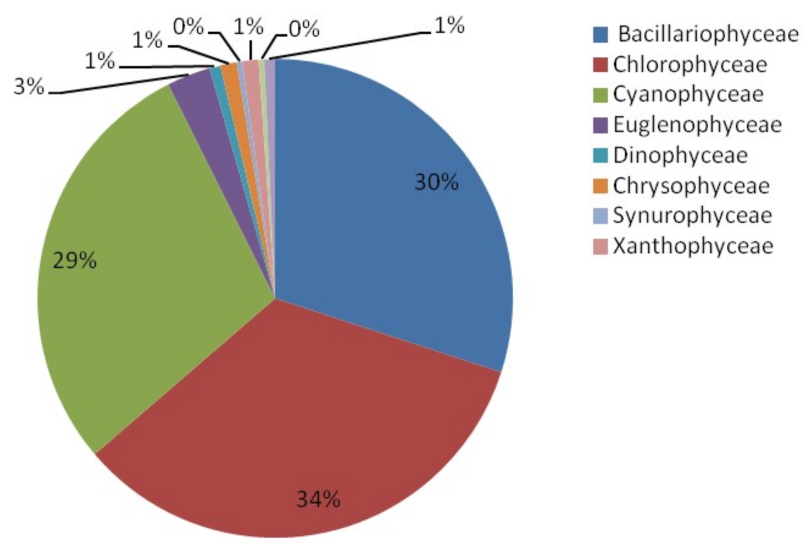

Figure 3: Distribution of various classes of algae in lower Ganga (LG-A)

2.2. Zooplankton

Zooplankton comprises of Protozoans, Rotifers and Crustaceans (Copepods and Cladocerans). In this stretch all groups are represented though are low in specific composition. In normal routine biomonitoring surveys when plankton samples are collected through plankton nets (bolting silk) protozoans escape and are not caught. For them, either Sedgwick rafter funnels or centrifuge usage is desired. The complete list of zooplankton is mentioned in Appendix II. The distribution of zooplankton in LG-A along with important genera is:

Protozoa (Total taxa reported 8 under 5 genera**):** *Acella, Centropyxis, Difflugia, Paramecium, Vorticella*

Rotifera (Total taxa reported 26 under 12 genera**):** *Asplanchna, Brachionus, Euchlanis, Filinia, Keratella, lecane, Monostyla, Polyarthra, Rotaria, Synchaeta, Testudinella, Trichocera*

Cladocerans (Total taxa reported 13 under 8 genera**):** *Alona, Bosmina, Bosminopsis, Ceriodaphnia, Daphnia, Diaphanosoma, Moina, Simocephalus*

Copepoda (Total taxa reported 5 under 4 genera**):** *Cyclops, Diaptomus, Mesocyclops, Neodiaptomus*

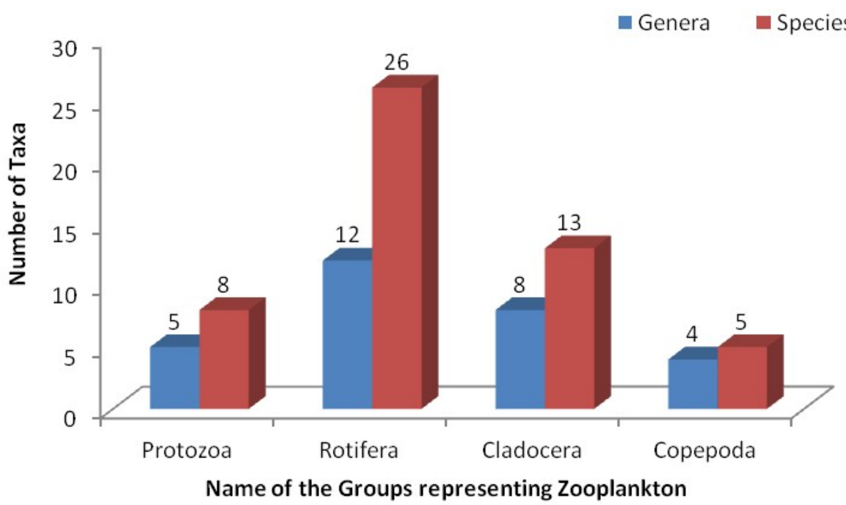

Figure 4: Distribution of Genus/Species in zooplankton

2.3. Zoobenthos and Macro-invertebrates

The Ganga is a natural repository of a wide range of fauna. Besides fish, higher vertebrates and zooplankton some other animals constitute a link of operative food chain in the system. They include zoobenthos and macro-invertebrates. A large number of insects, annelids, crustaceans and molluscs have been reported in the entire stretch depending largely on the type of substratum. Hard substratum consisting of boulders, cobbles, stone and pebbles support breeding places of insect larvae. In the upper Ganga and some parts of middle Ganga where substratum is hard and stony and at places mixture of sandy and stony largely supports insect larvae of families of Plecoptera, Trichoptera, Ephemeroptera, Odonata and

Diptera. Later part of middle and lower Ganga with soft substratum and accumulation of lignocellulosic materials supports insects of order Diptera, Coleopteran, and Hemiptera. In addition soft substratum supports Annelids, Nematodes and Molluscs.

The benthic community of lower Ganga (LG-A) is reported to be very rich in diversity and high in abundance in the region around Patna. Ninety five invertebrate taxa have been recorded including Annelids, Molluscs, Insects and Crustaceans which included 12 taxa of marine originated families also (Nereididae, Nephtheidae, Ozobranchidae, Stenothyridae, Arcidae, Psammobiidae, Mysidae, Corallanidae and Hymenosomatidae) (Nesemann *et al.* 2011). The percent and group wise distribution are shown in Figure 5 and 6.

The data reveals a high representation of Annelids (21%), Molluscs (36%), Insects and others Arthropods (43%). The Molluscs (46 taxa) of which Gastropods are represented by 26 taxa and Pelecypoda by 20 taxa. Among Annelids Nesemann *et al.* (2011) reported, Oligocheaetes 14 taxa which are predominant over Polycheates (3 taxa) and Hirudinea (9 taxa). Order Mysida, Isopoda, Decapoda and Insecta represented Arthropods. The Insecta was however, more than other Arthropods constituted with Odonata, Trichoptera, Lepidoptera, Diptera, Heteroptera, Coleoptera (30 sp.) (Nesemann *et al.* 2011). A list of zoobenthos recorded by Bilgrami (1991) and Nesemann *et al.* (2011) in lower stretch is given in Appendix III.

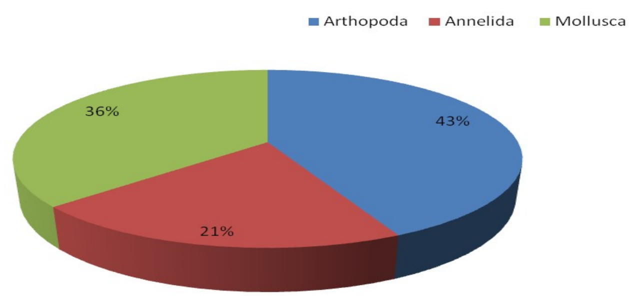

Figure 5: Distribution of zoobanthos in lower Ganga (LG-A)

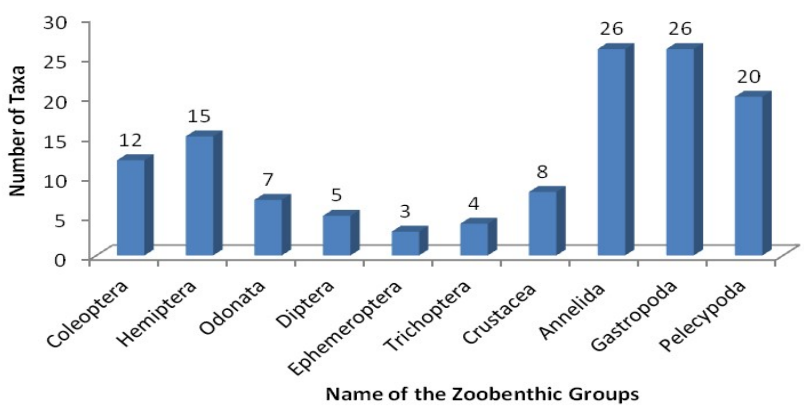

Figure 6: Distribution of zoobenthos in lower Ganga (LG-A)

Twelve species of macro invertebrates present at Patna belong to marine-originated (primary brackish) water families:

Family	Species
Nereididae	*Namalycastis indica*
Nephtheidae	*Nephthys oligobranchia*
Ozobranchidae	*Ozobranchus shipleyi*
Stenothyridae	*Stenothyra ornata, Gangetia miliacea*
Arcidae	*Scaphula celox, S. deltae*
Pammobiidae	*Novaculina gangetica*
Mysidae	*Gangemysis assimilis*
Stenothyridae	*Tachaea spongillicala*
Hymenosomatidae	*Hymenicoides carteri, Neorhynchoplax* spp.

Nesemann *et al.* (2011)

2.4. Fish

The lower Ganga from Varanasi to Farakka is one of the largest productive stretch for the inland catch fisheries. This is also borne out by the fact that out of nine important fish catch centers located on the river Ganga five are located on this stretch viz. Varanasi, Buxar, Ballia, Patna and Bhagalpur. This stretch supports 121 species belonging to 36 families out of a total of 179 species reported in the fresh water zone of river Ganga (UG-1 to LG-A). Thirty five commercially important fishes are included in the taxa along with six invasive species. Every third fish caught belongs to the family Cyprinidae. The important fish reported are the four Indian major carps viz. *Labeo rohita, L. calbasu, Catla catla,* and *Cirrhina mrigala,* some other carps viz. *Labeo dero, Cirrhina reba, Labeo bata,* Cat fish *Ailia coila* and other fish *Puntius sophore*. A complete list of the fishes recorded is given in the Appendix IV along with their families. Out of four exotic (invasive fishes), *Cyprinus carpio* (Chinese carp) and *Oreochromis niloticus* (Tilapia) grows luxuriantly in the stretch. The relative abundance of various fish families are depicted below:

Cyprinidae (40 sp.) > **Sisoridae, Bagridae (9 sp. each)** > **Channidae (5 sp.) > Clupeidae, Cobitidae, Schilbeidae, Siluridae (4 sp. each) > Chandidae, Mestacembelidae, Sciaenidae (3 sp. each)** > **Ambassidae, Engraulidae, Gobiidae, Mugilidae, Notopteridae, Pangasiidae, Tetraodontidae, Osphronemidae (2 sp. each)** > **Anabantidae, Anguillidae, Badidae, Balitoridae, Belonidae, Chacidae, Cichlidae, Clariidae, Heteropneustidae, Latidae, Megalopidae, Muraenidae, Nandidae, Osphronemidae, Polynemidae, Sillaginidae, Synbranchidae (1 sp. each).**

Tenulosa ilisha which at one time was a prominent commercially important fish prior to the construction of Farakka barrage in 1975 has now become a rarity. *Tenulosa* is not able to migrate upstream for breeding upto Varanasi due to physical barriers at Farakka dam. At Patna the total catch of *Tenulosa ilisha* before and after the construction of Farakka barrage has gone down from 12.9% to 0.17% while at Lalgola the fish catch which was about 92.02% of *Tenulosa* has a mere 16.8% representation now.

Among other important fishes are *Sperata aor, Sperata seenghala, Silonia silondia, Wallago attu, Bagarius bagarius, Rita rita, Eutropiicthys vacha, Ompak bimaculatus, Notopterus notopterus and Notopterus chitala.* A graphic representation of families with species recorded is shown in Figure 7.

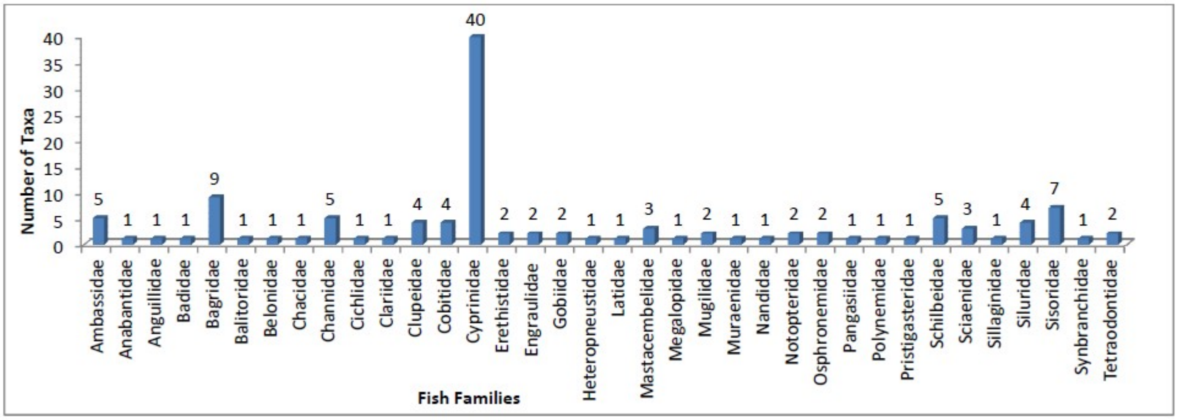

Figure 7: The distribution of fishes of Lower Ganga (LG-A)

Aristichthys nobilis, Cttenopharyngodon idella, Hypophthalmicus molitrix, Clarias gariepinus, other invasive species have also been reported as stray catch by Singh *et al.* (2010).

It has been reported in the annual reports of central Inland Fisheries Research Institute (CIFRI) and other documents that due to water obstruction in the upper Ganga, water abstraction in middle Ganga and rampant pollution by treated and untreated domestic and industrial wastes the fish catch has been reduced drastically and the yield rate kg/km at Patna and Bhagalpur along with all other centers has gone down drastically.

The most characteristic fish of the reach in addition to *Tenualosa ilisha* are Indian major carps. (Jhingran, 1974, 1975, 1989, 1991; Jhingran and Ghosh, 1978; Jingran and Pathak, 1988; Payne *et al.* 2003; Rao, 1995; Sehgal, 1973; Sinha and Prasad, 1988; Singh *et al.* 2010; Vass *et al.* 2010).

2.5. Higher vertebrates

Beside the preponderance of fish species in this zone, an aquatic mammal, Gangetic dolphin *Platanista gangetica gangetica* has been reported to be present in this stretch. Indian Gangetic Gharyals *Gavialis gengeticus* has been reported in Hooghly river. Salt water crocodile *Crocodylus porosus* has however, been reported in the deltaic region. Number of fresh water turtles has been reported in between Varanasi to Farakka.

As per existing reports, dolphin population has been reported in the lower Ganga are given below:

Allahabad to Buxar (425 km)	172 d/s Survey Sinha *et al.* (2000)
Buxar to Manihari Ghat (500 km)	24 d/s Survey Unpublished Data Dec. 2004
Farakka feeder canal (38 km)	21d/s Survey Sinha *et al.* (2000)

References

Bilgrami, K.S. (1991). Biological profile of the Ganga: Zooplankton, fish, birds and other minor fauna. *In*: Krishna Murti, C.R., Bilgrami, K.S., Das, T.M., Mathur, R.P. (eds.). The Ganga: A scientific study. Northern Book Centre, New Delhi, India. pp. 81-94.

Jhingran, V.G. (1975). Fish and fisheries of India. Hindustan Publishing Corporation, Delhi, India.

Jhingran, A.G. and Ghosh, K.K. (1978). The fisheries of the Ganga river system in the context of Indian aquaculture, *Aquaculture.* **14:** 141-162.

Jhingran, A.G. and Pathak, V. (1988). Impact on man-induced environmental modifications on productivity potential and energy dynamics of river Ganga. *Journal of Inland Fisheries Society of India*. **20:** 43-53.

Jhingran, A.G. (1989). Impact of environmental perturbations on the fisheries ecology of river Ganga, A synopsis, CIFRI, Barrackpore (W.B.), India. pp. 26.

Jhingran, V.G. (1991). Fish and Fisheries of India. Revised and enlarged third edition. Hindustan Publishing Corp., New Delhi, India. pp. 727.

Jhingran. V.G. (1974). Fish and Fisheries of India, Hindustan Publishing Corporation, Delhi, India. pp. 136-139.

Mathur, R.P. (1991). Stretches of the Ganga covered in the study. *In:* The Ganga: A Scientific study. Krishna Murti, C.R., Bilgrami, K.S., Das, T.M. and Mathur, R.P. (eds.). Northern Book Center, New Delhi, India. pp. 19-21.

Nesemann, H., Sharma, G., and Sinha, R.K. (2011). Benthic-macroinvertebrate fauna and Marine Elements SENSU ANNADALE (1992) highlight the valuable dolphin habitat of river Ganga in Bihar-India. *Taprobanica*. **3(1):** 18-30.

Payne, A.I., Sinha, R., Singh, H.R. and Huq, S. (2003). A review of the Ganges Basin: Its fish and fisheries. *In:* Welcomme, R.L. and Petr, T. (eds.) Proceedings of the Second International Symposium of Management of Large Rivers for Fisheries, Vol. 1. Bangkok, Thailand: RAP Publication, FAO Regional Office for Asia and the Pacific, pp. 229-252.

Rao, R.J. (1995). Studies on Biological Restoration of Ganga River in Uttar Pradesh: An indicator species approach, School of Studies in Zoology, Jiwaji University, Gwalior, India.

Ray, P. (1998). Limnological studies. *In:* Ecological imbalance of the Ganga River system: Its impact on aquaculture. Daya Books, New Delhi, India. pp. 69-101.

Sehgal, J.K. (1973). Fish and Fisheries of Aligarh with notes on the fish catches. *Journal of Inland Fishery Society*. **5:** 23-30.

Singh, A.K. (1988). Ecophysiological studies on algae of river Ganga in relation to heavy metal pollution. *Ph.D. Thesis.* Banaras Hindu University, India.

Sinha, R.K. and Prasad, K. (1988). Final Technical Report of Ganga Basin Research Project, Patna University, India. pp. 88.

Sinha, M., De, D.K., Jha, B.C. (1998). The Ganga–Environment and fishery. *Central Inland Fisheries Research Institute*, Barrackpore, India.

Sinha, M. and Khan, M.A. (2010). Impact of environmental aberrations on fisheries of the Ganga (Ganges) river. *Journal of Aquatic Ecosystem Health and Management*. **4(4):** 493-504

Singh, A.K., Pathak, A.K. and Lakra, W.S. (2010). Invasion of an exotic fish-common carp, *Cyprinus carpio* (Actinopterygii: Cypriniformes: Cyprinidae) in the Ganga river, India and its impacts. *Acta ichthyologica et piscatorial*. **40(1):** 11-19.

Sreenivasaprasad, S. (1991). Biological profile of the Ganga: Phytoplankton. *In*: Krishna Murti, C.R., Bilgrami, K.S., Das, T.M. and Mathur, R.P. (eds.) The Ganga: A Scientific Study. Northern Book Centre, New Delhi, India. pp. 55-63.

Tiwari, D. (1983). Pollution phycology of the Varanasi frontage of river Ganga. *Ph.D. Thesis.* Banaras Hindu University, India.

Vass, K.K., Mondal, S.K., Samanta, S., Suresh, V.R. and Katiha, P. K. (2010). The environment and fishery status of the river Ganges. *Aquatic Ecosystem Health and Management*. **13(4):** 385-394.

Appendix I

List of phytoplankton in lower Ganga from Varanasi to Farakka

Bacillariophyceae
Achnanthes delicatula
A. microcephalla
Achnanthidium clevei
Amphora sp.
A. ovalis
A. veneta
Asterionella japonica
Caloneis sp.
Chaetoceros sp.
Cocconeis placentula
Cyclotella sp.
Cymatopleura sp.
Cymbella sp.
C. microcephala
C. turgida
C. turgidula
C. tumida
C. ventricosa
Diatoma elongatum
D. vulgare
Eunotia sp.
Fragillaria sp.
F. intermedia
Gomphonema constrictum
G. clevei
G. intricatum
G. lanceolata
G. parvulum
G. sphaerophorum
G. subclavatum
Grammatophora sp.
Gyrosigma sp.
G. distortum
G. scalproides
Hantzschia sp.
Leptocylindrus sp.

Bacillariophyceae
Mastogloia sp.
Meridian sp.
Melosira ambigua
Navicula sp.
N. cincta
N. cryptocephala
N. cuspidata
N. gracilis
N. gregaria
N. minima
N. mutica
N. salinarum
N. viridula
Nitzschia sp.
N. acicularis
N. amphibia
N. communis
N. filiformis
N. gandersheimiensis
N. gracilis
N. linearis
N. palea
N. parvula
N. perspicillata
N. rostellata
N. sigma
N. subtilis
N. thermalis
Pinnularia sp.
P. interrupta
P. nobilis
P. viridis
Pleurosigma sp.
P. angulatum
Sellaphora pupula
Surirella sp.
S. elegans
Synedra sp.

Bacillariophyceae
S. acus
S. rumpens
S. ulna
Tabellaria sp.
T. flocculosa
Thalassiosira sp.
Terpsinoe sp.
Chlorophyceae
Actinastrum hantzschii
Ankistrodesmus sp.
A. falcatus
A. spiralis
Bulbochaete sp.
Chaetophora sp.
Chara wallichii
Chlamydomonas mirabilis
Chlorella sp.
C. vulgaris
Chlorococcum sp.
Chodatella sp.
Cladophora sp.
C. glomerata
Closteriopsis sp.
Closterium sp.
C. acutum
C. calosporum
C. cynthia
C. ehrenbergii
C. leibleinii
C. nematodes
C. rostratum
C. tumidulum
Cosmarium sp.
C. auriculatum
C. blyttii
C. ctenoideum
C. galeritum
C. gostyniense

Chlorophyceae
C. isthmochondrum
C. pseudobroomei
C. pseudopyramidatum
C. sublatereundatum
C. tenue
Coelastrum cambricum
C. microporum
Crucigenia crucifera
Cylindrocapsa sp.
Desmidium sp.
Dictyosphaerium sp.
Dictyosphaerium pulchellum
Enteromorpha sp.
Euastrum sp.
E. carinatum
Eudorina sp.
Gloeotaenium loitlesbergerianum
Golenkinia radiata
Hydrodictyon sp.
H. reticulatum
Kirchneriella sp.
K. contorta
K. obese
Microspora sp.
Nitella acuminata
Oocystis elliptica
Oedogonium sp.
Pandorina morum
Pediastrum sp.
P. duplex
P. simplex
P. tetras
Protococcus sp.
Schroederia planctonica
Selenastrum sp.
Scenedesmus sp.
S. abundans
S. arcuatus

Chlorophyceae
S. armatus
S. bijugatus
S. dimorphus
S. falcatus
S. quadricauda
Sorastrum spinulosum
Sphaeroplea sp.
Spirogyra sp.
S. affinis
S. borgeana
S. hyaline
S. inflata
S. maravillosa
S. paludosa
S. setiformis
S. singularis
Stigeoclonium sp.
Tetraedron minimum
Treubaria triappendiculata
Ulothrix sp.
U. zonata
Volvox sp.
Zygnema sp.
Cyanophyceae
Anabaena sp.
A. circularis
A. cylindrica
A. fertilissima
A. laxa
A. orientalis
Anabaenopsis arnoldi
Anacystis montana
Aphanocapsa sp.
Aphanothece sp.
A. microscopica
A. pallida
Arthrospira sp.
A. jenneri

Cyanophyceae
A. tenuis
Aulosira fertilissima
Calothrix elenkini
C. fusca
Chroococcus minor
C. turgidus
Cylindrospermum sp.
C. licheniforme
Gloeocapsa sp.
G. quternata
Gloeotrichia echinulata
Lyngbya sp.
L. gracilis
L. heironymusii
L. limnetica
L. magnifica
L. confervoidis
Mastigocladus sp.
Merismopedia aeruginea
M. elegans
M. glauca
M. punctata
Microcoleus sp.
M. chthonoplastes
Microcystis aeruginosa
M. flosaquae
M. protocystis
Myxosarcina sp.
Nostoc sp.
N. linckia
Nodularia sp.
N. spumigena
Oscillatoria sp.
O. amphibia
O. chilkensis
O. chlorine
O. formosa
O. limosa

Cyanophyceae
O. proteus
O. princeps
O. raciborskii
O. subbrevis
O. tanganyikae
O. tenuis
O. willei
Phormidium sp.
P. calcicola
P. inundatum
P. purpurascens
P. uncinatum
Pseudanabaena schmidlei
Raphidiopsis curvata
Rivularia aquatic
Schizothrix sp.
Spirulina gigantea
S. major
S. meneghiniana
S. subsalsa
Symploca sp.
Synechococcus elongatus
Synechocystis sp.
S. aquaticus
Trichodesmium sp.
Tolypothrix sp.
Euglenophyceae
Euglena sp.
E. acus
E. oxyuris
E. proxima
E. viridis
Heteronema sp.
Phacus sp.
P. caudatus
Dinophyceae
Ciratium sp.
Peridinium sp.

Chrysophyceae
Chrysococcus sp.
Dinobryon sp.
D. sertularia
Synurophyceae
Synura sp.
Xanthophyceae
Tribonema sp.
T. bombycinum
Voucheria sp.
Cryptophyceae
Chroomonas sp.
Rhodophyceae
Batrachospermum sp.
Compsopogon sp.

Appendix II

Zooplankton of the lower Ganga from Varanasi to Farakka

Protozoa	*Arcella* sp.
	A. discoides
	Centropyxis aculeta
	C. ecornis
	Difflugia sp.
	D. oblonga
	Paramecium sp.
	Vorticella sp.
Rotifera	*Asplanchna* sp.
	A. peroodonota
	Brachionus angularis
	B. caudatus
	B. calyciflorus
	B. diversicornis
	B. falcatus
	B. forficula
	B. quadridentatus
	B. rubens
	Euchlanis dilatata
	Filinia longiseta
	F. terminalis
	Keratella sp.
	K. cochlearis
	K. tropica
	K. serrulata
	Lecane elasma
	Monostyla sp.
	M. bulla
	M. closterocerca
	Polyarthra vulgaris
	Rotaria sp.
	Synchaeta sp.
	Testudinella sp.
	Trichocera multicrinis

Cladocera	*Alona* sp.
	A. dentifera
	Bosmina sp.
	B. longirostris
	Bosminopsis sp.
	Ceriodaphnia sp.
	C. rigaudi
	Daphnia lumholtzi
	D. carinata
	Diaphanosoma excisum
	Moina sp.
	M. brachiata
	Simocephalus sp.
Copepoda	*Cyclops* sp.
	Diaptomus sp.
	Mesocyclops leuckarti
	M. hyalinus
	Neodiaptomus sp.

Appendix III

Zoobenthos of the lower Ganga from Varanasi to Farakka

Coleoptera
Berosus indicus
B. pulchellus
Cybister tripunictatus
Dineutes spinosus
Guignotus pradhani
Haliplus pulchellus
Hydrophilus olivaceous
Laccobius sp.
L. anticatus
L. purvulus
Laccophilus chinensis
Regimbartia attenuata
Hemiptera
Amphiops sp.
Anisops sardea
Belostoma sp.
Canthydrus sp.
C. lactabilis
Corixa heiroglyphica
C. promontoria
Diplonychus annulatum
Gerris fossarum
Hydrometra sp.
Laccotrephes griseus
Micronecta merope
Notonecta sp.
Plea frontlis
Ranatra filiformes
Odonata
Asiagomphus sp.
Cordulegaster sp.
Ischnura delicata
I. senegalensis
Macrogomphus sp.
Paragomphus lineatus
Potomarcha obscura
Diptera
Anopheles sp.
Chironomus sp.
Clinotanypus sp.
Culex sp.
Monopelopia sp.
Ephemeroptera
Baetis sp.
Cloeon sp.
Ephemerella sp.
Trichoptera
Glossosoma sp.
Hydropsychidae sp.
Limephilus sp.
Triaenodes sp.
Crustacea
Barythelphusa lugubris
Caridina sp.
Gangemysis assimilis
Hymenicoides carteri
Macrobrachium sp.
Neorhynchoplax sp.
Parathelphusa martensi
Tachaea spongillicola
Annelida
Alboglossiphonia pahariensis
A. weberi
Allonais paraguayensis
Asiaticobdella birmanica
Aulodrilus pigueti
Aulophorus indicus
Barbronia weberi
Branchiodrilus semperi
Branchiura sowerbyi
Annelida

Chaetogaster limnaei
Dero pectinata
Glyphidrilus gangeticus
Limnodrilus hoffmeisteri
Nais sp.
N. bretscheri
Namalycastis indica
Nephthys oligobranchia
N. polybranchia
Odontobdella krishna
Ozobranchus shipleyi
Perionyx excavatus
Placobdelloides fulvus
Pristina acuminata
P. biserrata
Salifa biharensis
S. lateroculata
Mollusca
Gastropoda
Amnicola sp.
Assiminia sp.
Bellamya bengalensis
Brotia costula
Digoniostoma pulchella
Ferrissia baconi
F. verruca
Gangetia miliacea
Glessula sp.
Gyraulus convexiusculus
Haitia mexicana
Hydrobia sp.
Indoplanorbis exustus
Lymnaea sp.
L. acuminate
Mekongia crassa
Gastropoda

Melania tuberculata
Melanoides tuberculatus
Pila globosa
Planorbis sp.
Quickia bensoni
Stenothyra ornate
Thiara granifera
T. lineata
T. scabra
T. tuberculatus
Pelecypoda
Corbicula assamensis
C. aurea
C. bensoni
C. regularis
C. striatella
Lamellidens consobrinus
L. corrianus
L. marginalis
Novaculina gangetica
Parreysia caerulea
P. corugata
P. favidens
P. lima
P. occata
P. olivaria
P. pachysoma
Pisidium clarkeanum
P. nevillianum
Scaphula celox
S. deltae

Appendix IV

Fishes of the lower Ganga from Varanasi to Farakka

Species	Families
Ailia coila	Schilbeidae
Anabas testudineus	Anabantidae
Amblypharyngodon mola	Cyprinidae
Anguilla bengalensis	Anguillidae
Aspidoparia jaya	Cyprinidae
A. morar	Cyprinidae
Badis badis	Badidae
Bagarius bagarius	Sisoridae
Barilius bendelensis	Cyprinidae
B. bola	Cyprinidae
Botia dario	Cobitidae
B. dayi	Cobitidae
B. lohachata	Cobitidae
Catla catla	Cyprinidae
Chaca chaca	Chacidae
Chagunius chagunio	Cyprinidae
Chanda baculis	Ambassidae
C. nama	Ambassidae
C. ranga	Ambassidae
Channa orientalis	Channidae
C. gachua	Channidae
C. marulius	Channidae
C. punctatus	Channidae
C. striatus	Channidae
Chela atpar	Cyprinidae
C. bacaila	Cyprinidae
C. laubuca	Cyprinidae
Cirrhinus mrigala	Cyprinidae
C. reba	Cyprinidae
Clarias batrachus	Clariidae
Clupisoma garua	Schilbeidae
Colisa chuna	Osphronemidae
C. fasciata	Osphronemidae
Cyprinus carpio	Cyprinidae
Danio devario	Cyprinidae
D. rerio	Cyprinidae
Erethistes hara	Sisoridae
Species	**Families**

E. pusillus	Sisoridae
Esomus danricus	Cyprinidae
Eutropiichthys vacha	Schilbeidae
Gacata cenia	Sisoridae
G. gagata	Sisoridae
Garra annandalei	Cyprinidae
G. gotyla gotyla	Cyprinidae
Glossogobius giuris	Gobiidae
Goniolosa manmina	Clupeidae
Gobiopterus chuno	Gobiidae
Gudusia chapra	Clupeidae
G. variegate	Clupeidae
Hara hara	Sisoridae
Heteropneustes fossilis	Heteropneustidae
Ilisha motius	Pristigasteridae
J. coitor	Sciaenidae
Johnius gangeticus	Sciaenidae
Labeo bata	Cyprinidae
L. boga	Cyprinidae
L. boggut	Cyprinidae
L. calbasu	Cyprinidae
L. dero	Cyprinidae
L. fimbriatus	Cyprinidae
L. gonius	Cyprinidae
L. pangusia	Cyprinidae
L. rohita	Cyprinidae
Lates calcarifer	Latidae
Lepidocephalus guntea	Cobitidae
Lycodontis tile	Muraenidae
Macrognathus aral	Mastacembelidae
M. pancalus	Mastacembelidae
Mastacembelus armatus	Mastacembelidae
Megalops cyprinoides	Megalopidae
Monopterus cuchia	Synbranchidae
Mystus bleekeri	Bagridae
M. cavasius	Bagridae
M. gulio	Bagridae
M. menoda	Bagridae
M. tengara	Bagridae
M. vittatus	Bagridae
Nandus nandus	Nandidae

Species	Families
Nangra nangra	Sisoridae
N. punctata	Sisoridae
Nemacheilus botia	Balitoridae
Notopterus chitala	Notopteridae
N. notopterus	Notopteridae
Ompok bimaculatus	Siluridae
O. pabda	Siluridae
O. pavel	Siluridae
Oreochromis niloticus	Cichlidae
Osteobrama cotio	Cyprinidae
Oxygastor gora	Cyprinidae
Pama pama	Sciaenidae
Pangasius pangasius	Pangasiidae
Parambassis ranga	Ambassidae
Polynemus paradiseus	Polynemidae
Pseudoambasis ranga	Ambassidae
Pseudotropius atherinoides	Schilbeidae
Puntius chola	Cyprinidae
P. chrysopterus	Cyprinidae
P. conchonius	Cyprinidae
P. sarana sarana	Cyprinidae
P. sophore	Cyprinidae
P. ticto	Cyprinidae
Rasbora daniconius	Cyprinidae
Rhinomugil corsula	Mugilidae
Rita rita	Bagridae
Salmostoma bacaila	Cyprinidae
S. phulo	Cyprinidae
S. untrahi	Cyprinidae
Sciamugil cascasia	Mugilidae
Securicula gora	Cyprinidae
Setipinna brevifilis	Engraulidae
S. phasa	Engraulidae
Sillaginopsis panijus	Sillaginidae
Silonia silondia	Schilbeidae
Sisor rabdophorus	Sisoridae
Sperata aor	Bagridae
S. seenghala	Bagridae
Tenulosa ilisha	Clupeidae
Tetraodon cutcutia	Tetraodontidae

Species	**Families**
T. fluviatilis	Tetraodontidae
Wallago attu	Siluridae
Xenentodon cancila	Belonidae

Floral and Faunal Diversity in Lower Ganga

Farakka to Gangasagar

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

The river Ganga comprises a lotic water series, which originates at Gaumukh and flows down to Gangasagar traversing a distance of 2525 km. During its course through eleven states, the river receives numerous tributaries (with characteristic quality, pollution load and biota) including Bhilangana, Alaknanda, Ram Ganga, Kali, Yamuna, Gomti, Ghagra, Gandak, and Kosi.

A thorough review of a large number of studies available in the form of student's project reports and theses, reports produced through sponsored, consultancy, investigatory and Environment Impact Assessment studies, published papers/articles in journals/ conference/ workshop/ symposia proceedings, books, news paper articles, etc. has led to collection of fragmented information on ecology and biodiversity in the Ganga Basin. The information is in different time domain and isolated stretches largely governed by the period of the study and the proximity of a river stretch/water body to the investigating institutions, organizations or individuals involved in the study. Due to lack of definitive bio-monitoring programme like river water quality monitoring programmes by the Central Pollution Control Boards, State Pollution Control Boards and National River Conservation Directorate, the analysis is based on extrapolation and interpolation of scattered, mostly qualitative data/information.

The entire stretch of the river Ganga (main stem) can be viewed into three segments:

A.	Upper Ganga	≈ 294 km	Gaumukh to Haridwar
B.	Middle Ganga	≈ 1082 km	Haridwar to Varanasi
C.	Lower Ganga	≈ 1134 km	Varanasi to Ganga Sagar

(The Upper Ganga Segment for all practical purposes and studies carried out, starts at Gangotri as the terrain between Gaumukh to Gangotri is essentially devoid of biota due to hostile conditions)

These three segments not only differ in their geomorphology, ecology and rheology but are different in terms of issues that need to be addressed (refer report 001_GBP_IIT_GEN_ANL_01_Ver 1_Dec 2010). Considering this, floral and faunal diversity of the main stem of Ganga is reported in a series of four reports. This report covers the estuarine zone of lower Ganga stretch from Farakka to Gangasagar (LG-B). The lower Ganga comprises of a fresh water zone (Varanasi to Farakka) 701 km (LG-A) and estuarine zone (Farakka to Gangasagar) 286 km (LG-B). The LG-B zone spreads through a state viz. West Bengal.

Ganga is about 2525 km long and its basin is 861404 km^2, draining about one fourth area of the country. The river system covers cool upland streams and warm water stretches, including deltaic habitats. It has an annual runoff of about 493 km^3 and carries approximately 616 x 10^6 tons of suspended solids to the Hooghly estuary. Downstream the river becomes wider and shallower. This is the "depositional zone" where conditions allow particles to sediment out to produce the typical lowland river forms.

River Ganga bifurcates near Farakka into a major offshoot Padma, which flows further eastwards to Bangladesh and a minor offshoot Bhagirathi which flows southwards to Bay of Bengal through deltaic region of west Bengal. Below the confluence of river jalangi with Bhagirathi, the river flows under the name of Hooghly, through Kolkata and Diamond Harbor and finally reaches its destination (Bay of Bengal). During the course of its 286 km run from Farakka to sea face, the Bhagirathi-Hooghly river system receives water from some of its tributaries and begin to spread into many small distributaries, forming the great Gangetic Delta.The tidal Hooghly estuary lies between the latitude 21°31'N and 23°30'N and longitude 87°45'E and 88°45'E and covers the districts of Nadia, Hooghly, North and South 24 Parganas, Howrah and Medinipur in West Bengal. In lower reaches it is joined by several tributaries like Ajay, Damodar, Roopnarayan and Haldi. Before meeting Bay of Bengal the estuary bifurcates near Sagar Island into main estuary Hooghly and river Muri Ganga which has got connection with river Thakuran and river Matlah, forming the Sundarban estuarine complex. The river Matlah flows in almost in the centre of the system. Since the river has lost its main freshwater connection, it has become practically a backwater for major part of the year. The estuarine complex which is a culmination of the interaction of land, sea and freshwater offers diverse specialized habitats such as mangroves, non-vegetated mudflats, intertidal zones, reclaimed areas etc.

The Hooghly-Matlah estuarine system is the largest among the estuaries of Indian coast and is characterized by mixing of freshwater and regular tidal influxes which create a steady gradient of marine to freshwater conditions. It extends for 300 km from North to South and 150 km from East to West. The entire estuarine system is estimated to be about 8029 km^2 and the total area of Sundarbans estuarine water is about 2340 km^2 (in India). The entire estuary is a tide dominated delta, which has a funnel shape. Tides facilitate transportation of sediments, replenishment of nutrients, flushing out of wastes and mixing of fresh and salt waters. The tides are semidiurnal with two high tides and two low tides in a day. The tides are unequal, varying in time and range depending on the location in the estuary. The estuary is characterised by strong tides with meso-macrotidal amplitude (5 to 7 m amplitude) during summer season from February to May and during pre-winter season, relatively weaker tides during the winter months. This corresponds to the rising of mean sea level at the Hooghly mouth in February, reaching a peak by September and falling down by winter months. The tides create an important intertidal zone, which harbour characteristic biota. Tides have strong influence on water quality parameters. In addition to tides, water movement is caused by surface and bottom currents. The latter carry plankton upstream and also maintain salinity gradients. Mean current velocities are between 108 and 117 cm s^{-1} during low and high tide. The salt front rarely penetrates beyond Diamond Harbor, which is 80 km from the mouth of the Hooghly estuary. The circulation of water is important in maintaining populations of sessile and sedentary benthic organisms, majority of which have planktonic dispersal stages. Tides also help in transporting some of the euryhaline marine organisms from the sea to the estuary. The main river and its tributaries carry huge amount of sediments from the alluvial plains of northern India and also from Himalaya during monsoon which gets deposited throughout their course and their continuous upheavel from coastal areas through flood tides, keep the entire estuary very turbid. Coarser sand particles get deposited quickly in upper reaches of the riverine courses, the finer silt particles in the form of suspenoids, alongwith highly enriched detritus reach the deltaic region and settle gradually in the lower parts. This forms huge deltaic mudflats of Sundarbans.

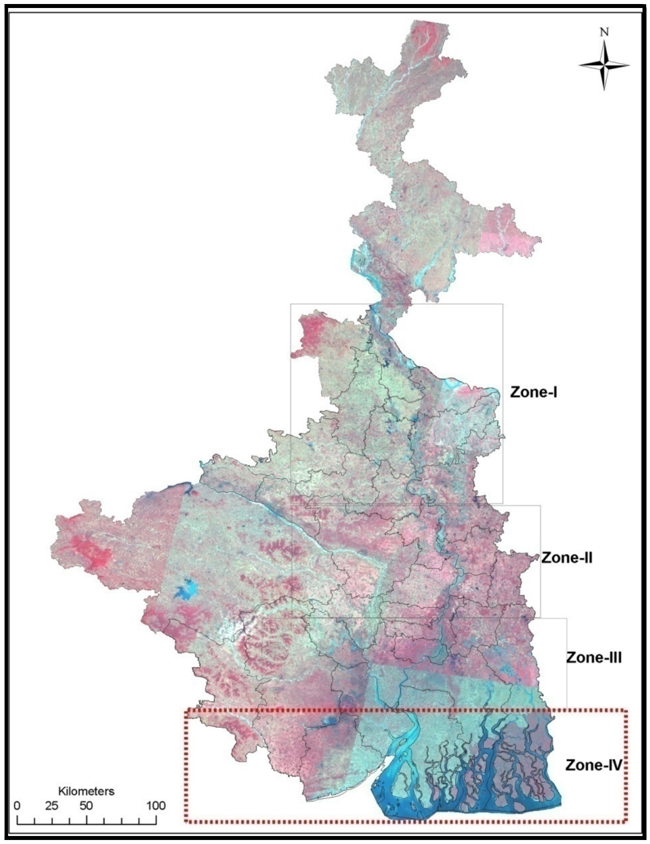


Figure 1: The lower Ganga (LG-B) basin with zone I - zone IV

1.1. Climate

Climate in the region is characterized by the southwest monsoon (June-September), northeast monsoon or post-monsoon (October-January), and pre-monsoon (February-May); 70-80% of annual rainfall occurs during the summer monsoon (southwest monsoon), resulting in high river discharge (2952 and 11897 m^3s^{-1}), which gradually diminishes to 900-1500 m^3s^{-1} during non-monsoonal months (Mukhopadhyay *et al.* 2006). Average air temperatures are 30.7±1.5°C in the pre-summer monsoon period and 21.5±4.6°C in the post-monsoon period.

The distributional pattern of both salinity and biota clearly demarcated the different stretches of the estuary. Stretch I and II with almost negligible or slight level of salinity is classified as freshwater and nearly freshwater zone. The wide fluctuation of salinity levels in Stretch III exhibited considerable alteration of the natural system of true estuarine gradient zone. The constant high salinity levels and lesser fluctuations confirmed the almost marine nature of Stretch IV (Figure 1).

Stretch I (Zone I- Freshwater): Farakka to Nabadwip (24°48’13.79’’ N to 23°24’27.59’’N, 87°55’58.99’’ E to 88°22’39.09’’ E)

The water temperature generally varies between 18.5-31.0°C. The highest transparency values are found in this zone (~ 9.5-93.0 cm). The pH value varies between 7.3-8.8. Lowest salinity values were recorded from this zone (~ 0.02-0.06 g/l). Gross primary productivity ranges between 33.3-142.0 (mgC/m^3/hr).

The bottom sediment of this stretch consists approximately of equal amount of sand and silt.

Stretch II (Zone II- Nearly Freshwater): Nabadwip to Konnagar (23°24’27.59”N to 22°42’45.66”N, 88°22’39.09”E to 88°20'51”E)

The water temperature generally varies between 18.5-32.0°C. The transparency values found in this zone varies ~ 8.0-30.0 cm. The pH value varies between 7.4-8.4. Salinity values were less in this zone (~ 0.04-2.86 g/l). Gross primary productivity ranges between ~ 50.0-93.7 (mgC/m^3/hr).

The bottom sediment of this stretch consists of sand, clay and silt with higher percentage of silt followed by sand.

Stretch III (Zone III- Estuarine): Konnagar to Diamond Harbour (22 42’45.66’’ N to 22 11’27.11’’ N, 88° 20' 51" E to 88°11’22.67’’E)

The water temperature generally varies between 18.0-32.0°C. This zone exhibits comparatively lower transparency values almost throughout the year. The pH value fluctuated around 8.1±2.0. Maximum variation in salinity values were observed in this zone (~ 0.07-18.98 g/l). Lowest gross primary productivity was between ~ 20 - 40 mgC/m^3/hr.

The bottom sediment is basically silty.

Stretch IV (Zone IV- Marine): Diamond Harbour to the mouth of the river covering whole Sundarbans. (22°11’27.11’’ N to 21°33’23.55’’N, 88°11’22.67’’E to 88°32’32.47’’E)

The water temperature generally varies between 18.6-30.4°C. This zone exhibits comparatively high transparency values almost throughout the year (~ 10.0 - 60.0 cm). The pH value fluctuated between 7.6 to 8.3. Maximum salinity was observed in this zone (~ 6.06-30.70 g/l). Gross primary productivity was found to be in between ~ 35.0-137.5 mgC/m^3/hr). The bottom sediment of stretch IV is basically clayey with small amount of sand. Some sandy flats are also observed near the mouth of the estuary.

2. Biological profile of Lower Ganga Basin

The biodiversity of the lower Ganga Basin is largely controlled by freshwater flux, nutrient inputs and changing environmental condition like salinity, rainfall and temperature. Salinity is the most important chemical factor which affects the diversity and abundance of the biota of this basin directly. Because of the different physiological adaptability of different species of animals and plants to salinity ranges, specific biotic communities colonize different stretch of the basin depending upon the prevailing level of salinity and the tolerance limits of individuals in the community.

Depending on the different groups of animals and plants found in the basin, the diversity can be differentiated between Phytoplankton, Zooplankton, Macrobenthos, Nekton, Macrofauna and Angiosperms (Figure 2).

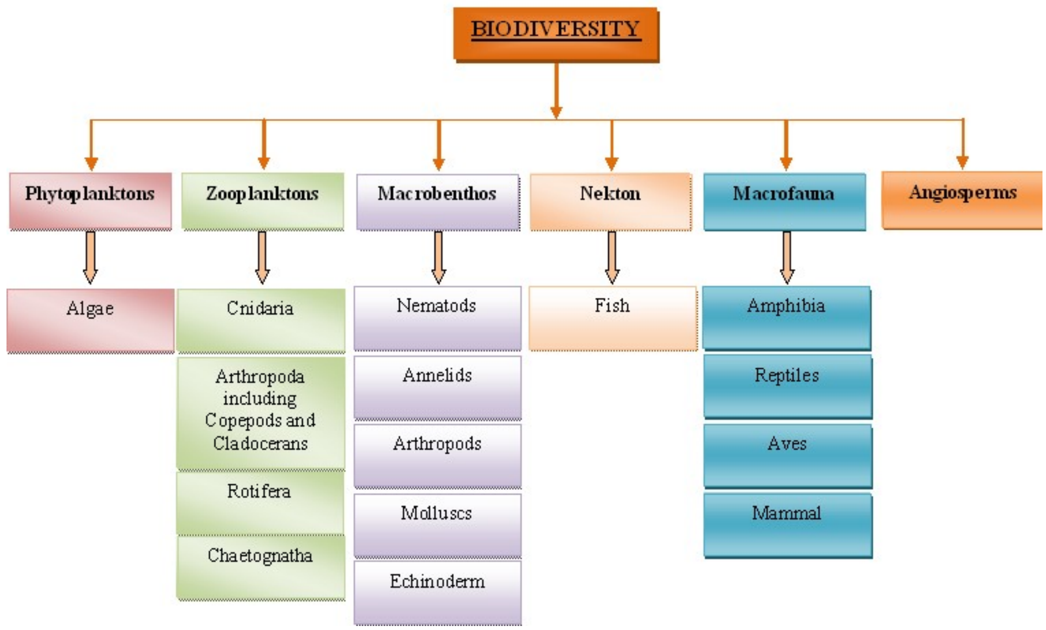


Figure 2: The Biodiversity of lower Ganga Basin (As per this study)

2.1. Phytoplankton

Phytoplankton communities are key to primary production and resulting flow of energy along the trophic levels. Phytoplankton is a good indicator of trophic states and every change in the environment affects this community. Many species of this community are very sensitive and respond to changes quickly (Manna *et al.* 2010). The most important elements for phytoplankton growth are nitrogen (N) and phosphorus (P). While the growth of phytoplankton cells in freshwater system is limited by P, growth in estuarine and marine environments is commonly N limited. Diurnal variations of phytoplankton and ancillary parameters follow the semi-diurnal tidal pattern. Abundance of phytoplankton was higher during high tide compared with low tide.

Various published reports on phytoplankton distribution in the lower Ganga basin (LG-B) provide only a patchy picture as they are usually based on short term surveys of small areas in the ecoregion. Compilation of various studies reveals a total of 641 algal species under

169 genera from lower Ganga basin (ZSI and WWF, 2011). From an inter-annual perspective, mean numerical abundance of phytoplankton was 3-fold higher in 2007 (Biswas *et al.* 2010) than 1990 (De *et al.* 1991) and 2000 (Biswas *et al.* 2004). Various species are found in all the stretches like *Aphanotheca microscopia, Calothrix bharadwajae, Chlorogloean fritschii, Gleocapsa crepidinum, G. pleurocapsoides, Microcystis bengalensis, M. elongata, Phormidium rotunda* and *Raphidiopsis curvata*.

The predominant species observed in the stretch IV during the monsoon included *Coscinodiscus radiatus* (17.11%), *C. eccentricus* (29.78%), *C. lineatus* (5.58%), and *Rhizosolenia alata* (3.9%) in 1990; *Ceratium tripose* (1.09%), *Chaetoceros affinis* (0.42%), *C. eccentricus* (14.22%), *C. radiatus* (14.75%), *Pleurosigma elongatum* (3.11%), *Rhizosolenia alata* (1.29%), *R. styliformes* (5.27%), and *Skeletonema costatum* (5.92%) in 2000; and *Coscinodiscus radiatus* (3.18%) and *Skeletonema costatum* (61.69%) in 2007. Sarkar (2010) reported for the first time, the occurrence of green benthic algae *Codium taitense* from the Indian Sundarbans. In general, Cyanophycean community with species of *Oscillatoria, Lyngbya, Phormidium* and *Microcoleus* occurs on bare mud flats and muddy soil between phanerogams. The pneumatophores of mangrove plants are covered with a number of blue green algae *viz.*, species of *Calothrix, Anabaena, Lyngbya, Hydrocoleum,* along with some red algae *viz.*, *Caloglossa, Catenella* and *Bostrychia*. Several epiphytic blue-green algae like *Dermocarpa, Xenococcus, Chaemosiphon* are also recorded. The planktonic blue green forms are dominated by species of *Trichodesmium, Synechococcus, Apanothece, Gloeocapsa, Gloeothece, Merismopedia, Oscillatoria, Fohannesbaptistia* and *Microcystis*. These planktonic species presumably contribute very much to primary production of the estuary. In partly reclaimed areas, the water-logged rice fields or brackishwater fish tanks are also colonised by a number of cyanophycean algal forms viz., species of *Aulosira, Spirulina, Arthrospira, Gloeotrichia, Calothrix, Nostoc, Anabeana, Oscillatoria, Aphanocapsa, Myxosarcina, Crinalium, Polyclamydum, Lyngbya, Rhaphidiopsis* and *Microchaete* etc., along with some salt tolerant green algae like *Enteromorpha* and *Ulva*. These forms provide a significant contribution to the soil fertility and nutrient balance in the wet land eco-system. Studies on the phytoplankton of the lower Ganga basin suggest that Cyanophyceae constitute the most important and dominant algae in freshwater, estuarine and marine habitats, whereas desmids and other green algae are important in freshwater and brackishwater habitats and the diatoms are found to prefer brakish and marine water zone.

A compendium of algal species stretch wise is given in Appendix I. Distribution of phytoplankton in different stretches is given in Figure 3. The presence and preponderance of important groups of algae stretch wise is given in Table 1.

Table 1: Group wise distribution of important algal classes

Group	Number of taxa	Species in different stretches			
		I	II	III	IV
Cyanophyceae	280	70	124	115	192
Chlorophyceae	206	13	34	62	156
Bacillariophyceae	115	0	0	86	105
Dinophyceae	14	0	0	7	14
Xanthophyceae	4	1	0	2	2
Rhodophyceae	17	0	0	6	14
Euglenophyceae	3	1	1	1	2
Phaeophyceae	2	0	0	0	2

The distribution of algae can be represented as:

Cyanophyceae (280 taxa) > **Chlorophyceae** (206 taxa) > **Bacillariophyceae** (115 taxa) > **Rhodophyceae** (17 taxa) > **Dinophyceae** (14 taxa) > **Xanthophyceae** (4 taxa) > **Euglenophyceae** (3 taxa) > **Phaeophyceae** (2 taxa)

The total data indicates that the dominant algae in lower Ganga is Cyanophyceae followed by Chlorophyceae. Bacillariophyceae are rare in fresh water zone but are represented by good numbers in the marine zone.

All the data tends to indicate that blue green algae dominates in the entire lower Ganga (LG-B).

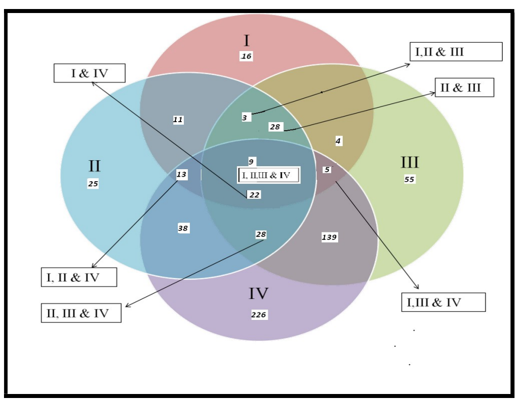


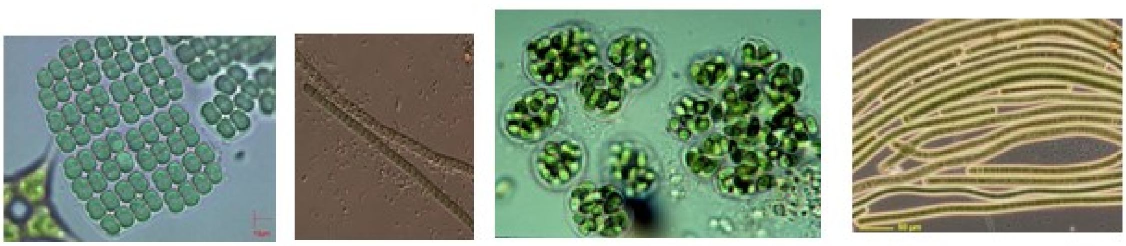
Figure 3: Distribution of phytoplanktons in different stretches

A large number of plankton in the classes Cyanaophyceae, Chlorophyceae and Bacillariophyceae are specific to each stretch as depicted in the Table 2 below and in Figure 3.

Table 2: Distribution of the algal taxa specific to the particular stretch

Classes	I	II	III	IV
Cyanophyceae	10	19	18	59
Bacillariophyceae	-	-	11	30
Chlorophyceae	6	6	21	114
Dinophyceae	-	-	-	7
Rhodophyceae	-	-	3	11
Xanthophyceae	-	-	2	1
Phaeophyceae	-	-	-	2
Euglenophyceae	-	-	-	1
Total	16	25	55	225

Most algae are found to show substratum preferences. The blue green algae are noted to prefer a soft, hydrophilic, biologically active mud, rich in organic matter; whereas, the green algae prefer a more consolidated type of soil rich in nutrients. Similarly, the red and brown algal groups seem to prefer hard consolidated soil in supra littoral zones or peripheral zones which are regularly inundated. Some common species are shown in Plate 1.



Merismopedia sp. *Oscillatoria* sp. *Gleocapsa* sp. *Lyngbya* sp.

Plate 1: Common species of algae

The phytoplankton as a group have immense contribution towards the natural environment that they inhabit. They are most important contributors as the primary producer group, which sustains the total ecosystem at large and takes care of the diverse consumer groups. The most algal productions enter the food web through detrital pathways. Maity *et al.* (1987) have highlighted the importance of algalization in effectively altering the physicochemical status of soil, mainly increased salinity. The algae, as such, play important ecological role as pollution remediators, bio-fertilizers, bio-indicators and also associated in the process of soil reclamation.

2.2. Zooplankton

Most of the zooplankton studies are centered on Hooghly estuary. Studies on zooplankton communities from the upper stretches are very few. The zooplankton communities in lower Ganga basin are represented by members of Cnidaria, Rotifera, Chaetognatha, Copepod and larval forms of Decapods and Cyclopods. Along with phytoplankton, they also form a major part of the trophic states. A compendium of zooplankton is attached in Appendix II.

Cnidaria

Out of 25 species reported from lower Ganga basin, 22 species have been reported from stretch IV only like *Bougainvillia fulva, Obelia* sp.*, Octaphialucium indicum, Liriope tetraphylla, Edwardsia jonesii.* While *Blackfordia virginica* and *Moerisia gangetica* have been observed only from stretch III and *Eirene menoni* has been reported both from Stretch III and IV citing the adaptability of the species to both marine and estuarine conditions. *Limnocnida indica* is the only species from stretch II. Cnidarians have been found to be totally absent from the true freshwater stretch i.e. Farakka to Nabadwip. The distribution of Cnidarian genera and species are shown in Figure 4.

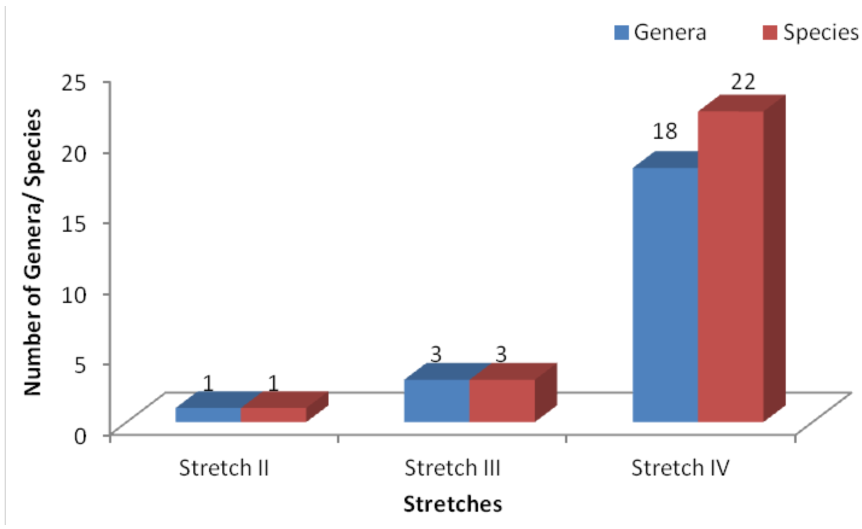


Figure 4: Distribution of Cnidarians across different stretches

Chaetognatha

Chaetognaths, popularly known as Arrow worms or Glass worms form one of the important constituents of zooplankton which play an important role in the food cycle. Moreover, they act as good indicator organisms for the origin of water masses and their movement in the sea. Marine Chaetognaths have received more attention as most of the species inhabit in neritic and oceanic waters. Only some species under two genera, namely, *Sagitta* and *Krohnnitta* are reported from the Hooghly-Matlah estuary by Baidya and Choudhury (1984) and Sarkar *et al.* (1984; 1985). Out of the four species *Sagitta bedoti* is found in abundance followed by *Sagitta enflata*. Both these species along with *S. pulchra* are euryhaline species. *S. pulchra* can withstand high salinity (18-25%) and during low salinity periods their occurrence is noted near the mouth of Moori Ganga and Saptamukhi rivers near the Hooghly estuary and Jharkhali onwards in Matlah river. The common Chaetognatha are shown in Plate 2.

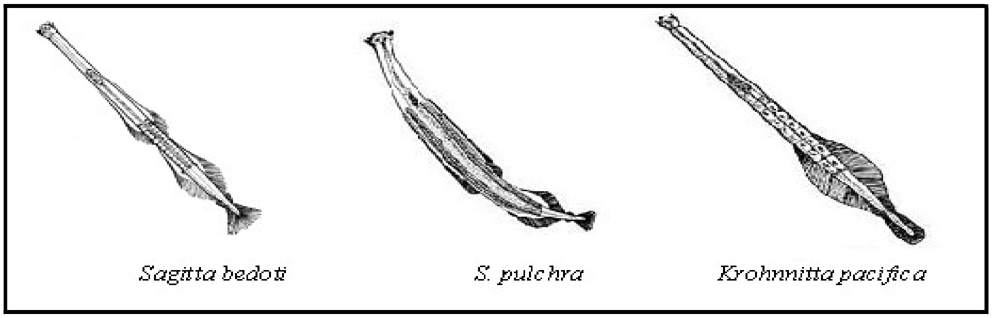


Plate 2: Common Chaetognaths of lower Ganga

Rotifera
The data reported for wheel animicules reveals the presence of 102 species under 29 genus and 16 families. The family Brachionidae (21 species), Colurellidae (14 species) and Lacanidae (31 species) constitute the large group. The genus *Brachionus, Lecane, Lapadale, Keratella* and *Filinia* are the most common. In the stretch IV *Asplancha* sp. and *Brachionus* sp. are mainly represented.

Copepoda
The importance of the copepods in the trophic dynamics is well known as they constitute nearly two third of the total zooplankton number and biomass throughout the year. They form the food of both larvae and adults of many commercially important fishes whose abundance in a particular area has been directly related to the availability of either a particular species or assemblage of few copepod species. The abundance of most of the species of Copepods is related to salinity. Pseudodiaptomidae and Acartiidae can tolerate wide range of salinity whereas; Diaptomids are generally intolerant to higher levels.
Copepods constitute more than 80% of the zooplankton population in these waters followed by Chaetognaths and Mysids. Copepod genera are mostly dominated by *Acartiella, Labidocera* and *Pseudodiaptomus* in the last stretch (WWF, 2011). Species like *Heliodiaptomus viduus* have been reported from all the stretches. *Microcyclops varicans, Paracyclops fimbriatus, Tropocyclops prascinus* and *Tropodiaptomus australis* have been observed exclusively in stretch III and *Phyllodiaptomus blanci* and *Neodiaaptomus schmackeri* have been observed in stretch I only. A total of 26 species under 13 genera and 5 families of Copepods have been reported from lower Ganga basin with the largest number reported from stretch IV. The common Copepods of lower Ganga (LG-B) are shown in Plate 3.

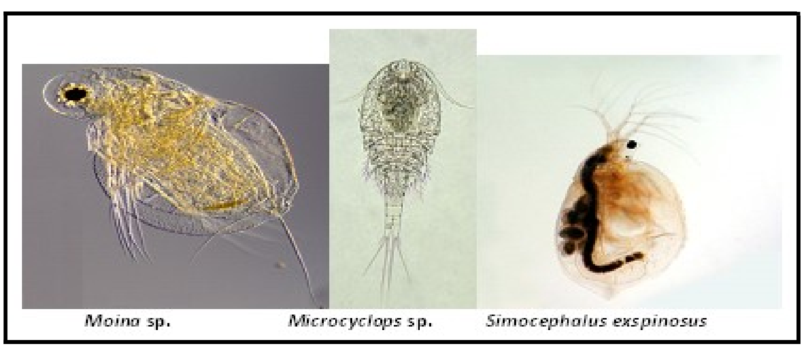


Plate 3: Common Copepods of lower Ganga (LG-B)

Cladocerans

Cladocerans along with copepods constitutes the important group of zooplankton. Cladocerans are represented by 53 species under 25 genera and 7 families. Cladocerans are conspicuous by their absence in the fresh water zone. Maximum species has been recorded in the eustarine zone and is represented by family Chydoridae genus *Alona, Kurzia, Ceriodaphnia, Daphnia* and *Simocephalus*. The stretch wise distribution of Cladocerans is 28 in Zone II; 46 in Zone III and 24 in Zone IV.

2.3. Macrobenthos

Annelida

Annelids constitute one of the largest important macrobenthic fauna. The majority of annelids are benthic, only a few are pelagic. Benthic annelids prefer sandy or muddy substrata extending from the sea shore to the greatest depths of tidal zones; some are ever found in rocks and crevices. As many of these worms are sedentary in nature and very specific in terms of different environmental parameters, they are used as bio-indicators in environmental monitoring particularly in case of estuaries. Most of the annelids are very small in size, are in diet of many demersal fishes and considered as an important link in marine and estuarine food webs. The variety and abundance of species present can often be used as an indication of the cleanliness of the environment in which they live.

A total of 90 species under 66 genera have been reported of which 48 species of Polychaetes, 35 species of Oligochaetes and 7 species of Hirudinia are found. Stretch IV recorded highest number of species i.e. 60 number of species followed by 59 number of species in stretch III; 27 in stretch II and 19 in stretch I. Species like *Gattyana fauveli, Eteone barantollae, Ceratonereis burmensis, Dendroneries dayi, Marphysa mossambica* and *Pontodrilus bermudensis* have been reported exclusively from the Stretch IV. There is a high diversity of polychaete species towards the mouth of the estuary. The fluctuations of salinity in estuary compel the colonization of annelids with such severe problems that a decrease in species number with increased distance from the sea is almost a certainty. *Haemadipsa sylvestris, Hemiclepsis marginata, Lampito mauritti* among the Oligochaetes and Clitellates are freshwater forms reported mostly from stretch I and II. Species like *Eutyphoeus orientali,* has been observed in all the stretches. Distribution of Annelids across different stretches are shown in Figure 5.

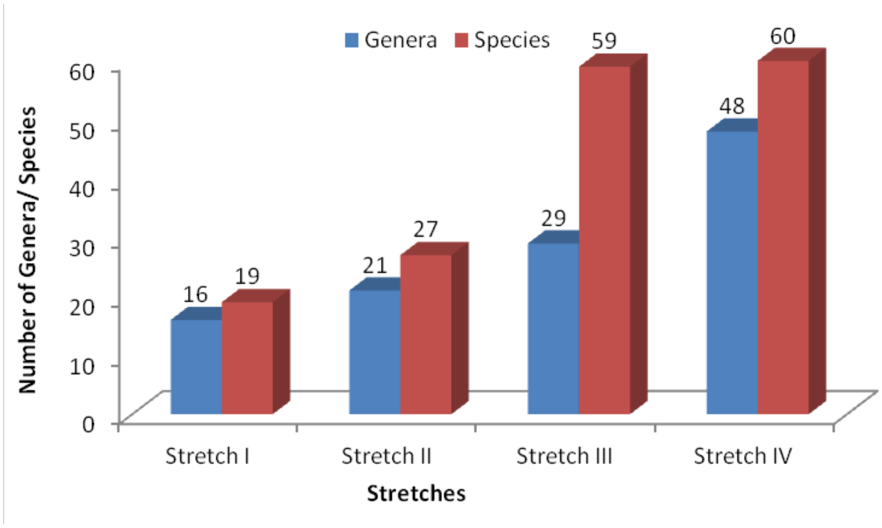


Figure 5: Distribution of Annelids across different stretches

Arthropoda

The group Arthropoda is a major group under benthic fauna. It consists of Crustaceans, Spiders, Ticks, Mites and Insects. Spiders are among the oldest and most diverse groups of terrestrial organisms. They are the dominant predators of insects. Spiders are an integral part of diversity since they play important roles in ecosystems as predators and sources of food for other creatures. The mites especially the soil inhabiting forms are of great ecological importance. They constitute an integral part of ecosystem as pest, predator, and decomposer and an active constituent of nutrient cycling in the ecological system. Insect herbivores can cause changes in nutrient cycles and nutrient availability in soils: deposit significant quantities of fecal material onto litter and soil. Insects are important components of several biogeochemical cycles as well as mediators of energy transformation. They also play an important role in the carbon cycle by playing the role of decomposers. Insects are among the groups of organisms most likely to be affected by climate change because climate has a strong direct effect on their development, reproduction and survival.

A total of 476 species of Arthropods have been reported of which 240 species of Crustaceans, 33 species of Arachnids, 201 species of insects and 2 species of Merostomata (Gopal and Chauhan, 2006). The distribution of Arthropods excluding insects are shown in Figure 6. The common Arthropods of lower Ganga (LG-B) are shown in Plate 4. Appendix III provides a list of 147 taxa of Arthropods commonly found in lower Ganga.

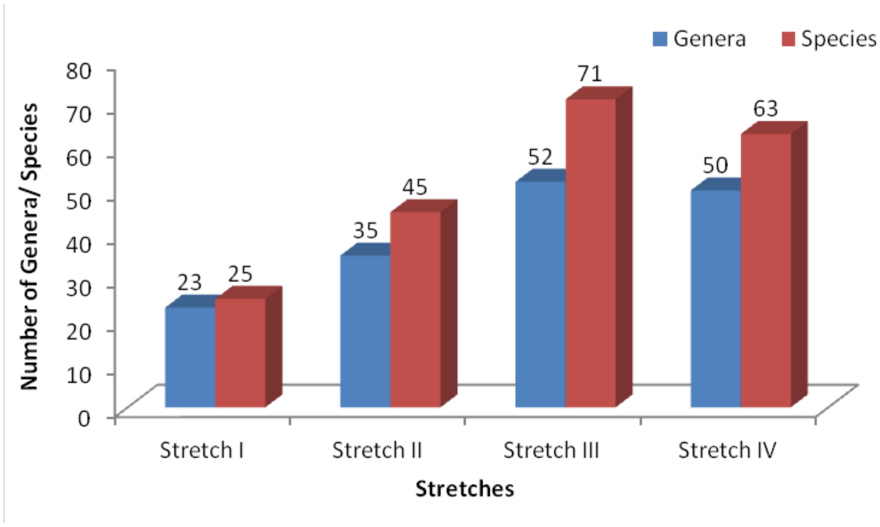


Figure 6: The distribution of Arthropods excluding insects in lower Ganga basin

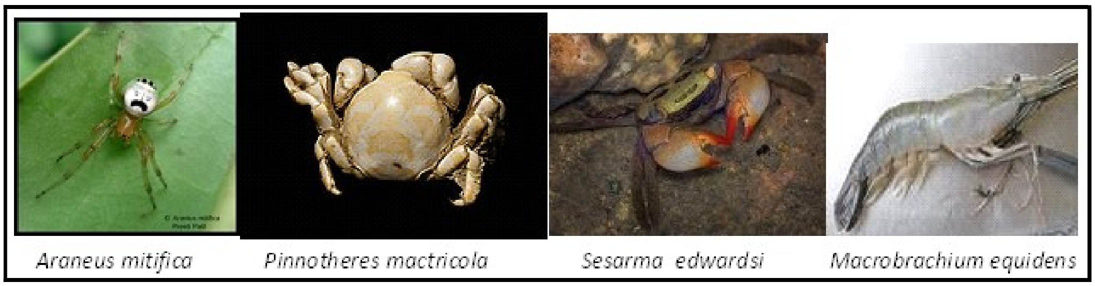


Plate 4: Some important Arthropods in lower Ganga

Mollusca

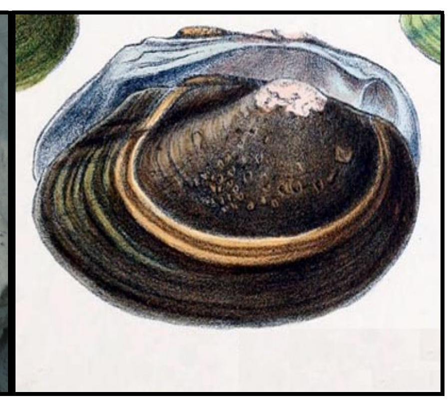
Molluscs are the largest group of animal kingdom after insecta, highly adaptive and occupy all possible habitats except aerial. Molluscs have an important role in the ecosystems by drawing a small amount of calcium from the environment and releasing more into it. The estuarine molluscs play important role in formation of organic detritus in the estuaries. Molluscs are characterized by low mobility, small populations, patchy and isolated distributions. They are very sensitive to environmental changes, hence, are used as effective bio-indicators. Recently 25 species in India (10 under Schedule I and 15 under Schedule IV) of molluscs have been included in Wildlife Protection Act, 1972. *Windowpane oyster, Placuna placenta* which is also found in Sundarbans is banned under Schedule IV. The macrobenthic molluscs can be broadly grouped under three categories (i) those living attached to stems, pneumatophores and leaves of living plants (arboreal) (ii) those living attached to or in the crevices of dykes, bricks, wooden pillars, jetties etc., and (iii) those living in the muddy substratum, either moving freely on it (epifauna) or burrowing into it (infauna). A few of the molluscan species may have overlapping habitats.

A total of 68 species have been reported from the lower Ganga basin. Distribution of Molluscs in different zones are given in Table 8. Stretch IV has the highest diversity with a total of 60 species, of which 32 species are Gastropods; Bivalves are represented by 22 species, Cephalopoda by 5 species and Scaphopoda by a single species. In stretch I no species of Gastropods and 4 species of Bivalves have been reported of which species like *Lamellidens marginalis* and *Parreysia corrugata* have wider distribution in all the stretches (Figure 7). No single species have been observed which is confined to stretch I. Species like *Bellamya dissimilis*, *Bellamya crassa*, *Parreysia favidens* and *Thiara lineatus* have been reported only from Stretch II. Species like *Natica (Dostia) violacea,* has shown truly estuarine characteristics and are confined to stretch III whereas rest of the species found in Stretch III have overlapping distribution in either stretch II or IV. Species like *Amalda ampla, Assiminea beddomeana, A. woodmasoniana, Asthenotoma vertebrata, Cassidula nucleus, Cerithidea alata, Clithon reticularis, Cuspidaria chilkaensis, Iravadia ornate, Natica gualteriana, N. smithi, Olivancillaria gibbosa, Pitar alabastrum, Polinices didyma, Potamacmaea fluviatilis, Pseudanachis duclosiana, Stenothyra blanfordiana, Terebra tenera, Thais blanfordi, T. lacera, Tubiola microscopic, Umbonium vestiarum, Barnea candida, Corbicula gracilis, Glauconome sculpta, Laternula truncate, Mactra luzonica, Martesia fragilis, Novaculina gangetica, Nucula (Nucula) mitralis, Paphia malabrica, Parreysia (Radiatula) occata, Solen brevis, Sphenia perversa, Theora opalina, Trachycardium asiaticum, Loligo duvanceli, L. investigatoris, Octopus macropus, Sepia aculeate, Sepiella inermis* and *Dentalium octangulatum* have been reported only in stretch IV. The common Molluscs of lower Ganga (LG-B) are shown in Plate 5.

Table3: Distribution of Molluscs- Stretch wise in lower Ganga basin

	Gastropoda		Bivalvia		Scaphopoda		Cephalopoda		Total	
	Genus	**Species**	**Genus**	**Species**	**Genus**	**Species**	**Genus**	**Species**	**Genus**	**Species**
Stretch I	-	-	2	4	-	-	-	-	2	4
Stretch II	5	8	4	7	-	-	-	-	9	15
Stretch III	10	12	4	6	-	-	-	-	14	18
Stretch IV	25	32	19	22	1	1	4	5	49	60

Telescopium telescopium



Lamellidens corrianus

Plate 5: Some common Gastropods

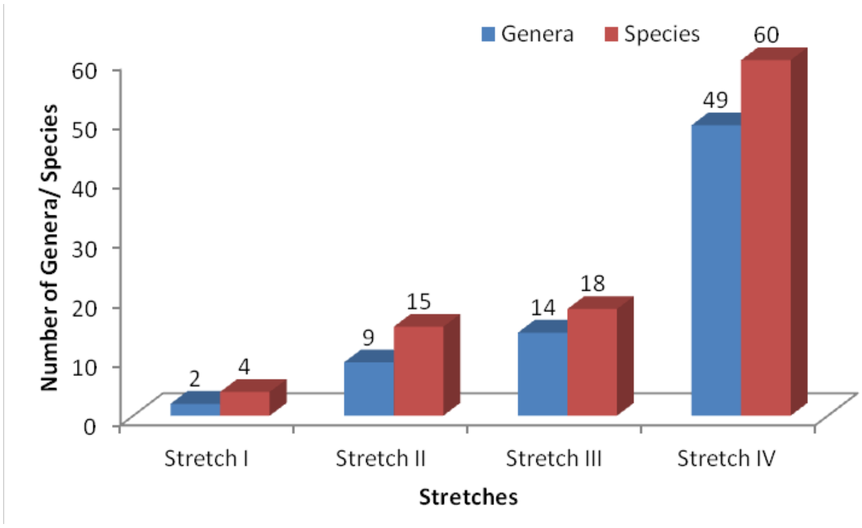


Figure7: Distribution of Molluscs across different zones

Echinodermata

Echinoderms are exclusively marine inhabitants with little or no osmoregulatory mechanism and with only limited tolerance to narrow ranges of salinity variations. Hence their occurrence in truly estuarine, brackish water or freshwater stretches is very rare.

A total of 17 species under 15 genera have been observed only from stretch IV. 4 species of Asteroids like *Luidia hardwicki, Astropecten euryacanthus, A. indicus* and *Goniopecten* sp., 4 species of Ophiuroides like *Amphioplus (Lymanella)* sp., *Ophiactis delagoa, O. modesta, Ophiocnemis marmorata* and 4 species of Holothuroides (*Acaudina molpadioides, Synaptula recta, Labidoplax* sp., *Thorsonia investigatoris*) and 5 species of Echinoidea (*Laganum decagonale, Echinodiscus auritus, Chaetodiadema granulatum, Clypeaster rarispinus* and *Temnopleurus toreumaticus*) have been reported. No echinoderm data have been found from rest of the stretches. Appendix III provides a list of macrobenthos in lower Ganga.

Luidia hardwicki

Sea Urchin

Plate 6: Echinoderms from lower Ganga

2.4. Fishes

Towards the end of 18th century, it was freshwater zone in Kolkata and except *Hilsa* all other freshwater species were available in plenty. It was around 1943, considerable changes in the fish composition were noticed and in 1953 mainly brackishwater fishery extended upto Barrackpore. Subsequently the deltaic tidal plain which covered Nabadwip to Diamond Harbour, besides its usual flow was influenced by tidal waters. In the 60's the catch was fairly high. The composition in the upper stretch was *Tenualosa ilisha*, freshwater prawn species, *Harpodon nehereus* etc. while in the lower region besides the above; some more forms like *Polynemus indica, Tachysurus jella, Pama pama* were dominating in commercial scale. Miscellaneous group formed an important rank in the catch and their landing exceeded the *Hilsa* fishery. With the coming up of numerous irrigation projects on the Ganga and its tributaries, the fishery in the main river has considerably dwindled in recent years while in the Bhagirathi-Hooghly, with the additional release of water from Farakka the condition became more grave.

In stretch I, 25 species of fish belonging to 16 different families have been identified. Majority of them are carnivorous fishes. The commercially important fish species*, Catla catla, Labeo rohita, Cirrhinus mrigala, Labeo calbasu* etc, are getting depleted in this region. In stretch II i.e., Nabadwip to Konnagar, the main fish fauna available are: *Catla catla, Labeo rohita, Puntius ticto, Wallago attu, Mystus vittatus, M. aor, Rita rita, Eitropiichthys vacha, Mastacembelus pancalus, Tenulosa ilisha, Boleophthalmus slaucus, Cirrhinus mrigala, Gudusia Chapra* and *Xenentodon cancila*, besides *Macrobrachium rosenberghii* and *Penaid prawns*. The fish landing of *Hilsa ilisha* showed that the river stretch between Kalyani to Tribeni in stretch II is a good catchment area for *Hilsa,* along with other migrant species like *Pama pama, Sillago panijius*, migrating within the gradient and low saline stretch. In Stretch IV, 176 taxa of fishes have been reported from the report of Gopal and Chauhan (2006) and Das (1999) which categorise in 22 taxa of Chondrichthyes and 154 taxa of Osteichthyes. The species richness and abundance decrease with increasing distance from the mangrove forest. Some species were found in higher numbers in the mangroves and others are more abundant over mudflat habitats. Among the fishes found in this stretch, the highly priced *Hilsa* (*Tenulosa ilisha),* Bhetki (*Lates calcarifer*), Bhangon (*Liza tade*), and Mullets (*Liza parsia)* form a lucrative fishery of this region. A detailed report on "*Hilsa* - An assessment in lower Ganga river basin, India" is given in a seprate report. Hooghly-Matlah estuary is known for its faunastic richness. The icthyean fauna is represented by 156 species in 119 genera and 67 families (CIFRI-Ghosh, A. 2008) and 13 species of cartillaginous fishes (Chardrichthyes) in nine families. The common esturine fishes of lower Ganga (LG-B) are shown in Plate 7.

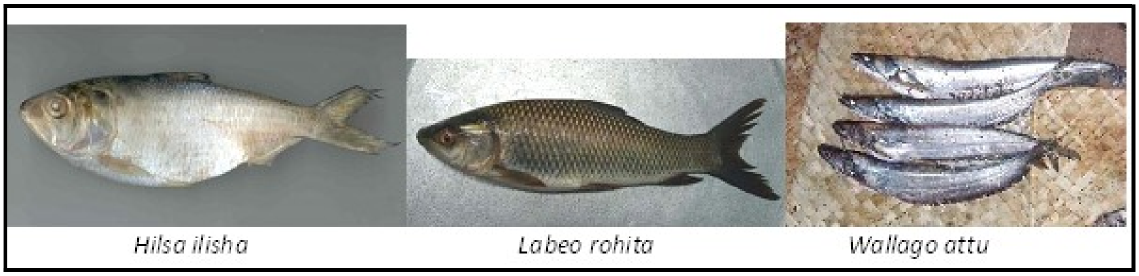


Plate 7: Common fishes of estuarine region

The catch of purely marine forms and typically neritic species, such as *Liza parsia* among mullets, *Eleuthheronema tetradactylum* among polynemids, *Coilia* sp. among Anchovies*,* *Tenulosa toli* and *Ilisha elongata* among Clupeids and *Harpodon nehereus* and *Trichiurus* sp. among other groups, have shown a sharp decline or total absence in the upper estuary during the post-Farakka period. A few purely freshwater species (*Rita rita, Wallago attu, Mystus aor, Ailia coilia, Catla catla, Labeo rohita,* and *Labeo bata)* have made their appearance in the estuary and contributed notably to community structure. But these species are not reported in zone I. A significant decline in the availability of certain non-commercially important estuarine and marine species (*Chanos chanos* and *Plotosus* sp. etc.) was also observed. A list of fishes in the lower Ganga is given in Appendices IV and V.

2.5. Higher Vertebrates

The higher aqatic vertebrates of Hooghly-Matlah estuary is represented by turtles, crocodiles, mammals, dolphin and porpoises. The turtle population is represented by *Batagur baska, Petochelys bibrone* and *Chelonia mydas* (endangered species) and marine turtles olive ridley turtle *Lepidochelys olivacea* and green turtle *Chelonia mydas, logger head Caretta caretta* and *Eretmochelys palustris*. Among other reptiles *Crocodylus palustris* (now extinct) and estuarine crocodile, *Crocodylus olivaceae* (in small numbers) have been reported. Among mammals dolphin and porpoise *Neophocaena phocaenoides* have been recorded. A list of higher vertebrates of lower Ganga is given in Appendix VI.

