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ASSESSMENT OF BIOLOGICAL WATER QUALITY OF RIVER GANGA IN PATNA (INDIA) USING BENTHIC MACRO-INVERTEBRATES

Annu Goel[1*], Jaya Sharma[1] and Navin Chandra Durgapal[2]

Bio-science Laboratory, Central Pollution Control Board, Parivesh Bhawan, East Arjun Nagar, Shahdara, New Delhi - 110 032 (India)
*e-mail: *anugoel.micro@gmail.com*

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ABSTRACT

The present study was carried out to assess the macro-invertebrate diversity in Patna stretch of river Ganga at four sites during 2017-18. Considering fluctuations in river hydrology after rainy season, the study was conducted twice i.e. in summer and late winter. A total 1523 organisms belonging to 11 orders and 43 families were recorded. The operculate members of Gastropoda were found dominating in summer season at all the sampling sites and almost identical values of Shannon-Wiener index in river indicated stabilized ecosystem with moderate level of decomposable organic matter. Occurrence of pollution-sensitive Ephemeroptera families and good quantity of dissolved oxygen at two upstream sites i.e. Digha Ghat and Gandhi Ghat in winter indicated comparatively good biological water quality of river in this stretch. Presence of families like Corixidae and Nephthyidae indicated moderate level of organic matter decay at Malsalami and abundance of Chironomidae larvae at Fatuha reflected the impact of wastewater discharge into the river. Gradual decrease in Shannon-Wiener diversity index supported the impact of pollution at these two downstream sites of Patna stretch of river Ganga.

Keywords: Bio-monitoring, diversity, macro-invertebrates, seasonal variation, water quality

INTRODUCTION

Anthropogenic activities impact the inhabiting aquatic biota by altering one or more of the five basic factors - physical habitat, seasonal flow of water, the food base of the system, interactions within the stream biota, and chemical quality of water (Karr, 1998). These organisms can be used to evaluate the changes in aquatic environment, often referred to as bio-monitoring, or biological monitoring (Li *et al.,* 2010). Biotic communities integrate environmental conditions over a long period of time and can be performed at low-frequency unlike physicochemical sampling (Patang *et al.,* 2018).

Various groups of organisms have been used for biomonitoring of surface water bodies like bacteria (Zhang *et al.,* 2018; Wu *et al.,* 2019, Viji *et al.,* 2019), protozoa (Tanwar and Mane, 2020), planktons (Naskar *et al.,* 2020), macro-invertebrates and fishes (Saxena and Singh, 2020). Any group can act as indicator organism but an ideal indicator organism should have two main characteristics; it should be i) macroscopic and ii) sedentary/sessile/should not migrate with impact of pollutants (Hellawell, 1977). Macro-invertebrates belonging particularly to the phyla Annelida, Arthropoda and Mollusca are used worldwide as the best suited organisms for biomonitoring of rivers due to their macroscopic nature and limited migration patterns (Ghosh and Biswas, 2015). In biomonitoring, taxonomic richness and composition characterization of macro-invertebrates is used. Various indices [biological monitoring working party (BMWP) score, average score per taxon (ASPT), Shannon-

Wiener index, Simpson index, Margalef index, etc.] are used all over the world to evaluate the degree of alterations in riverine environment. BMWP scoring system is the most commonly used index for the assessment of biological water quality. The score has also been published as a standard method by an international panel (ISO-BMWP, 1979). The BMWP score was devised in the United Kingdom. The original saprobic score system with some minor modifications, was found suitable in research studies on Indian rivers *viz.*, Ganga, Yamuna, Chaliyar and Tungbhadra (Zwart and Trivedi, 1995a). ASPT represents the average of tolerance scores of all the observed families and is considered to be a more consistent index than BMWP method (Patang *et al*., 2018).

Studies on the use of macro-invertebrates as bioindicator of water quality of Indian rivers have been documented (Kumar *et al.*, 2013; Agrawal *et al*. 2019, Saxena and Singh 2020) but river Ganga being unique with its fertile plains and large basin has been declared as the National river of India. Of the 2525 km long stretch, the river section in Bihar is distinct due to its natural and free flowing course and an irreplaceable habitat to the endangered Gangetic dolphin, *Platanista gangetica gangetica* (Nesseman *et al.,* 2011). Patna, being capital city, is supposed to have major impact on the river fauna and biological water quality. The benthic macro-invertebrate community composition in this stretch has been characterized and documented (Sinha *et al.*, 2003; (Nesemann *et al.,* 2004, Nesemann *et al*., 2005, Nesseman *et al.*, 2011, Kumar *et al.*, 2013) but the literature on biological water quality assessment using ASPT index is very limited. Keeping this in view, the present study was carried out to assess the current macro-invertebrates and the biological water quality status of river Ganga in Patna stretch using ASPT and Shannon Wiener index.

