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Structural and functional status of benthic macroinvertebrate fauna in the rivers of central highlands ecoregion, India

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ABSTRACT : Biome dependency hypothesis was tested in the rivers of central highlands ecoregion by using benthic macroinvertabrate fauna. Three different rivers (Dhasan, Ken and Tons) were selected to determine the structural and functional condition of the benthic macroinvertebrate fauna. Four stations selected for collecting invertebrate data from each river during the summer season. Standard methods were followed for collection, identification and analysis of benthic macroinvertebrate fauna. Ephemeroptera was most abundant taxa in the Dhasan river at D1, while Gastropoda was abundant to rest of the stations (D2 to D4). However, in the Ken, Ephemeroptera was also most abundant taxa in each section (except Diptera at K4), while in the Tons river Trichoptera, Gastropoda and Ephemeroptera were most abundant taxa at T1, T2-T4 and T3, respectively. In the assemblage farming group, Caenidae and Thiaridae were dominant taxa in the Dhasan river, while Neoephemeridae, Caenidae, Leptophlebidae and Thiaridae in the Ken river and Thiaridae and Neoephemeridae in the Tons river. Functional feeding group analysis indicated that scrapers were dominant in Dhasan river (except D1) and collectors in the Ken and Tons (except T2 in the Tons). In the study it observed that benthic macroinvertebrate structure varied within the rivers but among the rivers abundant fauna was common. However, functionally they were similar within the river but different among the rivers.

Key Words : Benthic macroinvertebrate, caenidae, Dhasan, central highlands, thiaridae.

A fundamental characteristic of stream ecosystem is the unidirectional movement of water, nutrients, inorganic materials and organic matter down altitudinal gradients from headwater mountain streams to low land rivers (Suren, 1994). The distribution of the benthic community may be explained as an adjustment between hydrological conditions and life history of the populations (Statzner *et al.,* 1997). The distribution of organisms changes in relation to hydrological and geomorphological conditions at different spatial scales: drainage, reach and habitat (Hildrew, 1996; Maddock, 1999). According to Corkum (1989) similar assemblages of macroinvertebrates are most likely to occur at river sites within or among drainage basins if the drainages occur within a single biome. However, if macroinvertebrates in rivers are biome dependent, there should be a strong link between the lotic fauna and the climax vegetation that characterizes the biome.

The adequate knowledge regarding the variation in distributional patterns and taxonomic composition of benthic macroinverebrate fauna are available in the individual rives around the world (Milesi *et al.,* 2009; Mesa, 2010; Ezekiel *et al.,* 2011; Singh *et al.,* 1994; Nautiyal *et al*., 2004; Mishra *et al.,* 2013a; Mishra and Nautiyal, 2011; Nautiyal and Mishra, 2012; Mishra and Nautiyal 2013a; Sivaramakrishnan *et a1*., 1995; Nautiyal *et al.,* 2017; Semwal and Mishra, 2019), but no information is available for the structure of benthic macroinvertebrate fauna among the rivers of similar biome. Thus the Biome dependency hypothesis (Corkum, 1989) was tested on three central highlands rivers; Dhasan, Ken and Tons to determining the structure and function of benthic macroinvertebrate fauna.

Materials and Methods

In the Peninsular Plateau in of Vindhayn region of Central India, the rivers; Chambal, Kali, Sindh, Parbati, Betwa, Dhasan, Ken, Paisuni and Tons are north flowing rivers. Among these rivers Chambal, Kali, Sindh, Parbati, Betwa, Ken and Paisuni are tributaries of the Yamuna river, while Dhasan is tributary of Betwa, and Tons is the tributary of the Ganga. These rivers are the major source for irrigation, drinking and have high religious significance. Among these river Ken will be linked to Betwa under National River Linkng Project (NRLP) as this ink has been approved (NWDA, 2006; www.economictimes. indiatimes.com/news, 2017). Three rivers (Dhasan, Ken and Tons) of similar length (approx. 300 km) were selected for study. These three rivers belong three different river systems; the Dhasan (Betwa R.S.), the Ken (Yamuna R.S.) and the Tons (Ganga R.S.). Four sampling stations were studied in Dhasan river (D1 to D4; Table-1, Fig.-1). The earlier published benthic macroinvertebrate data was used for the rivers of Ken (Nautiyal and Mishra 2012) and Tons (Mishra and Nautiyal, 2013).