2.6. Angiosperms

More than 1175 plant species in 680 genera under 154 families has been identified by Naskar (1993) in the lower Ganga basin. 301 species are Moncotyledons under 149 genera and 30 families and 874 species of Dicotyledons under 531 genera and 124 families have been identified. The most dominant families having high number of species are Poaceae (128), Cyperaceae (62), Euphorbiaceae (47), Compositae (64), Papillionaceae (88), Malvaceae (31), Caesalpiniaceae (30), Rubiaceae (27), Convulvulaceae (26), and Acanthaceae (27) etc. A total of 296 species under 158 genera of aquatic, semi-aquatic and moist loving plants have been observed in lower Ganga basin. Some of the aquatic, indigenous plants species are: *Ranunculus sceleratus, Bergia capensis, Oxalis latifolia*, *Neptunia natans, Aldrovanda vesiculosa, Myriophyllum indicum, Rotala indica, Ipomoea carnea* etc. and some of the semi-aquatic plants are: *Pentapetes phoenicea, Hydrocera triflora, Ammannia baccifera, Ludwigia perennis* etc. Detailed distribution of Angiosperms has been included in the report on riparian vegetation. The report on mangroves give details of Sunderbans. The distribution of Angiosperms in lower Ganga are shown in Figure 8.

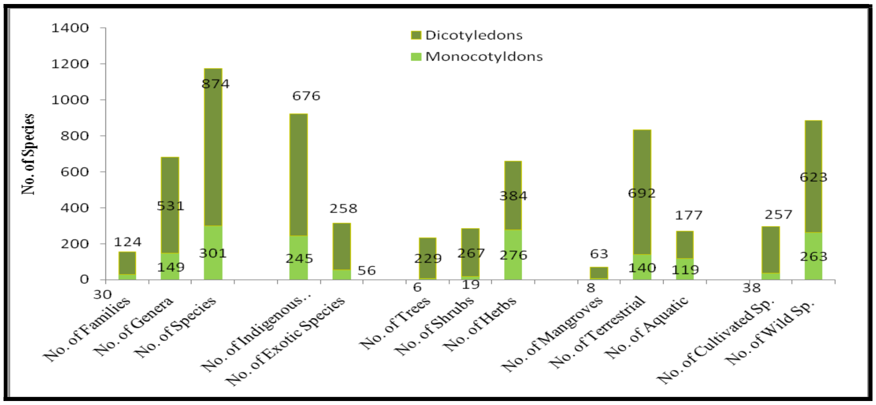


Figure 8: Distribution of angiosperms in lower Ganga

2.7. Scenario analysis

The Sundarbans has experienced a balanced growth of flora and fauna in association with the fresh water flow from the upper stream Ganges at the north and the salty water inflow from the Bay of Bengal at the southern border. But the balance is being threatened due to decreasing freshwater flow from upstream as a result of increasing siltation and unplanned construction of embankments along the river banks. As the salinity of the Sundarbans increases from west to east, density of vegetation growth and canopy closure decreases from east to west. Height and growth of different species in the Sundarbans are related with the salinity. Salinity in the Sundarbans is highly dependent on the volume of freshwater coming from the upstream. The variation is subject to the nature of tide in the area. Annual pattern of salinity changes inside the Sundarbans is also related with the changes of freshwater flow from upstream rivers.

Estuarine regions along riverine systems are highly influenced by freshwater discharge and marine water inflow where plankton abundance and species composition are characterized by a high degree of spatial and temporal variability. A variety of ecological processes regulate phytoplankton assemblages and abundances in natural systems. The Bhagirathi–Hooghly estuary is an important coastal region in the Indian subcontinentwhere the river Ganges (referred as Bhagirathi-Hooghly) gradually confluences with the Bay of Bengal. Due to the vastness of the area and theproximity of the Bay of Bengal, mixing is pronounced, based upon which the study area can be categorized as riverine, estuarine, and coastal stretches. Significant works on the nutrient and hydrobiological dynamics from this estuary are not very common. The analysis of environmental variables and plankton population from the surface waters ofthe study area indicates that a regular and recurrent pattern of variation in species assemblage was present with low inter annual variability.

The increased flushing of freshwater from the Farakka Barrage to Bhagirathi river and consequently river Hooghly has naturally resulted in major changes in the ecology and chemistry of this estuary. Concurrently, significant structural changes in fishery resources and fishing pattern has also emerged. The ecological changes due to opening of the Farakka Barrage are reflected in the community composition of freshwater, marine and euryhaline forms of plankton.

References

Alam, M.A., Gomes, A., Sarkar, S.K., Shuvaeva, O.V., Vishnevetskaya, N.S., Gustaytis, M.A., Bhattacharya, B.D. and Godhantaraman, N. (2010). Trace metal bioaccumulation by soft-bottom Polychaetes (Annelida) of Sundarban mangrove wetland, India and their potential use as contamination indicator. *Bulletin of Environmental Contamination and Toxicology,* **85:** 492-496.

Baidya, A.U. and Choudhury, A. (1984). Distribution and abundance of zooplankton in a tidal creek of Sagar Island, West Bengal. *Environment and Ecology*, ***2*(4):** 333-338.

Banerjee Anando (1998). Studies of Planktons of rivers in mangrove delta region of Kalyani University, West Bengal, India. *Ph.D. Thesis*.

Biswas, H, Mukhopadhyay, S.K., De, T.K., Sen, S. and Jana, T.K. (2004). Biogenic controls on the air water carbon dioxide exchange in the Sundarban mangrove environment, northeast coast of Bay of Bengal. India. *Limnology and Oceanography*, **49:** 95-101.

Biswas, H., Det, M., Ganguly, D., De, T.K., Ghosh, S. and Jana, T.K. (2010). Comparative analysis of phytoplankton composition and abundance over a two decade period at the land-ocean boundary of a tropical mangrove ecosystem. *Estuaries and Coasts,* **33:** 384-394.

Nandita, C. (1996). Biomonitoring of pollution in Hooghly estuary through plankton species diversity. *Ph.D. Thesis*, Dept. of Environmental Science, Kalyani University, India.

Chaudhary, A.B. (2007). Biodiversity of mangroves. *Daya Publishing House*, New Delhi, India.

Das, M.K. (1999). Fish and prawn disease epizoobiotics in aquatic ecosystems around Sundarban – an overview. *In:* D.N. Guha Bakshi, P. Sanyal and K.R. Naskar (eds.), Sundarbans Mangal. Naya Prokash, Calcutta, India. pp. 485-492.

De, T.K., Ghosh, S.K., Jana, T.K., Chowdhury, A. and Choudhory, A.B. (1991). Phytoplankton bloom in the Hooghly estuary. *Indian Journal of marine Science*, **20**: 134-137.

Dey, A. (2006). Handbook on mangrove associate molluscs of Sundarbans. *Zoological Survey of India,* West Bengal, India. pp. 10-15.

Ghosh, A., Mukherjee, S., Sen, N., Dasgupta, M. and Naskar, K.R. (2003). Floral diversity of mangroves and mangrove associated species in the India Sundarbans with special reference to distribution and abundance. *Journal of the Indian Society of Coastal Agricultural Research,* **21** (1): 53-58.

Ghosh, A. (2008). Fishes of Hooghly estuary. Bulletin No. 155, *Central Inland Fisheries Research Institute,* India*.*

Gopal, B. and Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban mangrove ecosystem. *Aquatic Science,* **68:** 338-354.

Hugli Matla Estuary West Bengal, (1995). Estuarine ecosystem series Part 2, *Zoological Survey of India,* West Bengal, India.

Maity, H., Bandyopadhyay, G. and Santra, S.C. (1987). Algal flora of saline habitats of Sunderban, West Bengal and its possible role in reclamation of soil. *Journal of the Indian Society of Coastal Agricultural Research*, **5(1):** 325-331.

Majumdar, S.C. (2007). Pictorial handbook on Spiders of Sunderbans, *Zoological Survey of India*, West Bengal, India.

Kumar, M.A. (2003). The Sundarbans of India: *A Development Analysis*, *Indus Publishing Company, New Delhi*.

Manna, S., Chaudhuri, K.,S., Bhattacharya, S. and Bhattacharya, M. (2010). Dynamics of Sundarban estuarine ecosystem: eutrophication induced threat to mangroves. *Saline Systems,* **6**: 8.

Mitra, P.M., Karmakar, H.C., Sinha, M., Ghosh, A. and Saigal, B.N. (1997). Fisheries of the Hooghly-Matlah estuarine system. *An Appraisal, Bulletin of Central Inland Fisheries Research Institute*, **67:** 49.

Mukherjee, P. (1995). Estuarine ecosystem Series, Part 2: Hugli Matla Estuary. *Zoological Survey of India,* West Bengal, India. pp. 345-388.

Mukherjee, S. (2004). Ecological investigations on the mangroves of the Sundarbans Tiger Reserve in West Bengal (India) with special reference to effective conservation through management practices. *Ph.D. Thesis.* University of Calcutta, India.

Mukhopadhyay, S.K., Biswas, H., De, T.K. and Jana, T.K. (2006). Fluxes of nutrients from the tropical river Hoogly at the landocean boundary of Sunderbans, NE coast of Bay of Bengal. *Indian Journal of Marine System,* **6**: 9-21.

Nath, D., Mishra, R.N. and Karmakar, H.C. (2004). The Hooghly estuarine system: Ecological flux, Fishery resouces and production potential. Bulletin No. 130, *Central Inland Fisheries Research Institute,* India.

Naskar, K.R. (1993). Plant wealth of the lower Ganga delta-An Eco-Taxonomical approach. *Daya Publishing House, Delhi,* India. pp. 1-810.

Naskar, K.R. (1990). Aquatic and Semi aquatic plants of the lower Ganga Delta: its taxonomy, Ecology & Economic importance. *Daya Publishing House, New Delhi,* India. pp. 1-402.

Roy, S. (2002). Gastropod Distribution in mangrove areas of Sundarbans. *M.Sc.Thesis.* Kalyani University, India.

Saha, B.K. and Nandi, N.C. (2005). A checklist of ophidian fauna of West Bengal, India along with their status, Distribution and conservation. *Journal of Environmental and Sociobiolgy,* **2(1&2):** 49-60.

Sarkar, D.D. and Chaudhuri, A.B. (2004). Golden Triangle of Ecoeducation tourism. (*In: Andamans, Sundarbans and Himalayas).*

Saskar, N.S. (2010). Algae- a potential resource promoting rural economy. *ENVIS Newsletter, Deptarment of Environment, Government of West Bengal*, India, **2(1):** 15-16.

Sarkar, S.K., Singh, B.N. and Choudhury, A. (1986). The ecology of copepods from Hooghly estuary, West Bengal, India. *Mahasagar-Bulletin of National Institute of Oceanography,* **19(2):** 103-112.

Sarkar, S.K., Singh, B.N. and Chaudhury, A. (1984). Distribution of Chaetognatha, *Sagitta bedoti* Beraneck, in a tidal creek of Hugli estuary, West Bengal. *Journal of Bengal Natural History*, **3(1):** 36-47.

Sarkar, S. K., Singh, B.N. and Chaudhury, A. (1985). Ecology of Chaetognaths in Hugli estuary of Bay of Bengal, India. *Indian Journal of marine Sciences,* **14:** 98-101.

State Fauna Series 3: Fauna of West Bangal, Part 1-12, *Zoological Survey of India.*

WWF, (2011). Environmental management and biodiversity conservation plan for Sundarbans biodiversity. *Draft of State of the Art Report,* India.

Appendix I

Distribution of phytoplankton in the lower stretch of Ganga river from Farakka to Gangasagar.

Species	I	II	III	IV
Cyanophyceae				
Anabaena aginicola		+		+
A. ambigua		+		+
A. anomana	+			+
A. cercinalis		+		+
A. doliolum	+	+		+
A. fertilissima				+
A. fuellebornii		+	+	+
A. gelatinicola	+			+
A. iyengarii				+
A. hannae		+		
A. naviculoides			+	+
A. orientalis	+	+		
A. olzii				
A. oryzea		+		+
A. oscillarioides		+	+	+
A. sphaerica		+		+
A. spiroides				+
A. totulosa				+
A. utermohlii		+		
A. vaginicola forma fertilissima				+
A. variabilis				
Anabaenopsis arnoldii		+		+
Aphanocapsa banaresensis	+	+		+
A. biformis	+	+		+
A. grevillei		+		+
A. koorders		+	+	
A. littoralis		+	+	
A. montana	+		+	
A. pulchra	+		+	+
A. roeseana		+		+
A. thermalis	+		+	+
A. virescens				+
Aphanothece bullosa			+	
A. castagnei			+	
A. microscopia	+	+	+	+
A. naegelii	+		+	
A. pallida		+	+	+
A. stagnina		+	+	
Arthosporia gomotiana		+	+	+
A. jenneri		+		+
A. massartii		+		+
Arthrospira platensis				+
Aulosira aenigmatica	+	+		
A. fertilissima		+	+	+
A. fritschii				+
A. implexa	+			+
A. prolifica	+			+
A. pseudodarmosa				+
Calothrix bharadwajae	+	+	+	+
C. braunii	+	+	+	
C. brevissima		+	+	
C. castellii				+
C. contarenii		+	+	+
C. elenkinii			+	+
C. fusca	+		+	+
C. ghosei	+			
C. membranacea		+	+	
C. parietina	+			+
C. thermalis		+	+	+
Camptylonemorpsis lahorensis				+
Chamaesiphon curvatus		+	+	+
Chlorogloean fritschii	+	+	+	+
Chroococcus cohaerens		+	+	
C. minutes			+	+
C. pallidus			+	
Crinalium magnum	+	+		
Cylindrospermum alatosporium		+		+
C. cuvatum				+
C. doryphorum		+		
C. indicum	+	+		+

C. licheniforme		+		+
C. majus			+	
C. michailoukoense			+	
C. muscicola			+	+
C. sphaerica		+		
C. stagnale		+		
Dermocarpa sp.		+	+	+
D. hemisphaerica				+
D. leibleiniae				+
D. sphaerica				+
Fischerella muscicola			+	+
Gloeocapsa aeruginosa				+
G. calcarea			+	+
G. crepidinum	+	+	+	+
G. decortican	+		+	
G. kuetzingiana			+	+
G. luteo-fusca	+			+
G. montana	+			+
G. pleurocapsoides	+	+	+	+
G. polydermatica	+			+
G. punctata				+
G. rupestris		+	+	+
Gleothece maxima	+			+
G. membranacea	+	+		+
G. rupestris		+	+	+
G. samoensis		+	+	+
Gloeotrichia echinulata		+	+	+
G. intermedia				+
G. natans	+			
G. raciborskii			+	+
G. pisum				
Hapalosiphon welwitschii		+		
Homeothrix juliana	+		+	+
Hydrocoleum sp.				
H. lyngbyaceum			+	+
Johannesbaptistia sp.				
Katagnymene pelagica	+			
Lyngbya aerugineo-coerulae			+	
L. aestuarii		+		
L. agerheimii forma lacerata			+	

L. allorgei				+
L. birgei				+
L. ceylanica				+
L. confervoides	+			+
L. cryptovaginata			+	+
L. gracilis				+
L. hieronymusii				+
L. lachneri				+
L. largerheimii			+	
L. laxespiralis		+		+
L. lutea		+		+
L. magnifia		+		+
L. major				+
L. majuscula		+	+	+
L. martensiana			+	+
L. mesotricha				+
L. perelegems			+	+
L. rubida		+		
L. semiplana				+
L. sordida				+
L. spiralis	+	+		
L. pirulinoides	+	+		
L. stagnina	+	+		
Mastigocladus laminosus		+	+	
Merismopedia sp.		+		+
M. convoluta			+	+
M. glauca		+		
M. tenuissima	+	+	+	
Microchaete loktakensis			+	+
M. tenera		+	+	+
M. uberrima	+	+		+
Microcoleus sp.		+		
M. chthonoplastes	+			+
M. lacustris		+		
M. paludosus	+			
M. subtorulosus			+	+
M. vaginatus			+	
Microcystis aeruginosa			+	+
M. bengalensis	+	+	+	+
M. elongata	+	+	+	+

M. flos-aquae		+	+	+
M. littoralis	+	+		+
M. marginata	+			+
M. pseudofilamentose			+	+
M. pulverea				
M. robusta		+	+	+
M. viridis				+
Myxosarcina spectabilis		+	+	+
Nostoc calcicola			+	+
N. comminutum				+
N. commune		+	+	+
N. depressum		+		+
N. ellipsosporum	+		+	+
N. errucosum				+
N. hatei		+	+	+
N. humifusum		+		+
N. labatus	+			+
N. linckia	+	+		
N. muscorum				+
N. paludosum		+	+	+
N. piscinale		+	+	
N. punctiforme			+	
N. spongiaeforme				+
Nostocopsis hangsgirgi				+
N. lobata			+	
Oscillatoria acuta	+			
O. acuminata		+		+
O. amaena		+	+	+
O. amphigranulata			+	
O. ambhibia		+	+	+
O. anguina			+	+
O. animalis	+	+		
O. annae		+	+	
O. breis	+	+		
O. chalybea		+	+	
O. chilkensis				+
O. chlorina		+		
O. corallinae		+	+	+
O. cortiana				+
O. curviceps		+		+
O. earlei		+	+	+

O. formosa			+	+
O. irrigua	+			
O. jasorvensis				+
O. limosa			+	+
O. margaritifera			+	+
O. mougeotii				+
O. nigroviridis			+	+
O. obscura	+			+
O. okeni			+	+
O. princeps				+
O. proboscidea			+	+
O. prolifica			+	
O. proteus	+	+		+
O. rooi	+			+
O. scanta				+
O. schultzii		+	+	
O. simplicissima			+	+
O. splendida			+	+
O. subbrevis			+	
O. tenuis		+		
O. terebriformis				+
Phormidium angustissimum				+
P. ambiguum		+		+
P. anomala			+	
P. bohneri			+	
P. corium	+		+	+
P. faosum		+		+
P. fragile	+	+	+	
P. jadinianum	+	+	+	
P. laminosum		+	+	+
P. molle	+	+		+
P. papyraceum		+	+	
P. purpurascens				+
P. retzii				+
P. rotanda	+	+	+	+
P. stagnina				+
P. tenue		+		+
P. ulderianum	+		+	+
Plectonema nostocorum	+	+		
P. notatum				+

P. tomasinianum				+
Porphyrosiphon nostarisii	+			
Pseudanabaena sp.		+		+
P. schidlei				+
Raphidiopsis curvata	+	+	+	+
R. indica				
Schizothrix arenaria				+
S. calcicola		+	+	
S. friesii				+
S. lacutris		+	+	+
S. lamyii		+		+
S. muelleri	+			
S. penicillata		+		+
S. rubella	+			+
S. tamyl	+			
S. telephoroides				+
Scytonema bohneri		+		
S. burmanicum				+
S. caldarium		+		+
S. ciricinnatum				+
S. coactile		+		
S. fermyii			+	+
S. fritschii		+		
S. guyanense		+		
S. hofmanni		+		+
S. javanicum			+	
S. leptobasis		+	+	
S. myochrous				+
S. schmidtii		+		+
S. simplex		+		
S. stuposum				+
S. tolypothrichoides		+		
Spirulina labyrinthiformis		+		
S. major		+		+
S. meneghiniana				+
S. princeps			+	+
S. subalsa			+	+
S. subtilissima				+
Stichosiphon sansibaricus				+
Stigonema hormoides	+			

S. ocellatum			+	
Symploca muralis				+
Synechocystis aquatitis			+	+
Trichodesmium erytthraeum		+		
T. thiebauti	+		+	+
Wollea bharadwajae			+	
Xenococcus acervatus				+
X. chaetomorphae	+			+
X. cladophorae				+
Bacillariophyceae				
Achnanthes microcephala			+	+
A. minutissima			+	+
Amphiprora sp.			+	+
Amphora sp.			+	+
A. veneta				+
Anomoeoneis exilis				+
Asterionella formosa			+	
A. japonica			+	+
Asteromphalus flabellatus				+
Bacillaria paradoxa				+
Bacteriastrum cosmosum				+
B. delicatulum				+
B. hyalinum			+	+
B. varians			+	+
Biddulphia heteroceros			+	+
B. longicruris			+	+
B. mobiliensis			+	+
B. pulchella			+	+
B. sinensis			+	+
Caloneis madraspatensis			+	+
Campylodiscus clypeus			+	+
Chaetoceros anheurckii			+	+
C. curvisetus			+	+
C. diversus			+	+
C. eibenii				+
C. flexuosus				+
C. indicus			+	+
C. laciniosus				+
C. lorenzianus			+	+

C. peruvianus			+	+
C. subsecundus			+	+
C. tenuissimus			+	+
Climacodium frauenfeldianum			+	+
Climacosphenia elongata			+	+
Cocconeis placentula.			+	+
Corethron hystrix			+	+
C. inerme			+	+
Coscinodiscus asteromphalus			+	+
C. concinnus				+
C. eccentricus				+
C. gigas				+
C. granii				+
C. jonesianus			+	+
C. oculusiridis				+
C. perforatus				+
Cyclotella sp.			+	+
C. glomerata				+
C. striata				+
Cymbella chandolensis			+	+
C. ehrenbergii				+
Diatoma vulgare			+	+
Diploneis robustus				+
Ditylum brightwelli			+	+
D. sol			+	+
Eucampia balaustium			+	+
E. cornuta			+	+
E. zodiacus			+	+
Eunotia sp.			+	+
Fragilaria canica			+	+
F. vaucheriae			+	+
Frustulia sp.			+	+
Gomphonema sphaerophorum			+	+
Gyrosigma acuminatum			+	
G. alticum			+	+
Hemiaulus sp.			+	+
Hemidiscus cuneiformis			+	+
Isthmia enervis			+	+
Lauderia annulata			+	+
Leptocylindrus danicus			+	+
Lithodesmium undulatum			+	+
Melosira moniliformis				+
M. sol				+
M. sulcata				+
Navicula cryptocephala			+	
N. radiosa			+	+
N. similis			+	+
N. stauroptera			+	
N. viridis			+	
Nitzschia acicularis			+	+
N. closterium			+	+
N. eriata			+	
N. linearis			+	+
N. longissima			+	+
N. obtusa				+
N. pelagica			+	+
N. scalaris			+	
N. sigma			+	+
N. sublinearis			+	+
Paralia sp.			+	+
Pinnularia viridis				+
Planktoniella sp.			+	+
P. sol				+
Pleurosigma angulatum				+
P. elongatum			+	+
P. normanii			+	+
Rhizosolenia alata			+	+
R. imbricata			+	+
R. robusta			+	+
R. setigera			+	+
R. stolterfothii			+	
Rhopalodia gibba			+	
Skeletonema costatum			+	+
Stauroneis phoenicenteron				+
Stephanopyxis palmeriana				+
S. turris			+	+
Surirella eximia			+	+
Synedra ulna			+	

Thalassiosira sp.			+	+
Thalassiosirs coramandeliana			+	+
Thalassiothrix frauenfeldii			+	+
T. ongissima			+	+
Thalassionema nitzschioides			+	+
Triceratium elengans			+	+
T. favus				+
Tropidoneis elegans			+	+
Chlorophyceae				
Bambusina sp.				+
B. brebissonii				+
Boodleopsis sundarbanensis				+
Chaetomorpha aerea				+
C. brachygona				+
C. gracilis				+
Chara andalurensis	+			
C. braunii	+			
C. coralina				
C. erythrogyna			+	
C. fibrosa			+	
C. flaccidus			+	
C. globularis			+	+
C. hydropitys				+
C. setosa			+	
C. socotrensis			+	
C. zeylanica			+	+
Chlorella marina				+
C. salina				+
C. vulgaris				+
Cladophora echinus				+
Cladophorella sundarbanensis				+
Closterium abrupum		+		+
C. acerosum				+
C. acutum				+
C. baillyanum				+
C. calosporum				+
C. cynthia		+		+
C. ehvenbergii	+			
C. enus		+		
C. lanceolatum				+
C. libellula				+
C. lineatum				+
C. moniliferum				+
C. moniliformis	+			+
C. parvulum				+
C. ralfsii				+
C. rectimarginatum		+		+
C. striolatum				+
C. ulna				+
Cosmarium amoenum	+			+
C. angulatum forma majoris				+
C. auriculatum	+			+
C. bipunctatum				+
C. connatum				+
C. cuneatum				+
C. ceylanicum				+
C. cyclicum				+
C. cylanicum				+
C. decoratum				+
C. depressum				+
C. formosulum				+
C. freemanii				+
C. geminatum		+		+
C. granatum		+		+
C. laeve		+		+
C. lundellii		+		+
C. margispinatum		+		+
C. obsolatum			+	
C. paucigranulatum				+
C. perforatum				+
C. phaseolus		+		
C. planogranatum				+
C. platydesminum				+
C. pseudoconnatum			+	+
C. pseudoretusum			+	
C. pseudopyramidatum forma minor				+
C. punctulatum			+	
C. quadrum				+
C. regenlii				+

C. speciosissimum			+	
C. speciosum				+
C. striolatum				+
C. subauriculatum				+
C. subtumidum				+
Desmidium coarctatum				+
D. grevilli			+	+
D. swarrzii				+
D. waetzii			+	
Dictyosphaerium pulchellum				+
Enteromorpha clathrata				+
E. compressa			+	+
E. intestinalis				+
E. prolifera			+	+
Euastrum acanthophorum				+
E. ansatum				+
E. coralloides				+
E. didelta				+
E. dubium			+	
E. elegans				+
E. gnathophorum				+
E. horikawae				+
E. longicolla				+
E. serratum				+
E. sinuosum				+
E. spinulosum		+		+
E. subhexalobum				+
Eudorina sp.				+
Franceia dorescheri				+
Gonatozygon sp.		+		
Heterosiphonia sp.				+
H. dendroidea				+
Hyalotheca dissiliens				+
Lola capillaries				+
L. implexa				+
L. tortuosa				+
Micrasterias alata				+
M. foliacea				+
M. mahabuleahwarensis				+

M. rotata				+
Netrium digitus	+			+
Nitella acuminata				+
N. furcata			+	
N. gracillis			+	
N. hyaline	+		+	
N. mucronata			+	
N. polycarpa	+			+
N. tuberculata		+		+
Oedogonium undulatum				+
Onychonema leave				+
Pediastrum boryanum				+
P. uplex				+
P. simplex				+
P. tetras		+		
Phyllobium dimorphum				+
Pleurotaenium coroniferum				+
P. ehrenbergii		+	+	
P. eugeneum				+
P. irregulare				+
P. kayei				+
P. lagerheimii forma minor				+
P. nodosum			+	+
P. ovatum				+
P. subcoronulatum		+		
P. rabecula				+
P. trabecula				+
Radiococcus sp.				+
Rhizoclonium sp.			+	+
R. grande				+
R. hookeri				+
R. riparium			+	+
Scenedesmus bijuga				+
S. quadricauda				+
Sphaeroplea soleirolli				+
Spirogyra bellis		+	+	
S. brunna	+			
S. condensala		+	+	
S. corrugata		+	+	
S. crenulata		+	+	

S. daedalea		+	+	
S. dubia				+
S. elliptica		+	+	
S. farlowii		+	+	
S. gujaratensis	+	+		+
S. hunanensis		+	+	
S. irregularis				+
S. juergensii				+
S. kundaensis		+	+	
S. maxima			+	+
S. minor		+	+	
S. neglecta			+	
S. nitida			+	
S. porticalis		+	+	
S. rhizobrachialis		+	+	
S. setiformis		+	+	
S. ternata				+
Spirotaenia condensata				+
Spondylosium sp.				+
S. nitens			+	
S. planum				+
Staurastrum bellum		+	+	+
S. corniculatum				+
S. gladiosum				+
S. indentatum forma minus				+
S. longispinum			+	+
S. saltans				+
S. wildemanii				+
Stigeoclonium aestivale			+	+
S. curvirostrum		+		+
S. farclum			+	+
S. fasciculore			+	+
S. flagellifera			+	+
S. geraldii			+	+
S. indicum			+	+
S. longipilum			+	+
S. pachydermum			+	+
S. penicillatum		+		
S. pusillum			+	+
S. tenue			+	+
Tetradinium sp.			+	+
Triplastrum abbreviatum				+
T. simplex				+
Triploceras gracile				+
Ulothrix ariablis	+			
U. fimbriata	+			
U. munaliformis		+	+	
U. zonata			+	
Ulva sp.			+	+
U. fasciata				+
U. lactuca				+
U. lobata			+	+
U. patengensis				+
Uronema confervicola				+
Zygnema kiangsiense			+	
Z. majus			+	
Z. pectinatum			+	
Dinophyceae				
Ceratium extensum			+	+
C. furca			+	+
C. horridum			+	+
C. inflatum				+
C. teres				+
C. tripos			+	+
C. trichoceros				+
Dinophysis caudata			+	+
Noctiluca sp.			+	+
Peridinium brevipes				+
Protoperidinium crassipes				+
P. depressum			+	+
P. ovatum				+
Pyrophacus horologicum				+
Xanthophyceae				
Trbonema bomybcinum			+	
Vaucheria sp.			+	
V. prescotti				+
V. sessilis	+			+
Rhodophyceae				
Bostrychia radicans				+

B. tenella				+
Caloglossa adnata			+	+
C. leprieurii				+
Catenella impudica				+
C. nipae			+	+
C. repens				+
Ceramium elegans			+	+
C. gracillimum			+	
Compsopogon lividus			+	
C. coeruleus			+	
Gelidium pusillum				+
Gelidiella acerosa				+

Polysiphonia denudata				+
P. mollis				+
Porphyra sp.				+
Pterosiphonia pinnata				+
Euglenophyceae				
Euglena viridis	+	+		
Phacus pleuronectes				+
P. triqueter			+	+
Phaeophyceae				
Colpomenia sinuosa				+
Dictyota ceylanica				+

Appendix II

Distribution of zooplankton in the lower stretch of Ganga River from Farakka to Gangasagar

Species	I	II	III	IV
Cnidarians				
Acromitus flagellatus				+
A. rabanchatu				+
Aequorea pensilis				+
Blackfordia virginica			+	
Bougainvillia fulva				+
Cassiopea andromeda				+
Diadumene schilleriana				+
Edwardsia tinctrix				+
E. jonesii				+
Eirene ceylonensis				+
E. menoni			+	+
Limnocnida indica		+		
Liriope tetraphylla				+
Moerisia gangetica			+	
Netrostoma typhlodendrium				+
Nevadne glauca				+
Obelia sp.				+
Paracondylactis indica				+
Pelocoetes exul				+
P. minima				+
Phytocoeteopsis ramunnii				+
Phytocoetes gangeticus				+
Pseudodiaptomus tollingerae				+
Tamoya gargantua				+
Versuriga anadyomene				+
Copepoda				
Family: Acartidae				
Acartia chilkaensis			+	
A. plumose			+	
Acartiella keralensis				+
A. major				+
A. minor				+
A. sewelli				+
A. tortanifoprmis				+
Family: Diaptomidae				
Heliodiaptomus cinctus	+	+		
H. contortus		+	+	+
H. viduus	+	+	+	+
Neodiaaptomus madrasensis		+		+
N. schmackeri	+			
Pseudochydorus globosus			+	
Tropodiaptomus australis			+	
Family: Pontellidae				
Labidocera acuta				+
L. pavo				+
Family: Cyclopidae				
Mesocyclops leukarti	+		+	+
Microcyclops varicans			+	
Paracyclops fimbriatus			+	
Phyllodiaptomus blanci	+			
Tropocyclops prascinus			+	
Family: Pseudodiaptomidae				
Pseudodiaptomus annandalei			+	
P. aurivilli				+
P. binghami				+
P. lobipes				+
P. tollingerae				+
Cladocera				
Family: Chydoridae				
Alona affinis		+	+	+
A. costata			+	
A. davidi				+
A. intermedia		+	+	
A. kurua		+		+
A. kwangsiensis			+	
A. monacantha			+	
A. pulchella		+		+
A. quandrangularis				+
A. rectangular				+
A. verrucosa		+	+	
Alonella excisa		+	+	
Dunhevedia crassa			+	
D. serrata		+	+	
Euryalona orientalis				+

Graptoleberis testudinaria			+	
Guernella raphaelis			+	
Kurzia latissima			+	+
K. longirostris		+	+	+
Leydigia acanthocercoides			+	
Notoalona globulosa		+	+	+
Oxyurella singalensis		+	+	+
Pleuroxus denticulatus			+	+
P. similes			+	+
Family: Bosminidae				
Bosmiopsis deitersi		+	+	
Family: Daphnidae				
Ceriodaphnia cornuta		+	+	+
C. barroisi		+	+	+
C. eurynotus		+	+	
C. faviformis			+	
C. pubescens			+	
C. reticulata			+	
C. sphaericus			+	+
C. ventricus		+	+	
Daphnia carinata			+	+
D. lumholtzi		+	+	+
D. similis			+	
Scapholeberis kingi		+	+	
Simocephalus exspinosus		+	+	+
S. latirostris		+	+	
S. vetulus		+	+	+
Family: Sididae				
Diaphanosoma brachyurum		+	+	
D. excisum		+	+	+
D. sarsi			+	
Latonopsis australis		+	+	
Pseudosida bidentata			+	+
Family: Ilyocryptidae				
Ilyocryptus spinifer		+	+	
Family: Macrothridae				
Eschinisca triserialis		+	+	+
Grimaldina brazzai			+	
Macrothrix goeldii			+	
M. spinosa		+	+	
Family: Moinidae				
Moina micrura		+	+	+
M. weismanni		+		
Moinodaphnia macleayi			+	
Other Crustaceans				
Conchoecete alcocki				+
C. artificious				+
Dorippe dorspes				+
D. facchino				+
D. fachhinovar alcocki				+
Euryalona orientalis				+
M. dentipes				+
M. indica				+
M. intermedia				+
Metopograpsus maculates				+
M. messar				+
Pachygrapsus propinquus				+
Ptychognathus dentatus				+
P. onyx				+
Pyxidognathus fluviatilis				+
Susarma bidens				+
S. edwardsi				+
S. intermedia				+
S. kraussi				+
S. longipes				+
S. quadrata				+
S. smithi				+
S. taenialatum				+
S. tetragona				+

List of rotifers in lower Ganga basin

Brachionidae	*L. (Lepadella) rhomboidula*	*Scaridium longicaudu*
Anuraeopsis coelata	*L. (Lepadella) triptera*	*Trichocerca (Trichocerca) rattus*
A. fissa	*L. (Lepadella) triprojectus*	*T. (Trichocerca) elongata*
Brachionus angularis	*L. (Heterolepadella) aspicora*	*T. (Trichocerca) pasilla*
B. bidentatus	*L. (Heterolepadella) eherenbergi*	*T.(Diurella) weberi*
B. budapestinensis	*L. (Heterolepadella) heterostyla*	**Asplanchnidae**
B. calyciflorus	**Lacanidae**	*Asplanchna brightwelli*
B. caudatus	*Lecane (Lcane) aculeata*	*A. priodonata*
B. diversicornis	*L. (Lcane) arcula*	**Dicranophoridae**
B. forficula	*L. (Lcane) bifastigata*	*Dicranophorus forcipatus*
B. mirabilis	*L. (Lcane) crepida*	*D. lutkeni*
B. plicatilis	*L. (Lcane) flexilis*	**Gastrophoridae**
B. pteridinoides	*L. (Lcane) hornemanni*	*Ascomorpha ovalis*
B. quadridentatus	*L. (Lcane) lateralis*	**Synchaetidae**
B. rubens	*L. (Lcane) leontina*	*Polyarthra valgaris*
B. sessilis	*L. (Lcane) ludwigi*	**Conochilidae**
B. urceolaris	*L. (Lcane) luna*	*Conochilus natans*
Keratella cochlearis	*L. (Lcane) nana*	**Hexarthridae**
K. lenzi	*L. (Lcane) ohioensis*	*Hexarthra mira*
K. procurva	*L. (Lcane) papuana*	**Testudinellidae**
K. quadrata	*L. (Lcane) ungulata*	*Pompholyx sulcata*
K. tropica	*L. (Lcane) vasishti*	*Testudinella emarginula*
Platyias quadricornis	*L. (Hemimonostyla) inopinata*	**Filinidae**
Euchilanidae	*L. (Hemimonostyla) sympoda*	*Filinia longiseta*
Beauchampiella sp.	*L. (Hemimonostyla) syngenes*	*F. opoliensis*
Dipleuchlanis propatula	*L. (Monostyla) bulla*	*F. pejleri*
Euchlanis dilatata	*L. (Monostyla) closterocera*	*F. terminalis*
E. oropha	*L. (Monostyla) decipiens*	**Trochosphaeridae**
Ttripleuchanis plicata	*L. (Monostyla) furcata*	*Horaella brehmi*
Mytilinidae	*L. (Monostyla) hamata*	**Philodinidae**
Mytilina ventralis	*L. (Monostyla) lunaris*	*Rotaria neptunia*
Trichotridae	*L. (Monostyla) pawlowskii*	**All the above mentioned taxa are reported in Burdwan, Nadia, Midnapore, Kharagpur, Kolkata, N 24 Pgs , Hooghly*
Trichotria tetractis	*L. (Monostyla) pyriformis*	
Macrochaetus sericus	*L. (Monostyla) quadridentata*	
Colurellidae	*L. (Monostyla) sinuata*	
Colurella uncinata	*L. (Monostyla) stenroosi*	
Lepadella (Lepadella) acuminata	*L. (Monostyla) thalera*	
L. (Lepadella) aspida	*L. (Monostyla) unguitata*	
L. (Lepadella) imbricata	*Cephalodella auriculata*	
L. (Lepadella) ovalis	*C. catellina*	
L.(Lepadella) patella	*C. forficula*	
L. (Lepadella) quadricarinata	*C. gibba*	
L. (Lepadella) rhomboids	*C. mucronata*	

Appendix III

Distribution of macrobenthos in the lower stretch of Ganga River from Farakka to Gangasagar

	I	II	III	IV
Arthropoda				
Achaearanea durgae		+		
Aculops abutiloni				+
Anilocra laticauda				+
Aphis fabae	+	+	+	
A. gossypi		+		+
Araneus dehaanii		+	+	
A. excelsus		+		
Arctosa himalayensis			+	
A. indicus			+	
Argiope catenulata		+	+	+
A. latia			+	
Artema atlanta	+	+	+	
Bomis bengalensis			+	
B. kolkataensis			+	
Calappa lophos				+
C. pustulosa				+
Catantops erubescens				+
Cheiracanthium insigne			+	
C. mysorensis				+
C. trivialis		+	+	
Cirolana parva		+		+
Clubiona drassodes			+	+
C. filicata		+	+	+
C. ludhianaensis		+	+	
Conchoecete alcocki				+
Crossopriza lyoni	+	+	+	+
Cyclosa confraga		+		
Cymothoa indica				+
Cyrtophora cicatrosa	+	+	+	+
Diplatys brindlei				+
Dorippe dorsipes				+
D. facchino				+
Euborellia stali			+	+
Euophrys chiriatapuensis		+	+	
Exosphaeroma parva				+
Forcipula indica			+	+
Gasteracantha kuhli			+	
G. mammosa			+	
Geocoris ochropterus	+			
Gerenia bengalensis				+
Hersilia savignyi	+	+	+	+
Heteropoda sexpunctata		+	+	+
Hippasa partita			+	
Hysteroneura setariae			+	
Labidura riparia			+	
Larinia phthisica		+	+	
Leucauge decorata	+	+	+	
L. tessellata				+
Lutica bengalensis			+	
Lycosa choudhuryi				+
L. kempi			+	
Lyssomanes andamanensis			+	
L. bengalensis			+	+
L. santinagarensis			+	
Marpisa bengalensis			+	+
M. calcuttaensis			+	
M. decorata			+	+
Matuta lunaris				+
M. planipes				+
Melanaphis sacchari	+			
Mesambria dubia	+	+	+	+
Metisolabis caudelli	+	+		
Myrmarachne orientalis			+	+
Nala nepalensis			+	
Neoscona excelsus				+
N. molemensis				+
N. mukerjei		+	+	+
N. poonaensis	+	+	+	
Nephila kuhlii			+	
N. maculata			+	
Nerocila madrasensis				+
N. phaeopleura				+
N. serra				+
N. sundaica				+
Nysius ceylonicus	+	+	+	+
Oecobius putus			+	
Oedignatha scrobiculata		+	+	

Oligonychus biharensis			+	+
O. coffeae		+		
O. indicus	+			+
O. magniferous	+		+	+
Oxyopes ratnae	+	+	+	+
O. shweta		+	+	
Pachygrontha bipunctata	+	+		+
Paraconophyma scabra		+	+	+
Paradiplatys gladiator				+
Parawixia dehaani				+
Pardosa birmanica	+	+	+	
P. burasantiensis		+	+	
P. sumatrana		+	+	
Paromius pallidus			+	+
Phidippus bengalensis		+	+	
P. indicus	+	+	+	+
P. pateli	+	+	+	+
Plexippus paykulli	+		+	+
Poekilocerus pictus		+	+	+
Pseudopachybrachius guttus		+	+	+
Pyrgomorpha conica		+		+
Rhene indicus			+	
R. khandalaensis		+		
R. pantharae		+		
Salticus ranjitus	+	+	+	+
Scalopidia spinosipes				+
Schizotetranychus cajani	+	+		
Scytodes propinqua			+	+
Simalio biswasi			+	
Singa chota			+	
Spariolenus tigris				
Sphaeroma triste				+
Sphingius paltaensis			+	
Stegodyphus sarasinorum	+		+	+
Tagasta indica	+	+		
Toxoptera odinae			+	
Uloborus danolius	+		+	+
Zygeilla melanocrania		+	+	+
Molluscs				

Gastropoda				
Amalda ampla				+
Architectonica perspectiva			+	+
Assiminea beddomeana				+
A. woodmasoniana				+
Asthenotoma vertebrata				+
Bellamya bengalensis		+		+
B. crassa		+		
B. dissimilis		+		
Brotia costula		+	+	
Cassidula nucleus				+
Cerithidea alata				+
Clithon reticularis				+
Columbella ducolosiana			+	+
Iravadia ornata				+
Larina burmana			+	+
Natica gualteriana				+
N. smithi				+
N. tigrina			+	+
N. violacea			+	
Olivancillaria gibbosa				+
Pila globosa		+		+
Polinices didyma				+
Potamacmaea fluviatilis				+
Pseudanachis duclosiana				+
P. sulculosa			+	+
Septaria caerulescens		+	+	+
S. lineata		+	+	+
Stenothyra blanfordiana				+
S. deltae			+	+
Telescopium telescopium			+	+
Terebra tenera				+
Thais blanfordi				+
T. lacera				+
Thiara lineatus		+		
T. scabra			+	+
Tubiola microscopica				+

Umbonium vestiarium				+
Pelycepoda				
Barnea candida				+
Corbicula bensoni		+		+
C. gracilis				+
C. striatella			+	+
Cuspidaria chilkaensis				+
Gafrarium pectinatum		+		+
Glauconome sculpta				+
Lamellidens corrianus	+	+	+	
L. marginalis	+	+	+	+
Laternula truncata				+
Mactra luzonica				+
Martesia fragilis				+
Meretrix meretrix			+	+
Novaculina gangetica				+
Nucula mitralis				+
Paphia malabarica				+
Parreysia caerulea	+	+	+	
P. corrugata	+	+	+	+
P. favidens		+		
P. occata				+
Pitar alabastrum				+
Solen brevis				+
Sphenia perversa				+
Theora opalina				+
Trachycardium asiaticum				+
Cephalopoda				
Loligo duvanceli				+
L. investigatoris				+
Octopus macropus				+
Sepia aculeata				+
Sepiella inermis				+
Scaphopoda				
Dentalium octangulatum				+
Annelida				
Polycheatae				
Barantolla sculpta			+	
Capitella capitata				+
Ceratonereis burmensis				+
Chloeia parva			+	+
Dendronereides gangetica			+	+
D. heteropoda		+	+	+
Dendronereis arborifera				+
D. aestuarina				+
D. dayi				+
Diopatra neapolitana				+
Eteone barantollae				+
Eunice aphroditois				+
Ganganereis sootai				+
Gattyana fauvele				+
Glycera alba				+
G. lancadive				+
Hesione splendida				+
Heteromastus similis				+
Hyalinoecia tubicola				+
Isolda pulchella				+
Laonome indica				+
Lumbrineris heteropoda				+
Lycastonereis indica			+	+
Lysidice collaris				+
L. natalensis				+
Marphysa sp.				+
M. mossambica				+
Mastobranchus indicus			+	+
Minuspio cirrifera				+
Namalycastis fauveli		+	+	+
N. indica		+	+	+
N. meraukensis				+
Neanthes chingrighattensis			+	+
N. cricognatha				+
N. glandicincta			+	
N. meggitti		+	+	+
Owenia fusiformis				+
Perinereis cavifrons				+
P. cultrifera				+
Pherusa bengalensis				+
Polydora kempi				+
P. normalis				+

Prionospio cirrifera				+
Pseudopolydora kempi				+
Sabellaria pectinata				+
Spio bengalensis				+
Sternaspis scutata				+
Talehsapia annandalei				+
Oligocheata				
Aelosoma bengalensis			+	
Allonais inaequalis		+	+	
A. paraguayensis	+		+	
Aulodrilus remex	+			
Branchiodrilus hortensis		+		
B. semperi		+	+	+
Branchiura sowerbyi	+	+		
Chaetogaster langi			+	
Dero cooperi	+	+		+
D. dorsalis	+	+	+	
Dichogaster bolaui			+	
D. modiglianii		+	+	
Drawida nepalensis		+	+	
Eutyphoeus incommodus	+	+	+	
E. nicholsoni	+	+	+	
E. orientalis	+	+	+	+
E. waltoni			+	
Lampito mauritti	+	+	+	+
Lennogaster pusillus			+	
Limnodrilus hoffmeisteri	+	+	+	
Metaphire planate	+	+	+	
M. posthuma				+
Nais barbata			+	
N. simplex			+	+
Octochaetona beatrix	+	+	+	+
O. compta		+		
Pellogaster bengalensis		+		
Perionyx excavatus	+	+	+	+
Polypheretima elongata				+

Pontodrilus bermudensis				+
Priatina aequiseta			+	
P. sperberae		+		
Slavina appendiculata			+	
Stylarias fossularis	+		+	
Tubifex tubifex	+			
Hirudinia				
Glossiphonia weberi	+	+	+	+
Haemadipsa sylvestris	+	+	+	+
Helobdella nociva			+	+
Hemiclepsis marginata	+	+		
Hirudinaria manillenses	+	+		
Ozobranchus shipleyi			+	
Pontobdella aculeata				+
Echinodermata				
Acaudina molpadioides				+
Amphioplus sp.				+
Astropecten euryacanthus				+
A. indicus				+
Chaetodiadema granulatum				+
Clypeaster rarispinus				+
Echinodiscus auritus				+
Goniopecten sp.				+
Labidoplax sp.				+
Laganum decagonale				+
Luidia hardwicki				+
Ophiactis delagoa				+
O. modesta				+
Ophiocnemis marmorata				+
Synaptula recta				+
Temnopleurus toreumaticus				+
Thorsonia investigatoris				+

Appendix IV

Distribution of fishes in the lower stretch of Ganga River from Farakka to Gangasagar

Anguillidae
*Anguilla bengalensis**
Ophichthdae
Psidodonophis boro
Notopteridae
*Notopterus notopterus**
*N. chitala**
Clupeidae
Andontostaoma manmina
A. chacunda
Corica soborna
*Gadusia chapra**
*Gonealosa manmina**
Hilsa kelee
Sardinella melanura
*Tenualosa ilisha**
Chirocentridae
Chirocentrus dorab
Pristigasteridae
Ilisha feligera
I. megaloptera
Raconda russeliana
Engraulidae
Coilia dussumiere
C. ramcorti
C. reynalidy
*Setipinna phasa**
S. taty
S. brevifilis
Stolephorus indicus
Thryssa purava
Cyprinidae
*Amblypharyngodon mola**
*Catla catla**
*Cirrhina mrigala**
*C. reba**
*Dani devario**
D. dangila
*Esomus danricus**
*Labeo bata**
*L. calbasu**
*L. rohita**
*Puntius conchonius**
*P. sarana sarana**
*P. sophore**
*P. ticto**
*Rasbora daniconius**
*Salmostoma bacaila**
Cobitidae
*Botia lohochata**
*B. dario**
*Lepidocephalus guntea**
Bagridae
*Mystus vittatus**
M. cavasius
*M. gulio**
*Rita rita**
*Sperata aor**
*S. seenghala**
Schilbeidae
*Aila coila**
*Clupisoma garua**
*Eutropiichthys vacha**
*Silonia silondia**
Pangasidae
*Pangasius pangasius**
Siluridae
*Ompak bimaculatus**
*O. pabo**
*O. pabda**
*Wallaga attu**
Sissoridae
*Bagarius bagarius**
*Gagata cenia**
Clariidae
*Clarius batrachus**
Heteropneustidae
*Heteropneustis fossalis**
Aridae
Arius arius
A. gagora
A. Jella
A. sagar
A. sona
Batrachocephalus mino
Osteogeneiosus militaris
Harpadontidae
Harpodon nehereus
Synodontidae
Saurida tumbil
Bregmacerotidae
Bregmaceros mcclellandi
Centropomidae
*Lates calcarifer**
Ambassidae
Ambasis baculis
A. commersoni
*Pseudombasis ranga**
*P. lala**
Leiognathidae
Leiognathus equulus
Gazza minuta
Secutor ruconis
S. insidiator
Gerridae
Gerres filamentosa
G. oyena
Gerreomorpha setifer
Lutjanidae
Lutjanus johni
L. argenti maculates
Nandidae
*Nandus nandus**
Badidae
*Badis badis**
Anabantidae
*Anabastes testudineus**
Osphronemidae
*Colisa fasciatus**
C. lalius
Scatophagidae
Scatophagus argus
Polynemidae
Eleutheronema tetradactylum
*Polynemus paradiseus**
Uranoscopidae
Uranoscopus congnatus
Gobiidae
Apocryptes bato
Brachygobius nunus
Boleopthalmus dussumieri
*Glossogobius giuris**
Gobiopterus chuno
Pseudapocryptes lanceolatus
Periopthalmodon schlosseri
Stigmatogobius sadanundio
Gobiodidae
Bathygobius orbicularis
Odontamblyopus rubicundus
Taenioides anguillaris
T. cirraatus
Eleotrididae
Eleotris fusca
Sillaginidae
Sillago sithama
Sillaginopsis panejus

Carangidae
Carangoides malabaricus
Caranx carangus
Megalaspis cordyla
Parastromateidae
Parastromateus niger
Stromateidae
Pompus argenteus
Ephippididae
Drepene punctata
Mullidae
Parupeneus indicus
Upeneus vittatus
U. Sulphureus
Teraponidae
Terapon jarbua
Terapon theraps
Trituridae
Triturus haumala
T. savala
Sciaenidae
Johnius coitor
J. gangeticus
*Pama pama**
Otolithoides biauritus
Lobotidae
Lobotes surinamensis
Haemulidae
Pomadasys maculatus
P. argenteus
Sparidae
Acanthopagrus latus
Cichlidae
Oreochromis nloticus
Mugilidae
Liza parsia
L. tade
L. macrolepis
Mugil cephalus
*Rhinomugil corsula**
*Sciamugil cascasia**
Valamugil cunnesieus
Mastacembelidae
*Mastacembelus armatus**
M. pancalus
*Macrognatus aculeatus**
M. puncalus
Tetradontidae
*Tetradon cutcutia**
Triacanthidae
Triacanthus brevirostris

Hemirasmphidae
Hyporhampus limbatus
Belonidae
*Xentendon cancila**
Strongylura strongylura
Oryziidae
Oryzias melastegma
Aplocheilidae
Aplocheilius panchax
Syngnathidae
Microphis cuncalus
Dactylopteridae
Dactylopterus orientalis
Channidae
*Chanda nama**
*Channa marulius**
*C. orientalis**
*C. punctatus**
*C. striatus**
Symbranchidae
Monopterus cuchia
Cyanoglossidae
Cyanoglossus arel
C. cyanoglossus
C. lingua
Soleidae
Euryglossa orientalis
Synaptura albomaculata
Scorpaenidae
Pterois russellii
Synancellidae
Minous coccineus
Platycephalidae
Platycephalus indicus
Batrachoidae
Batrichthys grunnies
Plotosidae
Plotosus canius
Kurtidae
Kurtus indicus
Muraenidae
Lycodontis tile
Megalopidae
Megalops cyprinoides
Trichiuridae
Trichiurus spp.

Appendix V

Distribution of carlillngineous fishes (Class- Chondrichthyes) in the Hooghly Estuary

Families	Species
Carcharhinidae	*Aetobatus narinari*
Carcharhinidae	*Carcharhinus limbatus*
Carcharhinidae	*Glyphis gangeticus*
Dasyatidae	*Dasyatis bleekeri*
Dasyatidae	*D. marginata*
Dasyatidae	*D. stephen*
Dasyatidae	*D. uarnak*
Dasyatidae	*D. zugei*
Hemiscylliidae	*Chiloscyllium griseum*
Pristidae	*Pristis microdon*
Rhinobatidae	*Rhinobatos annandalei*
Sparidae	*Eusphyra blochii*
Stegostomalidae	*Stegostoma fasciatum*

Appendix VI

Distribution of higher vertebrates in the lower stretch of Ganga River from Farakka to Gangasagar

i. **Dolphin**

Distribution: Hooghly (Shrirampore; But occurrence in recent time is very doubtful)

Family: Delphinidae

1. *Orcaella brevirostris* (Gray) Status : Sch.-I, App.-II

Common Name: Irrawaddy Dolphin
Distribution: South 24 Pgs (Bay of Bengal)

2. *Sousa chinensis* (Osbeck) Status : Sch.-II, App.-I

Common Name: Plumbeous Dolphin
Distribution: South 24 Pgs.

3. *Stenella attenuata* (Gray) Status : Sch.-II

Common Name: Malay Dolphin
Distribution: South 24 Pgs (Sunderban; Only report of sighting in 1891 by W.T. Blandford)

Family: Phocoenide

4. *Neophocaena phocaenoides* (Cuvier) Status : Sch.-II, App.-I, Vulnerable

Common Name: Black Finless Porpoise
Distribution: South 24 Pgs (Sunderban)

Family: Platanistidae

5. *Platanista gangetica* (Roxburgh) Status : Sch.-I, App.-I

Common Name: Gangetic Dolphin
Distribution: Hooghly, Nadia (Mayapur)

ii. **Gharial and Turtles**

1. *Gavialis gangeticus* (Gmelin) Schedule I, App-I, Endangered

Common name: Gharial
Distribution: Nadia (Ranaghat)

Family: Crocodylidae

2. *Crocodylus porosus* Schneider Schedule I, App-I, Endangered

Common name: Estuarine/Saltwater crocodile
Distribution: North 24 pgs (Bhagabatpur), South 24 Pgs (Sunderban).

Order: Testudines
Family: Chelonidae

3. *Chelonia mydas* Linnaeus

Common name: Green sea turtle
Distribution: Sunderban (South 24 Pgs)

4. *Eretmochelys imbricata* Linnaeus
Common name: Hawksbill or tortoise shell sea turtle
Distribution: Sunderban (South 24 pgs) with rare occurrence.

5. *Lepidochelys olivacea* (Eschscholtz) Schedule I, App-I, Endangered
Common name: Pacific Ridley Turtle
Distribution: Medinipur (Digha), South 24 Pgs (Sunderban).

Family: Emydidae

6. *Batagur baska* (Gray) Schedule I, App-I, Endangered
Common name: River terrapin
Distribution: South 24 Pgs (Sunderban)

7. *Geoclemys hamiltonii* (Gray) Schedule I, App-I
Common name: Spotted pond turtle
Distribution: South 24 Pgs (Hooghly river).

8. *Geomyda indopeninsularis*
Distribution: Jalpaiguri (Gorumara).

9. *Kachuga kachuga*
Common name: Red crowned roof turtle
Distribution: Koch Bihar (Baneswar), Kolkata (Golf green)

10. *Kachuga tecta* (Gray) Schedule I, App-I, Vulnerable
Common name: Indian tent turtle
Distribution: North 24 pgs. (Palta), South 24 Pgs (Sunderban), Kolkata, Haora (Botanical garden) and Jalpaiguri (Gorumara).

Riparian Floral Diversity of Ganga River

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. Introduction

The river Ganga, life line for millions of people is aptly called the “River of India”. This river is the most widely written about and worshipped of all the renowned rivers throughout the world. Although, ~~by~~ a number of rivers feature in the civilization in pre-history and ancient history; Ganga is the most sacred, mythical and reverred. It is symbol of our tradition~~s~~ and values, providing physical and spiritual nourishment to millions of devotees. There are extensive classical and folk literatures related to this heavenly river known by many as “Divine river or Devnadi”   (Kumar, 2001). It is the largest and most important water shed of India covering 1,28,411 sq km as shown in Figure 1, The main features are mentioned in Table 1.

Table 1:   The main features of Ganga basin (Kumar, 2001)

S.No	Features	Measurements
1.	Total geographical area and annual discharge	8,61,404 sq km; 4,59,040 million cubic meters
2.	Surface water availability	446 million acre feet (MAF)
3.	Irrigation potential	27,350 thousand hectares
4.	Hydel potential	11,579 mega watts (at 60% load factor)
5.	Average annual rainfall	364 cm (Total)
6.	Sediment load	2.4 billion metric tons per year
7.	Temperature gradients	10-40°C

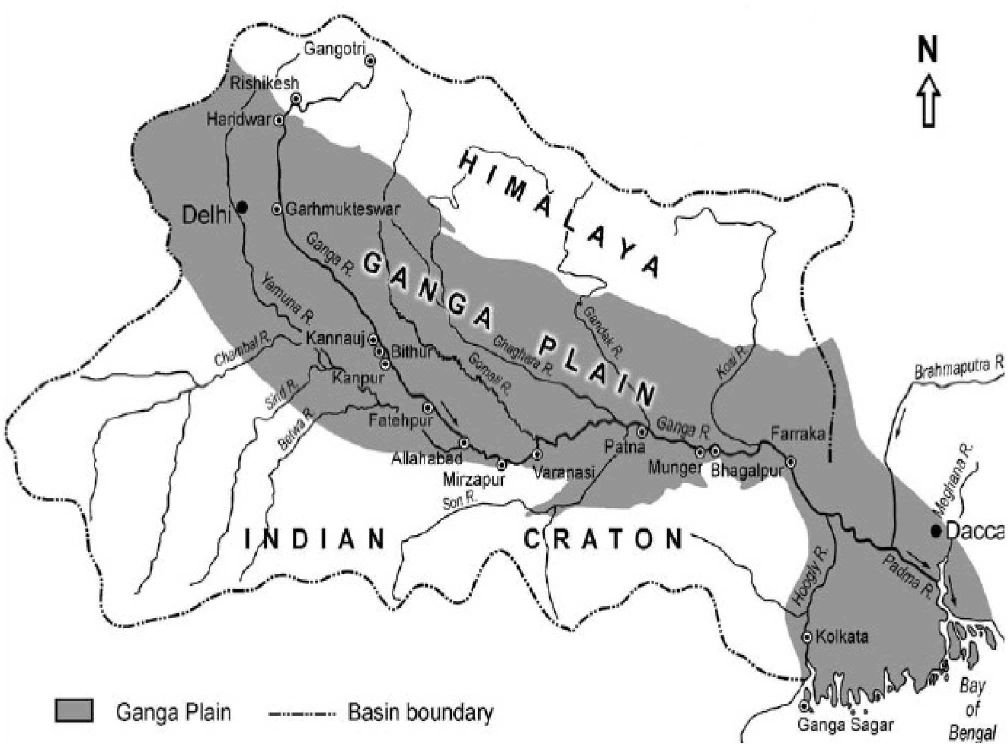

Figure 1:   Ganga plain in India

1.1. The riparian flora of Ganga basin

River bank vegetation is ecologically termed as riparian flora, and is highly dynamic. It links terrestrial and aquatic habitat, under the influence of waterways such as rivulet banks or riverbanks, is represented by a particular type of vegetation that grows along the sides of rivers, which are called the river's riparian zone (Dutta *et al*., 2011). Riparian plant habitats and communities are characterized by hydrophilic plants (Figure 2). Riparian vegetation consists of macrophytes, native grasses, sedges, climbers, shrubs and trees (Dutta *et al.*, 2011). Riparian zones are significant in ecology and environmental management, because of their role in soil conservation, their habitat biodiversity, and the influence they have on fauna and aquatic ecosystems, including grassland, woodland, wetland or even non-vegetative. Buffer strips of riparian vegetation are effective in reducing sediment and nutrient loads (Groffman *et al*., 1990; Castelle *et al.,* 1994). In the Himalayan region, riparian forests play a pivotal role in the life of people, to fulfil their daily requirements like timber, fuel, fodder, medicine, fruits and other purposes (Shyam, 2008). Water current plays a decisive role in dispersal of vegetative propagates and in influencing the marginal vegetation. After the floods, new and more fertile lands emerge, containing sprout luxuriant herbaceous vegetation. Some of these plants are ecologically very important as they provide shelter to the aquatic animals for breeding and spawning (Bilgrami, 1991).

Figure 2: Riparian flora of Ganga river near Haridwar

There is no systematic account available for plant diversity along the entire stretch of Ganga. The first written account of journey to Gangotri dates back to 1820 by Fraser. Subsequently, Pallis (1934), Auden (1941), Sahai (1953), Gupta (1960), Bhattacharyya and Goel (1982), Groffman *et al.* (1990), Krishanmurti (1991), Castelle *et al. (*1994), Shyam (2008), Gangwar and Joshi (2006) and Gangwar and Gangwar (2011) explored the Ganga river biodiversity. In this report effort has been made to compile the scattered data available on riparian floral diversity.

Total 475 riparian species have been documented in book "*THE GANGA–A SCIENTIFIC STUDY*", edited by Krishanmurti (1991) from Rishikesh to Chinasura. Some of the represented riparian flora is presented in **Annexure-I.** Out of 49 types of trees 16 have medicinal value. Total climbers reported were 28 of which 9 have medicinal value. Shrubs have total taxa of 55 with 15 being used for medicinal purposes. Herbs have the highest number of 317 in which 13 are medicinal herbs. Grasses and sedges have 17 and 9 species, respectively (Figure 3 and 4).

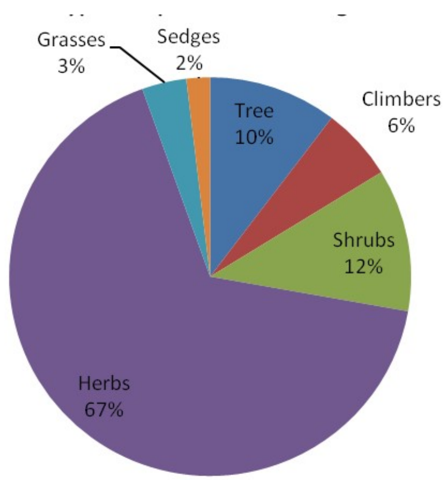

Figure 3: Riparian flora along Ganga river

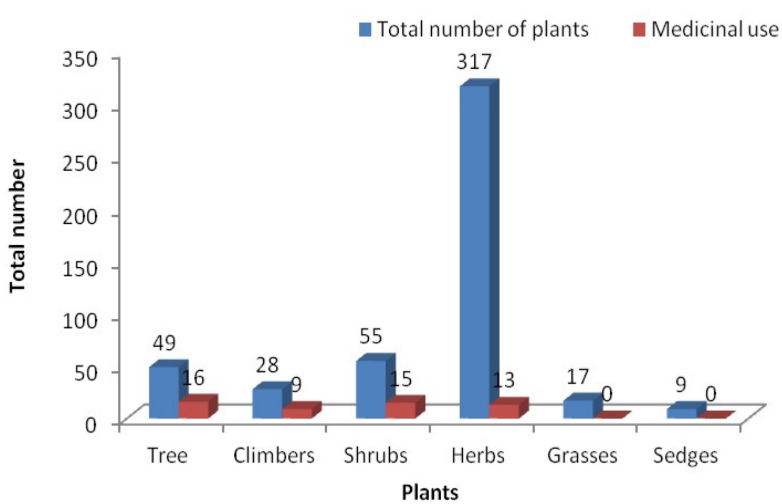

Figure 4: Medicinal use of riparian flora of Ganga river

1.2. Forest cover in Ganga Basin area

In the states like Haryana, Delhi, Bihar, Uttar Pradesh and Rajasthan, the forest cover is as low as 3.61 to 11.94% of the geographical area. Most of forest tracts within the Ganga basin are severely degraded on account of over exploitation. As a result, the forest ecosystem in the Ganga basin is under severe stress. Even in the states of Uttarakhand (45.8%), Madhya Pradesh (25.21%), Himachal Pradesh (26.35%) and West Bengal (14.64%) where the forest cover is higher, the proportion of the land under dense tree cover is very low due to extensive clear felling of trees carried out in recent decades. The state-wise forest cover in Ganga basin is shown in Table 2 and 3.

Table 2: State-wise forest cover in Ganga basin (Source: Environmental and Social Management Framework, NGRBP, 2011)

State	Geographical area (Sq km)	Forest				Geographical area (%)
		Very dense forest (Sq km)	Moderatly dense forest cover (Sq km)	Open forest (Sq km)	Total (Sq km)	
Bihar	94,163	231	3,248	3,325	6,804	7.23
Delhi	1,483	7	50	120	177	11.94
Haryana	44,212	27	463	1,104	1,594	3.61
Himachal Pradesh	55,673	3,224	6,383	5,061	14,668	26.35
Jharkhand	79,714	2,590	9,899	10,405	22,894	28.72
Madhya Pradesh	3,08,245	6,647	35,007	36,046	77,700	25.21
Rajasthan	3,42,239	72	4,450	11,514	16,036	4.69
Uttar Pradesh	2,40,928	1,626	4,563	8,152	14,341	5.95
Uttarakhand	53,483	4,762	14,165	5,568	24,495	45.80
West Bengal	88,752	2,987	4,644	5,363	12,994	14.64
Ganga Basin States	**1,308,892**	**22,173**	**82,872**	**86,658**	**1,91,703**	**14.65**
India	**3,287,263**	**83,510**	**3,19,012**	**2,88,377**	**6,90,899**	**21.02**

Table 3: Extent of forest cover in Ganges basin (Source: Forest Survey of India, 1995)

Catchment area	Dense forest	Open forest	Mangrove	Total	Scrub	Non-Forest	Grand total
Ganga Basin	63,011	47,682	2,119	1,12,812	9,898	7,28,965	8,51,675
% of Basin Area	7.40	5.60	0.25	13.25	1.16	85.60	100.00

1.3. Riparian flora in the stretches of the Ganga river

Riparian flora of the Ganga has been reported into three main stretches:

- Gangotri to Narora stretch
- Mirzapur to Farakka stretch
- Berhampur to Gangasagar stretch

1.4. Riparian flora in the Gangotri to Narora stretch

The upper Ganga basin spreads through two Indian states *viz*. Uttarakhand and Uttar Pradesh. This area includes four important towns *viz*. Rishkesh, Haridwar, Garhmukteshwar and Narora.

The main vegetation in the catchment area of Bhagirathi River in the upper stretch comprise of *Primula floribunda*, *Stellaria webbiana, Elatostema sessile* and *Geranium rotundifolium*. The shrubs like *Betula utilis, Rhododendron communis, R. anthopogon, Juniperus wallichiana* and *Salix flabellaris* are found growing near Bhojbasa (3794 m) among which *Betula utilis* being dominant (Kumar, 2001). *Cedrus deodara* borders the bed on both the sides of river on the flood plain deposit. *Pinus wallichiana* starts from near Jhala (Gupta, 1960). Between Gangotri to Haridwar 276 riparian plant species belonging to 82 families and 225 genera have been identified and documented (Figure 5), of which 56.16% species have medicinal value. Some of the important families are represented in Figure 6. Poaceae having 19 species reported to be the dominant family followed by Asteraceae, Euphorbiaceae, Moraceae, Malvaceae, Lamiaceae, Mimosaceae, Papilionaceae, Convolvulaceae and Urticaceae (Gangwar and Gangwar, 2011).

A taxonomic and economic characteristic of riparian floral diversity along river Ganga between Gangotri to Haridwar is listed in **Annexure-II** (Gangwar and Gangwar, 2011; Gangwar and Joshi, 2006). Gangwar and Gangwar (2011) also recorded dominant and rare flora along the Bhagirathi-Ganga at various sites between Gangotri to Haridwar during 2005-2007 (**Annexure-III).**

THDC Report (2009) on enviromental studies for Vishnugad Pipalkoti Hydro electric project submitted the name of important riparian plants species along the Alaknanda river and its tributaries as shown in Table 4.

Table 4: Riparian vegetation along the Alaknanda river and its tributaries (THDC Report, 2009)

Name of the riparian plant species	
*Acorus calamus**	*Nasturtium officinalis*
Aeginetia indica	*Phragmites kakara*
Ageratum conzoides	*Phyla nudiflora*
Anagallis arvensis	*Polygonum numbenus*
Artemisia nilagarica	*Potentilla sundarica*
Bistortia vacenifolia	*Ranunculus scleratus*
Cirsium arvense	*Rumex hastatus*
Cypres iria	*Saccharum arundinaceum*
C. rotundus	*Sorghum miliaceum*
Drymasia cordata	*Stellaria media*
Eclipta prostrate	*Stephmia eligans*
Eupatorium adscendensce	*Urtica dioica*
Mazus pumilus	*Viola canescens**

** Conservation status: Rare*

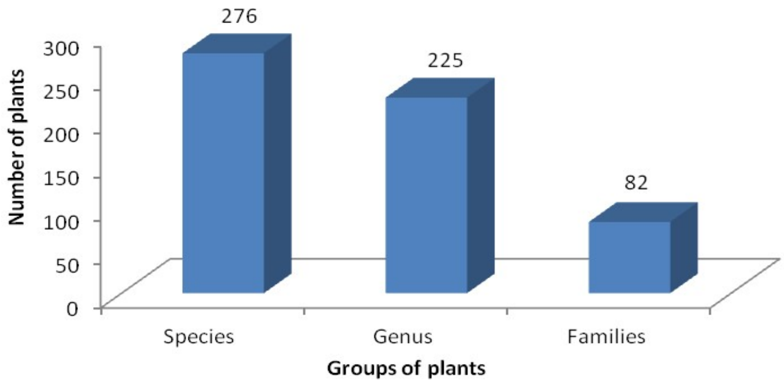

Figure 5: Riparian flora diversity of Ganga from Gangotri to Haridwar (Gangwar and Gangwar, 2011)

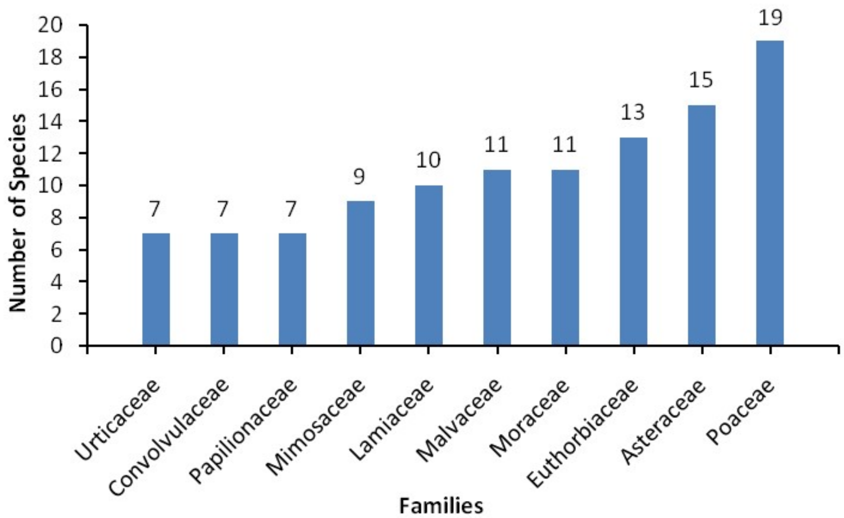

Figure 6: Families wise distribution of riparian flora from Gangotri to Haridwar (Gangwar and Gangwar, 2011)

1.5. Riparian flora of middle stretch between Mirzapur to Farakka

The middle Ganga basin spreads through three Indian states *viz*. Uttar Pradesh, Bihar and West Bengal. This area includes five important towns *viz*. Varanasi, Buxar, Patna, Bhagalpur and Farakka. This region has seven major tributaries, five of which are of Himalayan origin (Gomti, Ghaghara, Gandak, Burhi Gandak and Kosi), and two rivers originate from the heartland of India.

Uttar Pradesh: Important rivers in this stretch are mainly Ganga, Ramganga, Ghaghara, Yamuna and Gomti. Siddiqui (1991) gave an account of 40 riparian macrophytes from Narora-Kannauj region of which species of *Ammania*, *Eclipta, Polygonum, Ipomoea, Rumex, Saccharum, Scirpus* and *Tamarix* are amphibious in nature. The vegetation of Mirzapur-Ballia region was studied by Tripathi (1991) who reported total 36 macrophytes in which some species like *Ruellia prostrata, Amaranthus spinosus, Calotropis procera* and *Polygonum plebeium* were present along the bank of river (Table 5). Canopy cover is formed by the trees, Saal (*Shorea robusta*), Teak (*Tectona grandis*), Sheesham (*Dalbergia sissoo)*, Mango (*Magnifera indica*), Neem (*Tamarindus indica*), Banyan (*Ficus* sp.), Peepal (*Ficus religiosa*), Jamun (*Syzygium cumini*), Mahua (*Madhuca longifolia*) and Semal (*Bombax ceiba*).

Table 5: Riparian macrophytes in Mirzapur-Ballia stretch (Tripathi, 1991)

Family	Species
Acanthaceae	*Ruellia prostrata*
Amaranthaceae	*Achyranthes aspera, Amaranthus spinosus, Chenopodium album*
Asclepiadaceae	*Calotropis procera*
Asteraceae	*Ageratum conyzoides, Eclipta alba, E. Prostrara, Grangea madersapatana, Launaea asplenifolia*, *Tridax procumbens, Xanthium strumarium*
Boraginaceae	*Heliotropium indicum*
Caesalpiniaceae	*Cassia occidentalis, C. tora*
Convolvulaceae	*Convolvulus arvensis, C. microphyllus, Evolvulus alsinoides*
Euphorbiaceae	*Croton bonplandianum, C. sparciflorus, Euphorbia hirta, E. thymifolia, Ricinus communis*
Papaveraceae	*Argemone Mexicana*
Fabaceae	*Alhagi pseudalhagi, Crotalaria medicaginea*, *Desmodium triflorum, Melilotus indica*
Poaceae	*Cynodon dactylon, Dichanthium annulatum*, *Saccharum munja, S. spontaneum*
Polygonaceae	*Rumex dentatus, Polygonum plebeium*
Ranunculaceae	*Ranunculus scleratum*
Verbenaceae	*Phyla nodiflora*

Bihar: The main tributaries of Ganga in this region are Kosi, Gandak, Son and Burhi Gandak. Earlier workers have reported from Buxar to Barh, the presence of 7 shrubs, 41 herbs, 6 grasses and 2 sedges, besides these a number of tree species along the banks of river during 1987-88 (Kumar, 2001). The canopy is mainly composed of *Shorea robusta, Diospyros melanoxylon, Boswellia serrata, Terminalia tomentosa, Terminalia bellayoica, Terminalia arjuna, Pterocarpus marsupium, Madhuca indica, Justicia peploides, Rungia pectinata, Achyranthes aspera* and *Ipomoea aquatica* (Kumar, 2001). Bilgrami (1991) during the study on impact of flood on productivity of Diara land and vegetation reported 23 families comprising of 48 species in Diara land of Ganga amd its tributaries in Bihar (Table 6). The important species of this land were *Justicia peploides, Rauwolfia serpentine, Eclipta prostrate, Leucas aspera, Desmodium gangeticum, Lippia javanica* and *Scoparia dulcis* (Kumar, 2001).

Table 6: Vegetation of Diara Lands of Ganga and its tributaries in Bihar (Bilgrami, 1991)

Family	Species
Acanthaceae	*Justicia peploides, Rungia pectinata*
Polygonaceae	*Polygonum plebegum, Rumex dentatus*
Apocynaceae	*Rauwolfia serpentine, Calotropis gigantea*
Asteraceae	*Eclipta prostrata, Tridax procumbens*, *Vernonia cinerea*
Boraginaceae	*Heliotropium indicum*
Amaranthaceae	*Chenopodium album*
Cleomaceae	*Cleome viscosa*
Convolvulaceae	*Ipomoea aquatica*
Cyperaceae	*Cyperus rotundus, Fimbristylis dichotoma, Kyllingia brevifolia, Scirpus maritimus*
Euphorbiaceae	*Acalypha indica, Croton bonplandianum, Phyllanthus simplex, Euphorbia hirta, E. Parviflora, Chrozophora rotleri*
Lamiaceae	*Leucas aspera*
Malvaceae	*Hibiscus abelmoschus, Sida cordata, S. obovata*
Nyctaginaceae	*Boerhavia diffusa*
Pedaliceae	*Pedalium murex*
Papaveraceae	*Argemone mexicana*
Fabaceae	*Desmodium ganeticum, Lathyrus sativa, Indigofera* sp.*, Melilotus indica, Vicia sativus*
Poaceae	*Cynodon dactylon, Dicanthium annulatum, Digitara sanguinalis, Hygroryza aristata, Panicum repens, Saccharrum spontaneum, Setaria verticillata*
Portulaceae	*Portulaca quadrifolia*
Ranunculaceae	*Ranunculus scleratus*
Rubiaceae	*Oldenlandia corymbosa*
Scrophylariaceae	*Scoparia dulcis*
Tamaricaceae	*Tamarix dioica*
Verbenaceae	*Lippia javanica*

West Bengal: The climatic condition of this region is humid, subtropical, and tropical. Humidity is less near Farakka as compared to deltaic region of the state. Bilgrami (1991) ~~also~~ reported 212 macrophytes along the river Ganga in the region in Munger-Farakka (Table 7). Datta (1991) enumerated 32 species of macrophtes from Bally to Bandel (Table 8). The list included 7 species of Asteraceae, 4 species of Euphorbiaceae, 2 of Amaranthaceae and 3 of Cyperaceae, 2 of Polygonaceae and 1 of Poaceae. Some other important families are also showing its presence in the stretch. The canopy is mainly comprised of Semal (*Bombax ceiba),* Mango (*Magnifera indica*), Peepal (*Ficus religiosa*), Neem (*Tamarindus indica)*, Jackfruit (*Artocarpus heterophyllus*) and Pakur (*Ficus lacor*). Frequently inundated areas are covered with seedy grasses.

Table 7: Macrophytes along Ganga river Munger-Farakka stretch (Bilgrami, 1991)

Family	Species
Acanthaceae	*Adhatoda zeylanica, Barleria prionitis, B. cristata, Dipteracanthus prostratus, Hygrophila auriculata, Justicia peploides, J. simplex, Peristrophe bicalyculata, Rungia pectinata*
Acoraceae	*Acorus calamus*
Aizoaceae	*Trianthema portulacastrum*
Alismataceae	*Sagittaria guyanensis, S. sagittifolia*
Amaranthaceae	*Achyranthes aspera, Alternanthera pungens, A. sessilis, Amaranthus spinosus, A. viidis, Celosia argentea, Chenopodium album, Digera muricata, Gomphrena celosioides*
Anacardiaceae	*Mangifera indica*
Annonaceae	*Polyalthia suberosa*
Apiaceae	*Centella asiatica*
Apocynaceae	*Asdepias* sp., *Catharanthus roseus, Hemidesmus Indicus, Ichnocarpus frutescens, Rauvolfia serpentine*
Aponogetonaceae	*Aponogeton crispum, A. nantans*
Asclepiadaceae	*Calotropis procera, Leptadenia reticulate, Tylophora indica*
Asparagaceae	*Asparagus* spp.
Araceae	*Pistia stratiotes, Spirodela polyrhiza*
Asteraceae	*Artemisia* sp., *Ageratum conyzoides, Blainvillea acmella, Blumea mollis, Caesulia axillaris, Echinops echinatus, Eclipta prostrata, Erigeron asteroids, Grangea maderaspatana, Launea asplenifolia, Parthenium hysterophorus, Pulicaria crispa, Tridax procumbens, Vernonia anthelmintica, Vernonia cinera, Volutarella divaricata, Xanthium strumarium*
Bignoniaceae	*Oroxylum indicum, Stereospermum suaveolens*
Boraginaceae	*Cynoglossum lanceolatum,*
Brassicaceae	*Coronopus didymus, Nasturtuim indicum*
Cannabinaceae	*Cannabis sativa*
Caryphyllaceae	*Polycarpon prostratum*
Celastraceae	*Celastrus peniculatus*
Ceratophyllaceae	*Ceratophyllum demersum*
Cleomaceae	*Cleome gynandra, C. Viscosa*
Combretaceae	*Terminalia arjuna*
Commelinaceae	*Commelina benghalensis, C. nudiflora, Cyanotis axillaris, Murdannia nudiflora*
Convolvulaceae	*Convolvulus arvensis, C. microphylla, Cuscuta reflexa, Evolvulus alsinoides*
Costaceae	*Costus speciosus*
Cucurbitaceae	*Bryonopsis lanciniosa*
Cyperaceae	*Cyperus rotundus, Eleocharis dulcis, E. palustris, Fimbristylis dichotoma, Kyllinga brevifolia, Schoenoplectus articulatus, S. maritrimus*
Dioscoreaceae	*Dioscorea bulbifera*
Elatinaceae	*Bergia ammanioides*
Euphorbiaceae	*Acalypha indica, Chrozophora rottleri, Croton bonplandianum, Emblica*

	officinalis, Euphorbia thymifolia, Excoecaria agallocha, Jatropha gossypifolia, J. curcas, Mallotus repandusm, M. philipensis, Ricinus communis, Trewia nudiflora
Fabaceae	*Alhagi pseudalhagi, Alysicarpus vaginalis, Cassia fistula, C. occidentalis, C. tora, Crotalaria medicaginea, Pongamia pinnata, Pueraria tuberosa, Desmodium gangeticum, D. triflorum, Psoralea corylifolia, Indigofera linnaei, I. linifolia, Lathyrus sativus, Medicago polymorpha, Melilotus alba, M. indica, Phaseolus trilobus, Uraria picta, Vicia sativa*
Fagaceae	*Quercus* spp.
Flacourtiaceae	*Casearia tomentosa, Flacourtia* sp.
Gentianaceae	*Canscora decussate*
Hydrocharitaceae	*Hydrilla verticillata, Ottelia alismoides, Vallisneria spiralis*
Hypericaceae	*Hypericum hirsutum*
Lamiaceae	*Anisomeles indica, Leonurus sibiricus, Leucas aspera, Nepeta hindostana, Ocimum canum, Salvia plebeian, Vitex negundo*
Lecythidaceae	*Barringtonia acutangula*
Lemnaceae	*Lemna paucicostata*
Lythraceae	*Ammannia baccifera*
Malvaceae	*Abelmoschus esculentus, Abutilon indicum, Hibiscus rosasinensis, H. vitifolius, Malvastrum coromandelianum, Sida acuta, S. cordata, S. cordifolia, S. rhmbifolia*
Marsileaceae	*Marselia minuta*
Meliaceae	*Amoora rohituka, Azadirachta indica*
Menispermaceae	*Cissampelos pareira, Tinospora cordifolia*
Molluginaceae	*Glinus lotoides*
Moringaceae	*Moringa oleifera*
Myrtaceae	*Syzygium cumini*
Myrsinaceae	*Anagallis arvensis*
Najadaceae	*Najas graminea*
Nyctaginaceae	*Boerhavia diffusa*
Onagraceae	*Jussia repens*
Oxalidaceae	*Oxalis corniculata*
Papaveraceae	*Argemone mexicana*
Pedaliaceae	*Pedalium murex*
Phyllanthaceae	*Phyllanthus fraternus, P. simplex*
Plantaginaceae	*Scoparia dulcis*
Plumbaginaceae	*Plumbago zeylanica*
Poaceae	*Cynodon dactylon, Dichanthium annulatum, Imperata cylindrica, Panicum repens, Paspalum distichum, Setaria verticillata, Sacchanum spontaneum*
Polygonaceae	*Polygonum hydropiper, P. glabrum, P. plebium, Rumex dentatus*
Pontederiaceae	*Eichhornia crassipes*
Portulacaceae	*Portulaca quadrifida, P. oleracea*
Potamogetonaceae	*Potamogeton crispus, P. nodosus, P. pectinatus, P. crispus, Zannichellia palustris*

Primulaceae	*Primula umbellate*
Rubiaceae	*Oldenlandia corymbosa, O. paniculata*
Ranunculaceae	*Ranunculus scleratus*
Rosaceae	*Potentilla supine*
Rutaceae	*Aegle marmelos*
Scrophulariaceae	*Lindernia crustacea, L. indica, Mazus pumilus, Mecardonia procumbens, Verbascum chinense*
Solanaceae	*Datura alba, D. metel, Nicotiana plumbaginifolia, Physalis minima, Solanum indicum, S. khasianum, S. surattense, S. erianthum, S. torvum, S. nigrum, Withania somnifera*
Tamaricaceae	*Tamarix dioica*
Typhaceae	*Typha nodiflora*
Verbenaceae	*Clerodendrum inerme, Lantana indica, L. camara, Lippia javanica, Phyla nodiflora*
Zygophyllaceae	*Tribulus terrestris*

Table 8: List of macrophytes (aquatic and semi aquatic) in Bally Bandel stretch (Datta, 1991)

Family	Species
Alismataceae	*Sagittaria sagittifolia*
Amaranthaceae	*Alternanthera philoxeoroides, Amaranthus spinosus*
Asteraceae	*Blumea lacera, Eclipta alba, Grangea maderaspatana, Tridax procumbens, Veronia cinerea, Xanthium strumarium, Wedelia calendulacea*
Boraginaceae	*Heliotropium indicum*
Brassicaceae	*Nasturtium indicum*
Chenopodiaceae	*Chenopodium indicum*
Cyperaceae	*Juncellus* sp., *Cyperus* sp., *Fimbristylis dichotoma*
Euphorbiaceae	*Chrozophora plicata, Croton bonpandianum, Phyllanthus niruri, Jatropha gossypifolia*
Lamiaceae	*Leonurus sibiricus*
Malvaceae	*Sida rhombifolia*
Molluginaceae	*Mollugo stricta*
Nyctaginaceae	*Boerhavia repens*
Papaveraceae	*Argemone mexicana*
Plantaginaceae	*Scoparia dulcis*
Poaceae	*Paspalum disticum*
Polygonaceae	*Polygonum* sp., *Rumex dentatus*
Pontederiaceae	*Eichhornia crassipes*
Typhaceae	*Typha* sp.
Verbenaceae	*Phyla nodiflora*

Stretch between Baharampur to Gangasagar:

Farakka to Nabadwip follows the freshwater flora pattern. After Nabadwip to Konnagar the habitat become nearly freshwater. From Konnagar estuarine zone start and this habitat ends up at Diamond Harbour. From Diamond Harbour marine zone start. Table 9 summarizes some of the plant species available in middle lower and lower Ganga region.