MATERIALS AND METHODS

Study area

Patna city is situated on the right bank of river Ganga located at 25˚37' N and 85˚21' E. The total length of Ganga river in Bihar is 405 km. The selected study stretch in Patna city is about 29 km long. Four locations of river Ganga were selected (Fig. 1) to study the taxonomic richness of macro-invertebrates. Digha Ghat is the uppermost location of the stretch situated upstream of Patna city. Gandhi Ghat is 9 km downstream of Digha Ghat situated before the confluence of river Gandak and about 3.5 km upstream of Gandhi Setu. Next downstream location is Malsalami about 8.0 km away from Gandhi Ghat and about 4.5 km downstream of Gandak river. Fatuha is the last location of river stretch situated about 12.0 km downstream of Malsalami and 2 km downstream of Punpun river confluence. Considering the fluctuations in river hydrology after rainy season, the study was carried out twice i.e. in summer and winter.

Fig. 1: Sampling locations in Patna stretch of river Ganga

Sample collection

Riverbed substratum influences greatly the macro-invertebrate community structure by providing different habitats for colonization. Composition and dominant populations of macro-invertebrates differ widely with the substrata having variable particle sizes (Duan *et al.*, 2008). Substratum of river Ganga in Patna stretch was devoid of boulders and cobbles but mainly consists of pebbles, sand, silt, clay, detritus and macrophytes. Therefore, the samples were collected qualitatively from all the habitats using shovel sampler and kick net, and washed using standard sieve (mesh size 0.6 mm) (APHA, 2017a). For animal collection from macrophytes, water plants found on river bank were uprooted and placed on the sieve. The animals were washed in tray and picked with the help of forceps. The collected animals were stored in a wide mouth 500 mL plastic container and preserved in 4% formalin solution. Preserved animals were transported to the laboratory for further analysis.

Physicochemical analysis

Physicochemical parameters of water samples *viz*., dissolved oxygen (DO) which indicates presence of decaying organic matter and water temperature, were recorded at the time of sampling. DO was measured as per Winkler method (APHA, 2017b) and water temperature measured using a calibrated thermometer.

Segregation and taxonomic identification

Preserved macro-invertebrates were washed using rectangular sieve (dimension: 11 × 15 mm; mesh size 0.6 mm) with water to remove all the preservative, fine sediment and any other unwanted material and segregated as per taxonomic orders. The segregated organisms were identified up to family level. Mollusca, Crustacea and Annelida were identified using taxonomic key developed by Nessemann *et al.* (2007), whereas Arthropods and Platyhelminthes (flat worms) were identified using reference keys developed by Zwart and Trivedi (1995b), Jessup *et al.* (2003), Graf *et al.* (2006) and Akolkar *et al.* (2017). ASPT score was calculated by placing all the identified families in BMWP score chart modified as per the Indian conditions (Akolkar *et al.*, 2017). The biological water quality was evaluated and classified as 7.0 - 10.0 very good; 5.0 - 6.9 good; 3.0 - 4.9 moderate; 1.1 - 2.9 poor; and $\leq$ 1.0 severe.

Shannon-Wiener diversity index

Diversity of invertebrates was analyzed using Shannon-Wiener diversity index as per formula described by Shannon and Weaver (1964):

$$H = -\sum_{i=1}^{s} (Pi * \ln P_i)$$

where, H = Shannon-Wiener diversity index, Pi = relative abundance of each family calculated as the proportion of individuals of a given family to the total number of individuals in the community; S = the number of families. ∑ = sum from the family 1 to family S.

Shannon-Wiener diversity index (H): If H is 0: there is only one species present in the sample and if H is maximum then all the species present in the sample are represented by the same number of individuals i.e. there is perfect even distribution of abundances (Ludwig and Reynolds, 1988).

