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Diversity and composition of macroinvertebrate in floodplain lakes of North Bihar, India

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Abstract
The benthic macroinvertebrate fauna and physico-chemical parameters in floodplain lakes were studied monthly from September, 2012 to August, 2013. The investigated lakes, Tarawe *chaur* and Gamharia *chaur* are located in district Madhepura of north Bihar, India between 25°34′N to 26°07'N latitude and 86°19'E to 87°07'E longitude. In total, 26 species belonging to 17 genera and 17 families were recorded. Benthic macroinvertebrate communities consist of Oligochaeta, Hirudinea, Insecta, Pelecypoda and Gastropoda. Number of species was highest in clean-water environments at Tarawe *chaur* (21 species) than in poor-water quality at Gamharia *chaur* (15 species) where sewage disposal eliminate pollution-sensitive species. However, the population density of benthic fauna was highest in poor-water conditions at Gamharia *chaur* than in clean-water environments at Tarawe *chaur*. Gastropod was the most abundant group (12 species) followed by pelecypod (5 species), insect (1 larva and 3 nymphs), oligochaete (3 species) and hirudinea (2 genera). Of these, 10 benthic macroinvertebrate species were common. Variations in the abundance of total macroinvertebrate and the species in it were clearly influenced by water quality. Highest percentage of Sørensen's similarities for total macroinvertebrate and its groups revealed more homogeneity between species in communities, while dissimilarities showed minor differences between species in communities probably due to habitat heterogeneity.

Keywords: Floodplain lakes, water quality, benthic macroinvertebrate, diversity, abundance, similarity

1. Introduction
Benthic macroinvertebrate are found in almost all water bodies living on or inside deposits of the bottom substrate. Macroinvertebrates serve numerous functions, such as, mineralization, nutrient cycles, constitute important link in food chain and energy flow, thus, play important role in the ecosystem dynamics [1, 2] besides serving good food for fish and other aquatic organisms. Factors like substrate types, climates, catchment areas and physico-chemical parameters not only involve in shaping benthic macroinvertebrate communities, but also influence dominance and diversity by altering habitat and species. Biological monitoring of physico-chemical quality of water using benthic macroinvertebrate fauna is more accurate and beneficial [3, 4, 5], as they live on sediments, spend main part of life cycle in water, long life span, limited mobility thus cannot escape adverse condition and tolerate different level of pollution [6, 7, 8], these characteristics make them reliable indicators of ecosystem health [9, 10, 11]. The different species of benthic macroinvertebrate have different habitat and niche requirements in an ecosystem depending on feeding, breeding and habitudinal needs. Investigation on benthic macroinvertebrate in the floodplain lakes of India is limited. Some early studies have reported abundance and seasonal variations of macroinvertebrate including physico-chemical parameters of Indian floodplain wetlands in selected localities [7, 12, 13, 14, 15, 16, 17, 18], but similar studies still lacking in this region. The present study is, thus, aimed to determine abundance and composition of benthic macroinvertebrate fauna and water quality status in floodplain lakes of North Bihar, India. Similarities and dissimilarities between species in communities were evaluated by using Sørensen's similarity index [19].

2. Materials and methods
2.1 Study Area
The present study was conducted on two perennial floodplain lakes (*chaurs*) presenting different ecological conditions. Both lakes are situated in Madhepura district of North Bihar,

India. These lakes, Tarawe *chaur* and Gamharia *chaur* are low laying floodplain of river Kosi basin, located between 25°34′N to 26°07'N latitude and 86°19'E to 87°07'E longitude. Location of the flood plain lakes are illustrated in Figure 1. Of the lakes studied Gamharia *chaur* is situated nearby village Gamharia, though Tarawe *chaur* is situated 3km away from it. Tarawe *chaur* is fairly deep large water body, whereas Gamharia *chaur* is shallow small water body receive sewage effluents from village. This lake is heavily infested with aquatic vegetation. Lakes investigated are inundated by flood water during monsoon. Water is used for irrigation, fisheries and cultivating aqua-fruit, makhana (*Euryale ferox* Salisb.), besides offering several other benefits to local people and fisher families. Upper marginal land is used for agriculture. Muck accumulation and depth decreases in summer are important characteristics of the lakes.