Table 9: Some of the plant species available in middle lower and lower Ganga region (Krishnamurti, 1991)

Botanical name	Family	Type	Common names	Economic value
Dicotyledons				
Clematis gouriana	Ranunculaceae	Shrub	Chhagalbati	Used as insecticides
Narvelia zeylanica	Ranunculaceae	Shrub	Chhagalbati	Food and medicinal
Nigella sativa	Ranunculaceae	Herb	Kalojira	Culinary and medicinal
Dillenia indica	Dilleniaceae	Tree	Chalta, Elephant apple	Food and medicine
Magnolia grandiflora	Magnoliaceae	Tree	Champa	Cosmetic and medicinal
Annona reticulata	Annonaceae	Tree	Nona	Food and medicinal
Annona squamosa	Annonaceae	Tree	Ata, Custard apple, Sugar apple	Food and medicinal
Artabotrys hexapetalus	Annonaceae	Shrub	Kantali Champa, kat champa	Ornamental and medicinal
Stephania japonica	Menispermaceae	Shrub	Nimusha	Medicinal
Cissampelos pareira	Menispermaceae	Shrub	Akanadi, Ekleja, Velvet leaf	Medicinal
Nelumbo nucifera	Nelumbonaceae	Herb	Padma, Kamal	
Monocotyledons				
Costus speciosus	Costaceae	Herb	Kust, Keu	Medicinal
Blyxa octandra	Hydrocharitaceae	Submerged herb	Pata syola	Used in aquarium
Hydrilla verticillata	Hydrocharitaceae	Submerged herb	Jhangi	Aquarium plant, food for fish
Vanda tessellata	Orchidaceae	Epiphytic	Rashna	Ornamental
Zeuxine strateumatica	Orchidaceae	Epiphytic	Swet huli	Ornamental
Curcuma amada	Zingiberaceae	Herb	Amada	Culinary
Curcuma aromatica	Zingiberaceae	Herb	Ban haldi	Cosmetic and medicinal

The mangroves are the dominant flora of this zone. The typical mangrove species include *Avicennia* spp., *Amoora cuculata, Bruguiera* spp., *Excoecaria agallocha, Heretiera fomes, Kandelia candel, Phoenix paludosa* and *Rhizophora apiculata.* Naskar and Guhabakshi (1987) reported true mangroves species. Out of these, 30 are trees, 20 shrubs and 20 herbs. Das (1991) listed all the true mangroves species of this zone as listed in Table 10.

Table 10: Family name and species of Mangrove from Sunderban delta (Das, 1991)

Family	Species
Acanthaceae	*Acanthus ilicifolius*
Arecaceae	*Phoenix paludosa, Nypa fruticans*
Acanthaceae	*Avicennia alba, A. marina, A. officinalis*
Caesalpiniaceae	*Cynomertra ramiflora*
Combretaceae	*Lumnitzera racemosa*
Euphorbiaceae	*Excoecaria agallocha, E. bicolor*
Lythraceae	*Sonneratia apetala, S. caseolaris*
Malvaceae	*Hibiscus tortussus, Thespesia lampus*
Meliaceae	*Amoora cucullata, Xylocarpus granatum, X. mulucensis*
Myrsinaceae	*Aegiceras corniculatum*
Plumbaginaceae	*Aegialitis rotundifolia*
Poaceae	*Porterisia coarctata*
Rhizophoraceae	*Bruguiera cylindrica, B. gymnorhiza, B. parviflora, B. sexangula, Kandelia candel, Rhizophora apiculata, R. mucronata*
Sterculiaceae	*Heritiera fomes*
Tiliaceae	*Brownlowia lanceolata*

1.6. Floristic diversity

A floristic study was carried out by Naskar (1993) as a part of database preparation of middle lower Ganga river basin based on the available secondary data. The available literature of this region is rather scanty. A total of 154 angiosperm families were recorded from this region. Out of this, 124 families belong to Dicotyledons and other 30 Monocotyledons (Figure 7, Table 11). Verma and Prakash (2010) reported 293 species and 49 genera of epilithic diatoms in this region.

Table 11: The statistics of the plants available in middle lower and lower Ganga River Basin

Class	Families	Genera	Trees	Shrubs	Herbs	Weeds	Terrestrial spp.	Cultivated spp.
Dicotyledons	124	531	229	261	384	623	692	251
Monocotyledons	30	149	6	19	276	263	140	38
Total Angiosperms	154	680	235	280	660	886	832	289

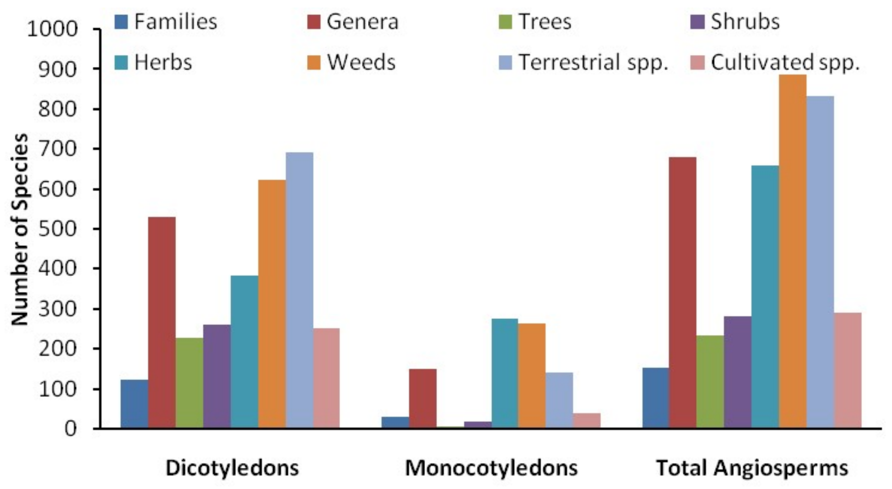

Figure 7: Account of total Angiosperms in the middle lower and lower Ganga river delta (Source: Plant Wealth of Ganga Delta, Naskar, 1993)

Status of the indigenous and exotic plants available in middle lower and lower Ganga river basin are shown below (Table 12 and Figure 8).

Table 12: Indigenous and exotic status of total Angiosperms in middle lower and lower Ganga river basin (Source: Plant Wealth of Ganga Delta, Naskar, 1993)

Class	No. of species	Indigenous sp.	Exotic sp.
Dicotyledons	874	616	258
Monocotyledons	301	245	56
Total Angiosperms	1175	861	314

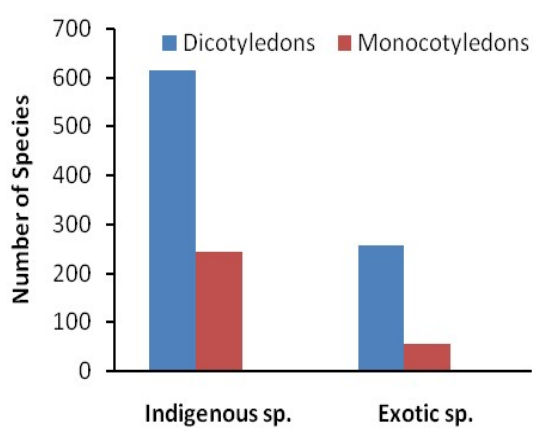

Figure 8: Indigenous and exotic status of Angiosperms of middle lower and lower Ganga basin

Studies done by Naskar (1993) showed 10 dominant angiosperm families of middle lower and lower Ganga river basin (Figure 9) while Gopal and Chauhan (2006) gave an account of rare, threatened and endangered flora of the Indian Sundarbans (Table 13).

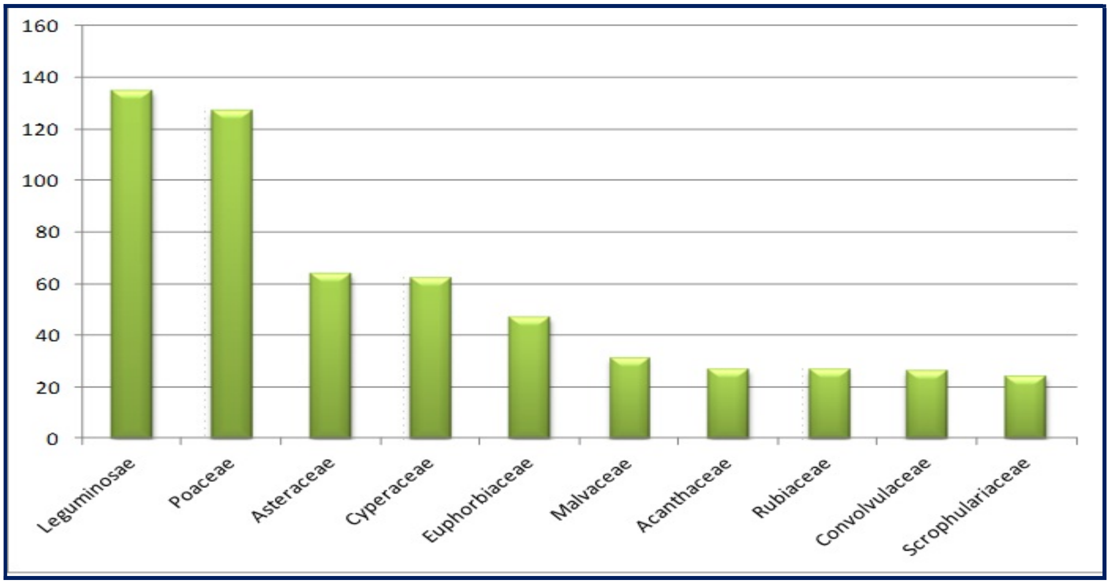

Figure 9: Dominant angiosperm families of middle lower and lower Ganga river basin

Table 13: Rare, threatened and endangered flora of the Indian Sundarbans (Gopal and Chauhan, 2006)

Family	Species	Status
Meliaceae	*Aglaia cucullata*	Rare
	Xylocarpus mekongensis	Threatened
	Xylocarpus granatum	Threatened
Rhizophoraceae	*Rhizophora apiculata*	Occasional
	Bruguiera parviflora	Occasional
	Ceriops decandra	Occasional
	Kandelia candel	Occasional
Sterculiaceae	*Heritiera fomes*	Threatened
Rubiaceae	*Scyphiphora hydrphyllacea*	Rare
	Hydrophylax maritima	Rare
Tiliaceae	*Brownlowia lanceolata*	Occasional
Arecaceae	*Nypa fruticans*	Occasional
Acanthaceae	*Acanthus volubilis*	Very Rare
Caesalpiniaceae	*Cynometra ramiflora*	Rare
Fabaceae	*Dalbergia spinosa*	Rare
Sapotaceae	*Manilkara hexandra*	Rare
Rutaceae	*Atalantia correa*	Very Rare

1.7. Effect of riparian flora on river Ganga

River bank health is a term used to illustrate the ecological condition of a river bank or riparian zone. Health is more than just the plants and animals that live in a river bank, and the role of plants in stabilizing the river banks and maintaining the river health. It depends on the diversity of habitats, plant and animal species, the effectiveness of linkages and the maintenance of ecological processes (Dutta *et al.,* 2011) as shown in Figure 10.

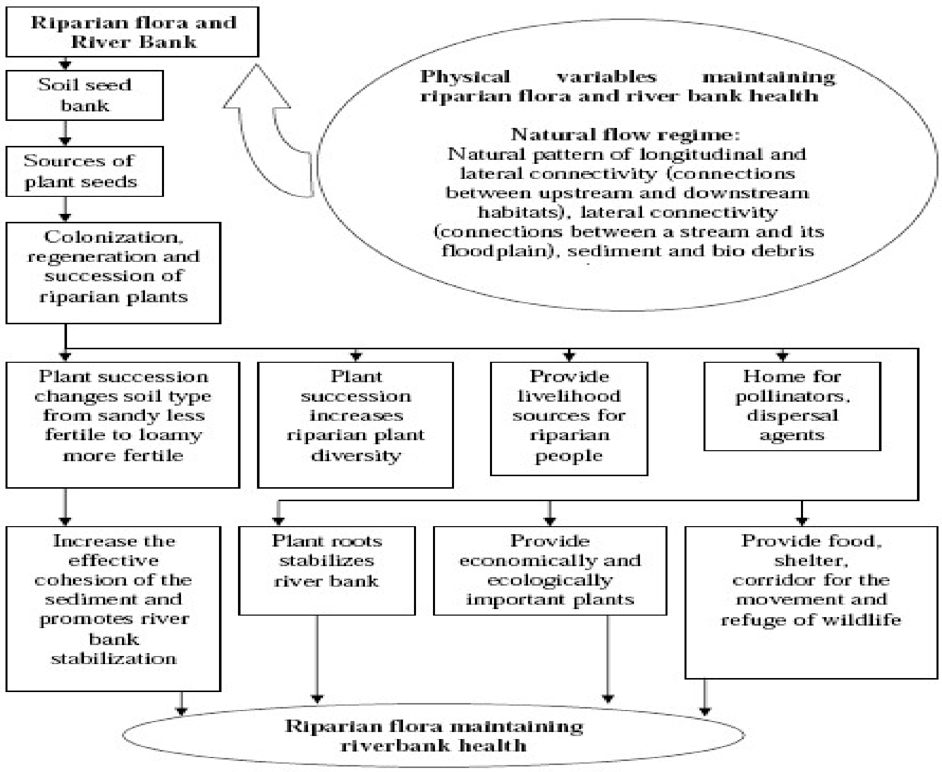

Figure 10: Schematic representation of maintenance and influence of riparian flora on the river bank health (Dutta *et al.*, 2011)

Saccharum species exhibited the highest conservation value (CV) in checking erosion (Ambasht, 1970). *C. dactylon* reported by Gangwar and Gangwar (2011) at right bank of Ganga near Uttarkashi also have high soil conservation value. *Saccharum munja* and *Saccharum spontaneum* are also reported near Rishikesh and Shyampur (Gangwar and Gangwar, 2011). But these species were reported as rare at Ganga bank by Shyam (2008).

Native macrophytes and grasses on the river bank strips considerably check the erosion by binding soil and "roughness", that reduces stream flow rates in most downstream areas. Vegetation keeps banks drier by intercepting precipitation, transpiration, and increased drainage through soil (Dutta *et al.*, 2011). But very low diversity of grasses was recorded by Shyam (2008). *Saccharum spontaneum* and *Imperata cylindrica* grass species were found in very low density at Rishikesh and Shaympur station (Shyam, 2008).

Plant hydrochory is an important biological way of maintaining the riparian ecosystem health. Allochthonous inputs contained in the detritus collected by the floods also add nutrients (Dutta *et al.,* 2011).

Emblica officinalis, Dioscorea bulbifera, Leptadenia reticulata, Sida cordifolia and *Tribulus terrestris* etc. species are dwindling species of Ganga basin (Krishanmurti, 1991).

The biodiversity of mangroves has also been of increasingly greater interest, because the mangrove ecosystems are the most threatened ones by the global climate changes, particularly the sea level rise (Macintosh and Ashton, 2002, 2004). Mangroves are relatively well known for their floral diversity which is comprised of only 65-69 species of vascular plants which have several specific adaptations to the dynamic coastal environment (Kathiresan and Bingham, 2001).

The Indian part of the Sundarban with higher salinity supports sparse *Excoecaria agallocha*, a dense understory of *Ceriops*, and dense patches of the hantal palm (*Phoenix paludosa*) on drier soils. *Xylocarpus* sp. and *Bruguiera* sp. occur sporadically throughout the area. *Oryza coarctata*, *Nypa fruticans* and *Imperata cylindrica* are prevalent on mud flats (Khan, 1986). Large stands of *Sonneratia apetala* occur on newly accreted mud banks. Sand dunes bordering the sea are primarily colonized by grasses such as *Paspalum vaginatum, Panicum repens, Aeluropus lagopoides* and *Phragmites karka*, which are followed by *Sesuvium portulacastrum* and *Ipomoea pescaprae* (= *I. biloba*) which constitute the climax dune vegetation. *Salicornia brachiata, Hygrophyllus asiatica* and *Scirpus fruticans* occur occasionally (Hussain and Acharya, 1994).

The mean volume per hectare of the Sundari (*Heritiera fomes*) tree was 34.5 in 1959. The volume was reduced to 19.9 in 1983 and 17.8 in 1996. The decrease is blamed on their over exploitation, legally and illegally, because of their commercial value and subtle changes in the ecosystem. Most of the distributaries of the river Ganga on the Indian side have already silted up. Thus, increased levels of salinity, particularly during the dry season (low flow period) affect biodiversity, with the salinity-tolerant species gradually overtaking species dependent upon regular freshwater inputs. Many plant species like *Heritiera fomes, Nypa fruticans* and *Phoenix paludosa* were very abundant in the Sundarban 50 years ago, but recently they have declined relatively as the salinity has increased. As a long-term consequence *Heritiera* is being replaced by *Excoecaria*. Increased levels of salinity, particularly during the dry season (low flow period) affect biodiversity, with the salinity-tolerant species gradually overtaking species dependent upon regular freshwater inputs.

In general, the forest structure is becoming simpler and the average height of the trees is decreasing. *Heritiera fomes* (the most important timber species from which Sundarban derives its name), which is abundant on the Bangladesh side, is not common on the Indian side where it is considered endangered. *Nypa fruticans* also has a limited occurrence within the Indian Sundarban; it is rapidly disappearing because of extensive exploitation. Based on their present status, *Aegiceras corniculatum, Kandelia candel, Rhizophora* sp., *Sonneratia acida, Sonneratia apetala* and *Sonneratia caseolaris* also require conservation measures (Gopal, 2006).

1.8 Reason of riparian biodiversity degradation

The major causes of riparian biodiversity degradation are both natural and anthropogenic (Figure 11). Anthropogenic effects are a major concern including construction activities, expansion of agriculture land for food and grazing pressure (Figure 11 and 12).

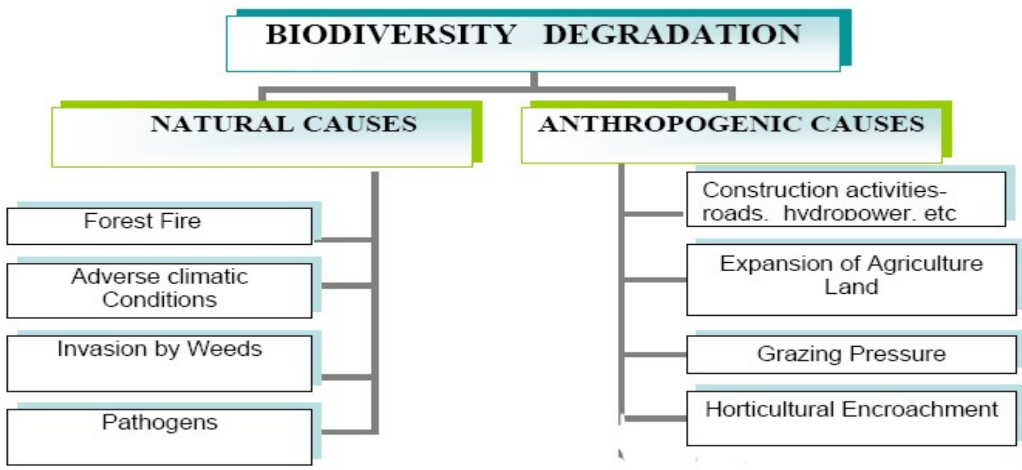

Figure 11: Riparian biodiversity degradation

Figure 12: Reason of biodiversity disruption (a) Due to forest fire (b) Construction activity

Thus major factors responsible for loss of biodiversity of mangrove have been depicted by Gopal (2006).

2. Strategies to conserve riparian biodiversity

Ecological restoration is the re-establishment of processes, functions, and related biological, chemical, and physical linkages between the aquatic and terrestrial ecosystems. Some conservation stretegies suggested are:

- To determine the root cause, which may be biological or non-biological, for the depletation of vegetation.
- To prepare an inventory of riparian flora through primary data collection and preserved through information retrieval system.
- To increase water flow as siltation is one of the major problems of the river. In some areas the river bed has risen so much (Dakshineswar, Naihati and Bandel) that in coming year the river itself may cease to exist. Therefore, more water flow is needed, which would save Ganga from being moribund, and it will reduce salinity level.
- To make awareness programme for conservation of plant resources at social level.
- Preserve Indigenous knowledge of ethenic people of that region regarding plants.
- Government should take the steps for reforestation and strong implementation of laws for the purpose of conservation.

References

Ambasht, R.S. (1970). In: Proc. Nat. Acad. Sc. X1 Tech. Meeting, Switzerland, pp. 44-48.

Auden, J.B. (1941). An excursion to Gangotri. *Himalayan Journal,* **7:** 96-102.

Bhattacharyya, U.C. and Goel, A.K. (1982). Studies on the vegetation of Tehri dam and some rare plants in Garhwal Himalayas, B.S.I. Howrah. pp. 1-38.

Bilgrami, K.S. (1991). The Living Ganga. Narendra Publishing House, Delhi, (India).

Bilgrami, K.S. (1991). Impact of flood on productivity of Diara land an vegetation. (Eds. C.R. Krishnamurti). pp. 99-100.

Castelle, A.J., Johnson A.W. and Conolly, C. (1994). Wetland and stream buffer size requirements: A review. *Journal of Environmental Quality,* **23:** 878-882.

Das, T.M. (1991). Some aspects of the biogeography of the Ganga. (Eds. C.R Krishanmurti). pp. 187-193.

Datta, N.C. (1991). Assesment of pollution load on the Ganga in stretch Bally to Bandel. (Eds. C.R. Krishnamurti). pp. 171-186.

Dutta, R., Debojit, B. and Kanta, S.S. (2011). Influence of riparian flora on the river bank health of a Himalayan river before being regulated by a large dam in North East India. *Annals of Biological Research*, **2(4):** 268-280.

Fraser, J.B. (1820). Journal of a tour through part of the Snowy range of the Himalaya Mountain and to the sources of rivers Jumna and Ganga. London. http://www.archive.org/stream/journaloftourthr00fras#page/n19/mode/2up.

FSI, (1995). Extent, composition, density, growing and annual increment of India's forests. Forest Survey of India, Dehradun, India.

Gangwar, R.S. and Joshi, B.D. (2006). Some Medicinal flora in the riparian zone of river Ganga at Saptrishi, Haridwar, Uttaranchal. *Himalayan Journal of Environment and Zoology*, **20(2):** 237-241.

Gangwar, R.S. and Gangwar, K.K. (2011). Taxonomic and economic classification of riparian floral diversity along river Ganga in Garhwal Himalayan region of India. *Researcher*, **3(4):** 5-14.

Gopal, B. and Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban mangrove ecosystem. *Aquatic Science,* **68:** 338-354.

Gopal, B. (2006). Wetlands and Biodiversity. (Eds. E. Maltby). In: The Wetlands Handbook. Blackwell Science, Oxford, U.K.

Groffman, P.M., Gold, A.J., Husband, T.P., Simmons R.C. and Eddleman W.R. (1990). An investigation into multiple uses of vegetated buffer strips. RI: University of Rhode Island, Kingston.

Gupta, R.K. (1960). On a botanical trip to the source of the rive Ganga in Tehri Garhwal Himalayas. *Indian Forester*, **86:** 547-552.

Hussain, K. and Acharya, G. (1994). Mangroves of the Sundarbans. Volume II: Bangladesh. IUCN Wetlands Programme, Bangkok, Thailand. pp. 257.

Kathiresan, K. and Bingham, B.L. (2001). Biology of mangroves and mangrove ecosystems. *Advance in Marine Biology,* **40:** 81-251.

Khan, (1986). www.unepwcmc.org/medialibrary/2011/06/24/61601219/sunderbans%20 india.pdf.

Krishanmurti, C.R. (1991).The Ganga: A Scientific Study, Ganga Project Directorate Report, New Delhi, India.

Kumar, S. (2001). Plant diversity along river Ganga, BSI, Sai Publisher Dehradun.

Macintosh, D.J. and Ashton, E.C. (2002). A review of mangrove biodiversity conservation and management. Report to World Bank. Centre for Tropical Ecosystem Research, University of Aarhus, Denmark. Vol. VIII. pp. 71.

Macintosh, D.J. and Ashton, E.C. (2004). Principles for a code of conduct for the management and sustainable use of mangrove ecosystems. World Bank, International Society for Marine Ecosystems (ISME) and Centre for Tropical Ecosystem Research, University of Aarhus, Denmark. pp. 104.

Naskar, K. (1993). Plant wealth of lower Ganga delta. Vol. I and II. Daya Publishing House, Delhi, India.

Naskar, K.R. and Guhabakshi, D.N. (1987). Different Phyto-ecological zones in the 24-Parganas District of West Bengal with special Reference to its land utilization patterns. *Journal of the Indian Society of Coastal Agricultural Research,* **5(1):** 183-187.

NGRBP, (2011). Environmental and Social Management Framework (ESMF): Report. pp. 1-101.

Pallis, M. (1934). Gangotri und Leo Pangal. *Himalayan Journal,* **7(6):** 106-126.

Sahai, (1953). Treck to Gangotri (Source of the Ganga). *Indian Forester*, pp. 147-151.

Shyam, R. (2008). Thesis a study on riparian floral biodiversity of river Ganga between Haridwar and Gangotri, submitted to Gurukul Kangri Unversity, Haridwar, India.

Siddiqui, A.M. (1991). Intergrated study of Ganga ecosystem between Narora and Kannauj (U.P.). (Eds. C.R. Krishnamurti). pp. 117-124.

THDC Report (2009). Enviromental studies for Vishnugad Pipalkoti Hydro Electric Project. Doc. No. 2008026/EC/Final Report.

Tripathi, B.D. (1991). An overview of the hyderobiological features of the Ganga in stretch Mirzapur to Ballia. (Eds. C.R. Krishnamurt). pp. 157-160.

Verma, J. and Prakash, N. (2010). Floristic composition of the epilithic Diatoms of central highland region of Indian subcontinent; Thalassiosiraceae, Fragilouriaceae, Eurotiaceae and Achanthaceae. *Journal of Indian Botanical Society,* **80(3 and 4):** 397-400.

Annexure-I

Riparian Floral Diversity from Rishikesh to Chinasura (Krishnamurti et al., 1991)

Names of Plants	Ecoregions of Ganga River							Medicinal Importance
	1. Rishikesh to Garhmukteshwar	2. Kalakankar to Phaphamau	3. Mirzapur to Ballia	4. Buxar to Barh	5. Munger to Farakka	6. Bandel to Bally	7. Katwa to Chinasura	
Trees								
Acacia catechu	+					+		M
A. nilotica	+					+		
Aegle marmelos	+					+		M
Amoora rohituka	+					+		
Averrhoa carambola	+					-		
Azadirachta indica	+					+		M
Barringtonia acutangula	+					+		M
Buchanania lanzan	+					-		
Cassia fistula	+					+		M
Crataeva nervala	+					-		M
Emblica officinalis	+					+		M
Excoecaria agallocha						+		
Flacourtia sp.	+					+		
Gmelina arborea	+					-		M
Hibiscus tiliaceus						+		
Mangifera indica	+					+		
Mollotus philippensis						+		
Moringa oleifera	+					+		M
Oroxylum indicum						+		M
Pongamia pinnata	+					+		M
Quercus spp.	+					+		
Stereospermum suaveolens	+					+		
Syzygium cumini	+					+		M
Tamarix dioica						+		
Tecomella undulata	+					-		
Terminalia arjuna	+					+		M
T. bellirica	+					-		M
T. chebula	+					-		
Trewia nudiflora						+		
Vitex negundo	+					+		M

Climbers								
Asparagus spp.	+				+			M
Bryonopsis laciniosa	+				+			
Celastrus paniculatus					+			
Cissampelos pareira	+				+			M
Cuscuta reflexa		+			+			M
Dalbergia spinosa						+		
Derris trifoliate							+	
Dioscorea bulbifera	+				+			M
Hemidesmus indicus	+				+			M
Ichnocarpus fructescens	+				+			M
Ipomoea cairica							+	
I. sepiaria							+	
Leptadenia reticulate	+				+			
Mikania cordata							+	
Pueraria tuberose	+				+			M
Tinospora cordifolia	+				+			
Tylophora indica	+				+			M
Shrubs								
Abelmoschus esculentus	+				+			
Abutilon indicum				+	+			M
Acanthus ilicifolius							+	
Adhatoda zeylanica	+	+			+	+		M
Barleria spp.	+				+			
B. cristata						+		
B. prionitis	+	+			+		+	
Caesalpinia crista							+	
Casearia tomentosa						+		
Cassia occidentalis		+			+			M
C. sophera							+	M
Calotropis gigantean	+				+			M
C. procera		+	+		+			M
Clerodendrum inerme			+	+	+			M
Datura sp.			+	+	+			
Glycosmis arborea							+	
Hibiscus rosasinensis	+				+			
Jatropha curcus		+			+			M
J. gossypifolia					+	+	+	
Kirganelia reticulate							+	
Lantana camara			+	+	+			
L. indica		+			-			
Leonurus sibiricus						+		
Lippia javanica				+	+			
Mallotus repandus						+		
Polyalthia suberosa						+		
Plumbago zeylanica	+				+			M
Rouwolfia serpentina	+				+			M
Solanum khasianum	+				+			M

S. indicum	+				+			M
S. torvum	+				+			
S. erianthum	+				+			
Urena lobata							+	
Vernonia anthelmintica	+				+			M
Withania somnifera		+			+			M
Herbs								
Acalypha indica		+			+	+	+	
Achyranthes aspera	+	+	+	+	+			M
Ageratum conyzoides	+				+			M
Alhagi pseudoalhagi			+		+			
Alternanthera pungens		+			+	+	+	
Alternanthera sessilis		+		+	+			
Alternanthus spinosus							+	
Alysicurpus monilifer			+	+				
A. vaginalis		+						
Amaranthus spinosus		+			+			
A. spirtosus					+		+	
A. viridis		+		+	+			
Ammannia baccifera	+				+			
Anagallis arvenis		+			+			
Anisomeles indica		+			+			
Argemone mexicana		+	+	+	+			
Artemisia sp.	+							
Asclepias sp.	+							
Asphodelus tenuifolius		+	+	-	+			
Bergia ammannioides		+		+	+			
Blainvillea acmella		+	+		+			
Blumea amplectans		+						
Boerhavia diffusa	+	+	+	+	+			M
Caesulia axillaris				+	+			
Callicarpa nudiflora		+			+			
Cannabis sativa		+	+	+	+			
Canscora decussate		+			+			
Cassia tora			+		+			
Catharanthus roseus	+				+			M
Celosia argentea				+	+			
Centella asiatica	+				+			M
Chenopodium album		+	+	+	+	+	+	
Chrozosphora rottleri		+	+	+	+			
Chrysopogon aciculatus							+	
Cleome gynandra				+	+			
C. viscose				+	+			
Commelina bengalensis		+	+		+			
Convolvulus arvensis			+		+			
C. microphyllus			+		+			
Corchorus acutangulus			+	+				
C. didymus		+						
Costus speciosus	+				+			

Crotalaria medicaginea		+	+		+			
Croton bonplandianum		+		+	+			
Cyanotis axillaris			+	+	+			
Cynoglossum lancelatum	+				+			
Depteracanthus prostrates			+		+			
Desmodium gangeticum					+			M
D. trifolia		+		+	+			
Digera muricata		+			+			
Echinops echinatus		+			+			
Eclipta prostrate	+	+	+	+	+			M
Erigeron asteroids					+			
Euphorbia rosea				+				
E. thymifolia			+		+			
Evolvulus plumbaginifolia		+			+			
E. alsinoides				+	+			
Glinus lotoides	+				+			M
Gomphrena celosiodes		+			+			
Grangea maderasptana		+			+	+	+	
Heliotropium hirsutum				+	+			
H. indicum		+			+			
Hibiscus vitifolius					+			
Hydrolea zeylanica							+	
Hygrophila auriculata					+		+	
Indigofera linifolia	+	+			+			
I. linnaei	+	+			+			
Justicia peploides					+			
J. simplex		+						
Lathyrus sativus		+			+			
Launaea asplenifolia		+	+		+			
Leucas aspera		+			+			
Lindenbergia indica			+		+			
Lindernia crustacean		+	+		+			
Malva parviflora		+						
Malvastrum coromandelianum		+		+	+			
Mazus pumilus		+		+	+			
Mecardonia procumbens				+	+			
Medicago polymorpha		+			+			
Melilotus alba		+			+			
M. indica		+			+			
Murdannia nudiflora					+			
Nasturtium indicum					+	+	+	
Nepeta hindostana					+			
Nicotiana plumbaginifolia		+		+	+			
Ocimum canum		+			+			
O. sanctum					+			M
Oldenlandia corymbosa	+				+			M
Oldenlandia diffusa				+				
O. paniculata					+			
Oxalis comiculata			+	+				

Parthenium hysterophorus				+	+			
Pedalium murex					+			M
Peristrophe bicalyculata		+						
Phaseolus trilobus		+			+			
Phyla nodiflora					+	+	+	
Phyllanthus fratemus								
P. simplex				+	+			
Physalis minima		+			+			
Polycarpon prostratum		+	+					
Polygala erioptera		+						
Polygonum glabrum		+			+	+	+	
P. hydropiper					+	+	+	
P. orientale						+		
P. plebeium		+			+			
Portulaca oleracea				+	+			
P. quadrifida		+			+			
Potentilla supine	+				+			
Primula umbellata		+			+			
Psoralea corylifolia					+			M
Ranunculus sceleratus		+			+			
Ricinus communis			+		+			
Rumex dentatus		+	+	+	+			
Rungia pectnata		+	+	+	+			
Salvia plebeian		+		+	+			
Scirpus articulates					+			
Scoparia dulcis		+	+	+	+			
S. dulds							+	
Sida acuta			+	+				
S. cordata	+				+			M
S. cordifolia	+							M
S. obovata	+				+			
S. rhombiolia	+	+			+			
Solanum nigarum		+	+	+	+			
S. surattense	+				+			
Trianthema portulacastrum	+				+			
Tribulus terrestris	+	+			+			M
Tridax procumbens		+	+	+	+	+	+	
Ureria picta	+				+			M
Verascum chinense					+			
V. thaspus		+			+	+	+	
Vernonia cinerea		+			+	+	+	
Vicia sativa		+			+			
Volutarella divaricata				+	+			
Wedelia calendulacea						+	+	
Xanthium strumarium			+	+	+			
Grasses								
Cynodon dactylon			+	+	+		+	
Dichanthium annulatum				+	+			

Hygroryza aristata						+	+	
Imperata cylindrica					+			
Panicum repens				+	+			
Paspalum distichum				+	+			
Saccharum spontaneum				+	+			
Setaria verticillata				+	+			
Sedges								
Cyperus rotundus								M
Fimbristylis dichotoma					+	+		
Kyllinga brevifolia			+	+	+			
Scirpus articulates			+	+	+			
S. maritimus					+			

Annexure-II

Families, Botanical name, Common/Local name, Habit and Economic uses of riparian floral diversity along river Ganga between Gangotri to Haridwar (Gangwar and Gangwar, 2011; Gangwar and Joshi, 2006)

Families	Botanical Name and Common/ Local Name*	Habit	Economic Uses
Acanthaceae			
	Adhatoda zeylanica (Adusa)*	S	MD
	Barleria cristata (Saundi)*	H	MD
	Barleria prionitis (Peela-bansa)*	H	MD
	Rungia pectinata (Pindikunda)*	H	MD
Aceraceae			
	Acer cappadocicum (Kainchali)*	T	FL
Agavaceae			
	Agave americana (Rambans)*	S	MD
Amaranthaceae			
	Achyranthus aspera (Chirchita)*		
	Aerva lanata (Chaya)*	H	FD
	Alternanthera sissilis (Gudrisag)*	H	FD
	Amaranthus spinosus (Kanta-Chaulai)*	H	MD
	Amaranthus virdis (Chaulai)*	H	FD
	Pupalia lappacea (Nagdaminee) *	S	MD
Amaryllidaceae			
	Zephyranthes carinata (Rain Lily)*	H	MS
Anacardiaceae			
	Mangifera indica #	T	MS
	Lannea coromendelica (Jhinghan)*	T	TR,FD
	Rhus cotinus (Tung)*	S	MS
	Rhus parviflora (Tungla)*	S	MD
Apiaceae			
	Centella asiatica (Brahmi)*	H	MD
Apocynaceae			
	Carissa opaca (Karonda)*	S	MS
	Holarrhena antidysenterica (Kura/Kurchi)*	T	TR,FL
	Rauwolfia serpentina (Sarpgandha)*	S	MD
	Vallaris heynei (Dudhi-bel)*	CL	MS
	Wrightia tomentosa (Dudhali)*	T	TR
Asclepiadaceae			
	Calotropis procera (Aak)*	S	MD
	Calotropis gigantea (Mudar)*	S	MD

	Cryptolepis buchananii (Medha-singhi)*	CI	MD
Arecaceae			
	Phoenix sylvestris (Khajur)*	S	MD
Asteraceae			
	Ageratum conyzoides (Visadodi)*	H	MD
	Artemisia vulgaris #	---	MD
	Artemisia nilagirica (Kunja)*	H	MD
	Artemisia roxburgiana	H	MD
	Bidens biternata (Mangrinya)*	H	MD
	Blumea lacera (Kukronda)*	H	MD
	Cirsium arvense (Kardra)*	H	MD
	Eclipta alba (Bhangaru)*	H	MD
	Eclipta prostrata (Keshraj)*	H	MD
	Emilia sonchifolia (Dudhi)*	H	MD
	Eupatorium odoratum (Tivra gandha)*	S	MD
	Galinsoga ciliata (Blake)*	H	MS
	Gnaphalium leuto-album (Bal-raksha)*	H	MD
	Launnea procumbens (Van-gobhi)*	H	FD
	Parthenium hysterophorus (Gazarghas)*	H	MS
	Sonchus oleraceus (Dudhi)*	H	MD,FD
	Taraxacum afficinale (Dudhiphen)*	H	MD
	Tridax procumbens (Keshraj)*	H	MD
	Xanthium strumarium (Chota-dhatura)*	H	MD
Berberidaceae			
	Berberis lycium (Kingori)*	S	MD
	Berberis asiatica (Kilmora)*	S	MD
	Berberis aristata (Kingora)*	S	MD
Betulaceae			
	Alnus nepalensis (Utis)*	T	TR,FL
	Betula utilis (Bhojpatra)*	T	TR,FL
Bignoniaceae			
	Jacaranda mimosifolia (Nila Gulmohar)*	T	MS
Bombacaceae			
	Bombex ceiba (Semal)*	T	TR,MD
Boraginaceae			
	Cynoglossum zeylanicum (Andhahuli)*	H	MD
	Ehretia leavis (Lasaura)*	T	TR
	Cordia dichotoma (Chamror)*	T	FD,TR
Brassicaceae			

	Capsella bursa-pastoris (Tuntkya)*	H	MD
Buddlejaceae			
	Buddleja asiatica (Bhati)*	S	MD,MS
	Buddleja paniculata (Sendroi)*	S	FL
Cactaceae			
	Opuntia dilleni (Nagphani)*	S	MD
Cannabinaceae			
	Cannabis sativa (Bhang)*	S	MD
Capparaceae			
	Crateva magna (Barna)*	T	MD
Capparidaceae			
	Capparis zeylanica (Hins)*	CL	MD
	Cleome viscosa (Hurhur)*	H	MD
Cornaceae			
	Alangium lamarckii (Bismar)*	T	MD
Caprifoliaceae			
	Viburnum cotonifolium (Bhatyanu)*	S	MD
Caesalpinaceae			
	Bauhinia purpurea (Guiral)*	T	FD,MS
	Bauhinia racemosa (Jhanjhora)*	T	FL
	Bauhinia vahlii (Maljhan)*	CL	FD
	Bauhinia variegata (Kachnar)*	T	FD,MD
	Caesalpinia bonducella (Kath Karanj)*	CL	MD
	Cassia fistula (Amaltas)*	T	ES
	Cassia mimosoides (Patwa ghas)*	H	MD
	Cassia occidentalis (Chakunda)*	H	FL
	Cassia saemea (Kasondi)*	T	MS
	Cassia tora (Panwar)*	H	MD
Chenopodiaceae			
	Chenopodium ambrosioides (Bathua)*	H	MS
	Chenopodium album (Bathua)*	H	MS
Combretaceae			
	Anogeissus latifolia (Bakali)*	T	FD,TR
	Terminalia alata (Sain)*	T	TR
	Terminalia arjuna (Arjun)*	T	TR
	Terminalia bellerica (Bahera)*	T	TR,MD
Commelinaceae			
	Commelina benghalensis (Kanchara)*	H	MD,MS
Convolvulaceae			

	Argyreia nervosa (Ghav bel)*	CL	MD
	Convolvulus arvensis (Heyranpatu)*	H	MD
	Evolvulus alsinoides (Shankhpushpi)*	CL	MD
	Ipomoea carnea (Sadasuhagan)*	S	FL,MD
	Ipomoea nil (Guj)*	CL	FD
	Ipomoea pes-tigris (Panch patri)*	CL	FD
	Merremia tridentate (Prasarini)*	H	MD
Crassulaceae			
	Rhodiolla hytrophylla *	H	MD
	Rosularia adenotricha (Looniya)*	H	MD
	*Sedum adenotrichum**	H	MD
Cupressaceae			
	Juniperus squamata (Thelu)*	S	ES,FL
Cyperaceae			
	Cyperus rotundus (Motha)*	H	MD
Dipterocarpaceae			
	Shorea robusta (Sal)*	----	TR
Ericaceae			
	Rhododendron campanulatum (Don Simris)*	T	MD
Euphorbiaceae			
	Bridelia retusa (Ekdania)*	T	FD,MS
	Emblica officinalis (Aonla)*	T	MD,MS,FD
	Euphorbia hirta (Dudhi)*	H	MD
	*Euphorbia hetrophylla**	H	MD,FD
	Euphorbia rothiana (Thor)*	H	MD
	Jatropha philippinensis (Jatropha)*	S	MS
	Mallotus philippinensis (Rohini)*	T	FD,MD,FL
	Putranjiva roxburghii (Jiaputa)*	T	FD
	Ricinus communis (Arandi)*	S	FL
	Sapium insigne (Khinda)*	T	MD
	Sapium sebiferum (Tarcharvi)*	T	MD
	Trewia nudiflora (Gutel)*	T	MD
Gentianaceae			
	Swertia ciliata (Chirotu)*	H	MD
Geraniaceae			
	Geranium nepalense (Phori)*	H	MD
Grossulariaceae			
	*Curculigo orchioides**	H	MD
	Ribes orientale (Darbag)*	H	MD

	Ribes alpestre (Kali-musli)*	H	MD
Lamiaceae			
	Anisomeles indica (Goplya)*	H	MD
	Calamintha umbrosum (Birchee)*	H	MD
	Colebrookia oppositifolia (Binda/ Pansra)*	S	MD
	Coleus barbatus (Fiwain)*	S	MD
	Hyptis sauveolense (Vilayti tulsi)*	H	MS
	Leucas aspera (Gopha)*	H	MD
	Micromeria biflora (Gorakhopan)*	H	MD
	Ocimum basilicum (Jungli-tulsi)*	H	MD
	Pogostemon plecranthoides (Raudera)*	S	MS
	Roylea cinerea (Baillon Karu)*	H	MD
	Salbia plebeia (Sathi, Samundarsok)*	H	MD
Leeaceae			
	Leea aspera (Kunwai)*	S	MD
Liliaceae			
	Polygonatum cirrhifolium (Khakan)*	H	MD,MS
	Asparagus racemosus (Satrawal)*	S	MD
	Urginea indica *	H	MD
Lythraceae			
	Lagerstroemia parviflora (Dhaudi)*	T	TR
	Punica granatum (Anar)*	T	MS
	Woodfordia fruticosa (Dhaula)*	S	ES
Malvaceae			
	Abutilon indicum (Kanghi)*	S	MD,FL
	Azanza lampas (Jangli bhindi)*	S	MD
	Kydia calycina (Pula)*	T	FD,FL
	Malvastrum coromandelianum (Garcke Suchi)*	H	MD
	Malva parviflora (Soncheli)*	H	MS,MD
	Sida acuta (Bala)*	H	MD,MS
	Sida cordata (Bhiyli)*	H	MD
	Sida cordifolia (Kunghi) #	H	MD
	Sida rhambifolia (Kharenti)*	H	MD,FL
	Thespesia lampas (Ban kapasi)*	S	FL
	Urena lobata (Ungoo)*	H	MD
Martyniaceae			
	Martynia annua (Hathajori)*	H	MD,MS
Meliaceae			
	Azadirachta indica (Neem)*	T	MD,TR,ES

	Toona ciliata (Bakain)*	T	TR
	Melia azedarach (Tun)*	T	TR
Mimosaceae			
	Acacia catechu (Khair)*	T	MD,TR,ES
	Acacia nilotica (Babool)*	T	TR,FL
	Albizia chinensis (Siris) *	T	MS
	Albizia julibrissin (Bhondir)*	T	TR
	Albizia lebbeck (Kala siris)*	T	TR,FL
	*Albizia odoratissima**	T	TR
	*Albizia procera (*Safed siris)*	T	TR
	Mimosa pudica (Lajwanti)*	H	MD
	Mimosa himalayana (Alay)*	S	MD
Moraceae			
	Broussonetia papyrifera (Paper Malburry)*	T	FD,ES
	Ficus bengalensis (Bargad)*	T	TR,ES
	Ficus carica (Anjir)*	T	TR,MS
	Ficus elastica (Rubber)*	T	TR
	Ficus glomerata#	---	FD,MS
	Ficus hispida (Gobla)*	T	FD,MS
	Ficus palmata (Khemri)*	T	FD,MS
	Ficus racemosa (Gular)*	T	ES
	Ficus religiosa (Pipal)*	T	TR
	*Ficus roxburghii (Timal)**		
	Garuga pinnata (Kharpat)*	T	TR,FD
	Morus alba (Tatri)*	T	MS
Myrsinaceae			
	Ardisia solanacea (Bhatmal)*	S	MD
	Embelia robusta (Gaia)*	S	MD
Myrtaceae			
	Syzygium cumini (Jamun)*	T	TR,MS
Nyctaginaceae			
	Boerhavia diffusa (Punarnava)*	H	MD
	Celosia argentia (Sarwari)*	H	MS
Oleaceae			
	Nyctanthes arbortristis (Harsingar)*	T	ES,FL
Onagraceae			
	Oenothera rosea *	H	MD
Oxalidaceae			
	Oxalis corniculata (Tinpatia)*	H	MD

Papaveraceae			
	Argemone maxicana (Satyanashi)*	H	MD
Pedaliaceae			
	Sesamum indicum (Til)*	H	MD
Pinaceae			
	Abies pindrow (Morinda)*	T	FL,TR
	Cedrus deodara (Deodar)*	T	TR
	Picea smithiana (Roi)*	T	MS,FL
	Pinus roxburghii (Chir)*	T	TR,MS
	Pinus wallichiana (Chir)*	T	TR
Plumbaginaceae			
	Plumbago zeylanica (Chitrak)*	H	MD
Poaceae			
	Apluda mutica (Charol)*	H	FD
	Arundinella nepalensis (Bichhla)*	H	FD
	Arundo donax (Naldura)*	H	ES
	Chloris dolichostachya (Paneri)*	H	FD
	Chrysopogon fulvus (Bhuri)*	H	FD
	Chrysopogon serrulatus (Golden beard grass)*	H	FD
	Cynodon dactylon (Doovghas)*	H	FD,ES
	Dendrocalamus strictus (Bans)*	S	FD,TM
	Deshmostachya bipinnata (Dav, Kush)*	H	MS
	Digiteria sp.*	H	FD
	Eliliopsis binata (Bhabhar ghas)*	H	FD,ES,MS
	Eragrotis cynosuroides #	H	MD
	Heteropogon contortus (Kumeria)*	H	FD
	Imperata cylendrica (Siru pula)*	H	FD,ES,MS
	Oplismenus compositus (Dumdobra kukaria)*	H	FD
	Phragmitis karka (Narkul)*	H	MD
	Polypogon fugax *	H	FD
	Saccharum spontaneum (Muni)*	H	FD,MS
	Vetiveraia zizaniodes (Kans)*	H	ES,FD,MS
	Saccharum munja (Khus)*	H	FD,ES,MS
Polygonaceae			
	Polygonum capitatum (Kaflya)*	H	MS
	Polygonum hydropiper *	H	MD
	Polygonum plebeium (Dondya)*	H	MS
	Rumex hastatus (Chilmora)*	H	MD
	Rumex nepalensis (Khatura)*	H	MS,MD

Portulacaceae			
	Portulaca oleracea (Badinoni)*		MD
Primulaceae			
	Anagallis arvensis (Krishan-neel)*	H	MD
Proteaceae			
	Grevillea robusta (Silver aak)*	T	TR
Papilionaceae			
	Astragalus candolleanus (Rudravanti)*	H	MD
	Butea monosperma (Dhak)*	T	TR,MD
	Dalbergia sissoo (Shisham)*	T	TR
	Desmodium motorium #	------	MD
	Desmodium triflorum (Kandaliya)*	H	MD
	Millettia auriculata (Gauj)*	CL	FD,MS
	Mucuna prurita (Kaircha)*	CL	MD
	Ougeinia oojeinensis (Sandan)*	T	TR,FD
	Psorelea corylifolia #	-------	MD
Ranunculaceae			
	Ranunculas sceleratus (Jaldhania)*	H	MD
	Thalictrum foliolosum (Mamiri)*	H	MD
Rhamnaceae			
	Zizyphus nummalaria (Makoy)*	S	MD,FL
	Zizyphus oenoplia (Ber)*	S	FL,ES,MS
	Zizyphus mauritiana (Jharber)*	S	FL,FD
	Zizyphus xylopyra (Bhander)*	T	FD,MS
Rosaceae			
	Fragaria nubicola (Gand-Kaphal) *	H	MS
	Potentilla cuneata *	H	MD
	Potentilla polyphylla *	H	MD
	Prinsepia utilis (Bhekar)*	S	MS
	Pyracantha crenulata (Panya)*	T	MD
	*Prunus cerasoide*s (Ghangharu)*	S	MD
	Fragaria nubicola (Kujoi)*	S	MS,MD
	Rubus ellipticus (Hisalu)*	S	MD,MS
	Rubus niveus (Bhera)*	S	MS,MD
	Sorbaria tomentosa (Bhiloka)*	S	ES,MS
Rubiaceae			
	Adina cordifolia (Haldu)*	T	TR,ES
	Mitragyna parvifolia (Phaldu, kaim)*	T	TR,ES
	Hymenodictyon excelsum (Phaldu, kaim)*	T	FD,ES

	Wendlandia exserta (Bathua)*	T	MS
Rutaceae			
	Aegle marmelos (Bel)*	T	MD,FD,ES
	Glycosmis mauritiana (Bannimbu)*	S	MD
	Hesperethusa crenulata (Kathbel)*	T	TR,FL
	Murraya koenigii (Karipatta)*	S	MD
	Zanthoxylum armatum (Timru)*	S	MD
Samydaceae			
	Casearia tomentosa (Chilla)*	T	MS
Sapindaceae			
	Dodonaea angustifolia (Wilayti Mehndi)*	S	MD,MS
	Scheichera oleosa (Kusum, Gosum)*	T	TR,FD,ES
Scrophulariaceae			
	Bacopa monnieri (Wilayti Mehndi)*	H	MD
	Verbascum thapsus (Kusum, Gosum)*	H	MD
Simaroubaceae			
	Ailanthus excelsa (Maharukh)*	T	TR
Solanaceae			
	Datura metel (Dhatura)*	S	MD
	Datura suaveolens (Dhatura)*	S	MD
	Physalis minima (Tulatipati)*	H	MS
	Solanum anguivi (Barhanta)*	S	MD
	Solanum indicum (Bhut-Kataia)*	S	MD
	Solanum nigrum (Makoi)*	H	MD
	Solanum surratense (Kantakari)*	S	MD
	*Solanum virginianum**	S	MD
	Withania somnifera (Ashwagandha)*	S	MD
Sterculiaceae			
	Helicteres isora (Kapasi)*	S	MD,MS
	Pterospermum acerifolium (Kanakchampa)*	T	FD
Tamaricaceae			
	Tamarix dioica (Jhau)*	S	MS
Tiliaceae			
	Grewia optiva (Bhimal)*	T	FD,MS
	Triumfetta rhomboidea (Chiki)*	H	MD
Typhaceae			
	Typha elephantina (Patera)*	H	MS
Ulmaceae			
	Celtis australis (Khirak)*	T	TR,FD

	Holoptelia integrifolia (Papari/ Kanju)*	T	TR
Urticaceae			
	Boehmeria platyphyla (Khaksha)*	S	MD
	Boehmeria rugulosa (Genthi)*	T	MS
	Debregeasia longifolia (Tushiari)*	S	MD
	Gerardinia diversifolia (Bichchhu)*	S	MD,MS
	Pouzolzia hirta (Atainyaa)*	H	MD
	Streblus asper (Dahia)*	T	MD,FL
	Urtica dioica (Bichhubooti)*	S	MD,MS
Verbenaceae			
	Callicarpa macrophylla (Daia)*	S	MD
	Clerodendrom viscosum (Bhant)*	S	MD
	Clerodendrom serratum (Banbahri)*	S	MD
	Lantana camera (Kurrii)*	S	FL
	Tectona grandis (Sagaun)	T	TR
	Vitex negundo (Nirgundi)	S	MD

- **Abbreviations**: T-Tree; S-Shrub; H-Herb; Cl-Climber; MD-Medicinal; FD-Fodder; TR-Timber; FL-Fuel; ES-Ecological/ Environmental specific and MS-Miscellaneous value.
- Common name is given in brackets.
- Station/ Location

  * Gangotri to Haridwar

  # Saptrishi

Annexure-III

Dominant and rare flora along the Bhagirathi-Ganga at various sites between Haridwar to Gangotri during 2005-2007 (Gangwar and Gangwar, 2011)

Dominant/Rare species at different sites	
Haridwar	
Left Bank	**Right Bank**
Dominant Species *Accacia catechu, Dalbergia sissoo, Mallotus philliensis, Syzygium cumini, Trewia nudiflora, Lantana camera, Murraya koenigii, Sida cordata, Sida cordifolia* ***Rare Species*** *Ficus carica, Putrangiva roxberghii, Streblus asper, Terminalia arjuna, Citrus medica, Ocimum basillicum, Rauwolfia serpentine, Ricinus cummunis, Solanum indicum, Apluda mutica, Argemone maxicana, Centella asiatica, Cleome viscose, Emilia sonchifolia, Hyptis sauveolense, Ipomoea nil, Leucas aspera, Phyla nudiflora, Portulaca oleracea, Ranunculus sceleratus, Saccharum spontaneum, Xanthium strumarium*	***Dominant Species*** *Holoptelia integrifolia, Bombex ceiba, Trewia nudiflora, Lantana camera, Sida cordifolia, Sida acuta, Dasmodium trifloreum* ***Rare Species*** *Aegle mermelos, Azadirachta indica, Casearia tomentosa, Lannea coromandelica, Sapium sebiferum, Terminalia bellarica, Citrus medica, Dendrocalamus strictus, Uraria rufescens, Vitex negundo, Cassia mimosoides, Martynia annua, Merremia tridentala, Phyla nudiflora. Polygonum hydropiper, Porulaca oleracea, Ranunculus sceleratus, Rungia pectinata, Urginea indica*
Shaympur	
Left Bank	**Right Bank**
Dominant Species *Accacia catechu, Cassia fistula, Holarrehena antidysenterica, Bombex ceiba, Mallotus phillipinensis, Sida acuta* ***Rare Species*** *Emblica officinalis, Ficus religosa, Pterospermum acerifolium, Cannabis sativa, Nyctanthes arbortristis, Solanum indicum, Argemone maxicana, Boerhavia diffusa, Cassia tora, Eclipta prostrate, Euphorbia hitra, Imperata cylindrica,*	***Dominant Species*** *Accacia catechu, Aegle, marmelos, Bombex ceiba, Dalbergia sissoo, Sapium sebiferum, Lantana camera,, Colebrookia oppositifollia,, Parthenium hysterophorus* ***Rare Species*** *Azairachta indica, Casearia tomentosa, Crateva magna, Crateva magna, Ehretia leasis, Emblica officinalis, Ficus benghalensis, Schleichera oleosa, Sygyzium cumini, Tectona grandis, Termina bellerica, Wrightia*

Triumfetta rhomboidea, Urena lobata	*tomentosa, Abutilon indicum, Ardisia solanaceas, Callicarpa macerophylla, Ipomoea carnea, Jatropha curcas, Nyctanthes arbortristis, Opuntia dilleni, Tamarix dioica, Abrus precatoriuns, Apluda mutica, Ipomoea nil, Martynia annua, Physalis minima, Polygonum hydropiper, Saccharum munja, Solanum nigrum, Solanum surratense, Typha elephantine, Urena lobata*
Rishikesh	
Left Bank	**Right Bank**
<u>Dominant Species</u> *Mallotus phillipinensis, Holoptelia integrifolia, Adina cardifolia* ***<u>Rare species</u>*** *Acacia catechu, Ailanthus excels, Albizia procera, Azadirachta indica, Cassia saemea, Dalbergia sissoo, Ficus benghalensis, Ficus racemosa, Ficus religosa, Garuga pinnata, Holarrehena antidysenterica, Kydia calycina, Lannea coromandelica, Melia azadirachta, Terminalia bellerica, Calotropis procera, Carissa opaca Anagallis arvensis, Cynoglossum zeylanicum*	***<u>Dominant Species</u>*** *Holoptelia integrifolia, Adina cardifolia, Parthenium hysterophorus* ***<u>Rare species</u>*** *Acacia catechu, Albizia procera, Ficus elastic, Ficus religosa, Hesperethusa crenulata, Melia azadirachta, Terminalia arjuna, Bauhinia vahlii, Boehmeria platyphyla, Calotropis procera, Ipomoea carnea, Opuntia dilleni, Solanum indicum, Apluda mutica, Barleria priontis, Boerhavia diffusa, Chloris dolichostachya, Deshmostachya bipinnata, Phragmitis karka, Saccharum munja, Saccharum spontaneum, Urena lobata*
Shivpuri	
Left Bank	**Right Bank**
<u>Dominant Species</u> *Dalbergia sissoo, Shorea robusta, Holoptelia integrifolia, Colebrookia oppositifolia, Adhatoda zeylanica, Cassia occidentalis*	***<u>Dominant Species</u>*** *Mallotus phillipinensis, Holoptelia integrifolia, Adina cardifolia, Adhatoda zeylanica, Lantana camera, Ageratum conyzoides, Parthenium hysterophorus*

Rare Species *Melia azedirach, Calotropis gigautia, Cryptolepis buchananii, Jatropa curcas, Abrus precatorius, Anisomeles indica, Solanum surratense, Triumfetta rhomboidea*	***Rare Species*** *Bridelia retusa, Wrightia tomentosa, Millettia auriculata, Plumbago zeylanica, Solanum anguivi, Thespesia lanpas, Centella asiatica, Cynoglossum zeylanicum, Desmostachya bipinnata, Mucuna prurita, Ocimum bacillicum, Sida cordata, Xanthium strumasium*
Devpryag	
Left Bank	**Right Bank**
Dominant Species *Adhatoda zeylanica, Murraya koenigii, Lantana camera, Tridax procumbens* ***Rare Species*** *Adina cardifolia, Dalbergia sissoo, Ficus racemosa, Ficus benghalensis, Hymenodictyon excelsum, Mitragyna parvifolia, Agave americana, Euphorbia royleana, Ricinum communis, Withania somifera, Apluda mudica, Celosia argentia, Chrysopogon serrulatus, Eclipta alba, martynia annua, Physalis minima, Scutellaria scandens, Xanthium strumarium*	***Dominant Species*** *Tamarindus indica, Mallotus phillipinensis, Lantana camera, Adhatoda zeylanica, Murraya koenigii, Eupatorium odoratum* ***Rare Species*** *Bridelia retusa, Emblica officinalis, Lagerstroemia parviflora, Lannea coromandelica, Ougeinia oojeionensis, Azanza lampas, Emblica robusta, Withani somifera, Euphorbia hirta, Leucas aspera, Oplismenus composites, Physalis minima, Solanum nigrum, Vernonia cinera*
Tehri	
Left Bank	**Right Bank**
Dominant Species *Dalbergia sissoo, Bombex ceiba* ***Rare Species*** *Aegle marmelos, Albizia odoratissima, Broussonetia papyrifera, Ficus religosa, Syzygium cumini, Toona ciliate, Calotropis gigantean, Withania somifera, Achyranthes aspera, Amaranthus caudatus, Boerhavia*	***Dominant Species*** *Varbascum thapsus* ***Rare Species*** *Accacia catechu, Albizia odoratissima, Ficus roxburghii, Punaca granatum, Schleichera oleosa, Buddlega astatica, Carisa opaca, Debregeasia longifolia, Datura metel, Zyzyphus mauritiana, Achyranthus aspera, Ageratum*

diffusa, Cassia occidentalis, Eclipta prostrate, Euphorbia procumbens, Polygonum hydropiper, Sida cordata, Tridax procumbens, Xanthium strumarium	*connyzoides, Centella asiatica, Cynodon dictilon, Cyprus rotundus, Eclipta prostrate, Indigofera cordofolia, Mimosa pudica, Oxalix corniculata, Polygonum hydropiper, Urena lobata*
Uttarkashi	
Left Bank	**Right Bank**
Dominant Species *Pinus roxburgii , Urtica dioica, Rumex haxtatus* ***Rare Species*** *Albizia odoratissima, Ficus religosa, Toona ciliate, Indigofera girardiana, Achyranthus aspera, Datura metel, Zyzyphus mauritiana, Morus alba, Agave americana, Euphorbia rothiana, Jatropha curcas, Prinsepia utilis, Woodfordia friticosa, Altenanthera sissilis, Anagalis arvensis, Argemone maxicana, Bidens biternata, Blumea lacera, Cassia tora, Coleus bartus, Digiteria sp. Fragaria nubicola, Galinosa ciliate, Imperata cylindrica, Micromeria biflora Rosularia* sp.*, Sedum adenotricum, Sonchus oleraceus, Typha elephantine*	***Dominant Species*** *Urtica dioica* ***Rare Species*** *Ficus religosa, Morus alba, Galinosa ciliate, Jatropha curcas, Agave americana, Euphorbia rothiana, Ficus carica, Grewia oppositifolia, Boehmeria platyphyla, Pyracantha crenulata, Alternanthera sissilis, Amaranthus spinosus, Argemone maxicana, Blumea lacera, Cynodon dactylon, Lannea nudicaulis, Polypogon fugax, Solanum indicum, Xanthium strumarium*
Maneri-Bhali	
Left Bank	**Right Bank**
Dominant Species *Alnus nepalensis, Eupatorium odoratum, Rubus ellipticus, Urtica dioica* ***Rare Species*** *Albizia julibrissin, Bauhinia purpurea, Bombex ceiva, Ficus auriculata, Grivillea robusta, Bidens biternata, Cannabis sativa, Lantana camera, Rosa moschata, Solanum indicum, Artimissia nilagrica, Calamintha umbrosa, Geranium*	***Dominant Species*** *Eupatorium odoratum, Rumax hastatus, Rubus niveus* ***Rare Species*** *Alnus nepalensis, Ficus auriculata, Bidens biternata, Debregeasia longifolia, Prunus cerasoides, Zanthoxylum armatum, Calamintha umbrosa, Fragaria nubicola, Oenothera rosea, Zephyanthes carinata*

nepalense, Oenothera rosea, Polygonium capitatum, Polypogon fugax	
Lanka	
Left Bank	**Right Bank**
Dominant Species *Cedrus deodara* ***Rare Species*** *Berberus aristata, Sorbaria tomentosa*	***Dominant Species*** *Cedrus deodara* ***Rare Species*** *Berberus aristata, Cannabis sativa, Cotoneaster acuminalis, Sorbaria tomentosa*
Gangotri	
Left Bank	**Right Bank**
Dominant Species *Cedrus deodara* ***Rare Species*** *Betula Utilis, Picea smithiana, Juniperus squamata, Brassica juancea, Salvia plebeian, Taraxacum afficinala*	***Dominant Species*** *Cedrus deodara* ***Rare Species*** *Acer cappadocicum, Berberis aristata, Salix flabellasis, Sorbesia tomentosa, Polygonatum cirrhifolium, Salvia plebeian, Taraxacum afficinale*

Floral and Faunal Diversity in Alaknanda River

Mana to Devprayag

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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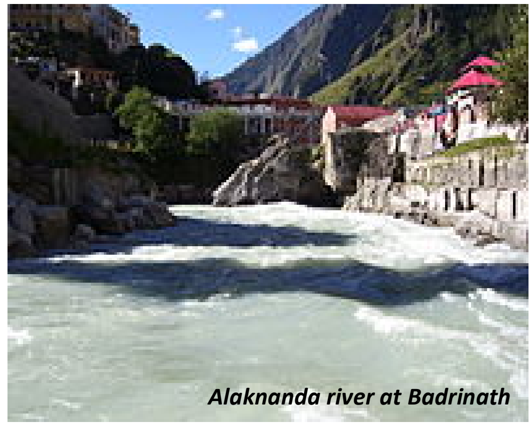
1. Introduction


Alaknanda river at Badrinath

The Alaknanda basin is characterized by hilly terrain, deep gorges, and river valleys. The region is broadly divided into four major divisions (i) The Great Himalayan ranges (snow covered regions), (ii) Alpine and pasture land (covered by snow during the four months of winter season) (iii) Middle Himalaya (characterized by high concentration of population) and (iv) River valleys. Among the major rivers of India, the Alaknanda river and its tributaries (Dhauliganga, Vishnuganga, Nandakini, Pindar, Mandakini, and other numerous perennial streams) originate and flow here (Sati, 2010).

Alaknanda river originates at the water divide between Satopanth and Bhagirathi glaciers (near Vashundhara falls), flows eastward and joins Saraswati river at Mana and then flows in a Southeast direction up to Joshimath where it meets Dhauliganga. After this confluence, it takes a swerve and starts flowing in the Southwest direction to meet Bhagirathi river at Devprayag traversing approximately 179 km (Krishna Murti *et al.* 1991). The Alaknanda contributes significantly a larger portion to the flow of the Ganga than the Bhagirathi. The Hindu pilgrimage centre of Badrinath (one of the four 'Dham') lies along the banks of the Alaknanda river. Several rivers in the Garhwal region merge with the Alaknanda at Panch Prayag or 'holy confluence of rivers' *i.e.* Vishnuprayag (Dhauliganga), Nandaprayag (Nandakini), Karnaprayag (Pindar), Rudraprayag (Mandakini) and Devprayag (Bhagirathi) to become the Ganga river.

One hydroelectric project (at Vishnuprayag) is under operation and 36 others are proposed or under constructions on the river Alakananda and Mandakini. These projects are run-of-the river projects (ROR) and when completed will influence the free flow of the river by storing water in big reservoirs or channeled through tunnels.

Rapids are major habitat type in the stretch followed by riffles and pools. Mature cobbles, pebbles and boulders constitute the major substrate type. However, at Devprayag rock is dominant substratum. Water is clear with transparency of 0.3 m to 2.0 m depth. It is a cold water river (temperature 8°C - 21.5°C) with high velocities (0.6 - 4.2 ms^{-1})(Nautiyal 1985; Kishor 1998; Nautiyal *et al*., 2004). The river Alaknanda can be differentiated in to two stretches:

Pool habitat with Stony Substratum

A) Mana to Vishnuprayag- low temperature, high velocity stretch

B) Vishnuprayag to Devprayag- medium temperature, moderate velocity stretch

The stretch (A) is characterized by the absence of fish, while stretch (B) has Trout as the dominant fish.

2. Locations and meeting points of various tributaries in river Alaknanda

The geographical location of various stations and meeting points of tributaries are represented in Plate 1.

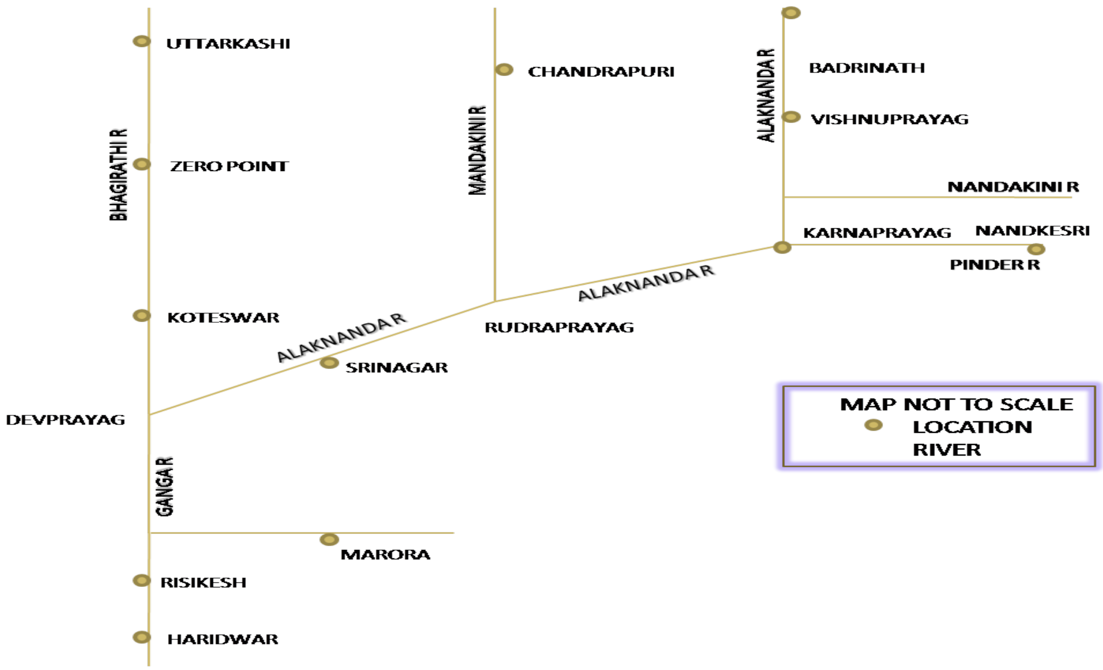


Plate 1: Line Digram of Alaknanda River

3. Biodiversity of Alaknanda river

Zooplankton (*Tetrahymena* sp.)

Stretch A: Mana to Vishnuprayag

This stretch lies between latitude (^{o}N) 30°46’21.39" to 30°33’45.15", longitude (^{o}E) 79°29'43.22" to 79°34'32.59" and altitude from 3208 to 1443 m (a msl). This stretch is characterized by the phytoplankton belonging to Bacillariophyceae, Chlorophyceae and Myxophyceae and zooplankton represented by protozoans (Cilliates). The distribution of phytoplankton along Mana to Vishnuprayag is given in Table 1. In each stretch (Mana to Vishnuprayag and Vishnuprayag to Devprayag) the members of Bacillariophyceae were dominant, followed by members of Chlorophyceae and Myxophyceae (Figure 1).

Table 1: Distribution of Phytoplankton in the Alaknanda river from Mana to Vishnuprayag (Joshi *et al.,* 1995)

Family/ Genus	Joshi *et al.,* 1995
Bacillariophyceae	
Achnanthes sp.	+
Cocconies sp.	+
Cymbella sp.	+
Diatoma sp.	+
Stauroneis sp.	+
Stephanodiscus sp.	+
Chlorophyceae	
Spirogyra sp.	+
Myxophyceae	
Phormidium sp.	+
Total	**8**

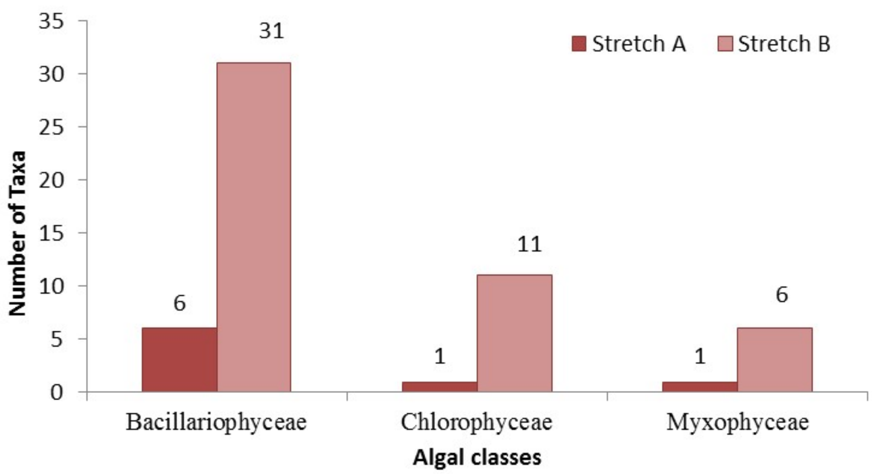


Figure 1: Distribution of phytoplankton in river Alaknanda

Stretch B: Vishnuprayag to Devprayag

Geographically this stretch lies between latitude (°N) 30°33'45.15" to 30°8'40.56", longitude (°E) 79°34'32.59" to 78°36'3.71" and altitude 1443 to 476 m (a msl). This stretch is represented by Diatoms in both phytoplankton and periphyton (Appendix I and II). In phytoplankton, total number of class and taxa are 3 and 48, respectively. However, Nautiyal (1985) has reported 12 taxa in the river Alaknanda (Appendix I). In the periphyton community, the total number of class and taxa are 4 and 157, respectively (Appendix II and Figure 2). In case of periphyton the members of Bacillariophyceae were also dominant in stretch B followed by Chlorophyceae, Myxophyceae and Desmidiaceae. Most common genera were *Achnanthes, Cymbella, Fragilaria, Gomphonema* and *Navicula*.

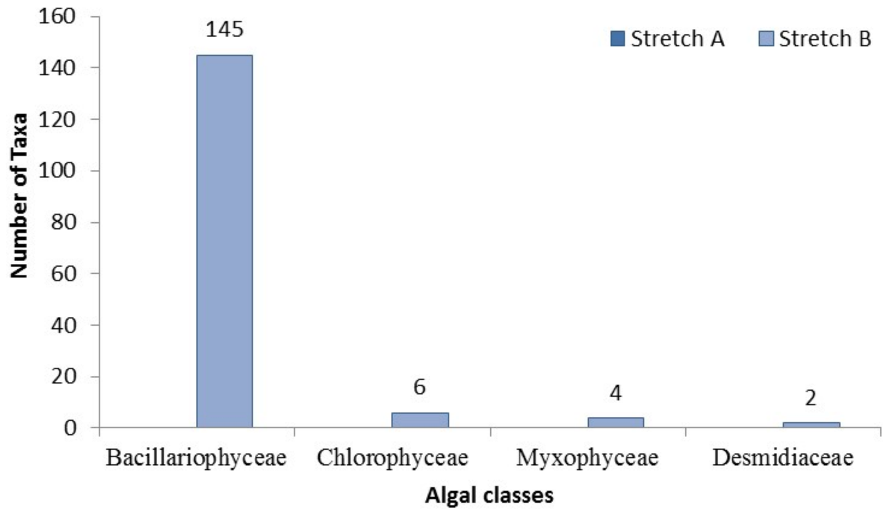


Figure 2: Distribution of periphyton in river Alaknanda

Zooplankton is mainly represented by Protozoans (8) followed by Crustaceans (3) and Rotifers (2) (Appendix III and Figure 3). Cladocera was represented by two species; however the Copepoda was represented by only one species. Rotifera was represented by two species (*Asplanchna* sp. and *Keratella* sp.). Zooplankton genera showing abundance are *Cyclops* and *Keratella*. The **Zoobenthos** is represented mostly by Arthropoda (Figure 4); caddis fly (Trichoptera), may fly (Ephemroptera) and wing fly (Diptera) with occasional presence of Annelida (worms) and molluscs (Appendix IV). Bottom dwelling aquatic macro zoobenthos were represented by 16 taxa from 6 orders (EIA, 2009).

Plate 2: Some nektonic species reported in river Alaknanda

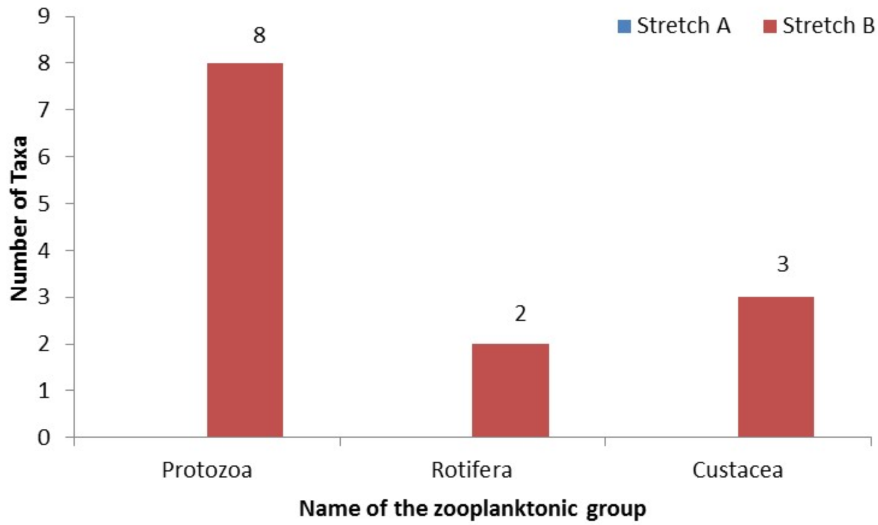


Figure 3: **Distribution of zooplankton in river Alaknanda**

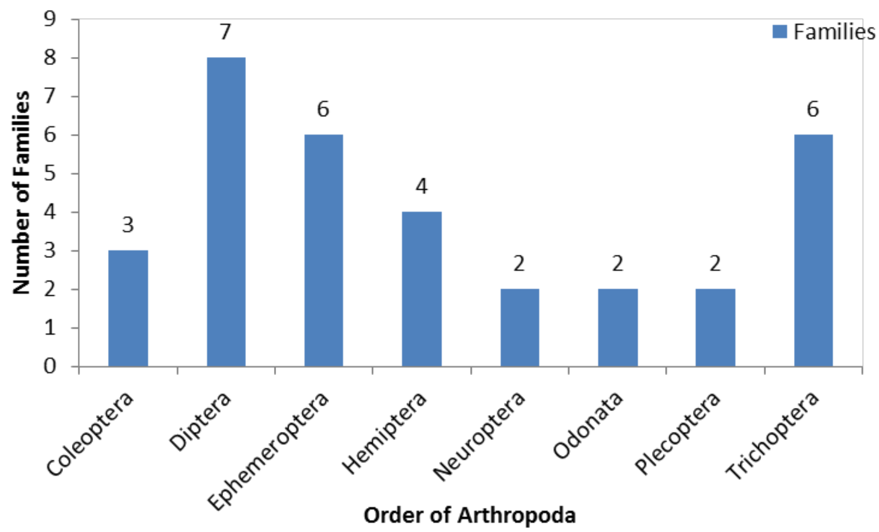


Figure 4: **Distribution of Arthropoda in river Alaknanda (Stretch B)**

In **nektonic** communities; snow trout (*Schizothorax* sp.) is most abundant fish followed by *Glyptothorax* sp. and *Nemacheilus* sp. (Appendix V). Total 43 fish species are recorded. Cyprinidae (26 species) is most abundant family followed by Sisoridae (7) and Balitoridae (6) (Figure 5). The abundance of producers (phytoplankton and periphyton) and consumers (zooplankton and zoobenthos) govern the population of fish community. The trouts breed at stony substrate of 1-3 m depth during August to October and migrate towards upper reaches in search of suitable environment for breeding.