RESULTS AND DISCUSSION

The temperature of river water was found in the range of 32-34°C in summer season and 26-29°C in winter season (Table 1). Decrease in water temperature may be attributed to the changes in weather conditions. DO concentration was in the range of 6.5-7.8 mg L^{-1} in summer and 7.8-9.8 mg L^{-1} in

Table 1: Physicochemical characteristics at studied sites in Patna stretch of river Ganga

Locations	Summer			Winter		
	Water temperature (°C)	DO (mg L^{-1})	DO (% saturation)	Water temperature (°C)	DO (mg L^{-1})	DO (% saturation)
Digha Ghat	32.0	7.4	96	27.5	9.2	113
Gandhi Ghat	30.0	7.8	106	28.2	9.8	115
Malsalami	33.0	6.5	84	26.0	8.7	99
Fatuha	34.0	6.8	99	29.0	7.8	91

winter. The increase in the range was due to reduced water temperature and comparatively more water quantity in the river. Reduction in DO level in downstream locations indicated the impact of wastewater discharges from Patna city into the river. DO and water temperature influence the existence of different aquatic species (Kale, 2016).

Macro-invertebrate community

The community structure of macro-invertebrates was diverse at all the studied sites Ganga river stretch. The community of macro-invertebrates was comprised of 11 orders and 43 families (Table 2). A total of 1,523 organisms were collected from all the four locations. Nearly half (47.47%) of the

Table 2: Occurrence of macro-invertebrate families at studied sites in Patna stretch of Ganga

Order	Family	Digha Ghat		Gandhi Ghat		Malsalami		Fatuha	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Ephemeroptera	Ephemerilidae	-	-	-	+	-	-	-	-
	Ephemeridae	-	+	-	-	-	-	-	-
Odonata	Gomphidae	-	+	+	+	-	+	+	+
	Protoneuridae	+	-	-	-	-	-	+	-
	Coenagrionidae	+	-	-	-	-	-	-	-
Mollusca	Viviparidae G: *Bellamya bengalensis*	+	+	+	+	+	+	+	+
	Viviparidae G: *Meckongia crassa*	+	+	-	+	-		-	+
	Amblemidae G: *Parreysia*	+	+	-	-	+	+	-	-
	Stenothyridae	-	-	-	-	-	-	+	-
	Pleuroceridae G: *Brotia*	-	-	+	-	-	-	-	-
	Succinidae	-	-	+	-	-	-	-	-
	Bithynidae G: *Digoniostoma*	-	-	+	-	+	-	+	-
	Thiaridae G: *Thiara requitii*	-	-	+	+	-	-	+	+
	Thiaridae G: *Thiara tuberculate*	-	-	+	+	-	-	+	+
	Thiaridae G: *Thiara lineata*	-	-	-	+	-	-	-	-
	Unionidae *G: Lamellidens*	-	+	-	-	-	+	+	+
	Planorbidae G: *Indoplanorbis*	+	-	+	-	+	-	+	-
	Physidae G: *Physa Mexicana*	-	+	+	+	+	+	-	+
	Lymnaeidae G: *Lymnaea accuminata*	+	+	+	-	+	-	+	-
	Corbiculidae G: *Corbicula striatella*	-	+	+	+	-	+	+	+
	Corbiculidae G: *C. assamensis*	-	-	-	-	-	-	-	-
Crustacea	Palaemonidae	+	-	+	-	+	-	+	-
	Atyidae	+	-	+	-	-	-	+	-
	Gamaridae	+	-	-	-	-	-	-	-
	Cirolanidae	+	-	+	-	-	-	+	-
Polychaeta	Nephthyidae	-	+	-	-	-	+	-	-
	Nereidae	-	+	-	-	-	-	-	-
Trichoptera	Hydropsychidae	-	+	-	-	-	-	-	-
Hemiptera	Belastomatidae G: *Diplonychus*	-	-	-	-	-	-	+	-
	Corixidae	+	+	+	+	-	+	-	+
	Nepidae *G: Laccotrephes*	-	-	+	-	-	-	+	-
Coleoptera	Haliplidae	-	+	-	-	-	-	-	-
	Dytiscidae	-	+	+	+	+	+	-	-
	Gyrinidae	-	-	-	-	+	-	-	-
	Psephenidae	-	-	-	-	-	+	-	-
	Dryopidae	-	-	+	-	+	-	-	-
	Hydrophilidae	+	-	+	+	-	-	+	-
	Heteroceridae	-	-	-	-	-	-	+	-
	Noteridae	-	-	+	-	-	+	+	-
Hirudinea	Piscicolidae	-	-	+	-	-	-	-	-
	Glossiphonidae	+	-	+	+	-	-	-	+
	Hirudidae	-	-	+	-	-	-	-	-
Diptera	Culicidae	-	-	-	+	-	-	-	+
	Stratiomyidae	-	-	+	-	-	-	+	-
	Syrphidae G: *Eristalis*	-	-	+	-	-	-	-	-
	Chironomidae	+	+	-	+	-	+	+	+
Oligochaeta	Naididae	-	-	-	-	-	-	-	+

