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Research Article

BIO-MAPPING, A BIOLOGICAL CLASSIFICATION OF RIVER BHAGIRATHI IN HIMALAYA BASIN

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ABSTRACT
Bio-mapping is the use of benthic macro-invertebrates (benthos) for classification and zoning of rivers in the form of a colour map which indicates various grades of water quality according to its level of ecological degradation in terms of clean, slight pollution, moderate pollution and severe pollution. River Bhagirathi has unique bio-diversity of benthic macro fauna as compared to any other river in India. Water quality of River Bhagirathi favored establishment of nearly 18 numbers of families of benthic macro-invertebrates during November, 2004, which indicated biologically clean water quality of Class 'A' for more than 60% stretch of the river. Further studies have shown decreasing trend of benthos families representing Class'A' water quality in River Bhagirathi resulting in reduction of Class 'A' water quality stretch of river from 60 to 30% during year 2004 to 2008. At Gangotri, percent dominance of rare genera of family Heptageniidae like *Iron, Ironodes, Epeorus/Ironopsis* and *Rithrogena* has been reduced significantly from 55% in 2006 to 5% in 2008. Presence of rare genera of stone flies such as, *Kyphopteryx, Leuctra, Perlomyia*, and *Eucapniopsis* are known from the Oriental region and the Himalayas at high altitude require special attention for habitat protection at Gangotri. Their was total loss of habitat for *Olgoneuriella*, a rare genus of family Oligonuriidae, observed at upstream of Uttarkashi during 2007, which gradually disappeared with construction of Joshiyara barrage on River Bhagirathi during 2008. Bio-mapping has resulted in development of a saprobic scoring system, universally known as BMWP (Bio Monitoring Working Party) Score of River Bhagirathi comprising of 47 number of families and 62 genera of benthic macro-invertebrates identified during 2004 to 2008. This can be used as the base line information for formulating the action plans for conservation as well as restoration of ecological status of River Bhagirathi in the future course of time.

Key Words: *Biomonitoring, Benthic Macro-Invertebrates, BMWP Score, Saprobic Score, Diversity Score*

INTRODUCTION
The long term objective of water quality management is to ensure the wholesomeness of water quality of surface water bodies. Water quality monitoring of rivers is a measure to identify the reaches where the gap between the desired and the existing water quality is significant. The observations based on results of water quality analysis help in identification of water bodies which are in need of improvement. The existing water quality management system in India (based on physio- chemical parameters) is not sufficient to link the desired quality of river water for various designated uses of mankind. The constraints of physico-chemical parameters make it difficult to assess the quality status in terms of the 'health' of a water body. Over the years, it has been realized that the inclusion of biological parameter will enhance the quality evaluation in a cost-effective manner. The benthic macro-invertebrates (benthos) communities have been considered as the most suitable biological parameter to assess water quality of surface water bodies (Semwal *et al.,* 2008). In country like Germany, bio-monitoring has been practicing for almost more than 50 years, for effective water quality assessment. The maps based on bio-monitoring have proved as a powerful tool for preparation of action plan for control of pollution and for improvement of water quality of rivers (CPCB, 1999). This was possible because of availability of sufficient knowledge

on the taxonomic identification of benthos of rivers in western countries. Deterioration in water quality of Indian rivers over the past several years has gradually rendered the river water quality unsuitable for various beneficial purposes. The Water (Prevention and Control of Pollution) Act, 1974 is aimed to maintain and restore the wholesomeness of river water in terms of their ecological sustainability. There are 14 major river basins in India and as a group, these basins cover 80% population and 85% of total river discharge. Among the 44 medium river basins, four are international and eleven are interstate river basins. A total of 17 rivers having a combined basin area of 63,500 sq km join the Arabian sea, while 23 rivers having a combined basin area of 2,10,596 sq km, join Bay of Bengal. There are fifty five minor river basins having a combined basin area of about 2 lakh sq km. Most of these originate from Eastern and Western Ghats of India. The total area of minor basins is about 9% of the total basin area of Indian rivers (CPCB, 1998-99). The concept of Bio-monitoring in India has been initiated with the identification of best designated use of river water quality in terms of Clean (Class A), Slight pollution (Class B), Moderate pollution (Class C), Heavy pollution (Class D) and Severe Pollution (Class C) respectively (CPCB,1999). The method of bio-monitoring is based upon proper establishment of benthos on natural substratum of river bed. Unlike fish, benthos cannot move around much so they are less able to escape the effects of sediment and other pollutants that diminish water quality. Therefore, benthos can give us reliable information on prevailing river water quality. River Bhagirathi is an important river in Garhwal Himalayas, originating from Gaumukh in Gangotri glacier at an altitude of 3892 msl and passes via thickly populated towns like Uttarkashi,Tehri and DevPrayag. At DevPrayag, it meets River Alaknanda and from the confluence downstream, it is called the River Ganga. River Bhagirathi has unique bio-diversity of benthic macro fauna as compared to any other river in India, but in recent time this unique faunal diversity got disturbed due to number of upcoming large hydro-electric power projects, whereby the natural substratum and hydrology of the river basin got a make over (Semwal and Akolkar, 2006). Some of the largest upcoming / operational hydro power projects are; Loharinag-Pala (600MW), Pala-Maneri (480MW), Maneri Bhali PhaseI (90MW) and PhaseII (304MW), Tehri Dam (2000MW), Koteshwar Dam (400MW), Kotibhel project(530MW). Keeping in view the importance of River Bhagirathi, bio-mapping technique is applied to make an assessment of the present ecological status of River Bhagirathi in Uttarakhand state.

