International Journal of Innovations in Engineering and Technology (IJIET)
http://dx.doi.org/10.21172/ijiet.154.09

Distribution and Diversity of Macro Invertebrates of River Bodies at Arrah, Bihar: A Comparative Study

Sunita Kumari Sharma[1], Punita Kamari[2], Dina Nath Pandit[2]
[1]*PG Department of Zoology,*
Maharaja College, Arrah, India
[2]*Department of Zoology,*
VKS University, Arrah 802 301

Abstract- This paper reports a comparative study of distribution and diversity of macro invertebrates in Ganga River, Gangi River and Sone River at Arrah, Bihar. A total of 30744 individuals/m^2 of macro invertebrates of 37 taxa were collected from these water bodies from Jan 2017 to Dec 2018. Annelida with 8 taxa was the dominant group constituting 52.34 % followed by arthropoda with 17 of 35.84% and mollusca with 12 of 11.82%. The total number of macro-invertebrates showed significant increasing trend from summer to winter seasons. Significant temporal and spatial differences were also observed in abundance of macro invertebrates. Range of Shannon-Weiner index (1.74-2.52), Simpson reciprocal index (4.39-9.63), Pielou evenness index (0.72-0.87), Berger-Parker index (0.20-0.43) and Margalef richness index (0.77-2.09) indicate moderately polluted nature of these water bodies. This indication was confirmed with the abundance of *Tubifex, Chironomous* and *Lamellidens*. The work suggests that the macro invertebrates of these water bodies face stress due to different factors.

Key words: Macro invertebrates, River bodies, Biodiversity indices, Arrah.

I. INTRODUCTION

Macro-invertebrates are good indicators of long-term environmental change due to their restricted range and persistence over time [1]. Aquatic macro-invertebrates are useful bio-indicators of changing aquatic conditions and micro biological variables [2]. In riverine ecosystems, they show a patchy distribution varying largely in time and space [3].

Biodiversity provides the basis for life on earth. A diversity index is a mathematical measure of generic/species diversity in a community. In a particular ecosystem, it is divisible into α diversity constituting diversity of genus/species within sites and β diversity measuring the increase in diversity along transects and is particularly applicable to the study of environmental gradients [4].

Investigation on different aspects of macro invertebrate resources has been reported within the country and abroad but few in Bihar [5-8]. But, information of distribution and biodiversity indices of macro-invertebrates of Arrah is lacking.

Therefore, an attempt has been made to study distribution and biodiversity of macro-invertebrates of river bodies at Arrah. The results may be used as an effective contribution to holistic studies in the riverine management.

II. MATERIALS AND METHODS

Arrah is the district headquarter of Bhojpur having coordinates: 25°33′27″N 84°40′12″E /25.55750°N 84.67000°E. The district encompasses rivers running almost three sides-North, East and some part of Southern boundary.

Samples were collected fortnightly between 10.00am to 2.00pm from Jan 2017 to Dec 2018 during winter (Nov to Feb), summer (Mar to Jun) and rainy (Jul to Oct) season from Ganga River, Gangi River and Sone River by sweeping 500-µm mesh D-shaped net. The samples were transferred to enamel buckets and sieved with the help of water through sieve no. 40 which retained macro-organisms. These samples were brought to the Departmental Laboratory and preserved in 10% formalin for making a detailed analysis. The animals were sorted out into different taxonomic groups and identified up to lowest possible taxon under low powered stereo binocular microscopes and identified by standard methods [9-10].

The abundance of these organisms was calculated as number per square meter by applying the following formula [11]:

$N = \frac{O}{AS}$ x 10,000. Where, N = No. of individuals/m^2, O = No. of individuals collected, A = Biting area of sampler and S = No. of samples taken.

Following diversity indices were calculated:

I. Shannon Wiener index [12]: $H' = \Sigma(p_i)(\ln \times p_i)$ Where H'=Shannon index of general/species diversity, p_i= total number of individuals, ln=loge=log10×2.303.