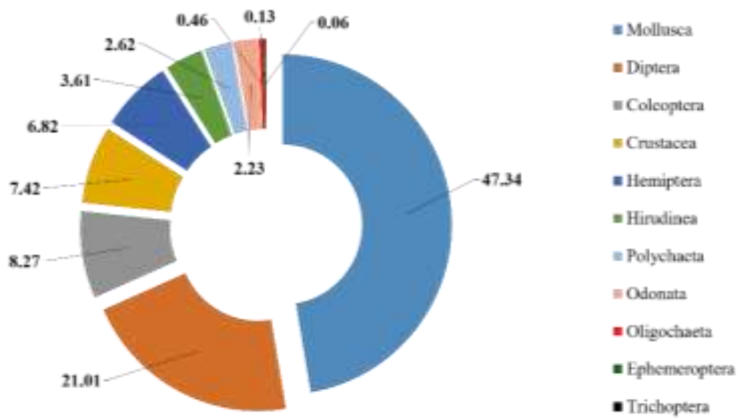

Fig. 2: Taxonomic order-wise distribution of macro-invertebrates in Patna stretch of river Ganga

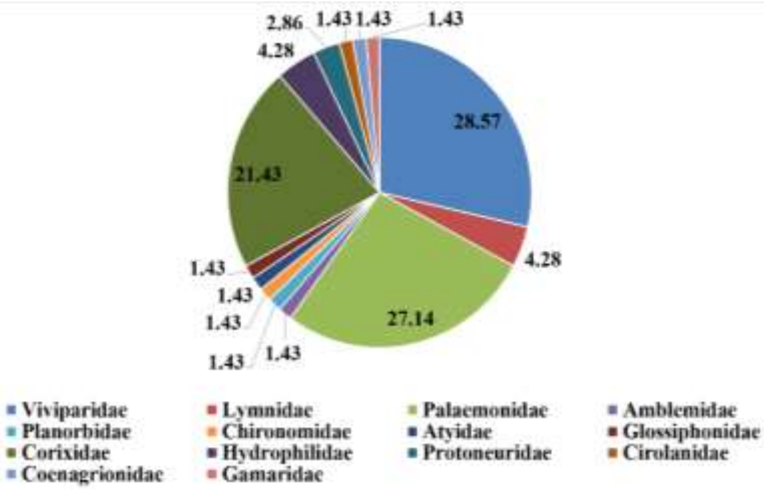

Fig. 3: Distribution of macro-invertebrate families at Digha Ghat in summer season

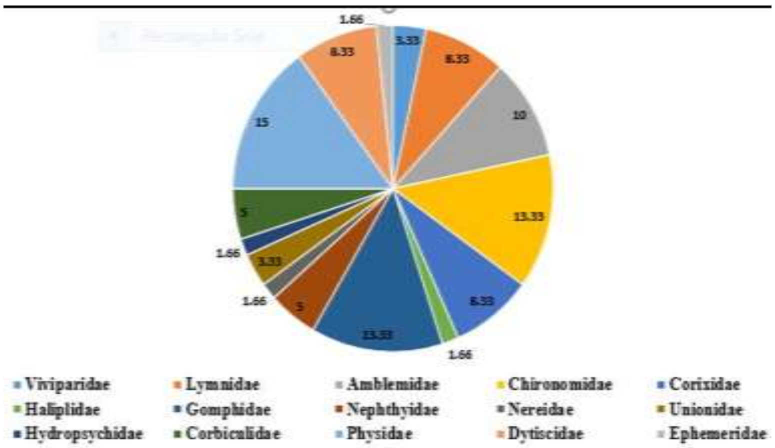

Fig. 4: Distribution of macro-invertebrate families at Digha Ghat in winter season

total macro-invertebrates belonged to the phylum Mollusca, including both moderate pollution (BMWP score 6) and pollution tolerant (BMWP score 3) families of class Gastropoda (Fig. 2). Order Ephemeropetra comprising of pollution sensitive families were also reported though very small in number (0.13%). The highest diversity of Mollusca (16 species) has also been reported by Kumar *et al.* (2013) in a study on seasonal distribution of macro-benthic assemblages in river Ganga at Munger and Bhagalpur, Bihar. Similarly, Singh *et al.* (2019) have reported the dominance of Gastropod families in flood plain lakes of Tarawe Chaur and Gamharia Chaur of North Bihar, India during 2012-2013. Higher density of Gastropods indicates sewage borne organic pollution (Dudhani *et al.*, 1998).