MATERIALS AND METHODS

Benthic macro-invertebrates were collected for bio-mapping of River Bhagirathi from its origin at Gangotri to DevPrayag during year 2004-2008. Fig. 1 depicts the sampling locations on River Bhagirathi which changed every year with frequent developmental activities particularly hydel projects. Altogether, 8 locations on River Bhagirathi were selected during year 2004, 13 locations during year 2005, 11 locations during year 2006, 15 locations during year 2007 and 10 locations during year 2008 (Table 2). Samples were also collected from glacial melt streams joining River Bhagirathi near Gangotri. The sampling locations on River Bhagirathi, were selected on the basis of impact of various human activities practiced in and around River Bhagirathi during the year 2004 – 2008. Field studies were undertaken to assess the biological water quality for evaluation of actual health of River Bhagirathi. The ecological assessment of River Bhagirathi was made using Biological Water Quality Criteria, Table 1(CPCB, 1998-99).

RESULTS AND DISCUSSION

In European countries like Italy, Spain, France and United Kingdom, a biotic index based on family or genus level, is used. It was calibrated and modified for each region. To show the results of the investigated water bodies in an easily and understandable way, maps were drawn for each year by indicating different colors to each water quality classes. The water quality map of the same state after few

years showed clearly that the decision makers had taken corrective action. In most of the river stretches water quality had improved which was indicated by a color change on the river stretches (CPCB, 1999).