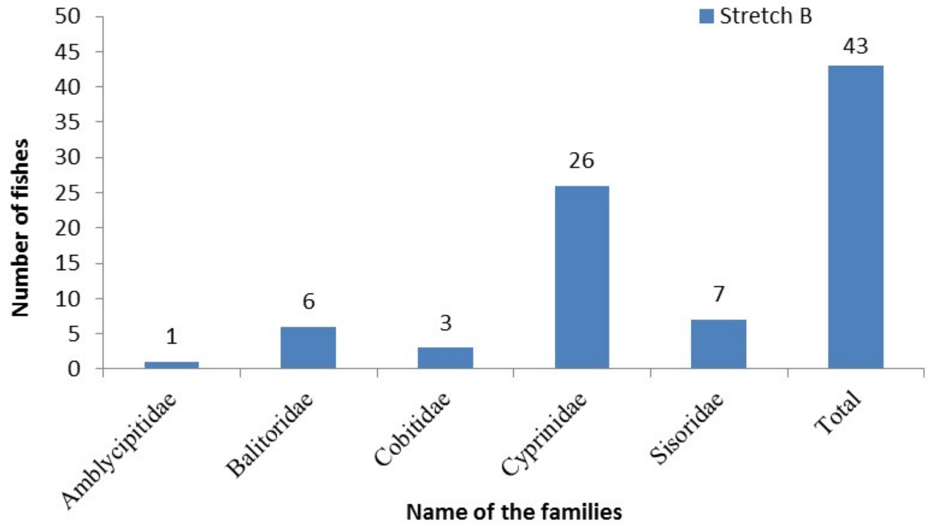


Figure 5: Distribution of fishes in river Alaknanda

4. Conclusions

- ✓ In stretch A (from Mana to Vishnupryag), the biotic community is unexplored, attributed to low temperature and very high water current. However, Joshi *et al.,* (1995) recorded only phytoplankton as dominant community. This stretch is not reported as habited by any fish species.
- ✓ The stretch B has diatoms (Bacillariophyceae) as dominant group in the phytoplankton and periphyton communities. Green algae (Chlorophyceae) and blue green algae (Myxophyceae) contribute one third share in the total planktonic community. Protozoans contribute highest share in the zooplankton community. Wing fly (Diptera) is dominant taxa followed by cadis fly (Trichoptera) and may fly (Ephemeroptera). The dominance of the indicated flies indicated the presence of both type of food particles i.e. coarse particulate organic matter (CPOM) and fine particulate organic matter (FPOM). According to 'River Continuum concept' (Vannote *et al*., 1980), the community composition changes from headwater to downstream of the river due to change in physical and chemical characteristic of the river. Snow trout is characteristic fish in this stretch because of moderate water temperature, current velocity and preferred physical habitat (rocks and boulders).

References

EIA Project, (2009). Baseline environment, impacts and mitigation measures. Final Technical report of environmental studies for Vishnugad- Pipalkoti Hydro- Electric Project. pp. 72.

Joshi, H., Shishodia, S.K., Kumar, S.N., Saikia, D.K., Nautiyal, B.P., Mathur, R.P., Pande, P.K., Mathur, B.S. and Puri, N. (1995). Ecosystem studies on upper region of Ganga river, India. *Environmental Monitoring and Assessment*, **35:**181-206.

Kishor, B. (1998). Foraging patterns of *Tor putitora* (Hamilton) with reference to entomofauna and its population dispersal. D. Phil. Thesis, HNB Garhwal University, Srinagar, Uttarakhand, India.

Krishna Murti, C.R., Bilgrami, K.S., Das, T.M. and Mathur, R.P. (1991). The Ganga: A scientific study. The Ganga Project Directorate, Northern Book Center, New Delhi, India.

Nautiyal, R., Nautiyal, P. and Singh, H.R. (1996). Pennate diatom flora of a coldwater mountain rivers Alaknanda III. Suborder biraphidae. *Phykos*, **35(1&2)**: 65-75.

Nautiyal, P. (1985). Studies on the riverine ecology of torrential waters in the Indian uplands of the Garhwal region I. Seasonal variations in percentage occurrence of planktonic algae. *Uttar Pradesh Journal of Zoology*, **5(1)**: 14-19.

Nautiyal, P., Nautiyal, R., Kala, K. and Verma, J. (2004). Taxonomic richness in the diatom flora of the Himalayan streams (Garhwal, India). *Diatom*, **20**: 123-132.

Nautiyal, P., Shivam, A., Rawat, G., Singh, K.R., Verma, J. and Dwivedi, A.C. (2004). Longitudinal variation in the structure of benthic communities in the upland Vindhyan and Himalayan river: River continuum concept approach. *National Journal of Life Sciences*, **1(1)**: 85-88.

Nautiyal, R. (2005). Altitudinal variations in the abundance pattern of benthic diatoms in a mountain river. *In:* Biological Diversity in Freshwater Environments (eds. P. Nautiyal, J.P. Bhatt, O.P. Gusain, A.K. Dobriyal). Transmedia, Srinagar, Uttaranchal, India. pp. 224-241.

Negi, M. (1993). Phytobenthos of the hill stream Alaknanda of Garhwal Himalaya. *In:* Advances in Limnology, (Eds. H.R. Singh). Narendra Publishing House, New Delhi, India. pp. 139-144.

Negi, M. and Singh, H.R. (1990). Substratum as determining factor for bottom fauna in the river Alaknanda. *Proceedings of Indian National Science Academy*, **B56 (5&6)**: 417-423.

Rawat, G. and Nautiyal, P. (2005). Diversity of Ephemeroptera community in lesser Himalayan streams and rivers (Garhwal region). *In:* Biological Diversity in Freshwater Environments (Eds. P. Nautiyal, J.P. Bhatt, O.P. Gusain, A.K. Dobriyal). Transmedia, Srinagar, Uttaranchal, India. pp. 213-223.

Sati, V.P. (2010). The Alaknanda basin (Uttarakhand Himalaya): A study on enhancing and diversifying livelihood options in an ecologically fragile mountain terrain. Final report. *Indian Council of Social Science Research*. New Delhi, India. pp. 29.

Singh, H.R., Badola, S.P. and Dobriyal, A.K. (1983). Geographical distributional list of Ichthyofauna of the Garhwal Himalaya with some new records. *Journal of Bombay Natural History Society*, **84:**126-132.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R. and Cushing C.E. (1980). The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences*, **37**:130-137.

Appendix I

Distribution of Phytoplankton in the Alaknanda river from Vishnuprayag to Devprayag

Taxa	Joshi *et al.,* 1995	Kishor, 1998	EIA, 2009	Nautiyal, 1985
Bacillariophyceae				
Achnanthes sp.				+
A. fragilariodes		+		
A. minutissima		+		
Asterionella sp.	+			
Caloneis sp.	+			
Cocconies placentula		+		
Cyclotella sp.	+			
Cymatopleura sp.	+			
Cymbella sp.				+
C. affinis		+		
C. cistula			+	
C. laevis		+		
Diatoma elongate			+	
Diatomella sp.	+			
Diploneis sp.	+			
Fragillaria sp.				+
F. inflata			+	
Frustulia sp.	+			
Gomphonema sp.				+
G. sphaerophorum		+		
Gyrosigma sp.	+			+
Hantzschia sp.	+			
Meridion sp.	+			
Navicula sp.				+
N. radiosa		+		
Nitzschia sp.	+		+	+
Pinnularia sp.	+			
Stauroneis sp.	+			
Stephanodiscus sp.	+			
Synedra sp.	+			+
Tabellaria fenestris			+	
Chlorophyceae				
Chaetophora sp.	+			
Cladophora sp.	+			+
Closteriopsis sp.	+			
Eudorina sp.	+			
Hydrodictyon sp.	+			
Scenedesmus sp.	+			+

Selenastrum sp.	+			
Spirogyra sp.	+		+	+
Ulothrix sp.				+
U. zonata			+	
Zygnema sp.	+			
Myxophyceae				
Anabaena sp.	+		+	
Lyngbya sp.	+			
Merismopoedia sp.	+			
Oscillatoria tenuis			+	
Phormidium sp.	+			
Spirulina sp.	+			
Total	**29**	**7**	**9**	**12**

Appendix II

Distribution of Periphyton in the Alaknanda river from Vishnuprayag to Devprayag

Taxa	Negi (1993)	Nautiyal *et al.*, 1996	Kishor (1998)	Nautiyal *et al.*, 2004	Nautiyal (2005)	EIA (2009)
Bacillariophyceae						
Achnanthes affinis			+		+	
A. biasolettiana					+	
A. clevei					+	
A. exigua					+	
A. exilis					+	
A. fragilarioides					+	
A. grimmei					+	
A. hauckiana					+	
A. kryophila					+	
A. lemmermannii					+	
A. laterostrata				+	+	
A. lanceolata					+	
A. lanceolata					+	
A. minutissima			+		+	
A. nodosa					+	
A. orientalis				+	+	
A. plonensis					+	
A. saxonica					+	
A. suchlandti					+	
A. trigibba			+		+	
Amphora ovalis		+			+	
A. veneta		+				
Caloneis bacillum		+			+	
C. boccariana		+				
C. obtusa				+	+	
C. silicula		+				
Cocconeis diminuta				+	+	
C. disculus				+	+	
C. placentula			+		+	
C. pediculus					+	
Ceratoneis sp.	+					
Cymbella affinis		+	+		+	
C. amphicephala					+	
C. angustata				+	+	
C. austriaca				+	+	
C. biporlita				+	+	

C. cistula					+	+
C. cymbiformis		+			+	
C. gonzalvesii		+			+	
C. gracilis		+			+	
C. helvetica		+			+	
C. hustedtii		+			+	
C. kappii				+	+	
C. lacurstris		+				
C. laevis		+			+	
C. nagpurensis		+			+	
C. naviculiformis				+	+	
C. parva		+			+	
C. perpusilla		+				
C. pusilla		+			+	
C. reinhardtii				+	+	
C. tumida		+			+	
C. tumidula		+			+	
C. turgidula		+			+	
C. turgida		+			+	
C. ventricosa		+	+			
Denticula sp.						+
Diploneis ovalis		+			+	
D. puella				+	+	
Diatoma anceps					+	
D. hymale					+	
D. subovalis		+				
D. tenue					+	
D. vulgaris					+	+
Encyonema brehmii					+	
E. gracile					+	
E. lacustre					+	
E. minutum				+	+	
E. silesiacum				+	+	
Epithemia hebridicum					+	
E. sorax					+	
Eunotia tenella					+	
Fragilaria bidens					+	
F. capucina				+	+	
F. inflate						+
F. intermedia				+	+	
F. vaucheriae					+	
F. virescens					+	

Gomphonema acuminatum		+			+	
G. angustatum		+			+	
G. augur				+	+	
G. bohemicum		+				
G. constrictum		+			+	
G. gracile		+				
G. intricatum		+			+	
G. lanceolatum		+			+	
G. nagpurense		+				
G. olivaceum		+		+	+	
G. parvulum		+			+	
G. pseudoaugur				+	+	
G. sphaerophorum		+			+	
G. subtile		+				
G. tergestinum		+				
G. ventricosum				+	+	
Gyrosigma scalproides		+				
G. spencerii		+				
Hannaea arcus					+	
Hantzschia sp.	+					
Meridion circulare						+
Navicula bacillum		+				
N. bryophila				+	+	
N. cari		+				
N. cincta		+	+			
N. cryptocephala		+		+	+	
N. grimii		+			+	
N. halophila		+		+		
N. intergracilis				+	+	
N. minima		+				
N. pupula		+				
N. radiosa		+			+	+
N. rostellata					+	
N. rhynchocephala		+	+		+	
N. viridula		+			+	
Nitzschia amphibia			+		+	
N. dentucula					+	
N. capitellata					+	
N. dissipata					+	
N. filiformis					+	
N. frustulum			+		+	
N. hybrida					+	

N. linaris					+	
N. microcephala					+	
N. paleacea					+	
N. sinuata					+	
N. sublinaris					+	
Neidium sp.	+					
Pinnularia appendiculata				+	+	
P. borealis		+			+	
P. braunii		+				
P. microstauron				+	+	
Reimeria sinuta					+	
Rhoicosphenia abbreviata					+	
R. vanheurkii					+	
Sellaphora pupula					+	
S. leptostauron					+	
S. pupula					+	
Stauroneis sp.	+					
Staurosira construens					+	
S. pinnata					+	
Surirella angusta					+	
Synedra amphicephala				+	+	
S. rumpens					+	
S. ulna			+	+	+	+
Tabellaria sp.	+					
T. fenestris						+
Chlorophyceae						
Cladophora sp.						+
Closterium leibleinii	+					+
Spirogyra sp.	+					+
Stigeoclonium sp.	+					
Ulothrix zonata						+
Zygnema sp.						+
Myxophyceae						
Anabaena sp.						+
Nostoc sp.	+					
Oscillatoria tenuis						+
Phormidium sp.						+
Desmidiaceae						
Desmidium sp.	+					
Gonatozygon sp.	+					
Total	**11**	**52**	**11**	**28**	**115**	**16**

Appendix III

Distribution of Zooplankton in the Alaknanda river from Vishnuprayag to Devprayag

Phylum/ Genus	**Joshi *et al.*, 1995**	**EIA, 2009**
Protozoa		
Actinophrys sp.	+	
Amoeba sp.	+	
Colpoda sp.	+	
Loxodes sp.	+	
Oxytricha sp.	+	
Paramecium sp.	+	
Tetrahyemna sp.	+	
Vorticella sp.	+	
Rotifera		
Asplanchna sp.		+
Keratella sp.		+
Arthropoda (Custacea)		
Ceriodaphnia sp.		+
Cyclops sp.		+
Daphnia sp.		+
Total	**8**	**5**

Appendix IV

Distribution of Zoobenthos in the Alaknanda river from Vishnuprayag to Devprayag

Taxa	Alaknanda					Mandakini
	Negi & Singh, 1990	Kishor, 1998	Nautiyal *et al.*, 2004	Rawat & Nautiyal, 2005	EIA, 2009	Semwal, 2002
Phylum-Annelida				+		
Phylum-Arthropoda Coleoptera						
Dryopidae						+
Elmidae						+
Psephenidae	+	+	+	+	+	+
Diptera						
Athericidae	+				+	
Blepharoceridae	+					+
Chironomidae	+	+	+		+	+
Culicidae	+					
Muscidae	+					
Simulidae	+				+	+
Tabanidae	+					+
Ephemeroptera						
Baetidae	+	+	+	+		+
Caenidae	+			+	+	+
Ephemerillidae	+		+		+	+
Heptageniidae	+	+	+	+	+	+
Leptophlebiidae	+			+	+	+
Siphlonuridae	+				+	
Hemiptera						
Belostomatidae	+					
Corixidae	+					
Naucoridae	+					
Nepidae	+					
Neuroptera						
Corydalidae	+				+	
Sialidae						+
Odonata						
Agrionidae						+
Gomphidae	+			+		+
Plecoptera						
Perlidae	+	+		+	+	+
Perlodidae	+				+	+
Trichoptera						
Brachycentridae	+				+	+
Hydropsychidae	+	+			+	+
Leptoceridae	+	+			+	+
Limnephilidae	+	+			+	+
Glossosomatidae						+
Psychomyiidae		+				+
Phylum-Mollusca				+		
Total	**26**	**9**	**5**	**9**	**16**	**23**

Appendix V

Distribution of fishes in the Alaknanda river from Vishnuprayag to Devprayag

Taxa	Singh *et al.*, 1983	EIA, 2009
Amblycipitidae		
Amblyceps mangois	+	
Balitoridae		
Nemacheilus beavani	+	+
N. montanus	+	+
N. multifasciatus	+	+
N. rupicola	+	
N. savona	+	
N. zonatus	+	+
Cobitidae		
Botia dario	+	
B. geto	+	
Lepidocephalus guntea	+	
Cyprinidae		
Barilius barna		+
B. bendelisis		+
B. bola	+	+
B. vagra		+
Crossocheilus latiuslatius	+	+
Danio devario	+	
Garra gotylagotyla	+	+
G. lamta	+	+
G. prashadi	+	
Labeo dero	+	
L. dyocheilus	+	
Pseudecheneis sulcatus		+
Puntius chilinoides		+
P. sophore		+
Schizothoraichthys progastus	+	+
Schizothorax curvifrons	+	
S. esosinus	+	
S. intermedius	+	
S. micropogan	+	
S. niger	+	
S. plagiostomus	+	
S. richardsonii	+	+
S. sinuatus	+	
Tor chilinoides	+	
T. putitora	+	+
T. tor	+	+
Sisoridae		
Glyptothorax brevipinnis	+	
G. cavia	+	
G. conirostris	+	
G. madraspatnum	+	+
G. pectinopterus	+	+
G. trilineatus	+	
Pseudecheneis sulcatus	+	
Total	**37**	**20**

Floral and Faunal Diversity in Yamuna River

Yamnotri – Allahabad

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay **IIT Delhi** **IIT Guwahati** **IIT Kanpur** **IIT Kharagpur** **IIT Madras** **IIT Roorkee**

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

River Yamuna, the largest tributary (1376 km) of river Ganga, originates from Yamunotri glacier at Bandar Punch in the region of Simla (30° 58' N, 78° 27' E) at 6,387 m above mean sea-level (msl), in the lower Himalayas. It has a total catchment area of 3,425,848 km^2 (Moza and Mishra, 2003). After flowing through the Sivaliks, river Yamuna emerges on the plains near Tajewala at 370 m (msl). The river then flows south-west to southwards for 224 km to enter the National Capital Territory of Delhi at 215 m (msl). After meandering through Delhi for about 22 km to Okhla, the river continues southwards for 272 km to Agra (146 m msl) and then turns South-East until its confluence with the river Ganga at Allahabad (100 m msl) (Figure 1: Flow chart of the Yamuna river basin). All along its 1,170 km flow through the Gangetic plain, the average slope of the river bed decreases from about 0.56 m/km between Tajewala and Delhi to less than 20 cm/km between Delhi and Agra before becoming less than 5 cm/km thereafter (Gopal and Sah, 1993).

Based on the hydrological and ecological information river Yamuna can be differentiated into 5 sub stretches, as (CPCB, 2006):

a)	Himalayan stretch	From origin to Tajewala barrage (172 kms.)	(YR_1)
b)	Upper stretch	Tajewala barrage to Wazirabad barrage (224 kms.)	(YR_2)
c)	Delhi stretch	Wazirabad barrage to Okhla barrage (22 kms.)	(YR_3)
d)	Eutrophic stretch	Okhla barrage to Chambal confluence (490 kms.)	(YR_4)
e)	Diluted stretch	Chambal confluence to Ganga confluence (468 kms.)	(YR_5)

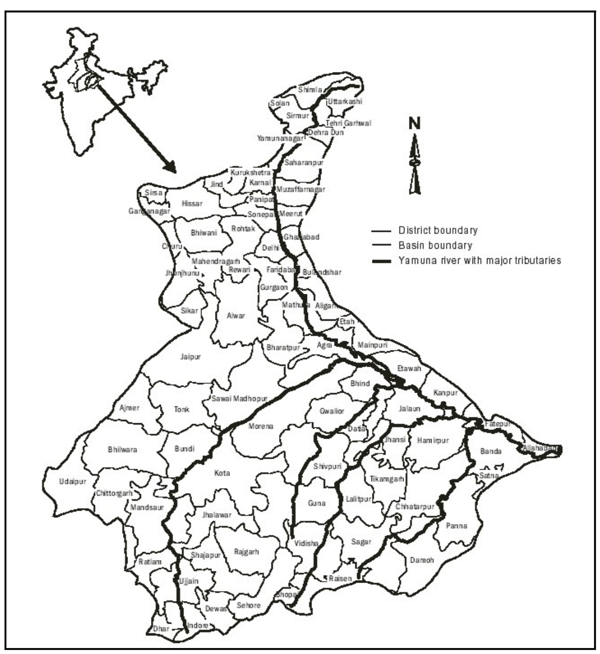

Figure 1: Yamuna river basin

2. Salient feature of Yamuna river

Several tributaries join it along its path, transforming it into a fourth-order river. Several major tributaries join river Yamuna in the Gangetic plain. Some of the important tributaries are river Hindon, Chambal, Sind, Betwa and Ken. The salient features of all the tributaries of river Yamuna are described in Table 1. The total catchment basin of the Yamuna river is 42.5% of the Ganga basin and 10.7% of the total geographical landmass of the country. River Chambal, well known for its deep ravines, is the largest of these tributaries, with a catchment area of 139,789 km^2 (40% of the Yamuna river basin).

Table 1: Tributaries of river Yamuna

	Tributaries					
Characteristics	**Hindon**	**Chambal**	**Sind**	**Betwa**	**Ken**	**Paisuni**
Position	Left bank tributary	Right bank tributary	Right bank tributary	Right bank tributary	Right bank tributary	Right bank tributary
Region of origin	Sivalik hills	North wards slope of the Vindhyan mountains in native state of Indore (M.P.)	North wards slope of the Vindhyan mountains originates at Hatoli (District Vidisha)	North wards slope of the Vindhyan mountains	North Western slope of the Vindhyan mountains in native state of Bhopal	Kaimur hills parts of the Vindhyan mountains
Length (km)	400	960	415	590	360	100
Width (m)	20-160	-	-	-	477	95
Depth (m)	-	1.4-9.2	-	2.7-9.4	2-10	1-15
Altitude (m)	-	-	-	-	193	140
River bed	Sand	Stony rapid, sand banks and gravel bars	-	Stones, Sand, Riffle and Pools; Pebbles and Cobble	Rocks, Stones, Sand	Stones, Sand, Mud
Benthic macrofauna	-	-	-	-	Insects, few mollsuca and annelida	Insects, few mollsuca and annelida

- Represented data not found **Gopal and Sah (1993); Dwivedi (2006)**

2.1. Physical conditions of the Yamuna river

The Himalayan part of the basin experiences very low winter temperatures and high rainfall (1,200 to > l,600 mm). In the plains, peak temperatures rise above 45°C during summer (late May-June), but during winter the temperature (average 2-9°C December-January) rarely drops below the freezing-point. The soils of the Yamuna basin vary considerably, as they have developed under different lithological, climatic, and pedogenetic conditions (Raychaudhury *et al.,* 1963). River bed of the upper Yamuna is primarily sandy in texture having sand in the range of 70.52-74.76%, silt in the range of 17.74-18.56% and clay in the range of 7.35-11.55%. Due to large variation in climate and soils, the natural vegetation is also highly variable in the Yamuna river basin.

2.2. Major abstraction of the Yamuna river

The river water is abstracted at different locations for multiple uses. At two places i.e. Hathnikund/ Tajewala and Okhla, the water abstraction is significant. The points of abstraction and addition in water of Yamuna river are shown in Figure 2.

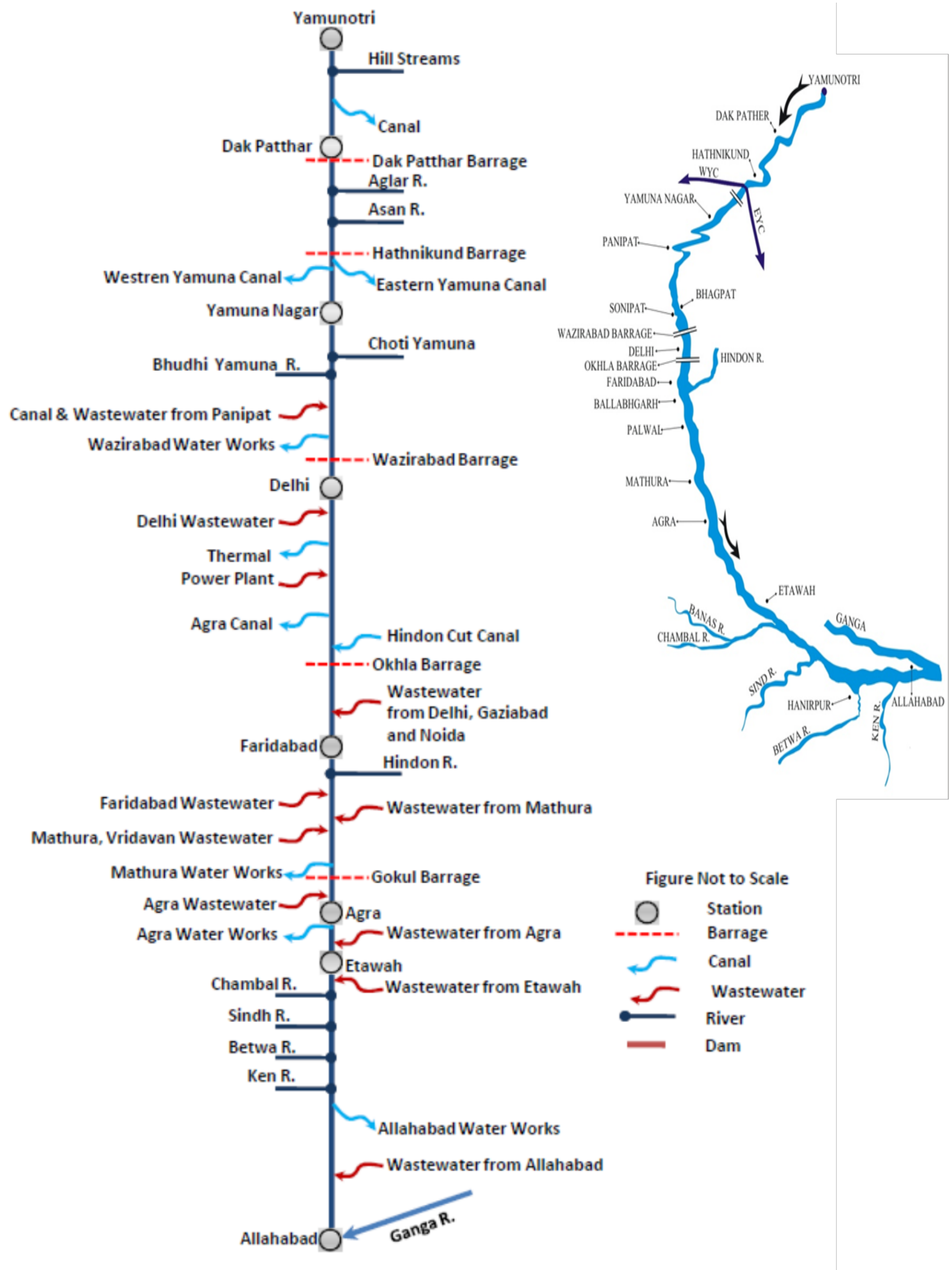

Figure 2: Points of water abstraction and additions in Yamuna river (CPCB, 2006)

3. Biological diversity of Yamuna river

Aquatic ecosystem harbours a variety of communities, which constitute the characteristics and functioning of the ecosystem in terms of maintaining production and food chain. Water qualities also strongly influence distribution and extent of biodiversity in Yamuna river. Planktonic and benthic communities determine processes, functions and attributes of aquatic ecosystem. These organisms were critically linked to changes in ambient environment and species present were either tolerant to the rigorous chemical milieu or had wide ecological amplitude. The average standing crop of total plankton in upper Yamuna was 308 u/l showing a gradual increase down the gradient. It being 273 u/l at Hathnikund, 289 u/l at Kalanour, 329 u/l at Badoli and 380 u/l at Sanoli (Moza and Mishra, 2003). The present report highlights characteristics features of community structure and diversity of phytoplankton, zooplankton, benthic communities and vertebrates of river Yamuna. The analysis of biodiversity present in Yamuna is based on data collected from secondary sources.

3.1. Phytoplankton

Phytoplanktons are the primary producers and constitute the first level in aquatic food chain for all aquatic animals. The density and diversity of phytoplankton and their association as biological indicators in the assessment of water quality or trophic status has been made by some workers (Chaturvedi *et al.,* 1999). Phytoplankton of river Yamuna was studied Sharma, 2000; Sankar, 2002; Atul, 2002; Nautiyal, 2004, but the studies conducted by them did not highlight the overall scenario of phytoplankton in the river from Yamunotri to Ganga confluence. The distribution of phytoplankton along the entire stretch of river Yamuna is shown in Appendix Ia and Figure 3.

The total number of algal taxa present in the entire stretch of river Yamuna is 220. The major contributors are Bacillariophyceae (56), Chlorophyceae (111), Myxophyceae (38) and Euglenophyceae (7). Chrysophyceae (1) and Xanthophyceae (3) are present in YR_4/ YR_5 and YR_3, respectively, while Dinophyceae (4) is present in YR_2, YR_3 and YR_4.

The dominant species of Bacillariophyceae in the Yamuna river are *Amphora* sp., *Navicula* sp., *Synedra* sp. and *Tabellaria* sp. Sarkar (2011) reported 10 prominent genera in YR_4 stretch as *Cyclotella*, *Gomphonema*, *Stauroneis*, *Nitzshia*, *Fragillaria*, *Syndra*, *Navicula*, *Melosira*, *Frustulia* and *Amphora*.

It is observed that the group Chlorophyceae represents the highest number of species. The maximum numbers of species are *Celastrum*, *Pediastrum*, *Pleurotaenium*, *Scenedesmus*, *Schroederia*, *Spirogyra* and *Ulothrix* genera. Sarkar (2011) also reported the dominance of 11 chlorophyceae genera namely *Eudorina, Chlamydomonas, Volvox, Zygnema, Closterium, Actinastrum, Pediastrum, Trachelomonas, Staurstrum, Scendesomus* and *Spirogyra* in the Agra (YR_4) stretch.

Myxophyceae was found chiefly at polluted sites. The population was largely composed of *Lyngbya* sp., *Merismopoedia* sp., *Oscillatoria* sp. and *Phormidium* sp. Sarkar (2011) reported the predominance of genus *Nostoc* in the year 2005-2007 in the YR_4 stretch. The two genera of Euglenophyceae, *Euglena* sp. and *Phacus* sp. are important in YR_3 and YR_4 stretch of river.

The causative factors for variation in phytoplankton in different stretch of Yamuna are not clearly understood. But a relationship could be established between free carbon dioxide and phytoplankton. However, Munawar (1970) suggested that Euglenophyceae prefer higher concentration of free carbon dioxide for their growth. This view favours the presence of free carbon dioxide at elevated level in the YR_3 stretch.

The other critical factor reflected the growth of phytoplankton in the ecosystem is dissolved oxygen. Dissolved oxygen (DO) ranged from 7.75-9.34 mg/l in YR_1 (Moza and Mishra, 2003) which is close to saturation level of oxygen in water. This indicated the low level of organic pollution in upper stretch of the river Yamuna, or the pollution landing is well within the carrying capacity of river. The DO was alarmingly low and it varied between 8.5-1.8 from Yamuna nagar to Delhi, due to the combined waste discharge from domestic and industrial sources. These values indicated the high organic pollution in the river Yamuna in the stretch between YR_2-YR_3. At Mathura, the river showed better condition (DO=8.6-4.8 mg/l) due to availability of diluting water added by the Mathura refineries, improving the self purification capacity of the river. At Agra the quality of water in the upper stretch of the river Yamuna exhibited buffering as a result of which only limited fluctuations were noticed. But Agra downstream (DO=0.5-3.2 mg/l) the continuous discharge adversely effected the self purification of water in the river Yamuna. At Firozabad (DO=3.7-4.8 mg/l) the condition of river was almost same as at Agra. The river showed great improvement in water quality downstream at Etawah due to the confluence of various tributaries (Figure 2) (Prakash and Panwar, 2005). There was a gradual improvement in water quality from Auria to Allahabad (DO=7.2-8.4 mg/l). Dissolved oxygen is directly dependent on the density of phytoplankton. Zafer (1964) attributed the higher percent of chlorophyceae to high value of dissolved oxygen. The composition of phytoplankton shifted from Bacillariophyceae dominated community at YR_1 (21) to Chlorophyceae at YR_3: Delhi (72) and Myxophyceae at YR_4: Mathura and Agra (23) and again Bacillariophyceae (23) between Mathura to Firozabad (YR_4).

It is generally believed that temperature is one of the most important factor in an aquatic ecosystem, but Hutchinson (1967) suggested that it was never a critical factor for considerable variation in the growth of phytoplankton. This appears to be more appropriate that in all habitats (YR_1-YR_5 stretch), high temperature (YR_3-YR_5 stretch) were found to be more conductive to the increase of phytoplankton. On the other hand, the low temperature (YR_1 stretch) also favoured the growth of certain phytoplankton as the minor peak was also observed in the same stretch.

Tabasum (2006) reported some phytoplankton indicator species based on the inter-relationships of population density with water quality. The indicator species decreased in the presence of high pollution load were *Rivularia* sp., *Oscillatoria priniceps*, *Mesotaenium endlicherianum* and *Tabellaria* sp. At the same time, indicator species increased in presence of high pollution load namely *Navicula viridula* and *Pleurogaster lunaris*.

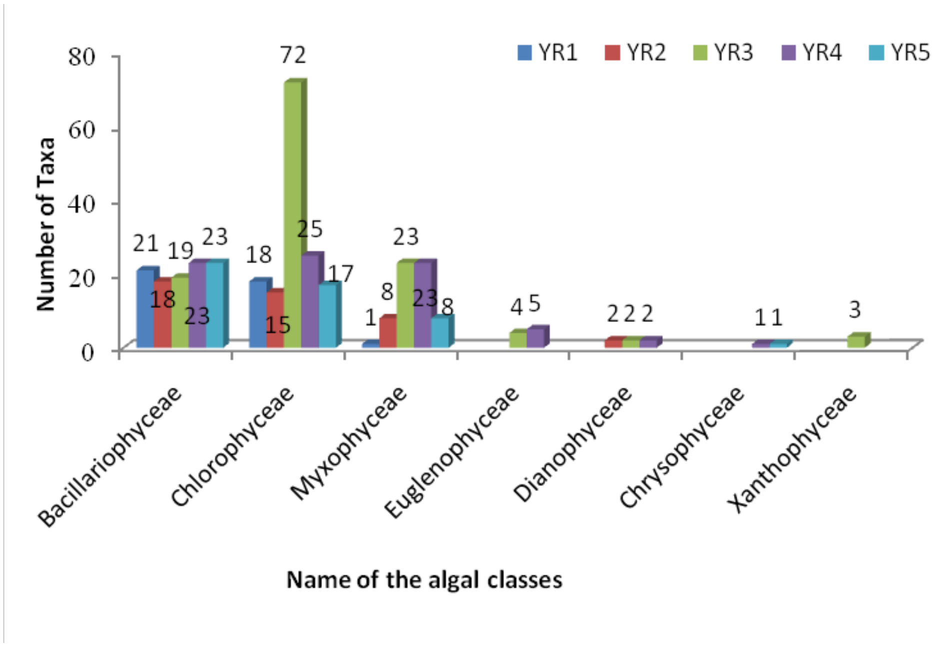

Figure 3: Distribution of phytoplanktonin river Yamuna (YR_1-YR_5)

3.2. Periphyton

Periphyton are benthic (attached) algae that grow attached to surfaces such as rocks or larger plants. Periphyton are primary producers and sensitive indicators of environmental change in lotic waters. Because periphyton are attached to the substrate, this assemblage integrates physical and chemical disturbances to the stream reach. The periphyton assemblage serves as a good biological indicator due to:

- ✓ A naturally high number of species
- ✓ A rapid response time to both exposure and recovery
- ✓ Identification to a species level by experienced biologists
- ✓ Ease of sampling, requiring few people
- ✓ Tolerance or sensitivity to specific changes in environmental condition are known for many species

Mishra and Singh (1968) were among the first to report on epiphytic algae on both natural and artificial substrates. Studies on periphyton are relatively few in river Yamuna, the only stretch having almost complete information is YR_3. The total number of algal taxa present in the entire stretch of river Yamuna is 396, mainly found in the 3 streches, YR_1 (72), YR_3 (227) and YR_5 (137).

Some reports revealed the presence of 12 taxa in YR_2 (Moza and Mishra, 2003) and 3 new taxa in YR_4 stretch (Tiwari and Chauhan, 2000). In case of periphyton the members of Bacillariophyceae were dominant over Chlorophyceae and Myxophyceae in the three stretches (YR_1, YR_2 and YR_5). Most common genera of Bacillariophyceae in the entire Yamuna stretch were *Achnanthes*, *Achnanthidium*, *Amphora*, *Caloneis*, *Cymbella*, *Cymbopleura*, *Gomphonema*, *Melosira*, *Navicula*, *Nitzschia*, *Pinnularia*, *Stauroneis*, *Surirella* and *Synedra*. According to Nautiyal (2004) the most dominant taxa of Yamuna basin were *Achnanthes linearis*, *A. microcephala*, *A. minutissima, Cymbella excisa* and *Gomphonema parvulum*. Moza and Mishra (2003) reported 6 dominant Bacillariophyceae genera of YR_2 stretch namely *Diatoma*, *Frustulia*, *Tabellaria*, *Cocconeis*, *Navicula* and *Synedra*.

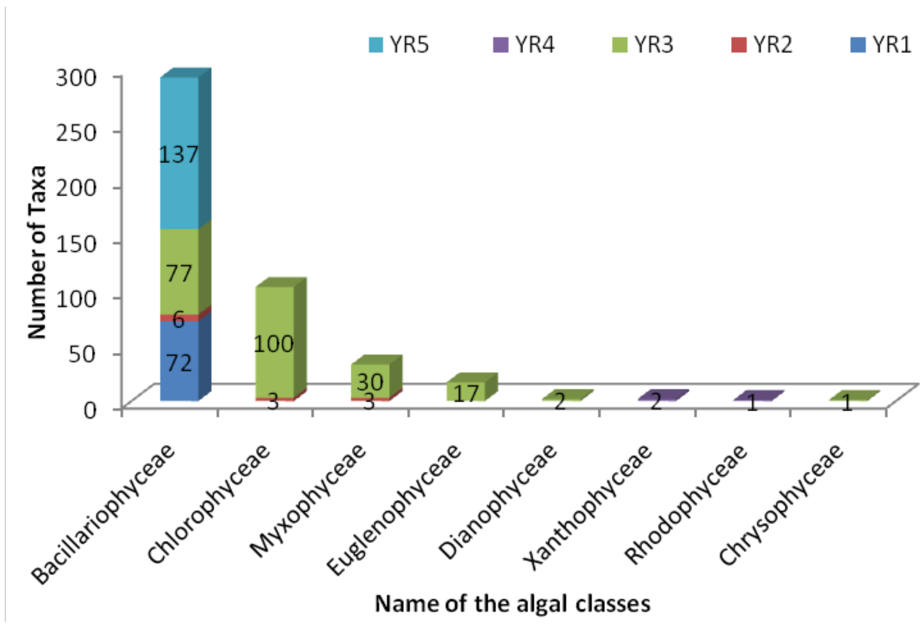

Figure 4: Distribution of periphytonin river Yamuna (YR_1-YR_5)

The Chlorophyceae and Myxophyceae algae mainly represented by *Closterium*, *Cosmarium*, *Pediastrum*, *Zygnema*, *Staurastrum*, *Syndesmus* and *Anabena*, *Merismopedia*, *Oscillatoria* and *Phormidium* in the YR_3 stretch. No relevant data available regarding the presence of periphyton except members of Bacillariophyceae in YR_5 stretch. Moza and Mishra (2003) reported 3 dominant genera of Chlorophyceae namely *Spirogyra*, *Trochschia* and *Cladophora* and 3 dominant genera of Myxophyceae namely *Oscillatoria*, *Sprilulina* and *Nostoc* in YR_2 stretch. The distribution of periphyton along the entire stretch of river Yamuna is given in Appendix Ib and depicted in Figure 4.

3.3. Zooplankton

Zooplankton are microscopic organisms which do not have the power of locomotion and move at the mercy of the water movements. Rotifers, Cladocerans, Copepods and Ostracods constitute the major groups of zooplankton. They occupy an intermediate position in the food web. Zooplankton mediatethe transfer of energy from lower to higher trophic level (Waters, 1977). Thus zooplankton represent an important link in aquatic food chain and contribute significantly to secondary production in fresh water ecosystem. Zooplankton also plays an important role as indicators of trophic condition in both cold temperate and tropical waters (Sharma, 1998).

In the entire stretch of Yamuna zooplanktons were represented by Protozoa, Rotifers, Crustacean, Molluscs, Nematodes, Annelids and Insects. The total number of zooplanktons taxa present in YR_2-YR_5 is 298. No reported literature was available showing the presence of zooplanktons in YR_1 stretch, this condition is almost similar to the Ganga river in which no zooplankton has been reported in UG_1 (Gangotri to Gangnani).

Zooplankton in the entire Yamuna stretch were represented by 38 orders and 1 subclass (Acari). In Yamuna river about 14 order of Protozoa, 4 order of Rotifers, 6 order of Crustacean, 1 order of Molluscs, 3 order of Nematodes, 3 order of Annelids and 7 order of Insects were reported. The details related to the name of the order and the numbers of taxa present in the respective order are depicted in Figure 5. The zooplankton community was represented by 14 order and 47 taxa at YR_2, 18 order and 196 taxa at YR_3, 18 order and 58 taxa at YR_4 and while members of 27 orders and 70 taxa were presented at YR_5.

Among the various groups of organisms, the Rotifer population was predominant in the YR_3-YR_5 stretch and represented by Philodinida, Bdelloida, Ploima and Eurotatoria. Rotifers are also essential food source for Indian Major Carps. The second most dominant group of organism was Protozoa in the same stretch. Protozoa mainly represented by the orders Ciliphora, Hypotrichida, Heterotrichida, Spirotricha, Armophorida, Bryometopida, Odontostomida, Peniculida, Hymenostomatida, Peritrichida, Suctorida, Testacea, Arcellinida and Amoebida. The third and fourth largest group of organisms in the same stretch was Arthropoda and Insecta, respectively. The distribution of zooplankton along the entire stretch of river Yamuna is shown in Appendix Ic and Figure 5 and 6.

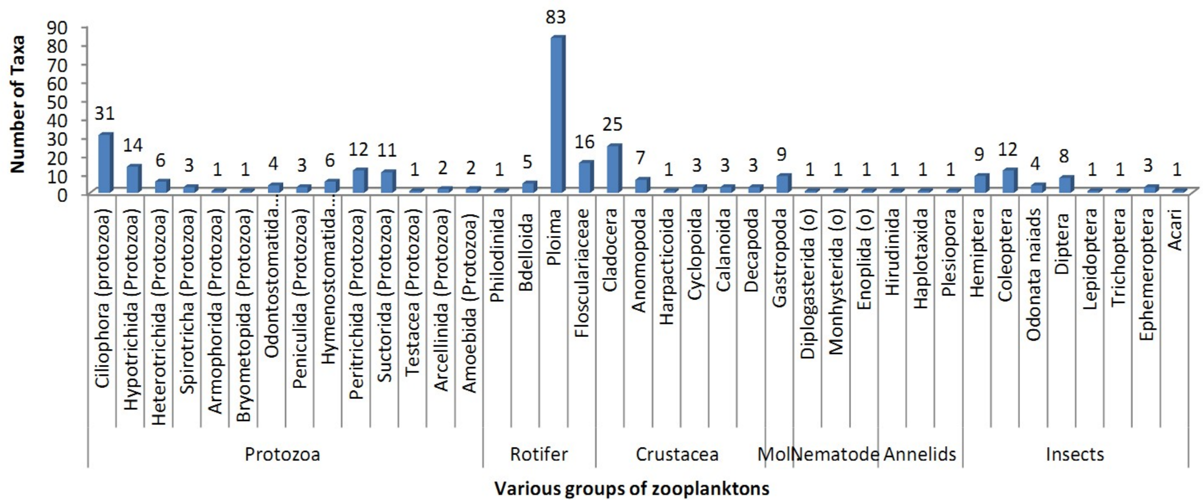

Figure 5: Distribution of various groups of zooplankton in Yamuna

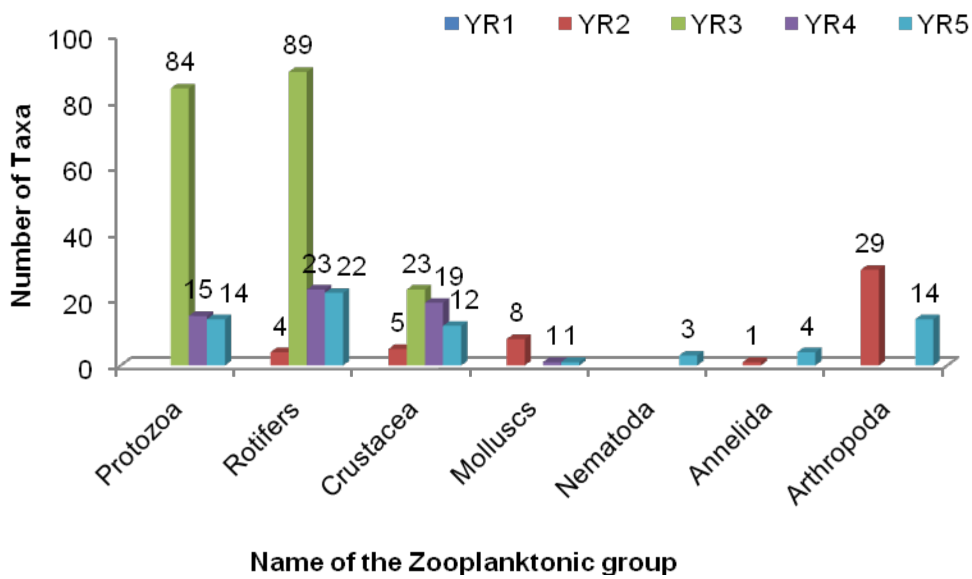

Figure 6: Distribution of zooplankton in Yamuna river (YR_1-YR_5)

3.4. Zoobenthos

It is widely accepted that benthic macroinvertebrates play a major role in the evaluation of environmental quality of aquatic ecosystems (Stewart *et al.,* 2000). They reflect the combined effects of various stresses influencing water quality in time and space (Timms, 2006). The abundance of benthic fauna mainly depends on physical and chemical properties of the substratum. Because of their extended residency period in specific habitats and presence or absence of particular benthic species in a particular environment these can be used as bio-indicators of specific environment and habitat conditions.

Zoobenthic population varied between 412-66 u/m^2. The maximum density of 412 u/m^2 at Hathnikund may be due to shallow clean water, stony bed and river soil having highest organic carbon and the minimum 66 u/m^2 at Karnal may be due to high sand and low clay percentage in texture. Diversity of zoobenthos at various sites in upper Yamuna showed that species confined to reference zone were *Nymphula*, *Ephemerella*, *Ephemera* and *Plea* sp. as such these classify as Saprophobic forms (non-tolerant species) in context of Yamuna basin (Moza and Mishra, 2003). Zoobenthos in the Yamuna river was represented by 3 orders of Arthropods, 9 orders of insecta, 2 classes of Molluscs, 4 classes/subclasses of Annelids and 1 order of Nematoda (Appendix-Id). The zoobenthic community was represented by 43 families of Insecta, 17 families of Mollusca, 9 families of Annelids and 1 family of Nematode. The data revealed the dominance of Insecta over Molluscs and Annelida in the YR_1 stretch. The class insecta in YR_1 stretch represented mainly by order Trichoptera (1), Hemiptera (2), Ephemeroptera (2), Coleoptera (3) and Diptera (2). In YR_2 stretch molluscs are clearly dominant over insecta and Annelida. Mollusca were represented by two major classes Gastropoda (7) and Bivalvia (2). YR_3 stretch showed the dominance of class Insecta over the other groups (Mollusca, Annelida and Crustacea). The class Insecta represented by 5 order and 24 families in this stretch. The same trend was followed by the next stretch YR_4 in which class Insecta (21 families) showed its dominance over Mollusca (15 families), Annelida (4 families) and Nematoda (1 family). The presence of crustacean was also recorded in YR_4 stretch. The data about the zoobenthos at YR_5 was not available. The distribution of zoobenthos along the entire stretch of river Yamuna is shown in Appendix Id and Figure 7.

The species composition of Yamuna (YR_4) at Vrindhavan range from fresh water indicator, *Baetis* (Chandler, 1970) to low pollution indicator, *Aelosoma* and leech (Barbhuyan and Khan, 1992) to organic pollutant indicators, *Chironomus, Tubifex* and *Cypris* (Krishnamoorthi and Sarkar, 1979; Moza, 1996), thereby showing that Yamuna at this site too is organically rich to some extent. Thus the YR_4 can be classified as mildly polluted or β-mesosaprobic and the benthic organisims present as saproxenic species, having wide range of organic pollution tolerance from low to high. The benthic population at Etawah was dominated by *Chironomus* and *Cypris* at different sites represents the nature of the stretch, polysaprobic and α-mesosaprobic. The decrease in benthic population after the confluence of Chambal (YR_5) showed the absence of organic pollutant and indicated comparatively clear zone (Moza and Kolekar, 2002).

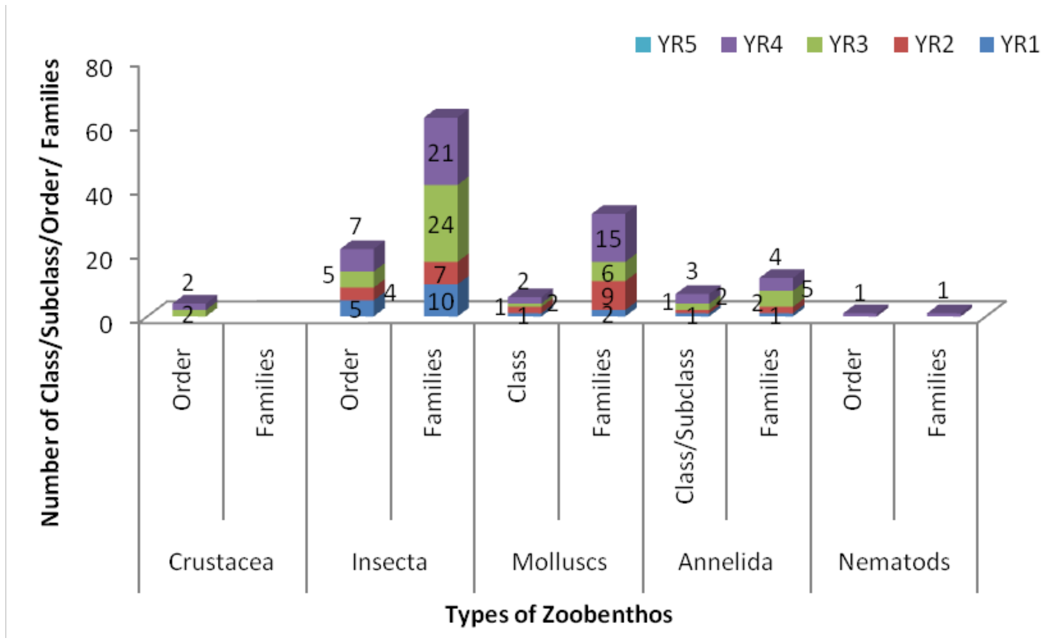

Figure 7: Distribution of zoobenthos in Yamuna river (YR_1-YR_5)

3.5. Fishes

The distribution and status of fish fauna of Yamuna river depicted is listed in Appendix Ie and shown as bar digram in Figure 8. Overall 139 species belonging to 78 genus and 33 families have been reported from Yamuna river. A total of 88 species belonging to 47 genus and 21 families has been recorded from YR_1, while in YR_2, 20 species belonging to 11 genus and 4 families has been reported. In YR_3 stretch 49 species belonging to 33 genus and 19 families has been reported. YR_4 and YR_5 stretch represented by 50 species, 35 genus, 19 families and 67 species, 51 genus, 23 families, respectively.

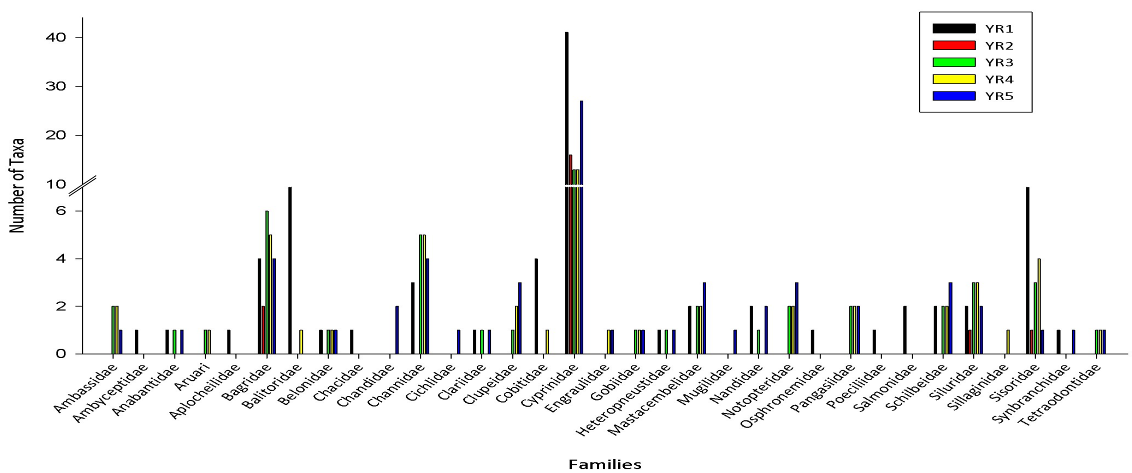

Figure 8: Distribution of fishes in Yamuna river (YR_1-YR_5)

Moza and Mishra (2001) recorded high share of others (57.42%), *Cyprinus carpio* (5.20%), *Aorichthys aor* and *A. seenghala* (7.31%) and *W. attu* (6.92%) compared with small proportions of *L. rohita*, *C. catla*, *C. mrigala* and *L. calbasu* (1.72%, 0.52%, 1.96%, and 2.37%, respectively) in the upper stretch of Yamuna. *T. putitora* was present in small proportions 3.11%.

The upper stretch of river Yamuna (YR_1-YR_2) contains fish biomass of 22.98 t per year ranging from 6.31 t at Yamuna nagar to high of 15.54 t at Panipat though a low of 1.13 t at Karnal. The overall fish population from Yamunanagar to Panipat shows dominance of miscellaneous groups (70.71%) while Cat fishes forming 14.23%; IMC 6.64%; common carps 5.20% and Mahseer 3.11% of the total population (Figure 9) (Moza and Mishra, 2001). Exotic carps like *Ctenopharyngodon idella* (0.04%) and *Aristichthys nobilis* (0.07%) were negligible. Among the miscellaneous minor carps form sizeable group representing 11.69% of total population while as a group "others" contain assorted fishes being represented by *Chela* sp., Murrels, *Notopterus*, *Bagarius* sp. etc. (Moza and Mishra, 2001). In the Yamuna at Kulal (Poonta Sahib) the composition differed, *Tor* spp. (52.78%), *L. calbasu* (36.11%), *L. dero* (5.55%) and miscellaneous groups (4.17%).

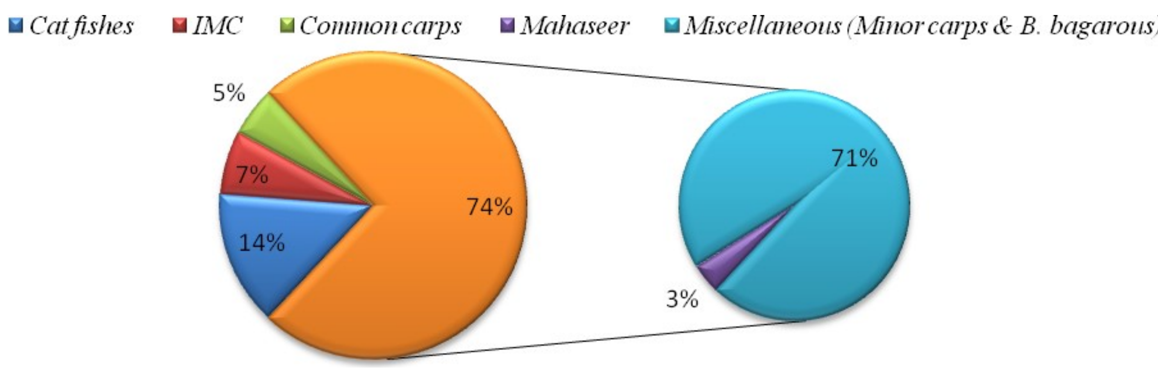

Figure 9: Status of fish population in Yamuna river (YR_2)

In the western Yamuna canal, scenario of the catch was different, *Cyprinus carpio* was dominated (17.95%), other fish accounted for 18.23% while *Aarichthys* spp. and *T. putitora* contributed small proportions, 9.88% and 9.67%. *C. catla*, *L. rohita, C. mrigala* and *L. calbasu* contributed small proportions, 0.31%, 1.82%, 3.45% and 3.08%, respectively. Thus in the river other and cat fish contributed 70.71% and 14.23%, while in the canal exotic carps and cat fishes accounted for 18.42% and 16.23%.

The main cause of low production in upper region of Yamuna may be mainly due to:

i. Water abstraction ii. Siltation of river bed

The average yield in the river Yamuna between Delhi and Etawah stretch (YR_3-YR_4) with Agra as a focal point decreased from 100.76 t (1989) to 46.83 t (1993), with an average of 64.16 t. IMC except *L. calbasu* (8.2 to 13.64%) was on decline, showed *C. mrigala* (7.81%), *L. rohita* (5.89%)

and *C. catla* (2.20%). Catfishes increased especially *Mystus* sp. (31.5%) and *W. attu* (18.0%). Miscellaneous fishes (21.14%) were also present in this stretch. Common carps were also established in the system and forms 0.16% of the population (Figure 10) (Mishra and Moza, 1997).

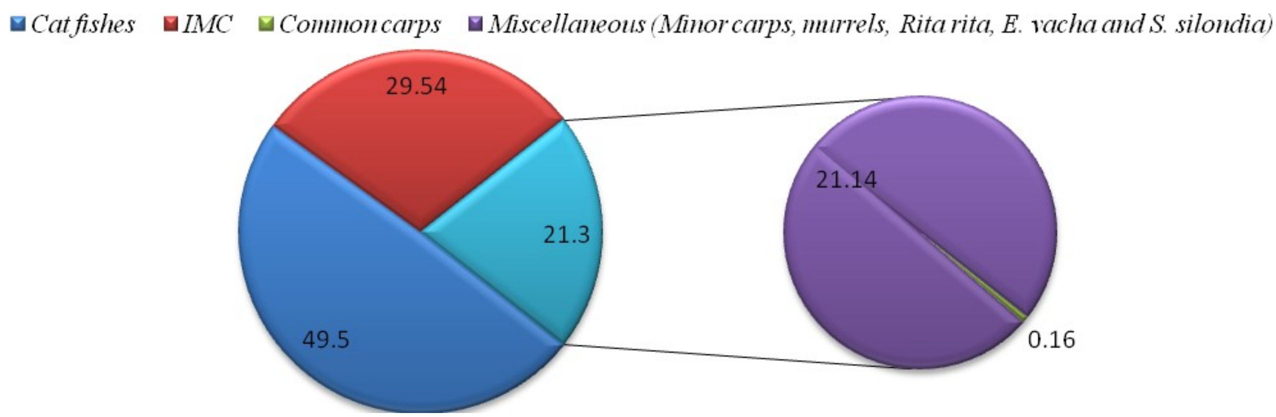

Figure 10: Status of fish population in Yamuna river (YR_3-YR_4)

The *L. rohita*, *C. catla* and *C. mrigala* contributed small proportions in the Yamuna river (Delhi to Etawah), showed dominance of large size cat fishes (≈49.26%) followed by major carps (≈28.54%).

The presence of exotic carp *C. carpio* in the Yamuna along with small share of other exotic carp formed 17.8% of the total landing at Allahabad (Anon, 2003). It account for 4.5% of the landing at Panipat in Haryana (Moza and Mishra, 2001), located before Delhi and much upstream of Allahabad. After common carp, the miscellaneous and cat fishes are emerging as a major fishery in Yamuna (Anon, 2002; 2003). Singh *et al.* (1998) found that *S. aor* and *S. seenghala* were dominant sp. (45.2%) compared with miscellaneous (28.2%) and *L. calbasu* (14.6%) in the Yamuna at Allahabad (Figure 11). Grover and Gupta (1977) reported 58 fish taxa in river Yamuna at Chilla.

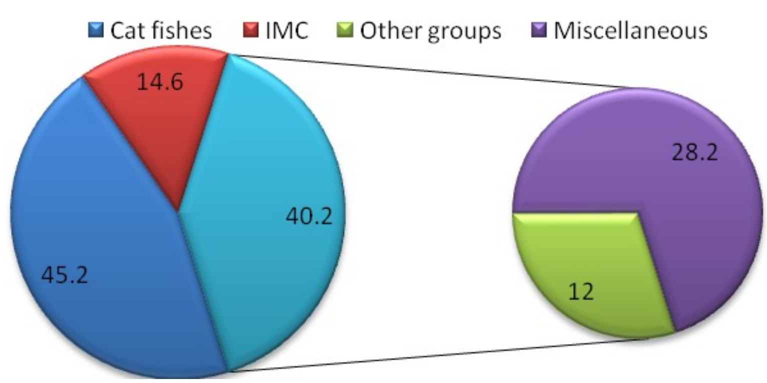

Figure 11: Status of fish population in Yamuna river (YR_5)

3.6. Higher vertebrates

Among the important higher vertebrates reported in Yamuna river are dolphin *Platanista gangetica gangetica*, Gharial (*Gavialis gangeticus*), turtles, *Lissemys punchata, Chitra indica, Aspideretes gangeticus* and three species of *Kachuga, K. kuchuga, K. tentoria* and *K. dhongoka*.

In the Yamuna river from confluence of Chambal to Hamirpur (350 km) 60 dolphins has been reported by WWF (2010) and by Sinha *et al*. (2010). In the major tributaries of Yamuna river; in Chambal (Pali to Barhi) 89; in Ken (from confluence of Yamuna at Chilla to Sindhan Kala village) 08; in Betwa (from confluence of Yamuna at Hamirpur to Orai) 06; in Sind (from confluence with the Yamuna) 05 number of dolphins have been reported (Sinha, 2000).

In case of Gharial (*Gavialis gangeticus*) Chambal river holds the largest population with an upper estimate of 306 adults animals (Converse, 2009). The other small population of Gharial is in Ken river.

Tiwari (2003) reported six species of turtles in the Yamuna at Etawah. Three species belongs to one genera and one family of hard shell turtle and other 3 species belonging to 3 other genera and one family of soft shell turtle. The six reported turtles are *Kachuga tentoria* (Indian tent turtle), *K. kuchuga* (Painted roofed turtle), *K. dhongoka* (Three stripped roofed turtle), *Lissemys punchata* (Indian flap-shell turtle), *Aspideretes gangeticus* (Indian soft-shell turtle) and *Chitra indica* (Narrow headed soft-shell turtle). Out of all reported turtles *K. tentoria* is the most common turtle found in Yamuna river. *K. dhongoka* was reported in Yamuna river at Bateswar (U.P.). Occurrence of *K. dhongoka* in Chambal was reported by Rao (1990). Moll (1987) reported *Kachuga tentoria*, *K.* t. *flariventor* and *K.* t. *circumdata* in Hindon river, Yamuna river at Gaziabad and Etawah. Rao (1995) also reported *Aspideretes gangeticus* in Chambal and Yamuna river.

4. Conclusions

i. The water quality of the Yamuna river under study has confirmed that the pollution load of up stream of Yamuna river (YR_1) is less as compared to down stream (YR_3 and YR_4).

ii. The water characteristics considered for the study indicate that the river water in YR_3 stretch is highly polluted and can not serve as a good habitat for many aquatic animals including endangered species.

iii. The poor quality trend continues downstream Delhi with values of DO fluctuating upto Majhawali and also downstream Agra. However, the values improved at Auraiya.

iv. In stretch YR_1 (from origin to Tajewala barrage), the biotic community is very less explored, attributed to very low temperature. However, phytoplankton, periphyton, zoobenthos and fishes are presented. In the YR_1, Bacillariophyceae are more than Chlorophyceae and Myxophyceae in both forms (phytoplankton and periphyton).

v. The stretch YR_1 are facing more pressure on fish resources due to high frequency of unscientific fishing methods, which completely disturb the population of fish and pollute the river water quality (Badola and Singh, 1977; Nautiyal and Lal, 1994; Uniyal *et al.,* 2006).

vi. At Yamuna nagar (YR_2) reduction of Bacillariophyceae and presence of rotifers, crustacean, molluscs, annelids and other arthopoda indicating the presence of organic pollution.

vii. In Delhi stretch (YR_3) the plankton comprised of 6 algal classes (Bacillariophyceae, Chlorophyceae, Myxophyceae, Euglenophyceae, Dianophyceae and Chrysophyceae). Chlorophyceae is more than other classes in this stretch. Chlorophyceae and Myxophyceae are higher in the Delhi stretch due to the combined sewage and industrial effluents, as compare to the YR_1 stretch, the clearest zone of the river.

viii. Apearence of number of Cladocerans and Rotifers in form of zooplankton and zoobenthos in YR_3 stretch also reflected high load of organic contaminants.

ix. In the river stretch affected by Mathura oil refinery waste, the Bacillariophyceae population has been found thriving well, showing the oil refinery effluent making the river water more suitable for the development of Bacillariophyceae population (Prakash and Panwar, 2005). In this stretch water condition in the river improve in comparision to the Delhi stretch (YR_3). The condition with respect to Bacillariophyceae population is same afterwords Mathura stretch.

x. At Etawah the composition of benthic population represented the heavy dose of organic population. Moza and Kolekar (2002) reported the benthic population dominated by *Chironomus* sp. (indicator of polysaprobic zone) and *Cypris* sp. (indicator of organic pollution).

xi. After the confluence of Chambal river (YR_5) the Yamuna is comperatively clean (Anon, 1991). The plaktonic population also reflected the same showing the dominance of Bacillariophyceae over other algal classes.

xii. The status of fishery showed considerable changes from upstream to downstream. The number of IMC showed incline 7.0% in YR_2 to 29.54% in YR_3-YR_4 and 14.6% in YR_5. Whereas Catfishes population enhanced from 14% in YR_2 to 49.5% in YR_3-YR_4 and 45.2% in YR_5. The number of minor carps showed decline from 71% (YR_2)-21.14% (YR_3-YR_4). All these changes in fishery composition point might be due to ecodegradation of the river Yamuna.

xiii. The total amount of annual water use in Yamuna basin from all the sources is approximately 44 bilion cubic meters out of which as much as 42.2 billion cubic meter *i.e.* 96% is used for irrigation alone (CPCB, 1982), leaving very little water in the river apart for its own beneficial uses for pollution dilution and assimilation (Mishra and Moza, 1997).

xiv. To keep the river living and useful it is necessary to take some conservation work early and to maintain the minimum amount of water which is necessary for biodiversity point of view and for self purification of the river.

References

Agrawal, S.P. (2002). Studies on the effect of various pollutants on the planktonic population of river Yamuna at Mathura. Ph.D. Thesis, Bhim Rao Ambedkar University, Agra, India.

Anon. (1991). Annual Report, CIFRI (ICAR), Barrackpore, Kolkata, W.B., India.

Anon. (2003). Annual report, CIFRI (ICAR), Barrackpore, Kolkata, W.B., India. pp-48.

Anon. (2002). Annual report, CIFRI (ICAR), Barrackpore, Kolkata, W.B., India. pp-16.

Badola, S.P. and Singh, H.R. (1977). Fishing methods in Garhwal hills. *Proceedings in Natural Academy of Science,* **47(B):**176-181.

Barbhuyan, S.I. and Khan, A. (1992). Studies on the structure and function of benthic ecosystem in an eutrophic body of water. Temporal and spatial distribution of benthos. *Journal of Freshwater Biology,* **4(40):**239-247.

Chaturvedi, R.K., Sharma, K.P., Sharma, K., Bharadwaj S.M. and Sharma, S. (1999). Plankton community of polluted water around Sanganer, Jaipur. *Journal of Environment and Pollution*, **6(1):**77-84.

Chandler, J.R. (1970). A biological approach to water quality management. *Journal of Water Pollution Control*, **69:**415-422.

Converse, L. (2009). Katerniaghat Gariyal Project 2008-2009. Report of Preliminary findings. A report to GCA and James Cook University.

CPCB, (2006). Water quality status of Yamuna river (1999-2005), Central Pollution Control Board, Ministry Of Environment and Forests, Assessment and Development of River Basin Series: ADSORBS/41/2006-07.

Dwivedi, A.C. (2006). Age structure of some commercially exploited fish stocks of the Ganga river system (Banda-Mirzapur section). D.Phil Thesis, Allahabad University, Allahabad, India.

Gopal, B. and Sah, M. (1993). Conservation and management of rivers in India: Case study of the river Yamuna. *Envirironmental Conservation,* **20:**243-254.

Grover, S.P. and Gupta, S.K. (1977). Fish and fishery of Banda district (U.P.). *Proceedings of the National Acadimy of Sciences, India,* **47(4):**204-217.

Hutchinson, G.E. (1967). A treatise on limnology. Vol. 2: Introduction to lake biology and limnoplankton. John Wiley and Sons Inc. New York.

Kaur, P. (1996). Spatio-temporal variation in epiphytic communities in relation to water quality of the Delhi segment of river Yamuna, and experiments on the patterns of colonization of epiphyton in natural and artificial substrate. Ph.D. Thesis, University of Delhi, New Delhi, India.

Krishnamoorthi, K.P. and Sarkar, R. (1979). Macroinvertebrates as indicators of water quality. *Proceedings Symposium Environmental Biology*. pp-133-138.

Kulshrestha, A. (2002). Limnological investigation of river Yamuna at Agra with special reference to pollution. Ph.D. Thesis, Bhem Rao Ambadker University, Agra, India.

Kumar, S. (1999a). A limnological study of river Yamuna in district Etawah with special reference to pollution. Ph.D. Thesis. C.S.J.M. University, Kanpur, India.

Kumar, A.P. (1999b). Physico-chemical and biological studies on river Yamuna, from Vrindavan to Gokul barrage, with reference to the effect of pollutants. Ph.D. Thesis, Bhem Rao Ambadker University, Agra, India.

Mishra, D.N. and Moza, U. (1997).Changing scenario of fish and fishery of river Yamuna-Part II. *Proceedings of the National Seminar*, *Changing Perspectives of Inland Fisheries. Inland Fishery Society, India.* pp-57-62.

Mishra, D.N. and Moza, U. (1998). Changing scenario of fish and fishery of river Yamuna-Part I. *Bull. Environmental Science B,* **1:**5-10

Mishra, D.N. and Moza, U. (2001). Evaluation of fish and fishery resources in river Yamuna Part-1. *Journal of Indian Fishery Society, India*, **33(1):**93-99.

Misra, J.N. and Singh, C.S. (1968). A preliminary study on periphyton growth in a temporary pond. *In*: (Eds.) R. Misra and B. Gopal, Proceedings of the Symposium on Recent Advances in Tropical Ecology, *International Society for Tropical Ecology*, Banaras Hindu University, Varanasi, India. pp-311-315.

Moll, E.O. (1987). Survey of fresh water turtles of India Part-II: The Genus *Kachuga*. *Journal of Bombay Natural History Society*, **84(1):**7-25.

Moza, U. (1996). Benthic macroinvertebrates as indicators of aquatic environment. An advances in fish and wildlife ecology and biology. Daya Publishing House, Delhi, India. pp-135-149.

Moza, U. and Kolekar, V. (2002). Benthos-The water quality indicator in river Yamuna. *Journal of Inland Fish Society, India,* **34(2):**66-77.

Moza, U. and Mishra, D.N. (2001). Evaluation of fish biomass and community structure in the context of environmental modification in upper stretches of river Yamuna-Part-II. *Applied Fisheries and Aquaculture,* **1(1):**17-21.

Moza, U. and Mishra, D.N. (2003). Ecodynamics and fishery status of upper stretch of river Yamuna and associated canals. *CIFRI- Barrackpore, Kolkata, Report* Bull. No. 123. pp-1-51.

Munawar, M. 1970. Limnological studies on fresh water ponds of Hyderabad India. IV. The biocenose distribution of unicellular and colonial phytoplankton in polluted and unpolluted environments. *Hydrobiologia*, **36:**105-128.

Nautiyal, P. and Lal, M.S. (1994). Fishing techniques and the status of Himalayan Mahseer in the Nayar (Garwal). *In: Masheer the Game fish, Natural history, status and conservation practecies in India and Nepal* (Eds. P. Nautiyal). Jagdamba Prakashan, Dehradun. pp-C 545-564.

Nautiyal, R. (2004). Diatoms biodiversity in Doon valley. DST report, New Delhi, India.

Prakash, S. and Panwar, R.S. (2005). Impact of sewage, industrial and petroleum effluents on the composition and diversity of plankton in the river Yamuna. *Biological Diversity in fresh* *water environment* (Eds. P. Nautiyal, J.P. Bhatt, O.P. Gusain and A.K. Dobriyal) Transmedia Srinagar (Uttranchal), India. pp-315-331.

Rao, R.J. (1990). Ecological relationship among fresh water turtles in the National Chambal Sanctuary. Study report. WII.mimeo. pp-1-212.

Rao, R.J. (1995). Conservation status of Indian Chelonians. India. *In*: *Proccedings of International Conferance of Chelonians*. Gonfran, France. pp-33-37.

Rauthan, J.V.S., Srivastava, S., Sharma, B., Negi, M. and Rauthan, G. (2009). Biodiversity of Asan wetland Doon vally Uttrakhand. *U.P. Journal of Zoology,* **297(2):**221-228.

Sarkar, A. (2011). Some biological characteristics of river Yamuna at Agra. *Journal of Advanced Laboratory Research in Biology,* **2(3):**91-96.

Sankar, K. (2002). Physico-chemical and biological analysis of river Yamuna at Agra district with relation to morphological common Yamuna fishes. Ph.D. Thesis, Bhim Rao Ambedkar University, Agra, India.

Sharma, B.K. (1998). Faunal Diversity in India: Rotifera. (Eds. J.R.B. Alferd, A.K. Das and A.K. Sanyal), Zoological Survey of India, Envis Centre. pp-57-70.

Sharma, S. (2000). Limnological observation of river Yamuna of Firozabad with reference to the effect of glass industrial effluents on the microfauna. Ph.D. Thesis, Bhim Rao Ambedkar University, Agra, India.

Sinha, R.K. (2000). Status of the Ganges River dolphin (*Platanista gangetica*) in the vicinity of Farakka Barrage, India. *In:* (Eds. R.R. Reeves, B.D. Smith, T. Kasuya) Biology and conservation of freshwater cetaceans in Asia.Occasional Paper of the IUCN Species Survival Commission (No. 23, pp-42-48). Gland, Switzerland and Cambridge, IUCN-United Kingdom.

Sinha, R.K., Sinha, S.K., Sharma, G. and Kedia, D.K. (2010). Surfacing and diving behaviour of free-ranging Ganges river dolphin, *Platanista gangetica gangetica*. *Current Science,* **98(2):**230-236.

Singh, S., Sharma, L.I. and Saini, V.P. (1998). Age, growth and harvestable size of *Labeo rohita* (Ham.) from the lake Jaisamand, India. *Indian Journal of Fishery,* **45(2):**169-175.

Stewart, P.M., Butcher, J.T. and Swinford, T.O. (2000). Land use, habitat, and water quality effects on macroinvertebrate communities in three watersheds of a Lake Michigan associated marsh system. *Aquatic Ecosystem Health and Management*, **3:**179-189.

Sucarcha, S. (1994). Limnological observation of river Yamuna at Firozabad with reference to the effects of glass industrial effluents on the microfauna. Ph.D. Thesis, Bhim Rao Ambedkar University, Agra, India.

Tabasum, T. (2006). Studies on biodiversity of floodplain wet lands of river Yamuna in Delhi stretch. Ph.D. Thesis, Jamia Milia Islamia, New Delhi, India.

Timms, B.V. (2006). A study of the benthic communities of twenty lakes in the South Island, New Zealand. *Freshwater Biology*, **12:**123-138.

Tiwari, A. (2003). Studies on limnology of river Yamuna near Etawah (U.P.) with special reference to the ecology of “*Kachuga tentoria*”. Ph.D. Thesis. C.S.J.M. University, Kanpur, India.

Tiwari, A. and Chauhan, S.V.S. (2000). Three new algal forms from Agra. *Journal of Indian Botanical Society,* **79:**79-81.

Uniyal, D.P. (2009). Diversity and conservation of fish resources of Tons valley, Uttarakhand, Western Himalayas, India. Advanced Research Article (Eds. R. Dobhal and B.S. Kotlia). *Science and technology in Uttarakhand*. pp-139-150.

Uniyal, D.P. and Mehta, H.S. (2007). Fishes: (Pisces): Faunal diversity Western Doon Shiwaliks. *Zoological Survey of India*. pp-41-59.

Uniyal, D.P., Bahaguna, S.N., Uniyal, M. and Kumar, A. (2006). Further notes on fishing methods and their impact on fish resources of Jaunsar-Bawar tribal area (Chakrata Hills, District Dehradun, Uttaranchal), Western Himalayas, India. *Annals of Forestry,* **14(2):**340-349.

Verma, H.K.L. (1999). Physico-chemical and biological studies on river Yamuna (From Kila Ghat to Vyas Kshetra). Ph.D. Thesis. C.S.J.M. University, Kanpur, India.

Verma, J. (2008). Biodiversity pattern of lotic (fresh water) diatoms in mountain chains (North India). D.Phil Thesis. Allahabad University, Allahabad, India.

Waters, T.F. (1977). Secondary production in inland waters. Advances in Ecological Research, **10:**11-164.

WWF-Pakistan (2010). Conservation of Indus River Dolphin-Disaster Management Plan. pp-1-34.

Zafer, A.R. (1964). On the ecology of algae in certain fish ponds of Hyderabad India. I Physicochemical complexes. *Hydrobiologia*, **23:**179-195.