2.1 Sampling

2.2.1 Water

The triplicates subsurface water samples for the analysis of physico-chemical parameters were collected using a polyethylene cane of five liter monthly from September, 2012 to August, 2013. Water temperature and the light permeability in water (transparency) were determined directly by using mercury thermometer (0ºC-50ºC) and the Secchi disc of 20 cm diameter. Hydrogen ion (pH), dissolved oxygen, carbonate and bicarbonate were determined in the field. Conductivity, chloride, nitrate-nitrogen, phosphate-phosphorus and BOD (Biochemical oxygen demand) were analyzed in the laboratory. The physico-chemical parameters were analysed following standard methods [20, 21].

2.2.2 Macroinvertebrate

Samples for the analysis of benthic macroinvertebrate fauna were collected using Ekman's grab of 225cm^2 monthly at each sampling lake at the sampling time. Sampled materials were taken to the laboratory for sorting and analysis. In the laboratory, sampled materials were washed through 0.5mm sieve no. 40 of 425µm mesh to remove debris. The benthic fauna retained on sieve were placed in an enamel tray, sorted out and preserved in 5% formalin. The macroinvertebrates were identified upto the lowest possible taxonomic level using the standard keys [22, 23, 24, 25, 26, 27], and counted individuals per square meter. The Sørensen's similarity index [19] was used to determine similarities and dissimilarities between species in communities.

3. Results and Discussion

3.1 Water Quality

Floodplain lakes investigated are natural water bodies in the study area, showed different water quality. Physico-chemical characteristics of water are presented in Table 1. Present data showed no marked difference in water temperature, though, it was little higher at Gamharia *chaur* (27.92 ± 5.25 °C) than at Tarawe *chaur* (27.38±4.49 °C). The Secchi disc transparency measured depth to which light penetrates in the water body. Water was more transparent at Tarawe *chaur* (37.85± 17.86 cm) than at Gamharia *chaur* (29.71 ± 12.10 cm). The transparency of water decreased with increasing suspended and dissolved solid. Conductivity of water reflects its ability to conduct an electric current. In this study, it was higher at Gamharia *chaur* (284.04±108.24 µS cm^{-1}) than at Tarawe *chaur* (160.32±43.39 µS cm^{-1}). The pH shows alkaline water throughout the study period. It was higher at Tarawe *chaur* (7.40±0.41) than at Gamharia *chaur* (6.81±0.17). The recorded dissolved oxygen was good enough to hold biota. It was higher at Tarawe *chaur* (6.67 ±1.15 mg L^{-1}) than at Gamharia *chaur* (5.23±0.87 mg L^{-1}). The carbonate and bicarbonate were higher at Gamharia *chaur* probably attributed to sewage disposal increasing contents. The higher concentration of chloride is toxic to biota. It was higher at Gamharia *chaur* (27.82±5.47 mg L^{-1}) than at Tarawe *chaur* (15.44±3.0 mg L^{-1}). Higher chloride concentration could be attributed to the discharge of sewage effluents mainly of animal origin. Major nutrients, nitrate-nitrogen and phosphate-phosphorus measured were enough to maintain productivity, and both were higher at Gamharia *chaur* (0.51±0.11 mg L^{-1} and 0.21±0.04 mg L^{-1}) than at Tarawe *chaur* (0.27±0.10 mg L^{-1} and 0.13±0.04 mg L^{-1}). Biochemical oxygen demand measured pollution level in water. BOD was low (2.23±0.52 mg L^{-1}) at Tarawe *chaur* reflect clean-water conditions, no pollution, while, high (4.15±1.37 mg L^{-1}) at Gamharia *chaur* indicate moderately polluted water might be due to sewage disposal added huge amounts of organic matter, breakdown of these materials consume oxygen. The overall results revealed clean-water environments at Tarawe *chaur* and poor-water quality at Gamharia *chaur*.