II. Simpson index [13]: It includes A. Simpson dominance index (D): $D = \Sigma(pi/N)^2$ Where, N=total number of organisms. B. Simpson diversity index (1-D) and C. Simpson reciprocal index ($\frac{1}{D}$) and D. Gini–Simpson coefficient is known as the probability of inter-specific encounter (PIE).

III. Menhinick richness index (D_{Mn}): $D_{Mn} = \frac{S}{\sqrt{N}}$. Where S = the number of genera/species recorded.

IV. Margalef richness index (M_d) [14]: $M_d = \frac{S-1}{\ln N}$.

V. Pielou evenness (=equitability) index (J) [15]: $J = \frac{H}{H_{max}}$.

VI. Berger-Parker index: $d = \frac{N_{max}}{N}$ or max (p_i). Where N_{max} = number of individuals in the most abundant genus/species.

VII. Reciprocal Berger-Parker Index: 1/d.

Two-way ANOVA was applied to test whether any significant difference occur among the water body and macro benthic invertebrates.

III. RESULTS AND DISCUSSION

The macro invertebrates were analyzed for distribution, diversity, richness, dominance and evenness. The analysis showed the abundance of 3 genera of annelids, 6 of arthropods from crustacea, Ephemeroptera, Diptera and Coleoptera and 3 of molluscs from class gastropoda and pelecypoda (Table 1). In previous studies, Khan[16] observed abundance of 1 taxon of annelids (*Limnodrillus)*, 4 of arthropoda (*Chironomus, Limnogonus, Culex and Anophele*) and mollusca (*Bellamya, Digoniostoma, Lymnaea* and *Gyraulus*) in water bodies of southern Kolkata. Sharma *et al.* [17] reported 3 taxa of annelids (*Tubifex, Branchiura*, *Dero)*, 8 of arthropoda (*Chironomus, Pentaneura*, *Culicodes*, *Tabanus, Berosus*, *Paracymus*, *Hydroglyphus and Canthydrus*) and 3 of mollusca (*Melanoides*, *Physa* and *Gyraulus*) at Datte-da-Pond, Birpur, J&K. *Chironomous* showed a correlation between previous results while of *Tubifex* and *Chironomous* [16-17].

Maximum abundance of macro invertebrates of 14719 individuals/m^2 was recorded from Gangi River followed by 9667individuals/m^2 from Sone River and 6358 individuals/m^2 from Ganga River, Arrah. Sharma *et al.* [17] found maximum abundance of macro invertebrates was 11558 individuals/m^2 recorded in station II followed by 10958, 7712 and 8189 individuals/m^2 in station IV, III and I at Datte Da Talab, Birpur, J&K. The observation proved a resemblance between earlier findings [17].

A total of 37 macro invertebrates belonging to 17 of arthropods, 12 of molluscs and 8 of annelids were recorded in this observation. The taxa of crustaceans were maximum (10) in number followed by equal share of 7 by oligochaetes, insects and gastropods (Table 1). Khan [16] reported 29 taxa of arthropods followed by 8 of molluscs and 5 of annelids in some lakes and ponds of southern Kolkata. Fourteen taxa belonging to annelida (3), arthropoda (8) and mollusca (3) were identified by Sharma *et al.* [17] in Datte-da-Pond, Birpur, J&K. The present work showed similarity with the earlier results [16-17]. The difference may be due to nature of water bodies and distance covered in the study.

Individuals of annelida with 8 taxa were the dominant group constituting 52.34 %, followed by arthropoda with 17 of 35.84% and mollusca with 12 of 11.82%. Arthropoda (70.54%) dominance followed by annelida (28.11%) and mollusca (0.95%) was observed by Sharma and Chowdhary [18] at river Tawi, Jammu. While, Sharma *et al.* [17] observed arthropoda as the dominant group (43.19%) followed by mollusca (38.55%) and annelida (18.26%) in Datte-da-Pond, Birpur, J&K.