Appendix-I: Distribution of all aquatic organisms in the Yamuna River from Yamunotri to Ganga confluence

Ia. Distribution of phytoplankton in the Yamuna river from Yamunotri to Ganga confluence

Bacillariophyceae	YR_1	YR_2	YR_3	YR_4	YR_5
Achnanthes sp.	+	+			
Actinella sp.			+		
Amphora sp.		+		+	+
A. acutiuscula	+				
A. bangrainii	+				
Amphicampa sp.			+		
Amphipleura sp.			+	+	+
Anomoeoneis sp.					+
Asterionella sp.				+	+
Caloneis sp.		+			
Campylodiscus cribrosus			+		
Ceratoneis sp.			+		
C. arcus			+		
Cocconeis sp.	+	+			
Coscinodiscus sp.				+	+
Cyclotella sp.	+	+	+	+	+
Cylindrotheca gracilis			+		
Cymbella sp.		+		+	+
Denticula sp.			+		
Diatoma sp.	+	+		+	+
D. ellipitica			+		
Eutonia sp.	+			+	
Fragillaria sp.	+	+		+	+
F. capucina	+				
Frustulia sp.	+	+		+	
Gomphonema sp.		+		+	+
Gyrosigma sp.		+		+	+
G. kutzingii			+		
Meridion sp.		+			
M. circulare			+		
Melosira sp.	+	+		+	+
M. varians			+		
Navicula sp.	+	+		+	+
N. viridula			+		
N. cryptocephalon	+				

Bacillariophyceae	YR_1	YR_2	YR_3	YR_4	YR_5
Nedium sp.					+
Nitzschia sp.	+	+		+	+
N. sigmoidea			+		
Pinnularia sp.				+	+
Pleurosigma sp.				+	+
Rhaphoneis sp.					+
Rhapolodia sp.				+	
R. gibba			+		
Rhizosolenia sp.					+
Stauroneis sp.		+			
Stephanodiscus sp.				+	+
Surirella sp.	+				+
Synedra sp.		+		+	+
S. acus	+				
S. capitata			+		
S. miniscula	+				
S. tabulata	+				
S. ulna	+		+	+	
Tabellaria sp.	+	+		+	+
T. binalis	+				
T. fenestrata			+		
Chlorophyceae					
Actinastrum sp.		+		+	
A. fluvialitte			+		
Ankistrodesmus sp.		+		+	+
A. falcatus			+	+	
Arthrodesmus convergens			+		
Batryococcus sp.		+			
B. sudeticus			+		
Binuclearia sudeticus			+		
Celastrum sp.		+			
C. elegans			+		
C. incrassate			+		
C. pisiformis			+		
Chaetophora incrassate			+		

Chlorophyceae	YR$_1$	YR$_2$	YR$_3$	YR$_4$	YR$_5$
C. pisiformis			+		
Chara zeylanica	+				
Characium sp.		+			
Chlamydomonas sp.				+	+
Chlorella sp.				+	+
C. vulgaris				+	
Chlorococcum sp.			+	+	
C. humicola					
Chlorococcus sp.				+	
Cladophora sp.	+	+		+	+
C. glomerata	+		+		
Closteriopsis sp.		+			
C. longissima			+		
Colelastrum chodati			+		
C. microporum			+		
Coleochaete sp.			+		
Cosmarium sp.	+	+			
Cystodinium sp.		+			
Dactylococcum sp.			+		
Desmidium sp.				+	
Dichotomosiphon tuberosus	+				
Dimorphococcus sp.					+
Echinosphaerella sp.			+		
Elakatothrix viridis			+		
Enteromorpha intestinalis			+		
Eudorina sp.				+	+
E. elegans			+		
Genicularia sp.			+		
Golenkinia radiata			+		
Hormidium subtile			+		
Hydrodictyon sp.			+	+	+
H. reticulatum			+	+	
Hyalotheca dissiliens			+		
Kirchneriella sp.		+			
Mesotaenium sp.					+
M. endlicherianum			+		
Microspora flocossa	+		+		
Mougeotia willeana	+		+		

Chlorophyceae	YR$_1$	YR$_2$	YR$_3$	YR$_4$	YR$_5$
Netrium sp.					+
N. lamellosa			+		
Oedogonium crassum			+		
O. solataria			+		
Ophioceticum sp.				+	
Ophiocytium cochleare			+		
O. parvulum			+		
Oocystis solitaria			+		
Pandorina sp.			+		+
Pediastrum sp.		+		+	+
P. boryanum			+		
P. duplex			+		
P. simplex				+	
P. tetras				+	
Protococcus sp.				+	
Pleurogaster lunaris			+		
Pleurotaenium coronatum			+		
P. ehrenbergii			+		
P. trabecula			+		
Protosiphon sp.			+		
Rhizoclonium heiroglyphicum			+		
Schroederia sp.			+		
S. opoliensis			+		
S. quadricauda			+		
S. thomassoni			+		
Selenastrum sp.				+	
Scenedesmus sp.			+	+	+
S. quadricauda				+	
Sphaeroplea annulina			+		
Sphaerocystis sp.			+		
Spirogyra sp.	+	+		+	+
S. bichromatophora	+				
S. crassa			+		
S. communis	+		+		
S. ellipsospora			+		
S. narcissiana			+		
S. pratensis			+		
S. rectangularis			+		

Chlorophyceae	**YR$_1$**	**YR$_2$**	**YR$_3$**	**YR$_4$**	**YR$_5$**
Spirotaenia sp.					+
Staurastrum sp.	+	+		+	
Stigeoclonium longicollum			+		
S. pachydermum			+		
S. tenue			+		
Tetraspora sp.	+				
Tetrastrum sp.			+		+
T. crassa			+		
Tribonema bombycinum	+				
Trochiscia sp.	+	+			
T. vestitus			+		
Ulothrix sp.	+	+		+	
U. aequalis			+		
U. cylindricum			+		
U. subtilissima			+		
U. variabilis	+		+		
U. zonata	+		+		
Volvox sp.					+
V. tertius			+		
Voucheria terrestris	+				
Zygnema sp.			+	+	+
Z. insigne			+		
Myxophyceae					
Agmenellum sp.				+	+
Anabaena sp.				+	+
A. aequalis			+		
Ancystis sp.				+	+
Aphanocapsa sp.			+		
A. delicatissima			+		
Aphanothecea sp.				+	
Coelosphaerium sp.		+		+	
Gleocapsa sp.				+	
Gomphospaeria sp.		+		+	+
Lyngbya sp.			+	+	+
L. contorta			+		
L. major			+		
Merismopoedia sp.		+		+	
M. glauca			+	+	

Myxophyceae	**YR$_1$**	**YR$_2$**	**YR$_3$**	**YR$_4$**	**YR$_5$**
M. punctata			+	+	
Microcystis sp.		+	+	+	
M. aeruginosa			+	+	
Nostoc sp.		+	+	+	+
Oscillatoria sp.	+	+		+	+
O. chlorina			+	+	
O. limosa			+	+	
O. prolifica			+		
O. princeps			+		
O. subbrevis				+	
O. splendida			+		
O. tenuis			+	+	
O. willei					
Phormidium sp.		+		+	
P. favosum			+		
P. uncinatum			+		
Polycystis sp.				+	
Rivularia sp.				+	+
R. haemititis			+		
Spirulina sp.		+		+	
S. major			+		
S. muscorum			+		
Tolypothrix sp.			+		
Euglenophyceae					
Euglena sp.				+	
E. acus			+	+	
E. viridis			+	+	
Peranema trichophorum			+		
Phacus sp.				+	
P. caudatus				+	
P. triqueter			+		
Dianophyceae					
Ceratium sp.		+		+	
C. hirundinella			+		
Peridinum sp.		+		+	
Gloeodinium quadridens			+		
Chrysophyceae					
Dinobryon sp.				+	+

Xanthophyceae	YR$_1$	YR$_2$	YR$_3$	YR$_4$	YR$_5$
Ophiocytium cochleare			+		
O. parvulum			+		
Pleurogaster lunaris			+		

Agrawal (2002); Kaur (1996); Kumar (1999); Moza and Mishra (2003); Rauthan (2009); Tabasum (2006); Verma (1999)

Ib. Distribution of periphyton in the Yamuna River from Yamunotri to Ganga confluence

	YR1	YR2	YR3	YR4	YR5
Bacillariophyceae					
Achnanthes crenulata	+				
A. marginulata	+				
A. minutissima	+		+		+
A. sphacelata	+				
Achnanthidium biasolettianum	+				
A. conspicua	+				
A. exigua	+				+
A. petersenii	+				
A. subhudsonis	+				
Adlafia miniscula	+				+
A. muscora	+				
Amphora sp.					+
A. aequalis					+
A. inariensis					+
A. libyaca					+
A. montana	+				
A. normanii					+
A. ovalis			+		
A. pediculus	+				+
A. twentiana					+
A. veneta	+				+
Atteya sp.			+		
Aulcoseira granulata					+
Brachysira sp.					+
B. vitrea					+
Caloneis sp.	+				+
C. bacillum					+
C. beccariana					+
C. silicula					+
Cocconeis sp.					+
C. pediculus	+		+		
C. placentula			+		
Craticula ambigua					+
C. buderi					+
C. citrus					+
C. minusculoides					+
Cyclotella comta			+		
	YR1	**YR2**	**YR3**	**YR4**	**YR5**
C. kuetzingiana			+		
C. meneghiniana	+		+		
C. ocellata			+		
C. pseudostelligera					+
Cymbella sp.					+
C. aequalis			+		
C. australica					+
C. cymbiformis					+
C. diversa					+
C. excisa	+				+
C. kolbei					+
C. cancettuliformis					+
C. metzeltinii	+				
C. nova.zeelandiana					+
C. parva					+
C. pervarians					+
C. prostrata			+		
C. tropica	+				+
C. turgidula	+				+
C. tumida	+		+		+
C. ventricosa			+		
C. vulgata	+				+
Cymbopleura angustata					+
C. citrus					+
C. falaisensis					+
C. lapponica					+
C. rupicola					+
C. microcephala					+

C. varna					+
Cymatopleura sp.					+
C. elliptica			+		
C. solea			+		
Delicata sparsistriata					+
Denticula sp.					+
D. kuetzingii					+
D. tenuis			+		
Diadesmis sp.					+
D. confervacea					+

	YR1	**YR2**	**YR3**	**YR4**	**YR5**
Diatoma sp.		+			
D. hiemale			+		
Diatoma mesodon					+
D. minus					+
Diploneis sp.					+
D. oblongella					+
D. smithii					+
D. subovalis					+
Encyonema sp.					+
E. leei	+				
E. minutum	+				+
E. silesiacum	+				+
Epithemia ocellata			+		
E. pseudopectinalis					+
E. turgida			+		
E. zebra			+		
Eunotia pectinalis			+		
E. sudelica					+
Fallacia pygmea					+
Fragillaria sp.					+
F. capucina			+		
F. crotonensis			+		+
F. virescens			+		
Frustulia sp.		+			+
F. rhomboides			+		
F. vulgaris			+		
Gesslaria decussis					+
Gomphonema sp.					+
G. acuminatum			+		
G. angustatum	+		+		+

G. clevei	+				+
G. constrictum			+		
G. gracile	+				+
G. lagenula	+				
G. lanceolata	+				
G. olivacum			+		
G. parvulum	+		+		+
Gomphoneis minutum	+				+
Gomphocymbelopsis ancyli					+
Gyrosigma eximum			+		

	YR1	**YR2**	**YR3**	**YR4**	**YR5**
G. kutzingee			+		
G. scalproides					+
Hantzschia amphioxys			+		
Hippodonta ruthnielseniae	+				
Luticola mutica	+				+
L. saxophila					+
Melosira sp.	+				
M. crenulata			+		
M. granulata			+		
M. italica			+		
M. juergensii			+		
M. tenuissima			+		
M. varians	+		+		
Mougeotia sp.			+		
M. calcarea			+		
M. robusta			+		
M. sphaerocarpa			+		
M. tumidula			+		
Navicula sp.		+			
N. alineae	+				
N. angusta					+
N. antonii	+				+
N. broetzii	+				
N. capitatoradiata	+				+
N. cataracta-rheni	+				+
N. caterva	+				+
N. cincta					+
N. confervaceae			+		
N. cryptocephala	+		+		+

	YR1	YR2	YR3	YR4	YR5
N. cryptotenella	+				+
N. cryptotenelloides					+
N. cryptofallax					+
N. cuspidate			+		
N. dicephala			+		
N. erifuga					+
N. exigua			+		
N. exilis	+				+
N. germainii					+
N. minima	+				
N. notha	+				+
N. phylleptosoma					+
N. radiosa			+		
N. reichardtiana	+				+
N. radiosafallax					+
N. rostellata	+				+
N. rynchocephala			+		
N. schorteri					+
N. simplex			+		
N. stagnorum	+				+
N. subrhynchacephala					+
N. symmetrica					+
N. trivialis					+
N. veneta					+
N. viridula	+		+		+
N. viridulacalcis					+
Nedium sp.					+
N. productum			+		
Nitzschia acuta	+				
N. acicularis					+
N. amphibia	+				
N. capitellata					+
N. closterium			+		
N. communis					+
N. debilis					+
N. denticula	+				
N. dissipata	+				+
N. fonticola	+				
N. frustulum	+				
N. ganderheimensis					+

	YR1	YR2	YR3	YR4	YR5
N. hantzchiana					+
N. hungarica			+		+
N. intermedia					+
N. linearis	+				
N. obtuse					+
N. ovalis	+				
N. palea	+		+		+
N. punctata					+
N. sinuata					+
N. tenuis	+				+
N. tripunctata	+				
N. vitabunda	+				
N. walterecki	+				
Pinnularia sp.					+
P. cardinalis			+		
P. gibba			+		
P. interrupta			+		
P. maior			+		
P. nobilis			+		
P. trauenbergiana					+
Placoneis elegans					+
Planothidium lanceolatum	+				+
Reimeria sinuata	+				
R. uniseriata	+				
Rhizosolenia gibba			+		
Sellaphora hostedtii					+
S. mutatoides					+
S. pupula					+
Stauroneis acuta			+		
S. anceps	+		+		+
S. phoenicenteron			+		
S. phyllodes			+		
S. pinnata	+				+
S. producta			+		
Surirella sp.					+
S. apiculata					+
S. aungusta	+		+		+
S. didyma			+		
S. linearis			+		+
S. minuta					+

S. ovalis			+		
S. robusta			+		
S. splendida					+
Synedra sp.		+			
S. acus			+		
S. amphicephela					+
S. capitata			+		
S. dorsiventralis					+
S. rumpens					+
S. ulna	+		+		+
Tabellaria sp.		+			
	YR1	**YR2**	**YR3**	**YR4**	**YR5**
Chlorophyceae					
Achinestrum hantzschii			+		
Ankistrodesmus falcatus			+		
Binuclearia tetrana			+		
Bulbochaete giganta			+		
B. nana			+		
Chlamydomonas globosa			+		
C. variabilis			+		
Cladophora sp.		+			
Closterium acerosum			+		
C. acutum			+		
C. braunii			+		
C. dianae			+		
C. ehrenbergii			+		
C. gracile			+		
C. lanceolatum			+		
C. leiblenii			+		
C. lunula			+		
C. moniliferum			+		
C. parvulum			+		
C. strigosum			+		
C. turgidum			+		
C. venus			+		
Colelastrum microporum			+		
C. reticulatum			+		
Cosmarium botrytis			+		
C. constrictum			+		
C. depressum			+		
C. formosulum			+		

C. granatum			+		
C. moniliforme			+		
C. nitidulum			+		
C. protractum			+		
C. quadrum			+		
C. sexangulare			+		
C. speciosum			+		
C. subcrenatum			+		
C. subimpressulum			+		
C. supraspeciosum			+		
Crucigenia tetrapeda			+		
	YR1	**YR2**	**YR3**	**YR4**	**YR5**
Errerella bornhemiensis			+		
Euastrum gemmatum			+		
E. oblongum			+		
E. pulchellum			+		
Eudorina elegans			+		
Gonium formosum			+		
G. pectorale			+		
Hydrodictyon sp.			+		
H. reticulatum			+		
Hormidium sp.			+		
Micrasterias americana			+		
Micractinium pusillum			+		
Microspora quadrata			+		
Oedogonium cardiacum			+		
Oocystis punchatostriatum			+		
O. vulgare					
Pandorina sp.			+		
P. morum			+		
Pediastrum boryanum			+		
P. duplex			+		
P. integrum			+		
P. simplex			+		
P. tetras			+		
Pleurotaenium coronatum			+		
P. ehrenbergii			+		
P. rabecula			+		
Spirogyra sp.		+			
S. communis			+		

S. rectangularis			+		
S. silvicola			+		
S. setiformis			+		
Staurastrum chaetoceros			+		
S. crenatum			+		
S. gracile			+		
S. margaritaceum			+		
S. oxyacanthum			+		
S. punctulatum			+		
Stigeoclonium sp.			+		
S. tenue			+		
	YR1	**YR2**	**YR3**	**YR4**	**YR5**
Syndesmus abundans			+		
S. acuminatus			+		
S. arcuatus			+		
S. armatus			+		
S. bicellularis			+		
S. brasiliensis			+		
S. dactylococcoids			+		
S. dimorphus			+		
S. ecornis			+		
S. nanus			+		
S. opoliensis			+		
Tetraedron caudatum			+		
T. gracile			+		
T. muticum			+		
Tetrastrum sp.			+		
Treubaria crassipina			+		
Trochiscia sp.		+			
T. reticularis			+		
Ulothrix aequalis			+		
U. zonata			+		
Volvox globator			+		
V. spermatosphaera			+		
Wislouchiella plantonica			+		
Zygnema cylindricum			+		
Z. insigne			+		
Z. pectinatum			+		
Myxophyceae					
Anabena circularis			+		
A. flos-aquae			+		

A. spiroides			+		
A. variablis			+		
Aphanocapsa sp.			+		
Aphanizomenon flos-aquae			+		
Cylindrospermum majus			+		
Lyngbya aeruginea coerulea			+		
L. birgei			+		
Merismopedia convulata			+		
M. glauca			+		
M. tenuissima			+		
	YR1	**YR2**	**YR3**	**YR4**	**YR5**
Microcystis sp.			+		
Nodularia harveyana			+		
Nostoc sp.		+			
N. ellipsosporum			+		
N. muscorum			+		
Oscillatoria sp.		+			
O. aghordhii			+		
O. chlorina			+		
O. curviceps			+		
O. formosa			+		
O. limosa			+		
O. tenuis			+		
Phormidium foveolarum			+		
P. incrustatum			+		
P. inudatum			+		
P. tenue			+		
Schizothrix purpurascens			+		
Spirulina sp.		+			
Spirulina major			+		
S. nordstedtii			+		
Symploca muscorum			+		
Euglenophyceae					
Anisonema ovale			+		
Euglena acus			+		
E. acutissima			+		
E. gracilis			+		
E. oblonga			+		
E. sanguinea			+		
E. spirogyra			+		

	YR1	YR2	YR3	YR4	YR5
E. spiroides			+		
E. viridis			+		
Lepocinclis ovum			+		
Mallomonas caudata			+		
Phacus longicauda			+		
P. pleuronectes			+		
P. pyrum			+		
P. torta			+		
P. triqueter			+		
Trachelomonas hispida			+		
Dianophyceae					
Ceratium hirundinella			+		
Gloeodinium quadridens			+		
Chrysophyceae					
Dinobryon cylindricum			+		
Xanthophyceae					
Mischococcus confervicola				+	
Ophiocytium variable				+	
Rhodophyceae					
Compsopogan coeruleus				+	

Kaur (1996); Verma (2008)

Ic. Distribution of zooplankton in the Yamuna river from Yamunotri to Ganga confluence

	YR_1	YR_2	YR_3	YR_4	YR_5
Ciliophora					
Acineria incurvata			+		
Actinobolina sp.			+		+
Amphibothrella sp.			+		
Amphileptus sp.			+		
Askenasia sp.			+		
Chaenea sp.			+		
Carchesium sp.				+	+
Chilodonella uncinata			+		
C. cucullus			+		
Coleps hirtus			+		
C. elongates			+		
Didinium nasutum			+		
Dileptus binucleatus			+		
Enchelyodon sp.			+		
Enchelys sp.			+		
Glaucoma sp.					+
Holophrya sp			+		
Homalozoon vermiculare			+		
Lacrymaria olor			+		
L. elegans			+		
Litonotus fasciola			+		
Loxophyllum sp.			+		
Mesodinium sp.			+		
Paradileptus sp.			+		
Prorodon teres			+		
Pseudoprorodon sp.			+		
Spathidium depressum			+		
S. spathula			+		
Trachelium ovum			+		
Trachellophylum sp.			+		
Trichopelma sp.				+	+
Hypotrichida					
Aspidisca costata			+		
A. turrita			+		
Euplotes sp.			+		
E. patella			+		
Gastrostyla steinii			+		
Holosticha sp.			+		
Oxytricha sp.			+		
Paraurostyla sp.			+		
Steinia sp.			+		
Strongylidium crassa			+		
Stylonychia sp.			+		
Uroleptus sp.			+		
Urosoma sp.			+		
Urostyla sp.			+		
Heterotrichida					
Blepharisma coeruleum			+		
B. lateritium			+		

Bursaria truncatella			+		
Stentor muelleri			+		
S. polymorphus			+		
S. roeselli			+		
Spirotricha					
Metopus sp.			+	+	+
Spirostomum sp.				+	+
S. ambiguum			+		
S. minus					
S. teres					
Armophorida					
Caenomorpha medusala			+		
Bryometopida					
Bryometopus sp.			+		
Odontostomatida					
Halteria grandinella			+		
H. cirrifera			+		
Saprodinium dentatum			+		
Strombidium viridae			+		
Peniculida					
Paramecium sp.				+	+
P. aurelia			+		
P. caudatum			+	+	
Hymenostomatida					
Cinetochilum margaritaceum			+		
Colpidium colpoda			+		

	YR_1	**YR_2**	**YR_3**	**YR_4**	**YR_5**
C. cucullus			+		
Frontonia leucas			+		
Glaucoma sp.			+	+	
Tetrahymena pyriformis			+		
Peritrichida					
Astylozoon faurei			+		
Carchesium sp.				+	
C. polypinum			+		
Epistylis sp.				+	+
E. plicatilis			+		
E. rotans			+		
Opisthonecta sp.			+		
Vorticella sp.				+	+
V. campanula			+		

V. convallaria			+		
V. similis			+		
Vaginicola crystalline			+		
Suctorida					
Acineta sp.			+		
Cothurnia trabeculae			+		
Discophrya sp.			+		
Metacineta sp.			+		
Podophrya fixa			+		
Pyxicola carteria			+		
Rhabdostyla sp.			+		
Scyphidia hyaline			+		
Sphaerophrya magna			+		
Thuricola folliculata			+		
Tokophrya fallax			+		
Testacea					
Arcella sp.				+	+
Arcellinida					
Diffugia sp.				+	+
Nebela sp.				+	+
Amoebida					
Amoeba sp.				+	+
Entamoeba histolytica				+	+
Rotifers					
Philodinida					
Habrotrocha sp.			+		

	YR_1	**YR_2**	**YR_3**	**YR_4**	**YR_5**
Bdelloida					
Philodina citrina			+		
Rotaria sp.				+	+
Rotaria macroceros			+		
R. neptunia			+	+	
R. ratatoria			+		
Ploima					
Anuraeopsis fissa			+		
Ascomorpha saltans			+		
Asplanchna sp.				+	+
A. brightwellii				+	
A. herricki			+		
A. intermedia			+	+	+
A. priodonta			+		

A. sieboldi			+		
Brachionus sp.		+		+	+
B. angularis			+	+	+
B. bidentata			+		
B. budapestinensis			+		
B. caudatus			+	+	+
B. calyciflorus			+	+	+
B. diversicornis			+		
B. falcatus			+	+	+
B. forficula			+	+	+
B. leydigii			+		
B. patulus			+		
B. plicatilis			+	+	+
B. quadridentatus			+	+	
B. rubens			+	+	
B. urceolaris			+		
Cephalodella exigua			+		
C. forficula			+		
C. gibba			+		
C. mucronata			+		
Chromogaster ovalis			+		
Colurella obtuse			+		
Dicranophorus forcipatus			+		
Dipleuchlanis propatula			+		
Encentrum longipes			+		
Epiphanes brachionus			+		
	YR_1	**YR_2**	**YR_3**	**YR_4**	**YR_5**
E. clavulata			+		
E. senta			+		
Euchlanis sp.					+
E. dilatata			+		
E. macrura			+		
E. triquetra			+		
Hurringia sp.			+		
Keratella sp.		+		+	+
K. cochlearis			+	+	+
K. quadrata			+	+	+
K. tropica			+	+	+
K. procurva			+		
K. serrulata				+	+
K. valga				+	+

Lecane leontia			+		
L. nana			+		
L. ohioensis			+		
L. bulla			+		
L. furcata			+		
L. lunaris			+		
L. obtusa			+		
L. pyriformis			+		
L. quadridentata			+		
Lepadella sp.					+
L. ovalis			+		
L. patella			+		
Manfredium eudactylotum			+		
Monommata sp.			+		
Monostyla sp.		+			
Mytilina mucronata			+		
M. ventralis			+		
Nothalca sp.		+			
Notommata copeus			+		
Polyarthra sp.				+	+
Polyarthra euryptera			+		
P. longiremis			+		
P. multi appendiculata				+	
Pompholyx sulcata			+		
Proales decipiens			+		
Resticula sp.			+		
	YR_1	**YR_2**	**YR_3**	**YR_4**	**YR_5**
Scaridium longicauda			+		
Squatinella mutica			+		
S. pectinata			+		
S. stylata			+		
Trichocerca sp.					+
T. cylindrical			+		
Trichocerca longiseta			+		
T. similis			+		
Trichotria tetractis			+		
Wulfertia sp.			+		
Floscularaceae					
Conochilus dossuarius			+		
C. arboreus			+		
Filinia sp.				+	

F. longiseta			+		+
F. opaliensis			+		
F. terminalis			+		
Floscularia conifera			+		
Hexarthra sp.					+
H. intermedia			+		
H. mira			+		
H. oxyuris			+		
Horaella brehmi			+		
Limnios melicerta			+		
Pompholyx sulcata			+		
Ptygura stephanion			+		
Testudinella patina			+		
Crustacea					
Cladocera					
Alona sp.				+	+
A. pulchella			+		
A. rectangula			+		
Alonella exigua			+		
Bosmina sp.		+		+	+
B. longirostris			+	+	
Bosminopsis deitersi			+		
Chydorus sp.				+	+
C. sphaericus			+		
C. parvus			+		
C. ventricosus			+		

	YR_1	**YR_2**	**YR_3**	**YR_4**	**YR_5**
Daphnia sp.		+		+	+
D. carinata			+		
D. lumholtzi			+		
D. pulux			+		
Danhevedia crassa			+		
Macrothrix rosea			+		
M. spinosa			+		
Moinodaphnia sp.				+	
M. maclaeyi			+		
Prinocypris sp.					+
Anomopoda					
Camptocercus rectirostris			+		
Ceriodaphnia sp.				+	+
C. cornuta			+		

C. reticulata			+		
Moina sp.				+	
M. brachiata			+	+	
Scapholebris kingi			+		
Harpacticoida					
Canthocamptus sp.				+	+
Cyclopoida					
Cyclops sp.		+		+	+
Cypris sp.				+	+
Nauplii sp.		+			
Calanoida					
Diaptomus sp.				+	+
Cladocera					
Sida sp.				+	
S. crystallina			+		
Simocephalus sp.				+	+
S.serrulatus			+		
Calanoida					
Acartia sp.				+	
Pseudodiaptomus annandalei				+	
Decapoda					
Palaemon sp.				+	
Shrimps		+	+	+	
Plaemon sp.					+
Gastropoda					
Bostrycapulus aculeatus				+	+

	YR_1	**YR_2**	**YR_3**	**YR_4**	**YR_5**
Carbicula sp.		+			
Lymnaea sp.		+			
Gyraulus sp.		+			
Melanies stritella		+			
Physa sp.		+			
Planorbis sp.		+			
Valvata sp.		+			
Viviparus bengalensis		+			
Nematoda					
Diplogasterida					
Diplogasteroides sp.					+
Monhysterida					
Trilobus sp.					+
Enoplida					

Prismatolaimus sp.					+
Annelida					
Chaetogaster sp.					+
Hirudinida					
Leeches		+			
Haplotaxida					
Aeolosoma sp.					+
Plesiopora					
Nais andina					+
Pristina sp.					+
Insects and other larvae					
Hemiptera					
Belostoma sp.		+			
Corixa sp.					+
Corixa heiroglyphica		+			
Diplonynchus annulatum		+			
Gerris sp.		+			+
Laccotrophes robustus		+			
Limnometra micronecta		+			
Plea sp.		+			
Notonecta sp.		+			+
Coleoptera					
Berosus indicus		+			
Cybistus sp.		+			
Dytiscus sp.					+
Eretes sp.		+			

	YR$_1$	**YR$_2$**	**YR$_3$**	**YR$_4$**	**YR$_5$**
Gyrinus sp.					+
Halipus sp.		+			
Hydrophilus sp.		+			+
Laccphilus sp.		+			
Ranatra sp.					+
Ranatra filiformis		+			
Regimbartea attenutta		+			
Rhantaticus sp.		+			
Odonata naiads					
Epicordulia sp.		+			
Enallogoma sp.		+			
Gomphidae nymphs		+			
Plecoptera nymphs					+
Diptera					
Chironomus larvea		+			+
Culex nymphs & larvae		+			
Culicidae larvae					+
Dixa pupa		+			
Elliptera sp.		+			
Ephydra larvae					+
Tanypus larvae					+
Tipula larvae					+
Lepidoptera					
Nymphula larvae		+			
Trichoptera					
Caddis fly larvae		+			
Ephemeroptera					
Ephemeridae nymphs					+
Ephemerella nymphs		+			
Baetis nymphs		+			
Acari					
Water mite		+			

Agrawal (2002); Kaur (1996); Kumar (1999a); Kumar (1999b); Moza and Mishra (2003); Sucarcha (1994); Tabasum (2006); Verma (1999)

Id. Distribution of zoobenthos in the Yamuna river from Yamunotri to Ganga confluence

	Genus	YR_1	YR_2	YR_3	YR_4	YR_5
Ostracods				+		
	Cypris **sp.**				+	
Conchostraca				+		
Decapoda	***Palaemon*** **sp.**				+	
Trichoptera				+		
Hydropsychidae	***Hydropsyche*** **sp.**	+				
Hemiptera						
Aphididae				+		
Belostomatidae				+		
	Belostoma **sp.**				+	
Corixidae	***Corixa*** **sp.**				+	
Gerridae	***Gerris*** **sp.**	+	+		+	
Mesoveliidae				+		
Nepidae	***Lacotrephes*** **sp.**				+	
	Nepa **sp.**				+	
Notonectidae	***Notonecta*** **sp.**				+	
Pleidae				+		
	Plea **sp.**	+	+		+	
Odonata						
Coenagrionidae				+		
Gomphidae						
	Gomphus **sp.**		+		+	
	Macrogomphus **sp.**				+	
	Dromogomphus**sp.**				+	
Libellulidae				+		
Lepidoptera						
Pyralidae				+		
Orthoptera						
Gryllotalpidae	***Gryllotalpa*** **sp.**				+	
Ephemeroptera						
Baetidae	***Baetis*** **(nymphs)**	+			+	
Ephemeridae	***Ephemera*** **sp.**	+				
Ephemerellidae					+	
Coleoptera						
Belostomatidae	***Laccotrephes*** **sp.**		+			
Chrysomelidae				+		

	Genus	YR_1	YR_2	YR_3	YR_4	YR_5
Curculionidae				+		
	***Bagous* sp.**	+				
Dytiscidae	***Cybister* sp.**			+		
	***Rhantaticus* sp.**				+	
	***Laccophilus* sp.**				+	
	***Hyphoporus* sp.**				+	
Elmidae	***Stenelmis***			+		
Gyrinidae	***Gyrinus* sp.**				+	
Haliplidae	***Haliplus* sp.**	+				
Hydrophilidae	***Hydrophilus* sp.**			+	+	
	***Berosus* sp. (larvae)**		+		+	
Psephenidae	***Psephenus* sp.**	+				
Staphylinidae				+		
Diptera						
Anthomyiidae				+		
Ceratopogonidae				+		
	***Culicoides* sp.**				+	
	***Probezzia* sp.**				+	
Chaoboridae	***Chaoborus* sp.**				+	
Chironomidae				+		
	***Chironomus* sp.**	+	+		+	
	***Tanipus* sp.**				+	
Culicidae				+	+	
Cylindrotomidae	***Triogma* sp.**	+				
Dixidae	***Dixa* sp.**		+		+	
Dolichopodidae				+		
Ephydridae	**Ephydra larvae**				+	
Muscidae	**House fly larvae**				+	
Psychodidae				+	+	
	***Psychoda* sp.**				+	
Stratiomyidae				+		
Syrphidae				+		
Tabanidae				+		
Tendipedidae				+		
Tipulidae				+		
	***Tipula* sp.**				+	
Plecoptera					+	
Gastropoda						

	Genus	YR_1	YR_2	YR_3	YR_4	YR_5
Ariophantidae	***Macrochlamys* sp.**		+		+	
Bithyniidae				+		
	***Bithynia* sp.**				+	
Hydrobiidae				+		
	***Amnicola* sp.**				+	
Lymnaeidae	***Lymnaea* sp.**	+	+	+	+	
Melaniidae				+		
Pachychilidae	***Faunus ater***				+	
Physidae	***Physa* sp.**		+		+	
Planorbidae				+		
	***Gyraulus* sp.**				+	
	***Planorbis* sp.**	+	+			
Pleuroceridae	***Pleurocera* sp.**				+	
Pomatiasidae	***Cyclotopsis* sp.**				+	
Subulinidae	***Glessula* sp.**		+			
Thiaridae	***Melania tuberculata***				+	
	M. straitella		+			
Valvatidae	***Valvata* sp.**				+	
Viviparidae				+		
	***Vivipara* sp.**				+	
	V. bengalensis		+		+	
	***Campeloma* sp.**				+	
Bivalvia						
Unionidae	***Lemillidens* sp.**		+		+	
	***Unio* sp.**				+	
Sphaeriidae	***Spaerium* sp.**				+	
Corbiculidae	***Corbicula straitella***				+	
	C. regularis		+			
Annelida						
Hirudinea				+	+	
Erpobdellidae				+		
Glossiphoniidae				+		
Oligochaeta				+		
Aeolosomatidae	***Aelosoma* sp.**		+		+	
Branchiurinae	***Branchiura* sp.**				+	
Lumbricidae				+		
Lumbriculidae				+		
Naididae	***Nais* sp.**				+	

	Genus	YR_1	YR_2	YR_3	YR_4	YR_5
	N. andina				+	
	***Tubifex* sp.**				+	
	***Dero* sp.**				+	
	***Chaetogastor* sp.**				+	
	***Lemnodrilus* sp.**				+	
	***Pristina* sp.**				+	
	***Tubifex* sp.**				+	
	Tubifex tubifex	+	+			
Tubificidae				+		
Clitellata						
Lumbricidae	***Lumbricus* sp.**				+	
Nematods						
Diplogasteridae	**Diplogasteroids**				+	

Kaur (1996); Moza and Mishra (2003); Moza and Kolekar (2002)

Ie. Distribution of nektons in the Yamuna River from Yamunotri to Ganga confluence

Species	Families	YR_1	YR_2	YR_3	YR_4	YR_5
Ailia coila	**Schilbeidae**					+
Ambasis name	**Ambassidae**			+	+	
A. ranga	**Ambassidae**			+	+	
Amblyceps mangois	**Ambyceptidae**	+				
Amblypharyngodon mola	**Cyprinidae**					+
Anabas testudineus	**Anabantidae**			+		
Aplocheilus panchax	**Aplocheilidae**	+				
Aspidoparia jaya	**Cyprinidae**	+				
A. morar	**Cyprinidae**	+				+
Badis badis	**Nandidae**	+				+
Bagarius bagarius	**Sisoridae**	+	+	+	+	+
B. yarrelli	**Sisoridae**	+				
Barilius barna	**Cyprinidae**	+				+
B. bendelensis	**Cyprinidae**	+				
B. bola	**Cyprinidae**					+
B. dimorphicus	**Cyprinidae**	+				
B. pectorilus	**Cyprinidae**	+				
B. vagra	**Cyprinidae**	+				
Botia dario	**Cobitidae**				+	
B. rostrata	**Cobitidae**	+				
Carassius carassius	**Cyprinidae**	+				
Catla catla	**Cyprinidae**	+	+	+	+	+
Chaca chaca	**Chacidae**	+				
Chagunius chagunio	**Cyprinidae**	+				+
Chanda nama	**Chandidae**					+
C. ranga	**Chandidae**					+
Channa sp.	**Channidae**			+	+	
C. gachua	**Channidae**	+		+	+	+

Species	Families	YR_1	YR_2	YR_3	YR_4	YR_5
C. marulius	**Channidae**			+	+	+
C. punctatus	**Channidae**	+		+	+	+
C. striatus	**Channidae**			+	+	+
Chela atpar	**Cyprinidae**					+
Chitala chitala	**Notopteridae**					+
Cirrhinus mrigala	**Cyprinidae**	+	+	+	+	+
C. reba	**Cyprinidae**	+	+	+	+	+
Clarias batrachus	**Clariidae**	+		+		+
Clupisoma garua	**Schilbeidae**			+	+	+
C. montana	**Schilbeidae**	+				
Colisa fasciata	**Anabantidae**	+				+
Crossocheilus latius latius	**Cyprinidae**	+				+
Ctenopharyngodon idellus	**Cyprinidae**	+	+			
Cyprinus carpio	**Cyprinidae**	+	+	+	+	+
C. specularis	**Cyprinidae**	+				
Danio devario	**Cyprinidae**	+				
D. rerio	**Cyprinidae**	+				
Esomus danricus	**Cyprinidae**	+				+
Eutropiichthys vacha	**Schilbeidae**			+	+	+
Gagata cenia	**Sisoridae**				+	
Gambusia affinis	**Poeciliidae**	+				
Garra gotyla gotyla	**Cyprinidae**	+				
G. lamta	**Cyprinidae**	+				
Glossogobius giuris	**Gobiidae**			+	+	+
Glyptothorax cavia	**Sisoridae**	+				
G. dakapathari	**Sisoridae**	+				
G. garhwali	**Sisoridae**	+				
G. horai	**Sisoridae**	+				
G. pectinopterus	**Sisoridae**	+				
G. telchitta	**Sisoridae**			+	+	
Goniolosa manmina	**Clupeidae**					+
Gudusia chapra	**Clupeidae**			+	+	+
Heteropneustes fossilis	**Heteropneustidae**	+		+		+
Hypophthalmichthys molitrix	**Cyprinidae**		+	+	+	
H. nobilis	**Cyprinidae**		+			
Ilisha motius	**Clupeidae**					+
Labeo bata	**Cyprinidae**		+	+	+	+
L. boggut	**Cyprinidae**					+
L. calbasu	**Cyprinidae**	+	+	+	+	+
L. dero	**Cyprinidae**	+	+			
L. dyocheilus	**Cyprinidae**	+	+			
L. fimbriatus	**Cyprinidae**					+
L. gonius	**Cyprinidae**		+			+
L. rohita	**Cyprinidae**	+	+	+	+	+
Lepidocephalus annandalei	**Cobitidae**	+				
L. caudofurcatus	**Cobitidae**	+				
L. guntea	**Cobitidae**	+				
Macrognathus aculeatus	**Mastacembelidae**					+
Mastacembelus armatus	**Mastacembelidae**	+		+	+	+
M. pancalus	**Mastacembelidae**	+		+	+	+
Monopterus cuchia	**Synbranchidae**	+				+
Mystus bleekeri	**Bagridae**	+				

M. cavasius	**Bagridae**			+	+	
M. tengara	**Bagridae**			+		+
M. vittatus	**Bagridae**	+		+	+	
Mugil carsula	**Aruari**			+	+	
Nandus nandus	**Nandidae**	+		+		+
Nemacheilus botia	**Balitoridae**	+			+	
N. corica	**Balitoridae**	+				
N. doonensis	**Balitoridae**	+				
N. gangeticus	**Balitoridae**	+				
N. montanus	**Balitoridae**	+				
N. punjabensis	**Balitoridae**	+				
N. rupicola	**Balitoridae**	+				
N. submontanous	**Balitoridae**	+				
Notopterus chitala	**Notopteridae**			+	+	+
N. notopterus	**Notopteridae**			+	+	+
Ompok bimaculatus	**Siluridae**			+	+	+
O. pabda	**Siluridae**	+		+	+	
Ophiocephalus punctatus	**Channidae**	+				
O. mossambicus	**Cichlidae**					+
Osphronemus goramy	**Osphronemidae**	+				
Osteobrama cotio cotio	**Cyprinidae**					+
Oxygaster bacaila	**Cyprinidae**			+	+	+
Pangasius pangasius	**Pangasiidae**			+	+	+
Species	**Families**	**YR_1**	**YR_2**	**YR_3**	**YR_4**	**YR_5**
Parambassis ranga	**Ambassidae**					+
Porliuciosoma daniconius	**Cyprinidae**	+				
Pseudecheneis sulcatus	**Sisoridae**	+				
Pseudeutropius atherinoides	**Schilbeidae**	+				
Puntius carletoni	**Cyprinidae**	+				
P. chelynoides	**Cyprinidae**	+				
P. chola	**Cyprinidae**	+				+
P. conchonius	**Cyprinidae**	+				
P. sarana sarana	**Cyprinidae**	+		+	+	+
P. sophore	**Cyprinidae**	+		+	+	+
P. ticto ticto	**Cyprinidae**	+		+	+	+
Raiamas bola	**Cyprinidae**	+				
Rasbora daniconius	**Cyprinidae**	+		+	+	+
Rhinomugil corsula	**Mugilidae**					+
Rita rita	**Bagridae**			+	+	+
Salmo gairdneri gairdneri	**Salmonidae**	+				
S. trutta fario	**Salmonidae**	+				
Salmostoma bacaila	**Cyprinidae**					+
Sciaena coitor	**Cyprinidae**					+
Setipinna phasa	**Engraulidae**				+	+
Schizothorax progastus	**Cyprinidae**	+				
S. richardsonii	**Cyprinidae**	+	+			
Sillaginopsis panijus	**Sillaginidae**				+	
Silonia silondia	**Pangasiidae**			+	+	+
Sisor rabdophorus	**Sisoridae**			+	+	
Sperata aor	**Bagridae**	+	+	+	+	+
S. seenghala	**Bagridae**	+	+	+	+	+
Tenulosa ilisha	**Clupeidae**				+	
Tetraodon cutcutia	**Tetraodontidae**			+	+	+

Tor sp.	**Cyprinidae**		+			
T. chelynodies	**Cyprinidae**	+				
T. chilinoides	**Cyprinidae**	+				
T. putitora	**Cyprinidae**	+	+			
T. tor	**Cyprinidae**	+				
Wallago attu	**Siluridae**	+	+	+	+	+
Xenentodon cancila	**Belonidae**	+		+	+	+

Grover and Gupta (1977); Mishra and Moza (1997); Mishra and Moza (1998); Mishra and Moza (2001); Moza and Mishra (2001); Uniyal (2009); Uniyal and Mehta (2007)

Floral and Faunal Diversity of River Ramganga

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

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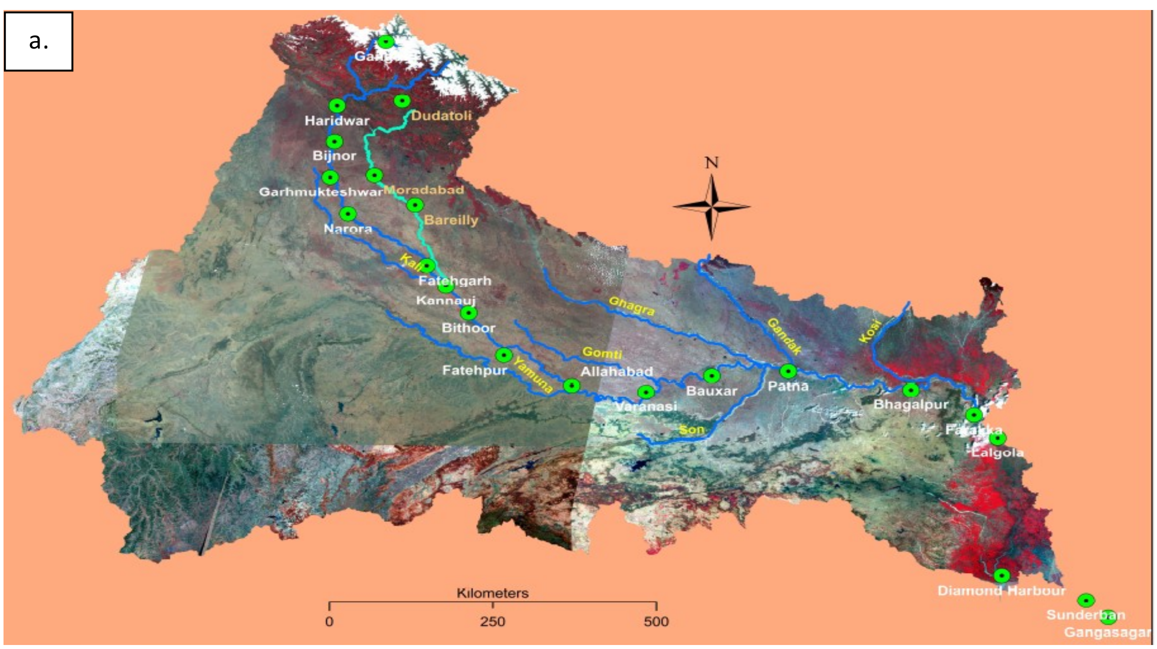
Contents

1. Introduction

The river Ramganga one of the major tributaries of river Ganga, originates as two separate streams as Western and Eastern Ramganga and flows down into the plains independently.

Western Ramganga originates near Gairsain (Uttarakhand) of Doodha-Toli ranges in the lower Himalayas of Pauri Garhwal at an altitude of about 3,110m (amsl). It lies between and latitude of 29° 51' N and 80° 11' E. It enters the Nainital district before re-entering the district Pauri Garhwal. The river then flows through Patali Dun of lower Shivaliks and passes through Moradabad, Rampur, Bareilly, Badaun and Shajahanpur districts of Uttar Pradesh and finally merges with river Ganga at Farrukhabad. Ramganga during its course traverses more than 100 km before entering Corbett National Park near Marchula. Inside the park it flows roughly for 40 km and comes out at Kalagarh where it enters the plain. It is the precious perennial sources of water in Corbett National Park. Three main tributaries of Ram Ganga: Palain, Mandal and Sonanadi merge with it during its course through the park. Total length of Ramganga river is 569 km and the drainage basin is 30,641 sq km Figure 1 (a-b).

The Kalagarh dam on the river Ramganga was built for irrigation and power generation in 1963-1973. It provides water for irrigation of 57,500 ha farm land and generates 198 MW of energy. A feeder canal (82 km long) downstream of Harveli barrage diverts water from Ramganga to Ganga river 10 km upstream to Garhmukteshwar to augment flow for Narora atomic power station. The river flows another 300 km before draining into the Ganga downstream of Farrukhabad.



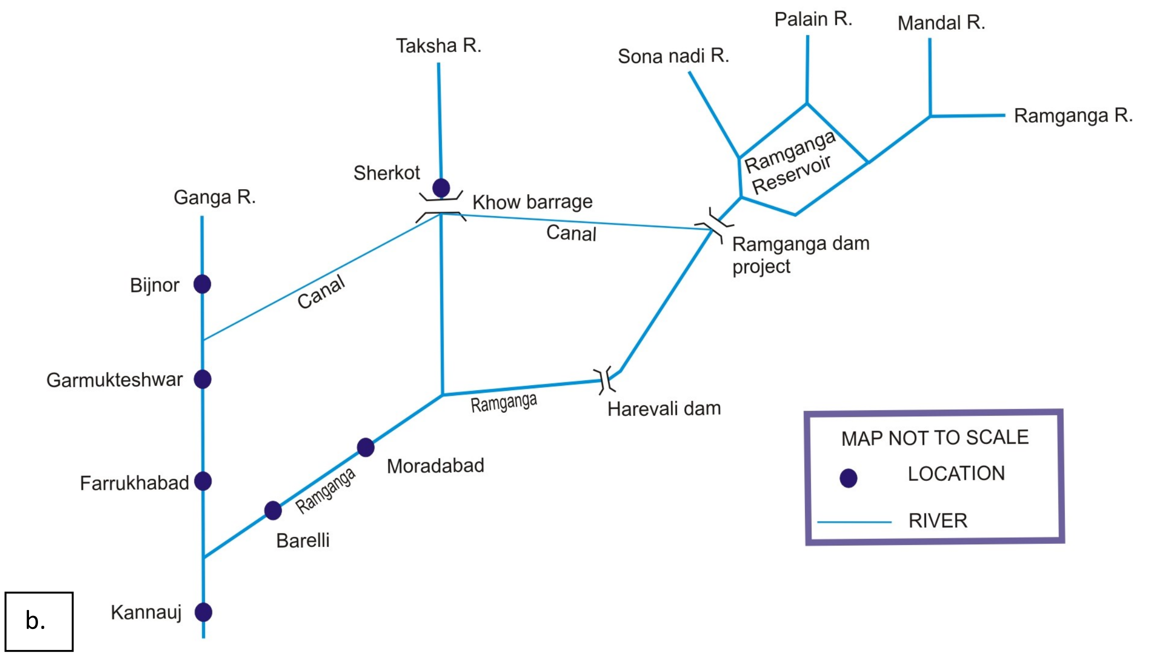


Figure 1a-b: (a) Ganga basin map showing the confluence of Ramganga at Farrukhabad
(b) Line digram of Ramganga river

The important tributaries of Ramganga are:

I. The **Sonanadi** was so named due to the presence of gold particles in alluvial sand sometimes. It adjoins Wild Life Santuary, Jim Corbett National Park from the north-west direction and meets the Ramganga at the reservoir.

II. The **Mandal** rises in the eastern height in Talla Salan in Chamoli district and flows for 32 km before joining the Ramganga at Domunda a little distance above Gairal. During the dry season, the Mandal contains very little water but during the monsoons it turns into a rapid torrent. It is an important breeding sites for the endangered Mahseer.

III. The **Palain** is the third important tributary of the Ramganga and enters the park from northern direction. It meets the Ramganga about 3 km north of the Ramganga reservoir.

Eastern Ramganga originates from the hills of Nandakot of Namik glacier in Pithoragarh district of Uttarakhand and flows towards east. The river is fed by numerous streams and finally joins river Sarju at Rameshwar ghat near Pithoragarh. Thereafter this river is called Saryu, it finally confluences with river Kali, which originates from Milan glacier in Kumaon region. The Kali finally merges with Ganga at Farrukhabad.

The condition of water in river Ramganga is reported to be good till Kalagarh dam. The fresh water of the river provides platform for the survival a number of fish species, some higher vertebrates and other microorganism. Bulk of the water downstream of Kalagarh is drawn for irrigation and the flows are meagre at Moradabad and Downstream. Domestic waste and industrial effluents find their way at number of places in Uttarakhand and Uttar Pradesh making it a polluted stretch.

2. Biological diversity of Ramganga river

The available data on floral and faunal diversity of the river Ramganga is very meager and fragmentary. The information is only as presence of an organism at a surveyed location. The biotic communities of an aquatic system sum up the prevailing abiotic parameters which have a telling effect on biota. There is no reference available historically to compare the prevailing situation.

2.1. Phytoplankton

Phytoplankton which constitutes the main autotrophic component comprises of three important classes Bacillariophyceae (26 taxa), Chlorophyceae (9 taxa), Myxophyceae (11 taxa) and Xanthophyceae (1 taxa). They together make up 92% of the total population. The important genera are *Anabaena* and *Oscillatoria* of Myxophyceae, *Achnanthidium, Cymbella, Navicula* among diatoms, *Spirogyra, Ulothrix* and *Rhizoclonium* of Chlorophyceae at Corbett National Park (Khare and Suseela, 2004). The list of algae reported in Ramganga is given in Table 1 and Figure 2.

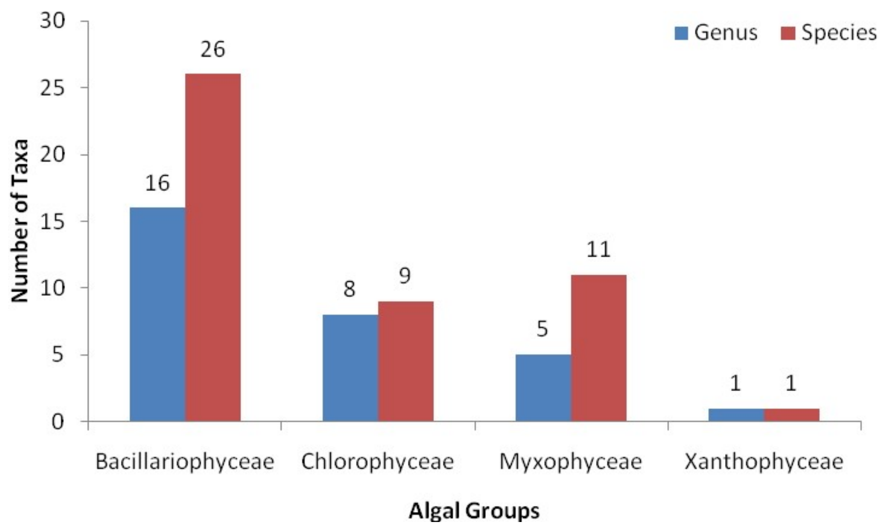


Figure 2: Distribution of various classes of algae in Ramganga

Table 1: List of phytoplankton present in river Ramganga

Bacillariophyceae	
	Achnanthidium biasolettianum
	A. minutissimum
	Achnanthes inflata
	Anomoeoneis sphaerophora
	A. subhudsonis
	Cymbella cymbiformis
	C. tumida
	C. ventricosa
	Diatoma vulgare
	Diploneis subovalis
	Epithemia turgida
	Gomphonema gracile
	Gyrosigma moresbyana
	G. spencerii
	Hantzschia amphioxys
	Licmophora flabellata
	Navicula cuspidata
	N. subrhynchocephala
	Nitzschia frustulum
	N. palea
	N. subtilis
	N. sinuata
	Pinnularia braunii
	Rhopalodia gibba
	R. ventricosa
	Tabellaria flocculosa
Chlorophyceae	
	Actinastrum hantzschii
	Closterium moniliforme
	Cosmarium moniliferum
	Geminella sp.
	Mongeotia sp.
	Rhizoclonium hieroglyphium
	R. hookeri
	Spirogyra africana
	Ulothrix variabilis
Myxophyceae	
	Anabaena circinalis
	A. fertilissima
	A. oscillaroides
	A. sphaerica
	Crinalium magnum
	Oscillatoria curviceps
	O. hamelii
	O. limosa
	O. nigra
	Phormidium purpurascens
	Spirulina meneghiniana
Xanthophyceae	
	Ophiocytium cochleare

2.2. Periphyton

Periphytons are the complex mixture of algae, Cyanobacteria, heterotrophic microbes and detritus that are attached to submerged surface in the euphotic zone of the aquatic ecosystems**.** In terms of group composition Chlorophyceae and Bacillariophyceae are the sole component of periphyton. Chlorophyceae comprised of 24.4-47.9% whereas diatoms constitute 52.1-75.6% of the total annual population. Green algae were most dominant in Khoh river, tributary of Ramganga (Sharma and Mishra, 2002).

2.3. Zooplankton

Zooplankton occupies an intermediate position in the food web in an aquatic ecosystem. Zooplankton comprises of Protozoans, Rotifers and Crustaceans. In Ramganga all groups of zooplankton are present although they are very less in number. The important genera of the river Ramganga are mentioned below:

Protozoa: *Arcella, Centropyxis, Diffugia, Volvox* and *Vorticella*
Rotifera: *Asplanchna, Brachionus, Philodina, Pompholix, Polyarthra* and *Trichocera*
Crustacea: *Bosmina, Ceriodaphnia, Cyclops, Daphnia, Helobdella* and *Nauplius* stages

The zooplankton population ranged between 58 and 77 ind./l. Protozoans comprised 24-44.7% of total zooplankton. The percent population of the other zooplankton varied from 59.1-76.0%. Annually, the population was apportioned between protozoans (35.6%) and other zooplankton (64.4%) (Sharma and Mishra, 2002; Pathani and Upadhyay, 2006). A graphical representation of various zooplankton in river Ramganga is given in Figure 3.

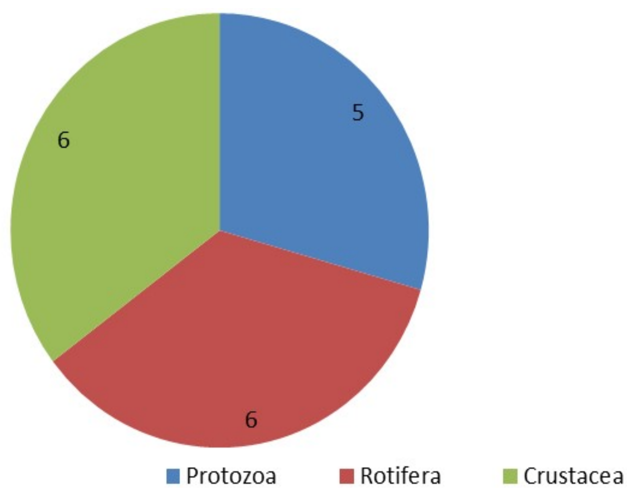


Figure 3: Distribution of Zooplankton in Ramganga

2.4. Zoobenthos

The benthic fauna of the river comprised of larvae of Ephemeroptera, Odonata, Plecoptera, Hemiptera and Diptera. The Ephemeroptera are most abundant. Only single mollusc, *Lymnaea* has been reported (Sharma and Mishra 2002; Pathani and Upadhyay, 2006). A list of zoobenthos reported in Ramganga is given in Table 2 and a graphical representation in Figure 4.

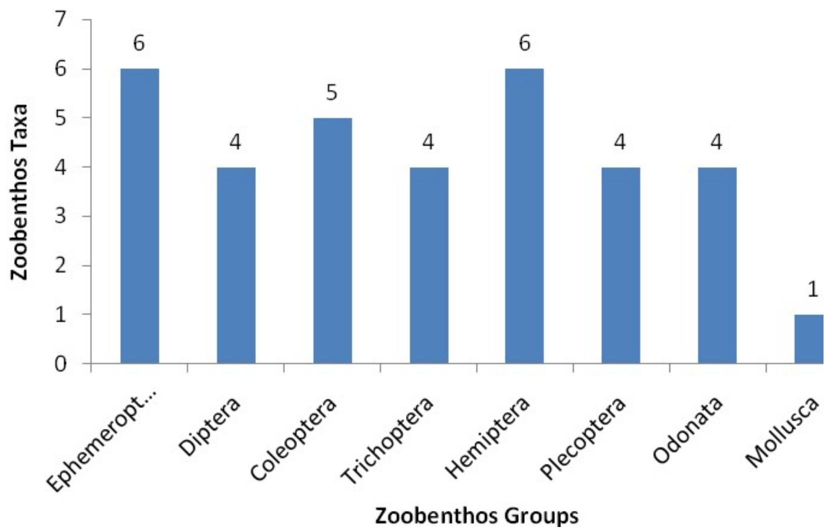


Figure 4: Distribution of Zoobenthos in Ramganga

Table 2: List of zoobenthos present in river Ramganga

Ephemeroptera			*Stenopsyche* sp.
	Ameleus sp.	**Hemiptera**	
	Baetis sp.		*Gerris* sp.
	Caenis sp.		*Heleoceris* sp.
	Cynigima sp.		*Laccotrephes* sp.
	Ephemera sp.		*Micronecta* sp.
	Leptophlebia sp.		*Ptelomera* sp.
Diptera	*Antoch* sp.		*Ranatra* sp.
	Chironomus sp.	**Plecoptera**	
	Dixa sp.		*Capnia* sp.
	Simulium sp.		*Isoperla* sp.
Coleoptera	*Hydraticus* sp.		*Kamimuria* sp.
	Laccobius sp.		*Perla* sp.
	Paedurus sp.	**Odonata**	
	Potamonectes sp.		*Agrion* sp.
	Strenolophus sp.		*Corixa* sp.
Trichoptera			*Matrona* sp.
	Glossoma sp.		*Rhinocypha* sp.
	Hydropsyche sp.	**Mollusca**	
	Limenephilus sp.		*Lymnaea* sp.

2.5. Fish

The river Ramganga is one of the principal rivers from Shivaliks of lower Himalaya, rich in the fish diversity. Mainly Corbett National Park is the home to many species of fresh water fish. The most celebrated of the fish is Golden Mahseer, *Tor putitora* a large fresh water fish belonging to the family Cyprinidae. Fresh water fish are reported in three tributaries of Ramganga in the foothills of Western Himalayas. One tributary is within a protected area (Corbett Tiger Reserve) the other two are outside the protected area. The river supports 49 species of fish belonging to 7 families under 22 genera. Family Cyprinidae is represented by the maximum number of species (Atkore, 2005; Atkore *et al.* 2011; Pathak, 2010). The important fish reported are game fish, *Schizothorax* sp. and *Tor* sp., *Labeo, Catla* and *Puntius.* The relative abundance of various fish families is depicted as below:

Cyprinidae (11/28) > Balitoridae (2/8) > Sisoridae (4/5) > Cobitidae (2/4) > Channidae (1/2) > Belonidae and Mastacembelidae (1/1)*

(Genus/ species)

Species wise distribution of fish is shown in Figure 9. A list of fish is given in Table 3.

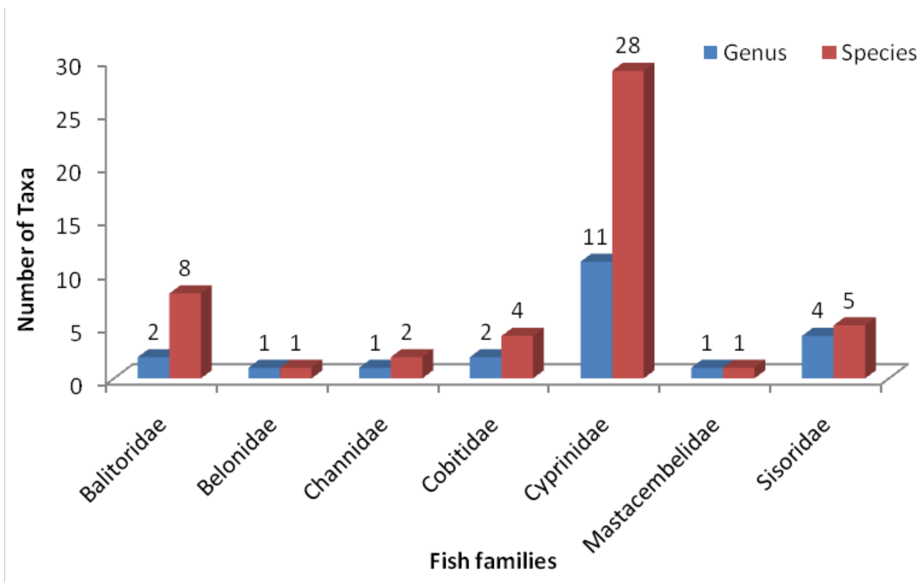


Figure 5: Distribution of fish in Ramganga

Table 3: List of fish present in river Ramganga

Balitoridae	*Homaloptera rupicola*
	Nemachelius bevani
	N. botia
	N. gharwali
	N. montanus
	N. rubdipinnis
	N. rupecola
	Table continues to next page……………….
	N. submontanus
Belonidae	

	Xenentodon cancila
Channidae	
	Channa gachua
	C. punctatus
Cobitidae	
	Botia almorhae
	B. lohachata
	B. rostrata
	Lepidocephalus guntea
Cyprinidae	
	Barilius barila
	B. bama
	B. bendelisis
	B. shacra
	B. vagra
	Catla catla
	Chagunius changunio
	Crossocheilus latius latius
	Garra gotyla gotyla
	G. *lamta*
	Labeo calbasu
	L. dero
	L. dyocheilus
	L. rohita
	Oxygaster bacaila
	Puntius chilinoides
	P. conchonius
	P. sophore
	P. ticto
	P. tor
	P. vittatus
	Raiamas bola
	Schizothorax plagiostomus
	S. progatus
	S. richardsonii
	Tor mosal
	T. putitora
	T. tor
Mastacembellidae	
	Mastacembelus armatus
Sisoridae	
	Bagarius bagarius
	Glyptothorax pectinoptrus
	G. yelchitta
	Luguvia sp.
	Pseudoecheneis sulcatus

2.6. Higher vertebrates

Beside the fish river Ramganga, support the presence of Gharial and Mugger. Corbett has two of the India's three crocodilian species. It is considered to be one of the best spot to see the Gharial. About 100 Gharials have been reported in the Ramganga and can be seen swimming or basking in the sun on its bank. These include Indian Gangetic Gharial *Gavialis gangeticus* and other Mugger *Crocodylus palustris*. Three turtle species have also been reported from river Ramganga. These are *Melanochelys trijuga, M. tricarinata and Lissemys punctata* are present in the river system.

3. Conclusions

i. Ramganga originates in the ranges of lower Himalayas of Pauri Gharwal as two streams Eastern and Western Ramganga.

ii. The quality of water is good and supports biodiversity upto Kalagarh and deteriorates downstream of Harveli barrage.

iii. Diatoms constitute the dominant group of phytoplankton and periphyton, some Blue green algae and Green algae are also reported in good numbers.

iv. Zoobenthos is represented largely by insect larvae belonging to seven orders.

v. The fish population is represented by the class Cyprinidae and includes Trout, Mahseer, *Labeo* and *Puntius*.

vi. Gharials and Mugger are the two higher forms reported in the river.

References

Atkore, V. (2005). Conservation status of fishes in the tributaries of Ramganga with special reference to golden Mahseer (*Tor putitora*) Hamilton. Master's Degree Dissertation Submitted to Saurashtra University, Rajkot. pp. 1-67.

Atkore, V., Sivkumar, K. and Johnsingh, A.J.T. (2011). Patterns of diversity and conservation status of freshwater fishes in the tributaries of river Ramganga in the Shivaliks of the Western Himalaya. *Current Science*, **100(5):**731-736.

Chandra, R., Bahadur, Y. and Sharma, B.K. (1996). Monitoring the water quality of river Ramganga at Bareilly. Pollution and Biomonitoring of Indian rivers. pp. 275-280.

Joshi, V.D. (1978). Fish fauna of Khoh basin, district Pauri Garhwal, Uttar Pradesh. *Prani*, **1:** 12-19.

Joshi P.C. (1994). Status of fish conservation in river Ramganga. *In:* Threatened fishes of India, *Natcon publication,* **4**:149-153.

Khare, R. and Suseela, M.R. (2004). Fresh water algal flora of Corbett Tiger Reserve, Uttranchal, India. *Ann. For.* **12**(2):233-242.

Kumar, S. (2007). The destructed lotic ecosystem of Ramganga river near Moradabad city. *Himalayan Journal of Environment and Zoology*, **21(2):**307-310.

Pathak, J.K., Alam, M. and Pant, J.C. (2007). Application of multivariate analysis in hydrochemical data: An example of river Ramganga. *Him. J. Env. Tool.* **21(2):**269-275.

Pathak, J.K. and Alam, M. (2010). A check list of fish fauna of Ramganga river. *J. Env. Bio. Sci.* **24(2):**239-241.

Pathni, S.S. and Upadhyay, K.K. (2006). An inventory on zooplankton, zoobenthos and fish fauna in the river Ramganga (W) of Uttarakhand, India. Himalayan Ecology, *ENVIS Bulletin*. Vol. **14**(2).

Sharma, A.P. and Mishra A. (2002). Present status and prospects of Mahseer fishery in Garhwal region of central Himalayas. *In:* Cold water fisheries in the trans-Himalayan countries. Eds. T. Petr and D.B. Swar, Food and Agriculture Organization of the United Nations. Rome. pp. 257-272.

Status of Fish and Fisheries of Ganga River Basin

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Contents

1. Introduction

The Ganga river basin is one of the largest inland river basin of India, draining a catchment of 0.86 million km^2 and supporting 43% of India's population. The Ganga rises as Bhagirathi in Himalyas at 'Gaumukh' at the height of 4255 m in Uttrakashi region in Uttarakhand. The basin lies between Longitude 73^{o} 30' and 89^{o} East and Latitude 22^{o} 30' and 31^{o} 30' North and covers eleven states *viz.* Uttarakhand, Uttar Pradesh, Delhi, Madhya Pradesh, Rajasthan, Haryana, Himachal Pradesh, Chhattisgarh, Jharkhand, Bihar and West Bengal. During its course of 2525 km, it is joined by numerous tributaries, large and small with varying flows with characterstic flora and fauna. Some of the important tributaries include Alaknanda (Mandakini, Pindar, Nandakini), Ramganga, Kali, Yamuna (Chambal, Sind, Betwa and Ken), Gomti, Ghagra, Gandak, Tons, Son, Punpun, Burhi Gandak and Kosi. Plate 1, shows the flow chart of the river Ganga.

The river Ganga supports a copious biological growth with rich flora and fauna represented by producers (periphyton and phytoplankton), consumers (zoobenthos and zooplankton), fishes and higher aquatic vertebrates. The fish population of the river Ganga includes the Indian Major Carps, other Carps, Mullets, Clupeids, Feather backs, large/ small Catfishes and miscellaneous fishes.

The main stem of Ganga has been differentiated into three stretches and ten sub-stretches based on habitat, substrate and ecology. The upper stretch is mountainous with cold water, high velocities and low nutrient concentration. The middle and lower reaches are in plains with river meandering, flood plains, comparatively moderate water temperatures, reduced velocity and increased sediment load with nutrients present in sufficient quantities due to large human interventions. The salient features of each reach and subreach has been described in the GRBEMP report number 001_GBP_IIT_GEN_Dat_01_Ver_1 Dec 2010.

Stretch 1: Upper Ganga *Gangotri to Haridwar (294 km)*	**Stretch 2: Middle Ganga** *Haridwar to Varanasi (1082 km)*
UG-I. Gangotri-Gangnani	**MG-1.** Haridwar-Bijnor
UG-2. Gangnani-Devprayag	**MG-2.** Bijnor-Narora
UG-3. Devprayag-Haridwar	**MG-3.** Narora-Fatehgarh
(U/s of Bhimgauda barrage)	**MG-4.** Fatehgarh-Allahabad
	MG-5. Allahabad-Varanasi

Stretch 3: Lower Ganga *Varanasi to Ganga Sagar (1134 km)*			
LG - A	**LG-1.** Varanasi-Patna **LG-2.** Patna-Bhagalpur **LG-3.** Bhagalpur-Farakka	**LG - B**	**LG-4.** Farakka-Ganga Sagar

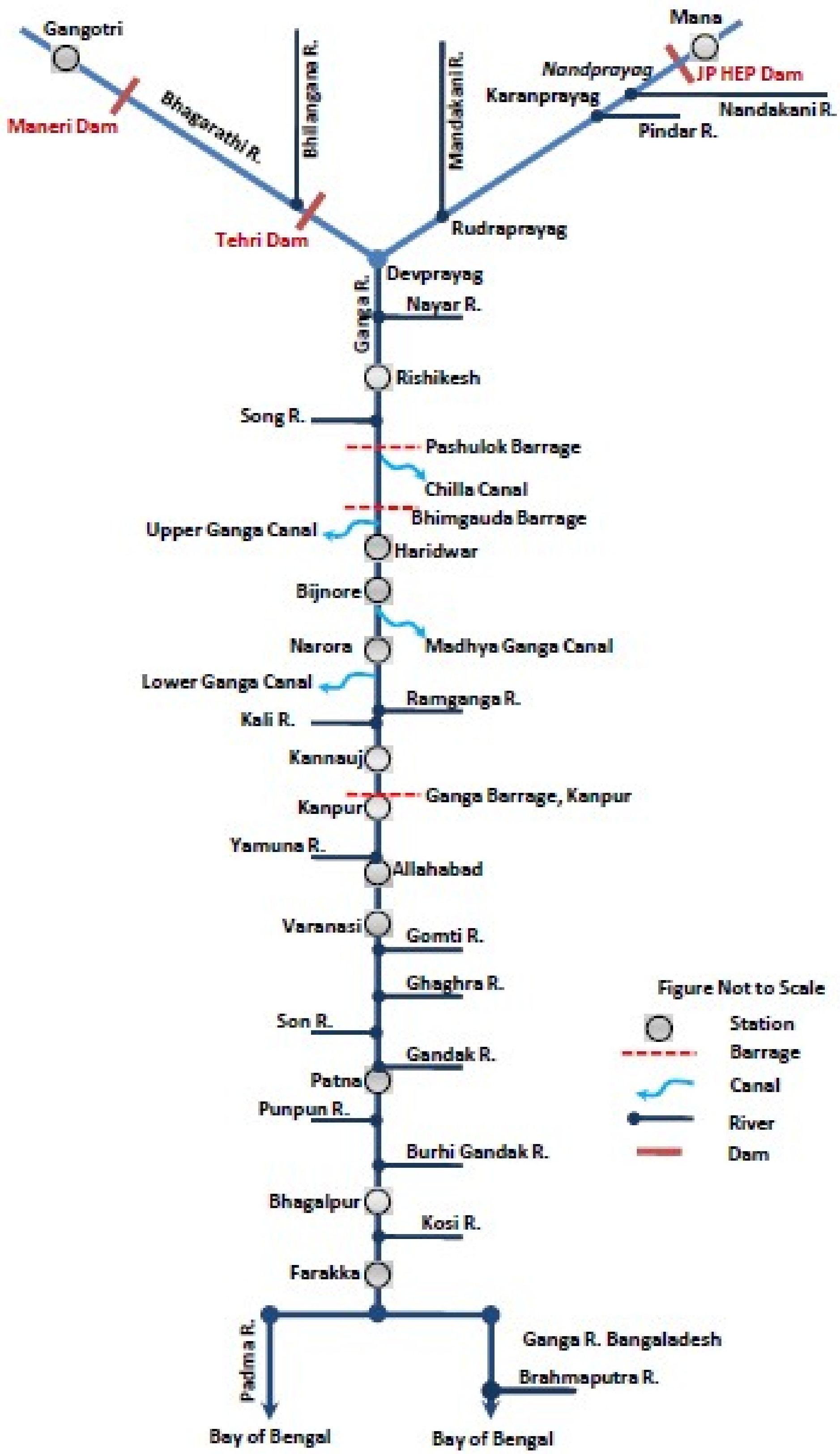


Plate 1: Line diagram of river Ganga with major tributaries

2. Habitat

The river in the upper reach flows on steep bed and narrow terrain. The substrate is mostly bedrocks, boulders and cobbles. The water is very cold, having turbulent flow, and high velocities, sometimes up to 2.0-3.0 m/sec. Rapids are the major habitat, followed by deep pools and riffles. The water is pristine or near pristine with little or no pollution from anthropogenic sources except bathing and cremation on the banks of urban agglomerates. The flow in the river has been obstructed due to the construction of hydroelectric projects at Maneri Bhali I and II, Tehri and Koteshwar.

The middle reach is in plains. The river bed is wide with extensive flood plains, meandering streams on sand and pebbles. The temperature of water is moderate (15-25°C) and low velocities (20-30 cm/sec). The river habitat consists of pools and run of the river. In the upper portions of the stretch the pollution level is less and, as the river traverses down the urban centres the pollution increases gradually. Downstream of Fatehgarh upto Allahabad, passing through Kannauj, Kanpur, Fatehpur and Allahabad, it becomes intensely polluted.
The reach is also characterized by large abstractions of water for multiple purposes at Haridwar, Bijnor and Narora. The flows in the river downstream of abstractions are small and critical during lean-season.

The river in lower reach has problems of sediment load, flooding and silt deposition through a meandering water course. The flows are comparatively higher after the confluence of major tributaries. The substrate is usually of silt over sand. A significant length of the stream lies in the Hooghly estuary where varied levels of salinity and tidal frequency determine biodiversity.

3. Biological communities

The fish population of Ganga is largely dependent on the flora and fauna produced in the system including phytoplankton, zooplankton, periphyton and zoobenthos which establishes itself in the form of food chain. Appendix-I represents the comparative account of the available flora and fauna in river Ganga. The perusal of the data in other reports and summary tabulated in Appendix-I reveals that diatoms (Bacillariophyceae) are predominantly present throughout the river with increase in diversity through upper Ganga, middle Ganga and lower Ganga. The green algae (Chlorophyceae) appear scantily in upper Ganga, gradually increases in species richness in middle Ganga and becomes dominant in Lower Ganga (LG-A). The blue green algae (Cyanophyceae) are poorly represented in the upper Ganga. The forms, however, increase in middle Ganga and lower Ganga and shows up as dominant group in Lower Ganga stretch (LG-B).
The zooplanktons are scanty in upper Ganga. They are represented by Protozoans, Rotifers, Copepods, Cladocera and other Crustaceans/ Arthropods in middle and lower Ganga. The notable contributors in LG-B, in addition to those mentioned earlier, are the Cnidarians and Chaetognaths (common in estuarine environment).

The zoobenthos type is dependent on the substratum. Larvae of Insecta are common on hard substrates (upper Ganga) while Annelids, Nematodes and Molluscs on soft substrate (silt over sand) in middle and lower Ganga.

4. Fishes in the Ganga river

The river Ganga supports a large number of indigenous and exotic species of fishes (record of 268 fishes from the river Ganga was first ever documented by Hamilton 1822). Vass *et al.* (2008) reported the presence of 218 species in inland fresh waters and waters of Hooghly estuary. However, the compilation of records from other reports, research papers, dissertations and thesis of academic institutes add up to 297. A compendium of species and families is given at the end of the report as Appendix-II. These fishes are grouped under 81 families and 167 genera (Table 1).

Table 1: Total number of fishes (taxa) in river Ganga

Categories	Species	Genus	Families
(a) Number of fish from fresh water (UG-1 to LG-A)	178	89	37
(b) Number of fish from brackish waters (LG-B)	103+72*	69	37
(c) Common cartilaginous fishes (Chondrichthyes)	13	9	7
Total	**294**	**167**	**81**

* Common in fresh water zone

Out of 297 species recorded from the river, more than 100 species are reported to have commercial importance. Following species are known for their high commercial value:

I. **Species (fresh water) of varying commercial importance** (Misra, 1959; Jhingran, 1991)**:**

(A). Indian Major Carps

1) *Cirrhinus mrigala*
2) *Catla catla*
3) *Labeo rohita*
4) *L. calbasu*

(B). Other Carps

5) *Cirrhinus reba*
6) *Labeo bata*
7) *L. dero*
8) *L. pangusia*

(C). Large Cat fishes

9) *Sperata aor*
10) *S. seenghala*
11) *Silonia silondia*
12) *Wallaga attu*
13) *Pangasius pangasius*
14) *Bagarius bagarius*
15) *Rita rita*

(D). Other Cat fishes

16) *Ailia coila*
17) *Clupisoma garua*
18) *Eutropiichthys vacha*
19) *Ompok bimaculatus*
20) *Ompok pabda*

(E). Clupeoides

21) *Gudusia chapra*
22) *Setipinna phasa*
23) *Tenualosa* (*Hilsa*) *ilisha*

(F). Feather backs

24) *Notopterus chitala*
25) *N. notopterus*

Other fish

26) *Channa punctata*
27) *C. marulius*
28) *Puntius sophore*
29) *P. conchonius*

II. Commercially important fish/shrimp of Hooghly estuary:

1) *Tenualosa* (*Hilsa*) *ilisha*
2) *Polynemus paradiseus*
3) *Liza parsia*
4) *Pama pama*
5) *Lates calcarifer*
6) *Penaeus indicus* (Indian prawn)
7) *Harpodon nehereus*
8) *Setipinna phasa*
9) *Trichiurus* spp.
10) *Sciaena biauritus*
11) *Ilisha elongata*
12) *Arius jella*
13) *Stromateus cinereus*
14) *Coilia* spp.

4.1 Fishes in the upper Ganga

The upper Ganga represents the mountainous reach where temperature is low, habitat is strong snow melt currents, with rocks and boulders as substrate. The fallout of lignocellulosic materials from forest conopy is supportive to some insect larvae which grow underneath boulders and rocks as zoobenthos. This zone is ultra-oligotrophic and does not support biological growth. The reach Gangotri to Gangani (UG-1) has been refered as **NO FISH ZONE** by Singh (2008).

As per records, 60 fish species belonging to 27 genus and 12 families have been reported from the upper stretch of the river. Cyprinidae is the largest family with 35 species.

The reach between Gangnani to Devprayag (UG-2) is inhabited by hill stream fishes. The most prominent, being snow-trouts, *Schizothorax* and *Schizothoraichthys*. The nine species of both the genera have been reported out of which seven species of *Schizothorax*: *Schizothorax curvifrons*, *S. plagiostomus, S. richardsonii, S. sinuatus*, *S. niger*, *S. micropogan* and *S. intermedius* and two species of *Schizothoraichthys*: *S. esocinus* and *S. progastus* are prominent. Other fishes reported are *Pseudecheneis* (1 sp.), *Crossocheilus* (1 sp.), *Clupisoma* (1 sp.), *Labeo* (2 sp.), *Tor* (3 sp.), *Garra* (3 sp.), *Glyptothorax* (5 sp.), *Barilius* (5 sp.), *Nemacheilus* (6 sp.). **The snow trout *Schizothorax richardsonii* is the characterstic species of this stretch of Ganga**.

The population of some hill stream fishes (UG-2), their migration for breeding and over-wintering (Snow trout) has been severely impeded by a series of hydro-electric projects. The flow conditions in the river have been interrupted (Plate 2) and often the stretch (86 km) remains without water. The snow-trout, which are known to migrate upwards against current to safer places to breed, are stranded.

From Devprayag to Haridwar (UG-3) a few species of Mahseer (*Tor tor, T. putitora)* and few catfishes make their appearance. Golden Mahseer (*Tor putitora*) is the keystone species of the reach. Besides Mahseer, the other carps reported are *Crossocheilus latius latius*, *Esomus danricus, Garra gotyla gotyla*, *Raiamas bola*, *Rasbora daniconius*, *Salmostoma bacaila*, *Schizothoracthys progastus*, *Danio* (2 sp.), *Schizothorax* (2 sp.), *Puntius* (3 sp.), *Barilius* (4 sp.) and *Labeo* (5 sp.) (Plate 3). Some other members of the stretch are *Bagarius bagarius* (Sissoridae) and *Nemacheilus* (Balitoridae). The distribution of fish families and genus (UG-2 and UG-3) is given in Figures 1a and b. Some other fishes (*Clarias, Clupisoma, Mystus, Rita, Rhinomugil, Salmostoma*), not commonly inhabiting cold, clear and rapid streams of hilly terrain, have also been reported by Singh *et al.* (1983), Sharma (1988), Negi and Malik (2005) and Nautiyal e*t al.* (2009). They have been taken as rare/stray catch in the stretch.

Plate 2: River Ganga at Maneri Bhali I

Hill stream fishes of Ganga river

Snow-trout (*Schizothorax* sp.)

Mahseer (*Tor sp.*)

Cat Fishes

Major Carps

Bagarius bagarius

Catla catla

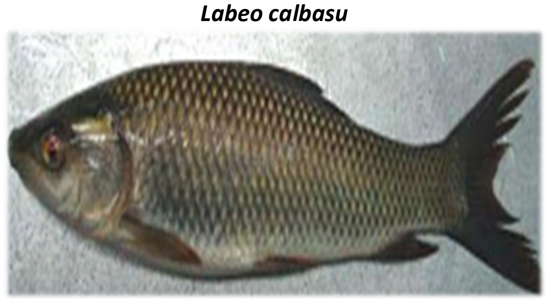
Heteropneustes fossilis

Cirrhinus mrigala

Sperata seenghala

Labeo calbasu

Mystus tengara



Labeo rohita

Plate 3: Snow-trout and Mahseer of upper Ganga and Major carps and Catfishes of middle and lower Ganga

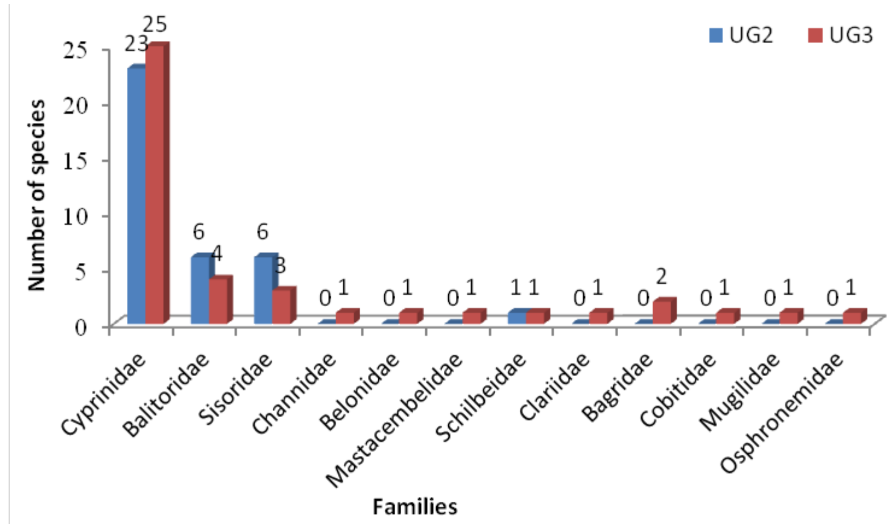


Figure 1a: The distribution of fish families in the two sub-stretches of the upper Ganga

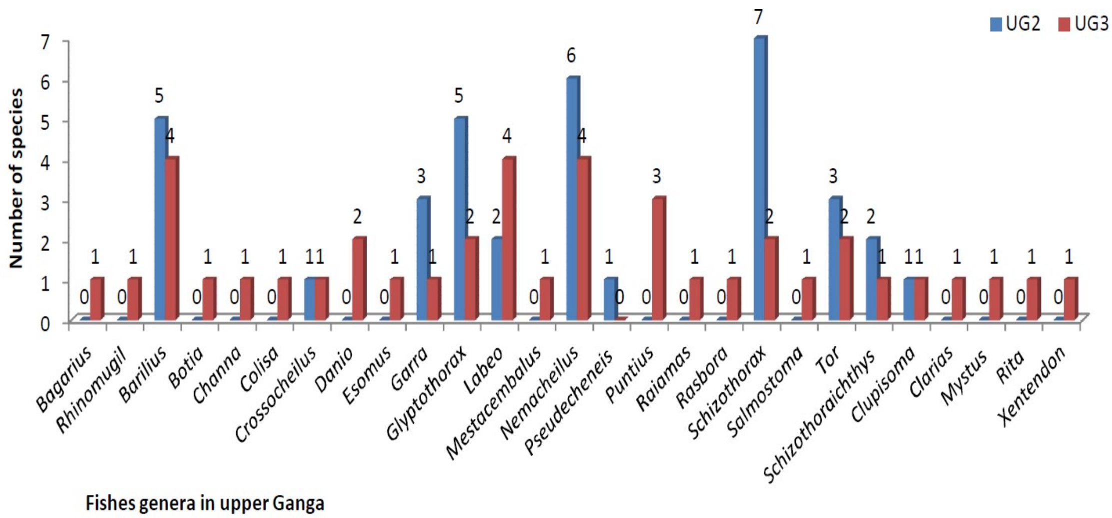


Figure 1b: The distribution of fish genera in the two sub-stretches of the upper Ganga (UG-2 and UG-3)

4.2 Fishes in the middle Ganga

The middle reach is a very long stretch of river Ganga and is about 1082 km long. The important tributaries (Song and Suswa) debouch into the river Ganga between Rishikesh and Haridwar; Ramganga and Kali at Kannauj and Yamuna at Allahabad. Ram Ganga and Kali are much degraded rivers and bring in large quantities of domestic and industrial wastes while Yamuna is the most important tributary of river Ganga.

The water abstraction from Ganga at three places, Haridwar, Bijnor and Narora in Upper Ganga Canal, Madhya Ganga Canal and Lower Ganga Canal reduces the flow in the main stem of Ganga, considerably.

As per records, 136 fish species belonging to 29 families have been reported from the middle stretch of the river (GRBEMP report: 024_GBP_IIT_ENB_DAT_02_Ver 1_Jun 2012). Cyprinidae is the largest family with 54 species which include Indian major carps and other minor carps, cat fishes, clupeids and feather backs. The family wise distribution of fish species is given in Figure 2.

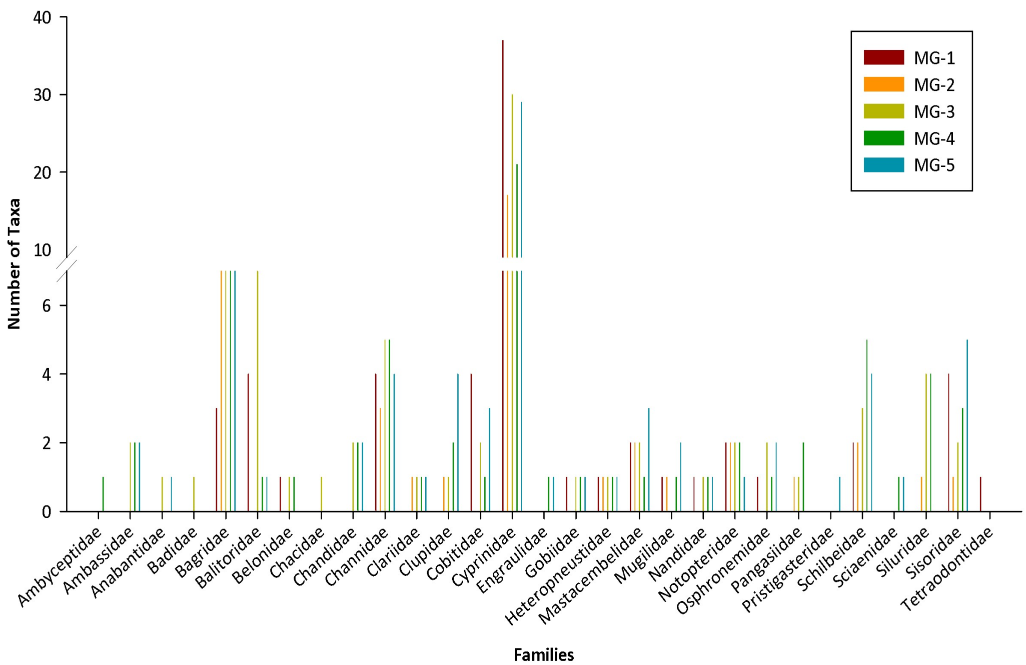


Figure 2: Family wise distribution of fishes in the middle Ganga

The distribution of economically important genera is given in Table 2. The perusal of the data reveals that **four Indian major carps are present throughout the length of the river, downstream of Haridwar and constitute the characteristic group of the river**. Other carps, large cat fishes and other cat fishes are also represented significantly.