3.2 Composition of the Fauna

Benthic macroinvertebrate collected is presented in Table 2. Variations in abundance of various groups are given in Table 3. In total, 26 species belonging to 3 phyla, 5 classes, 17 families and 17 genera were recorded during the study. Macroinvertebrate communities were comprised of 5 major groups, Oligochaeta (worms), Hirudinea (leech), Insecta (larvae and nymphs), Pelecypoda (bivalves) and Gastropoda (snails). Among these, gastropod (12 species) was the most dominant group followed by pelecypod (5 species), insect (1 larva and 3 nymphs), oligochaete (3 species) and leech (2 genera). Benthic macroinvertebrate community was more diverse at Tarawae *chaur* comprise of 1 species of oligochaete, 1 leech, 4 insect, 5 pelecypod and 10 gastropod, whereas, community less diverse at Gamharia *chaur* consist of 3 species of oligochaete, 1 leech, 1 insect, 2 pelecypod and 8 gastropod. Of these, 10 macroinvertebrate species were common. The results revealed that benthic fauna recorded at each lake has its own characteristics. Number of species was higher in clean-water environments at Tarawe *chaur* than in poor-water quality at Gamharia *chaur*. But, population density was highest at Gamharia *chaur* (43-2987 individual m^{-2}) than at Tarawe *chaur* (43-1580 individual m^{-2}). These differences could be due to habitat heterogeneity, i.e., variations in water quality, sediment types and the food quality and quantity [28]. Different groups of macro invertebrate fauna showed different requirement to survive in ecosystems. The number of species decreased at Gamharia *chaur* probably due to sewage disposal damage proper functioning of ecosystem. In this lake, macroinvertebrate fauna often dominated by pollution-tolerant species. While, the species numbers increased at Tarawe *chaur* probably due to clean-water environments increase chances of their survival, often dominated by pollution-sensitive species. It was seen that dense vegetation in shallow water areas provides rich food material and good environmental conditions for feeding and breeding of benthic fauna [29].

Oligochaete worms prefer to live in organic-rich muddy deposit in water bodies and dominate benthic communities in polluted water [30, 31, 32] and eutrophic conditions [33] besides

comprising a good food source for fry and adult fish. Present study reported 3 species of oligochaete belonging to 2 families, Naididae (*Branchiodrilus semperi*) and Tubificidae (*Limnodrillus hoffmeisteri* and *Branchiura sowerbyi*). Among these, *Limnodrillus hoffmeisteri* was the dominant species, while, the other 2 species, *Branchiodrilus semperi* and *Branchiura sowerbyi* were least abundant found only in poor-water conditions at Gamharia *chaur*. Factors, like sediment types and water quality structuring oligochaete communities in lakes. Contributions of oligochaete to total benthic fauna was negligible in clean-water environments at Tarawe *chaur*, although, the number of species and density was higher in poor-water conditions at Gamharia *chaur* probably due to the sewage disposal from nearby human habitation added huge amount of organic matter which offers an ideal medium and better food conditions for survival and growth of this worms.

Leeches were poorly colonized in the lakes investigated, comprise minor group of benthic fauna. The factor structuring leech communities is not clear, although, their presence indicates organic-rich environments [34]. Leeches reported in this study were belonging to 2 genera, the *Hirudo* was found in both lakes and the *Helobdella* recorded only at Gamharia *chaur* (Table 2).

Benthic insects recorded in this study comprise of larva and nymph of flying insects. They were often used as biological tool in water quality monitoring [33, 35]. Of the recorded benthic insects, *Chironomus* (dipterans larvae) was the most dominant species. Their population density was highest in poor-water conditions at Gamharia *chaur* as they are well adapted to oxygen-deficient water [36, 37], because their blood contains hemoglobin which traps dissolved oxygen [38]. Nymph collected during this study was juveniles of adult flying insects. Nymphs of mayflies, damselflies and dragonflies were recorded only in oxygen-rich water at Tarawe *chaur* because they need more oxygen for cellular metabolisms [39]. Nymph was absent at Gamharia *chaur* probably due to poor-water quality [40, 41].

Mollusca comprise of soft bodied animals, *viz*., Pelecypoda and Gastropoda, both dominant the benthic macroinvertebrate communities. Basic knowledge on pelecypod was currently very poor, but their presence signified clean-water conditions [42, 43]. The present study recorded 5 species of pelecypods, viz., *Lamellidens marginalis*, *Parreysia corrugata*, *Parreysia (parreysia*) *favidens*, *Corbicula bensoni* and *Corbicula striatella*. All species were collected in clean-water conditions at Tarawe *chaur*, whereas, only 2 species, *Parreysia (Parreysia*) *favidens* and *Corbicula bensoni*, were recorded in poor-water quality at Gamharia *chaur*. The study revealed that substrate types and water quality was important factor structuring bivalve communities [44]. Population density and diversity of pelecypod was high in clean-water environments at Tarawe *chaur*, as they prefer well-oxygenated waters [45], whereas, low in poor-water conditions at Gamharia *chaur* probably due to sewage disposal eliminate pollution-sensitive species [46, 47].