The benthic macroinvertebrates were collected during pre-monsoon season (March to May). For this, one-

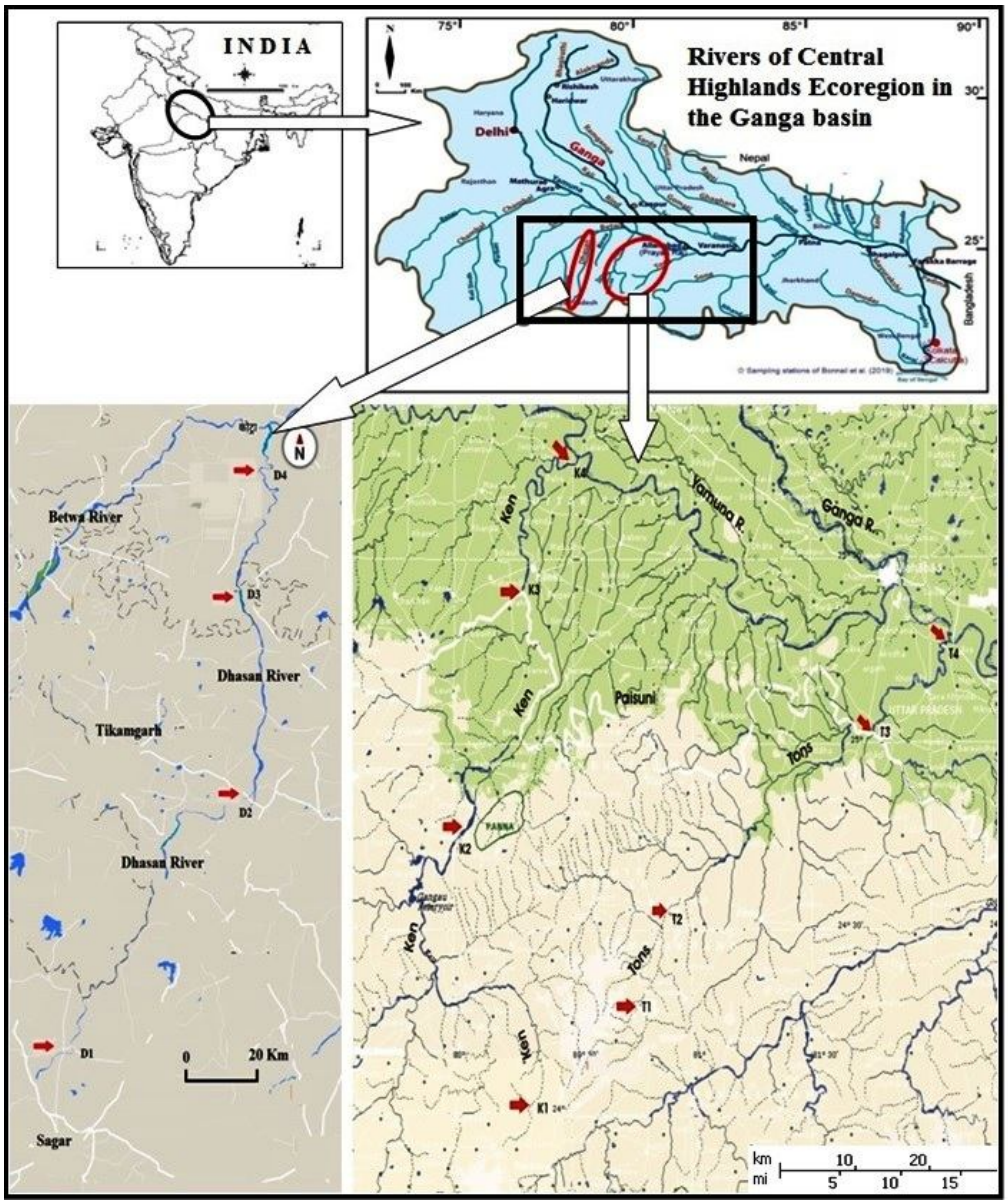

Fig.-1 : The geographical location of the Ganag river basin in India map and rivers of central highlands eco-region Ganga river basin maps. The sampling locations in the river Dhasan (D1-D4), Ken (K1-K4) and Tons (T1-T4)