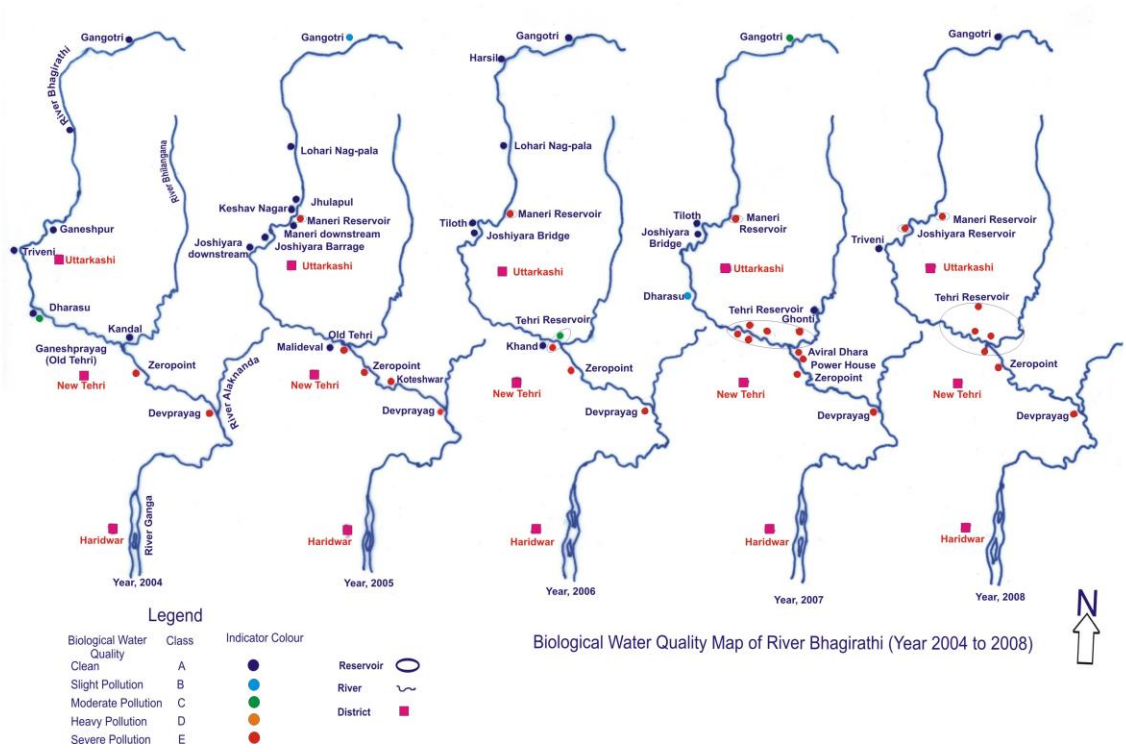

Figure 1: Bio-mapping of River Bhagirathi

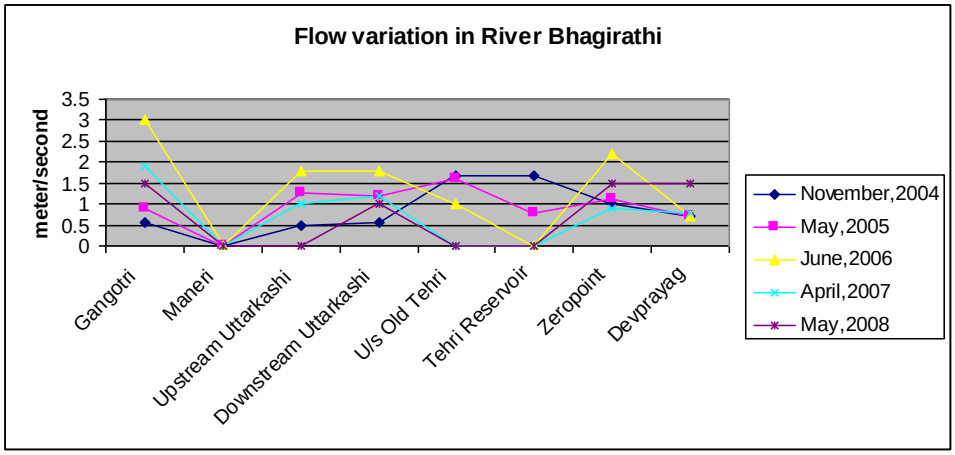

Figure 2: Annual flow variations in River Bhagirathi

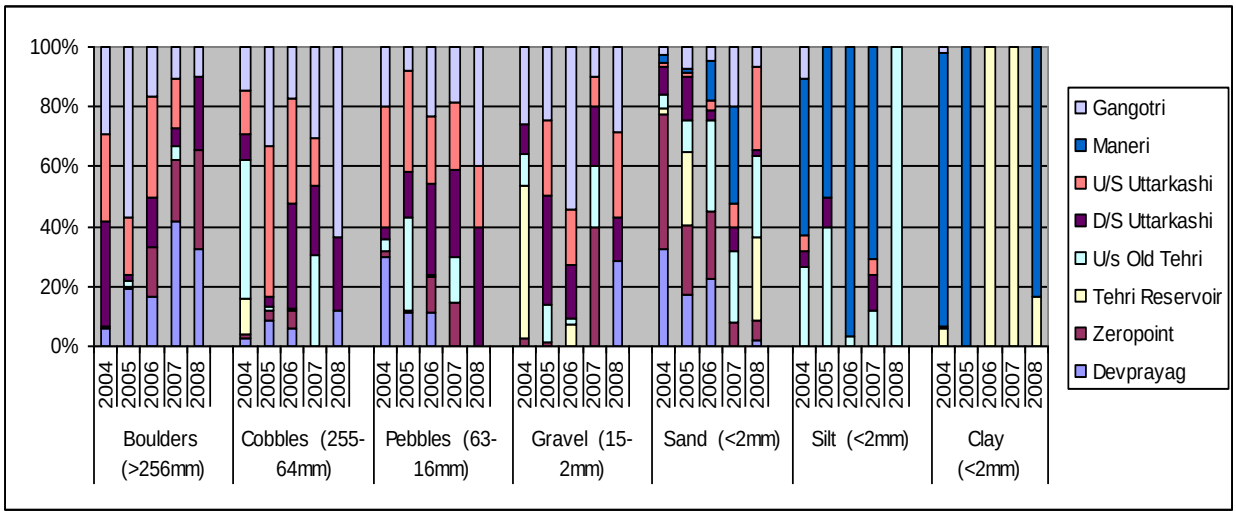

Figure 3 Annual variations in substratum type of River Bhagirathi

Table 1: Biological Water Quality Criteria (BWQC)

S. No	Taxonomic Groups	Range of saprobic score (BMWP)	Range of diversity Score	Water quality characteristic	Water quality class	Indicator Colour
1	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Diptera	7 and more	0.2 - 1	Clean	A	Blue
2	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Planaria, Odonata, Diptera	6 – 7	0.5 - 1	Slight Pollution	B	Light blue
3	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Odonata, Crustacea, Mollusca, Polychaeta, Diptera Hirudinea, Oligochaeta	3 – 6	0.3 - 0.9	Moderate Pollution	C	Green
4	Mollusca, Hemiptera, Coleoptera, Diptera, Oligochaeta	2 – 5	0.4 & Less	Heavy Pollution	D	Orange
5	Diptera, Oligochaeta No animals	0 – 2	0 - 0.2	Severe Pollution	E	Red