Gastropods dominate benthic communities in the lakes studied. Highest densities of gastropod indicate sewage born organic pollution [48]. In total, 12 species of gastropods were recorded in this study. Out of these, 10 species were recorded in clean-water environments at Tarawe *chaur*, whereas, 8 species in poor-water quality at Gamharia *chaur* (Table 2). The lakes studied harbor almost similar species of gastropod, but their density was fairly higher in poor-water conditions at Gamharia *chaur* than in clean-water environments at Tarawe *chaur* [45, 49]. The present results revealed that the species *Bellamya bengalensis*, *Pila globossa*, *Melanoides tuberculatus*, *Thiara* (*thiara*) *scabra*, *Lymnaea acuminata* and *Indoplanorbis exustus* were the dominant gastropod often found in both lakes probably due to facultative nature. It was seen that dense vegetation in shallow water areas offer a good breeding and nursery ground for snails [50].

3.3 Similarity and Dissimilarity

The results of Sørensen's similarity index [19] analysis are presented in Table 4. Data showed that similarities between benthic macroinvertebrate groups varied from 40% to 67% revealed more similar species shared by communities, whereas, dissimilarities ranged from 33% to 60% showed presence of different species in communities. Highest percentage of similarities revealed more homogeneity between species in communities probably due to stable environments involves high degree of organizations and the complexity of food webs [51]. While, percentage of dissimilarities showed differences between species in communities could be attributed to habitat heterogeneity [52, 53].

The data showed that similarity between total macroinvertebrate was 56%. This indicates more similar species present in communities probably due to the stable environment existing in both lakes, while dissimilarities 44% reflect differences between species in communities. During this study, 10 species of macroinvertebrate were common, as they successfully adapted environments and the other species in communities. The results of similarity index revealed that lakes situated on flood plains of same river, located in same geographical location and same climates and same hydrological conditions have almost similar species in communities [54]. In this study, percentage of similarities was highest for Gastropoda (67%) followed by Pelecypoda (57%) and Oligochaeta (50%), though, the dissimilarities for Hirudinea 100% is surprising probably attributed to habitat heterogeneity.

Table 1: Physico-chemical parameters (Mean ± SD) of two floodplain lakes (*chaurs*).

Parameters	Tarawe *chaur*	Gamharia *chaur*
Water temperature (°C)	27.38±4.49	27.92±5.25
Transparency (cm)	37.85±17.86	29.71±12.10
Electrical conductivity (µS cm^{-1})	160.32±43.39	284.04±108.24
pH	7.40±0.41	6.81±0.17
Dissolved oxygen (mg L^{-1})	6.67±1.15	5.33±0.87
Carbonate alkalinity (mg L^{-1})	13.20±1.55	19.95±2.64
Bicarbonate alkalinity (mg L^{-1})	131.61±19.44	218.49±32.56
Chloride (mg L^{-1})	15.44±3.00	27.82±5.47
Nitrate nitrogen (mg L^{-1})	0.27±0.10	0.51±0.11
Phosphate phosphorus (mg L^{-1})	0.13±0.04	0.21±0.04
BOD_5 (mg L^{-1})	2.23±0.52	4.15±1.37

Table 2: List of benthic macroinvertebrates found in two lakes (*chaurs*).