4.3 Fishes in lower Ganga

The lower Ganga includes a very large river stretch from Varanasi to Farakka and equally large estuarine zone of Hooghly Matlah Estuary. The fresh water portion lies partly in Bihar and partly in Uttar Pradesh and runs for about 701 km (LG-A). The conditions in fresh water zone and estuarine zone (LG-B) are different in water quality parameters and, more so, in diversity of flora and fauna.

The zone (LG-A) sustains 121 fish species belonging to 36 families and 74 genera. The most important groups, like in upper and middle Ganga, are Cyprinidae which include 40 species. The important species are *Catla catla, Labeo rohita, Labeo calbasu* and *Cirrhinus mrigala* and *Labeo bata, L. boga, L. dero, L. fimbriatus, L. gonius* and *L. pangasius.* Some other Cyprinids are *Amblypharyngodon mola, Aspidoparia morar, Barilius* (3 sp.), *Chagunius chagunio, Chela bacaila, C. laubuca, Danio, Esomus, Garra, Laubuca, Ostreobama* and *Puntius* (6 sp.). *Bagarius bagarius, Mystus, Clupisoma garua, Eutropiichthys vacha, Ompok* *bimaculatus, Ompok pabda, Rita rita, Pangasius pangasius, Silonia silondia* and *Wallago attu* are the reported groups of catfishes. Exotic fishes- *Cyprinus carpio* and *Oreochromis niloticus* are also present in the stretch in sizeable population. Another commercially important fish of the reach is *Hilsa ilisha*. The fish is now disappearing after the construction of Farakka barrage. The other species reported are *Notopterus notopterus* and *N. chitala* (Notoptridae), *Setipinna phasa* (Engraulidae), *Glossogobius giuris* (Gobeidae), *Heteropnuestis fossilis* (Heteropneustidae), *Clarias batracus* (Clariidae), *Xenentodon cancilla* (Belonidae) and *Mastacembalus armatus* (Mastacembalidae). The family-wise distribution of fishes is given in Figure 3 and the distribution of economically important genera (commercially important) is given in Table 3.

Table 2: Distribution of economically important fishes in middle Ganga

		MG-1	MG-2	MG-3	MG-4	MG-5
IMC						
	Catla catla	+	+	+	+	
	Cirrhinus mrigala	+	+	+	+	+
	Labeo calbasu	+	+	+	+	+
	L. rohita	+	+	+	+	+
Other Carps						
	Cirrhinus reba	+	+	+	+	+
	Labeo bata	+	+		+	+
	L. dero	+				
	L. pangusia	+		+		+
Large Cat fish						
	Bagarius bagarius	+	+	+	+	+
	Pangasius pangasius			+	+	
	Rita rita	+	+	+	+	+
	Silonia silondia		+		+	
	Sperata aor		+	+	+	+
	S. seenghala	+	+	+	+	+
	Wallaga attu		+	+	+	
Other Cat fish						
	Ailia coila			+	+	+
	Clupisoma garua	+	+	+	+	+
	Eutropiichthys vacha		+	+	+	+
	Ompok bimaculatus			+	+	
	O. pabda			+	+	
Clupeoides						
	Gudusia chapra		+	+	+	+
	Setipinna phasa				+	+
	Tenulosa ilisha				+	+

Table 3: Distribution of economically important fishes in lower Ganga

		LG-1	LG-2	LG-3	LG-4
IMC					
	Catla catla	+	+	+	+
	Cirrhinus mrigala	+	+	+	+
	Labeo calbasu	+	+	+	+
	L. rohita	+	+	+	+
Other Carps					
	Cirrhinus reba	+	+	+	+
	Labeo bata	+	+	+	+
	L. dero	+			
	L. pangusia	+	+	+	
Large Cat fish					
	Bagarius bagarius	+	+	+	+
	Pangasius pangasius		+	+	+
	Rita rita	+	+	+	+
	Silonia silondia		+	+	+
	Sperata aor	+	+	+	+
	S. seenghala	+	+	+	+
	Wallaga attu	+	+	+	+
Other Cat fish					
	Ailia coila	+	+	+	+
	Clupisoma garua	+	+	+	+
	Eutropiichthys vacha	+	+	+	+
	Ompok bimaculatus	+	+	+	+
	O. pabda	+	+	+	+
Clupeoides					
	Gudusia chapra	+	+	+	
	Setipinna phasa	+	+	+	+
	Tenualosa ilisha	+	+	+	+

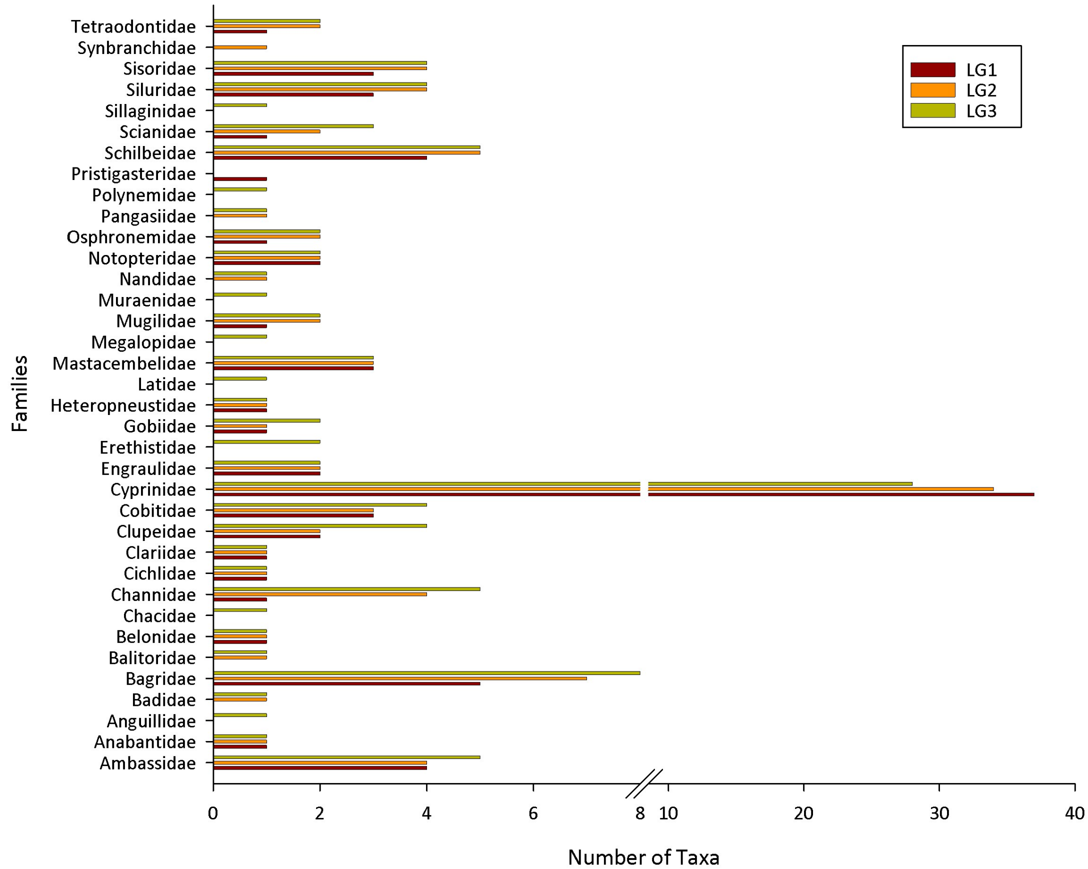


Figure 3: The family wise distribution of fishes in lower Ganga (LG-A)

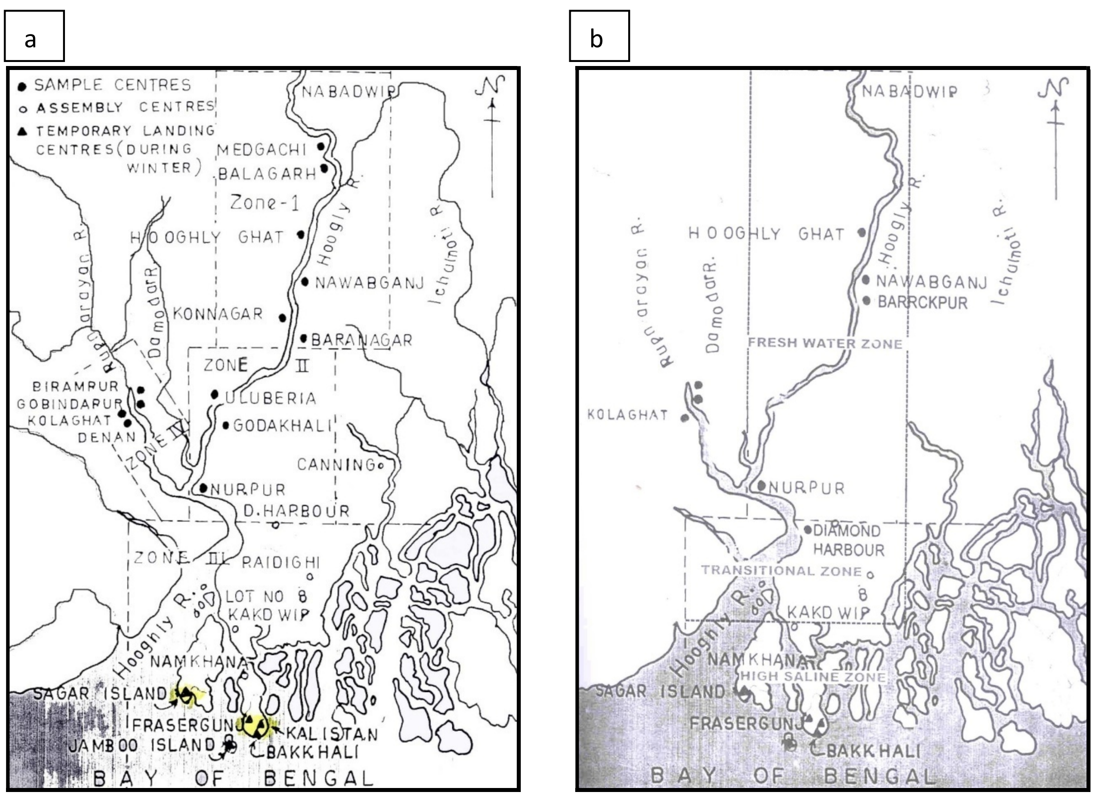
4.4 Fishes in lower Ganga Hooghly-Matlah estuary (LG-B)

Hooghly Matlah estuary is the largest estuary spanning to about 0.8 million ha with conditions of fresh water, brackish water and marine water present alongwith. The fresh water system is represented by river Hooghly and its tributary Rupnaryan and many estuarine distributaries and creeks. The Hooghly-Matlah estuary is known for its faunastic richness.

Salinity is a critical chemical factor in governing the faunal distribution in this zone. The changes in salinity pattern of the Hooghly estuary have led to changes in the biodiversity of the estuary, including fish diversity in different regions. The estuary now been re-zonated from the water salinity point of view (Plate 4a and b). The fresh water zone has extended to almost Diamond Harbour from Baranagar earlier, a transition zone upto Kakdwip, while the high salinity zone is restricted to Sagar and Frazergunj-Bakkhali in the lower most part of the estuary. The 12 km stretch in the fresh water zone of the Hooghly estuary between Bichalighat and Barrackpore (Ghosh, 2007) revealed a change in the fish fauna, compared to the Pre-Farakka period, with a shift of most of the brackish water fish species to further downstream. *Sicamugil cascasia,* a small Mullet, could be recorded for the first time from the fresh water zone of Hoogly eustuary (Mitra *et al.* 1997). On the other hand the Spotted Codlet, *Bregmaceros mcclellandi*, which was regarded rather a rare species, has now been found to be well available in the lower most part of Hooghly estuary and also in Sunderbans estuary. *Oreochromis niloticus* has been recorded for the first time from the fresh water zone of the Hooghly estuary which is probably the first record of any exotic species from the tidal zone of the river Ganga (Ghosh, 2008).

The ichthyo-fauna is represented by 175 species, out of which 103 species, under 69 genera and 37 families are strictly estuarine in nature, which is evidenced by annual (average) catch of about 40,000 tons. The estuary is large (290 km) and is influenced by tides. It is believed that the ecology of the Hooghly estuary has significantly changed after commissioning of Farakka barrage in 1975. It is reported that fresh water zone has extended and there is decline in salinity patterns by squeezing and intermingling with marine water. Plate 4a and b show Hooghly estuary and its various ecological zones, Zone I Nawadip-Baranagar; Zone II Baranagar-Diamond Harbour; Zone III Diamond Harbour-Ganga Sagar; Zone IV Containing Rupnarayan tributary, Birampur, Gobindapur and Kolaghat (Adopted from CIFRI Report of Mitra *et al.* (1997). Zone I, II and IV together constitute the upper estuary and zone III the lower estuary (Nath *et al.* 2004; Ghosh, 2008).

Among the 175 species, 72 species occur in fresh water zone. 26 species are mainly represented in the catches. Among the major contributors are *Tenualosa ilisha*, *Sciaena biauritus*, *Colia* sp., *Pama pama*, *Ilisha elongata*, *Setipinna* sp., *Tachysurus jella*, *Trichiurus* sp., *Harpodon nehereus*, *Stomateus cinereus*, *Prawns* and miscellaneous.



(Mitra *et al.* 1997) **(Nath *et al.* 2004; Ghosh, 2008)**

Plate 4: Hooghly estuary

The important families are Cyprinidae 15 sp. (*Catla catla, Labeo rohita, L. calbasu, L. bata, Cirrhinus mrigala, C. reba, Puntius ticto, P. conchonius, P. sarana, P. sophore, Salmostoma bacaila*, *Danio devario, Esomus danricus, Rasbora daniconius, Amblypharygodon mola*), Gobiidae 8 sp. (*Brachygobius nunus, Glossogobius giuris, Pseudapocryptus lanceolatus, Stigmatogobius sadanundio*, *Periopthalmadon schlosseri, Boleophthalmus dussumiere, Gobioptrus chuno, Bathygobins orbicularis*), Clupeidae 8 sp. (*Tenulosa ilisha, Hilsa kelee, Gudusia chapra, Gonialosa manmina, Corica soborna, Anodontostoma manmina, A. chachuna, Sardinella melasura*), Engraulidae 8 sp. (*Coilia dussumieri, C. ramcorti, C. reynalidy, Setipinna phasa, S. taty, S. brevifilis, Stolephorus indicus, Thryssa purva),* Mugilidae 7 sp. (*Liza parsia, L. tade, L. macrolepis, Mugil cephalus, Valamugil cunnesieus, Sciamugil cascasia, Rhinomugil corsula),* Schilbiedae 4 sp. (*Ailia coila, Eutropiichthys vacha, Clupisoma garua, Silonia silondia),* Siluridae 4 sp. (*Wallago attu, Ompok bimaculatus, O. pabo, O. pabda*), Bagridae 6 sp. *(Sperata aor, S. seenghala, Mystus cavasius, M. vittatus, M. gulio, Rita rita*), Notopteridae 2 sp. (*Notopterus notopterus, N. chitala*), Sissoridae 2 sp. *(Bagarius bagarius, Gagata cenia);* Aridae 7 sp. *(Arius jella*, *A. sona*, *A. arius, A. gagora, A. sagar, Batrachocephaly minor, Osteogeniosus militaris*); Channidae 4 sp. *(Channa striatus*, *C. marulius*, *C. punctatus*, *C. orientalis*). A combined list of fishes from the eustary is given in Appendix-III. Some exotic and commercially important fishes of Hooghly estuary are presented in Plate 5.

In addition, 13 species of Chondriichthys or Cartillagenous fishes belonging to 9 genus and 7 families have also been recorded in the estuarine zone. Of these genus Dasyatidae (5 sp.) is the most common (Appendix-IV).

5. Fishing gears

Hook and line are the main gear used in the upper Ganga where no organized fisheries exist. Nets and other gadgets can not be used as the river flows in narrow hilly terrain with high velocities. Since game fishes exist in the reach, the only possibility is angling.

Fishing is not permitted in down stream stretch of the river Ganga upto Haridwar. Use of fishing gear is operative in the middle Ganga and lower Ganga stretch. The variously designed gears are used to suit local conditions such as depth of water, water velocity and type of fish to be caught. Dragnets, gill nets, purse net, scoop net, cast nets, set barriers, traps and long lines are normally used in fresh water stretches. In estuarine system, trawl nets, seine nets, purse nets, drift nets, lift nets, cast nets, bag nets, set gillnets, set barrier nets and traps are used. A compilation of gears used, area of operation, season of operation and probable catch (after CIFRI, 1970) is given in Appendix-V and Plate 6.

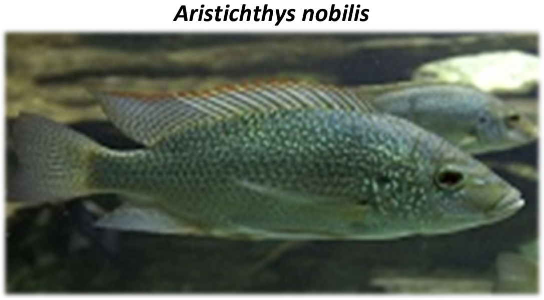
Exotic fishes

Ctenopharyngdon idella

Cyprinus carpio

Hypophthalmichthys molitrix

Aristichthys nobilis



Oreochromis niloticus

Hooghly estuary fishes

Ilisha elongate

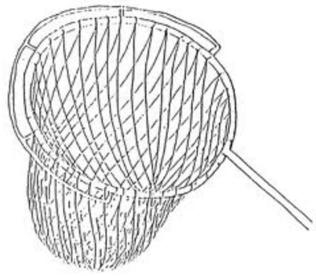
Setipinna phasa

Hilsa ilisha

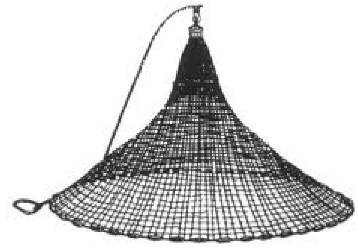
Tachysurus jella

Harpodon nehereus

Plate 5: Some exotic and commercially important fishes of Hooghly estuary

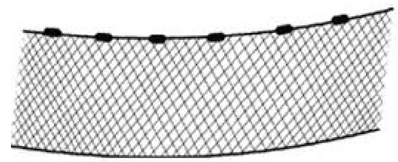


Scoop Net



Cast Nets

Sine nets



Gill Nets

Drag Net

Purse Net

Plate 6: Different types of gear and net used in Ganga river

6. Riverine fisheries of the river Ganga

The river Ganga is the most important source of livelihood for a large community of riparian population. A very large variety of fish have been reported which are of commercial importance.

The 1600 km of river from Haridwar to Lalgola ghat (West Bengal) is beset with large deep pools in the silt covered sand bed. Commercial fisheries are mainly observed in this stretch starting from Bulandshahr (Uttar Pradesh). Though there are 22 landing centres recognized for fish catch only seven of them were active viz. Kanpur, Allahabad, Varanasi, Buxar, Ballia, Patna and Bhagalpur and more recently the data is available at Allahabad only. All other centers have dispensed with the regular data collection on fish catch. Most of the records of fish catch/ landings, yield and species composition are based on records maintained by Central Inland Fisheries Research Institute, Regional Centre, at Allahabad.

6.1 Fish landings

The annual market arrivals at the seven landing centres are shown in Table 4a (Jhingran, 1975). Supplemantary data beyond 1965-66, as and where available (CIFRI annual reports), have been compiled in Table 4.

The perusal of data reveals that the annual average catch during the decade 1955-1956 to 1965-1966 at Allahabad was high of 243.25 tons as compared to other centers Patna, Bhagalpur, Varanasi, Balia, Buxar and Kanpur (Figure 4). The highest ever was 485 tons at Allahabad in 1956-1957 and the lowest at Kanpur 29.71 tons in 1961-1962 (Table 4). The downword trend continues and the values of decadal annual average have reached a value of 162.24 tons at Allahabad.

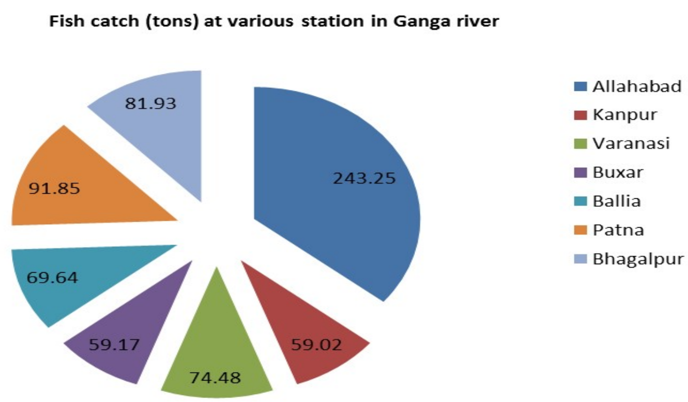


Figure 4a: Average fish landings at seven important centres during (1955-56 to 1965-66)

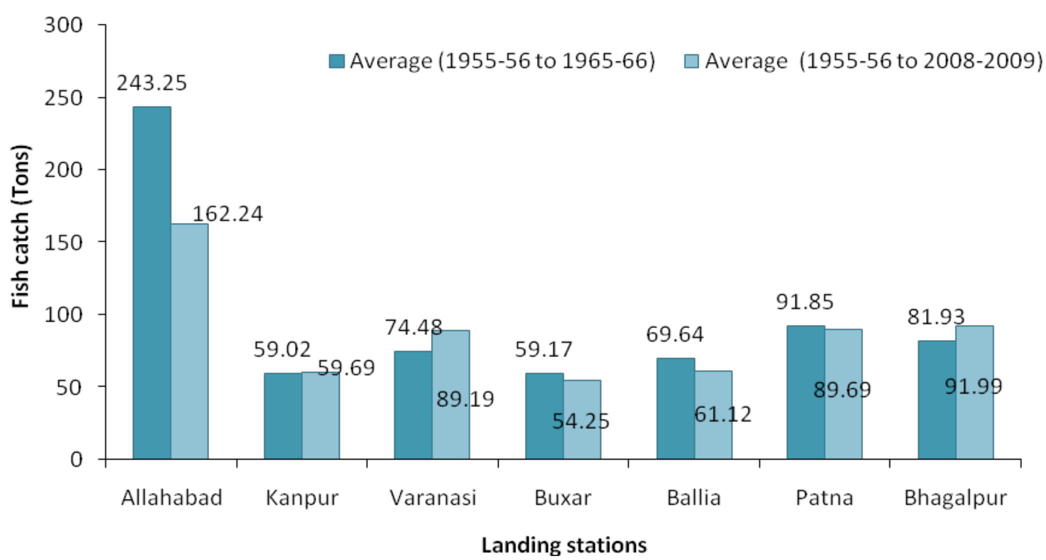


Figure 4b: Comparision of average fish landings at seven important centres between the period of (1955-56 - 1965-66) to (1955-56 - 2008-09)

Table 4: Fish landing at important landing centres (1955-56 to 1965-66) tons/year

Landing Centre	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1970	1971	1973	1975	1980-81
Allahabad	316.42	485	200.1	145.35	193.58	200.11	202.82	263.08	200.41	256.35	212.49	186.2	169.2	228.9	-	-	72.47	83.78	130.5
Kanpur	-	-	-	93.35	105.62	81.76	29.71	52.43	43.09	33.72	32.62	48.6	25.2	39.9	-	-	-	-	-
Varanasi	-	-	-	46.71	47.16	69.38	71.14	105.36	75.18	71.02	109.92	98.0	133.9	153.4	-	-	-	-	-
Buxar	-	-	-	108.62	71.77	54.27	-	-	32.58	31.63	56.12	64.5	48.3	125.4	-	-	14.6	-	16.49
Ballia	-	-	-	45.38	50.24	84.40	51.37	72.37	114.23	-	-	51.0	39.8	41.3	-	-	-	-	-
Patna	-	-	-	54.60	40.11	96.39	106.31	129.28	115.38	76.96	114.95	108.3	98.8	110.2	-	-	-	-	-
Bhagalpur	-	-	-	41.51	59.88	85.98	120.55	98.36	77.65	76.35	94.92	83.4	121.8	139.9	103.16	113.82	100.0	-	-

Landing Centre	1982	1985-89	1992-97	1996-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	Average (1955-56 to 2008-2009)
Allahabad	**125.3**	**125.4**	**69.58**	**77.88**	**69.65**	**68.37**	**94.67**	**-**	**74.25**	**86.85**	**115.9**	**88.1**	**162.24**
Kanpur	**-**	**-**	**-**	**-**	**-**	**101.5**	**88.54**	**-**	**-**	**-**	**-**	**-**	**59.69**
Varanasi	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**89.19**
Buxar	**-**	**26.75**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**54.25**
Ballia	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**61.12**
Patna	**-**	**25.1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**89.69**
Bhagalpur	**-**	**62.54**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**91.99**

There is paucity of data at many centres and the average data as available is shown in the pie diagram (Figure 4a) and bar diagram (Figure 4b). The values of fish landing at Allahabad were available for almost the entire period whereas for other centers the information is very little and it does not show up in the average values.

6.2 Catch composition

The fish yield of major Carps and other selected Catfishes during the period 1958-59 to 1968-69 was reported by Jhingran and Ghosh (1978) (Table 5) and comparative analysis of change in the catch composition at Allahabad and Patna between 1958 and 1994 was reported by Payne *et al.* (2003) (Table 6). The data compiled from Annual Reports of CIFRI, Barrackpore, for Kanpur during the period 2002-03 and 2003-04, Allahabad upto 2009, Buxar upto 1985-89, Patna upto 1985-89 and Bhagalpur upto 1985-89 has been reproduced in Table 5. The major Carps (MC) include *Cirrhinus mrigala, Labeo rohita, Labeo calbasu* and *Catla catla*. The Catfishes (CF) include *Wallaga attu, Sperata aor, Sperata seenghala* and Hilsa (H) as *Hilsa ilisha* while the other species were grouped under others (O).

Based on data reported, there is a constant decline not only in fish (catch) landing but also a shift in species composition. Vass *et al.* (2010) observed a declining pattern in the total fish catch to almost half (during the period where data was avilable) at different landing centres located at Allahabad, Buxar, Patna and Bhagalpur (Figure 5).

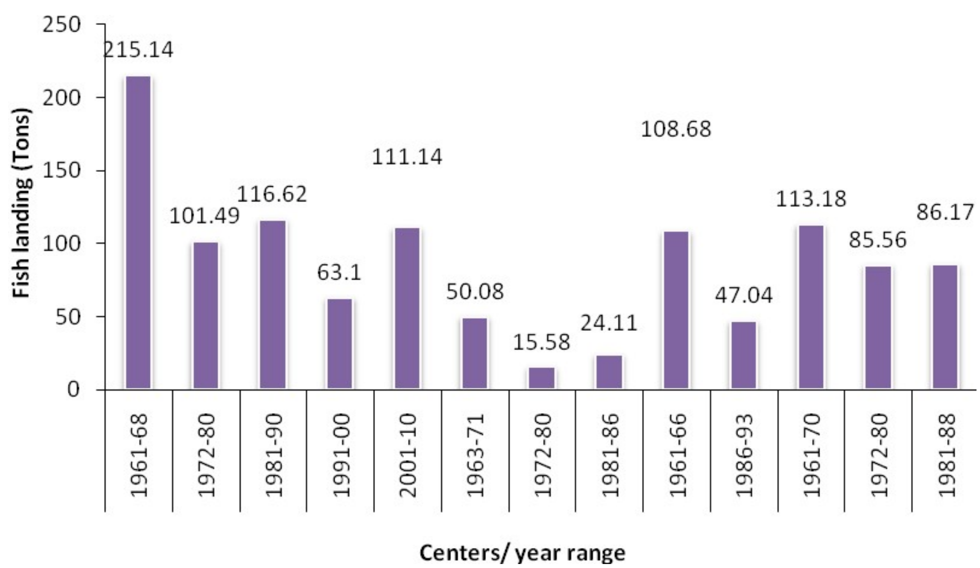


Figure 5: Fish landing at various centers in the river Ganga

Table 5: Market arrivals (tons) of major carps (MC), selected catfishes (CF), Hilsa (H) and other (O) fishes during the period 1958-69

Zones		1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69
Kanpur	MC	51.0	54.8	44.5	12.3	23.9	20.2	20.3	12.9	19.2	8.0	9.8
		(85.0)	(91.3)	(74.2)	(20.5)	(39.8)	(33.7)	(33.8)	(21.5)	(32.0)	(13.3)	(16.3)
	CF	30.4	36.9	20.4	8.3	14.2	13.4	8.6	11.7	15.6	12.1	18.0
	H	-	-	-	-	-	-	-	-	-	-	-
	O	12.0	13.9	16.9	9.1	14.3	9.5	14.9	8.0	13.8	5.1	12.1
Allahabad	MC	54.0	74.9	86.9	91.7	108.3	95.9	131.3	98.3	98.6	77.2	87.7
		(11.7)	(16.3)	(18.9)	(19.9)	(23.5)	(20.8)	(28.5)	(21.4)	(21.4)	(16.8)	(19.1)
	CF	42.4	42.5	42.9	50	68.7	40.0	51.0	37.1	37.6	40.4	50.6
	H	7.9	14.7	24.0	9.9	22.3	19.9	30.0	32.5	12.5	15.1	30.6
	O	42.1	61.5	46.3	51.2	53.7	44.6	44.1	44.7	37.5	36.5	60.0
Varanasi	MC	5.6	7.0	2.3	2.3	1.7	1.7	2.4	6.6	4.90	2.4	2.3
		(2.9)	(3.6)	(1.2)	(1.2)	(0.9)	(0.9)	(1.2)	(3.4)	(2.5)	(1.2)	(1.2)
	CF	7.9	7.7	9.6	14.1	18.2	21.0	20.5	28.3	19.6	24.8	27.0
	H	7.4	12.4	27.9	14.4	36.5	14.9	17.3	18.8	24.0	32.8	71.8
	O	25.8	20.1	29.5	4.5	48.9	37.6	30.4	59.1	49.5	73.9	52.3
Buxar	MC	13.7	7.5	1.8	-	-	1.4	1.3	3.0	2.1	0.6	1.5
		(30.4)	(16.7)	(4.0)	-	-	(3.1)	(2.9)	(6.7)	(4.7)	(1.3)	(3.3)
	CF	14.4	10.4	3.2	-	-	3.8	5.8	2.2	2.4	2.0	2.3
	H	29.4	19.9	33.8	-	-	8.0	7.4	36.8	48.6	34.1	112.7
	O	51.1	34.0	55.4			19.3	17.1	14.2	11.4	11.6	8.9
Ballia	MC	9.4	8.4	4.1	5.2	2.3	4.9	-	-	4.9	4.2	4.5
		(13.4)	(12.0)	(5.9)	(7.4)	(3.3)	(7.0)	-	-	(7.0)	(6.0)	(6.4)
	CF	6.9	3.8	4.6	15.9	4.7	14.1	-	-	4.1	7.2	6.0
	H	10.9	17.3	15.7	4.5	54.1	73.1	-	-	32.7	15.5	24.0
	O	18.2	20.8	60.0	25.6	11.2	22.2			9.3	12.9	6.8
Patna	MC	19.0	17.2	24.0	26.8	17.9	17.9	18.9	20.2	16.8	12.8	14.6
		(12.7)	(11.5)	(16.0)	(17.9)	(20.6)	(11.9)	(12.6)	(13.5)	(11.2)	(8.5)	(9.2)
	CF	9.0	3.5	15.5	22.1	22.9	34.1	17.8	14.3	10.7	23.0	24.9
	H	2.8	1.7	21.8	14.4	26.5	9.9	8.2	11.4	13.6	4.8	4.2
	O	23.8	17.7	35.2	42.0	49.4	53.5	32.2	67.0	67.2	58.2	66.5
Bhagalpur	MC	9.0	9.6	9.2	10.6	15.6	10.9	17.9	26.1	19.80	28.6	25.6
		(3.5)	(3.7)	(3.5)	(4.1)	(6.0)	(4.2)	(6.9)	(10.0)	(7.6)	(11.0)	(9.8)
	CF	8.2	10.9	24.6	36.9	39.0	16.9	7.9	14.1	8.8	19.6	26.8
	H	4.8	2.4	5.1	4.0	2.1	2.2	2.4	3.9	3.1	5.3	9.6
	O	19.5	37.1	47.1	69.0	41.8	47.7	48.1	50.8	51.7	68.3	77.9

Zones		1970	1971	1973	1975	1980-81	1982	1985-89	1992-97	1996-01	2001-02	2002-03
Kanpur	MC	-	-	-	-	-	-	-	-	-	-	19.18
	CF	-	-	-	-	-	-	-	-	-	-	42.83
	H	-	-	-	-	-	-	-	-	-	-	-
	Exotic	-	-	-	-	-	-	-	-	-	-	9.44
	O	-	-	-	-	-	-	-	-	-	-	30.04
Allahabad	MC	-	-	27.5	28.02	36.63	49.75	35.87	8.02	7.07	7.28	4.37
	CF	-	-	17.1	20.44	25.40	21.18	22.33	19.01	14.47	11.06	8.96
	H	-	-	2.9	0.45	0.20	0.46	1.71	0.31	0.38	1.24	0.008
	Exotic	-	-	-	-	-	-	-	-	-	-	12.17
	O	-	-	24.97	34.87	68.51	53.89	65.48	42.24	55.96	50.07	42.87
Buxar	MC	-	-	3.14	-	3.11	-	3.26	-	-	-	-
	CF	-	-	4.8	-	4.62	-	5.41	-	-	-	-
	H	-	-	1.96	-	0.50	-	2.60	-	-	-	-
	O	-	-	4.7	-	8.26	-	15.48	-	-	-	-
Patna	MC	-	-	-	-	-	-	1.473	-	-	-	-
	CF	-	-	-	-	-	-	4.55	-	-	-	-
	H	-	-	-	-	-	-	0.13	-	-	-	-
	O	-	-	-	-	-	-	18.93	-	-	-	-
Bhagalpur	MC	17.55	12.62	11.85				4.89	-	-	-	-
	CF	30.75	35.82	30.03	-	-	-	22.26	-	-	-	-
	H	1.47	3.95	2.30	-	-	-	0.18	-	-	-	-
	O	53.39	61.43	55.82	-	-	-	35.21	-	-	-	-

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Zones		2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11			
Kanpur	Total (T)	88.54	-	-	-	-	-	-	-			
	MC	-	-	-	-	-	-	-	-			
	CF	-	-	-	-	-	-	-	-			
	H	-	-	-	-	-	-	-	-			
	Exotic	-	-	-	-	-	-	-	-			
	Misc	-	-	-	-	-	-	-	-			
Allahabad	Total (T)	94.67	-	74.25	86.85	115.9	88.1	-	-			
	MC	-	-	10	9.0	24	-	-	-			
	CF	-	-	10	9.0	7.2	-	-	-			
	H	-	-	-	-	0	-	-	-			
	Exotic	-	-	-	-	-	-	-	-			
	Misc.	-	-	-	-	34.6	-	-	-			

*No data was available for the Varanasi and Balia centers after the year 1968-69 and for Buxar, Patna and Bhagalpur after the year 1985-89

Table 6: Change in the catch composition downstream from Allahabad between 1958 and 1994

	Allahabad				**Patna**	
	58-66	**72-76**	**79-80**	**93-94**	**58-66**	**93-94**
MC	**38.0**	**29.0**	**21.6**	**16.4**	**26.5**	**4.0**
CF	**22.6**	**23.7**	**21.8**	**44.3**	**17.5**	**7.5**
H	**9.4**	**4.9**	**1.3**	**0.1**	**12.1**	**0.6**
O	**30.0**	**42.2**	**55.5**	**39.2**	**43.9**	**87.9**

Payne *et al.* (2003)

There has been gradual decrease in total catch of major carps where as there is increase in other fishes and marginally of cat fishes at the following centres at different time domain (1958-86) (Figures 6-10).

Table 7: Fish landing (m tons) at different centres (compiled from CIFRI Reports: 1961-2010) (values in parenthesis depict % catch)

Centres	**Year**	**Major Carps**	**Cat fishes**	***T. ilisha***	**Exotic**	**Others**	**Total**
Allahabad	1961-68	97.73 **(45.0%)**	46.31 (21.5%)	22.35 **(10.3%)**	0.0	48.75 (22.6%)	215.14
	1972-80	31.09 (30.6%)	22.67 (22.3%)	2.22 (2.18%)	0.0	45.51 (44.8%)	101.49
	1981-90	35.82 (30.8%)	22.86 (19.6%)	0.99 (0.85%)	0.0	56.95 (48.8%)	116.62
	1991-00	6.65 (10.53)	14.43 **(22.87)**	1.04 (0.16)	0.0	40.99 (64.96)	63.1
	2001-10	14.7 **(13.23)**	10.41 **(9.37)**	0.18 **(0.16)**	39.18 (35.26)	46.68 (42.0)	111.14
Patna	1961-66	23.35 (21.4%)	22.43 (20.6%)	14.08 (12.9%)	0.0	48.82 **(44.9%)**	108.68
	1986-93	7.10 (15.09)	11.67 (24.8%)	0.08 (0.17%)	0.0	28.18 **(59.9%)**	47.04
Bhagalpur	1961-70	18.66 (16.4%)	31.23 (27.5%)	4.27 (8.7%)	0.0	59.02 **(52.1%)**	113.18
	1972-80	11.76 (13.7%)	24.67 (28.8%)	0.68 (0.8%)	0.0	48.45 (56.6%)	85.56
	1981-88	5.98 (6.9%)	26.75 (31.0%)	0.93 (1.07%)	0.0	52.52 **(60.9%)**	86.17

The data (Table 7) reveals that at Allahabad the % catch of carps reduced from 45.0% in 1961-68 to a mere 13.23% in the period (2001-2010) where as catfishes declined from 22.87 (1991-00) to 9.37% (2001-10). Hilsa, the migratory clupeid which used to be a good fishery at Allahabad as 10.3% (1961-68) dropped to a meagre 0.16% (2001-2010).

Similar trends were also reported at Patna and Bhagalpur. The carps decreased at Patna and Bhagalpur. Hilsa nearly disappeared and other fishes of less commercial importance value increased to 44.9 (1961-66) to 59.9% (1986-93) at Patna and 52.14 (1961-70) to 60.9% (1981-88) at Bhagalpur.

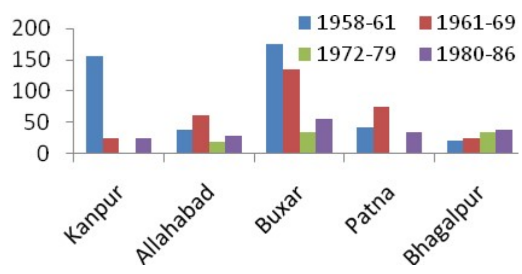

Figure 6: The trend in fish yield (kg/ha) from different stretches of the river Ganga during 1958-86

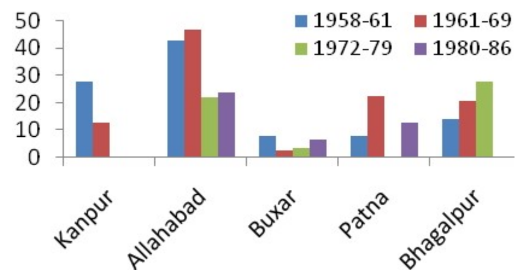

Figure 8: Average annual yield (tons) of catfishes from various stretches of river Ganga during 1958-86

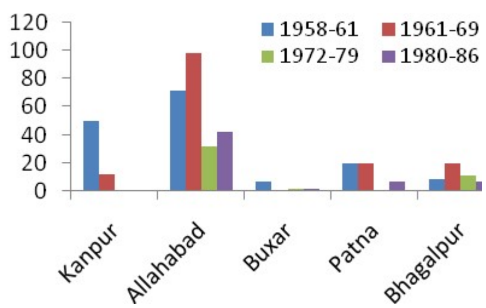

Figure 7: Average annual yield (tons) of major carps from various stretches of river Ganga during 1958-86

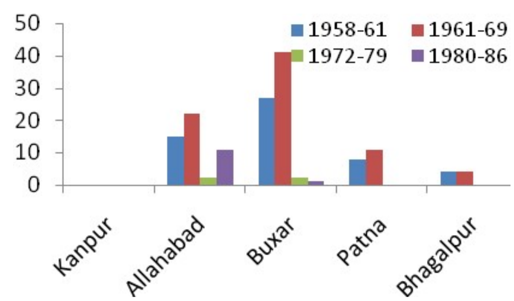

Figure 9: Average annual yield (tons) of Hilsa various stretches of river Ganga during 1958-86

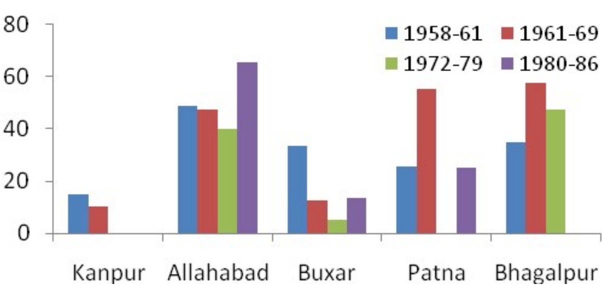

Figure 10: Annual average yield (tons) of miscellaneous fishes from various stretches of river Ganga during 1958-86

With the construction of Farakka barrage, the fishery scenario at Lalgola center about 45 km below Farakka, 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 8. The market arrivals (in tons) of major carps, selected catfishes at Bhagalpur, Rajmahal, Farakka and Lalgola centers during the period (1968) - (2002-03) are reported in Table 9.

Table 8: Catch composition (%) at Lalgola, pre and post Farakka period

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

Table 9: Market arrivals (tons) of major carps (MC), selected catfishes (CF), Hilsa (H) and other (O) fishes during the period 1968-03

		1968	1970	1971	1973	1974	1981	1982	1985-89	2000-01	2002-03
Bhagalpur	MC	-	**17.55**	**12.62**	**11.85**	**8.11**	-	-	4.89	-	-
							-	-		-	-
	CF	-	**30.75**	**35.82**	**30.03**	**15.96**	-	-	22.26	-	-
	H	-	**1.47**	**3.95**	**2.30**	**0.01**	-	-	0.18	-	-
	O	-	**53.39**	**61.43**	**55.82**	**43.33**	-	-	35.21	-	-
Rajmahal	MC	**2.04**	**1.12**	**2.33**	**8.5**	**1.94**	-	-	-	-	-
							-	-	-	-	-
	CF	**3.21**	**4.32**	**7.52**	**17.54**	**3.68**	-	-	-	-	-
	H	**22.48**	**13.75**	**8.80**	**17.66**	**2.83**	-	-	-	-	-
	O	**53.95**	**38.65**	**38.51**	**54.10**	**24.35**	-	-	-	-	-
Farakka	MC	-	-	**6.95**	**7.11**	**1.44**	-	-	-	-	-
							-	-	-	-	-
	CF	-	-	**9.45**	**9.9**	**4.15**	-	-	-	-	-
	H	-	-	**24.32**	**51.85**	**17.83**	-	-	-	-	-
	O	-	-	**18.75**	**31.14**	**19.23**	-	-	-	-	-
Lalgola	MC	**0.15**	**0.07**	-	-	-	**3.16**	**4.34**	**1.25**	**13.62**	**14.59**
	CF	**0.06**	**0.03**	-	-	-	**3.65**	**27.49**	**4.73**	**16.62**	**17.60**
	H	**92.27**	**72.37**	**89.27**	**94.33**	**97.92**	**11.06**	**2.18**	**20.53**	**20.78**	**16.79**
	O	**9.91**	**8.59**	**21.34**	**5.63**	**7.50**	**46.36**	**72.76**	**29.66**	**61.84**	**66.82**

(Pathak and Tyagi, 2010)

6.3 Exotic fishes

Of late, the total fish catches have registered some increase mainly due to increased foothold of exotic fish species, especially *Cyprinus carpio* and *Oreochromis niloticus*. An increase in the growth of exotic fisheries down stream of Allahabad has been observed. Singh *et al.* (2010) indicated that *Cyprinus carpio* and *Oreochromis niloticus*, has almost replaced the other major carps. The percentage which used to be 97.13 (1961-68) of IMC has come down to 14.7 (2001-10) while the population of exotic carps has risen from 0.0% (1961-68) to 39.18% (2001-10). A comparision of data from Singh *et al.* (2010) reveals that the growth of exotic fishes increased while that of local fishes declined in the 250 km stretch between Kanpur to Varanasi (Figure 11).

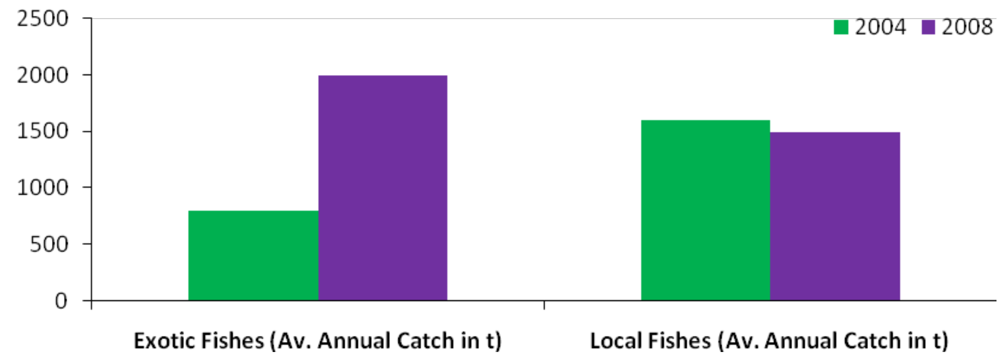

Figure 11: Comparison of data at Kanpur: carps vis-à-vis exotic fishes in the Ganga between Kanpur-Varanasi (2004-2008) (Singh *et al.* 2010)

6.4 Fisheries at Allahabad

Allahabad is a very important station for the potential fish production and catch in the Ganga river. At Allahabad, major carps were main component of fishery in comparison to cat fishes during the period of 1961-1980. Other fishes were the main fishery during 1991-2000. Hilsa was recorded the fourth major component of fishery during 1961-1968 (Figure 12). The catch from the river Ganga is declining gradually. The average catch per kilometer of stretch depict that in 1950s the catch was as high as 1343 kg whereas catch declined to 361 kg during 2000s and to a mere 300 kg/km in 2010 (Figure 13).

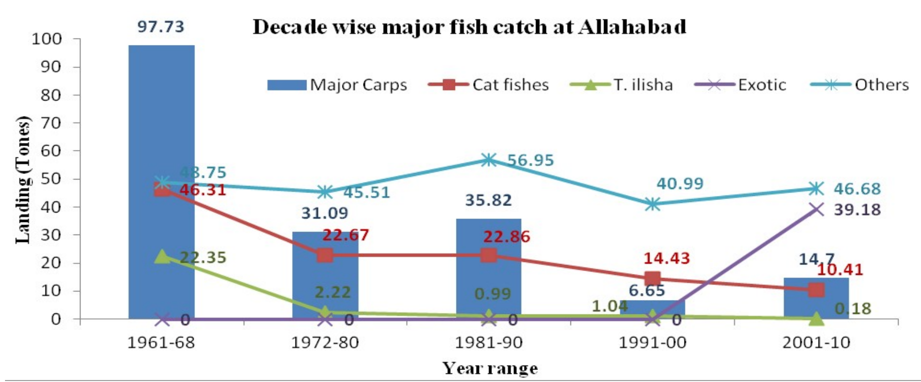

Figure 12: Fish landing at Allahabad (CIFRI Annual Reports 1961-2007)

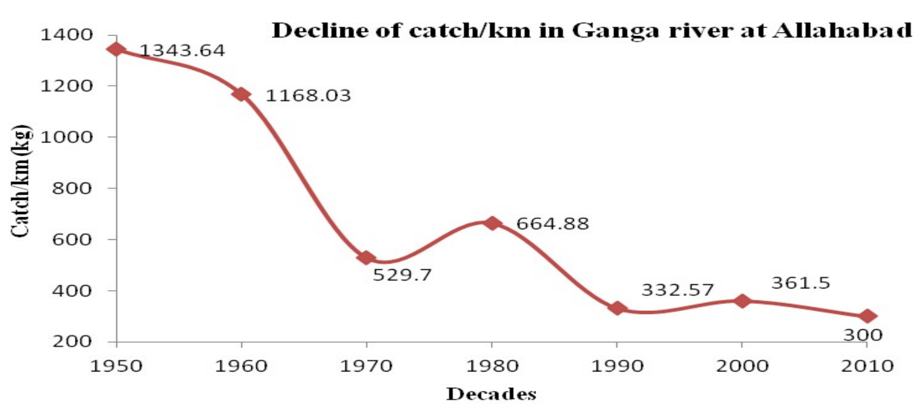

Figure 13: Decline of fish catch/km at Allahabad during 1950s to 2010s

7. Estuarine fisheries

Hooghly Matlah estuarine system is one of largest system of the world and is known for its faunastic richness. It is an important source of fisheries and sustains a large population of fishermen and its supporting trade. The system has fresh water system consisting of main riverine and tributary system, brackish water zone and tidal influence. The Central Inland Fisheries Institute, Barrackpore conducted a survey during 1960-61 to 1977-78 and have noticed significant changes due to:

(i) Commissioning of Farakka barrage in April 1975 which changed the ecology of delta in terms of decline in salinity (greater extension of fresh water zone) and changes in species spectrum of the fish catch, greater abundance of fresh water species and decline in marine species.

(ii) The income from fishing vis-a-vis other sectoral engagements in the fast developing urban complex of Calcutta has undergone a change in ~~depending~~ operational costs and returns of gear and their catch structure**.**

During pre-Farakka period, the tidal effect was felt upto Nabadwip. The entire region was demarcated into four zones (Figure 7a).

1. Nabadwip to Baranagar zone I: Salinity between 0.11-0.36 ppt.
2. Middle zone between Baranagar and Diamond Harbour zone II: Salinity ranged between 0.2-0.59 ppt.
3. Lower zone below Diamond Harbour on the main channel zone III: Salinity varied between 0.2 ppt to near marine values.
4. Zone containing the Rupnarayan tributary joining the main channel (19 km above Diamond Harbour) zone IV: Salinity ranges between 0.43-10.25 ppt.

Zone I, II and IV constitute the upper estuary and zone III the lower zone.

The current situation of the Hooghly estuary has changed entirely. Hooghly estuary extends to a total length of 300 km, with tidal extent reaching upto Nabadwip from seamouth. Based on the salinity distribution, the entire Hooghly estuary has been divided into 3 zones- the 36 km stretch from Fraserganj to Kakdwip as saline zone, the 40 km stretch from Kakdwip to Diamond Harbour as transition zone and the rest 230 km from Diamond Harbour to Nabadwip as freshwater zone (Figure 7b).

1. Freshwater zone (Nabadwip to Diamond Harbour): Salinity 0.04-0.06 ppt.
2. At Diamond Harbour: Salinity 0.09-0.90 ppt.
3. At Kakdwip: Salinity 5.6-26.0 ppt.
4. Saline zone (at Fraserganj): Salinity 22.2-36.3 ppt.

Transition zone

7.1 Total fish yield

The Hooghly Matlah estuary is biologically very productive. The total estimated catch fluctuated between 22,143- 41,564 m tons per year during 1984-85 to 1993-94 and 72098.7 and 63319.8 tonnes during 1998-99 and 2002-2003 (Table 10, Figure 14).

Table 10: Group wise yield (in tons) from Hooghly Matlah estuary (adopted from CIFRI, Barrackpore report of Feb. 1997)

Fish Species Group	1984-1985	1985-1986	1986-1987	1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	1992-1993	1993-1994	Average/Year	Percentage (%)
Clupeids	4492.1	3984.6	4948.4	7581.6	9454.8	6791.9	11958.1	10325.7	9621.1	10181.5	7933.98	24.1
Cat fish	550.9	718.4	425.4	1021.2	895.3	477.1	1811.7	2148.2	1304.1	975.1	1032.74	3.14
Polynemids	152.7	248.1	262	463.5	486.3	266.5	323.2	517.4	100.8	276.2	309.67	0.94
Scianids	3503	4484.9	1264.9	4091	6956.8	4058.3	5520.1	5207.8	4351.7	4291.6	4373.01	13.30
Mullets	10.7	36.4	25.8	25.7	21	12.3	18.2	11.9	9.6	16	18.76	0.05
Ribbon fishes	4812.2	1471.8	1449	2487.3	3784.7	3974.5	1858.1	2151.8	4461.4	2798.6	2924.94	8.9
Bombay duck	4143.5	5179	2548.9	4994.7	7998.9	4713.9	7064.4	4860.7	6247	5276	5302.7	16.13
Prawn	2135	2050	2303	1997	3344.2	2686.5	2618.7	4366.2	2761.8	3973.7	2823.61	8.59
Others	6244.8	5768	8915	8930	8580	10042.7	10391.9	7815.5	8042.5	6789.8	8152.02	24.80
Total	26044.9	23941.2	22142.4	31592	41522	33023.7	41564.4	37405.2	36900	34578.5	32871.43	100

Table cont….

Fish Sp. Group	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	Average/Year	Percentage (%)
Clupeids	20608.3	17243.5	23883.2	20600.2	14583.7	19383.9	29.4
Cat fish	3702.9	3739.9	4435.1	3696.3	3975.2	39.9.9	5.9
Polynemids	558.3	481.7	659.3	447.1	434.1	516.1	0.8
Scianids	8731.1	9761	11340.1	9571.5	7729.5	9426.6	14.3
Mullets	22	19	18.2	32.5	69.4	32.2	0.0
Ribbon fishes	5223.1	3655.5	4979	5735.7	5031.3	49.249	7.5
Bombay duck	8318.2	12302.8	9275.9	11815.1	12358.6	10814.1	16.4
Prawn	2729.9	3916.2	4359.4	4170.6	4615.1	3958.2	6.0
Others	15363.1	11045.8	13148.5	11224.4	14523.8	13061.1	19.8
Total	65258.9	62165.4	72098.7	67293.4	63320.7	66027.0	100

Mitra *et al.* (1997); Nath *et al.* (2004)

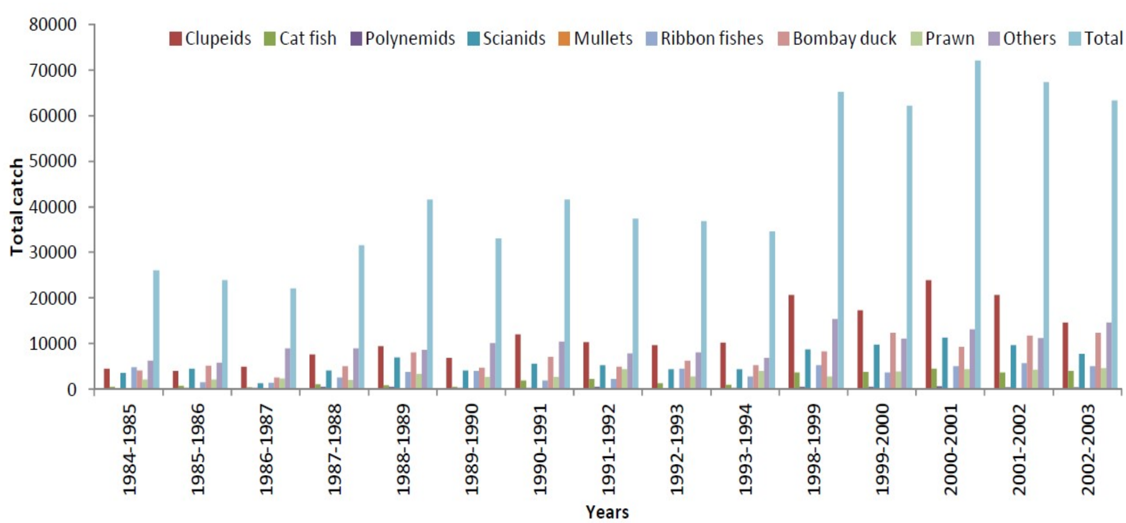

Figure 14: Group wise yield (tons) from Hooghly Matlah estuary

The perusal of the data reveals that the fish catch has increased from 1986-97 to 1992-93 with minor fluctuations. The catch further increased from 1998-99 to 2002-2003.

The fishing takes place throughout the year but increases manifold with onset of monsoon (July to Oct.) to winter months (Nov. to Jan.). The catch is minimal during summer months.

7.2 Zone wise catch

Zones I, II and IV (upper estuarine system) contribute together 6 to 10% of the annual catch and zone III (Lower estuarine system) 90-94%. Marine and neritic species *viz. Harpodon nehereus, Tachysurus jella, Osteogeniosus militaries, Polynemus indicus, Eleutheronem tetradactylum, Coilia* sp.*, Sciaena biauritus, Tenualosa ilisha, Lates calcarifer* and *Mullets* forms the bulk of the catch in zone III.

T. ilisha, Polynemus paradiseus, Pama pama and *Sillago panijus* contribute to the fisheries of the middle zone. All these fishes migrate to fresh water and low saline zones. Zone wise annual landings are given below in Table 11.

Table 11: Zone wise annual landings (m tons) from estuary

Year	Zone 1	Zone 2	Zone 3	Zone 4	Total
1984-85	545.6	457.2	24333	708.8	26045
1985-86	718.4	406.3	22057	760.3	23942
1986-87	505.5	693.6	20285	658.9	22143
1987-88	1034.1	692.6	29277	588.2	31592
1988-89	620	372.6	40000	529.7	41522
1989-90	638.3	407.9	31430	595.3	33078
1990-91	700.8	449.1	39869	550.9	41569
1991-92	691.1	437.4	35574	702.3	37405
1992-93	705.3	391.5	35229	574.3	36900
1993-94	614	450.1	32865	622.2	34557
1998-99	589.5	693.1	63361.8	612.5	65256.9
1999-2000	603.8	686.5	60367.9	507.2	62165.4
2000-2001	595.6	528.7	70264.2	710.2	72098.7
2001-2002	562.3	483	65670.8	577.3	67293.4
2002-2003	828.7	498	61356.7	637.3	63320.7

Mitra *et al.* (1997)

7.3 Species composition of the estuary

The year wise catch, species wise catch, average catch are given in Table 10. The dominant species in order of abundance comprised *Harpodon nehereus* (16.4%), *Tenualosa ilisha* (15.7%), *Pama pama* (11.2%), *Settipina* spp. (8.3%), *Trichiurus* spp. (7.5%), Prawns (6.0%), *Arius jella* (5.4%), *Sciana biauritius* (3.1%), *Coilia* sp. (2.7%), *Pampus argenteus* (3.1%), *Ilisha megaloptera* (1.9%) and *Mackerel* sp. (1.2%). These species together accounted for (82.0%) of the total catch.

Tenualosa ilisha, *Harpodon nehereus*, *Trichiurus* spp., *Ilisha megaloptera*, *Pomadasys argenteus* and prawns constitute the major portion (72.5-81.5%) of the lower zone catches.

Fresh water species were *Rita rita, Sperata aor, Glossogobius giuris, Eutropiichthys vacha* and *Rhinomugil corsula* constituted 2.5-5.1% of the total catch.

7.4 Fishery of important species

The most prized species are *Tenulosa ilisha, Liza parsia, Liza tade, Penaeus monodon, P. indicus, Metapenaeus monoceros, M. brevicornis, Leander styliferus* and *Acetes indicus.*
Tenualosa ilisha (Hilsa) is the most important commercial species. The Hilsa are prominent catch in monsoon (July to Oct.) and winters (Nov. to Jan.). It is reported that Hilsa follows a decadal fishery when they are higher in catch. *viz.*

Years	**Hilsa catch in m tons**
1971-72	6573.3
1981-82	6886.0
1991-1992	6256.5
2001-2002	11547.7

The Hilsa catch varies between 3.9-16.0% of total catch from the estuary.
The annual contribution of *Polynemus paradiseus,* also an important fish, varies between 105.6 to 314.1 m tons with an average of 187 m tons. The fish though constitutes a very small percentage (<1.0%) but, its economical value is high. This fish contributes in large quantities from zone IV and zone II (50-76%). The main season of its availability are April to July and Oct. to Nov.
The Bombay duck *Harpodon nehereus* (Mitra *et al.,* 1997) is also a very important commercial species constituting about 11.5-19.3%. The catch varies between 2,549 and 1,999 m tons per year. It is a typical marine and neritic species. It remains totally absent from upper fresh water stretches.

8. Summary statement

The procurement of sufficient secondary data from different sources and collation of information presented in the status report sums up the following (summary) statements:

1. The fresh water fish population from Gangnani to Farakka is represented by 181 species under 89 genera and 37 families.
2. The Hooghly-Matlah estuary is represented by 103 brackish water fish species belong to 67 families of Osteichthyes and other 13 species belong to 7 families of common fin fishes (Chondrichthys).
3. More than 100 fish species including fresh water and Hooghly estuary have commercial importance.
4. Gill nets drag nets and cast nets are most commonly used as commercial fishing gears. Other nets being used are scoop nets, traps, trawls and purse nets.
5. **(i)** The upper Ganga is characterized by the presence of snow-trout *Schizothorax richardsonii* (Gangnani to Devprayag) and Mahseer *Tor putitora* and *Tor tor* (Devprayag to Haridwar).

(ii) Indian major carps: *Labeo rohita, Labeo calbasu, Cirrhinus mrigala* and *Catla catla* are the important fishes of middle and lower Ganga (upto Farakka) and can be taken as indicators of system health.

(iii) Ganga also supports a good population of catfishes.

(iv) Exotic-species (*Cyprinus carpio* and *Oreochromis niloticus*) have started competing with carps especially in lower Ganga downstream of Allahabad (latest reports indicate that exotic fishes are moving upstream and have been sighted upstream of Allahabad also).

(v) Hilsa is a characteristic fish of Hooghly estuary along with *Harpodon nehereus* and *Polynemus paradiseus*.

7. There is a remarkable reduction in the production capacity of fresh water fishes, attributed mainly due to anthropogenic activities *viz.*

- Flow interception due to large Hydro-electric projects in upper Ganga.
- Abstraction of large quantities of water for irrigation in the form of canals (Upper, Madhya and Lower Ganga canals).
- Transport of large quantities of industrial pollution in rivers (Ram Ganga and Kali).
- Increase of pollution load from urban areas along the river (domestic, industrial, treated and untreated).
- Increase in the sediment load due to deforestation.
- Indiscrimnate fishing in middle and lower Ganga.
- Fishing of important juvenile species especially of Indian major carps.

8. The catch composition of commercially important fishes has under gone significant change.

- The total catch of fresh water species has gone down significantly at Allahabad. The total catch in year 1961-68 was 215.14 tons has been reduced to 111.14 in year 2001-2010 tons at Allahabad center, while at Patna center 108.68 tons (1961-66) to 47.04 tons (1986-1993) and at Bhagalpur center the value reduced from 113.18 tons (1961-70) to 86.17 tons (1981-88).
- At Allahabad the catch/km declined from 1343.64 to 300 kg between 1950-2010.
- The IMC at Allahabad decreased from 97.73 tons to 14.7 tons between 1961-68 to 2001-10.
- There is a gradual change in the large catfish population (but not as much as the fall of major carps).
- There is sufficient increase in other fishes of low commercial value.

9. In the Hooghly Matlah estuary the catch and catch composition has changed significantly. The total catch has gone up in the years between 1984-85 (26044.9 tons/year) to 2002-03 (63319.8 tons/year) ≈2.43 times and also the Hilsa fish in the years between 1984-85 (4492.1 tons/year) to 2002-03 (14583 tons/year) ≈3.2 times.

References

Behera, M.D., Basu, M. and Pal, M. (2012). Ecology and biodiversity of lower Ganga river basin: Farakka–Gangasagar. Gangapedia website; Report code: 026_GBP_IIT_ENB_DAT_04_Ver 1_Jun 2012.

Bora, U. and Rahman, S. (2012). Floral and faunal Diversity in lower Ganga: Varanasi – Farakka. Gangapedia website; Report code: 025_GBP_IIT_ENB_DAT_03_Ver 1_Jun 2012.

Bilgrami, K.S. and Munshi, J.S.D. (1979). *In*: Limnological survey and impact of human activates on the river Ganges, Technical report MAB. Project - 5 (UNESCO), pp. 91.

Bilgrami, K.S. (1991). Biological profile of the Ganga: Zooplankton, fish, birds and other minor fauna. *In*: Krishna Murti, C.R., Bilgrami, K.S., Das, T.M., Mathur, R.P. (eds.) The Ganga: A scientific study. Northern Book Centre, New Delhi, India. pp. 81-94.

CIFRI, (2008). Annual report for the year 2007. CIFRI, Barrackpore, West Bengal, India.

CIFRI, (1970-1984). Annual Reports. CIFRI, Barrackpore, West Bengal, India.

De, D.K. (1999). Environment and Fisheries. *In:* Ecology, Fisheries and stock assessment of Indian Rivers (Eds. Sinha, M., Khan, M.A. and Jha, B.C.). pp. 129-140. CIFRI. Bull. No. 90.

Ghosh, A. (2007). Present status of fish diversity in a 12 km stretch in the fresh water zone of the Hooghly estuary. Abstract, National Symposium on Ecosystem Health and Fish for Tomorrow. CIFRI and IFSI, Barrackpore. Dec, 14-16. pp. 22.

Ghosh, A. (2008). Fishes of Hoogly Eustary. CIFRI, Barrackpore. Bull. No. 155.

Gupta, R.A. and Tyagi, R.K. (1992). Analytical approach to analysis of fish stocks of the Ganga river system. *J. Inland Fish. Soc. India*, **24(2):** 20-27.

Hamilton, B. (1822). An account of the fishes found in the river Ganga and its branches. Archibad Constable and Company, Edinburg. pp. 405.

Jhingran, V.G. (1991). Fish and Fisheries of India. Revised and enlarged third edition. Hindustan Publishing Corp, New Delhi, India. pp. 727.

Jhingran, A.G. (1989). Impact of environmental perturbations on the fisheries ecology of river Ganga, A synopsis, CIFRI, Barrackpore (W.B.), India. pp. 26.

Jhingran, V.G. (1975). Fish and Fisheries of India, Hindustan Publishing Corporation, Delhi, India. pp. 136-139.

Jhingran, A.G. and Ghosh, K.K. (1978). The fisheries of the Ganga river system in the context of Indian aquaculture, *Aquaculture,* **14:** 141-162.

Jhingran, A.G. and Pathak, V. (1988). Impact on man-induced environmental modifications on productivity potential and energy dynamics of river Ganga. *Journal of Inland Fisheries Society of India*, **20:** 43-53.

Mathur, R.P., Shivam, A., Verma, J., Kapoor, V. and Shrivastava, A. (2011). Floral and faunal diversity of upper Ganga segment: Gangotri – Haridwar (Upstream Bhimgoda Barrage). Gangapedia website; Report code: 020_GBP_IIT_ENB_DAT_01_Ver 1_Dec2011.

Mathur, R.P., Verma, J., Shrivastava, A. and Kapoor, V. (2012). Floral and faunal diversity in middle Ganga segment: Haridwar – Varanasi. Gangapedia website; Report code: 024_GBP_IIT_ENB_DAT_02_Ver 1_Jun 2012.

Misra, K.S. (1959). An aid to the identification of common commercial fishes of India and Pakistan. *Rex. Indian Mus,* **5(1-4):** 1-320.

Mitra, P.M., Karmakar, H.C., Sinha, M., Ghosh, A. and Saigal, B. N. (1997). Fisheries of the Hooghly-Matlah estuarine system: An appraisal. Central Inland Capture Fisheries Research Institute (ICAR), Barrackpore, Bull. No. 67.

Mitra, P.M., Karmaker, H.C., Ghosh, A.K., Mondal, N.C., Sen, H.K. and Das, B.N. (2001). Fisheries of Hooghly-Matlah estuarine system: Further appraisal (1994-95 to 1999-2000). CIFRI, Bull No. 109.

Nath, D., Mishra, R.N. and Karmakar, H.C. (2004). The Hoogly Estuarine System- Ecological flux, fishery resources and production potential. CIFRI, Barrackpore, Bull. No. 130.

Nautiyal, P., Shivam, A., Verma, J. and Dwivedi, R. (2009). Quarterly progress report (September 09) for the Living Ganga Programme with respect to environmental flow. WWF, New Delhi, India.

Negi, K.S. and Malik, D.S. (2005). Fish fauna of Ganga river at Rishikesh. *Himalayan Journal of Environmental Zoology*, **19(2):** 145-148.

Pathak, V. and Tyagi, R.K. (2010). Reverine ecology and fisheries vis-à-vis hydrodynamic alterations: Impacts and remedial measures. CIFRI, Barrackpore, Bull. No. 161.

Payne, A.I., Sinha, R., Singh, H.R. and Huq, S. (2003). A review of the Ganges Basin: its fish and fisheries. In: Welcomme, R.L. and Petr, T. (eds) Proceedings of the Second International Symposium of Management of Large Rivers for Fisheries, Vol. 1. Bangkok, Thailand: RAP Publication, FAO Regional Office for Asia and the Pacific. pp. 229-252.

Rao, R.J. (1995). Studies on Biological Restoration of Ganga River in Uttar Pradesh: An indicator species approach, Project report, School of Studies in Zoology, Jiwaji University, Gwalior, India.

Ray, P., Singh, S.B. and Sehagal, K.L. (1966). A study of some aspects of the rivers Ganga and Yamuna at Allahabad (U.P) in 1958-59. *Proc. Nat. Acad Sci. India,* **36B(3):** 235-272.

Sahgal, J.K. (1973). Fish and Fisheries of Aligarh with notes on the fish catches. *J. Inland Fish. Soc.*, India, **5:** 23-30.

Sharma, R. C. (1988). Fish and fisheries of snow fed river Bhagirathi from of Garhwal Himalayas. In: Proceeding of the National Academy of Sciences, **58(B), II:** 181-192.

Sinha, M. and Khan, M.A. (2001). Impact of environmental aberrations of fisheries of the Ganga (Ganges) River. *Aquatic Ecosystem Health Management,* **4**(**4):** 493-504.

Sinha, M., Khan, M.A. and Jha, B.C. (1999). Ecology, fisheries and fish stock assessment of Indian rivers, CIFRI, Barrackpore, Bull. No. 90.

Sinha, M., De, D.K. and Jha, B.C. (1998). The Ganga–Environment and fishery. Central Inland Fisheries Research Institute, Barrackpore, India. pp. 142.

Sinha, M., Laal, A.K., Singh, B., Tyagi, R.K., Pathak, V. and Katiha P.K. (1997). Likely Impact on Aquatic ecology in the context of barrage construction across the River Ganga at Kanpur. CIFRI Consultancy Report, Barrackpore, West Bengal, India. pp. 1-44.

Sinha, R.K. and Prasad, K. (1988). Final Technical Report of Ganga Basin Research Project, Patna University, India. pp. 88.

Singh, A.K., Pathak, A.K. and Lakra, W.S. (2010). Invasion of an exotic fish-common carp, *Cyprinus carpio* (Actinopterygii: Cypriniformes: Cyprinidae) in the Ganga river, India and its impacts. *Acta ichthyologica et piscatorial*, **40(1):** 11-19.

Singh, H.R. (2008). Ecological parameters of the Bhagirathi, Final Technical Report, submitted to National Thermal Power Corporation (NTPC), India, pp. 1-78.

Singh, H.R., Badola, S.P. and Dobriyal, A.K. (1983). Geographical distributional list of Ichthyofauna of the Garhwal Himalaya with some new records. *Journal of Bombay Natural History Society*, **84:** 126-132.

Vass, K.K., Samanta, S., Suresh, V.R., Katiha, P.K. and Mandal, S.K. (2008). Current status of river Ganges. Central Inland Fisheries Research Institute, Barrackpore, India. Bull. No. 152. pp. 1-31.

Vass, K.K., Mondal, S.K., Samanta, S., Suresh, V.R. and Katiha, P. K. (2010). The environment and fishery status of the River Ganges. *Aquatic Ecosystem Health & Management*, **13(4):** 385-394.

Verma, N.S., Chitray, B.B. and Saxena, D.B. (1961). Fishes of Kanpur District. *Proc. of National Academy of Sciences*, pp. 213-232.

WWF, (2004). Information Sheet on Ramsar Wetlands (RIS), pp. 1-14.