Annelids represented by Oligochaeta and Hirudenea showed a significant increasing trend from summer to winter season with numerical abundance of *Tubifex* (4800 individuals/m^2) (Table 2). Thus, *Tubifex* dominated the total number of annelids (16090 individuals/m^2). Sharma and Chowdhary [18] also observed a peak of annelids during June due to abundance of *Tubifex* in comparison to total number of annelids. Among annelids, *Tubifex* was the dominant genus representing 29.83% of the total annelids followed by *Pheretima* and *Pristina* shared 25.59% and 16.74% along with the least share of 0.94% by *Helobella*. Numerical abundance of *Tubifex* is favoured by the organic environment and remains dominant in severally polluted conditions. However, presence of good organic detritus content to contribute the maximum quantity of Oligochaetes has been observed earlier [17, 19]. *Tubifex* has ability to tolerate low oxygen conditions, presence of heavy metals and other environmental conditions.

Arthropods showed a significant spike from summer to winter season in Gangi River. Insects contributed by order Coleoptera, Diptera, Ephemeroptera and Lepidoptera (Table 2). Maximum number of arthropods was observed

during rainy season in Ganga River and Sone River but during winter season in Gangi River, Ara. Sharma and Chowdhary [18] observed a peak of Arthropods during December and reported that insects contributed by order Diptera, Odonata, Ephemeroptera and Hemiptera at river Tawi, Jammu. Among arthropods, *Chironomous* was the dominant and contributed 25.29% to the total arthropods followed by Mayfly, Dragon fly and minimum by *Diaptomonas* with respective share of 15.36%, 10.59% and 1.05%. Numerical abundance of *Chironomous* indicates the pollution status of the river as chironomids are the common inhabitants of polluted waters [17, 18].

Molluscs were represented by Gastropoda and Pelecypoda also showed a significant increase from rainy to winter season (Table 2). Sharma and Chowdhary [18] observed that Phylum Mollusca was represented by Gastropoda and showed its peak during January which due to the presence of *Physa*. In case of molluscs, *Lamellidens* was the dominant to contribute 40.11% followed by 12.32% of *Corbicula,* 6.55% of *Pisidium* and minimum of 3.08% by *Thiara*. Abundance of *Lamellidens* indicates water pollution [20].The peak of molluscan density during winter season may be due to soft and organically rich bottom, alkaline nature of water as has been reported by earlier workers [21].

Application of two-way ANOVA concludes that spatial and temporal variation in these water bodies has significant effect on the abundance of macro invertebrates. At the same time, a significant effect occurs in the different replicates of macro invertebrates with regards to the water bodies. The effect of spatial variation was observed more in comparison to temporal variation in these water bodies (Table 2). Pronounced seasonal and temporal variations in the density of macro invertebrates in the lake and pond of southern Kolkata have earlier been reported [16].

Biodiversity represents the variety and heterogeneity at all levels of the hierarchy of life. During this work, following diversity indices were calculated and concerned consequences were explained.

(1) The Shannon-Weiner index (H' = 2.07; range: 1.74-2.52), Simpson reciprocal index ($\frac{1}{D}$ = 6.3; range: 4.39-9.63), Pielou evenness index (J = 0.84; range: 0.72-0.87) and Berger-Parker Index (d = 0.34; range: 0.20-0.43) was higher at Gangi River (Table 3). The hierarchical order of these indices is:

Gangi River > Ganga River > Sone River

Mackey et al. [22] reported that H' ranged from 1.3 to 2.5 from 50 polluted streams in their study. H' from Aba and Azumini River, Nigeria was calculated 2.56 and 1.50 by Obasi *et al.* (2013)[23]. After a study of Barak Valley of Cachar, Assam, Das [24] reported that the index ranged from 0.713 to 1.011. Wilhm and Dorris [25] proposed that value of H' <1.0 indicate heavy pollution, from 1.0 to 3.0 moderate pollution and >3.0 non-polluted water. Therefore, present observation showed moderately polluted water.