time intensive sampling was conducted as suggested by Corkum (1989) and the rationale for which has been described earlier by the authors (Mishra and Nautiyal, 2011; Nautiayl and Mishra, 2012). Standard techniques were used for collection, analysis, computation of the invertebrate samples (Mishra and Nautiyal, 2011; Nautiayl and Mishra, 2012) and functional feeding group (Cotta Ramusino *et al.*, 1995).

Results and Discussion

Corkum (1992) tested this biome dependency hypothesis and found that greatest difference in taxonomic composition occurred among biomes. It is related to site specific factors (i. e. riparian vegetation and land use). The water temperature ranges between 15-31.5°C, pH ranged between 7.2-7.8 and current velocity ranged between 0.05-1.0 m/s (Table-1). The benthic macroinvertebrate community comprised mainly three phylum; arthropoda, mollusca and annelida. In Dhasan river, the most abundant taxa was Ephemeroptera (50%) at D1, while Gastropoda at D2 (50%), D3 (69%) and D4 (74%). Nautiyal and Mishra (2012) reported that Ephemeroptera was most abundant taxa in the Ken river along the river stretch except mouth zone (Diptera). However, Mishra and Nautiyal (2013) indicated that in the Tons river Trichoptera was most abundant taxa at headwater, while Gastropoda at middle and mouth zone of the river but Ephemeroptera at lower