Appendix-I

Comparative account reflecting the avilable flora and fauna as food chain:

Ecological groups	Taxonomic categories	Ecological Stretch	Name of organisms
Phytoplankton	Bacillariophyceae	**UG1**	*Achnanthes, Amphipleura, Bacillaria, Ceratoneis, Cyclotella, Cymbella, Denticula, Diatoma, Fragilaria, Hantzschia, Meridion, Navicula, Nitzschia, Pinnularia, Rhoicosphenia, Stephanodiscus, Synedra*
		UG2	*Achnanthes, Amphipleura, Amphora, Bacillaria, Ceratoneis, Cocconeis, Cyclotella, Cymatopleura, Cymbella, Denticula, Diatoma, Epithemia, Fragilaria, Frustulia, Gomphoneis, Gomphonema, Hantzschia, Melosira, Meridion, Navicula, Nedium, Nitzschia, Pinnularia, Rhoicosphenia, Stauroneis, Stephanodiscus, Synedra, Tabellaria*
		UG3	*Achnanthidium, Amphipleura, Amphora, Aulacoseira, Bacillaria, Ceratoneis, Cocconeis, Cyclotella, Cymbella Denticula, Diatoma, Diploneis, Encyonema, Fragilaria, Frustulia, Gomphoneis, Gomphonema, Gyrosigma, Hantzschia, Melosira, Meridian, Navicula, Nedium, Nitzschia, Pinnularia, Planothidium, Rhoicosphenia, Stauroneis, Stephanodiscus, Synedra, Tabellaria*
		MG	*Achnanthes, Achnanthidium, Amphora, Anomoeoneis, Asterionella, Aulacoseira, Bacillaria, Caloneis, Ceratoneis, Cocconeis, Craticula, Cyclotella, Cymbella, Cymbopleura, Diatoma, Diploneis, Encyonema, Epithemia, Fallacia, Fragilaria, Frustulia, Gesslaria, Gomphonema, Gyrosigma, Hantzschia, Luticola, Mastogloia, Melosira, Meridian, Navicula, Nitzschia, Pinnularia, Placoneis, Planothidium, Reimeria, Rhopalodia, Sellaphora, Stauroneis, Stephanodiscus, Surirella, Synedra, Tabellaria*
		LGA	*Achnanthes, Achnanthidium, Amphora, Asterionella , Caloneis, Chaetoceros, Cocconeis, Cyclotella, Cymatopleura, Cymbella, Diatoma, Eunotia, Fragillaria, Gomphonema, Grammatophora, Gyrosigma, Hantzschia, Leptocylindrus, Mastogloia, Meridian, Melosira, Navicula, Nitzschia, Pinnularia, Pleurosigma, Sellaphora, Surirella, Synedra, Tabellaria, Thalassiosira, Terpsinoe*
		LGB	*Achnanthes, Amphiprora, Amphora, Anomoeoneis, Asterionella, Asteromphalus, Bacillaria, Bacteriastrum, Biddulphia, Caloneis, Campylodiscus, Chaetoceros, Climacodium, Climacosphenia, Cocconeis, Corethron, Coscinodiscus, Cyclotella, Cymbella, Diatoma, Diploneis, Ditylum, Eucampia, Eunotia, Fragilaria, Frustulia, Gomphonema, Gyrosigma, Hemiaulus, Hemidiscus, Isthmia, Lauderia, Leptocylindrus, Lithodesmium, Melosira, Navicula, Nitzschia, Paralia, Pinnularia, Planktoniella, Pleurosigma, Rhizosolenia, Rhopalodia, Skeletonema, Stauroneis, Stephanopyxis, Surirella, Synedra, Thalassiosira, Thalassiosirs, Thalassiothrix, Thalassionema, Triceratium, Tropidoneis*
	Chlorophyceae	**UG1**	*Gonatozygon*, *Ulothrix*
		UG2	*Characium, Cladophora, Closterium, Cylindrocystis, Desmidium, Genicularia, Gonatozygon, Hydrodictyon, Microspora, Oedogonium, Protococcus, Sphaeroplea, Spirogyra, Stigeoclonium, Ulothrix, Zygnema*
		UG3	*Cladophora, Chaetophora, Closterium, Cosmarium, Eudorina, Hydrodictyon, Oedogonium, Pandorina, Pediastrum, Scenedesmus, Spirogyra, Ulothrix*
		MG	*Actinastrum, Ankistrodesmus, Botryococcus, Bumillaria, Celastrum, Chlamydomonas, Chlorella, Chlorobottrys, Chlorococcum, Chlorogonium, Cladophora, Coelastrum, Closterium Cosmarium, Crucigenia, Desmidium, Dictyosphaerium, Diaspora, Eudorina, Gonatozygon, Hormidium, Hydrodictyon, Kirchneriella, Micractinium, Microspora, Mougeotia, Netrium, Oedogonium, Oocystis, Palmella, Pandorina, Pediastrum, Pleurodermus, Protococcus, Scenedesmus, Selenastrum, Sphaerocystis, Spirogyra, Staurastrum, Stigeoclonium, Tetrahedron, Tetraspora, Treubaria, Tribonema, Ulothrix, Volvox, Zygnema*
		LGA	*Actinastrum, Ankistrodesmus, Bulbochaete , Chaetophora, Chara, Chlamydomonas, Chlorella, Chlorococcum, Chodatella, Cladophora, Closteriopsis, Closterium, Coelastrum, Cosmarium, Crucigenia, Cylindrocapsa, Desmidium, Enteromorpha, Euastrum, Eudorina, Golenkinia, Gloeotaenium, Hydrodictyon, Kirchneriella, Microspora, Nitella, Oocystis, Oedogonium, Pandorina, Pediastrum,*

			Protococcus, Schroederia, Selenastrum, Scenedesmus, Sorastrum, Sphaeroplea, Spirogyra, Stigeoclonium, Tetraedron, Treubaria, Ulothrix, Volvox, Zygnema
		LGB	*Bambusina, Boodleopsis, Chaetomorpha, Chara, Chlorella, Cladophora, Cladophorella, Closterium, Cosmarium, Desmidium, Dictyosphaerium, Enteromorpha, Euastrum, Eudorina, Franceia, Gonatozygon, Heterosiphonia, Hyalotheca, Lola, Micrasterias, Netrium, Nitella, Oedogonium, Onychonema, Pediastrum, Phyllobium, Pleurotaenium, Radiococcus, Rhizoclonium, Scenedesmus, Sphaeroplea, Spirogyra, Spirotaenia, Spondylosium, Staurastrum, Stigeoclonium, Tetradinium, Triplastrum, Triploceras, Ulothrix, Ulva, Uronema, Zygnema*
	Cyanophyceae	**UG1**	*NO*
		UG2	*Anabaena, Oscillatoria, Phormidium, Rivularia*
		UG3	*Anabaena, Chroococcus, Gloeocapsa, Lyngbya, Microcystis, Nostoc, Oscillatoria, Phormidium, Rivularia, Spirulina*
		MG	*Agmenellum, Anabaena, Anacystis, Aphanocapsa, Chroococcus, Cylindrospermum, Lyngbya, Merismopedia, Microcystis, Nostoc, Oscillatoria, Phormidium, Raphidiopsis, Rivularia, Spirulina,*
		LGA	*Anabaena, Anabaenopsis, Anacystis, Aphanocapsa, Aphanothece, Arthrospira, Aulosira, Calothrix, Chroococcus, Cylindrospermum, Gloeocapsa, Gloeotrichia, Lyngbya, Mastigocladus, Merismopedia, Microcoleus, Microcystis, Myxosarcina, Nostoc, Nodularia, Oscillatoria, Phormidium, Pseudanabaena, Raphidiopsis, Rivularia, Schizothrix, Spirulina, Symploca, Synechococcus, Synechocystis, Trichodesmium, Tolypothrix*
		LGB	*Anabaena, Anabaenopsis, Aphanocapsa, Aphanothece, Arthosporia, Arthrospira, Aulosira, Calothrix, Camptylonemorpsis, Chamaesiphon, Chlorogloean, Chroococcus, Crinalium, Cylindrospermum, Dermocarpa, Fischerella, Gloeocapsa, Gloeotrichia, Hapalosiphon, Homeothrix, Hydrocoleum, Johannesbaptistia, Katagnymene, Lyngbya, Mastigocladus, Merismopedia, Microchaete, Microcystis, Myxosarcina, Nostoc, Nostocopsis, Oscillatoria, Phormidium, Plectonema, Porphyrosiphon, Pseudanabaena, Raphidiopsis, Schizothrix, Scytonema, Spirulina, Stichosiphon, Stigonema, Symploca, Synechocystis, Trichodesmium, Wollea, Xenococcus*
	Euglenophyceae	**UG1**	NO
		UG2	*NO*
		UG3	*Euglena, Genicularia*
		MG	*Euglena, Phacus, Trachelomonas*
		LGA	*Euglena, Heteronema, Phacus*
		LGB	*Euglena, Phacus*
	Dianophyceae	**MG**	*Ciratium, Peridinium, Gymnodinium*
		LGA	*Ciratium, Peridinium*
		LGB	*Ceratium, Dinophysis, Noctiluca, Peridinium, Protoperidinium, Pyrophacus*
	Synurophyceae	**LGA**	*Synura*
	Chrysophyceae	**MG**	*Botryococcus*
		LGA	*Chrysococcus, Dinobryon*
		LGB	*NO*
	Xanthophyceae	**UG1**	*Voucheria*
		UG2	*Voucheria*
		UG3	*Voucheria*
		MG	*Tribonema*
		LGA	*Tribonema, Voucheria*
		LGB	*Tribonema, Voucheria*

	Cryptophyceae	**LGA**	*Chroomonas*
	Rhodophyceae	**LGA** **LGB**	*Batrachospermum, Compsopogon* *Bostrychia, Caloglossa, Catenella, Ceramium, Compsopogon, Gelidium, Gelidiella, Polysiphonia, Porphyra, Pterosiphonia*
	Phaeophyceae	**LGB**	*Colpomenia, Dictyota*
Periphyton	Bacillariophyceae	**UG1** **UG2** **UG3** **MG** **LGA** **LGB**	*Achnanthidium, Amphora, Cymbella, Diatoma, Fragilaria, Frustulia, Gomphonema, Hippodonta, Nitzschia, Reimeria, Tabellaria* *Achnanthidium, Adlafia, Amphora, Caloneis, Ceratoneis, Cocconeis, Cyclotella, Cymbella, Denticula, Diatoma, Diatomenella, Encyonema, Encyonopsis, Fallacia, Frustulia, Gomphoneis, Gomphonema, Gyrosigma, Hantzschia, Hippodonta, Melosira, Meridion, Navicula, Nitzschia, Opephora, Pinnularia, Planothidium, Reimeria, Sellaphora, Staurosira, Stauroneis, Surirella, Synedra, Tabellaria, Tetracyclus* *Achnanthidium, Amphora, Cocconeis, Cymbella, Diatoma, Diploneis, Encyonema, Fragilaria, Gesslaria, Gomphonema, Gyrosigma, Hantzschia, Luticola, Melosira, Meridion, Navicula, Nitzschia, Planothidium, Reimeria, Sellaphora, Staurosira, Surirella, Synedra* *Achnanthes, Achnanthidium, Amphora, Anomoeoneis, Asterionella, Aulacoseira, Caloneis, Cocconeis, Cyclotella, Cymbella, Diatoma, Encyonema, Fragilaria, Frustulia, Gomphonema, Gyrosigma, Mastogloia, Melosira, Navicula, Nitzschia, Pinnularia, Placoneis, Planothidium, Pleurosigma, Stauroneis, Surirella, Synedra, Tabellaria* *NO* *NO*
	Chlorophyceae	**UG1** **UG2** **UG3** **MG** **LGA** **LGB**	*NO* *Chlorococcum, Cladophora, Closterium, Cosmarium, Desmidium, Hydrodictyon, Microspora, Oedogonium, Stigeoclonium, Ulothrix, Zygnema* *Cladophora, Oedogonium, Spirogyra, Stigeoclonium, Ulothrix* *Chlorella, Chlorogonium, Cladophora, Closterium, Cosmarium, Dictyosphaerium, Draparnaldia, Hydrodictyon, Kirchneriella, Oedogonium, Oocystis, Pandorina, Pediastrum, Scenedesmus, Schizogonium, Spirogyra, Ulothrix, Zygnema* *NO* *NO*
	Cyanophyceae	**UG1** **UG2** **UG3** **MG** **LGA** **LGB**	*NO* *Anabaena, Coccochloris, Oscillatoria, Phormidium* *Lyngbya, Oscillatoria, Phormidium, Spirulina* *Anabaena, Coelosphaerium, Lyngbya, Merismopedia, Microcystis, Nostoc, Oscillatoria, Phormidium, Rivularia* *NO* *NO*
	Euglenophyceae	**UG1** **UG2** **MG** **LGA** **LGB**	*NO* *NO* *Euglena* *NO* *NO*
	Xanthophyceae	**MG**	*Tribonema, Voucheria*

		LGA	*NO*
		LGB	*NO*
Zooplankton	Protozoans	**UG1**	*NO*
		UG2	*NO*
		UG3	*NO*
		MG	*Actinophrys, Actinosphaerium, Amoeba, Arcella, Colpidium, Difflugia, Euglena, Euplotes, Paramecium, Vorticella*
		LGA	*Arcella, Centropyxis, Difflugia, Paramecium, Vorticella*
		LGB	*NO*
	Rotifera	**UG1**	*NO*
		UG2	*NO*
		UG3	*NO*
		MG	*Asplanchna, Brachionus, Euchlanis, Filinia, Gastropus, Hexarthra, Keratella, Lecane, Notholca, Philodina, Platyias, Polyarthra, Rotaria, Testudinella*
		LGA	*Asplanchna, Brachionus, Euchlanis, Filinia , Keratella, Lecane, Monostyla, Polyarthra, Rotaria, Synchaeta, Testudinella, Trichocera*
		LGB	*Anuraeopsis, Ascomorpha, Asplanchna, Beauchampiella, Brachionus, Cephalodella, Colurella, Conochilus, Dicranophorus, Dipleuchlanis, Euchlanis, Filinia, Hexarthra, Horaella, Keratella, Lecane, Lepadella, Macrochaetus, Mytilina, Platyias, Polyarthra, Pompholyx, Rotaria, Scaridium, Testudinella, Trichocerca, Trichotria, Ttripleuchanis*
	Copepoda	**UG1**	*NO*
		UG2	*NO*
		UG3	*NO*
		MG	*Cletocamptus, Cyclops*
		LGA	*Cyclops , Diaptomus, Mesocyclops, Neodiaptomus*
		LGB	*Acartia, Acartiella, Heliodiaptomus, Labidocera, Mesocyclops Microcyclops, Neodiaaptomus Paracyclops, Phyllodiaptomus Pseudochydorus, Pseudodiaptomus, Tropocyclops, Tropodiaptomus,*
	Cladocera	**UG1**	*NO*
		UG2	*NO*
		UG3	*NO*
		MG	*Anura, Bosmina, Ceriodaphnia, Daphnia, Diaphanosoma, Diaptomus, Leydigia, Mesocyclops, Moina, Moinodaphnia, Nauplius, Simocephalus*
		LGA	*Alona, Bosmina, Bosminopsis, Ceriodaphnia, Daphnia, Diaphanosoma, Moina, Simocephalus*
		LGB	*Alona, Alonella, Bosmiopsis, Ceriodaphnia, Daphnia, Diaphanosoma, Dunhevedia, Eschinisca, Euryalona, Graptoleberis, Grimaldina, Guernella, Ilyocryptus, Kurzia, Latonopsis, Leydigia, Macrothrix, Moina, Moinodaphnia, Notoalona, Oxyurella, Pleuroxus, Pseudosida, Scapholeberis, Simocephalus*
	Other Crustaceans	**LGB**	*Conchoecete, Dorippe, Euryalona, Metopograpsus, Pachygrapsus, Ptychognathus, Pyxidognathus, Susarma*
	Cnidarians	**LGB**	*Acromitus, Aequorea, Blackfordia, Bougainvillia, Cassiopea, Diadumene, Edwardsia, Limnocnida, Liriope, Moerisia, Netrostoma, Nevadne, Obelia, Paracondylactis, Pelocoetes. Phytocoeteopsis, Phytocoetes. Pseudodiaptomus, Tamoya, Versuriga*
	Chaetognatha	**LGB**	*Krohnnitta, Sagitta*
	Miscellaneous	**MG**	Chironomus larva, Mosquito larvae, Nematodes, Oligochaetes
Zoobenthos	Plecoptera (nymph	**UG1**	Perlodidae (*Arcynopteryx, Isoperla*), Nemouridae (*Nemoura*), Chloroperlidae,

	of stone flies)		Peltoperlidae
		UG2	*Arcynopteryx, Isoperla, Nemoura*
		UG3	PRESENT
		MG	Chloroperlidae (*Alloperla*), Perlidae (*Neoperla*), Perlodidae (*Isoperla*)
		LGA	NO
		LGB	NO
	Odonata (nymphs of dragon flies)	**UG1**	NO
		UG2	*Argia*
		UG3	Agrionidae, Gomphidae
		MG	Aeshnidae (*Aeshna*), Corduliidae (*Epicordulia, Helocordulia, Macromia*), Gomphidae (*Hagenius*), Lestidae (*Lestes*)
		LGA	*Asiagomphus, Cordulegaster, Ischnura, Macrogomphus, Paragomphus, Potomarcha*
		LGB	NO
	Ephemeroptera (mayfly, nymphs)	**UG1**	Ameletidae (*Ameletus*), Baetidae (*Baetis*,), Heptageniidae (*Iron*), Caenidae (*Caenis*), Ephemeridae (*Ephemera*)
		UG2	*Ameletus, Baetis, Caenis, Cynigma, Ephemera,* Ephemerellidae (*Ephemerella*), *Iron,* Leptophlebiidae (*Leptophlebia*)
		UG3	Baetidae, Heptageniidae, Leptophlebiidae
		MG	Baetidae, Caenidae, Ephemerellidae, Heptageniidae (*Epeorus, Rhithrogena*), Leptophlebiidae, Neoephemeridae, Siphlonuridae
		LGA	*Baetis, Cloeon, Ephemerella*
		LGB	NO
	Trichoptera (caddis larvae)	**UG1**	Hydropsychidae (*Hydropsyche*)
		UG2	*Brachycentrus, Glossosoma, Hydropsyche, Leptocella, Limnephilids*
		UG3	Psychomyiidae, Hydropsychidae
		MG	Brachycentridae, Glossosomatidae, Helicopsychidae (*Helicopsyche*), Hydropsychidae, Hydroptilidae, Limnephilidae (*Hesperophylax*, *Limnephilus*), Leptoceridae (*Mystacides, Leptocella, Triaenodes*), Polycentropodidae (*Cyrnellus* sp.), Rhyacophilidae
		LGA	*Glossosoma, Hydropsychidae, Limephilus, Triaenodes*
		LGB	NO
	Diptera	**UG1**	Athericidae (*Atherix*), Blephariceridae (*Bibiocephala*), Chironomidae (*Chironomus*), Dixidae (*Dixa*), Simuliidae (*Simulium*), Tipulidae (*Megistocera*)
		UG2	*Antocha, Atherix, Bibiocephala, Chironomus, Dixa, Megistocera, Psychoda, Simulium*
		UG3	Helidae, Chironomidae, Tabanidae, Tipulidae
		MG	Athericidae (*Atherix*), Chironomidae, Culicidae (*Culex*), Dixidae (*Dixa*), Heleidae, Limoniidae (*Antocha*), Muscidae (*Limnophora*), Simuliidae (*Simulium*), Syrphidae (*Eristalis*), Tabanidae (*Tabanus*), Tipulidae (*Megistocera*)
		LGA	*Anopheles, Chironomus, Clinotanypus, Culex , Monopelopia*
		LGB	NO
	Coleoptera (water beetles)	**UG1**	Emidae (*Promoresia*)
		UG2	*Dytiscus, Hydrophilus, Promoresia, Psephenus*

		UG3	Elmidae, Dytiscidae, Psephenidae
		MG	Amphizoidae (*Amphizoa*), Chrysomelidae (*Donacia*), Dytiscidae (*Cybister, Dytiscus*), Elmidae (*Stenelmis*), Gyrinidae (*Dineutus*), Hydrochidae (*Hydrochus*), Hydrophilidae (*Hydrophilus*), Noteridae (*Hydrocanthus*), Psephenidae (*Psephenus*)
		LGA	NO
		LGB	NO
	Hymenoptera	**UG1**	NO
		UG2	NO
		UG3	NO
		MG	Agaonidae
		LGA	NO
		LGB	NO
	Nematodes & Molluscs	**UG1**	NO
		UG2	PRESENT
		UG3	PRESENT
	Molluscs (Gastropoda)	**MG**	Bithyniidae (*Bithynia*), Lymnaeidae (*Lymnaea*), Pleuroceridae (*Goniobasis*), Planorbidae (*Gyraulus, Indoplanorbis*), Subulinidae (*Subulina*), Thiaridae, Viviparidae (*Bellamya, Vivipara*)
	Pelycepoda		Corbiculidae (*Corbicula*)
	(Gastropoda)	**LGA**	*Amnicola, Assiminia, Bellamya, Brotia, Digoniostoma, Ferrissia, Gangetia, Glessula, Gyraulus, Haitia, Hydrobia, Indoplanorbis, Lymnaea, Mekongia, Melania, Melanoides, Pila, Planorbis, Quickia, Stenothyra, Thiara*
	Pelycepoda		*Corbicula, Lamellidens, Novaculina, Parreysia, Pisidium, Scaphula*
	Gastropoda	**LGB**	*Amalda, Architectonica, Assiminea, Asthenotoma, Bellamya, Brotia, Cassidula, Cerithidea, Clithon, Columbella, Iravadia, Larina, Natica, Olivancillaria, Pila, Polinices, Potamacmaea, Pseudanachis, Septaria, Stenothyra, Telescopium, Terebra, Thais, Thiara, Tubiola, Umbonium*
	Pelycepoda		*Barnea, Corbicula, Cuspidaria, Gafrarium, Glauconome, Lamellidens, Laternula, Mactra, Martesia, Meretrix, Novaculina, Nucula, Paphia, Parreysia, Pitar, Solen, Sphenia, Theora, Trachycardium*
	Cephalopoda		*Loligo, Octopus, Sepia, Sepiella*
	Scaphopoda		*Dentalium*
	Annelids	**UG1**	NO
		UG2	NO
		UG3	NO
		MG	Present (Glossoscolecidae)
	Polychaete	**LGA**	*Alboglossiphonia, Asiaticobdella, Aulodrilus, Aulophorus, Barbronia, Branchiodrilus, Branchiura, Chaetogaster, Dero, Glyphidrilus, Limnodrilus, Nais, Namalycastis, Nephthys, Odontobdella, Ozobranchus, Perionyx, Placobdelloides, Pristina, Salifa*
		LGB	*Barantolla, Capitella, Ceratonereis, Chloeia, Dendronereides, Dendronereis, Diopatra, Eteone, Eunice, Ganganereis, Gattyana, Glycera, Hesione,*

			Heteromastus, Hyalinoecia, Isolda, Laonome, Lumbrineris, Lycastonereis, Lysidice, Marphysa, Mastobranchus, Minuspio, Namalycastis, Neanthes, Owenia, Perinereis, Pherusa, Polydora, Prionospio, Pseudopolydora, Sabellaria, Spio, Sternaspis, Talehsapia
	Oligocheata		*Aelosoma, Allonais, Aulodrilus, Branchiodrilus, Branchiura, Chaetogaster, Dero, Dichogaster, Drawida, Eutyphoeus, Lampito, Lennogaster, Limnodrilus, Metaphire, Nais, Octochaetona, Pellogaster, Perionyx, Polypheretima, Pontodrilus, Priatina, Slavina, Stylarias, Tubifex*
	Hirudinea		*Glossiphonia, Haemadipsa, Helobdella, Hemiclepsis, Hirudinaria, Ozobranchus, Pontobdella*
	Arthopoda	**UG1**	NO
	Crustacea and others	**UG2**	NO
		UG3	NO
		MG	Cyprididae (*Cypris, Hetrocypris*)
		LGA	*Barythelphusa, Caridina, Gangemysis, Hymenicoides, Macrobrachium, Neorhynchoplax, Parathelphusa, Tachaea*
		LGB	*Achaearanea, Aculops, Anilocra, Aphis, Araneus, Arctosa, Argiope, Artema, Bomis, Calappa, Catantops, Cheiracanthium, Cirolana, Clubiona, Conchoecete, Crossopriza, Cyclosa, Cymothoa, Cyrtophora, Diplatys, Dorippe, Euborellia, Euophrys, Exosphaeroma, Forcipula, Gasteracantha, Geocoris, Gerenia, Hersilia, Heteropoda, Hippasa, Hysteroneura, Labidura, Larinia, Leucauge, Lutica, Lycosa, Lyssomanes, Marpisa, Matuta, Melanaphis, Mesambria, Metisolabis, Myrmarachne, Nala, Neoscona, Nephila, Nerocila, Nysius, Oecobius, Oedignatha, Oligonychus, Oxyopes, Pachygrontha, Paraconophyma, Paradiplatys, Parawixia, Pardosa, Paromius, Phidippus, Plexippus, Poekilocerus, Pseudopachybrachius, Pyrgomorpha, Rhene,Salticus, Scalopidia, Schizotetranychus, Scytodes, Simalio, Singa, Spariolenus, Sphaeroma, Sphingius, Stegodyphus, Tagasta, Toxoptera, Uloboru, Zygeilla*
	Echinodermata	**UG1**	*NO*
		UG2	*NO*
		UG3	*NO*
		MG	*NO*
		LGA	*NO*
		LGB	*Acaudina, Amphioplus, Astropecten, Chaetodiadema, Clypeaster, Echinodiscus, Goniopecten, Labidoplax, Laganum, Luidia, Ophiactis, Ophiocnemis, Synaptula, Temnopleurus, Thorsonia*

NO: Not reported in the stretch.

Appendix-II

Fishes in all stretches of river Ganga (UG1-LG4): **(Compilation from secondary data)**

Species	Families	UG1	UG2	UG3	MG1	MG2	MG3	MG4	MG5	LG1	LG2	LG3	LG4
Acanthopagrus latus	Sparidae												+
Ailia coila	Schilbeidae						+	+	+	+	+	+	+
Ambasis baculis	Ambassidae												+
A. commersoni	Ambassidae												+
Amblyceps mangois	Ambyceptidae				+								
Amblypharyngodon melettinus	Cyprinidae						+						
A. microlepis	Cyprinidae							+					
A. mola	Cyprinidae					+	+	+	+	+	+	+	+
Anabas testudineus	Anabantidae						+		+	+	+	+	+
Andontostaoma chacunda	Clupeidae												+
A. manmina	Clupeidae												+
Anguilla bengalensis	Anguillidae											+	+
Apocryptes bato	Gobiidae												+
Aplocheilius panchax	Aplocheilidae												+
Arius arius	Aridae												+
A. gagora	Aridae												+
A. jella	Aridae												+
A. sagar	Aridae												+
A. sona	Aridae												+
Aspidoparia jaya	Cyprinidae							+		+	+	+	
A. morar	Cyprinidae				+			+	+	+			
Badis badis	Badidae						+				+	+	+
Bagarius bagarius	Sisoridae			+	+	+	+	+	+	+	+	+	+
Barilius barila	Cyprinidae		+	+	+	+	+		+				
B. barna	Cyprinidae		+										
B. bendelisis	Cyprinidae		+	+	+				+	+			
B. bola	Cyprinidae		+	+	+	+	+	+	+	+	+		
B. dimophicus	Cyprinidae				+								
B. modestus	Cyprinidae						+						
B. tileo	Cyprinidae								+				
B. vagra	Cyprinidae		+	+	+	+	+						
Bathygobius orbicularis	Gobiidae												+
Batrachocephaly mino	Aridae												+
Batrichthys grunnies	Batrachoidae												+
Boleopthalmus dussumieri	Gobiidae												+
Botia almorhae	Cobitidae				+								
B. dario	Cobitidae			+	+		+	+	+	+	+	+	+
B. dayi	Cobitidae								+			+	
B. lohachata	Cobitidae				+					+	+	+	+
Brachygobius nunus	Gobiidae												+
Bregmaceros mcclellandi	Bregmacerotidae												+
Carangoides malabaricus	Carangidae												+
Caranx carangus	Carangidae												+
Catla catla	Cyprinidae				+	+	+	+		+	+	+	+
Chaca chaca	Chacidae						+					+	
Chagunius chagunio	Cyprinidae				+				+	+	+	+	
Chanda baculis	Ambassidae											+	

C. nama	Ambassidae						+	+	+	+	+	+	+
C. ranga	Ambassidae						+	+	+	+	+	+	
Channa orientalis	Channidae											+	+
C. gachua	Channidae			+	+		+	+	+		+	+	
C. marulius	Channidae				+	+	+	+	+		+	+	+
C. punctatus	Channidae					+	+	+	+		+	+	+
C. stewartii	Channidae						+	+					
C. striatus	Channidae				+	+	+	+	+	+	+	+	+
Chela atpar	Cyprinidae						+			+			
C. bacaila	Cyprinidae									+	+	+	
C. laubuca	Cyprinidae						+		+	+	+	+	
Chirocentrus dorab	Chirocentridae												+
Cirrhinus mrigala	Cyprinidae				+	+	+	+	+	+	+	+	+
C. reba	Cyprinidae				+	+	+	+	+	+	+	+	+
Clarias batrachus	Clariidae			©		+	+	+	+	+	+	+	+
Clupisoma garua	Schilbeidae		©	©	+	+	+	+	+	+	+	+	+
C. montana	Schilbeidae				+								
Coilia dussumiere	Engraulidae												+
C. ramcorli	Engraulidae												+
C. reynalidy	Engraulidae												+
Colisa chuna	Osphronemidae								+	+	+	+	
C. fasciata	Osphronemidae			+	+		+	+	+		+	+	+
C. lalia	Osphronemidae						+						+
Corica soborna	Clupeidae												+
Crossocheilus latius latius	Cyprinidae		+	+	+		+		+				
Cyanoglossus arel	Cyanoglossidae												+
C. cyanoglossus	Cyanoglossidae												+
C. lingua	Cyanoglossidae												+
Cyprinus carpio	Cyprinidae								+	+	+	+	
Dactylopterus orientalis	Dactylopteridae												+
Danio dangila	Cyprinidae												+
D. devario	Cyprinidae			+	+		+		+	+	+		+
D. rerio	Cyprinidae			+	+		+		+	+	+		
Drepene puncata	Ephippididae												+
Eleutheronema tetradactylum	Polynemidae												+
Eleotris fusca	Eleotrididae												+
Erethistes hara	Erethistidae											+	
E. pusillus	Erethistidae											+	
Esomus danricus	Cyprinidae			+	+	+		+	+	+	+	+	+
Euryglossa orientalis	Soleidae												+
Eutropiichthys murius	Schilbeidae							+	+				
E. vacha	Schilbeidae					+	+	+	+	+	+	+	+
Gagata cenia	Sisoridae							+	+		+		+
G. gagata	Sisoridae										+		
Garra annandalei	Cyprinidae										+	+	
G. gotyla gotyla	Cyprinidae		+	+	+		+	+	+			+	
G. lamta	Cyprinidae		+										
G. prashadi	Cyprinidae		+				+						
Gazza minuta	Leiognathidae												+
Gerres filamentosa	Gerridae												+
G. oyena	Gerridae												+
Gerreomorpha setifer	Gerridae												+
Glossogobius giuris	Gobiidae				+		+	+	+	+	+	+	+

Glyptothorax cavia	Sisoridae		+										
G. conirostris	Sisoridae		+										
G. dakpathri	Sisoridae				+								
G. indicus	Sisoridae				+								
G. lineatus	Sisoridae			+									
G. madraspatanum	Sisoridae		+										
G. pectinopterus	Sisoridae		+	+	+								
G. telchita	Sisoridae								+				
G. trilineatus	Sisoridae		+										
Goniolosa manmina	Clupeidae								+			+	+
Gobiopterus chuno	Gobiidae											+	+
Gudusia chapra	Clupeidae					+	+	+	+	+	+	+	+
G. variegata	Clupeidae											+	
Hara hara	Sisoridae											+	+
Harpodon nehereus	Harpadontidae												+
Heteropneustes fossilis	Heteropneustidae				+	+	+	+	+	+	+	+	+
Hilsa kelee	Clupeidae												+
Hypophthalmichthys molitrix	Cyprinidae								+				
Hyporhampus limbatus	Hemirasmphidae												+
Ilisha elongata	Pristigasteridae												+
I. filigera	Pristigasteridae												+
I. megaloptera	Pristigasteridae								+	+			+
Johnius coitor	Sciaenidae							+	+		+	+	+
J. gangeticus	Sciaenidae									+	+	+	+
Kurtus indicus	Kurtidae												+
Labeo angra	Cyprinidae			+									
L. bata	Cyprinidae				+	+		+	+	+	+	+	+
L. boga	Cyprinidae				+		+			+	+		
L. boggut	Cyprinidae									+	+	+	
L. calbasu	Cyprinidae			+	+	+	+	+	+	+	+	+	+
L. dero	Cyprinidae		+	+	+					+			
L. dyocheilus	Cyprinidae		+	+	+	+							
L. fimbriatus	Cyprinidae									+	+	+	
L. gonius	Cyprinidae			+	+	+	+	+	+	+	+		
L. pangusia	Cyprinidae				+		+		+	+	+	+	
L. rohita	Cyprinidae				+	+	+	+	+	+	+	+	+
Lates calcarifer	Latidae											+	+
Leiocassis rama	Bagridae							+					
Leiognathus equulus	Leiognathidae												+
Lepidocephalus guntea	Cobitidae				+		+		+	+	+	+	+
Liza macrolepis	Mugilidae												+
L. parsia	Mugilidae												+
L. tade	Mugilidae												+
Lobotes surinamensis	Lobotidae												+
Lutjanus argentimaculatus	Lutjanidae												+
L. johni	Lutjanidae												+
Lycodontis tile	Muraenidae											+	+
Macrognathus aculeatus	Mastacembelidae					+			+				+
M. aral	Mastacembelidae									+	+	+	
M. pancalus	Mastacembelidae				+		+		+	+	+	+	+
Mastacembelus armatus	Mastacembelidae			+	+	+	+	+	+	+	+	+	+
M. pancalus	Mastacembelidae												+
Megalaspis cordyla	Carangidae												+
Megalops cyprinoides	Megalopidae											+	+

Microphis cuncalus	Syngnathidae												+
Minous coccineus	Synancellidae												+
Monopterus cuchia	Synbranchidae										+		+
Mugil cephalus	Mugilidae												+
M. corsula	Mugilidae					+							
Mystus bleekeri	Bagridae					+	+	+	+		+	+	
M. cavasius	Bagridae					+	+	+	+	+	+	+	+
M. gulio	Bagridae											+	+
M. menoda	Bagridae							+				+	
M. tengara	Bagridae			©	+	+	+	+	+		+		
M. vittatus	Bagridae					+	+	+	+	+	+	+	+
Nandus nandus	Nandidae				+		+	+	+		+	+	+
Nangra nangra	Sisoridae						+					+	
N. punctata	Sisoridae								+	+	+	+	
N. viridescens	Sisoridae								+				
Nemacheilus beavani	Balitoridae		+	+			+						
N. botia	Balitoridae			+	+		+	+	+		+	+	
N. corica	Balitoridae				+		+						
N. montanus	Balitoridae		+	+	+		+						
N. multifasciatus	Balitoridae		+				+						
N. rupicola	Balitoridae		+		+								
N. savona	Balitoridae		+	+			+						
N. scaturingina	Balitoridae						+						
N. zonatus	Balitoridae		+				+						
Notopterus chitala	Notopteridae				+	+	+	+	+	+	+	+	+
N. notopterus	Notopteridae				+	+	+	+		+	+	+	+
Odontamblyopus rubicundus	Gobiodidae												+
Ompok bimaculatus	Siluridae						+	+		+	+	+	+
O. boopis	Siluridae						+						
O. pabda	Siluridae						+	+		+	+	+	+
O. pavel	Siluridae							+			+	+	
O. pabo	Siluridae												+
Ophiocephalus punctatus	Channidae				+								
Oreochromis niloticus	Cichlidae									+	+	+	+
Oryzias melastegma	Oryziidae												+
Osteogeneiosus militaris	Aridae												+
Osteobrama cotio	Cyprinidae						+	+	+	+	+	+	
Otolithoides biauritus	Sciaenidae												+
Oxygaster bacaila	Cyprinidae					+	+	+					
O. gora	Cyprinidae					+				+			
Pama pama	Sciaenidae											+	+
Pangasius pangasius	Pangasiidae						+	+			+	+	+
Parambassis ranga	Ambassidae									+	+	+	
Parastromateus niger	Parastromateidae												+
Parupeneus indicus	Mullidae												+
Periopthalmodon schlosseri	Gobiidae												+
Platycephalus indicus	Platycephalidae												+
Plotosus canius	Plotosidae												+
Polynemus paradiseus	Polynemidae											+	+
Pomadasys argenteus	Haemulidae												+
P. maculatus	Haemulidae												+
Pompus argenteus	Stromateidae												+
Pseudoambasis ranga	Ambassidae									+	+	+	+

P. lala	Ambassidae												+
Pseudecheneis sulcatus	Sisoridae		+										
Pseudapocryptes lanceolatus	Gobiidae												+
Pseudotropius atherinoides	Schilbeidae							+		+	+	+	
Psidodonophis boro	Ophichthdae												+
Pterois russellii	Scorpaenidae												+
***Puntius* sp.**	Cyprinidae							+					
P. chagunio	Cyprinidae					+		+					
P. chola	Cyprinidae				+		+			+	+	+	
P. chrysopterus	Cyprinidae									+	+		
P. conchonius	Cyprinidae				+					+	+	+	+
P. sarana sarana	Cyprinidae			+	+		+	+		+	+	+	+
P. sophore	Cyprinidae			+	+		+	+	+	+	+	+	+
P. ticto	Cyprinidae			+	+		+	+		+	+	+	+
Raconda russeliana	Pristigasteridae												+
Raiamas bola	Cyprinidae			+	+				+				
Rasbora daniconius	Cyprinidae			+	+		+			+	+	+	+
R. elanga	Cyprinidae						+						
Rhinomugil corsula	Mugilidae			©	+			+	+		+	+	+
Rita rita	Bagridae			©	+	+	+	+	+	+	+	+	+
Salmostoma bacaila	Cyprinidae			©	+				+	+	+	+	+
S. phulo	Cyprinidae										+		
S. untrahi	Cyprinidae								+	+	+	+	
Sardinella melanura	Clupeidae												+
Saurida tumbil	Synodontidae												+
Scatophagus argus	Scatophagidae												+
Schizothoracthys esocinus	Cyprinidae		+										
S. progastus	Cyprinidae		+	+	+								
Schizothorax curvifrons	Cyprinidae		+										
S. intermedius	Cyprinidae		+										
S. micropogan	Cyprinidae		+										
S. niger	Cyprinidae		+										
S. plagiostomus	Cyprinidae		+	+	+								
S. richardsonii	Cyprinidae		+		+								
S. sinuatus	Cyprinidae		+	+	+								
Sciaena biauritus	Sciaenidae												+
Sciamugil cascasia	Mugilidae								+	+	+	+	+
Securicula gora	Cyprinidae								+	+	+	+	
Secutor insidiator	Leiognathidae												+
S. ruconis	Leiognathidae												+
Setipinna brevifilis	Engraulidae									+	+	+	+
S. phasa	Engraulidae							+	+	+	+	+	+
S. taty	Engraulidae												+
Sillago sithama	Sillaginidae												+
Sillaginopsis panijus	Sillaginidae											+	+
Silonia silondia	Schilbeidae					+		+			+	+	+
Sisor rabdophorus	Sisoridae							+		+			
Sperata aor	Bagridae					+	+	+	+	+	+	+	+
S. seenghala	Bagridae				+	+	+	+	+	+	+	+	+
Stigmatogobius sadanundio	Gobiidae												+
Stolephorus indicus	Engraulidae												+
Stromateus cinereus	Stromateidae												+
Strongylura strongylura	Belonidae												+
Synapyura albomaculata	Soleidae												+

Taenioides anguillaris	Gobiodidae												**+**
T. cirraatus	Gobiodidae												**+**
Tenualosa ilisha	Clupeidae							**+**	**+**	**+**	**+**	**+**	**+**
Terapon jarbua	Teraponidae												**+**
T. theraps	Teraponidae												**+**
Tetraodon cutcutia	Tetraodontidae				**+**					**+**	**+**	**+**	**+**
T. fluviatilis	Tetraodontidae										**+**	**+**	
Triacanthus brevirostris	Triacanthidae												**+**
Triturus haumala	Trituridae												**+**
T. savala	Trituridae												**+**
Thryssa purava	Engraulidae												**+**
Tor chilinoides	Cyprinidae		**+**										
T. putitora	Cyprinidae		**+**	**+**	**+**	**+**	**+**						
T. tor	Cyprinidae		**+**	**+**	**+**		**+**	**+**					
Upeneus sulphureus	Mullidae												**+**
U. vittatus	Mullidae												**+**
Uranoscopus congnatus	Uranoscopidae												**+**
Valamugil cunnesius	Mugilidae												**+**
Wallago attu	Siluridae					**+**	**+**	**+**		**+**	**+**	**+**	**+**
Xenentodon cancila	Belonidae			**+**	**+**		**+**	**+**		**+**	**+**	**+**	**+**

© Species indicated are rare/ stray catch.

Besides the above list few taxas were reported for which no conformation was available. The list of the same is given below:

Fish*	Family	Zone
Rasbora elanga	Cyprinidae	MG3
***Puntius* sp.**	Cyprinidae	MG4
Nangra viridescens	Sisoridae	MG5
Mugil corsula	Mugilidae	MG2
Leiocassis rama	Bagridae	MG4
Glyptothorax telchita	Sisoridae	MG5
Colisa chuna	Belontiidae	MG5
Barilius modestus	Cyprinidae	MG3
Barilius tileo	Cyprinidae	MG5
Amblypharyngodon microlepis	Cyprinidae	MG4

*The list of fishes which were reported from only one substretch in middle Ganga for which confirmation could not be ascertained.

Appendix-III

Combined list of fishes from the estuary:

ANGUILLIDAE
*Anguilla bengalensis**
OPHICHTHDAE
Psidodonophis boro
NOTOPTERIDAE
*Notopterus notopterus**
*N. chitala**
CLUPEIDAE
Andontostaoma manmina
A. chacunda
Corica soborna
*Gadusia chapra**
*Gonealosa manmina**
Hilsa kelee
Sardinella melanura
*Tenualosa ilisha**
CHIROCENTRIDAE
Chirocentrus dorab
PRISTIGASTERIDAE
Ilisha elongata
I. feligera
I. megaloptera
Raconda russeliana
ENGRAULIDAE
Coilia dussumiere
C. ramcorti
C. reynalidy
*Setipinna phasa**
S. taty
S. brevifilis
Stolephorus indicus
Thryssa purava
CYPRINIDAE
*Amblypharyngodon mola**
*Catla catla**
*Cirrhina mrigala**
*C. reba**
*Dani devario**
D. dangila
*Esomus danricus**
*Labeo bata**
*L. calbasu**
*L. rohita**
*Puntius conchonius**
*P. sarana sarana**
*P. sophore**
*P. ticto**
*Rasbora daniconius**
*Salmostoma bacaila**
COBITIDAE
*Botia lohochata**
*B. dario**
*Lepidocephalus guntea**
BAGRIDAE
*Mystus vittatus**
M. cavasius
*M. gulio**
*Rita rita**
*Sperata aor**
*S. seenghala**
SCHILBEIDAE
*Aila coila**
*Clupisoma garua**
*Eutropiichthys vacha**
*Silonia silondia**
PANGASIDAE
*Pangasius pangasius**
SILURIDAE
*Ompak bimaculatus**
*O. pabo**
*O. pabda**
*Wallaga attu**
SISSORIDAE
*Bagarius bagarius**
*Gagata cenia**
CLARIIDAE
*Clarius batrachus**
HETEROPNEUSTIDAE
*Heteropneustis fossalis**
ARIDAE
Arius arius
A. gagora
A. jella
A. sagar
A. sona
Batrachocephalus mino
Osteogeneiosus militaris
HARPADONTIDAE
Harpodon nehereus
SYNODONTIDAE
Saurida tumbil
BREGMACEROTIDAE
Bregmaceros mcclellandi
CENTROPOMIDAE
*Lates calcarifer**
AMBASSIDAE
Ambasis baculis
A. commersoni
*Pseudombasis ranga**
*P. lala**
LEIOGNATHIDAE
Leiognathus equulus
Gazza minuta
Secutor ruconis
S. insidiator
GERRIDAE
Gerres filamentosa
G. oyena
Gerreomorpha setifer
LUTJANIDAE
Lutjanus johni
L. argenti maculates
NANDIDAE
*Nandus nandus**
BADIDAE
*Badis badis**
ANABANTIDAE
*Anabastes testudineus**
OSPHRONEMIDAE
*Colisa fasciatus**
C. lalius
SCATOPHAGIDAE
Scatophagus argus
POLYNEMIDAE
Eleutheronema tetradactylum
*Polynemus paradiseus**
URANOSCOPIDAE
Uranoscopus congnatus
GOBIIDAE
Apocryptes bota
Brachygobius nunus
Boleopthalmus dussumieri
*Glossogobius giuris**
Gobiopterus chuno
Pseudapocryptes lanceolatus
Periopthalmodon schlosseri
Stigmatogobius sadanundio
GOBIODIDAE
Bathygobius orbicularis
Odontamblyopus rubicundus
Taenioides anguillaris
T. cirraatus
ELEOTRIDIDAE
Eleotris fusca
SILLAGINIDAE
Sillago sithama
Sillaginopsis panejus
CARANGIDAE
Carangoides malabaricus
Caranx carangus
Megalaspis cordyla
PARASTROMATEIDAE
Parastromateus niger

STROMATEIDAE	
	Pompus argenteus
	Stromateus cinereus
EPHIPPIDIDAE	
	Drepene punctata
MULLIDAE	
	Parupeneus indicus
	Upeneus vittatus
	U. Sulphureus
TERAPONIDAE	
	Terapon jarbua
	Terapon theraps
TRITURIDAE	
	Triturus haumala
	T. savala
SCIAENIDAE	
	Johinus coitor
	J. gangeticus
	Pama pama*
	Otolithoides biauritus
	Sciaena biauritus
LOBOTIDAE	
	Lobotes surinamensis
HAEMULIDAE	
	Pomadasys maculatus
	P. argenteus
SPARIDAE	
	Acanthopagrus latus
CICHLIDAE	
	Oreochromis nloticus
MUGILIDAE	
	Liza parsia
	L. tade
	L. macrolepis
	Mugil cephalus
	Rhinomugil corsula*
	Sciamugil cascasia*
	Valamugil cunnesieus
MASTACEMBELIDAE	
	Mastacembelus armatus*
	M. pancalus
	Macrognatus aculeatus*
	M. puncalus
TETRADONTIDAE	
	Tetradon cutcutia*
TRIACANTHIDAE	
	Triacanthus brevirostris
HEMIRASMPHIDAE	
	Hyporhampus limbatus
BELONIDAE	
	Xentendon cancila*
	Strongylura strongylura
ORYZIIDAE	
	Oryzias melastegma
APLOCHEILIDAE	
	Aplocheilius panchax
SYNGNATHIDAE	
	Microphis cuncalus
DACTYLOPTERIDAE	
	Dactylopterus orientalis
CHANNIDAE	
	Chanda nama*
	Channa marulius*
	C. orientalis*
	C. punctatus*
	C. striatus*
SYMBRANCHIDAE	
	Monopterus cuchia
CYANOGLOSSIDAE	
	Cyanoglossus arel
	C. cyanoglossus
	C. lingua
SOLEIDAE	
	Euryglossa orientalis
	Synaptura albomaculata
SCORPAENIDAE	
	Pterois russellii
SYNANCELLIDAE	
	Minous coccineus
PLATYCEPHALIDAE	
	Platycephalus indicus
BATRACHOIDAE	
	Batrichthys grunnies
PLOTOSIDAE	
	Plotosus canius
KURTIDAE	
	Kurtus indicus
MURAENIDAE	
	Lycodontis tile
MEGALOPIDAE	
	Megalops cyprinoides
TRICHIURIDAE	
	***Trichiurus* spp.**

* The species marked were also recorded in fresh water zone (UG-LG3)

Appendix-IV

Cartillngineous fishes (Class- Chondrichthyes) of Hooghly estuary:

Families	Species
Carcharhinidae	*Aetobatus narinari*
Carcharhinidae	*Carcharhinus limbatus*
Carcharhinidae	*Glyphis gangeticus*
Dasyatidae	*Dasyatis bleekeri*
Dasyatidae	*D. marginata*
Dasyatidae	*D. stephen*
Dasyatidae	*D. uarnak*
Dasyatidae	*D. zugei*
Hemiscylliidae	*Chiloscyllium griseum*
Pristidae	*Pristis microdon*
Rhinobatidae	*Rhinobatos annandalei*
Sphyrnidae	*Eusphyra blochii*
Stegostomalidae	*Stegostoma fasciatum*

Appendix-V

Gears used in the Ganga river:

Gear Used In The Ganga River (Fresh Water Zone)			
(Major Drag Net)			
Gear with mesh Size	**Area of Operation**	**Season of Operation**	**Probable catch**
Mahajal (5-12 cm)	Haridwar d/s	Intensively used in winter Oct./Nov. to March/April	Large size *Catla, Rohu, Mrigal, Calbasu*, *Sperata*, *Pangus*.
Paundhi Jal (like Mahajal)(4-8 cm)	Varanasi to Patna at middle stretch only	October-July	Mostly Major Carps, Cat fishes, *Hilsa, Pangus, Silondia* etc.
Kadhiya Jal (Similar to Mahajal) (12-15 cm)	Operated mostly in deep waters during summer around Allahabad, Mirzapur & Varanasi	Summer	Mainly Major Carps and larger catfishes.
Par Jal (5-8 cm)	Yamuna	–	Mostly Major Carps and Catfishes.
Darwari (1.5-3.5 cm)	Allahabad Zone	Winter and summer November-June	Small fishes like *Garua, Vacha, Banspati, Juveniles of Carps.*
Chaundhi Jal (8-10 cm)	Most prevalent in stretches of Ganga around Allahabad	Whole year except during monsoon, Maximum in summer	Besides *Mystus* sp., *Mrigal* is also captured.
Chhanta Jal (4-8 cm)	Because of its entangling properties it is suitable even in deep waters.	Whole year except during monsoon, Maximum in summer	All species, but mostly juveniles of Carps and Cat fishes.
Joha Jal (4-8 cm)	Deep pools of Ganga where currents are mild	November to April	Mostly *Mrigal, Catla, Aor* and *Seenghala*.
Ghanaili Jal (1-4 cm)	Restricted to monsoon season only in Bihar and in UP-round the year	–	Almost all fishes that come in the sweep.
Berjal (largest of dragnets 5-10 cm)	Below Rajmahal in Bihar	After monsoon when water starts receding	Mostly *Hilsa*, *Silondia*, *Pangus* and Major Carps.
Tana Ber Jal- (Smaller dragnet 4-8 cm)	Lower reaches of Ganga around Bhagalpur.	–	–
Chandi Jal (2-3 cm)	Upper Ganga system, shallow clear and calm water towards mid river.	–	Mullets, *Garua, Vacha, Chela* spp. etc.
Patia Jal	Upper stretches of Ganga narrow and shallow nalas		Only small sized fishes caught.
(Minor Drag Net)			
(a) Dondi Jal (2 cm) **(b) Hala Jal (2-3 cm)**	– West Bengal	– –	Carp juveniles, smaller Catfish and others like *Chela* etc. Carp juveniles, smaller, Catfish and others like *Chela* etc.
Chote Jal	Lower reach of Yamuna around Allahabad Narrow sheet of water	During first monsoon when breeders ascend the fields to breed	Mostly matured Mrigal, *Catla, Rohu, Calbasu, Mystus* spp., *Wallago* etc.
Bayali Jal	Stretch of Yamuna around Allahabad.	–	*Calbasu* and *Rita* taking shelter in creeks of rocky bed.
Jhingur Jal	Middle Stretch of Ganga	October to May	–
(Gill Nets)			
Gochhali Jal	–	January to July	Big Catfishes and Carps, *Bagarius,*

(10-30 cm)		also during monsoon	*Wallago, Silondia, Mystus* sp.
Dharmo Jal (20-30 cm)	Ganga around Allahabad	Monsoon	Major Carps move for spawning.
Tiar Jal (15-30 cm)	Shallow waters	December to July	Mystus sp. Commonly captured.
Phasla Jal (16-25 cm)	Entire Ganga system	–	*Rohu, Catla,* Mrigal, Aor, *Wallago* and other bigger fishes are captured.
Chandi Jal (4-5 cm)	Mostly in West Bengal for *Hilsa* fishing	–	*Hilsa* fishing
Panjia Jal (15-20 cm)	Patna and Bhagalpur of Bihar		Major Carps and Catfishes.
Saraila Jal (15-30 cm)	Between Varanasi and Patna.	–	Cat fishes. Sometimes *Catla, Rohu* and Mrigal.
Phansa Jal (5 cm)	Buxar-*Hilsa* (Bihar)	November-March	*Hilsa*
Phans Jal (15-25 cm)	Lower Stretch in Murshidabad Dist.	–	Large size *Rohu, Catla* and other fishes.
Bhasa Kona Jal (5 cm)	–	July-October	Primary *Hilsa*.
	(Purse Net)		
Sangla Jal (5-10 cm)	Near Allahabad increases in concentration along Ganga down stream	Mostly monsoon and early winter months	Exclusively for *Hilsa*. Besides *Phasa, Garua* and *Vacha* are also rarely caught.
Sangila Jal (8-18 cm)	Middle and lower stretches of Ganga	October-December	Mostly bigger specimens of Major Carps and Cat fishes.
Kharki Jal similar to Sangla Jal	–	During monsoon	Hilsa
	(Scoop Net)		
(a) Ghanch Jal (4-8 cm) **(b) Kharra Jal (Similar to Ghanch Jal in measurement)**	Below Confluence (Allahabad) –	– October-March	Main catch-*Hilsa.*
Paunti Jal (5-8 cm)	Lower stretch of Ganga below Patna	Fast current during monsoon and post monsoon months	*Hilsa*, *Goonch*, *Silondia*, Major Carps.
Farhara Jal like Ghanch Jal (1-1.5 cm)	Allahabad and Varanasi	Round the year	Carp minmous and other small fishes.
Mang Bisara Jal (Biggest scoop net) (1-3 cm)	Buxar-Patna	–	All fishes big and small sizes.
Thehra Jal (Big scoap net)	Santal Parganas and Murshidabad districts of Bihar & W. B.	During monsoon when Hilsa ascend for spawing	Mostly *Hilsa.*
Bisari Jal (Common scoop net) (0.5-2 cm)	Entire stretch of Ganga.	Off seasons in shallow waters near bank.	*Chela, Morar, Chapra,* and other small fishes like carp, smaller Cat fishes shrimps etc.
Lokani Jal	Around Allahabad	Summer and Winter	Mullets only.
Bhesal Jal	Lower stretch of Ganga in West Bengal	–	Major Carps, *Hilsa,* Cat fishes occasionally.
	(Cast Nets)		
Jhinguri jal	Throughout the Ganga,		Small fishes like Carp minnows,

(0.5-2 cm)	generally from bank also from below Varanasi & Ballia.		Catfishes, *Chela* spp. Shrimps etc. Fingerlings of major carps and bigger prawns.
Adhaukhi Jal (5-8 cm)	River Yamuna and also between Patna-Baichal and West Bengal.		*Rita, Silondia, Calbasu.*
		(Traps)	
Kuriyar (5-10 cm)		–	Mainly major carp, carp, cat fishes, shrimps, Chela etc.
Sirki	Common in the middle stretch of Ganga from Allahabad-Patna.	–	Exclusively used for capture of *Mrigal, Chela* spp. *Aspidoparia morar* & other Carp minnows are also occasionally caught.

(Long Lines)

Gear with mesh Size	**Area of Operation**	**Season of Operation**	**Species Caught with sizes**
Jor	Used when most of the gears become in effective	–	*Garua, Vacha, Rita, Notopterus, Seenghala* and some times Silondia and *Pangus*.
Dori	–	–	All Major carps.
Dauni	Ganga near Bhagalpur	–	Exclusively for *Garua* catch.

Gear Used In The Estuarine Zone

Gear with local name	**Area of Operation**	**Season of Operation**	**Species Caught**
1. Trawl nets : (Moi, Ketta, Buro, Kantni & kachhi)	LG	Nov./ June	Prawns, also miscellaneous.
2. Sine nets : (a) Large : (Jungla, Kachal and Jagatber) (b) Medium & small (1) Ber (2) Charghers, (3) Kachal and (4) Chatber	LG	Nov.-Feb. (Occasionally in Monsoon) (1) All seasons, (2) All seasons, (3) March- July, (4) Nov.- August	*H. ilisha, T. jella, P. pama, Setipinna* spp. & *S. biauritus* (1) Mullets, Perches, Polynemids and sciaemids *(P. pama)* (2) Mullets, perches *(S. panijus)*, Polynemids & Sciaenids *(P. pama)* (3) *H. ilisha,* (young) and Others (4). *H. ilisha* (young). *S. phasa*, Prawns and other fishes.
3. Purse nets : (sanglo, Dar and Khorke)	LG	July-Oct. and Jan-March.	*H. ilisha* only.
4. Drift nets : (1) Chhandi, (2) Dholi (3) Kona (Bhasa-Kona, Ghai-Kona, Ghalo-Kona (4) Shele and Bhasa-larang	LG	(1) Monsoon and Winter (intensity in Monsoon) (2) Nov.-May (3) Feb.-Sept. (4) Nov.-May	(1) *H. ilisha*, other *(I. elongata, H. toli, Setipinna* spp.) and *S. cinereus* (2) *H. ilisha* & *S. phasa* (3) *H. ilisha* (4) *P. indicus* and *S. biauritus*
5. Lift nets : Bhesal, Garabheal, Naukabhesal, Pata, Thela, Seitki, Thapa, Dhain, Tana, Char and	LG	All seasons	Mullets, *I. elongata, Setipinna* spp. and Prawns.

Koli			
6. Cast nets : Bachari & Kepla	LG	All seasons	*P. paradiseus, P. pama, P. pangasius* and Prawns.
7. Bag nets : (Stationary) **(1) Been** **(2) Behundi** **(3) Thor** **(4) Atone** **(5) Gopa**	LG	All seasons	(1) (2) and (3) Almost all species especially, *H. nehereus,* Prawns*, P. pama,Trichiurus* spp., *Setipinna* spp. *I. elongata*, mullets & *S. paningus* (5) *L. Calearifer* and *S. biauriturs.*
8. Set gill nets : **(1) Barang** **(3) Khota** **(4) Khuti** **(5) Patang** **(6) Geba-Chandi**	LG	(1) Nearly all seasons (2)–(5) Monsoon and Winter	(1) *L. calcarifer* and *S. biauriturs* (2) – (5) *H. ilisha* & other clupeids.
9. Set- Barrier nets : **(1) Pata** **(2) Char-para** **(3) Khat pata,** **(4) Khal ghera** **(5) Kumor**	LG	All seasons	All species, particularly Prawns, *M. parsia, Setipinna* spp., *P. pama, E. tetradactylum, L. calcarifer,* and *I. elongata.*
10. Traps : Bitti, Dwarbitti, Chaibitto and Bhasapata	LG	Monsoon May-Oct.	Prawns
11. Hooks & Lines (Barsi)	LG	All seasons	Catfishes, Perches, Polynemids, Scienids and *Setipinna* spp.

Status of Higher Aquatic Vertebrates in the Ganga River, India

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. Introduction

Freshwater ecosystems are fragile environments, and are rich in biodiversity. No other group of organisms are believed to be more at risk than freshwater animals. Riverine wetlands are among the most productive life support systems in the world and are of immense socio-economic, ecological and bio-esthetic importance to mankind. Understanding the mechanism, driving losses in aquatic biodiversity, is important to the conservation and restoration of freshwater environments worldwide (Strayer and Dudgeon, 2010).

1.1 The River Ganga

The Ganga originating from the mighty Himalayas, transverses a distance of 2525 km to meet the sea, at Bay of Bengal (Krishnamurti *et al*., 1991). Of this total length, 1450 km falls in Uttar Pradesh (including Uttaranchal), 445 km in Bihar and 520 km in West Bengal. The Ganga basin, 8, 61, 404 sq. km is the largest in India. The Ganga is unique among the mighty rivers of the world because of its largest delta - the Sunderbans (Behera, 1995).
Ganga river system comprise of numerous torrents and tributaries. Most of the north-India tributaries like Ram Ganga, Sharda, Gandak, Gomti, Ghagra, Gandok and Kosi arise from the lower Himalayas passes through the Terai region before joining the Ganga. The major southern tributaries are the Chambal, Yamuna, Son and Subarnarekha rivers (Rao, 1995).

The land around the river is used largely for agriculture and fisheries. The fishery resources of the Ganga river system are of tremendous economic and nutritional sustenance to the people of riparian states.

2. Biological Resources (Higher Aquatic Vertebrates) of the River Ganga

The river Ganga sustains diverse group of flora and fauna. Record of 268 fishes from the Ganga was the first-ever scientific documentation of the fauna of the river (Hamilton, 1822). Before that, Roxburgh (1801) reported *Platanista gangetica* from the river Hooghly near Calcutta. Anderson (1879) gave a detailed account of biology of the Gangetic Dolphin *Platanista gangetica*. Menon (1963) recorded fishes of the Ganga river in Himalayan region. Jayaram (1974) gave an account on distribution of freshwater fishes, amphibians and reptiles of the river Ganga. Jhingran and Ghosh (1978) studied the fisheries of the Ganga river system in the context of aquaculture. Zoological Survey of India has documented 27 species of reptiles from the river (Sharma, 1991). Gharial (*Gavialis gangeticus*), a fish eating crocodile, *Aspideretes gangeticus*, a soft shell turtle, are some endemic reptiles of the river. One of the most rare, endemic and endangered mammals of the Ganga is the Ganga river dolphin, *Platanista gangetica gangetica*. These species have been heavily exploited in the last few decades, which have pushed them near to extinction.

2.1 Status of River Dolphin

River dolphins are represented mainly by three species (*Platanista gangetica gangetica, P. gangetica minor, Pontoporia blainvillei*). Two species of Ganga river dolphin (*Platanista gangetica gangetica*) and Indus river dolphin (*P. gangetica minor*) are found in the Indian subcontinent. The Ganga river dolphin, locally known as Susu, is restricted to the Ganga, Brahamputra, Karnaphuli- Sangu, and Meghna river systems and their tributaries, from the foot hills of the Himalaya to the limits of the tidal zone in India, Bangladesh, and Nepal. In Ganga river, Dolphins are also present in its tributaries like Yamuna, Chambal, Ghaghra, Gandak, Rapti, Narayani and Kosi rivers (Roberts, 1997; Reeves and Brownell, 1989; Shrestha, 1989; Mohan *et al.,* 1997; Smith *et al.,* 2001).
In recent years several workers estimated the population of Ganga river dolphin in different segments of Ganga river and its tributaries in Ganga and Brahmaputra river system and Sundarbans delta. Once believed to be in the tens of thousands their number has gradually reduced to four to five thousand with a further decline to a mere 1,800 individuals in all the tributaries of its distribution (Anderson, 1879; Jones, 1982; Behera *et al.,* 2008; Behera, 1995; Bashir *et al.,* 2007, 2010; Singh, 2008).

This species is exclusively riverine. Relatively high densities of dolphins are found at sites where rivers join or just downstream of shallow stretches, in areas where the current is relatively weak; off the mouths of irrigation canals; and near villages and ferry routes. In the river basins in India, the Ganga river dolphin is present mostly in plains where the rivers run slowly. This seems to be opposite to the habitat observed in Nepal, where the dolphin can be found in relatively clear waters and rapids. In both areas, however, there is a preference for deep waters (Reyes, 1991). Primary habitats are characterised by an eddy counter-current system in the main river flow caused by a fine sand/silt point bar formed from sediment deposits of a convergent stream branch or tributary. Marginal habitats are characterised by a smaller eddy counter-current system caused by an upstream meander. Dolphins concentrate in locations of high prey availability and reduced flow (Smith, 1993). South Asian river dolphins have been found in water as cold as 8°C and as warm as 33°C (Reeves and Brownell, 1989). In the river Bramaputra , the number of dolphins occurring in different depths were found to be significantly different and the highest numbers were found in depths of 4.1-6.0 m (Wakid, 2009). In the Sundarbans mangrove forest of Bangladesh, Ganga river dolphin distribution was conditionally dependent on low salinity, high turbidity, and moderate depth during both low and high freshwater flow. Animals prefer wide sinuous channels with at least two small confluences or one large confluence (Smith *et al.,* 2009).

Dolphins are social animals and live in small to large groups, associated with many animals like crocodiles, turtles and wetlands birds. But in adulthood they turn solitary, remain alone or best in pairs, and may group during mating season where several males display courtship for the attention of the females (Behera and Rao, 1999; Hussain, 1993; Singh and Sharma, 1985). Calving apparently can occur at any time of the year, but there may be peaks in

December to January and March to May. Newborn calves have been observed mainly in April and May. Calves are weaned within one year of birth (Jefferson *et al.,* 2008). Gestation lasts 10.5 months (Reidenberg and Laitman, 2009).

South Asian river dolphins feed on several species of small fish and invertebrates. They mostly feed at or near the bottom, echolocating and swimming on one side (Reeves and Brownell, 1989; Jefferson *et al.,* 1993). The Ganga river dolphins show seasonal and diurnal migration for feeding and maintaining their territorial behaviour. The marked seasonal changes in Susu distribution and density over much of its range at least in large part, are due to fluctuations in water levels. During the dry season from October to April, many dolphins leave the tributaries of the Ganga - Brahmaputra systems and congregate in the main channels, only to return to the tributaries the following rainy season. They may become isolated in pools and river branches during the dry season (Reeves and Brownell, 1989).

The species is facing a series of threats for its survival due to poaching, construction of dams and barrages pollution; mining of sand and stones, and incidental catches in gillnets. The Ganga river dolphin is important not only because it is endangered, but perhaps more so because, it is a reliable indicator of the health of the Ganga river, in fact the whole river ecosystem. In spite of being a "flagship" species, representing an ecosystem in need of conservation, its status has become a matter of grave concern over the past few decades. This is why the government of India declared this animal as the “National Aquatic Animal”, during the year 2009. Close monitoring of dolphins and their habitats involving local communities is required for long term conservation of the species. It has been placed in Schedule-I of Wildlife (Protection) Act of India (1972). Appendix-1 reported in the Convention on International Trade in Endangered Species (CITES) (IUCN, 2009) had listed the species as “Endangered” (Behera, 1995; Singh, 2001; Anon, 2006; Choudhary *et al.*, 2006; Behera *et al.,* 2008).

The population status of dolphins in the Ganga river and its tributaries are given in Table 1 and Table 2.

Table 1: Population status of dolphins in Ganga river and its tributaries

Name of the river	Length of the river surveyed	Dolphin number	Source
The Ganga main stem			
The Ganga (Haridwar to Bijnor Barrage)	100 km	Nil	Behera, 1995, Sinha *et al.* (2000)
The Ganga (Bijnor Barrage to Narora Barrage)	169 km	56	WWF-India Survey Report (pers. comm. S. Behera (2010)
The Ganga (Narora to Kanpur)	300 km	03	*Table continued to next page….* WWF-India Survey Report (pers. comm. S. Behera (2010)
Kanpur to Allahabad Survey Report	200 km	78	WWF-India Survey Report (pers. comm. S. Behera (2010)
The Ganga (Allahabad to Buxar)	425 km	172 (d/s survey)	Sinha *et al.* (2000)
The Ganga (Buxar to Maniharighat)	500 km	808 (u/s survey)	Sinha *et al.* (2000)
The Ganga (Maniharighat to Farakka)	100 km	24 (d/s survey)	unpublished data of Dec. 2004 (Sinha, 2004)
The Farakka Feeder canal	38 km	21 (d/s survey)	Sinha *et al.* (2000)
The Bhagirathi (Jangipur Barrage to Triveni)	320 km	119 (d/s survey)	Sinha *et al.* (2000)
The Hooghli (Triveni Ganga Sagar)	190 km	97 (d/s survey)	(pers. comm. G. Sharma 2008)
Tributaries of the Ganga			
The Yamuna (from Confluence of Chambal to Hamirpur)	350 km	60 (d/s survey)	WWF-India Survey Report (pers. comm. S. Behera 2010) Sinha *et al.* (2000)
The Kosi (Kosi Barrage to Kursela)	200 km	85 (discrete survey)	Sinha and Sharma (2003)
The Gandak (Gandak Barrage to confluence with Ganga at Patna)	320 km	290 (d/s survey)	multi-organizational survey 2010
The Gherua (India-Nepal border to Girijapuri Barrage)	20 km	23 (d/s survey)	Smith *et al.* (1994)
The Sarda (Sarda Barrage to Palya)	100 km	Nil	Sinha and Sharma (2003)
The Chambal (Pali to Pachhnada)	425 km	79	Singh (2010)
The Ken (from confluence of Yamuna at Chilla to Sindhan Kala village)	30 km	08 (d/s survey)	Sinha *et al.* (2000)
The Kumari (from confluence of Sind River)	100 km	Nil	Sinha *et al.* (2000)
The Betwa (from confluence of the Yamuna at Hamirpur to Orai	84 km	06 (d/s survey)	Sinha *et al.* (2000)
The Sind (from confluence with the Yamuna)	110 km	05 (d/s survey)	Sinha *et al.* (2000)
The Son	130 km	10 (d/s survey)	Sinha *et al.* (2000)
The Brahmaputra	600 km 856 km	400 (1996) 197 (2004-05)	Mohan (1997) pers. comm. A. Wakid
The Barak river	17 km	02 (1999), 08 (2004), 06 (2006)	Pers. comm. Paulan Singh
The river Subhansiri	99 km	26	Wakid (2009)
The river Kulsi	76 km	27	Wakid (2009)

2.2 River Dolphin in Ganga River

Study of the stretch from Bijnor to Narora to know the status of Ganga river dolphin began in 1993 and recorded a population of 22 Ganga river dolphins in 1993 to 95. This comprise of eight calves, four adolescents and ten adults (six females and four males) (Rao, 1995; Behera and Rao, 1999; Behera, 1995).

During the study period of 1997 a total of 35 dolphins were recorded in a stretch of 165 km from Bijnor to Narora. The concentrated population was recorded in between Brijghat and Narora. However during flood these animals migrate up to Bijnor. The crude population density is estimated as 1 dolphin per 4.71 km. Ecological density of dolphins in between Brijghat and Narora was also estimated as 1 dolphin per 2.34 km. During dry seasons the dolphins preferred only 82 km of the river stretch whereas during monsoon they inhabited in a stretch of 165 km. These results indicate that the dolphin in the study area gets a proper habitat of around 82 km during dry season and 165 km during monsoon (WWF, 1997, Unpublished). However, a year later (January 1998) the same stretch showed the population of 35 individuals of which 7 were identified as males, 8 were females, 11 were adolescents and 9 were calves. In the year 2002 WWF, India conducted a survey from 15th December to 31st December 2002 in the upper Ganga river from Brijghat to Narora covering a distance of approx. 85 km and estimated a population of around 39 dolphins (WWF-1998; Behera, 2002). Plate 1 showing the image of Ganga river dolphin (*Platanista gangetica gangetica*). Plate 1 showing the dolphin (*Platanista gangetica gangetica*) in the Ganga.

Plate 1: Ganges river dolphin (*Platanista gangetica gangetica*) in river Ganga

Table 2: The survey conducted by WWF (Year wise) between 2003-2010 recorded the dolphin population as

Year	Adult	Young	Calves	Total
2003	27	7	8	42
2004	19	7	13	39
2005	30	-	10	42
2007	30	-	15	45
2008	32	-	14	46
2009	32	18	4	54
2010	35	17	8	60

2.3 Status of Crocodiles

Crocodilians are survivors from the great reptilian age and are recognized as keystone species in their environment due to the role they play in maintaining the ecosystem and function by their activities. Gharial, a mythical creature, is revered as the vehicle (Vahana) of Ganga (River Deity) and Varuna (God of winds). Traditionally the animal has been identified with water, the source of all existence and fertility. It is the lone survivor of family Gavialidae.

In India many rivers, lakes and marshes offer a variety of habitats for three species of crocodiles (Gharial, mugger and salt water crocodile). Of these Gharials (*Gavialis gangeticus*, Hussain, 2009) are present in the Ganga river and its tributaries particularly in northern India. Gharials are also recorded in Mahanadi river of Orissa and Brahmaputra river in Assam, and the salt water crocodile live~~s~~ in the brackish waters in the coastal states. The early records reveal that these aquatic reptiles at one time were very abundant throughout their distribution range. However due to commercial exploitation and habitat destruction populations of crocodile species were reduced to near extinction. In many of the habitats the crocodile populations were totally wiped out. Considering their vulnerability, the Government of India enforced protective legislation through the Indian Wildlife (Protection) Act, 1972 which prohibits killing (Smith, 1933; FAO, 1974; Rao, 1994).

All the three species of Indian crocodiles have been extensively studied in different corners of the country but the microhabitat of the crocodiles was not studied in details. To conserve crocodiles generally and to develop crocodile farming in India, a captive breeding programme for all three species of crocodiles found in India (Indian mugger crocodile, saltwater crocodile, and the Gharial) was initiated in 1975. As a part of this programme, captive reared crocodiles were reintroduced into newly created protected wetland areas to boost wild populations (Singh, 1978, 1985; Bustard, 1980; Kar, 1981; Choudhury, 1981; Whitaker and Basu, 1983; Whitaker and Whitaker, 1989; Sharma and Basu, 2004).

The Gharials (*Gavialis gangeticus*, Hussain, 2009), endemic to the Indian subcontinent, was once common in the river systems of Pakistan, Northern India, Bangladesh, Myanmar and Bhutan. However, they are now restricted to a few, scattered locations in India and Nepal. The Gharial, is becoming increasingly rare due to land-use changes, reduction in water flow, modification in river morphology, loss of nesting sites, increased mortality in fishing nets, egg collection for consumption, and is especially at risk from flow regulation because it prefers fast flowing river habitats, which are prime sites for dams (Whitaker and Basu, 1983; Hussain, 1999; Dudgeon, 2000). By 1976, the estimated adult population of wild Gharial had declined from what is thought to have been 5,000 to 10,000 in the 1940s to less than 200. In 2006, the mature Gharial population in India stands at a similar figure, less than 200 (Whitaker *et al.*, 1974). The Gharial population is given in Table 3, 4 and current distribution (IUCN) in Figure 1.

In general the river Chambal holds the largest population with an upper estimate of 306 adult animals. Katerniaghat Wildlife Sanctuary holds the second largest population with an upper estimate of 68 adult animals (Converse, 2009). The other smaller populations of Gharial is in Ken and Son rivers in Madhya Pradesh, Hooghly river in West Bengal, Corbett Tiger Reserve in Uttarakhand and Gandak river in Bihar.

The Ganga river is a major habitat for both the species of freshwater crocodile. Old records indicate that the crocodile abounded in all the great rivers of northern India including the Ganga river. However, by early 1970’s populations of crocodiles has been very much reduced. Crocodiles in many rivers including river Ganga have been illegally hunted for skin, meat and medicine. Under the crocodile project, few important crocodile habitats were identified in India and protected by declaring them as crocodile sanctuaries. In these sanctuaries captive reared crocodile were released regularly since 1977. The Uttar Pradesh forest department had released a total of 225 captive reared Gharial in the Ganga river upstream of Bijnor in the Hastinapur sanctuary in the year 1991-92. Majority of the crocodile releasing sites have received protection under Indian Wildlife Protection Act 1972 (Shortt, 1921; FAO, 1974; Rao, 1994).

Rao (1995) conducted a survey in the river Ganga and found a significant record of adult Gharial from Anupsahar in district Bulandshahar. During October 1994, three Gharials were reported in the river Ganga downstream of Narora barrage. The Gharials in the Hastinapur sanctuary have been released in an area, where large scale fishing has been noticed. Due to the fishing activities in this stretch all Gharials might have been killed in fishing nets. Possibility of migration of released Gharial may be another factor for not locating them in the study area. These animals always avoid human interference in their habitats. Figure 1 showing the current distribution of the Gharial. Rao, in 1995 conducted a survey in the upper Ganga river and reported presence of mugger from many places of the Ganga river at Narora downstream of barrage, a total of 20 mugger hatchlings have been located. Since there is a heavy human activity along the river Ganga, it was observed that mugger prefer living in the lower Ganga river canal.

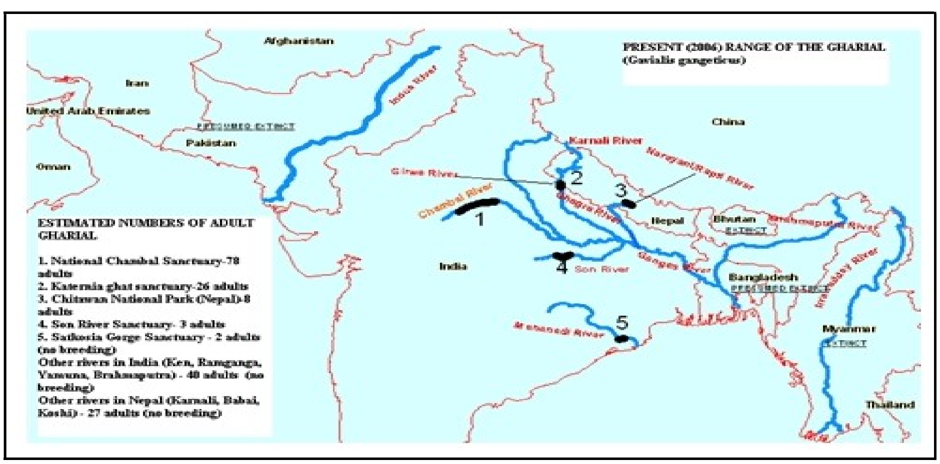

Figure 1: Current distribution of the Gharial (Source: IUCN)

Table 3: Gharial population size reduction (Source: IUCN, 2009)

River systems	Population size (inferred) three generations ago (1946)	Population size at present (2006)	Estimated reduction
Ganga River		<200	
Mahanadi River		2	
Overall	**5,000 to 10,000**	**<200**	**96%**

Table 4: Recent declines in the number of adult Gharial by subpopulation (Source: IUCN, 2009)

Sub population	Past	Present	Estimation % reduction within one generation
Chambal	226 (1977)	78 [2006] [68 f + 10 m]	13%
Katerniaghat	30 (1997)	26 [2006] [20 f + 6 m]	66%
Others	50 (1997)	40 [2006]	20%
Overall	**306**	**114**	

(f = females, m = males)

Gharial arguably are the most thoroughly aquatic of the extant crocodilians, and adults apparently do not have the ability to walk in a semi-upright stance as other crocodilians do. They are typically residents of flowing rivers with deep pools that have high sand banks and good fish stocks. Exposed sand banks are used for nesting (Whitaker and Basu, 1983).

Young gharials eat insects, larvae, and small frogs. Mature adults feed almost solely on fish, although some individuals have been known to scavenge dead animals. Their snout morphology is ideally suited for preying on fish. Their long, narrow snouts offer very little resistance to water in swiping motions to snap up fish in the water. Their numerous needle-like teeth are ideal for holding on to struggling, slippery fish. Gharials will often use their body to corral fish against the bank where they can be more easily snapped up (Piper, 2007).

The mating season is during November through December and well into January. The nesting and laying of eggs take place in the dry season of March, April and May. This is because during the dry season the rivers shrink a bit and the sandy river banks are available for nesting. Between 30 and 50 eggs are deposited into the hole that the female digs up, before it is covered over, carefully. After about 90 days, the juveniles emerge, although there is no record of the female assisting the juveniles into the water after they hatch (probably because their jaws are not suited for carrying the young due to the needle like teeth). However, the mother does protect the young in the water for a few days until they learn to fend for themselves.

2.4 Mugger Habitat

Mainly a freshwater species, the mugger crocodile is found in lakes, rivers and marshes. Muggers prefer slow-moving, shallower bodies of water rather than, fast-flowing, deep areas. Also known to thrive in man made reservoirs and irrigation canals. Although it prefers freshwater, it has some tolerance to saltwater therefore is occasionally reported from saltwater lagoons. It is sympatric with the gharial (*Gavialis gangeticus*) in some areas of India and with the saltwater crocodile (*Crocodylus porosus*) in other areas, but separated by habitat most of the time. It is adapted to terrestrial life like its cousin, the Cuban crocodile, more than most crocodilians, but is ecologically most similar to the African Nile crocodile. It is known to be more mobile on land, can migrate considerable distances over land in search of a more suitable habitat. It can chase prey on land for short distances. They are also known to dig burrows as shelters during the dry season.

Being a large carnivorous reptile, the mugger crocodile eats fish, other reptiles and small mammals, such as monkeys. In fact, most vertebrates who approach the river to drink water are potential prey, and may suffer being seized and dragged into the water to be drowned and devoured at leisure. Large adults will sometimes prey on large mammals such as deer, including the 225-kg sambar deer, and the 450-kg domestic water buffalo. At night they sometimes hunt on land, lying in ambush near forest trails (Dinets, 2011). This species is generally considered to be occasionally dangerous to humans, but no where near as notorious as the much larger (and, in India, less common) saltwater crocodile.

2.5 Status of Turtles

India is bestowed with a great variety of Chelonian fauna. Five families of Chelonians in the class Reptilia are represented in India. Among them 2 families Emydidae and Trionychidae are freshwater turtles, with 16 and 6 species, respectively. A nation wide project on distribution of turtles and tortoises has been carried out by Wildlife Institute of India in collaboration with U.S. Fish and Wild-life Service (Choudhury and Bhupathy, 1993).

Rao (1991) studied ecological relationship among turtles in the Chambal river. According to him, 7 species of freshwater turtles are distributed throughout the 500 km stretch of the Chambal river which is a major tributary in Ganga river system. Occurrence of freshwater turtles in Ganga river and its tributaries were recorded by many authors. In the middle Ganga (Haridwar- Allahabad) a total of 12 freshwater turtle species have been identified. The *Kachuga* sp. is dominated with 5 species (*K. smithii, K. tecta, K. tentoria, K. dhongoka* and *K. kachuga*) followed by two species of Aspideretes (*A. gangeticus* and *A. hurum*) and one each species of *Chitra indica*, *Lissemys punctata, Hardella thurjii, Geoclemys hamiltoni* and *Melanochelys trijuga* (Sharma, 1991; Choudhury and Bhupathy, 1993; Rao, 1995; Smith, 1933; Das, 1985; Sharma and Tikedar, 1985; Krishnamurthy *et al.,* 1991). *Kachuga dhongoka* was reported from Northeast India in river Ganga at Allahabad and in river Yamuna at

Bateswar (U.P.). Occurrence of *Kachuga dhongoka* in Chambal was reported by Rao (1991). In middle Ganga from Gangdaspur in Bijnor district distribution of common species of turtles in Ganga is given in Table 5.

Table 5: Status and distribution and of freshwater Turtles in river Ganga

S.N	Common name	Species	IUCN
1	Three striped roof turtle	*Batagur dhongoka*	Endangered
2	Red crowned roof turtle	*Batagur kachuga*	Critically Endangered
3	Narrow headed soft shell turtle	*Chitra indica*	Endangered
4	Spotted pond turtle	*Geoclemys hamiltonii*	Vulnerable
5	Crowned river turtle	*Hardella thurjii*	Vulnerable
6	Indian flap shell turtle	*Lissemys punctata*	Lower risk
7	Indian black turtle	*Melanochelys trijuga*	NT
8	Indian soft shell turtle	*Nilssonia gangeticus*	Vulnerable
9	Indian peacock soft shell turtle	*Nilssonia hurum*	Vulnerable
10	Brown roofed turtle	*Pangshura smithii*	NT (lower risk)
11	Indian roofed turtle	*Pangshura tecta*	Lower risk
12	Indian tent turtle	*Pangshura tentoria*	Lower risk

2.6 Turtle Habitats

In order to describe the habitat preference of the turtles, the Ganga river was classified into following habitat types depending on the nature of the bank and the river depth during hot season.

1) Both banks are muddy, formed by the soil erosion of the adjacent land. The river depth varies from 5-15 m. Most of these banks are used for extensive agricultural. These are the basking site of both hard-shell and soft-shell turtles.

2) One bank is sandy and the other bank is either muddy or hard soil. The river is shallow as well as deep, 2-15 m. Mid river islands with alluvial deposit are also present. There are alterations to the sand banks every year due to erosion and deposition during monsoon high water. Hard shell turtles construct nests on the sand banks or the islands are used for laying eggs. The sand banks are used for cultivation, mostly of water melons, vegetables, etc. during different seasons.

3) At many places long rivulets bring rain water from the surrounding catchments area. Some of these canals extend more than 1 km from the main river. During the monsoon season, the flood waters enter into the canals and thereby the water levels fluctuate depending on the rains. Soft shell turtles nest in these canals. Villagers carry out agricultural activities during the post monsoon season.

4) Due to the construction of the Madhya Ganga and Lower Ganga barrages at Bijnor and Narora, respectively the water has been stored upstream, resulting into large reservoirs and downstream barrages the river is very shallow with less flow of water. Soft shell turtles prefer to live in reservoirs here unlike the hard shell turtles which live in the flowing waters as these animals require large tracts of sand banks for nesting.

5) Freshwater turtles in the river Ganga use all the above mention habitat types for basking, feeding and nesting purposes. It was observed that all age classes of each species of turtles were encountered frequently. This is a good indication of successful natural breeding of turtles in the Ganga river. The nesting and breeding status of different turtle species occurring in the Ganga river are shown in Table 6 and Table 7. Plate 2 showing the Chelonian fauna in the Ganga and its tributaries.

Plate 2: Chelonian fauna in the Ganga and its tributaries

Table 6: Nesting sites of turtles between Bijnor to Kanpur

S. No.	Place	GPS location	
		Latitude	Latitude
1	Bijnor	29°34´214	78°05´971
2	Maqdoompur	29°08´743	78°04´546
3	Kalagarh	28°86´390	78°12´504
4	Tighri ghat	28°79´329	78°14´148
5	Garh	28°74´214	78°17´678
6	Pooth	28°69´419	78°18´501
7	Bhagwanpur	28°62´831	78°18´827
8	Farida	28°49´750	78°24´590
9	Awantika Devi	28°40´066	78°28´274
10	Anoopshehar	28°32´633	78°29´149
11	Karnavas	28°26´552	78°35´458
12	Rajghat	28°21´067	78°19´228

Table 7: Breeding status of fresh water Turtles occurs in the Ganga river between Rishikesh and Kanpur

S. No.	Species	Nesting season	Hatching season
1	*Geoclemys hamiltone*	?	?
2	*Melanochelys trijuga*	?	?
3	*Batagur dhongoka*	December-February-April	May
4	*Batagur kachuga*	December-February-April	May
5	*Pangshura smithii*	October-December	May
6	*Pangshura tentoria*	September-February	May
7	*Pangshura tecta*	October-December	May
8	*Lissemys punctata*	July-October	July
9	*Chitra indica*	September	October
10	*Nilssonia gangeticus*	August-October	June/July
11	*Nilssonia hurum*	?	?
12	*Hardella thurjii*	?	?

? – represents unknown nesting season

2.7 Conservation Constraints

A myriad range of anthropogenic activities have changed the site's ecological characteristic. Overpopulation in the Ganga basin has exerted the population pressure and has changed the water and land use patterns drastically. Water is being extracted in a significant proportion for industrial and irrigation purposes. A large amount of treated and untreated sewage is also being discharged into the river from the larger towns around the banks of the river. Large numbers of industries are situated on the banks of the river. The discharge from them enters the river Ganga directly or indirectly.

Agricultural activities in and around river basin is contributing to pesticides and herbicides through surface runoffs. Pollution through fertilizers is significantly high as the farmers are using more chemical fertilizers to increase the production. The contamination is further enhanced by flooding of irrigation lands caused by irregular water flow from the reservoirs in the upper reaches and inconsistent rainfall in the catchment.

Irregular water flow from the reservoirs in the upper reaches also cause disturbance to the natural habitat of different aquatic animals including the dolphins. Irrigation canals have further decreased the water flow in the river which made the river too shallow for the dolphins to navigate and survive.

The commercial over fishing along the river has affected the natural feeding habit of dolphins and crocodiles and life cycle of some endemic fishes. The sand mining activities have caused habitat destruction of turtles and disturbed the nesting and basking ground for the crocodiles.

Physiological or behavioral responses of aquatic organisms exposed to pollutants serve as important indicators of the environment. These animals in polluted environment accumulate toxic substances and suffer physiological stress i.e., diminished rate of growth, impaired reproductive capacity or modified behavior. The disturbance in habitat is also a great threat to the continued survival of the animals.

There are several riverine indicator species which are threatened by human activities in the Ganga basin. However, the Ganga river dolphin, otters, gharials and the riverine turtles are few reliable indicator species to understand the health of the Ganga river ecosystem. Studying indicator species could create the basis for a sustained research programme to see how the changes of the said species can be related to the health of Indicator species in the river. This would help to implement various programmes for restoration of the river system.

Barrages on the Ganga have an impact on the habitats of all aquatic animals like turtles, crocodiles and aquatic mammals. The other threats include fishing, hunting and pollution. River dolphin population has declined significantly due to construction of barrages in the upper reaches of the river systems, local populations have been cut off and new immigrants are blocked ultimately resulting to the extinction of the isolated population.

Habitat protection remain the only viable long term means to ensure the survival of different animals. The level of impact of fishing activity on the aquatic species population still remains scientifically unknown. Since both fishermen and the higher aquatic species rely on food from the rivers for survival they interact in many ways. Synthetic twine is widely used in the nets, this may be deadly, because it not easily detected visually or acoustically by species like dolphins in the murky run-off waters generated by annual monsoon.

At least two billion people on the earth depend upon rivers directly for provision of ecosystem services that can be characterized most simply as ‘food’, such as the benefits to be derived from fisheries, flood-recession agriculture, and dry-season grazing. Moreover, the value of freshwaters is bound to increase in the future, as ecosystems become more stressed and their goods and services scarcer. It will be a colossal challenge to reconcile human needs for water without compromising provision of goods and services that result from functioning ecosystems and the biodiversity that sustains them.

References

Anderson, J. (1879). Anatomical and Zoological Researches: Comparing an account of zoological results of the two expeditions to western Yamuna in 1868 and 1875; Platanista and Orcella, Berward Quaritch, London.

Anon, (2006). Species/Freshwater fact sheet: River Dolphins. WWF International Avenue du Mont- Blanc, CH-1196, Gland, Switzerland. pp. 1-4.

Bashir, T., Khan, A., Gautam, P. and Behera, S.K. (2007). Aspects of ecology of Gangetic Dolphin (*Platanista gangetica*) in Western Uttar Pradesh, India. A survey report funded by WWF-India; Department of Wildlife Sciences, AMU, Aligarh, U.P., India. pp. 68.

Bashir, T., Khan, A., Gautum, P. and Behera, S.K. (2010). Abundance and prey availability assessment of Ganges River dolphin (*Platanista gangetica*) in the upper Ganges river, India. *Journal of Aquatic Mammals*, **36:** 19-26.

Behera, S.K. (1995). Studies on population dynamics, habitat utilization and conservation aspects of Gangetic dolphin (*Platanista gangetica*) in a stretch of Ganga river from Rishikesh to Kanpur. Ph.D. Thesis, School of Studies in Zoology, Jiwaji University, Gwalior, India.

Behera, S.K. (2002). Ganges River dolphin-Wanted alive (Status report submitted to WWF-Sweden). New Delhi: Ganges River Dolphin Conservation Project, Research Report, World Wide Fund for Nature, India.

Behera, S.K. and Rao, R.J. (1999). Observation on the behavior of Gangetic Dolphins in the upper Ganga river. *Journal of Bombay Natural History Society*, **96(1):** 43-47.

Behera, S.K., Sagar, V. and Nawab, A. (2008). Environmental flow requirements vis-à-vis habitat use pattern of freshwater Dolphins. Proc. 11th International River Symposium, Brisbane, Australia. pp. 4.

Bustard, (1980). Status of Gharial *Gavialis gangeticus* (Gmelin) in Bhutan. *Journal of the Bombay Natural History Society*, **17(1)**: 130.

Choudhary, B.C., Singh, L.A.K., Rao, R.J., Basu, D., Sharma, R.K., Hussain, S.A., Andrews, H.V., Whitaker, N., Whitaker, R., Lenin, J., Maskey, T., Cadi, A., Rashid, S.M.A., Choudhury, A.A., Dahal, B., Win Ko Ko, U., Thorbjarnarson, J. and Ross, J.P. (2007). *Gavialis gangeticus*. *In:* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <http://www.iucnredlist.org/>. Downloaded on 29 July 2011.

Choudhary, S.K. (2010). Multispecies survey of river Ghandak, Bihar, with focus on Ghariyal and Ganga river Dolphin. TMBU, Bhagalpur. VBREC TM Bhagalpur University, India.

Choudhary, S.K., Smith, B.D., Dey, S. and Prakash, S. (2006). Conservation and biomonitoring in the Vikramshila Gangetic Dolphin Sanctuary, Bihar, India. *Oryx,* **40:** 189-197.

Choudhury, B.C. and Bhupathy, S. (1993). Turtle Trade In India: A study of Tortoise and freshwater Turtles, WWF India (Prepared by TRAFFIC India), New Delhi, India.

Choudhury, B.C., Bhupathy, S. and Hanfee, F. (2000). Status Information on the Tortoises and freshwater Turtles of India. In Asian Turtle Trade: Proceedings of a workshop on conservation and trade of freshwater Turtles and Tortoises in Asia (Ed. Van Dijk, Stuart & Rhodin). Chelonian Research Monographs, Number 2. pp. 86-94.

Choudhury, S. (1981). Some studies on the biology and ecology of *Gavialis gangeticus*, the Indian gharial (Crocodilia; Gavialidae). Ph.D. Thesis, University of Lucknow, India.