(2) The Simpson reciprocal index starts with 1 for only one genus/species. Its value increases with diversity and is influenced the equitability of percent of each genus present and richness. For a given generic richness, D will decrease as the percent of the genus becomes more equitable. The value of 4.39 to 9.63 of index shows conformity with the number of genera (8 to 17) observed of different phyla in this study.

(3) The Simpson diversity index (1-D = 0.20; range: 0.11-0.23), Gini Simpson coefficient (0.52; range: 0.38-0.66) and Reciprocal Berger-Parker Index ($\frac{1}{d}$ = 3.55; range: 2.31-4.98) was higher at Sone River (table: 3). The hierarchical order of these indices is:

Sone River > Ganga River > Gangi River

The Simpson diversity index also ranges from 0 to 1. Sharma and Chowdhary [18] calculated its value 0 to 0.102 in central Himalayan River, Tawi, J&K. A range of 0.31-0.52 of this index at a site of Datte-da-Pond, Birpur, J&K was calculated by Sharma *et al.* [17]. The value of 0.11 to 0.23 observed in this work showed similarities and indicates least diversity.

(4) Pielou evenness index (J) is a function of some diversity measure and number of individuals in a sample of collection. It permits considerable refinement in diversity studies. Sharma and Chowdhary [18] calculated its value 0 to 1.035 in central Himalayan River, Tawi, J&K. This index for Aba and Azumini River, Nigeria was calculated 0.15 and 0.79 by Obasi *et al.* [23]. The value of 0.72 to 0.87 of this index observed in this work showed similarities with earlier reports.

(5) Berger-Parker Index has an analytical relationship with generic/species abundance model. If the index is high, community is uneven and dominated by the most common species. The index significantly changes between undisturbed and disturbed ecosystems reaching the highest values in areas with strong physical disturbance. A range of 0.20 to 0.43 of Berger-Parker Index in this study indicates evenness of genera.

Reciprocal Berger-Parker Index is often used so that an increase in the value of the index accompanied an increase in diversity and a reduction in dominance. The value of 2.31 to 4.98 of this index observed in this work indicates an increase in diversity and a reduction in dominance.

(6) The Simpson dominance (D) and Menhinick index (D_{Mn}) ranged between 0.77 to 0.89 and 0.09 to 0.40 with a respective higher value of 0.82 and 0.29 were in the following order at different rivers (Table 3):

Ganga River > Gangi River > Sone River

Simpson dominance index (D) is more common in use. The value of D ranges from 0 to 1. 0 represents numerous genera/species and infinite diversity and 1 for no diversity. Its value of 0.6 to 0.9 shows mature communities. Sharma and Chowdhary [18] calculated its value 0 to 0.898 in central Himalayan River, Tawi, J&K. A range of 0.48 to 0.69 of this index at a site of Datte-da-Pond, Birpur, J&K was calculated by Sharma *et al.* [17]. Davari *et al.* [5] reported this index 0.837 and 0.847 at adjacent areas of Ramesar. The value of 0.77 to 0.89 of this index observed in this work showed similarities and indicates least diversity [17-18].

The D_{Mn} is used for comparison of samples of different sizes and that the effect of number if individuals are reduced. A range of 0.105-0.133 of this index at a site of Datte-da-Pond, Birpur, J&K was calculated by Sharma *et al.* [17]. Davari [5] reported this index 0.870 and 0.942 at Ramesar. A range of 0.09 to 0.40 of this work showed resemblance with the earlier works [17].