Dominant taxonomic families of macro-invertebrates

In summer season, at Digha Ghat the family Viviparidae [genus: *Bellamya bengalensis* and *Meckongia crassa*] (28.57%) was dominant and Palaemonidae (27.14%) as codominant family (Fig. 3). At next downstream location Gandhi Ghat, the dominance of Viviparidae (*B. bengalensis*) was 48.66% was followed by Thiaridae (*Thiara riquetii* and *T. tuberculata*) (16.51%) (Fig. 5). At Malsalami, Viviparidae (*B. bengalensis*) (46.8%) was dominent family followed by Lymnaeidae (*Lymnaea accuminata*) (12.76%) (Fig. 7). At Fatuha (Fig. 9), the major part of community was represented by Viviparidae (*B. bengalensis*) (39.2%), followed by Thiaridae (*T. riquetii* and *T. tuberculata*) (14.61%) and Bithynidae (13.62%). The presence of operculum in these Gastropod families enables them to survive in moderate dissolved

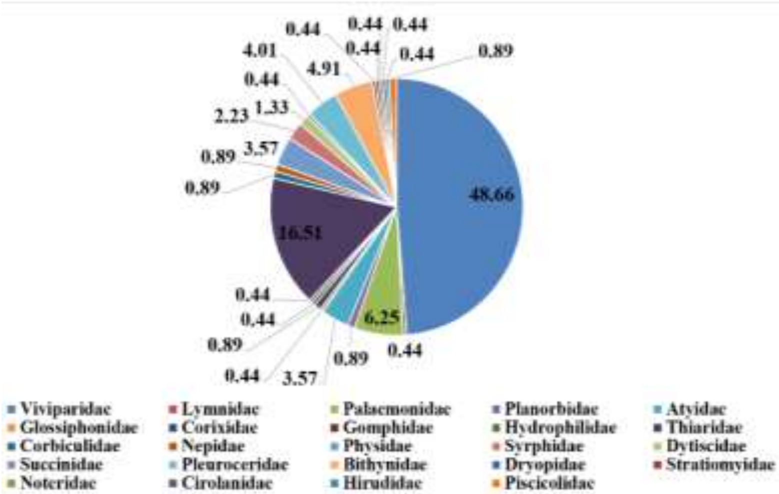

Fig. 5: Distribution of macro-invertebrate families at Gandhi Ghat in summer season

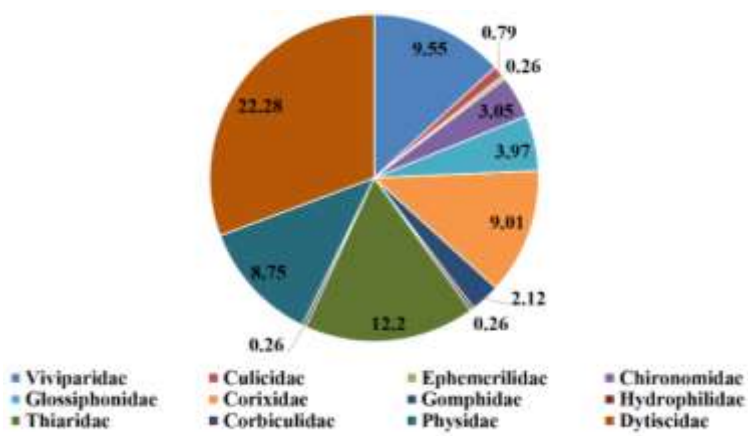

Fig. 6: Distribution of macro-invertebrate families at Gandhi Ghat in winter season