Table 2: Sampling locations showing annual variation in Biological Water Quality of River Bhagirathi from 2004 to 2008

S.No.	Sampling Location	Year 2004	Year 2005	Year 2006	Year 2007	Year 2008
1.	Gangotri	A	B	A	C	A
2.	Harsil	A	A	A	A	A
3.	Lohari Nag-Pala Hydro Project Site	-	A	A	-	C
4.	Maneri Reservoir	-	E	E	E	E
5.	D/s Maneri Reservoir	-	B	B	B	B
6.	U/s Uttarkashi at Ganeshpur	A	A	A	A	A
7.	U/s Uttarkashi near Tiloth bridge	A	A	A	A	A
8.	D/s Uttarkashi near Joshiyara bridge	A	A	A	B	E*
9.	D/s Uttarkashi at Triveni,	A	A	A	A	A
10.	U/s Tehri Town at Malideval	A	A	C	E*	E*
11.	Old Tehri Town, near Sangam	A	C	E	E*	E*
12.	Old Tehri at Kandal Village,	A	-	-	-	E*
13.	R. Bhilangana at Ghonti	A	A	A	A	E*
	Various locations at R. Bhagirathi which are submerged after creation of large Tehri Reservoir					
14.	Koti	A	A	-	E*	E*
15.	Bagi colony	A	A	-	E*	E*
16.	Serain	A	A	-	E*	E*
17.	Bhaldyana	A	A	-	E*	E*
18.	Lambgaon	A	A	-	E*	E*
19.	Lumpungari (on River Bhilangana)	A	A	-	E*	E*
20.	Old Tehri, near Hawa Mahal	A	A	-	E*	E*
21.	Power House outlet	-	-	-	E	E
22.	Zero point	E	E	E	E	E

Note: (-) Represents Sampling not done and (*) represents sampling locations inundated after creation of dams during 2004 to 2008.

Table 3: Families of benthic macro-invertebrates in Clean water stretches (Class A) of River Bhagirathi

Year	Locations on river stretch	TAXA/Families of benthic macro-invertebrates
2004	Gangotri, U/s and D/s of Uttarkashi, Dharasu, U/s Old Tehri Town, Old Tehri	EPHEMEROPTERA/Heptageniidae,Ephemerellidae,Baetidae,Caenidae,Siphlonuridae,Oligoneuriidae,Leptophlebiidae PLECOPTERA/Perlidae,Taeniopterygidae,Capniidae, Luctridae, Nemouridae TRICHOPTERA/Goeridae,Brachycentridae,Lepidostomatidae,Leptoceridae,Uenoidae,Odontoceridae,Glossosomatidae,Sericostomatidae,Stenopsychidae,Polycentropodidae,Hydroptilidae,Hydropsychidae DIPTERA/Tipulidae,Simulidae,Tabanidae,Chironomidae, Blepharoceridae COLEOPTERA/Psepheniidae, Dryopidae ODONATA/ Euphaeidae, Gomphidae MOLLUSCA/ Thiaridae HEMIPTERA/Corixidae OLIGOCHAETA/Naididae
2005	Lohari Nag-pala hydro project site, Maneri Reservoir, D/s Uttarkashi U/s Old Tehri Town	
2006	Gangotri Harsil, Lohari Nag-pala Project site, U/s Uttarkashi, D/s Uttarkashi	
2007	U/s Uttarkashi. R. Bhilangana at Ghonti	
2008	Gangotri, U/s Uttarkashi., D/s Uttarkashi, Glacial melt 3km from Gangotri,	

Table 4: Families of benthic macro-invertebrates in Slightly polluted water quality stretches (Class B) of River Bhagirathi

Year	Locations on river stretch	Taxa/Families of benthic macro-invertebrates
2005	Gangotri	EPHEMEROPTERA/Heptageniidae,Baetidae,Caenidae,Siphlonuridae PLECOPTERA/Capniidae,Nemouridae TRICHOPTERA/Brachycentridae,Leptoceridae,Hydropsychidae,Lepidostomatidae ODONATA/ Macromiidae, Gomphidae,Aeshnidae DIPTERA / Simulidae, Blepharoceridae,Psychodidae,Tipulidae COLEOPTERA//Dryopidae,Hydrophillidae MEGALOPTERA/ Corydallidae LEPIDOPTERA/Pyrulidae
2007	Joshiyara bridge downstream,Dharasu bridge	
2008	Glacial melt, Dabrani pul	