The value of Margalef richness index (M_d) ranged between 0.77-2.09 was in the following order at different rivers (Table 3):

Ganga River > Sone River> Gangi River

With special reference to M_d, its value <1 indicates heavy pollution, from 1 to 3 moderately polluted conditions and >3 no pollution [26]. Sharma and Chowdhary [18] calculated its value 0 to 1.326 in central Himalayan River, Tawi, J&K. A range of 1.08 to 1.22 of this index at a site of Datte-da-Pond, Birpur, J&K was calculated [17]. Davari *et al.* [5] calculated this index 2.21 and 2.23 at riparian and adjacent areas of Ramesar. The value of 0.77 to 2.09 of this index observed in this work also infers moderately polluted condition of the water bodies and show similarities with these reports.

IV. CONCLUSION

The observations report that these water bodies have (a) communities with moderate diversity, (b) macro-benthic invertebrates under stress due to natural and/or anthropogenic factors as well as (c) moderately polluted water. Therefore, it may be suggested that a good management programme for these water bodies are important as their social-economic values are numerous and of high importance to people.

REFERENCES

[1] N. Khudhair N, C. Yan, M, Liu, and H. Yu, "Effects of Habitat Types on Macroinvertebrates Assemblages Structure: Case Study of Sun Island Bund Wetland". BioMed Research International. 2019. https://doi.org/10.1155/2019/2650678.

[2] R. Alther, C. Thompson, B. Lods-Crozet, and C.T. Robinson, "Macroinvertebrate diversity and rarity in non-glacial Alpine streams". Aquatic Sciences. 81,42. 2019.

[3] J.S.D. Munshi, G.N. Singh, and D.K. Singh, "Ecology of Freshwater Polychaetes of River Ganga". J. Freshwater Biol. 1,103–108. 1989.

[4] S.S. Costa, and A.S. Melo, "Beta diversity in stream macroinvertebrate assemblages: among-site and among microhabitat components". Hydrobiol. 598, 131-138. 2008.

[5] N. Davari, M.H. Jouri, and Ah. Ariapour, "Comparison of Measurement Indices of Diversity, Richness, Dominance and Evenness in Rangeland Ecosystem (Case Study: Jvaherdeh -Ramesar)". J. Rangeland Sci. 2, 389-398. 2011.

[6] S. Dutta, S. Balapure, and V. Vyas, "Observation on benthic macro-invertebrate richness of Shahpura Lake of Bhopal, Central India". Abs. Internat. Confer. Environ Eco. Kol. 30. 2015.

[7] A. Roy, and S. Homechaudhary, "Comparing diversity of freshwater macro invertebrate community along habitat gradients within a riverine system in North Bengal, India". J. Entomo. Zoo. Studies. 5(4), 86-93. 2017.

[8] R. Kumar, H. Nesemann, and G. Sharma, "Community structure of macro benthic invertebrates in the River Ganga in Bihar, India". Aq. Ecosys. Health Manage. 16, 385–394. 2013.

[9] J.G. Needham, and P.R. Needham, "*A Guide to the Study of Freshwater Biology",* Holden Day Institute, San Francisco. 1970.

[10] A.P.H.A., *Standard methods for examination of water and wastewater.* 21st Edn. APHA, AWWA, WPCF, Washington DC, USA. 2005.

[11] P.S. Welch, "*Limnology".* 2nd Ed. McGraw Hill Book Co. Inc. New York. 1948.

[12] C.E. Shannon, and W. Weiner, "*The Mathematical Theory of Communication". Univ.* Illinois Press, Urbana, IL. 1949.

[13] E.H. Simpson, "Measurement of diversity". Nature. 163p. 688. 1949.

[14] R. Margalef, "*Perspective in Ecological Theory".* Univ. Chicago Press, Chicago, USA, p122. 1958.

[15] E.C..Pielou, "*Ecological diversity".* John Wiley, New York. p165. 1975.

[16] R.A. Khan, "Diversity of Freshwater Macro-Invertebrate Communities Associated With Macrophytes". Rec. Zoo. Sur. India. 100(1-2), 211-228. 2002.

