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Floral and Faunal Diversity in Upper Ganga Segment

Gangotri – Haridwar (Upstream Bhimgoda Barrage)

GRB EMP : Ganga River Basin Environment 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: Environment Management Plan (GRB EMP).

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: Environment Management Plan (GRB EMP). 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 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 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 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 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_DAT_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°59'56.2"N; Longitude: 78°54'56.5"E; Elevation: 3037 m above mean sea level) to Gangnani (Latitude: 30°55'15.4"N; Longitude: 78°40'43.2" 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 (*Salmo trutto fario*). 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 this sub-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)

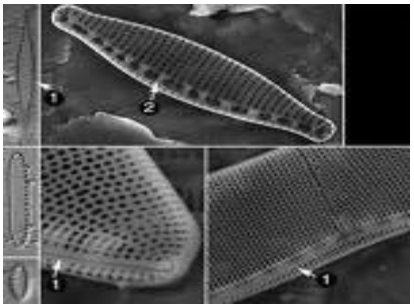
Bacillariophyceae	
Achnanthidium biasoletianum	*F. ragilaria vaucheriae*
A. minutissimum	*Frustulia rhomoids*
Amphora ovalis	*Gomphonema parvulum*
A. perpusilla	*Hippodonta* sp.
Cymbella turgida	*Nitzschia paleacea*
C. turgidula	*N. salinarum*
Diatoma hymale	*Reimeria sinuate*
Fragilaria rumpens	*Tabellaria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

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

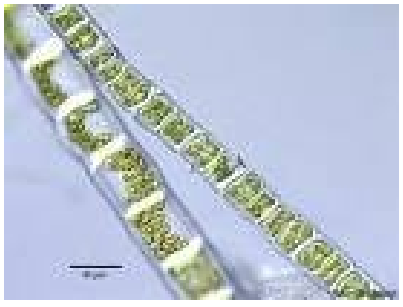
Bacillariophyceae			**Chlorophyceae**	**Xanthophyceae**
Achnanthes	*Denticula*	*Nitzschia*	*Gonatozygon*	*Vaucheria*
Amphipleura	*Diatoma*	*Pinnularia*	*Ulothrix*	
Bacillaria	*Fragilaria*	*Rhoicosphenia*		
Ceratonies	*Hantzschia*	*Stephanodiscus*		
Cyclotella	*Meridion*	*Synedra*		
Cymbella	*Navicula*			