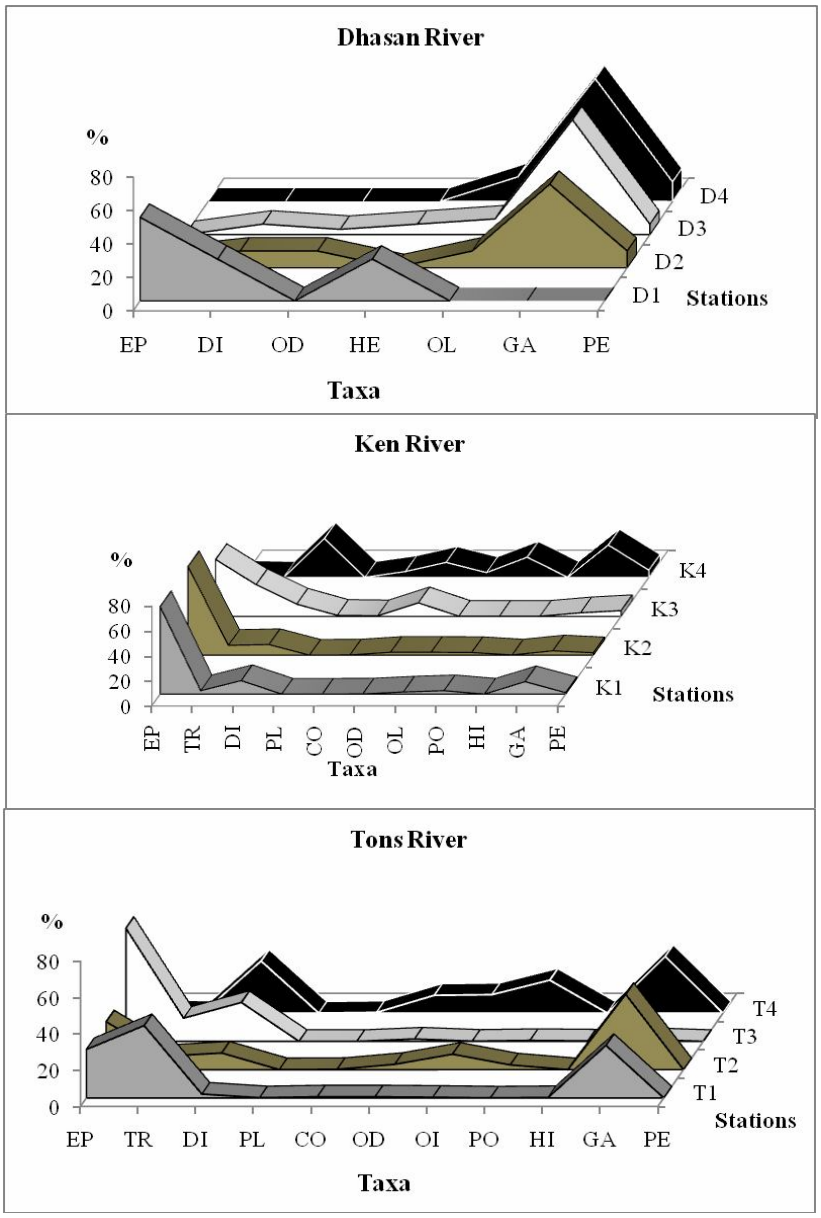

Fig.-2 : Taxonomic compositions of benthic macroinvertebrate fauna (order level) at various stations in the Dhasan, Ken and Tons river

zone (Fig.-2).

At family level, the benthic macroinvertebrate assemblages varied within and among the rivers of central highlands ecoegion (Table-1). In the Dhasan river, the most abundant taxa in the assemblage was Caenidae at D1, but Thiaridae was found to be most abundant taxa in the assemblages at remaining stations; D2, D3 and D4. This variation in abundant taxa was attributed to dominance of stony substratum and low current velocity (Death, 2003) at D1, while from D2 to D4 soft substratum (sand-silt-clay) provide burrowing forms of taxa and agriculture landuse supported chemical fertilizers input to the river, which increased calcium and phosphorous level for the abundance of mollusca and annelid (Tolkmap, 1980). In the Ken river, Nautiyal and Mishra (2012) reported Neoephemeridae was most abundant taxa at K1, while Caenidae, Leptophlebidae and Thiaridae were the most abundant taxa at K2, K3 and K4, respectfully. Mishra and Nautiyal (2013) reported that Thiaridae was moat abundant taxa in the assemblages at T1, T2 and T4, while Neoephimeridae at T3 in the Tons river. The variation was observed within and among the rivers (Fig.-3).

It was observed in the present study that the abundant taxa in the headwater section of Dhasan (D1), Ken

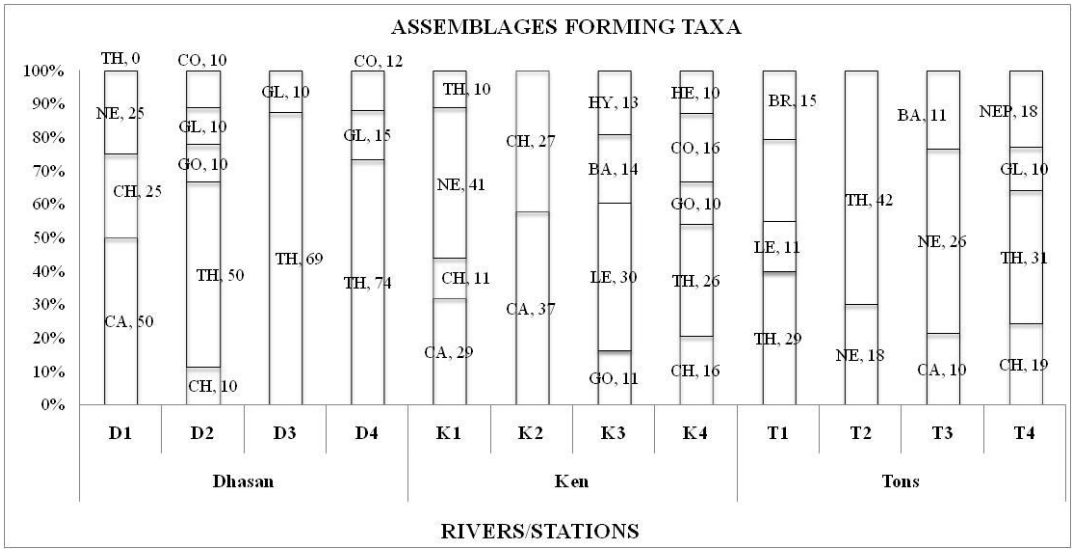

Fig.-3 : Percentage compositions of assemblages farming benthic macroinvertebrate fauna (family level) at various stations in the Dhasan, Ken and Tons river

Table-1 : Geographical locations and physico-chemical characteristics at various station in the river Dhasan, Ken and Tons.