[17] K.K. Sharma, N. Anta, and S. Kour, "Biodiversity and Abundance of Benthic Macro Invertebrates Community 0f Datte-Da-Talab Pond, Birpur (J&K) India'. Internat. Multidisciple. Res. *J.* 3(1), 13-17. 2013.

[18] K.K. Sharma, and S. Chowdhary, "Macroinvertebrate assemblages as biological indicators of pollution in a Central Himalayan River, Tawi (J&K)". Internat. J. Biodivers. Conserv. 3(5), 167-174. 2011.

[19] D. Chakraborty, and S.K. Das, "Alteration of macro invertebrate community in tropical aquatic systems in relation to sediment redox potential and overlaying water quality". Internat. J. Environ. Sci. Tech. 2(4), 327-334. 2006.

[20] P.S. Hamid, and A.I.M. Raj "Freshwater Mussel, *Lamellidens marginalis* (Lamarck) (Mollusca: Bivalvia: Unionidae) as an Indicator of River Pollution". Chem. Eco. 4, 57-64. 1990.

[21] R.K. Garg, R.J. Rao, and D.N. Saksena, "Correlation of molluscan Diversity with physic-chemical characteristics of water of Ramsagar reservoir, India". Internat. J. Biodivers. Conserv. 1(6), 202-207. 2009.

[22] D.W. Mackey, P.G. Sulbsy, and T. Poodie, "*The Biological Assessment of Pollution in Stream, Association of the River Authorities".* Year Book and Directory, London. pp. 188-197. 1973.
[23] K.O. Obasi, N.D. Ijere, and R.I. Okechukwu, "Species Diversity and Equitability Indices of Some Fresh Water Species in Aba River and Azumini Blue River, Abia State Nigeria". Internat. J. Sci. Tech. 2(3), 238-242. 2013.
[24] K. Das K. "Hemipteran Diversity and Water Quality Parameters of three Diverse Aquatic Systems of Cachar District, Barak Valley, Assam". *Biodivers. Environ*. 95-102. 2015.
[25] R.L. Wilhm and T.C. Dorris, "The biological parameters for water quality criteria". BioSci. 18, 477-492. 1996.
[26] D.R. Lenat, L.A. Smock, and D.L. Penrose, "*Biological Monitoring for environmental effects".* In: Douglass, LW(Ed). pp. 97-114. 1980.

Table-1 Distribution (individuals/m^2) of macro invertebrates at Ganga River, Gangi River and Sone River, Ara.