	Macro-invertebrates	Tarawe *chaur*	Gamharia *chaur*
	Phylum : Annelida		
	Class : Oligochaeta		
	Family: Naididae		
1	*Branchiodrilus semperi* (Bourne, 1890)	-	+
	Family: Tubificidae		
2	*Limnodrillus hoffmeisteri* Claparède, 1862	+	+
3	*Branchiura sowerbyi* Beddard, 1892	-	+
	Class : Hirudinea (Leeches)		
	Family: Glossiphoniidae		
4	*Helobdella* Linnaeus 1758	+	-
	Family: Hirudinidae		
5	*Hirudo* Linnaeus, 1758	-	+
	Phylum : Arthropoda		
	Class : Insecta		
	Family: Chironomidae		
6	*Chironomus* sp	+	+
	Family: Ephemeridae		
7	Mayfly nymph	+	-
	Family: Lestidae		
8	Damselfly nymph	+	-
	Family: Gomphidae		
9	Dragonfly nymph	+	-
	Phylum : Mollusca		
	Class : Bivalvia (Pelecypoda)		
	Family: Unionidae		
10	*Lamellidens marginalis* (Lamarck, 1819)	+	-
11	*Parreysia (parreysia) favidens* (Benson, 1862)	+	+
12	*Parreysia corrugata* (Benson, 1862)	+	-
	Family: Corbiculidae		
13	*Corbicula bensoni* Deshayes, 1854	+	+
14	*Corbicula striatella* Deshayes, 1854	+	-
	Class : Gastropoda		
	Family: Viviparidae		
15	*Bellamya bengalensis f. typica* (Lamarck, 1822)	+	+
16	*Bellamya crassa* (Benson, 1836)	+	-
	Family: Ampulariidae		
17	*Pila globossa* (Swainson, 1822)	+	+
	Family: Bithyniidae		
18	*Bithynia (Digoniostoma) cerameopoma* (Benson, 1830)	-	+
19	*Bithynia (Digoniostoma) pulchella* (Benson, 1836)	+	-
	Family: Thiaridae		
20	*Thiara (Thiara) scabra* (O. F. Müller, 1774)	+	+
21	*Thiara (Tarebia) lineata* Gray, 1828	-	+
22	*Melanoides tuberculatus* (Müller, 1774)	+	+
	Family: Lymnaeidae		
23	*Lymnaea acuminata f. typica* Lamarck, 1822	+	+
24	*Lymnaea luteola f. ovalis* Gray, 1822	+	-
	Family Planorbidae		
25	*Gyraulus convexiusculus* (Hutton, 1849)	+	-
	Family Bullinidae		
26	*Indoplanorbis exustus* (Deshayes, 1834)	+	+
	Total Zoo benthos	21	15

Table 3: Variation in abundances of different macroinvertebrate groups (individual m^{-2}).

Macroinvertebrates	Tarawe chaur	Gamharia chaur
Oligochaeta	21 - 479	43 - 1017
Insecta	21 - 162	21- 96
Pelecypoda (Bivalvia)	43 - 346	21 - 65
Gastropoda	21 - 974	43 - 1796
Total benthic invertebrates	43 - 1580	43 - 2987

Table 4: Coefficient of similarity and dissimilarity values for benthic macroinvertebrates.

Benthic fauna	Co-efficient of Similarity (%)	Index of Dissimilarity (%)
Oligochaeta	50.00	50.00
Hirudienea	-	100.00

Insecta	40.00	60.00
Pelecypoda	57.14	42.86
Gastropoda	66.67	33.33
Net macroinvertebrates	55.56	44.44