Rivers	St.	LAT (^{O}N)	LON (^{O}E)	ALT (masl)	LU	SUB	W T (^{O}C)	CV (m/s)	pH
Dhasan	D1	23.79711	78.56006	492	Ag	S>G>Cl	29	0.05	7.2-7.5
	D2	24.55406	79.04024	319	Ag-V	B>C>P	30	0.6-1.0	7.4-7.6
	D3	25.23274	79.28493	183	B-Ag	Cl>G>B	31	0.3-0.6	7.2-7.6
	D4	25.74187	79.39395	126	F-V	Sand	32	0.8-1.2	7.6-7.9
Ken	K1	23.99111	80.30027	365	Ag-V	R>C>P>Si	15-21.5	0.01	7.2–7.5
	K2	24.73805	80.01138	200	F	R>C>P>S>Si	16–22	0.1-0.6	7.0–7.2
	K3	25.47722	80.31416	95	Ag-C	R>C>P>G>S	17–24.5	0.02-0.12	7.2–7.5
	K4	25.77083	80.52666	86	Ag	Cl>Si	20.5–27	0.01	7.2–7.5
Tons	T1	24.27055	80.80500	326	Ag	B>C>P	17–30	0-0.38	7.0–7.6
	T2	24.56188	80.90722	290	Ag-C	C>P>G>S>B	17.5–28	0.016-0.48	7.4–7.6
	T3	25.03362	81.73083	94	Ag-T	C>P>B>R>G>S	17–27	0.015-0.15	7.4–7.6
	T4	25.27499	82.08305	72	Ag	Cl-Si	17–24.0	<0.001	7.5–7.8

Acronyms-

LAT-Latitude,	LON- Longitude,	ALT- Altitude,	LU- Landuse,	SUB- Substratum,
WT- Water temperature,	CV- Current,	B-Boulder,	C-Cobble,	P-Pebble,
S-Sand,	Cl—Clay,Velocity,	Ag-Agriculture,	V-Village,	D-Dam,
CA-Caenidae,	CH-Chironomidae,	NEP-Nepidae,	TH-Thiaridae,	CO-Corbiculidae,
GL-Glossoscolecidae,	NE-Neoephemeridae,	LE-Leptophlebidae,	BA-Baetidae,	HY-Hydropsychidae,
GO-Gomphidae,	HE- Helidae,	HYD–Hydroptelidae,	BR-Brachycentridae	

(K1) and Tons (T1) rives are different because during the summer season, D1 was almost dry with very slow current velocity (0.05 m/s) resulting abundance of Caenidae (Sivaramakrishnan *et al.*, 1995). However, at K1 and T1, the river water was in flowing condition range between 0.1 - 0.31 m/s and help in abundance of similar taxa. The middle section (D2, K2, T2) indicated that abundant taxa were similar at D2 and T2, but differs at K2. This was attributed to similar landuse (agriculture - human habitation) at D2 and T2 but reserve forest K2. The lower section (D3, K3, T3) of the all rivers comprised different type of the abundant taxa, attributed to high parallel space between every two rivers, help to minimize the rate of faunal exchange between

Table-2 : Functional feeding groups of benthic macroinvertebrate fauna at different stations in the river of Dhasan, Ken and Tons.