Sl. No.	Phylum/Class/Genus	Ganga River			Total	Gangi River			Total	Sone River			Total	Grand Total
		Winter	Summer	Rainy		Winter	Summer	Rainy		Winter	Summer	Rainy		
	Phylum-Annelida													
1.	Class-Oligochaeta *Chaetogaster*	58	15	0	73	144	37	0	181	135	19	08	162	416
2.	*Dero*	111	43	55	209	276	107	133	516	195	52	118	365	1090
3.	*Tubifex*	371	228	371	970	899	573	926	2398	683	238	511	1432	4800
4.	*Limnodrilus*	94	165	63	322	240	409	156	805	152	178	95	425	1552
5.	*Nais*	129	35	92	256	326	66	223	615	214	40	146	400	1271
6.	*Pheretima*	338	99	398	835	845	249	981	2075	551	106	550	1207	4117
7.	*Pristina*	159	223	157	530	420	575	384	1379	294	242	239	775	2693
1.	Class-Hirudinea *Helobella*	08	13	11	32	20	35	30	85	11	13	10	34	151
	Total	1268	821	1147	3236	3170	2051	2833	8054	2235	888	1677	1800	16090
	Phylum-Arthropoda													
1.	*Class-Crustacea Daphnia*	07	05	02	14	55	40	11	106	07	05	02	14	134
2.	*Ceriodaphnia*	14	18	03	35	119	133	21	273	11	14	02	27	335
3.	*Chydonus*	10	06	01	17	85	45	08	138	08	04	01	13	168
4.	*Alonella*	07	05	01	13	51	35	07	93	05	04	01	10	116
5.	*Diaptomonas*	18	10	08	36	150	68	61	279	14	07	01	22	337
6.	*Cyclops*	08	05	01	14	59	34	08	101	06	04	01	11	126
7.	*Nauplius*	72	18	21	111	608	145	172	925	49	11	01	61	1097
8.	*Macrobranchium*	24	05	15	44	202	45	79	326	18	03	09	30	400
9.	*Cardina*	08	08	01	17	66	69	08	143	06	05	01	12	172
10.	*Argulus*	20	0	17	37	181	0	5	186	18	0	18	36	259
1.	Class-Insecta Mayfly	128	15	232	375	244	27	425	696	214	25	383	622	1693
2.	Dragonfly nymph	86	08	160	254	170	14	308	492	142	13	266	421	1167
3.	Damselfly nymph	50	05	86	141	96	19	159	274	82	09	143	234	649
4.	Hydrophyllidae	74	17	41	132	139	31	72	242	122	27	66	215	589
5.	Mosquito larvae	65	16	27	108	118	30	51	199	106	32	142	280	587
6.	*Chironomous*	192	203	224	619	359	390	414	1163	312	338	355	1005	2767
7.	*Nymphulla*	49	04	38	91	91	09	62	162	81	06	63	150	403
	Total	832	348	878	2058	2793	1134	1871	5798	1201	507	1455	3163	11019
	Phylum-Mollusca													
1.	Class-Gastropoda *Lymnaea*	35	07	10	52	17	05	06	28	34	08	11	53	133
2.	*Brotia*	38	13	16	67	19	08	09	36	37	19	16	72	175
3.	*Bellamya*	33	33	26	92	16	14	13	43	36	34	30	100	235
4.	*Gyraulus*	19	25	18	62	09	12	09	30	20	29	18	67	159
5.	*Indoplanarbis*	33	35	16	84	14	18	10	42	34	38	17	89	215
6.	*Vivipara*	56	29	01	86	29	14	01	44	59	31	01	91	221
7.	*Thiara*	04	24	22	50	03	12	12	27	04	28	23	55	112
1.	Class-Pelecypoda *Corbicula*	45	25	37	107	52	29	44	125	91	50	75	216	448
2.	*Lamellidens*	107	109	139	355	118	122	135	375	217	227	284	728	1458
3.	*Parreysia*	13	27	08	48	15	31	04	50	28	54	17	99	197
4.	*Pisidium*	17	26	12	55	19	29	13	61	38	56	28	122	238
5.	*Monia*	02	04	0	6	02	04	0	6	04	08	0	12	24

	Total	402	357	305	1064	313	298	256	867	602	582	520	1704	3635
	Grand Total	2502	1526	2330	6358	6276	3483	4960	14719	4038	1977	3652	9667	30744

Table-2 Two-way ANOVA showing spatial and temporal variation of macro invertebrates.