Table 5: Families of benthic macro-invertebrates in Moderately polluted water quality stretches (Class C) of River Bhagirathi

Year	Locations on river stretch	Taxa/Families of benthic macro-invertebrates
2004	Dharasu downstream	EPHEMEROPTERA/Heptageniidae,Baetidae,Caenidae,Siphlonuridae PLECOPTERA/ Capniidae, Nemouridae TRICHOPTERA /Stenopsychidae,Polycentropodidae ODONATA / Libellulidae, Gomphidae,Euphaeidae HEMIPTERA /Naucoridae, Notonectidae,Corixidae PLANARIA/Planariidae HIRUDINEA/ Hirudidae DIPTERA/Chironomisae MOLLUSCA/Thiaridae OLIGOCHAETA/Naididae
2005	Maneri reservoir	
2006	Syansu (Tehri Reservoir)	
2007	Gangotri	

Table 6: Development of Biological Monitoring Working Party(BMWP) Score of River Bhagitathi

Taxonomical Group	Taxonomical families	Genus	Bmwp Score
EPHEMEROPTERA	Heptageniidae	*Rithrogena,Iron,Ironodes,,Epeorus/Ironopsis, Cinygmina, Heptagenia*	10
	Siphlonuridae	*Ameletus*	
	Ephemerellidae	*Drunella, Torelya,Ephemerella,*	
	Leptophlebiidae	*Choroterpes*	
	Oligoneuriidae	*Oligoneuriella*	
PLECOPTERA	Perlidae	*Neoperla*	
	Taeniopterygidae	*Kyphopteryx,*	
	Capniidae	*Eucpnopsis*	
	Luctridae	*Leuctra, Perlomyia*	
	Nemouridae	*Indonemura*	
TRICHOPTERA	Goeridae	*Goera*	
	Brachycentridae	*Brachycentrus*	
	Lepidostomatidae	*Lepidostoma*	
	Leptoceridae	*Setodes, Leptocerus*	
	Uenoidae	*Uenoa*	
	Odontoceridae	*Perissoneuria*	
	Glossosomatidae/Glossosomatinae	Glossosomatinae, Agapetinae/Glossosoma	
	Sericostomatidae	Gumaga	
ODONATA	Euphaeidae	*Euphaea decorata*	8
	Gomphidae	*Onychogomphus viridicostus*	
	Libellulidae	*Nannopha pygmmaea*	
	Macromiidae	*Macromia sp.*	
EPHEMEROPTERA	Caenidae	*Caenis*	7
TRICHOPTERA	Stenopsychidae	*Stenopsyche*	
	Polycentropodidae	Polycentropus, Polyplectropus	
PLECOPTERA	Nemouridae	*Indonemura, Mesonemoura*	
MOLLUSCA	Thiaridae	*Melanoides pyramis, Thiara scabra*	
TRICHOPTERA	Hydroptilidae	*Hydroptilla, Orthotrichia*	6
HEMIPTERA	Corixidae	*Corixa*	5
	Naucoridae	*Hycoris*	
	Notonectidae	*Notonecta*	
COLEOPTERA	Psephenidae	Eubrianacinae, *Psepheninae*	
	Hydrophillidae		
	Dryopidae	*larva*	
TRICHOPTERA	Hydropsychidae	*Cheumatopsyche*	

DIPTERA	Simulidae	Simulium, Simulium pupa	
	Tipulidae	*Antocha, Hexatoma*	
	Tabanidae	*Tabanus*	
	Blepharoceridae	*Blephericera*	
	Tabanidae	*.Tabanus*	
LEPIDOPTERA	Pyrulidae	*Nymphula*	
PLANARIA	Planariidae	*Dugesia lugubris*	
EPHEMEROPTERA	Baetidae	*Pseudocloeon,Platybaetis,Baetis,*	4
MEGALOPTERA	Corydellidae		
HIRUDINEA	Hirudidae		
DIPTERA	Chironomidae	*Subfamily/ Tanypodinae, Orthocladinae, Tanytarsini*	2
OLIGOCHAETA	Naididae	*Aulophorus hymanae*	1

Table 7: Taxonomic composition of benthic macro-invertebrates in water quality of River Bhagirathi

Biological Water Quality Class	% Taxonomic composition			
	Arthropoda	Mollusca	Annelida	Platyhelminthes
A	100	0.0	0.0	0.0
B	100	0.0	0.0	0.0
C	25.0	25.0	23.0	25.0
D	-	-	-	-
E	0.0	0.0	0.0	0.0

The concept of bio-mapping originated with use of biological system for classification and zoning of water bodies according to their level of ecological degradation.