Rivers	Stations	Scraper	Shredder	Collector	Predator	Miscellaneous
DHASA**N**	D1	-	-	75	25	-
	D2	50	-	35	15	-
	D3	70	-	21	9	-
	D4	74	-	26	-	-
KE**N**	K1	9.8	-	85.5	1.5	3.2
	K2	3.4	-	84.4	4.8	7.5
	K3	2.8	-	82.5	11.7	2.1
	K4	25.9	-	52.5	21	0.7
TON**S**	T1	29.6	1.9	62.2	2.5	3.6
	T2	41.5	0.5	40.9	16.6	0.3
	T3	1.5	9.3	78.1	7.9	3.1
	T4	31.3	-	53.5	14.9	0.4

and among the rivers. However, in mouth section (D4, K4, T4) of all the rivers, the abundant taxa were similar because of similar substratum type (soft substratum) and almost no current velocity at these stations due to impact of large rivers. Substratum was an important factor for distribution and abundance of benthic macroinvetebrate fauna (Singh *et al*., 2010; Mishra and Nautiyal 2016).

According to Corkum (1991) the benthic macroinvertebrate assemblage differed significantly among rivers within biome due to different landuse practice. She found that Leptophlebiidae, Brachycentridae were more common in the Credit river (forested) than Maitland river (agriculture land) and both taxa were absent in the Ausable river (agriculture land) of the eastern deciduous forest (EDF) biome. Schreiber *et al*. (2003) suggested that *Potamopyrgus antipodarum* (Gastropoda) populations may increase in the response to increased food resources that result from agriculture disturbances and by human disturbance (Kerans *et al*., 2005) in the Australian streams. In the present central highlands river, it is observed that Thiaridae was most common taxa among all the rivers and the most of the assemblage forming taxa were common among in all rivers either in most abundant form or 2nd or 3rd abundant form. Thus, Biome dependency hypothesis is partial applicable in the rivers of central highlands ecoregion.

Functional feeding groups

Functionally, scrappers were most abundant functional feeding groups in all sections of Dhasan river (except headwater D1 where collector abundant). However in Ken and Tons rivers, collectors were most abundant group in all the sections (except in Tons at T2 where scrapper abundant; Table 2). The River Continuum Concept (RCC, Vannote *et al.*, 1980) argued that along the river continuum relative proportion of collectors (filters and gatherers) should increase as river increase in size because of general reduction in detritus particle size in rivers that originate in forested areas in the shaded headwater streams. In present scenario, the headwater section of the Dhasan river was heterotrophic, while rest of the section was autotrophic. The presence of heterotrophic condition at headwater section appears due to modification in landuse for extensive agriculture and urbanization. The abundance of autotrophic condition was due to disruption of river continuum at D3 as presence of dam for river regulation. In the regulated section, the algal production (periphyton) the increased due to increase in nutrient concentrations as fertilizers from agriculture land sue favouring growth of benthic algae, thus accounting for the abundance of scrapers (Stone and Wallace, 1998). Thus, RCC was not applicable in the Dhasan river.

Mishra and Nautiyal (2013a) observed that the Ken and Tons (1-3 stream order) are in heterotrophic state. Since the Ken and Tons are 1-3 order rivers, they represent the headwater category. The predominance of collectors in them compared with dominance according to RCC suggests similarity in the functional feeding group (FFG) to a great extent. However, it is to be noted that the collectors in these rivers are likely to differ probably because the riparian vegetation is crop residues from

agriculture compared to the forested headwaters postulated in RCC. The dominance of collectors along the river length is also known in the tropical (Hyslop and Hunte-Brown, 2012) and subtropical rivers (Jiang *et al.*, 2011; Mishra and Nautiyal, 2011) of the world. In an Indian Himalaya river Bhagirathi, collectors are known to dominant in the headwater zone (Nautiyal, 2010).

The present study indicated that benthic macroinvertebrate structure varied within the river because of proximate factors like substratum and landuse, but at large scale the structure was almost similar as evident of some common abundant taxa were present the assemblage among the rivers. Thus, the rivers of central highlands ecoregion supported 'Biome Dependency Hypothesis'. This study also indicated the functional status of the river either autotrophic or heterotrophic. The river Dhasan was mainly autotrophic due to dominance of scraper while Ken and Tons were hetrotrophic due to abundance of collectors.

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