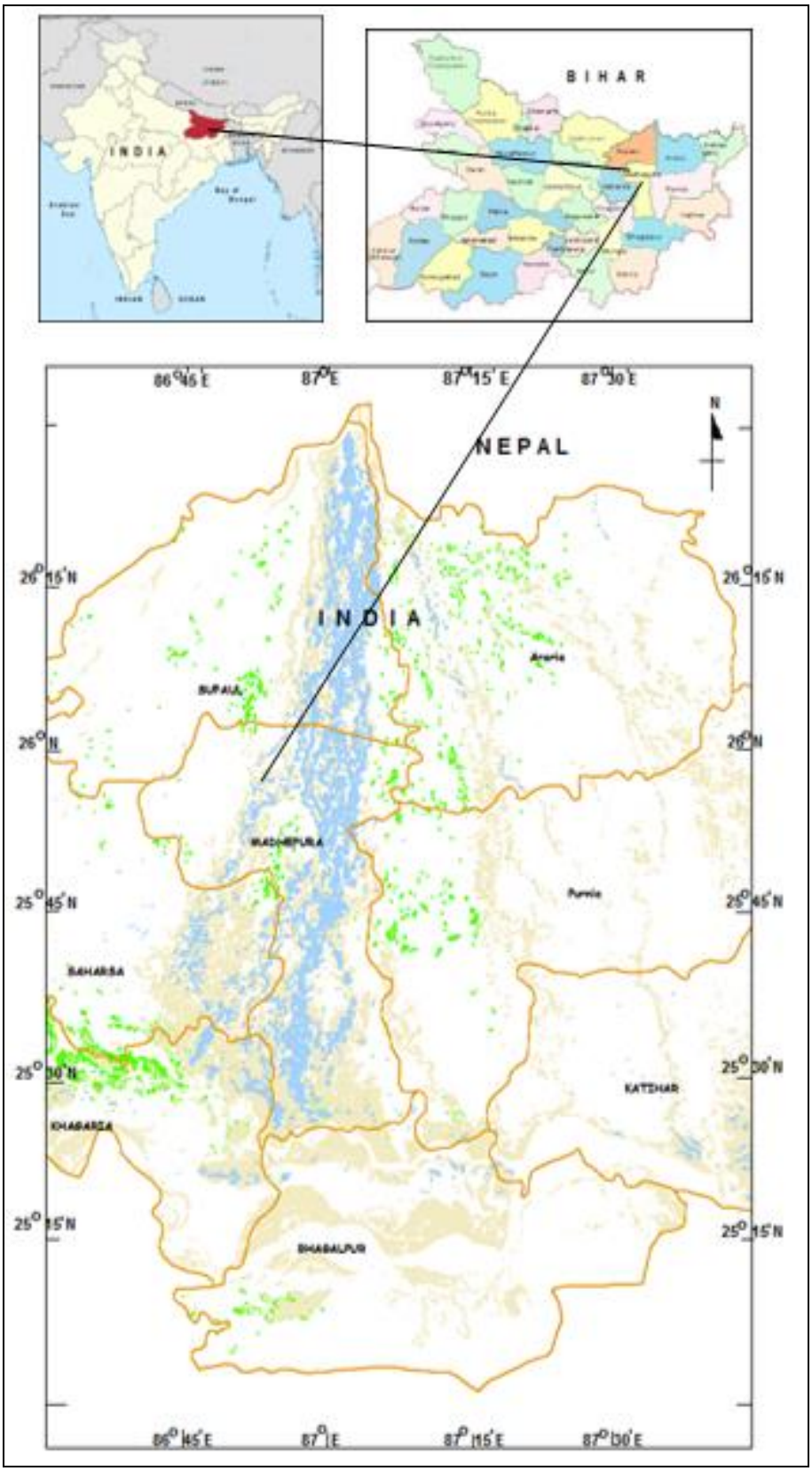

Fig 1: Flood inundation map showing Kosi basin ▭ of district Madhepura, North Bihar, India.

4. Conclusion

The study revealed that the lakes located on floodplains of same river support a rich biodiversity of macroinvetebrates. In total, 26 species belonging to 17 families and 17 genera were recorded in this study, mainly comprise of Oligochaeta, Hirudinea, Insecta, Pelecypoda and Gastropoda. However, their composition was different in clean-water environments at Tarawe *chaur* than in poor-water conditions at Gamharia

chaur. The most dominant group recorded was Gastropoda probably due to their facultative nature. Highest diversity and lowest population density of macro invertebrates indicate clean-water environments at Tarawe *chaur*, whereas the lowest diversity and highest density reflect poor-water conditions at Gamharia *chaur*. Factors, like sediment types and water quality influence population dynamics of Oligochaeta. Nymph was absent at Gamharia *chaur* probably due to poor-water quality. The similarity index data showed higher percentage of similarities reflecting more homogeneity between species in communities.