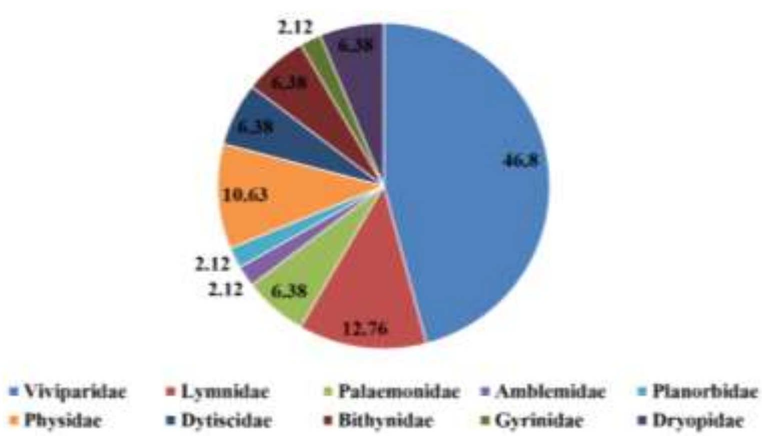

Fig. 7: Distribution of macro-invertebrate families at Malsalami in summer season

oxygen content and intermediate level of suspended particulate matter of riverine system (Mitchell *et al.*, 2007). The family Coenagrionidae of Order Odonata was observed at Digha Ghat only and was represented by a facultative organism that serves as indicator of moderate fluctuations in environmental conditions. The presence of *Coenagrion* species has been reported in rivers of other countries e.g. Pampang river of Indonesia (Patang *et al.*, 2018).

During winter season, at Digha Ghat dominance of family Physidae *(Physa mexicana*) and Lymnaeidae (*L. accuminata*) (13.33% each) was observed (Fig. 4). Mass occurrence of Physidae has also been reported at various locations of Patna (Sinha *et al.*, 2003) and Mokamah and Munger (Kumar *et al.*, 2013). At Gandhi Ghat dominant families observed were Dytiscidae (22.28%) and Thiaridae (*T. riquetii*, *T. tuberculate* and *T. lineata*) (12.2%) (Fig. 6); whereas at Malsalami, the prominence of Corixidae (24.38%) and Nephthyidae (23.52%) families were noted (Fig. 8). Pollution sensitive families Ephemeridae and Ephemerillidae (Order Ephemeroptera) were also observed at two upstream locations i.e. Digha Ghat and Gandhi Ghat of Patna city. Both these families are considered as the indicators of clean biological water quality with highest BMWP score of 10 as per the Biological Monitoring Working Party (BMWP) scoring system (ISO-BMWP, 1979). The presence of pollution sensitive

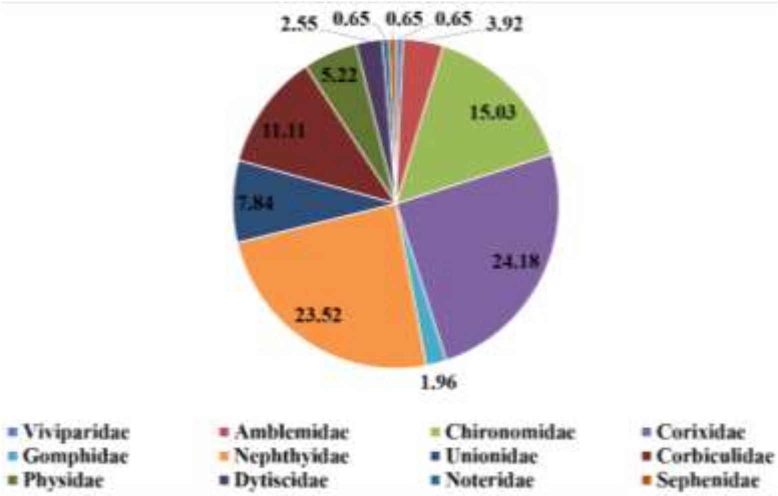

Fig. 8: Distribution of macro-invertebrate families at Malsalami in winter season