Converse, L. (2009). Katerniaghat Gharial Project 2008-2009. Report of Preliminary Findings. A report to GCA and James Cook University, Australia.

Das, I. (1985). Indian Turtles: A field guide. WWF, India. (Eastern Region), Eureka Pub. Serv. Calcutta, India.

Das, I. (1990). Distribution records of Chelonians from Northeastern India. *Journal of the Bombay Natural History Society*, **87(1)**: 91-97.

Dinets, V.L. (2011). On terrestrial hunting in crocodilians. *Herpetological Bulletin.* pp. 15-18.

Dudgeon, D. (2000). The ecology of tropical Asian rivers and streams in relation to biodiversity conservation. *Annual Review of Ecology and Systematics*, **31:** 239-263.

FAO, (1974). A preliminary survey of the prospects for crocodile farming (Based on the work of Bustard, H.R) F.O. Ind/71/033, 1-124.

Hamilton, B. (1822). An account of fishes found in the river Ganges and its branches. A. Constable and Co., Edinburgh. pp. 405.

Hussain, S. A. (2009). Basking site and water depth selection by gharial *Gavialis gangeticus* Gmelin, 1789 (Crocodylia Reptilia) In National Chambal Sanctuary, India and its implication for river conservation. *Aquatic conservation*: *Marine and Freshwater Ecosystem*, DOI: 10. 1002/aqc. 960.

Hussain, S.A. (1993). Aspects of the ecology of smooth-coated otter (*Lutra perspicillata*) in the National Chambal Sanctuary, India. Ph.D. Thesis, Centre for Wildlife and Ornithology, Aligarh Muslim University, Aligarh, India.

Hussain, S.A. (1999). Reproductive success, hatchling survival and growth of a managed population of Ganges gharial. *Biological Conservation*, **87:** 261-268.

Hussain, S.A. and Choudhury, B.C. (1995). Seasonal movement, home range and habitat use by smooth-coated otters in National Chambal Sanctuary, India. *In:* Proceedings VI. International Otter Colloquium, Pietermaritzburg 1993 (Reuther, C. and Rowe-Rowe, D. eds): Aktion Fischotterschutz Hankensbuettel, Habitat, **11:** 45-55.

Hussain, S.A., Sharma, R.K. and Choudhury, B.C. (1994). Morphometry of an accidentally caught Ganges river dolphin *Platanista gangetica* in National Chambal Sanctuary with comments on its mortality in fishing net. *Journal of the Bombay Natural History Society*, **93(2):** 214-218.

IUCN, (2009). IUCN Red List of Threatened Species. Version 2009. 2. <www.iucnredlist.org>.

Jayaram, K.C. (1974). Ecology and distribution of freshwater fishes, amphibians and reptiles. *In:* Ecology and biogeography in India. (Ed. M.S. Mani). pp. 517-584.

Jefferson, T.A., Leatherwood, S. and Webber, M.A. (1993). FAO Species identification guide.

Marine Mammals of the World. UNEP/FAO, Rome. pp. 320.

Jefferson, T.A., Webber, M.A. and Pitman, R.L. (2008.) Marine Mammals of the World.

Elsevier, Amsterdam. pp. 573.

Jhingran, A.G. and Ghosh, K.K. (1978). The fisheries of the Ganga river system in the context of Indian aquaculture. *Aquaculture*, **14:** 141-162.

Jones, S. (1982). The present status of the Gangetic Susu, *Platanista gangetica* (Roxburgh), with comments on the Indus Susu, *P. minor* (Owen). FAO Advisory committee on Marine Resources Research, Working party on marine mammals. *FAO Fisheries Series*, **5(4):** 97-115.

Kannan, K., Sinha, R.K., Tanabe, S., Ichihasi, H. and Tatsukawa, R. (1997). Heavy metals and organochlorine residues in Ganges river Dolphin from India. *Marine Pollution Bulletin*, **26:** 159-162.

Kar, S. (1981). Studies on the salt water crocodile, *Crocodylus porosus* Scheidae. Ph.D. Thesis, Utkal University, Orissa, India.

Kasuya, T. and Haque, A.K.M. (1972). Some information on the distribution and seasonable movement of the Ganges dolphin. *Scientific Reports of the Whales Research Institute* (Tokyo), **24:** 109-115.

Kelkar, N., Krishnaswamy, J., Choudhary, S. and Sutaria, D. (2010). Coexistence of fisheries with river dolphin conservation. *Conservation Biology*, **10:** 1523-1739.

Krishnamurti, C.R., Bilgrami, K.S., Das, T.M. and Mathur, R.P. (1991). The Ganga: A Scientific study. Publ. Northern, Book Centre, New Delhi, India.

Kumar, A., Sinha, R.K., Gopal, K. and Lata, S. (2002). Concentration of organochlorines in Ganges river dolphins from Patna, Bihar. *Journal Environmental Biology*, **23:** 279-281.

Menon, A.G.K. (1963). A distribution list of fishes of Himalayas. *Journal of Zoological Society of India*, **14:** 23-32.

Mohan, R.S.L. (1989). Conservation and management of Ganges river Dolphin *Platanista gangetica* in India. In Biology and Conservation of the River Dolphins (Ed. W. F. Perrin, *et al.*), IUCN Species Survival Commission Occasional Paper No. 3. IUCN, Gland, Switzerland, pp. 64-69.

Mohan, R.S.L., Dey, S.C., Bairagi, S.P and Roy, S. (1997). On a survey of Ganges river Dolphin *Platanista gangetica* of Brahmaputra river, Assam. *Journal of the Bombay Natural History Society*, **94:** 483-495.

Moll, E.O. (1984). Freshwater turtles in India. *Their status, conservation and management. Hamadrayad*, **9(3)**: 9-17.

Moll, E.O. (1987). Survey of freshwater turtles of India Part II: The Genus Kachuga. *Journal of the Bombay Natural History Society*, **84(1):** 7-25.

Moll, E.O. and Vijaya, J. (1986). Distributional records for some Indian Turtles. *Journal of the Bombay Natural History Society,* **83(1):** 57-62.

Perrin, W.F. and Brownel, Jr.R.L. (1989). Report of the workshop. *In:* W.F. Perrin, R.L. Brownell, Jr., Zhou Kaiya and Lin Jiankang (ed.), Biology and conservation of the River Dolphins. IUCN species survival commission occasional Paper No. 3 IUCN, Gland, Switzerland. pp. 1-21.

Piper, R. (2007). Extraordinary Animals: An Encyclopedia of Curious and Unusual Animals, Greenwood Press, USA.

Rao, R.J. (1991). Observations on hardshelled Turtles (*Kachuga* sp.) in Chambal river. *Zoos Print*, **6(6):** 15.

Rao, R.J. (1994). Ecological studies of Indian crocodile. An overview Proc. 12th working meeting of the IUCN/SSC/CSG. Thailand, **1:** 259-273.

Rao, R.J. (1995). Conservation status of Indian Chelonians, India. *In:* Proceeding International Conference of Chelonians. Gonfran, France. pp. 33-37.

Rao, R.J. (1995). Studies on biological restoration of Ganga river in Uttar Pradesh: An indicator species approach. Final technical report, Project No. J-11013/10/92 GPD.

Rao, R.J. (2001). Biological resources of the Ganga River, India. *Hydrobiologia*, **458:** 159-168.

Rao, R.J., Hussain, S.A. and Sharma, R.K. (1989). The status and conservation of Ganges river dolphin (*Platanista gangetica*) in the National Chambal Sanctuary. *Tiger Paper*, **16:(2)**, 6-10.

Reeves, R.R and Brownell, Jr.R.L. (1989). *Susu-Platanista gangetica* (Roxburgh, 1801) and *Platanista minor* Owen, 1853. *In:* Handbook of marine mammals (Ridgway SH, Harrison SR, ed.) Vol. 4: River Dolphins and the Larger Toothed Whales. Academic Press, London. pp. 69-100.

Reeves, R.R. (2009). Ganges Dolphin declared National Aquatic animal by Government of India: A Great Step Forward Zoos Print, Volume XXIV, (RNI 11:2). pp. 1.

Reidenberg, J.S. and Laitman, J.T. (2009) Cetacean prenatal development. *In:* Encyclopedia of marine mammals (Ed. W.F. Perrin, B. Würsig, J.G.M. Thewissen), Academic Press, San Diego. pp. 220-230.

Reyes, J.C. (1991). The conservation of small cetaceans: A review. Report prepared for the secretariat of the Convention on the Conservation of Migratory Species of Wild Animals. UNEP / CMS Secretariat, Bonn.

Roberts, T.J. (1997). The mammals of Pakistan. Karachi, Pakistan: Oxford University Press, Karachi, Pakistan.

Roxburgh, W. (1801). An account of a new species of Delphinus, an inhabitant of the Ganges. *Asiatick. Res*. (Calcutta), **7:** 170-174.

Saikia, B.P., Saud, B.J., Saikia, M.K and Saikia, P.K. (2010). Present distribution status and conservation threats of Indian Gharial in Assam, India. *International Journal of Biodiversity and Conservation*, **2(12):** 382-387.

Senthilkumar, K., Kannan, K., Sinha, R.K., Tanabe, S. and Giesy, J.P. (1999). Bioaccumulation profiles of polychlorinated biphenyl congeners and organochlorine pesticides in Ganges river dolphins. *Environmental Toxicology and Chemistry*, **18:** 1511- 1520.

Sharma and Basu (2004). Recent reversals in the population trends in the population of gharial in the national Chambal sanctuary in North India; implication and a suggested strategy for the conservation of one of the world's most endangered crocodilians. *In:* Crocodile proceedings of the 17^{th} working meeting of the crocodile specialist group, IUCN-The World Conservation Union, Gland, Switzerland and Combridge, UK, **26:**. 530.

Sharma, R.C. (1991). Reptiles: In Faunal Resources of Ganga Part I. (Ed. M.S Jairajpuri) ZSI Calcutta, India. pp. 27-50.

Sharma, R.C. and Tikader, B.K. (1985). Handbook: Indian testudines. Zoological survey of India, Calcutta, India.

Shortt, W.H.O. (1921). A few hints on crocodile shooting. *Journal of the Bombay Natural History Society*, **29:** 77.

Shrestha, T.K. (1989). Biology, status and conservation of the Ganges river dolphin *Platanista gangetica* in Nepal. *In:* W.F. Perrin, R.L. Brownell Jr., Zhou kaiya and Liu Jiankang (Ed.) Biology and Conservation of the River Dolphins. IUCN Species Survival Commission Occasional Paper No. 3. IUCN, Gland, Switzerland. pp. 70-76.

Singh, H. (2008). Status, distribution and conservation of Gangetic river Dolphin (*Platanista gangetica*) in National Chambal Sanctuary, India. M.Phil. Dissertation submitted to Jiwaji University, Gwalior, India. pp. 69.

Singh, H. (2010). Habitat characteristics, population dynamics and conservation of aquatic mammals (dolphin and otter) in National Chambal Sanctuary, Madhya Pradesh, India. Ph.D. Thesis, Jiwaji University, Gwalior, Madhya Pradesh, India. pp. 206.

Singh, L.A.K and Sharma, R.K. (1985). Gangetic dolphin, *Platanista gangetica*, observations on habits and distribution pattern in National Chambal Sanctuary. *Journal of Bombay Natural History Society*, **82(3):** 648-653.

Singh, L.A.K. (1978). Ecological studies on the Indian gharial *Gavialis gangeticus* (Gmelin) (*Reptilia crocodilia*). Ph.D. Thesis, Utkal University, Bhubaneswar, India.

Singh, L.A.K. (1985). Gharial population trends in National Chambal Sanctuary. With note on radio tracking. Study report CRC/WII, mimeo. pp. 167.

Singh, S. (2001). The Gangetic dolphin. *Sanctuary Asia* (Dec 2001), pp. 56-58.

Sinha, R.K. (2000). Status of the Ganges river dolphins *Platanista gangetica* in the vicinity of Farakka Barrage, India. *In:* Biology and conservation of Freshwater Cetaceans in Asia. IUCN species survival commission occasional paper No. 23 IUCN Gland, Switzerland. pp. 42-48.

Sinha, R.K. and Sharma, G. (2003). Current status of the Ganges river dolphin, *Platanista gangetica* in the rivers Kosi and Son, Bihar. *Journal of the Bombay Natural History Society*, **100(1):** 27-37.

Sinha, R.K., Das., N.K., Singh, N.K., Sharma, G. and Ahsan S.N. (1993). Gut contents of Gangetic Dolphin *Platanista gangetica gangetica*. *Journal of the Bombay Natural History Society*, **24:** 317-321.

Sinha, R.K., Sinha, S.K., Sharma, G. and Kedia, D.K. (2010). Surfacing and diving behaviour of free-ranging Ganges river dolphin, *Platanista gangetica*. *Current Science*, **98:** 230-236.

Sinha, R.K., Smith, B.D., Sharma, G., Prasad, K., Choudhury, B.C., Sapkota, K., Sharma, R.K. and Behera S.K. (2000). Status and distribution of the Ganges Susu. *Platanista gangetica*, in the Ganges river system of India and Nepal. *In:* Biology and Conservation of Freshwater

Cetaceans in Asia, Occasional Papers of the IUCN Species Survival Commission No. 23 (Ed. R.R. Reeves, B.D. Smith and T. Kasuya), IUCN, Gland, Switzerland. pp. 54-61.

Smith M.A. (1933). The fauna of British India, including Ceylon and Burma. Reptila and Amphibia. Vol I, Loricata, Testudines. Today and tomorrow's Printers and Publishers, New Delhi, India.

Smith, A.M. and Smith, B.D. (1998). Review of status and threats to river cetaceans and recommendations for their conservation. *Environmental Reviews*, **6:** 189-206.

Smith, B.D and Braulik, G.T. (2008). *Platanista gangetica*. *In:* IUCN 2010. IUCN Red List of Threatened Species. Version 2010.3. <http://www.iucnredlist.org/>.

Smith, B.D. (1993). Status and conservation of the Ganges river dolphin *Platanista gangetica* in the Karnali river, Nepal. *Biological Conservation*, **66:** 159-169.

Smith, B.D. and Reeves, R.R. (2000). Survey methods for population assessment of Asian river Dolphins. *In:* Biology and Conservation of Freshwater Cetaceans in Asia (Ed. R.R. Reeves, B.D. Smith, and T. Kasuya), Occasional Papers of the IUCN Species Survival Commission IUCN, Gland, Switzerland, **23:** 97-115.

Smith, B.D., Ahmed, B., Edrise, M. and Braulik, G. (2001). Status of the Ganges river dolphin or Shushuk (*Platanista gangetica*) in Kaptai lake and the southern rivers of Bangladesh. *Oryx*, **35:** 61-72.

Smith, B.D., Braulik, G. and Sinha, R.K. (2004). *Platanista gangetica* sp. *gangetica*. *In:* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <www.iucnredlist.org>. Downloaded on 29 July 2011.

Smith, B.D., Braulik, G., Strindberg, S., Ahmed, B. and Mansur, R. (2006). Abundance of Irrawaddy Dolphins (*Orcaella brevirostris*) and Ganges river Dolphins (*Platanista gangetica gangetica*) estimated using concurrent counts made by independent teams in waterways of the sundarbans mangrove forest in Bangladesh. *Marine Mammal Science*, **22 (3):** 527-547.

Smith, B.D., Braulik, G., Strindberg, S., Diyan, R.M. and Ahmed, B. (2009). Habitat selection of freshwater dependent cetaceans and the potential effects of declining freshwater flows and sea-level rise in waterways of the Sundarbans mangrove forest, Bangladesh. *Aquatic conservation*: *Marine and Freshwater Ecosystem*, **19:** 209-225.

Smith, B.D., Sinha, R.K., Regmi, U. and Sapkota, K. (1994). Status of Ganges river Dolphins (*Platanista gangetica*) in the Karnali, Mahakali, Narayani and Sapta Kosi rivers of Nepal and India in 1993. *Marine Mammal Science*, **10:** 368-375.

Strayer, D.L. and Dudgeon, D. (2010). Freshwater biodiversity conservation: recent progress and future challenges. *Journal of the North American Benthological Society*, **29,** 344-358.

Subramaiam, A.N., Mohan, R.S.L., Karunagaran, V.M. and Rajendran, R.B. (1999). Concentrations of HCHs and DDTs in the tissues of river Dolphins, *Platanista gangetica*, from the river Ganges, India. *Chemical Ecology,* **16:** 143-150.

Wakid, A. (2009). Status and distribution of the endangered Gangetic dolphin (*Platanista gangetica gangetica*) in the Brahmaputra river within India in 2005. *Current Science*, **97:** 1143-1151.

Webb, R.G. (1981). The narrow headed soft shell Turtle *Chitra indica* (Testudine: Trionychidae), In peninsular India. *Records of the zoological Survey of India*, **79(1-2)**: 203-204.

Whitaker, R. (1976). Gharial survey report. Mimeographed report for the New York Zoological Society. pp. 1-19.

Whitaker, R. and Basu, D. (1983). The gharial (*Gavialis gangeticus*): A review. *Journal of the Bombay Natural History Society*, **79(3)**: 531-548.

Whitaker, R. and Whitaker, Z. (1989). Ecology of mugger crocodile IUCN Publ. New series. pp. 276-296.

Whitaker, R., Rajamani, V., Basu, D. and Balakrishnan, V. (1974). Preliminary survey of the gharial, *Gavialis gangeticus*. *Madras Snake Park Trust Report*. pp. 1-16.

Zoological Survey of India. (1991). Faunal resources of Ganga. Part I. Zoological Survey of India. Calcutta. pp. 145.

Hilsa

An assessment in lower Ganga river basin, India

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRB EMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. Introduction

The *Tenualosa ilisha*, belongs to the subfamily Alosinae of family Clupeidae and is largely an anadromous species. It is capable of withstanding a wide range of salinity and travels great distances up-stream up to 1,200 km in inland water for breeding. The fish is highly priced in West Bengal, Orissa, and Tamil Nadu in India and also in Bangladesh. The largest yield of the *Hilsa* fishery comes from the deltaic region of the Gangetic system of India and Bangladesh. On account of its economic importance as well as its migratory habits, the *Hilsa* received the attention of fishery workers in India at a comparatively early date. Investigations on *Hilsa* first commenced in 1907 in the Department of Fisheries, Madras, followed by the Department of Fisheries, Bengal, Bihar and Orissa. However, very little information on the bionomics of the fish existed till 1938, when the Zoological Survey of India (ZSI) incidentally became interested on finding very small *Hilsa* in the settling tanks of the waterworks. The studies of Hora (1938 and 1941), Hora and Nair (1940a and b) and Prashad *et al.* (1940) brought out interesting facts on the life history and bionomics of the fish. Prashad *et al.* (1940) reported the seaward migration of *Hilsa*, and pointed out that very little attention has been paid to the marine phase of the fish's life history in spite of regular commercial fishery.

The marine distribution of the *Hilsa* coincides with the Indian monsoon region. Generally, the lower Ganga river basin region is characterized by relatively large continental shelf, monsoon winds, medium to high precipitation rate and run-off, surface temperature of 20°C to 30°C, surface current changing with the change of monsoons, medium to low organic productivity, presence of sub-surface oxygen minimum layer and relatively low salinity of coastal waters (Pillay and Rao, 1962). The estuarine areas of the rivers and the brackish water lakes in the area are characterized by strong tidal action, high turbidity and heavy silting. The salinity fluctuates considerably; and in areas far from inland, the water may become entirely fresh during the monsoon months. The water level in the freshwater areas of rivers fall appreciably during the dry months; very often large areas and long stretches of the river bed are converted into chains of pools in which the fish fauna take~~s~~ refuge. There is a fairly rich growth of plankton, except during the rainy season with greater abundance of zooplankton than phytoplankton (Pillay and Rao, 1962).

Hilsa is known to be a fast swimmer (Southwell and Prasad, 1918). Tagging experiments have shown that the fish is capable of covering as much as 70.8 km in one day. *Hilsa* is generally found to move on the sea surface whereas in the river they move at a depth of 14-18 m (Mojumdar, 1939); though, on a cool or drizzly day they may rise to within 2 m from the surface. During their migration upstream the fishes congregate, but do not form dense shoals; however during winter months, they are found to form very large shoals. *Hilsa* assemble in large numbers below dams or other obstructions to their upstream migrations (Pillay and Rao, 1962). It was also noticed that the *Hilsa* move near the bottom of rivers and rise to the surface when they meet obstructions such as dams or anicuts (Southwell and Prasad, 1918). During, the breeding season *Hilsa* ascends the rivers and after spawning, returns to the original habitat where they remain till the next breeding season. It has been observed that the males move in the surface zone and the females in deeper areas (Pillay, 1958). Eggs, larvae and juveniles of the *Hilsa* are found in the upper reaches of the river during the south west monsoons (July-September) and again during the second half of winter (January-February). From October till end of November and again during March, juveniles and young ones (up to 8 cm length) are found in the lower stretches and estuarine areas in lower Ganga river basin. Young fish of about 15-22 cm length occur along the foreshore areas during the winter months (December-February). The eggs occur in the sub-surface zones, while the juveniles appear to inhabit the subsurface waters, but later age groups move in deeper zones of water as well.

1.1 Reproduction

The species is mainly heterosexual. The breeding of *Hilsa* in the Ganga appears to be with the onset of the monsoon in July; with peak breeding from September-December (Motwani *et al.,* 1957). The peak periods were found to be co-related with the flooding of the rivers owing to the south-west monsoon. As for the factors influencing spawning, it is generally held that the upstream migration of fish during the monsoon period is largely dependent on the flooding of the rivers. The second spawning migration was attributed to the general rise in temperature of water in the estuaries after the end of winter (Jones, 1957). Further, it has been stated that the temperature has some influence on the ripening of the gonads and rainfall provides favorable conditions for spawning, during heavy rains the rivers are flooded, water becomes more turbid, current flow is faster, temperature is high and also there is low plankton production (Nair, 1939). Southwell and Prasad (1918) opined that in the absence of any fixed breeding grounds, the fish generally accepted sense of the term and that they probably breed during the rains when conditions such as weather, temperature and other undetermined factors are suitable. De *et al.* (1994) have reported that during the post Farakka period *Hilsa* underwent spawning in the entire freshwater and gradient stretches of the Hooghly estuary. Thus, there was a considerable extension of the spawning ground of *Hilsa* in the estuary during the post Farakka period. The distribution of *Hilsa* eggs in the estuary is greater than it was before barrage. This increase is largely due to the increased flow of fresh water into the estuary following construction. The higher rate of fresh water discharge into the Indian part of the rivers has significantly reduced the salinity downstream. As a result, the downstream zone is now almost fresh water and therefore better for spawning. The rate of development of *Hilsa* embryos is purportedly influenced by temperature conditions. Presently, there has been disappearance and decline in the number of larvae due to increase in water temperature in the lower Gangetic belt, because larval development is inversely proportional to increase in temperature. Before Farakka barrage, *Hilsa* ~~were~~ ascended only Hooghly estuaries. Now adult *Hilsa* ascend the Thakuran and Matlah estuaries as well. *Hilsa* fry, between four and nine centimeters long are also recorded in most of the West Bengal estuaries. Landing statistics for *Hilsa* shad show a large increase after the construction of Farakka barrage. Unfortunately, Farakka barrage has caused the decline of the *Hilsa* stock in the Padma river (Bangladesh) which was once more famous than that in the Ganga.

1.2 Migration

The upstream migration during the main breeding season depends vitally on the commencement of the south-west monsoons. The variations in the intensity of the monsoon during the breeding season appear to cause considerable fluctuations of the fish catches in different places. Day (1873) expressed the opinion that the fish spends a part of its life in the sea not far from the shallow coastal belt. Naidu (1939) added that the general migration pattern of adult *Hilsa* take place in the Ganga from May-June and they disappear by the second week of October. Hora (1941) pointed out that among the mature *Hilsa,* which swarm into the rivers during the flood season for spawning purposes, there are a number of young individuals also and these travel far up before they become sexually mature. He stated that spawning takes place in the tidal waters and in the middle reaches of the large rivers and inferred that the floods and sexual maturity induce the fish in the sea to undertake the upward migration. Pandit and Hora (1951) summarized the extant hypothesis on the movements of *Hilsa viz.*, (i) during the flood season, the adult *Hilsa* swarm up the rivers for breeding. While they probably breed in the lower reaches of the rivers, some immature fish associated with these swarms move up and probably breed much higher up next year; (ii) the young fish fall back to the sea or estuarine areas in large numbers during October-November; the numbers get reduced by February; (iii) at about the same time, November-February, the young which had migrated to the sea during the flood season and had grown to 7”-9” form a big fishery; (iv) during March-April, the young ones known as *Jatka* enter East Bengal waters in large swarms for feeding and form an independent fishery; (v) These swarms move up the river and fatten as they grow and mature in the middle and upper reaches, the movement being facilitated by the increase in the volume of water in the rivers due to the melting of the snow in the Himalayas during the spring hot months.

Fish passes constructed at the Farakka barrage also proved futile for the species (Malhotra and Shah, 1979). Besides, the obstructions of rivers by the construction of weirs and anicuts, silting also appears to affect the *Hilsa* migration. The occurrence of two runs of *Hilsa* in the main river system, one during the south west monsoon and the other during late winter has been established. The late winter run is of a smaller magnitude while the estuarine stocks migrate up the river for spawning and return to the river mouth and adjacent foreshore areas. Temperature, current, velocity, and volume of discharge are probably the significant directive factors to which *Hilsa* responds in its movements from the sea to the estuary (Pantulu *et al.,* 1966; Gopalakrishnan, 1973). The general assumption is that the maturing *Hilsa* ascend the river till they reach the spawning grounds and after spawning they migrate downwards.

1.3 Decline in *Hilsa* fishery

Loss of habitat, directly and indirectly through fishing or other processes, poses major threat to the continued existence of many marine species (Roberts and Hawkins, 1999; Rodwell *et al.,* 2003), particularly those that are already endangered (Wilcove *et al.*, 1998). Undeniably, mistreatment is alleged to have caused 55% of marine extinctions, while habitat degradation explains a further 37%

(Dulvy *et al.,* 2003), emphasizing the importance of these two processes for both conservation, sustainability and subsistence. Some studies have concluded that habitat is more important than fishing (Grigg, 1994), whilst others have found that the effects of fishing are still prevalent when accounting for spatial variation in habitat (Chapman and Kramer, 1999). The relative consequence of these two processes is likely to depend on the extent of fishing pressure compared to variations in habitat (Russ *et al.,* 2005) and will vary depending on species vulnerability to fishing versus habitat dilapidation (Wilson *et al.,* 2008).

The river Ganga has greatly influenced human habitations along its littoral zone, supporting the livelihoods of many people, but suffered from unregulated fishing, environment degradation, water abstraction and encroachment. The amplified fishing pressure due to higher claim for *Hilsa* fish, followed by indiscriminate fishing methods increased the fishing effort leading to over exploitation, which gradually led to a drop in the catch per unit effort. With the decreasing natural stocks, the fishers had to augment fishing effort for whatever species or size of fish were available to support their livelihoods. Interventions like regulations, wise use, or increased awareness may not yield desired results, and to reverse the trend, as fisher's livelihoods are affected. Although the ecology, fish species composition and landing trends are studied in Ganga, there is also acute paucity of sound empirical information on the fish population, maltreatment levels and sustainable yields from the river to implement effectual resource management plans.

It has been reported by several workers that variability of the monsoons cause considerable fluctuations in the *Hilsa* catches. The intensity of monsoon, its arrival, and the consequent flooding of the rivers along with high turbidity of the waters have been included as causal factors for *Hilsa* fishery decline. Hora and Nair (1940a) and Hora (1941) have recorded that besides the annual fluctuations, there is a five-year cycle in the *Hilsa* fishery. This view was supported by Biswas (1954) on the basis of the trend in prices. Hora and Nair have also observed that the long range fluctuations are due to large populations attaining maturity at particular periods. They have inferred that a majority of the fish attain maturity when they are five years old and hence every five years bulk of the stock on becoming mature swarms up the river and provides bumper catches. Dunn (1982) has also considered water level fluctuations and turbidity values, expressed as index of sediment load compared with water flow, as causal factors in the fluctuations in the *Hilsa* fishery.

In the recent years there has been a declining trend in the catches of *Hilsa* along the upstream and downstream (Digha, Talsari and Frazerganj) of the Hooghly estuarine region. Being a migratory fish, the adults that swarm at the lower estuaries and mature adults that make long journeys into the rivers are subject to noticeable fishing stress. Similarly, the fry that spend their life for a season in the river and juveniles that make long trip into the sea through the river and estuary are also subjected to extreme fishing stress. It is also a matter of concern that huge quantities of pre-adults are caught in the inshore areas by *jangal* and *kachal* fishing gears even before the fish attains size at first maturity (370 mm). Fishing on the migrating ripe *Hilsa* is also a matter of concern, causing failure of *Hilsa* fishery. The small mesh size of *jangal* and *kachal* and fishing in the river during

September and February when large scale movement of ripe fish is expected in the river, is a major cause of *Hilsa* decline. The overall rise in global temperatures has also affected the *Hilsa* migration.

In India, the *Hilsa* fishery is managed by the state, rather than by the central government. This is likely to mean that there is less capacity and resources to actively implement management measures. There is currently no control on fishing effort, that small size mesh nets are widely used to catch *jatka* and similar-sized juveniles of many species. Other scientist also undertook an assessment of the "total catchable potential" (TCP) of the Hooghly river system and some of the main species, including *Hilsa.* They estimated that the TCP for *Hilsa* was 3507.6 tons and this has already been exceeded. Thus, the limited studies on *Hilsa* suggest that *Hilsa* are almost certainly over-exploited in India. Thus, if India were to use management measures to improve sustainability, then major spawning and nursery areas need to be identified and mapped. Researches and investigators have also identified pollution and poor environmental flows as serious problems that are affecting *Hilsa* and other riverine and estuarine fishes in West Bengal.

Hilsa was the main fishery in comparison to major carps during the period between 1963-1971. But, with the commissioning of Farakka barrage, the fishery declined sharply between 1972-1980. Ghosh (1976) has mentioned that the production of the *Hilsa* fishery above the Farakka barrage has dropped from 116.1 kg/km^2 pre-construction to less than 1 kg/km^2 post construction. Catches of *Hilsa* dropped to just 1.01 tons at the same time the miscellaneous fishery recorded an increase. Total fish catch from this centre registered improvement, but shift in species composition was a direct result of hydrological changes caused by barrage. The fishery declined both in quantity and quality in time scale due to various anthropogenic factors. It has been reported by Gupta and Tyagi (1992) that the fishery is being harvested at much higher effort than the optimum fishing effort. Therefore, urgent steps are required to reduce the fishing pressure to achieve the goal of sustainable fishery from the river system. *Hilsa* fishery suffers badly. The per unit yield of major carps dropped to 46.0 kg/km from 143.5 kg/km recorded during the 1960s while *Hilsa* yield was only 7.1 kg/km. With the construction of Farakka barrage, the fishery scenario at Lalgola center about 45 km. below Farakka, 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. In recent years, between 1998-99 and 2002-2003, the average annual catch of *Hilsa* has been estimated at 10382.9 tons with an impressive increase of 63.3% from the corresponding five years (6279.6 tons). The average annual landing showed a sharp increase in the post barrage period. It was 1457.1 tons (15.3%) prior to 1975 and increased to 7352.9 tons (13.2%) during 1994-95 to 1999-2000. This unusual increase in the catch of *Hilsa* may be also due to the barrage construction, and due to migration of the *Hilsa* to areas above the barrage, resulting in severe depletion of *Hilsa* fisheries in the middle stretches of river Ganga. *Hilsa* juveniles (fry and fingerlings) constitute a substantial part of *Hilsa* catch from the upper freshwater stretches of the estuary. Indiscriminate exploitation of the young ones of *Hilsa* through small mesh nets took a heavy toll on the *Hilsa* juveniles, on the onset of downward migration of the young ones. Mitra *et al.* (2001) estimated *Hilsa* juvenile catch between 50.9-63.3

tons (57.5 tons) from Hooghly estuary, during the period 1994-1995 to 1999-2000, numerically when estimated it results to 13.1 million of young fish (weight range 2.2-27 g). In addition to this, wanton killing of *Hilsa* juvenile has been rampant in the upper stretch of the estuary, especially during November to May due to development of small mesh net.

Low water discharge from the river Ganga at the Farraka barrage and associated heavy siltation, indiscriminate exploitation of juveniles (*jatka*), disruption of their migration routes, loss of spawning, feeding and nursery grounds and increased fishing pressure have all contributed to a decline in the catch per unit effort in both the marine and river *Hils*a fishery. The radical decrease of catches of both mechanized and non-mechanized boats indicate the excess of fishing effort, which could lead to over-exploitation and vulnerability of the fishery. The declining trend of catch per unit effort of *Hilsa* fishing is threatening the livelihoods of about 464 thousand *Hilsa* fishermen. Fish stocks are renewable and a pragmatic approach is essential to maximize the sustainable benefits they can generate. It must be ensured that the resources are protected from the irreversible damage and managed on a sustainable basis. Dams and barrages constructed across the river to supply irrigation water, flood protection and hydropower not only prevent migration, change migration routes, and alter spawning and nursery grounds, but also concentrate the shad population in certain areas, thereby subjecting them to over-fishing. The average landing of *Hilsa* in metric tons is illustrated in Table 1.

Table 1: Average *Hilsa* landings (in metric tons) from the Hooghly-Matlah estuary during the pre- and post-Farakka Periods (Source: Sinha, 2004)

Period	Landings (in metric tons)
Pre-Farakka (1966-1975)	1,457.1
Post-Farakka (1975-1978)	2,126.2
Recent (1984-1994)	2,135.4

2. Conclusions

Thus, it can be concluded that the *Hilsa* decline thoroughly indicates habitat destruction and degradation in the lower Ganga river basin and at the same time it projects the rapid alteration in the ecology of the section concerned. The existing situation of the *Hilsa* fishery suggests that proper assessment is necessary and there is a need to find a way to stimulate the recovery of the fishery and make it sustainable, while maximizing economic benefits.

References

Biswas, J.C. (1954). Trends in *Hilsa* prices in Calcutta markets. *Journal Asiatic Society of Bengal, Science,* **20(1)**: 29–32.

Chapman, M.R. and Kramer, D.L. (1999). Gradients in coral reef fish density and size across the Barbados Marine Reserve boundary: effects of reserve protection and habitat characteristics. *Marine ecology progress series,* **181**: 81–96.

Day, F. (1873). Report on the fresh water fish and fisheries of India and Burma, pp. 22, 23, 35, 36.

De, D.K., Sinha, M. and Ghosh, A. (1994). Impact of Farakka barrage on the spawning of *Hilsa*, *Tenualosa ilisha* (Hamilton) in the Hooghly Estuary. *Journal of Inland Fisheries Society of India,* **6(1)**: 121–124.

Dulvy, N.K., Sadovy, Y. and Reynolds, J.D. (2003). Extinction vulnerability in marine populations. *Fish and Fisheries*, **4**: 25–64.

Dunn, I.C. (1982). The *Hilsa* fishery of Bangladesh: An investigation of its present status with an evaluation of current data. Fl:DP/BGD/81/034. *Field document* 2, FAO, Rome, pp. 71.

Ghosh, A.N. (1976). Observation on the *Hilsa* fishery of the river Jamuna during the years 1955-62, India. *Journal of Zoological society of India*, **17(172)**: 135–149.

Gopalakrishnan, V. (1973). Fishery resources of the Hoogly Matlah estuarine system and its relation to fisheries of The Bay of Bengal. *In:* Proceeding of the symposium on Living resources of the seas around India. *Special publication Central Marine Fisheries Research Institute*. pp. 373–386.

Grigg, R.W. (1994). Effects of sewage discharge, fishing pressure and habitat complexity on coral ecosystems and reef fishes in Hawaii. *Marine Ecology Progress Series*, **103**: 25–34.

Gupta, R.A. and Tyagi, R.K. (1992). Analytical approach to analysis of fish stocks of the Ganga river system. *Journal of the Inland Fisheries Society*, **24(2)**: 20–27.

Hora, S.L. (1938). A preliminary note on the spawning grounds and bionomics of the so called Indian shad, *Hilsa ilisha* (Ham.) in the river Ganges. *Records Indian Museum, Calcutta*, **40**: 147–158.

Hora, S. L. and Nair K. K. (1940a). Further observations on the bionomics and fishery of the Indian Shad, *Hilsa ilisha* (Ham.) in Bengal waters. *Records Indian Museum, Calcutta*, **42(1)**: 35–50.

Hora, S. L. and Nair, K. K. (1940b) Observation on the seaward migration of the of so called Indian shad, *Hilsa ilisha* (Ham.) in Bengal waters. *Records Indian Museum, Calcutta*, **42(1)**: 35–50

Hora, S.L. (1941). Life history and wandering of *Hilsa* in Bengal waters. *Journal Asiatic Society of Bengal, Science,* **6**: 93–112.

Jones, S. (1957). On the late, winter and early spring migration of the Indian Shad, *Hilsa ilisha* (Hamilton) in the Gangetic Delta. *Indian Journal of Fishery*, **04(2)**: 304–314.

Malhotra, J.C. and Shah, K. L. (1979). Souvenir: In commemoration of the ICAR golden jubilee year, QFRI, Barrackpore, **2**: 175–178.

Mitra, P.M., Karmaker, H.C., Ghosh, A.K., Mondal, N.C., Sen, H.K. and Das, B.N. (2001). Fisheries of Hooghly-Matlah estuarine system - Further appraisal. *Bulletin of Central Inland Fisheries Research Institute,* **109**: 18.

Mojumdar, C.H. (1939). Culture of *Hilsa*. *Mod. Rev.* **66**: 293–297.

Motwani, M.P., Jhingran V.G. and Karamchandani, S.J. (1957). On the breeding of the Indian shad, *Hilsa ilisha* (Hamilton) in fresh waters. *Society and Culture*, **23**: 47–48.

Naidu, M.R. (1939). Report on survey of the fisheries of Bengal, Calcutta.

Nair, K.K. (1939). On some early stages in the development of the so-called Indian Shad, *Hilsa ilisha* (Ham.). *Records Indian Museum, Calcutta*, **41**: 409–418.

Pandit, C.G. and Hora S.L. (1951). The probable role of the *Hilsa* fish, *Hilsa ilisha* (Ham) in maintaining cholera endemicity in India. *Records Indian Museum, Calcutta,* **15**: 343–56.

Pantulu, V.R., Alagaraja, K. and Bhimchar, B.S. (1966). Fisheries of the Damodar valley in relation to construction of dams. *Proceedings of the National Institute of Sciences of India*, **32B (556)**: 191–207.

Pillay, T.V.R. and Rao, K.V. (1962). Observation on the biology and fishery of the Hilsa, *Hilsa ilisha* (Ham.) of the river Godavari. *Proceedings Indo-Pacific Fishery Council.* **10(2)**: 37–61.

Pillay, T.V.R. (1958). Morphological and physiological character of the blood of *Hilsa ilisha* (Ham.) of the river Hoogly. *Proc. Indian Acad. Sci,* **B 47(3)**: 155–162.

Prashad, B., Hora, S.L. and Nair, K.K. (1940). Observation on the seaward migration of the so called Indian shad, *Hilsa ilisha* (Ham.). *Records Indian Museum, Calcutta,* **42(4)**: 529–552.

Roberts, C.M. and Hawkins, J.P. (1999). Extinction risk in the sea. *Tree*, **14(6)**: 241–245.

Rodwell, L.D., Barbier, E.B. Roberts, C.M. and McClanahan, T.R. (2003). The importance of habitat quality for marine reserve fishery linkages. *Canadian Journal of Fisheries and Aquatic Sciences*, **60**: 171–181.

Russ, G.R., Stockwell, B. and Alcala, A.C. (2005). Inferring versus measuring rates of recovery in no-take marine reserves. *Marine Ecology Progress Series*, **292**: 1–12.

Sinha, M. (2004). Farakka barrage and its impact on the hydrology and fishery of Hooghly estuary in M. Monirul Qader Mirza (ed.). *The Ganges Water Dispersion: Environmental Effects and Implications*, pp. 103–124.

Southwell, T. and Prasad, B. (1918). *Hilsa* investigations in Bengal, Bihar and Orissa. *Bulletin* II *Department of Fishery,* Bengal, Bihar and Orissa.

Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A. and Losos, E. (1998). Quantifying threats to imperiled species in the United States. *BioScience,* **48**: 607–615.

Wilson, S.K., Fisher, R., Pratchett, M.S., Graham, N.A.J., Dulvy, N.K., Turner, R.A., Cakacaka, A., Polunin, N.V.C. and Rushton, S.P. (2008). Exploitation and habitat degradation as agents of change within coral reef fish communities. *Global Change Biology,* **14**: 2796–2809.

The Status of Sundari (*H. fomes*) an indicators species in the Sunderbans

The Lower Ganga River Basin

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

The term "Sundarbans" has been coined from the (i) forests of Sundari (*Heritiera fomes*), or (ii) forests of beautiful plants or (iii) forests of *Samudra* (i.e., Ocean). This entire Gangetic Sundarbans extend over *ca* 14,600 km^2 distributed over both Bangladesh and India, with the latter occupying *ca* 4266.6 km^2 in West Bengal state (Plate 1). In comparison to the Bangladesh part, the Indian component of the Sundarbans has poor forest formation due to higher salinity and biotic interactions leading to different growth pattern and ecological succession. (Blasco, 1975).

Being on the land sea interface, mangroves are always associated with and subjected to saline seawater. However, saline condition is not a prerequisite for their development; rather mangroves choose saline conditions to avoid the competition with the more vigorous terrestrial plants. The Indian Sundarbans can be divided in to three parts *i.e*., **central** and eastern, based on their salinity level. The western part is the least saline due to the freshwater discharge from the Ganga-Bhagirathi-Hooghly rivers; whereas, the central part is most saline due to non-receipt of fresh water from the Ganges owing to heavy siltation since the late 15^{th} century (Chaudhuri and Choudhury, 1994) and the rising sea level (Hazra *et al.* 2002). The rate of sea level rise is 3.14 mm/yr, which is higher than the global and Indian coastline averages of 2.12 mm/yr and 2.50 mm/yr, respectively (Lal and Aggarwal, 2000). The sea level rise and subsequent saline water intrusion into the islands of Sundarbans, they are also vulnerable to extreme climatic events owing to their location below the average Mean Sea Level. Since, the Sundarbans is located in a low-lying floodplain, most of the silt carried out by the Gangetic rivers are lost in the trench of the Bay of Bengal. A large portion of the silt are deposited on the eastern side causing land accretion, particularly in the south-eastern region; and compensatory erosion in the southwestern part, thereby pushing the coastline towards the sea. The coastal geomorphology is regulated by a circulation system driven by high sediment load, coupled with strong tidal and wind actions. The rivers also carry untreated municipal wastes, industrial effluents, agro-chemical residues etc., further adding to the deterioration of the ecosystem.

Mangroves are rich in polyphenols and tannins (Kathiresan and Ravi, 1990). Phenols and flavonoids present in mangrove leaves serve as UV-screen compounds. Flavonoids increase during pre-monsoon period. Pigment concentrations may vary with environmental conditions and seasons. Oswin and Kathiresan (1994) found high level of chlorophyll and carotenoids during the summer but highest level of anthocyanin in the monsoon months. However, depletion of growing stock, post-dispersal predation of seeds by crabs, sporadic flowering, and poor seed set in the remnant mangrove forests have been reported (Robertson *et al.,* 1990). The primary threats to all mangrove species including *H. fomes* are habitat destruction and removal of mangrove areas for conversion to aquaculture, agriculture, urban and coastal development, and overexploitation.

A. Ecology

Kingdom : **Plantae**
Phylum : **Tracheophyta**
Class : **Magnoliopsida**
Order : **Malvales**
Family : **Sterculiaceae**
Genus : ***Heritiera***
Species : ***fomes***

Plate 1: Satellite FCC of Indian Sunderbans

Plate 2: *H. fomes* occurrence in the Indian Sunderbans; a. single canopy; b. multiple canopy; c. in association; d. a twig and e. fruits; Photographs taken during field visit on 8-9 May 2011

H. fomes, Sundari is a mangrove buttressed tree of 10 to 25 m tall with dense, robust pneumatophores about 50 cm height (Plate 2). It is the only *Heritiera* species that produces pneumatophores. The roots do not penetrate deep into the soil, but spread on the surface with numerous stout offshoots and often with narrow ridges forming plant like projections above the soil and also form flat narrow buttress to the basal trunk.

It prefers freshwater and is fast-growing in low-saline environments. The species is commonly found along the tidal creeks and channels of the coastal swamps, and regenerate naturally through seeds (Banerjee and Rao, 1990). The species is found in the upstream estuarine zone in the high intertidal region and adapted best along the seashore. Cluster analysis using the AFLP (Amplified Fragment Length Polymorphism) banding patterns of all the primer combination reveals that *H. fomes* in the due course of evolutionary process might have migrated to land and evolved as a new species (Mukherjee *et al.,* 2003).

Sundari contains 0.25% and 0.09% (dry weight) of chl-*a* and chl-*b*, respectively. Studies have reported that the carbon, polyphenol, tannin and protein content are 0.11%, 39.45%, 21.12% and 29.22% of dry weight, respectively for the species. The chemicals produced from the species can be used for gastro-intestinal disorders (including dysentery, diarrhea, indigestion, colic, acidity, constipation, bloating, lack of appetite, stomachache). Besides this, it can be used to treat hepatic disorders (including jaundice and hepatitis), insect repellent and skin diseases (including eczema, abscess, acne, boils, scabies, itch, infections, dermatitis, rash, sores, scar, warts, etc.). Sundari has been the main timber species and is the primary resource base for 221 small saw mills and 350 pitsaw units in the region (Bangladesh Bureau of Statistics, 1983).

According to **IUCN red list** Conservation Category, *H*. *fomes* is assigned with endangered status. With time, this species may go (locally) extinct as their population is rapidly declining due to various reasons so as Kathiresan (2008a) found the species in only 6% of the sampling sites in India.

The species is now on the extinction threat in West Bengal due to overcutting and increased salinity. Unlike other mangrove species *H. fomes* prefer extremely low saline condition (5 – 15 psu) and hence can act as biological indicator of climate change related to sea level rise. In the highly populated Bengal (India and Bangladesh) the dry season demand for freshwater has increased dramatically; major rivers have been dammed and the downstream effects are becoming apparent with increasing soil salinities and unexplained 'top dying' disease is threatening the *H. fomes* population. The first factor is clearly anthropogenic; the second, although aggravated by upstream diversions of Ganga water, is largely due to long-term geomorphic processes.

B. Drivers of Change

Past Alterations

In the past, the Government of India's policies had largely determined the pace, direction, mode and beneficiaries of exploitation in the Sundarbans. Under British rule, there was no state guarantee to the property rights to any person or under-tenants. British land policy in undivided Bengal had created an institutional basis for land clearance. Economic progress, human needs and the revenue demands of the state rested on continued mangrove clearance and reclamation. One model was to empower the energetic landlords, who would invest both energy and capital into reclaiming the waste lands. Timber and fuel wood were another resource tapped for the expanding market. Rice, rather than timber was the choice for the officers to gain from the profitable rice markets in nearby Kolkata (formerly Calcutta). Peace, order, and guaranteed ownership rights on firmly planted lands proved adequate to encourage spread of settlement embanked-rice paddy cultivation for the poor. The Sundarbans is an exception to the general trend of deltaic development in that it is the only area in which a state-organized barrier to agricultural expansion emerged. Wood prices followed a trajectory similar to that of the rice rates with steep ascent of 52% between 1950 and 1980. The pressure of population growth upon resources is evident from the fact that despite one hundred years of cropland expansion, the available cultivated land per capita dropped from 0.22 to 0.08 ha. More strikingly, the reduction in per capita area of all forms of natural vegetation (wetlands, forest, scrub, grassland) declined from 0.27 ha in 1880 to 0.04 ha in 1980.

Salinity Increase

H. fomes can flourish luxuriantly under low salinity conditions; however, it is gradually losing the species owing to increase of salinity level. Based on the physiological studies, Bowman (1917) and Davis (1940) concluded that mangroves are not salt lovers, rather salt-tolerant. But excessive saline conditions retard seed germination, impede growth and development of M~~m~~angroves. When the salinity increases, the species becomes stunted, rare and ultimately disappears. Alteration in growth of mangroves due to difference in salinity between western and central sectors of Indian Sundarbans has been reported by Mitra *et al.* (2004). The effects of salinity on mangroves have been studied in relation to antioxidative enzymes (Takemura *et al.,* 2000; Parida *et al.,* 2004b), leaf structure, rates of transpiration, stomatal conductance and rates of photosynthesis (Santiago *et al.,* 2000; Parida *et al.,* 2004a) and changes in chloroplast structure and function (Parida *et al.,* 2003).

H. fomes prefers an optimum salinity between 2 - 5 psu (Mitra *et al.,* 2004). The adverse impact of salinity on leaf chlorophyll of *H. fomes* may significantly affect the rate of photosynthesis as this pigment is an indispensable raw material for running the process. Various studies have shown that a number of mangrove species grow best at salinities between 4 psu and 15 psu (Connor, 1969; Clough, 1985; Downton, 1982; Burchett *et al.,* 1984 and Clough, 1984) and for *H. fomes*, the preferred salinity range is much lower (Chaudhuri and Choudhury, 1994). At 15 psu the plants become acclimatized to salt after one to two weeks of exposure, but at 20 psu the seedlings could hardly adapt. Salinity exerts its effect on photosynthesis mainly through changes in leaf water status. Clough (1985) stated that the rate of light saturated photosynthesis decreases with increasing salinity of ambient media, attributing this to co-limitation of assimilation rate by stomatal conductance and photosynthetic capacity in response to differences in water status induced by the various salinity treatments. Study reveals that the photosynthetic process may be affected at high saline condition due to decrease in Chl *a* and *b* concentrations in *H. fomes*. The pigments, being the key machinery in regulating the growth and survival of the mangroves require an optimum salinity range between 4 - 15 psu (Downton, 1982; Burchett *et al.,* 1984) for proper functioning.

Industrial Pollution

Oil or gas exploration, petroleum production and accidents by large oil tankers cause significant damage to mangrove ecosystems, causing defoliation of trees, mortality of all sessile and benthic organisms and contamination of many water fowls with minimum recovery period of 10-years (Kathiresan, 2008b). In Indian Sundarbans, several industrial effluents are released in to the adjacent coastal water bodies. For example the presence of Haldia port-cum-industrial complex releases several pollutants of organic load that contains several complex ions and different organic and inorganic compounds. When these compounds are mixed with the coastal water bodies they enter in the sediment through percolation and the pneumatophores contact with the sediment also take up the organic and inorganic compounds. These compounds hamper the circulatory system of the mangroves species such as *H. fomes*.

Disease and Infestation

Top dying of Sundari in the Sundarbans is considered to be the most important of all the diseases and disorder of tree crops in Bangladesh. It has been estimated that about 45 million trees have been affected by top dying in the Sundarbans (Rahman, 1990). This is about 20% of the entire forests in Bangladesh (Hussain and Acharya, 1994). The top-dying disease is believed to be caused by an array of factors *viz*., increased soil salinity due to reduced water flow, reduction in periodic inundation, excessive flooding, sedimentation, nutrient imbalances, pathogenic gall cankers, and cyclone-induced stress. When the salinity increases, the species becomes stunted, rare and ultimately disappears.

Sundari affected by top dying, where death of twigs and small branches gradually reduce the canopy and destroys the growth potential of such trees which may also suffer from death of the top of main stem and be truncated while the remaining portion of the main stem remain healthy. Dead but standing Sundari almost devoid of major branches, may result from infection by one or more sap wood rotting fungi which kill the sapwood and thereby the attacked tree is died. Moreover, Sundari trees are attacked by borers and wood decay fungi. Death of small twigs may be due to the occurrence of gall-cankers. Trees are also seen where only small twigs and branches die and there are no gall cankers. The initial stage of death of twigs and small branches has been seen to be associated with certain insect eating up tender bark of twigs. During October to December, dead twigs and branches have been seen on many hundreds of trees but in no case dying branches were seen. Further observation of January onward is needed to detect the early stage of symptom expression. In other cases, top dying trees are seen to develop very reduced, deformed and bronze colored leaves of very little photosynthetic potential. There are several other symptoms associated with the top dying disease of *H. fomes* that include:

Root rot and resultant die back: A large number of dead Sundari trees are affected by root rot disease. Characteristics symptoms are leaves become gradually discolored pale and light yellow, then yellow and finally fall off the tree.

Sap and heart rot associated with top dying: In general, top dying Sundari trees have a dead and truncated top with accompanied death of twigs and branches to a varying degree leaving a variable extent of healthy canopy. A proportion of Sundari are seen to be dead from top to bottom. Such trees seldom have any live branches. Examination of such dead trees reveals that the bark dies first and is followed by decay and deterioration of the wood. Occasionally both sap wood rot and heart wood rot may occur simultaneously. In other cases even in the absence of any sap wood rot, death and decay of heart wood by a white rot fungus provisionally identified as *Fomes badius* occurs. In this, rot generally destroys the heart wood of the trees, while sap wood remains healthy. Such damage does not cause death of trees, but it weakens the mechanical support of such trees and thereby renders these trees to be more prone to wind damage. Heart rot may occur from the basal part of a tree or it may occur both from the basal part of a trunk and/or from different locations on the main trunk through dead broken branch stubs and then progresses both up and down the trunk.

Dieback of the foliage: In a number of sites where excessive siltation has buried all or a portion of the pneumatophores, Sundari in particular and other trees in general have been seen to produce leaves of very diminished size, light bronze in color, having a general pale appearance. Such trees can add very little new growth. Quite often such branches are seen to die and ultimately most of the affected trees die or show rapid death from top to downward. Top-dying of Sundari appears as a decline and dieback of the foliage and twigs of a part of the crown, but ultimately the main stem becomes affected and may also be truncated having a variable extent of the crown. Top-dying of Sundari and dieback of the foliage and twigs of a part of the crown appears as a decline. In case of older trees, one or more of the major branches may die and gradually other branches die and ultimately the crown is substantially reduced (Rahman, M. A. Methodology of Pathological Research in Mangrove Forest unpublished).

Hence, the important causes that can be attributed to the top-dying diseases are: (i) soil salinity, (ii) burial of pneumatophores, production of reduced number of it creates reduced soil aeration affecting metabolism in the root system, (iii) deficiency of micronutrients and presence of high level of calcium, (iv) greater opening in the canopy, *Loranthus* infestations, higher dbh (Diameter at breast height) classes are associated with severity of top-dying disease, (v) Once top-dying starts a number of fungi degrade wood of the tree, and (vi) insect infestation of sapwood and wood decay fungi has linear positive association.

Invasion

Biological invasions are now considered one of the main threats to world's biodiversity. Impact of these invasive or associated species on Sundarban mangroves are that they (i) compete with indigenous plants for light, nutrients and moisture; (ii) impede natural regeneration; (iii) cause physical damage to the native species and (iv) change water quality or characteristics and habitat for fish and other aquatic organisms. Invasive species spread into natural vegetation due to disturbance. 23 invasive species belonging to 18 families and 23 genera are present in Indian Sundarbans (Biswas *et al.,* 2007). Among these identified species, 3-species are highly invasive, 6 are moderately invasive and the remaining are potentially invasive. However, *H. fomes* is positively associated with *Derris trifoliata, Hoya parasitica* and *Micania scanden* in the Sunderbans (Biswas *et al*., 2007).

Extreme Weather Events

The *Sundarban*s is already affected by climate change and extreme weather events such as tropical cyclones and storms. Mangrove forests protect all types of coastal communities from the fury of extreme weather events by means of their mere presence by providing the best shelterbelt. Tropical cyclones and storms are more common in the Bay of Bengal, severely affecting the eastern coast as compared to that of the western coast. According to Koteswaram (1984), there were about 346 cyclones that include 133 severe ones in the Bay of Bengal, between the years 1891 and 1970. These cyclones with tremendous speed hit the coastline and inundate the shores with strong tidal wave, severely destroying and disturbing coastal life.

Tsunami-induced human death and property loss were also behind mangroves and sand dunes. The mitigating effect of mangroves depends on their response to two physical processes of tsunami - (i) wave attack, and (ii) towing flow. Mangrove's response to wave attacks depends on its vegetation characteristics, whereas the response to towing flow relies on 'drag force' caused by the mangroves, resulting in prevention of coastal erosion. Thus the protective role of mangroves depends on: (i) vegetation characteristics such as, density, height, species composition, density of forest, diameter of mangrove roots and trunks, and elevation of habitats, as well as status of ecological degradation of the forests; and, (ii) tsunami wave characteristics such as wave height, wave period, and depth of water. Protection and restoration of mangroves, coastal forests and sand dunes would mitigate the impacts of not only tsunamis, but also storms and sea level rise.

C. Management Practices

H. fomes is the single most important species of the Sundarbans, but the dominance of *Heritiera* forest is decreasing. As a pure crop and in mixture with *Excoecaria agallocha*, the species occupies ca. 18.2% and 62.4% of the forest area respectively (Anon, 2001). The species necessitates mass vegetative propagation, an alternative to seed propagation, for perpetuation of the species and their re-establishment in the area (Hartmann and Kester, 1989). Few studies dealt with the effect of auxins (IAA, IBA & NAA) on rooting of the pre-girdled stem cuttings and air-layers and the biochemical changes during initiation and development of roots in *H. fomes.* Extensive physical and biological changes in last 50 years have led to artificial assemblage of *H. fomes*, *Sonneratia apetala* etc., species owing to economic needs and environmental change (Snedaker, 1982). There are reports of development of management plans for coastal plantations targeting to achieve many objectives *viz*., (a) to continue the establishment of coastal forest plantations and initiate management of existing ones for their timber value, (b) to protect and preserve areas of environmental value relating to conservation of biodiversity resources, (c) to integrate people's participation and development, (d) to enhance and promote recreational and tourism potential etc. (Canonizado, 1999). In addition to the forest department, some NGOs and local people's groups are now engaged in forest management activities using the following key management strategies.

Adoption of holistic management approach: The Sundarbans have been under systematic management for *ca.* 130 years. In the past, a sustained yield principle under the selection system was applied and main emphasis was given to two or three timber species. Recently, emphasis has been put on ecosystem management and timber felling is now banned. Salvage felling and enrichment planting has started to restore forest health (Siddiqi, 2001). However, continuous pilferages of valuable species are a major threat to sustainability (Naskar, 1999). Integrated regional development plans are necessary to increase the supply of freshwater to the Sundarbans through excavation of rivers and revision of treaties with India.

Biodiversity conservation and enhancement: Mangrove plantations are offering a new habitat to the wildlife of the Sundarbans. In addition, some parts of the mangrove forest and plantations are declared protected areas under a different status *e.g.*, wildlife sanctuaries, national park and ecologically critical areas.

People's participation in forest management: Under the Coastal Greenbelt Project (CGP), a people oriented participatory forestry program was targeted to improve the socio-economic condition of the rural poor, improve the role and status of women in rural enterprises, diversify and supplement farm income, substitution of locally produced coconut for improved oil and enhance the environmental quality including the restoration and/or protection of critical mangrove habitat (Canonizado, 1999).

Modeling for optimizing plantation design: The mangrove plantations are playing an important role in reducing the impact of these cyclones and accompanying surges. It is essential to maintain the shelter belt, but as yet, no fixed width has been determined. In Indian Sundarbans, modeling studies are being carried out to find the optimum plantation width and the number of rows to increase protective efficiency.

D. Discussion

H. fomes is one of the most important endangered/threatened species in Indian Sundarbans. Due to durability and hardness of wood, this species is very much useful for boat building and several domestic purposes as well as for furniture making. But, these days, it is occasionally found in the tidal swamps of the Sundarbans, especially in the western zone, where the salinity level is high up to 25 ppt and human interference is more. The trees of *H. fomes* are being exploited indiscriminately for its timber value, since long. Only a few plants of *H. fomes* are found in the eastern part of Indian Sundarbans in association with other species. But most of the *H. fomes* plants are noted for scanty growth and the sizes of those trees are not as big as the normal tree. Inside the ridge of tidal forest zones in the Sundarbans tidal forest some of the *H. fomes* are also found. Their growth is more vigorous than the river side trees. The differences in growth experienced may be due to higher salinity towards the river side forest than the inside higher level ridge forest area; and more human pressure on the river side trees.

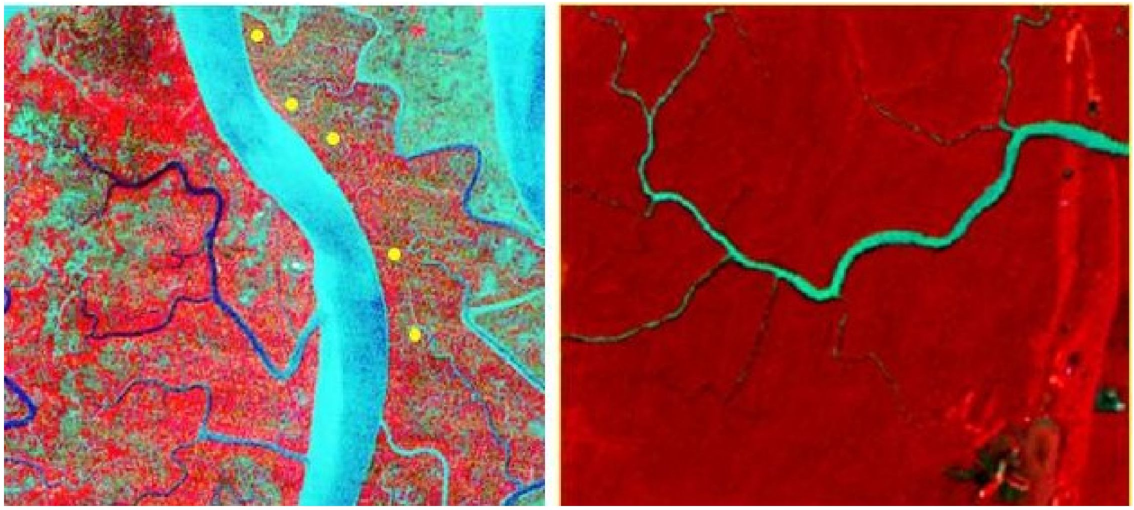

Plate 3: ***H. fomes*** **as seen on satellite image (LH) found in scattered patches in the Sundarbans, West Bengal; luxuriant growth in Dangamala region of Bhitarkanika WL Sanctuary, Orissa (RH)**

During field visit to the Indian Sunderbans, the senior author had to search for, to see the presence of the species; whereas luxuriant growth was evident in Bhitarkanika wildlife sanctuary (Orissa), which is also revealed from the satellite data (Plate 3). It emerged from all the above gathered evidences that the species *H. fomes* is approaching fast extinction. And if the *Sundarbans* name has been coined from the forests of *Sundari* (*Heritiera fomes*), then perhaps the world`s largest mangrove forest may need a name change in future days?

References

Agastian, P., Kingsley, S.J. and Vivekanandan, M. (2000). Effect of salinity on photosynthesis and biochemical characteristics in mulberry genotypes. *Photosynthetica*, **38:** 287-290.

Anon, (2001). The Bangladesh Sundarbans: A photoreal sojourn. IUCN Bangladesh country office, Dhaka, Bangladesh.

Anonymous, (2008). *State of Forest Report 2005*. Forest Survey of India, Dehradun, India.

Aschbacher, J., Ofren, R.S., Delsol, J.P., Suselo, T.B., Vibulsresth, S. and Charrupat, T. (1995). An integrated comparative approach to mangrove vegetation mapping using remote sensing and GIS technologies: preliminary results. *Hydrobiologia*, **295:** 285-294.

Ball, M.C. and Farquhar, G.D. (1984). Photosynthetic and stomatal responses of two mangrove species, *Aegiceras corniculatum* and *Avicennia marina*, to long term salinity and humidity conditions. *Plant Physiology*, **74:** 1-6.

Banerjee, L.K. and Rao, T.A. (1990). Mangroves of Orissa coast and their ecology. Bishen Singh and Mahendra Pal Singh, Dehradun, India. pp. 118.

Bangladesh Bureau of Statistics, (1983). Khulna Statistics, Dhaka. pp. 163.

Biswas, S.R., Choudhury, J.K., Nishat, A. and Rahman, M.M. (2007). Do invasive plants threaten the Sundarbans mangrove forest of Bangladesh? *Forest Ecology and Management,* **245:** 1-9.

Blasco, (1975). Red tides in the upwelling regions, Zn toxic dinoflagellate blooms. Proceeding International Conference (1st). *Massachusetts Science and Technology Foundation.* pp. 113-119.

Blasco, F. and Aizpuru, M. (1997). Classification and evolution of the mangroves of India. *Tropical Ecology*, **38:** 357-374.

Bowman, (1917). Mangrove regeneration and management. *In:* A.K.F. Hoque, 1995. Mimeograph.

Bruenig, E.F. (1996). Conservation and Management of Tropical Rainforests. University Press, Cambridge, U.K.

Burchett, M.D., Field, C.D. and Pulkownik, A. (1984). Salinity, growth and root respiration in the grey mangrove *Avicennia marina. Physiologia Plantarum*, **60:** 113-118.

Canonizado, J.A. and Hossain, M.A. (1998). Integrated forest management plan for the Sundarbans. Final draft, Mandala Agricultural Development Corporation and Bangladesh Forest Department, Bangladesh.

Canonizado, J.A. (1999). *Integrated Forest Management Plan Noakhali C/A Division (1999-2008).* Forest Resources Management Project, Mandala Agricultural Development

Corporation and Forest Department; Ministry of Environment and Forests, Dhaka, Bangladesh.

Chaudhuri, A.B. and Choudhury, A. (1994). Mangroves of the Sundarbans, India. Vol. I. IUCN. pp. 284.

Clark, L.D. and Hannon, N.J. (1967). The mangrove swamp and saltmarsh communities of the Sydney district, III. Plant growth in relation to salinity and waterlogging. *The Journal of Ecology*, **58:** 351-369.

Clough, B.F. (1984). Growth and salt balance of the mangroves *Avicennia mari*na (Forsk.) Vierh, and *Rhizophora slylosa* Griff. In relation to salinity. *Australian Journal of Plant Physiology*, **11:** 419-430.

Clough, B.F. (1985). Effect of nutrient supply on photosynthesis in mangroves. *In:* L.J. Bhosale (Eds.). The Mangroves. Proc. Natl. Symp. Biol. Util. Cons. Mangroves. Shivaji University, Kohlapur, India. pp. 80-88.

Connor, D.J. (1969). Growth of grey mangrove (*Avicennia marina*) in nutrient culture. *Biotropica*, **1:** 36-40.

Davis, J.H. (1940). The ecology and geological role of mangroves in Florida. Carnegie Institute of Washington. Publication 517. *Papers of the Tortugas Laboratory*, **52:** 303-412.

Downton, W.J.S. (1982). Growth and osmotic relations of the mangrove *Avicennia marina,* as influenced by salinity. *Australian Journal of Plant Physiology*, **9:** 519-528.

Gadallah, M.A.A. (1999). Effects of proline and glycinebetaine on *Vicia faba* in response to salt stress. *Biological Plant*, **42:** 249-257.

Green, E.P., Clark, C.D., Mumby, P.J., Edwards, A.J. and Ellis, A.C. (1998). Remote sensing techniques for mangrove mapping. *International Journal of Remote Sensing*, **19:** 935-956.

Hartmann, H.T. and Kester, D.E. (1989). Plant Propagation: Principles and Practices. Prentice Hall, New Delhi, India.

Hazra, S., Ghosh, T., Dasgupta, R. and Sen, G. (2002). Sea level and associated changes in Sundarbans. *Science and Culture*, **68:** 309-321.

Hill, R.A. (1999). Image segmentation for humid tropical forest classification in Landsat TM data. *International Journal of Remote Sensing*, **20:** 1039-1044.

Hotta, M., Nemoto, S. and Mimura, T. (2000). Re-evaluation of role of vacuole during salt adaptation in higher plant cells, *Plant Cell Physiology*, **41 (Suppl.):** 79.

Hussain, K. and Acharya, G. (1994). Mangroves of the Sundarbans. Volume 2: Bangladesh. IUCN Wetlands Programme, Bangkok, Thailand.

ISME, (1993). The economic and environmental values of Mangrove forests and their present state of conservation in the South East Asia/Pacific Region, Okinawa, Japan.

Kathiresan, K. and Ravi, V. (1990). Seasonal changes in tannin content of mangrove leaves. *The Indian Forester*, **116(5)**: 390-392.

Kathiresan, K. (2008a). Mangroves and carbon budget of coastal India: The first estimate. *Seshaiyana*, **16:** 1-2.

Kathiresan, K. (2008b). Threats to Mangroves. Degradation and destruction of mangroves. Centre of Advanced Study in Marine Biology. Annamalai University, India. pp. 476-483.

Koteswaram, P. (1984). Climate and mangrove forests. Report of the second introductory trainning course on mangrove ecosystems. Sponsored by UNDP and UNESCO, Goa, India. pp. 29-46.

Lal, M. and Aggarwal, D. (2000). Climate change and its impacts in India, Asia-Pacific. *Journal of Environment and Development* (Communicated).

Lichtenthaler, H.K. (1996). Vegetation stress: an introduction to the stress concept in plants. *Journal of Plant Physiology,* **148:** 4-14.

Lin, G. and Sternberg, L. (1992). Effect of growth form, salinity, nutrient and sulfide on photosynthesis, carbon isotope discrimination and growth of red mangrove (*Rhizophora mangle*). *Australian Journal of Plant Physiology,* **19:** 509-517.

Lin, G. and Sternberg, L. (1993). Effects of salinity fluctuation on photosynthetic gas exchange and plant growth of the red mangrove (*Rhizophora mangle*). *Journal of Experimental Botany*, **44:** 9-16.

Mas, J. (1999). Monitoring land-cover changes: a comparison of change detection techniques. *International Journal of Remote Sensing,* **20:** 139-152

Mitra, A., Banerjee, K., and Bhattacharyya, D.P. (2004). The other face of mangroves. Department of Environment, Govt. of West Bengal, India.

Mukherjee, A.K., Acharya, L.K., Mattagajasingh, I., Panda, P.C., Mohapatra, T. and Das, P. (2003). Molecular characterization of three *Heritiera* species using AFLP markers. *Biologia Plantation*, **47(3):** 445-448.

Naskar, K.R. (1999). Status of mangroves in Indian Sundarbans in the perspectives of India and world mangals. *In:* D.N.G. Bakshi, P. Sanyal and K.R. Naskar Acharya, (Eds.), Sundarbans mangals. Naya Prokash, Calcutta, India.

Odum, E.P. (1971). *Fundamentals of Ecology*, 3rd edn., W.B. Saunders Co., Philadelphia.

Oswin, S.D. and Kathiresan, K. (1994). Pigments in mangrove species of Pichavaram. *Indian Journal of Marine Sciences*, **23(1):** 64-66.

Parida, A.K., Das, A.B. and Mittra, B. (2004a). Effects of salt on growth, ion accumulation, photosynthesis and leaf anatomy of the mangrove *Bruguiera parviflora*. *Trees-Structure and Function*, **18:** 167-174.

Parida, A.K., Das, A.B. and Mohanty, P. (2004b). Defense potentials to Nacl in a mangrove, *Bruguiera parviflora*: differential changes of isoforms of some antioxidative enzymes. *Journal of Plant Physiology*, **161:** 531-542.

Parida, A.K., Das, A.B. and Mittra, B. (2003). Effects of NaCl stress on the structure, pigment complex composition and photosynthetic activity of mangrove *Bruguiera parviflora* chloroplasts. *Photosynthetica*, **41:** 191-200.

Rahman, M.A. (1995). *Mangrove plant pathology of the Sundarbans reserved forest in Bangladesh.* Field document no. 3 of FAO/UNDP project BGD/84/056 Integrated Resource Development of the Sundarbans Reserved Forest, Forest Department, Khulna, Bangladesh.

Rahman, M.A. (1990). A comprehensive report on Sundri (*Heritiera fomes*) trees with particular reference to top dying in the Sundarbans. *In:* M.A. Rahman, K. Khandakar, F.U. Ahmed, and M.O. Ali, (Eds.). Proceedings of the seminar on Top dying of Sundri (*Heritiera fomes*) Trees, held on 11 August, 1988. at Bangladesh Agricultural Research Council, Farmgate, Dhaka, Bangladesh. pp. 12-63.

Ramanathan, A.L., Rajkumar, K., Majumder, J., Singh, G., Behera, P.N., Santra, S.C. and Chidambaram, S. (2009). Textural characteristics of the surface sediments of a tropical mangrove Sundarban ecosystem India. *Indian Journal of Marine science*, **38(4):** 397-403

Ramsey, E.J. and Jensen, J.R. (1996). Remote sensing of mangrove wetlands: relating canopy spectra to site-specific data. *Photogrammetric Engineering and Remote Sensing,* **62:** 939-948.

Robertson, J.M., Hubick, K.T., Yeung, E.C. and Reid, D.M. (1990). Developmental responses to drought and abscisic acid in sunflower roots. I. Root growth, apical anatomy, and osmotic adjustment. *Journal of Experimental Botany*, **41:** 325-338.

Roy, P.S. and Tomar, S. (2000). Biodiversity characterization at landscape level using geospatial modeling technique. *Biological Conservation,* **95:** 95-109.

Roy, P.S., Padalia, H., Chauhan, N., Porwal, M.C., Gupta, S., Biswas, S. and Jagdale, R. (2005). Validation of geospatial model for biodiversity characterization at landscape level-a study in Andaman and Nicobar islands, India. *Ecological Modeling,* **185:** 349-369.

Santiago, L.S., Lau, T.S.P., Melcher, J., Steele, O.C. and Goldstein, G. (2000). Morphological and physiological responses of Hawaiian *Hibiscus tiliaceus* population to light and salinity. *International Journal of Plant Science*, **161:** 99-106.

Siddiqi, N.A. (1998). Enrichment planting in the mangrove of Sunderbans Arcview. *Bangladesh Journal of Forest Science,* **27:** 103-113.

Siddiqi, N.A. (2001). *Mangrove Forestry in Bangladesh.* Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh.

Snedaker, S.C. (1982). Mangrove species zonation: Why? Tasks for Vegetation Science Vol. 2. *In:* D.N. Sen and K.J. Rajpurobit (Eds.). Dr. W. Junk Publishers, pp. 111-125.

Sten, W.L. and Voigt, G.K. (1959). Effect of salt concentration on growth of red mangrove in culture. *Botanical Gazette*, **9:** 36-39.

Takemura, T., Hanagata, N., Sugihara, K., Baba, S., Karube, I. and Dubinsky, Z. (2000). Physiological and biochemical responses to salt stress in the mangrove, *Bruguiera gymnorrhiza. Aquatic Botany*, **68:** 15-28.

Tanaka, Y., Fukuda, A., Nakamura, A., Yamada, A. and Saito, T. (2000). Molecular cloning and characterization of mangrove Na^+/H^+ antiporter cDNA. *Plant Cell Physiology*, **41 (Suppl.):** 27.

UNESCO-UNDP, (1986). Mangroves of Asia and the Pacific: Status and Management. Quezon City, Philippines.

Verheyden, A., Dahdouh-Guebas, F., Thomaes, K., De-Genst, W., Hettiarachchi, S. and Koedam, N. (2002). High-resolution vegetation data for mangrove research as obtained from aerial photography. *Environment, Development and Sustainability,* **4:** 113-133.

Rahman, M.A. (2003). Methodology of pathological research in mangrove forest. Forestry and Wood Technology discipline, Khulna University, Khulna, Bangladesh. pp. 177-198.

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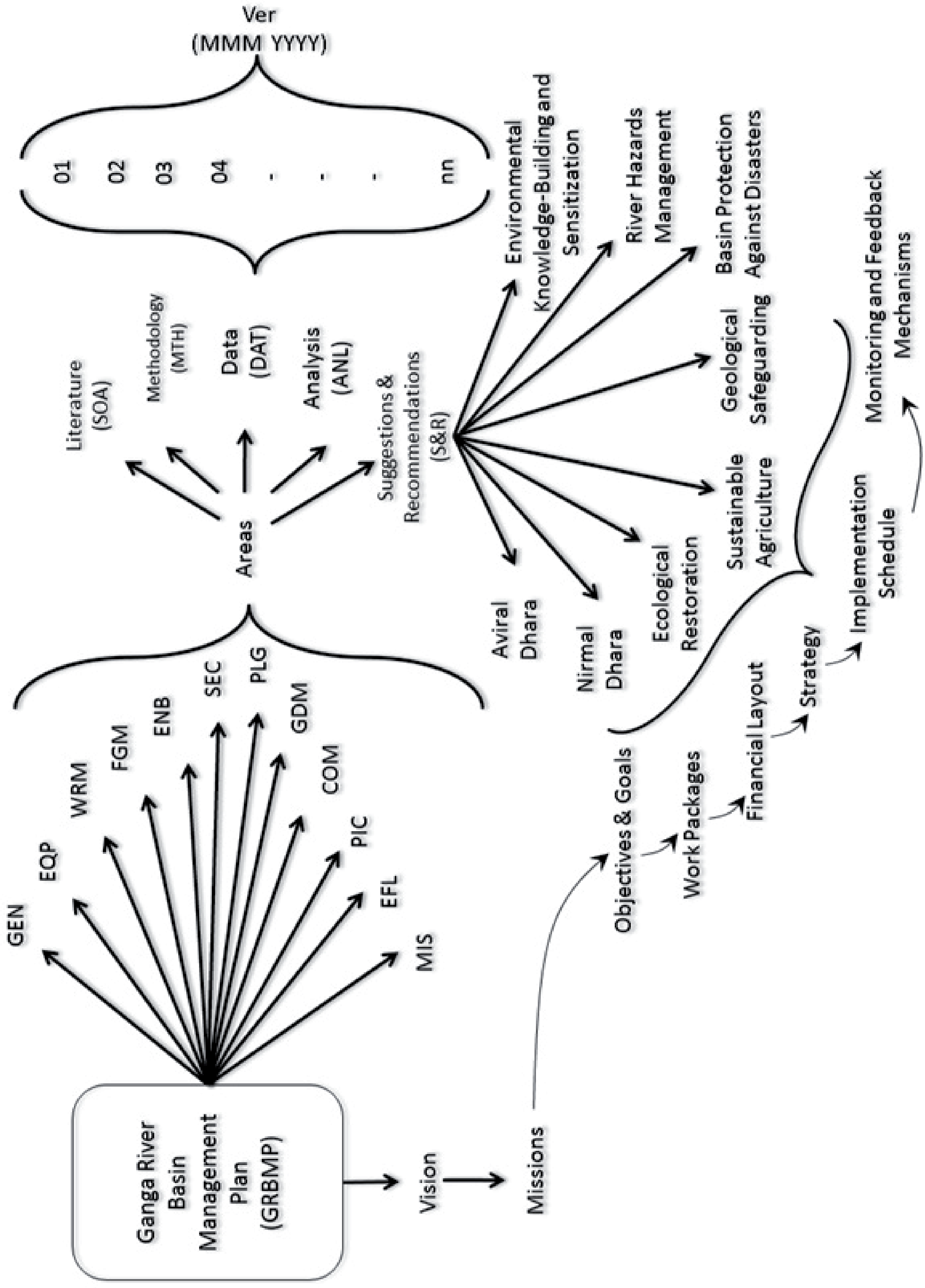
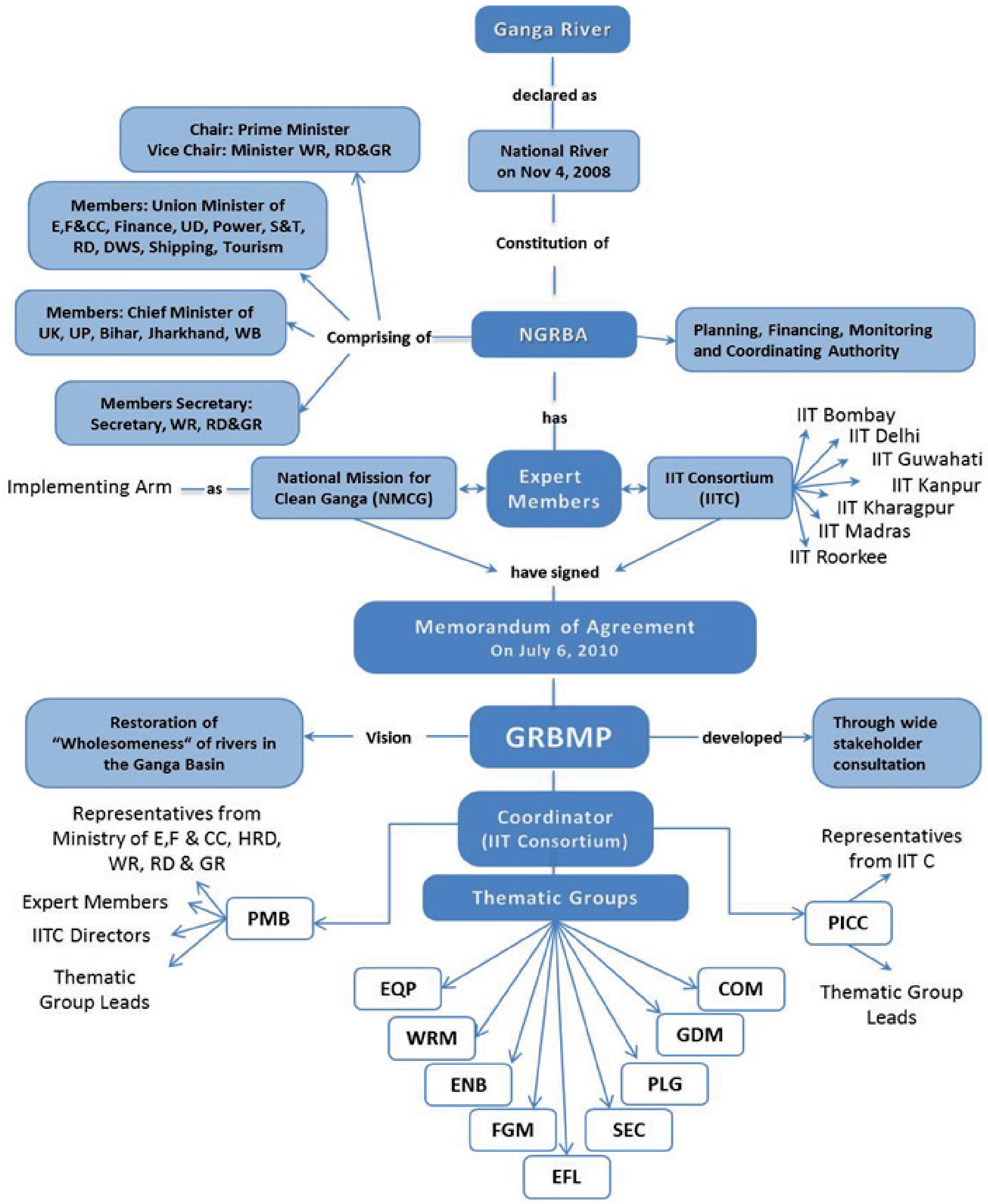


GRBMP WORK STRUCTURE

ORGANIZATIONAL STRUCTURE FOR PREPARING GRBMP



NGRBA: National Ganga River Basin Authority
NMCG: National Mission for Clean Ganga
MoEF: Ministry of Environment and Forests
MHRD: Ministry of Human Resource and Development
MoWR, RD&GR: Ministry of Water Resources, River Development and Ganga Rejuvenation
GRBMP: Ganga River Basin Management Plan
IITC: IIT Consortium
PMB: Project Management Board
PICC: Project Implementation and Coordination Committee

EQP: Environmental Quality and Pollution
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