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6. References

1. Odum EP. Fundamentals of Ecology. 3rd Edn. WB Saunders Co., Philadelphia-London-Toronto, 1971, 574.
2. George ADI, Abowei JFN, Daka ER. Benthic macro invertebrate fauna and physico-chemical parameters in Okpoka Creek sediments, Niger Delta. International Journal of Animal and Veterinary Advances. 2009; 1(2):59-65.
3. Adeogun AO, Fafioye OO. Impact of effluents on water quality and benthic macro invertebrate fauna of Awba stream and reservoir. Journal of Applied Sciences Environmental Management. 2011; 15(1):105-113.
4. Hellawell JM. Biological indicators of freshwater pollution and environmental management. Elsevier Applied Science, London, 1986, 546.
5. Rosenberg DM, Resh VH. Introduction to freshwater biomonitoring and benthic macroinvertebrates In: Rosenberg DM, Resh VH (eds.) Freshwater biomonitoring and benthic macroinvertebrates. Chapman & Hall, New York. 1993,1-9.
6. Smith MJ, Kay WR, Edward DHD, Papas PJ, Richardson K St J, Simpson JC Pinder AM *et al*. Using macroinvertebrates to assess ecological condition of rivers in Western Australia. Freshwater Biology. 1999; 41(2):269-283.
7. Sharma KK, Langer S, Sharma R. Water quality and macrobenthic invertebrate fauna of Behlol Nullah, Jammu (J&K). The Ecoscan, 2011; 5(3, 4):111-115.
8. Parmar TK, Rawtani D, Agrawal YK. Bioindicators: the natural indicator of environmental pollution. Frontiers in Life Science, 2016; 9(2):110-118, DOI:10.1080/21553769.2016. 1162753.
9. Bonada N, Part N, Resh VH, Statzner B. Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. Ann. Rev. Entomol. 2006; 51:495-523.
10. Moreno P, Franca JS, Ferreira WR, Paz AD, Monteiro IM, Callisto M. Use of the BEAST model for biomonitoring water quality in a Neotropical basin. Hydrobiologia. 2009; 630:231-242.
11. Abida S, Mir MF, Ifshana S, Mir SA, Ahangar IA. Macrozoobenthic community as biological indicators of pollution in river Jhelum, Kashmir. Universal Journal of Environmental Research and Technology. 2012; 2(4):273-279.
12. Yadava YS, Kolikar V, Singh RK, Chaudhary M. Studies on the macrobenthic fauna of Dighili beel (Assam). Proc. Nat. Acad. Sci. 1984; 54:179-186.
13. Sundér S, Vass KK. Seasonal dynamics of benthos in some Kashmir lakes. Proceedings of the National Academy of Sciences, India, 1988; 58(1)B:193-203.
14. Sahu P, Sethy PGS, Siddiqi SZ. Distribution and abundance of benthic macrofauna in Nalaban Island, Chilika, Orissa. Indian Journal of Fisheries. 2007; 54(3):251-258.
15. Sharma C, Rawat JS. Montoring of aquatic macroinvertebrates as bioindicator for assessing the health of wetlands: A case study in the central Himalayas, India. Ecological Indicators. 2009; 9:118-128.
16. Sharma S, Joshi V, Kurde S, Singhvi MS. Biodiversity and abundance of benthic macroinvertebrates commiunity of Kishanpura Lake, Indore (M.P.) India. Researcher. 2010; 2(10):57-67.
17. Latha C, Thanga VSG. Macroinvertebrate diversity of Veli and Kadinamkulam lakes, South Kerala, India. Journal of Environmental Biology. 2010; 31:543-547.
18. Sharma RK, Agrawal N. Molluscan Fauna of Surha Tal, District-Ballia (U.P.), India. Journal of Applied and Natural Science. 2011; 3(2):295-297.
19. Sørensen T. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. K. Dans ka Videnskab Selsk. Biol. Skr., 1948; 5(4):1-34.
20. APHA. Standard methods for examination of water and waste water analysis. American Water Association and Water Pollution Centre Federation, Washington, D.C. 1985, 1268.
21. Trivedy RK, Goel PK. Chemical and biological methods for water pollution studies, Environmental Publication, Karad Maharastra, India, 1986, 247.
22. Pennak RW. Freshwater Invertebrates of the United States. Jhon Wiely & Sons Inc., New York, 1978, 626.
23. Adoni AD, Joshi G, Ghosh K, Chourasia SK, Vaishya AK, Yadav M *et al*. Work Book on Limnology. Pratibha Publishers, Sagar, India, 1985, 216.
24. Brinkhurst RO. Guide to the freshwater aquatic microdrile oligochaetes of North America. Can. Spec. Publ. Fish. Aquat. Sci. 1986; 84:259.
25. Suba Rao NV. Freshwater molluscus of India. Zooplankton Survey of India, Calcutta, 1989; xxiii+289.
26. Edmondson WT. Ward and Whipple's Fresh Water Biology, 2nd Edn. Johan Wily & Sons, New York, 1993.
27. Naidu KV. The Fauna of India and the Adjacent Countries-Aquatic Oligochaeta. Zool. Surv. India, Kolkata, 2005.
28. Soldner M, Stephen I, Ramos L, Angus R, Wells NC, Grosso A *et al*. Relationship between macroinvertebrate fauna and environmental variables in small streams of the Dominican Republic. Water Research. 2004; 38:863-874.
29. Gleason JE, Bortolotti JY, Rooney RC. Wetland microhabitats support distinct communities of aquatic macroinvertebrates. Journal of Freshwater Ecology. 2018; 33(1):73-82.
30. Takamura N, Ito T, Ueno R, Ohtaka A, Wakana I, Nakagawa M *et al*. Environmental gradients determining the distribution of benthic macroinvertebrates in Lake Takkobu, Kushiro wetland, northern Japan. Ecological Research. 2009; 24:371-381.