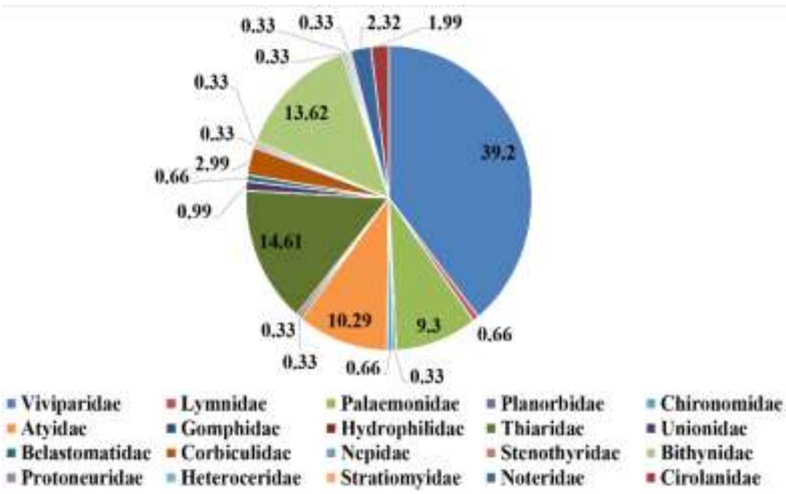

Fig. 9: Distribution of macro- invertebrate families at Fatuha in summer season

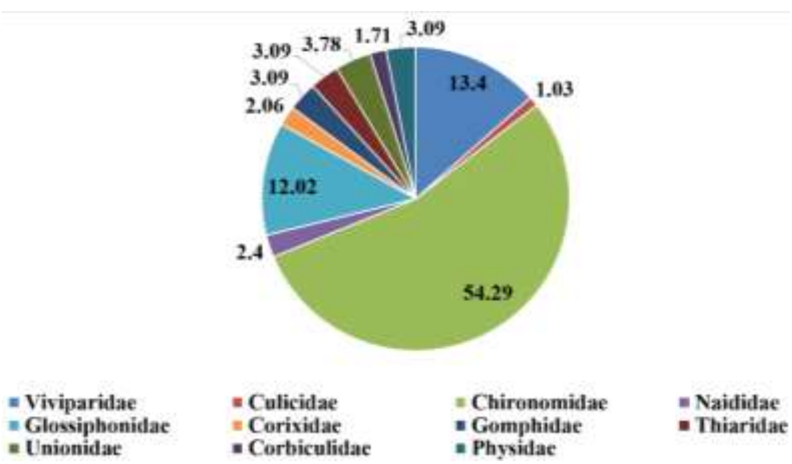

Fig. 10: Distribution of macro-invertebrate families at Fatuha in winter season

families is associated with high DO content 9.2 and 9.8 mg L^{-1} at these upstream locations (Fig. 4 & 6; Table 2). Similar observation has been reported in a research carried out by Kebede *et al.* (2020) on water quality monitoring of Awash river of Ethiopia. At Fatuha the most dominant family was Chironomidae (54.29%) [(Fig. 10]. Chironomidae larvae (red worms) are efficient indicators of mesotrophic waters. These tolerate low DO and are usually found at the locations having high decomposable organic matter (Varnosfaderany *et al.*, 2010, Mariantika and Retnaningdyah, 2014). The prominence of Chironomidae family was reported in Karang Mumus river of Indonesia by Patang *et al.* (2018). Agrawal *et al.* (2019) found the abundance of Chironomidae with the direct discharge of untreated/partially treated sewage from correlated STP outlet at Jagjeetpur (Uttarakhand). Kumar and Nautiyal (2019) studied benthic macro-invertebrate community in Bhagirathi river and reported moderate to heavily impacted water quality in river stretch fragmented by hydro-electric projects. Goncharov *et al.* (2020) reported strong impact on macro-invertebrate ecology of Selenga river in the vicinity of Ulan-Ude city of Russia where a decrease in benthic community species diversity and reduction in the number of invertebrate species was observed in the areas of waste water discharge from sewage treatment plant.

ASPT score values

As per ASPT criteria, the biological water quality at Digha

Table 3: ASPT score at studied locations in Patna stretch of river Ganga

Locations	Summer	Biological water quality	Winter	Biological water quality
Digha Ghat	4.9	Moderate	5.3	Good
Gandhi Ghat	5.1	Good	5.2	Good
Malsalami	4.5	Moderate	4.8	Moderate
Fatuha	5.2	Good	4.6	Moderate

Ghat improved from moderate to good in winter season (Table 3). This may be due to increase in water flow and consequent dilution of organic pollution at this site. At Gandhi Ghat, the biological water quality remained good in both the seasons. At Malasalami, the biological water quality was moderate; while at Fatuha the biological water quality deteriorated from good to moderate in winter season (Table 3). Dominance of Chironomidae taxa has also been observed at this site in winter samples which may be attributed to the wastewater discharge into the river at this site. Zeybek *et al*. (2014) studied the water quality of Değirmendere stream (Isparta, Turkey) and categorized the stream as unpolluted or slightly polluted as per their version of BMWP and ASPT indices. Patang *et al*. (2018) used different version of ASPT and the national sanitation foundation - water quality index (NSF-WQI) to assess water quality of rivers in east Kalimantan (Indonesia) and classified Karang Mumus river as polluted, Jembayan river as doubtful or moderate and Pampang river as the cleanest river. The literature on water quality classification of Indian rivers using ASPT index is limited and as such there is no nation-wide ASPT criteria. So, comparing our findings on biological water quality in rational with Indian literature is not appropriate.