Fig. 1 indicated bio-mapping of River Bhagirathi for classification of biological water quality data of river, collected during Year2004 to 2008, in the form of a colour map of various biological classes. Different colours such as Blue, Light Blue, Green, Orange & Red, on river stretch from Gangotri to DevPrayag indicated various grades of water quality in terms of clean, slight pollution, moderate pollution and severe pollution in River Bhagirathi, respectively. A saprobic scoring system,universally known as BMWP(Bio-monitoring Working Party) Score system has been developed on the basis of various environmental variables affecting the existence of all the families/genus of benthic macro-invertebrates identified so far from River Bhagirathi. All possible genus and the families having saprobic indicator value have been classified on a score scale of 1 to 10 according to their preference for saprobic water quality. The genus of the families which were most sensitive to pollution were scored maximum of 10 while the most pollution tolerant families were getting a score of 1 and 2 (Table 6).

Bio-diversity of River Bhagirathi

River Bhagirathi has a unique bio-diversity of benthic macro fauna to indicate its pristine water quality, as compared to any other river in India. Degradation in ecological habitats of River Bhagirathi, over the past several years, has gradually rendered the river water quality unsuitable for biological establishment of most sensitive benthic fauna from downstream of Tehri Dam to DevPrayag, before and after construction of Tehri Dam.and thus resulting in unpredictable water quality for various beneficial purposes. At Gangotri, percent dominance of family Heptageniidae has been reduced significantly from 54.5% in 2006 to 4.69% in 2008. Two tailed Heptageniidae of River Bhagirathi, such as, *Iron, Ironodes,*

Epeorus/Ironopsis are found in the swiftest mountain streams where the nymphs cling to the underside of stones, sticks, or leaf debris and the water passes over them continuosly. Three tailed Heptageniidae like *Rithrogena* attach themselves to stones in swift to moderate currents. When a rock is lifted from the water, some specimens remain perfectly motionless until an attept is made to remove them. They adhere so tightly to the rocks that they cannot be removed easily. *Ameletus* of famly Siphlonuridae was most common genus having maximum dominance of 90-92% at Gangotri. According to Mc Cafferty and Edmunds,1979), the nymphs are strong swimmers and do swim at currents up to two or three feet per second. *Ameletus* is described as living in clean high altitude streamlets only. It is found typically in parts with gravels where it is scraping Aufwuchs from the substrate (Schoenemund, 1930). In the rocky mountains " some species are abundant in tiny streams that are only a few inches wide and less than one inch deep"(Mc Cafferty and Edmunds,1979). The eggs of some species are laid in streams which become dry during part of year, hatching after the stream flow resumes. In the rocky mountains. *Ameletus* is found in streams at altitudes as high as 11000feet. *Ameletus* has been describedfrom the Hindukush (Ueno, 1966) and the Himalayas(Traver, 1939). Rare genera of family Oligonuriidae with 2.5% dominance was observed at upstream of Uttarkashi during 2007, their was total loss of habitat of this genera which disappeared with construction of Jushiyara barrage on River Bhagirathi. The nymph of *Olgoneuriella* are filter feeding insects. They have therefore developed a dense row of hairs on tibia and femora of the forelegs as filtering structures. Oligoneuriidae are known from the Indian Subregion of the Oriental Region with only one genus *Oligoneuriella* recorded (Ali,1970,1971) from Punch river in Kashmir and rivers in Pakistan. Among Plecoptera,Taeniopterygidae was very specific and restricted its 1.4 to 18.2% doinance at Gangotri. Taeniopterygidae are known from the Oriental region and the Himalayas. Two species of Kyphopteryx have been collected; one in Tibet and Sikkim,by British Everest expedition in 1924, another one in the Pamir mountain-ranges (Zhiltzova,1972). Similarly *Leuctra(1.2%) and Perlomyia(2.26%)* of family Luctridae was having habitat preference of Gangotri. Only few records of Leuctridae have been reported from the Indian Subregion of the Oriental region or from the Himalayas and adjacent mountain-ranges. Family Capniidae was dominant during year 2007 at Gangotri(23.37%) as well as D/s Uttarkashi (8.33%) at Dharasu bridge. Capniidae are small, black stoneflies. The *Eucapniopsis* pecies recorded from the Tien Shan, from Pakistan and from Nepal reaches 6,5-9 mm body length. *Mesonemoura* genus of family Nemouridae was uncommon at Gangotri. Genus of *Mesonemoura* occur in the high mountains of Central Asia. Perlidae was observed only at D/s Uttarkashi. Families of Trichoptera are having rare occurrence at high altitude. Sericostomatidae was found only once at Gangotri. Most of the families of Trichoptera are substratum specific for attachment of colonies of their cases. Brachycentridae preferred its 83.65% of dominance in glacial melt stream joinng directly to River Bhagirathi at 3km downstream of Gangotri. Lepidostomatidae was having specific preference towards habitat for 95% dominance of *Lepidostoma* at upstream of Uttarkashi durig year2007, However, later in year 2008, the habitat of this genus was lost due to submergence..Glossosomatidae, Odontoceridae, were Leptoceridae was most comonat lower altitude from Uttarkashi to site of Tehri Reservoir. Uenoidae and Hydroptillidae were observed at upstream of Old Tehri(submergence site). Caseless forms of Trichoptera,such as Stenopsychidae and Hydropsychidae were common at stretch of Uttarkashi to Tehri Reservoir. Among Diptera, Simulidae and Tipulidae preferred the substratum of higher altitude at Gangotri to Upstream of Uttarkashi. Blepharoceridae is most sensitive to water quality as well as substratum and was found attached to boulders only at downstream of Uttarkashi. Presence of Chironomidae indicated human influence throughout the stretch of River Bhagirathi from Gangotri to Tehri Reservoir. Among Odonates, Euphaeidae is the only Odonate preferred high flow and altitude and was restricted to upstream of Uttarkashi during year2005.Gomphidae indicated lowering of flow condition in river with the development of reservoir at Uttarkashi and Old Tehri. Libellulidae and Macromiidae appeared later in 2006-2007. Presence of families of Coleoptera, Hemiptera and Megaloptera did not indicate significant impact. Altogether 47 families and 62 genera of benthic macro-