31. Manoharan S, Murugesan VK, Palaniswamy R. Numerical abundance of benthic macroinvertebrates in selected reservoirs of Tamil Nadu. Journal of Inland Fisheries Society of India. 2006; 38(1):54-59.
32. Hawkes HA. Invertebrates as indicators of river water quality. In: James A, Evison L. (eds.) Biological indicators of water quality. John Wiley & Sons, New York. 1979; 2:1-45.
33. Lang C. Quantitative relationship between oligochaete communities and phosphorus concentrations in lakes. Freshwater Biology. 1990; 24:327-334.
34. Lenat DR. A biotic index for the southeastern United States: derivation and list of tolerance values, with criteria for assigning water-quality ratings. Journal of the North American Benthological society. 1993; 12:279-290.
35. Callisto M, Moreno P, Goncalves JF, Leal JJF, Esteves FA. Diversity and biomass of Chironomidae (Diptera) larvae in an impacted coastal lagoon in Rio De Janeiro, Brazil. Brazilian Journal of Biology. 2002; 62(1):77-84.
36. Epler JH. Identification manual for the larval Chironomidae (Diptera) of North and South Carolina. Version 1.0, Crawfordwille, 2001, 53.
37. Clemente JM, Mazzeo N, Gorga J, Maerhoff M. Succession and collapse of macrozoobenthos in a subtropical hypertrophic lake under restoration (Lake Rodo, Uruguay). Aquat. Ecol., 2005; 39:455-464.
38. Mason CF. Biology of Freshwater Pollution, 4th Edn., Prentice Hall, London, 2002.
39. Mophin-Kani K, Murugesan AG. Assessment of river water quality using macroinvertebrate organisms as pollution indicators of Tamirabarani River basin, Tamil Nadu, India. International journal of environmental protection. 2014; 4(1):1-14.
40. Gaufin AR, Robert C, Robert N. Studies on the tolerance of aquatic insects to low oxygen concentrations. Great basin naturalist. 1974; 34(1):45-59.
41. Prommi T, Payakka A. Aquatic insect biodiversity and water quality parameters of streams in Northern Thailand. Sains Malaysiana. 2015; 44(5):707-717.
42. Barkia H, Barkia A, Yacoubi R, Guamri YE, Tahiri M, Kharrim KE *et al*. Distribution of fresh-water mollusks of the Gharb area (Morocco). Environments. 2014; 1:4-13.
43. Nesemann H, Sharma S, Sharma G, Sinha RK. Illustrated checklist of large freshwater bivalves of the Ganga river system (Mollusca: Bivalve: Solecurtidae: Unionidae: Amblemidae). Nach-richtenblatt der Ersten Vorarlberger Malakologischen Gesellschaft. 2005; 13:1-51.
44. Gordon ME, Layzer JB. Mussels (Bivalvia: Unionoidea) of the Cumberland River: review of life histories and ecological relationships. U.S. Fish Wild. Serv. Biol. Rep., 1989; 89(15):99.
45. Singh AK. Abundance of macrozoobenthic organisms in relation to physico-chemical characteristics of river Ganga at Patna (Bihar), India. J Environ. Biol. 1997; 18(2):103-110.
46. Ellis MM. Detection and measurement of stream pollution. In: LE Kuep *et al*. (eds.) Biology of Water Pollution, USDI, FWPCA, Cincinnati. 1937; 129-185.
47. Horne FR, McIntosh S. Factors influencing distribution of mussels in the Blanco River of Central Texas. Nautilus. 1979; 94:119-133.
48. Dudhani VK, Kumar S, Pandey S. Gastropods and indicators of the trophic status of some ponds in Darbhanga, North Bihar. Proceedings of the National Academy of Sciences, India. 1998; 58(4)B:489-493.
49. Mason WT, Anderson JB, Kreis RD, Johnson WC. Artificial substrate sampling, macro-invertebrates in a polluted reach of the Klamath River, Oregon. J. Wat. Pollut. Cont. Fed. 1970; 42:315-327.
50. Keddy PA. Wetland ecology: principles and conservation. 2nd edn. Cambridge University Press, Cambridge (UK), 2010.
51. Margalef R. Information theory in ecology. Journal of General Systems. 1958; 3:36-71.
52. Victor R, Dance KW, Hynes HBN. Drift of Ostracod crustaceans in adjacent intermittent and permanent streams. Hydrobiologia. 1981; 80:216-223.
53. Ahmad SH, Singh AK. A comparative study of the benthic fauna of lentic and lotic water bodies in and around Patna (Bihar) India. Journal of environmental biology. 1989; 10(3):283-291.
54. Batzer DP. The seemingly intractable ecological responses of invertebrates in North American wetlands: A review. Wetlands. 2013; 33:1-15.