	Spatial Variation						Temporal Variation					
	Winter season	Taxa	Summer season	Taxa	Rainy season	Taxa	Ganga River	Taxa	Gangi River	Taxa	Sone River	Taxa
Annelida	** (11.47) $n_1 = 2$, $n_2=14$	*** (30.82) $n_1 = 7$, $n_2=14$	** (8.941) $n_1 = 2$, $n_2=14$	** (5.727) $n_1 = 7$, $n_2=14$	* (5.260) $n_1 = 2$, $n_2=14$	*** (11.33) $n_1 = 7$, $n_2=14$	* (4.325) $n_1 = 2$, $n_2=14$	* (4.582) $n_1 = 7$, $n_2=14$	* (5.367) $n_1 = 2$, $n_2=14$	** (5.441) $n_1 = 7$, $n_2=14$	NS (3.241) $n_1 = 2$, $n_2=14$	* (3.672) $n_1 = 7$, $n_2=14$
Arthropoda	** (8.663) $n_1 = 2$, $n_2=32$	* (2.132) $n_1 = 16$, $n_2=32$	*** (14.13) $n_1 = 2$, $n_2=32$	*** (17.99) $n_1 = 16$, $n_2=32$	* (3.707) $n_1 = 2$, $n_2=32$	*** (25.70) $n_1 = 16$, $n_2=32$	NS (2.214) $n_1 = 2$, $n_2=32$	** (3.19) $n_1 = 16$, $n_2=32$	NS (2.312) $n_1 = 2$, $n_2=32$	* (2.494) $n_1 = 16$, $n_2=32$	* (3.232) $n_1 = 2$, $n_2=32$	*** (4.830) $n_1 = 16$, $n_2=32$
Mollusca	*** (10.44) $n_1 = 2$, $n_2=22$	*** (11.92) $n_1 = 11$, $n_2=22$	** (9.500) $n_1 = 2$, $n_2=22$	*** (11.53) $n_1 = 11$, $n_2=22$	* (3.479) $n_1 = 2$, $n_2=22$	*** (18.012) $n_1 = 11$, $n_2=22$	* (5.231) $n_1 = 2$, $n_2=22$	*** (16.41) $n_1 = 11$, $n_2=22$	* (4.986) $n_1 = 2$, $n_2=22$	*** (34.81) $n_1 = 11$, $n_2=22$	* (5.164) $n_1 = 2$, $n_2=22$	*** (27.74) $n_1 = 11$, $n_2=22$

(*=Not significant, *=Significant, **=Moderately significant, ***=Highly significant)

Table-3 Values of various diversity indices of macro invertebrates at Ganga River, Gangi River and Sone River, Ara

Diversity Indices	Annelids			Arthropoda			Mollusca			Average			Average		
	Ganga River	Gangi River	Sone River	Ganga River	Gangi River	Sone River	Ganga River	Gangi River	Sone River	Annelida	Arthropoda	Mollusca	Ganga River	Gangi River	Sone River
1. Shannon-Wiener Index	1.74	1.74	1.76	2.21	2.52	2.04	2.17	1.94	1.97	1.75	2.26	2.03	2.04	2.07	1.92
2. Simpson Dominance Index	0.79	0.79	0.80	0.84	0.89	0.82	0.84	0.77	0.78	0.79	0.85	0.80	0.82	0.82	0.80
3. Simpson Diversity Index	0.21	0.21	0.20	0.16	0.11	0.18	0.16	0.23	0.22	0.21	0.15	0.21	0.18	0.18	0.20
4. Simpson Reciprocal Index	4.88	4.88	5.00	6.39	9.63	5.62	6.35	4.39	4.52	4.92	7.21	5.09	5.87	6.30	5.05
5. Gini-Simpson Coefficient	0.44	0.44	0.42	0.59	0.42	0.66	0.38	0.50	0.49	0.43	0.57	0.46	0.47	0.45	0.52
6. Pileos's evenness	0.84	0.84	0.85	0.78	0.89	0.72	0.87	0.78	0.79	0.84	0.80	0.82	0.83	0.84	0.77

Index															
7. Menhinick Index	0.14	0.09	0.11	0.37	0.22	0.30	0.36	0.40	0.29	0.12	0.26	0.35	0.29	0.24	0.23
8. Margalef Richness Index	0.86	0.77	0.82	2.09	1.84	1.98	1.57	1.62	1.47	0.82	1.93	1.57	1.51	1.41	1.42
9. Berger Parker Index	0.29	0.29	0.29	0.30	0.20	0.31	0.33	0.43	0.42	0.29	0.27	0.39	0.31	0.34	0.33
10. Berger Parker Reciprocal Index	3.34	3.35	3.35	3.32	4.98	3.14	2.99	2.31	2.34	3.35	3.81	2.54	3.22	3.35	2.94