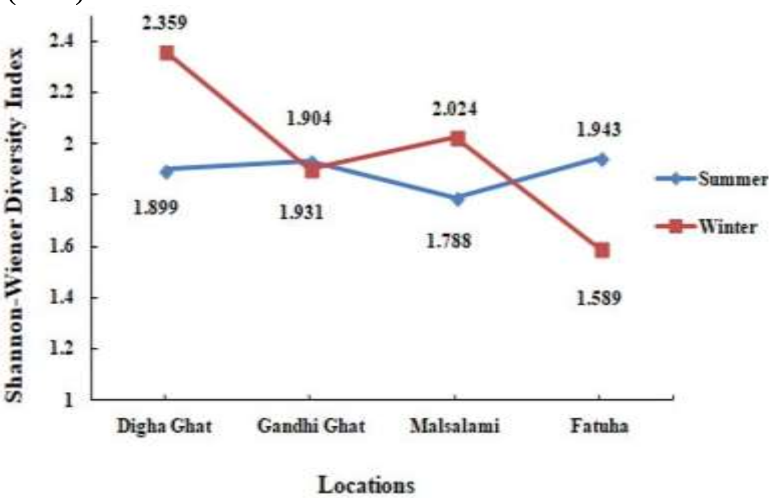

Fig. 11: Shannon-Weiner Diversity Index at studied location variation in Patna stretch of River Ganga

Shannon-Wiener diversity index

Shannon-Wiener is a preferred index used to assess macro-invertebrate diversity as its values vary only after severe changes in community structure involving gross reduction in density and/or replacement of species (Boyle and Fraleigh, 2003). The Shannon-Wiener index values generally ranged from 1.5 to 3.5 for the riverine system (Deo *et al.*, 2016). Higher index value is correlated with higher diversity of macro-invertebrates and low impact of pollution, whereas low index values show high impact of pollution and less macro-invertebrate diversity.

In present study, Shannon-Wiener index value ranged from 1.788 to 1.943 in summer season and from 1.589 to 2.359 in winter season which signified the moderate impact of anthropogenic activities on macro-invertebrate community in the studied river stretch. Increase in the values of diversity index in winter season as compared to summer at Digha Ghat from 1.899 to 2.359 and at Malsalami from 1.788 to 2.024 reflected increased diversity of macro-invertebrates at these sites. Insignificant difference in Shannon-Wiener index at Gandhi Ghat indicated no effect of seasonal variation on diversity at this site. At Fatuha, a slight decrease in diversity index from 1.943 (summer) to 1.589 (winter) was observed (Fig. 11). This may be attributed by the increase in wastewater discharges in river and increased human activities causing damage to the invertebrate habitat. Ghosh and Biswas (2015) reported Shannon-Wiener index of 2.10 and 2.12 in pre-monsoon and post-monsoon period in seasonal survey of macro-invertebrate communities on Chhariganga oxbow lake, Nadia district, West Bengal during 2013-14. Rawat *et al.* (2020) correlated the values of Shannon diversity index with human activities in Mandakini river in the vicinity of Kedarnath Wildlife Sanctuary, Indian Himalayan region and reported that these values varied from 2.048 to 2.25 in the least disturbed site (Sonprayag), 0.186-2.446 in medium disturbance (Ukhimath), and 1.362-2.271 in the highly disturbed site (Rudraprayag) in both pre- and post-monsoon season.

Conclusion: The present study revealed that the Ganga river in Patna stretch harbours a wide diversity of macro-invertebrates. The persistence of a well-structured macro-invertebrate community, including the families of pollution sensitive taxa indicated that the Ganga ecosystem is not significantly affected by various human activities. The occurrence of Ephemeroptera families *viz*., Ephemeridae and Ephemerillidae at Digha Ghat and Gandhi Ghat along with comparatively high dissolved oxygen indicated the presence of favourable conditions for existence of macro-invertebrate community; whereas, at downstream sites these conditions decline gradually affecting the community structure and biological water quality.

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Conflicts of interests: All the authors have contributed equally to the work and declare that they don't have any conflict of interest.

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