invertebrates have been identified so far. As per their ecological status and preference to water quality, a BMWP score has been developed (Table 2).

Clean water quality in River Bhagirathi

River Bhagirathi contributed establishment of maximum number of 18 families of benthic macro-invertebrates during year 2004 accounting for 62.5% of biologically clean water quality of ClassA(Table2). In the beginning, anthropogenic influences on River Bhagirathi was restricted to mainly religious activities. However, with the development of various hydal projects, the natural substratum of River Bhagirathi was totally transformed resulting in ecological disturbance in habitats of aquatic fauna of benthic macro-invertebrates (Semwal, Akolkar and Jangwan,,2009). 17 number of families represented Class A water quality in 54% of samples during year 2005. Number of families indicating clean water quality, reduced to 13 during year2006. 17 number of families indicated clean water quality for 13.33% of samples during year 2007. Altogether 13 number of families were from the entire stretch of River Bhagirathi which indicated clean water quality accounted for 30% of the total samples in year 2008. Water quality of ClassA was represented by families belonging to Ephemeroptera, Plecoptera, Trichoptera and Diptera. Occasionally, families of Coleoptera, Odonata, Mollusca, Hemiptera and Oligochaeta often appeared with the increasing human activities(Table 3). The clean water quality supported 100% domination of arthropod communities(Table 7). A comparision of biomap of two consecutive years for a single river may not indicate change in water quality (CPCB,2005 and NPCB,2008). However, bio-mapping of an entire river basin during a year may provide level of ecological degradation.(APSPCB, 2006).

Slightly polluted water quality in River Bhagirathi

Mass bathing in sacred water bodies is an age-old ritual in India. River Bhagirathi has an important place in Indian culture and tradition (Semwal and Akolkar, 2006). 7.69% of samples showed slight pollution in water quality at Gangotri during year 2005 represented by 4 number of families and 12 families showed slight pollution in 13.33% of the total river stretch downstream of Triveni,Uttarkashi at Dharasu during year 2007. Slight pollution in water quality of River Bhagirathi was mainly attributed to religious activities, represented by families belonging to Ephemeroptera, Plecoptera, Trichoptera, Odonata, Diptera and Megaloptera. Families of Coleoptera and Lepidoptera were having rare occurrence(Table 4). Slight pollution in water quality also supported 100% domination of arthropod communities(Table 7).

Moderately polluted water quality in River Bhagirathi

Moderate pollution in Water quality was observed from 2004 to 2007 at Gangotri, Maneri Reservoir, Tehri Reservoir and its upstream at Dharasu. indicated by 4-5 number of families belonging to Ephemeroptera, Plecoptera, Trichoptera,Odonata, Hemiptera,Hirudinea,Diptera, Mollusca, Planaria and Oligochaeta (Table 5). Due to anthropogenic impacts and change in hydrological conditions in river, moderate pollution in water quality was uniformly shared by each 25% of Arthropods, Molluscs, Annelids and Platyhelminthes communities (Table 7).

Highly Polluted water quality in River Bhagirathi

As per Biological Water Quality Criteria (Table 1), Highly polluted (Class D) water quality stretches did not exist in River Bhagirathi(Table 6).