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 < 0.5 m. 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			**Bacillariophyceae**		
Encyonema jemtlandicum		+	*N. amphibia*		+
E. leei		+	*N. capitellata*		+
E. minutum		+	*N. denticula*		+
E. silesiacum		+	*N. dissipata*		+
Encyonopsis leei		+	*N. fonticola*		+
Fallacia pygmaea		+	*N. frustulum*		+
Frustulia weinholdei		+	*N. gracilis*		+
Gomphoneis herculeana	+		*N. linearis*		+
Gomphonema sp.	+		*N. palea*		+
G. angustum		+	*N. recta*		+
G. brasiliense		+	*N. tenuis*		+
G. gracile		+	*Opephora* sp.	+	
G. lagenula		+	*Pinnularia* sp.	+	
G. lanceolatum		+	*Planothidium lanceolatum*		+
G. minutum		+	*Reimeria sinuata*		+
G. parvulum		+	*R. uniseriata*		+
G. pumilum		+	*Sellaphora pupula*		+
Gyrosigma kutzingee	+		*Starosira mutabilis*		+
Hantzschia sp.	+		*S. pinnata*		+
Hippodonta sp.		+	*S. utermohli*	+	
H. ruthnielseniae		+	*Stauroneis anceps*		+
Melosira varians		+	*S. phoenicenteron*	+	
Meridion circulare	+		*Surirella angusta*	+	+
Navicula alineae		+	*Synedra dorsiventralis*		+
N. antonii		+	*S. ulna*	+	+
N. broetzii		+	*Tabellaria fenestrata*	+	
N. capitatoradiata		+	*Tetracyclus rupestris*	+	
N. cataracta-rheni		+	**Chlorophyceae**		
N. caterva		+	*Chlorococcum humicola*	+	
N. cryptocephala		+	*Cladophora* sp.	+	
N. cryptotenella		+	*Closterium leibleinii*	+	
N. cryptotenelloides		+	*Cosmarium granatum*	+	
N. exilis		+	*Desmidium* sp.	+	
N. krammerae		+	*Hydrodictyon reticulatum*	+	
N. minima		+	*Microspora* sp.	+	
N. notha		+	*Oedogonium* sp.	+	
N. radiosa	+		*Stigeoclonium* sp.	+	
N. reichardtiana		+	*Ulothrix zonata*	+	
N. rostellata		+	*Zygnema* sp.	+	
N. seminulum		+	**Cyanophyceae**		
N. tripunctata		+	*Anabaena* sp.	+	
N. veneta		+	*Coccochloris stagnina*	+	
N. vitabunda		+	*Oscillatoria tenuis*	+	
Nitzschia sp.	+		*Phormidium* sp.	+	
N. acuta		+	**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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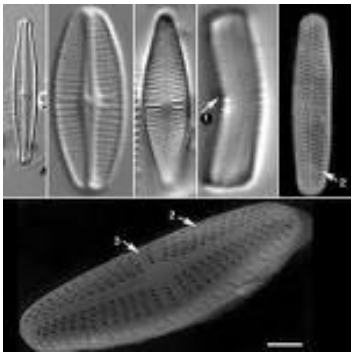
Taxa	Singh *et al.* (1994)	Agarwal *et al.* (2003)	Taxa	Singh *et al.* (1994)	Agarwal *et al.* (2003)
Coleoptera			**Odonata**		
Dytiscus	+		*Argia*	+	
Hydrophilus	+		**Water mites**	+	
Promoresia	+		**Plecoptera**		
Psephenus	+	+	*Arcynopteryx*	+	
Hemiptera			*Isoperla*	+	
Corixids	+		*Nemoura*	+	
			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 this sub-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: Snow trout spotted in the sub-stretch Gangnani to Devprayag

4. UG-3: Devprayag (Latitude: 30°08'49.4"N; Longitude: 78°35'51.9"E; Elevation: 474 m above mean sea level) to Haridwar (Latitude: 29°57'20.1"N; Longitude: 78°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 periphyton observed in the sub-stretch Devprayag to 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 Devprayag to 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 Devprayag to 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 fauna observed in the sub-stretch Devprayag to 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	+	+	*Schizothoracthys progastus*	+	+
Labeo angara		+	*Schizothorax plagiostomus*	+	+
L. calbasu		+	*S. sinuatus*	+	+
L. dero	+	+	*Tor putitora*	+	+

Table 11 continued to next page … … … …

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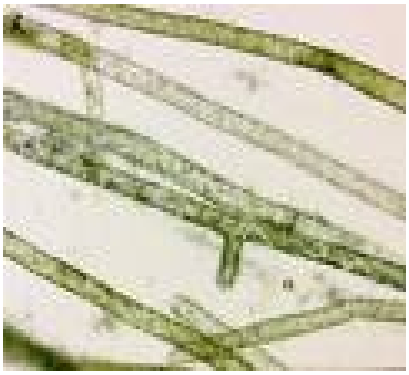
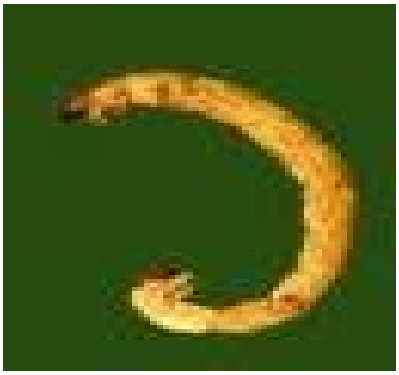
Taxa	Negi & Malik (2005)	Nautiyal *et al.* (2010)	Taxa	Negi & Malik (2005)	Nautiyal *et al.* (2010)
Cyprinidae			**Belonidae**		
Tor tor	+	+	*Xenantodon cancila*	+	
Sisoridae			**Channidae**		
Bagarius bagarius	+		*Channa gauchua*	+	
Glyptothorax lineatus		+	**Mastacembelidae**		
G. pectinopterus	+		*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 macroinvertebrate 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; 271 cm)
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.

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