Severely polluted water quality in River Bhagirathi

Total 75 observations were made on River Bhagirathi during the entire study period of year 2004-2008. Anthropogenic activities concentrating at high altitude near the origin of glacial fed rivers, may result in major changes in river ecosystem. In situ utilization of sulphur springs on the bank of river may also contribute to the physico-chemical and biological water quality of rivers at high altitudes. Glacial melt water is the main source of river flow and fresh water recharge to the River Bhagirathi. Altitudinal variation in river Bhagirathi, have major impact on hydro-biological characteristics compared to physico-chemical water quality. Most of the sensitive fauna of Benthic macro-invertebrates, found in high altitude at Gangotri may gradually disappear resulting from change in river habitats (Semwal, Akolkar and

Jangwan, August 2008).As a result of increasing anthropogenic activities, biologically severe pollution in River Bhagirathi gradually increased. In the beginning of the study, severe pollution in River Bhagirathi was restricted to only 22.22% of the stretch from downstream of Old Tehri at Zero point to DevPrayag (Table 2). Normally, the river bed substratum composed of boulders, cobbles, pebbles and gravel in Himalayan region, which however, is replaced by sand, silt and clay resulting from various anthropogenic activities (Fig. 3). The natural substratum of river bed is one of the major factor affecting the hydro-biological properties of water quality. The effects of impoundments on river due to construction of dam, include a series of changes in the physical condition downstream of dam, specially modification of the flow and temperature regimes (Semwal, Akolkar and Jangwan, January 2009). Flow interception in River Bhagirathi was observed at upstream of Uttarkashi with the development of reservoir at Maneri for power generation. With development of activities level of biologically degraded stretch in terms of severe pollution subsequently increased to 30.76% in year2005 with marginal increase of 36.365 in Year2006. An abrupt increase of 66.66% in pollution level of biological water quality was observed during Year2007 which ultimately reached to almost 70% in Year 2008 when almost all the hydal projects were commissioned on River Bhagirathi, specially the Tehri Dam. The severe pollution in water quality represented none of the benthic macro-invertebrate established in the river stretch (Table 7). Compare to northern region, himalayan rivers from north-east India are still undisturbed (CPCB, 2004) Development of sandy bed in river bed substratum did not allow biological establishments and thus affected the water quality of River Bhagirathi to a great extent. Their was 100% sandy substratum in River Bhagirathi due to diversion of confluence of River Bhagirathi and Bhilangana from Ganesh Prayag at Old Tehri to Kandal village for construction of Tehri Reservoir (Fig. 3). Sandy bed in River Bhagirathi increased due to various human activities from Gangotri to Dev Prayag. Maximum clay deposition was observed at Maneri and Tehri Reservoir.

At the places of impoundment on River Bhagirathi, the substratum composition was totally transformed in to clay, at Maneri reservoir, Joshiyara barrage at Uttarkashi and Lambgaon, Lumpungari ,Old Tehri on Tehri Reservoir during year 2008 (Fig. 3)

Lowest flow of River Bhagirathi was observed at upstream of Uttarkashi due to flow interception with the development of reservoir at Maneri. Maximum flow in River Bhagirathi was observed near the consruction of dam at before and after the confluence of River Bhagirathi and Bhilangana at Malideval, Old Tehri and Kandal village during Year 2004 (Fig. 2). Thus, flow interception was observed only on one location of entire river stretch, which increased with development of reservoir upto Syansu and upstream of Tehri reservoir near Khand village. During Year 2008 there was another barrage constructed at Joshiyara, and thus 60% stretch of River Bhagirathi was subjected to flow interception with development of impoundments for power generation during year 2008 (Fig. 1)

The entire stretch of RiverBhagirathi was found devoid of benthic fauna from downstream of Tehri Dam to DevPrayag, before and after construction of Tehri Dam.

Protection of habitats for high altitude rare genus of Kyphopteryx, *Leuctra, Perlomyia,* and *Eucapniopsis* are known from the Oriental region and the Himalayas, require special attention at Gangotri. Their was total loss of habitat of *Olgoneuriella,* a very rare genera of family Oligonuriidae observed at upstream of Uttarkashi during 2007, which disappeared with construction of Joshiyara barrage on River Bhagirathi during 2008.

Bio-mapping is a continuous bio-monitoring programme, which should be carried out every year to obtain information on changes in biological water quality to maintain an inventory of the biological life sustained by the river. The Water Act, 1974 as amended 1988, which is aimed to maintain and restore the wholesomeness of surface water quality in terms of ecological sustainability should also incorporate the bio-mapping concept for effective implementation of this Act, as it helps in the identification of water bodies, which are in need of improvement and provides information to know the extent of pollution control measures needed for restoration of water quality in the most simplest way. Based on this, action

plans can be prepared by simple colour comparison of the maps of water quality drawn for previous years. A number of wild life habitats are located on river stretches. Bio-mapping of these stretches will help in making policies for effective conservation and protection of rare and endangered wild life fauna and flora (CPCB, 2005).

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