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SPATIO-TEMPORAL VARIATIONS OF MACRO-INVERTEBRATES IN RIFFLES AND POOLS OF MARDI AND VIJAYPUR STREAMS POKHARA, NEPAL

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ABSTRACT

Present paper deals with the spatio-temporal variations in diversity and density of macro invertebrates in riffles and pools of the Mardi and the Vijayapur streams, Pokhara, Nepal. It was the pioneering work to study the biotic assemblage. Altogether 47 genera (32 from the riffles and 34 from the pools) belonging to 38 families and 12 orders were recorded during the study period. The taxa richness was higher (38 genera) in the Mardi stream than in the Vijayapur stream (30 genera). Total density at both sites observed major peak and down fall in the spring and summer seasons, respectively. The average total density during the spring peak was higher (967.42 m^{-2} in riffle and 652.10 m^{-2} in pool) at Site 1 (Mardi stream) than at Site 2 (Vijaypur stream) (541.02 m^{-2} in riffle and 537.43 in pool). This peak was mainly contributed by the order ephemeroptera. Ephemeroptera, diptera and trichoptera were found predominant orders comprising 11, 8 and 8 genera, respectively. Heptagenidae, baetidae and leptophlebidae; chironomidae, ceratopogonidae and tipulidae, and hydropsychidae, psychomyidae and polycentropodidae were dominant families among ephemeroptera, diptera and trichoptera respectively. The dominant genera were, *Heptagenia* Walsh, *Rhithrogena* Eaton and *Baetis* Leach; *Tendipes* Meigen, *Culicoides* Latreille and *Simulium* Hagen; *Hydropsyche* Pictet and *Psychomyia* Pictet; *Psephenus* Haldeman and *Heterlimnius* Hinton; *Octogomphus* Selys and *Argia* Rambur and *Planaria* Girard among ephemeroptera, diptera, trichoptera, plecoptera, coleoptera, odonata and tricladida, respectively. The lower taxa richness at Site 2 having urban influence reflects the perturbation of stream environment due to urbanization, industrialization and application of inorganic fertilizers and pesticides in the agricultural lands, which needs regular ecological monitoring and measures to control further deterioration.

Key words: Macro-invertebrates, stream biodiversity, density, spatio-temporal variations, Pokhara, Nepal.

INTRODUCTION

The invertebrates living on, in or near the bottom of the water body and playing a vital role in the aquatic ecosystem are macro-invertebrates or macro-zoobenthos. Several aquatic biologists have mentioned that many aquatic insects were evolved in cool lotic water-bodies prior to spreading to warmer riverine and lacustrine environments (Hynes 1970, Ward 1992, Wetzel 2001). Some of these biota form the food of fishes, while others are predators on young fishes and other aquatic organisms. Many investigators have focused their attention on the role of these bottom dwelling invertebrates as fish food, which are the most diverse fauna of running waters (Mohan and Bisht 1991, Allan 1995), some worked on their abundance for measuring diversity indices as biomonitors and indicators of water quality and environmental conditions of lotic waterbodies (Norris and Norris 1995, Dudgeon 1995), some others incorporated them into general methods of structure and function of stream ecosystem (Fisher and Likens 1973, Cummins and Meritt 1996) and recent works on riverine macro-invertebrates assemblage have concentrated on variations in population and community dynamics and secondary production in response to environmental variables (Minshall *et al.* 1985, Cummins 1992, Sharma *et al.* 2004).

Studies on aquatic macro-invertebrate fauna have been performed by several biologists (Das 1971, Walsh *et al.* 2001). Some works in this field have been conducted in Nepalese waterbodies (Sharma 1975, Yadav and Rajbhandari 1982, Vaidya *et al.* 1988, Ormerod *et al.* 1994, Brewin *et al.* 2000, Sharma *et al.* 2006, Pokharel 2011). However, those of the Mardi stream and Vijaypur stream in Pokhara valley have not been performed thoroughly. The Mardi, a snow-fed high altitude stream having origin at the base of Mardi Himal in Annapurna Himalayan range and the Vijaypur, a spring-fed mid-hill stream having origin at the base of Mahabharat hills towards the north-eastern side of Pokhara valley, Nepal represent typical Himalayan lotic ecosystem with unique physio-hydrological features such as, high velocity, low to moderate temperature, unstable stream-bed substrata, etc. Considering the role of macro-invertebrates in aquatic ecosystem and lack of literature, present work aims to study their spatio-temporal variations in the Mardi and the Vijaypur streams, Pokhara, Nepal.

STUDY AREA

Pokhara is situated in centro-western Nepal Himalaya, and has many fascinating water resources-river, streams, creeks, lakes, ponds, etc. It covers an area of about 200 sq km extending between 25°07' and 28°10' N latitude and 83°50' and 84°50' E longitude and lies 800 m asl (Tripathi 1984-85). The lotic waterbodies running through the valley are the Seti Gandaki river and its branches or tributaries. The Mardi stream (khola) and the Vijaypur stream (khola) are its main tributaries (Fig. 1). Two sites were selected on these streams which are mentioned below:

Site 1. Mardi stream

The first site was situated near the confluence of the Mardi stream with the Seti Gandaki river at Mardi, about 13 km upstream from the densely populated Pokhara city area and about 25 km upstream from site 2. It had erosion-sensitive banks and the watershed area had forests, agricultural lands and villages. The stream-bed had less sand and gravels but with more stones and boulders.

Site 2. Vijaypur stream

The second site was on the Vijaypur stream near its confluence with the Seti Gandaki river located about 12 km downstream from the city area and about 25 km downstream from the first site. Both the banks were severely eroded. The watershed area had agricultural lands, poultry farms and villages. The surface run-off from the watershed area as well as through human activities such as, bathing, washing of various items including the vehicles releasing toxic chemical substances into the water. The stream-bed was covered with pebbles, stones and boulders with less sand.

The prominent human activities observed at the sites during the study period were extraction of sand, pebbles, stones and breaking of boulders from the stream-bed and banks, movement of heavy vehicles for transportation of extracted materials, electrofishing, release of toxic substances from the agricultural lands (with application of chemical fertilizers and pesticides) and human settlements in the catchment area and direct disposal of urban wastes.

MATERIALS AND METHODS

Present study was conducted from September 2001 to August 2002. The macro-invertebrates inhabiting the bottom substrata (sand/mud/grovels) were sampled using Surber sampler (0.093 m^2). Five replicate samples were taken monthly from riffles and pools at each site. The samples were screened using the various mesh sieves (0.5 mm - 2.0 mm mesh net), kept in polythene bags, preserved in 4% formalin and carried to the laboratory for further works. Then the samples were sorted group-wise and preserved in vials containing 70% alcohol. The samples were identified using a dissecting microscope with magnification (10×), focusing and taking into consideration on the morphological features, to the lowest possible taxonomic level following the reputed taxonomic monographs/books of Edmondson (1959), Needham and Needham (1962), Mellanby (1963), Pennak (1978), Tonapi (1980), Dudgeon (1999) and Nesemann *et al.* (2007). The samples were stored in museum of Department of Zoology, Prithvi Narayan Campus (T.U.), Pokhara as reference material. Data has been presented season-wise as follows: autumn (months: September-November), winter (months: December-February), spring (months: March-April) and summer (June-August). Density was calculated as number of individuals per m^2 and percentage (%) was calculated by taking the percentage (%) of density of each taxa from the total density of all taxa in that season.

RESULTS

Altogether 47 genera belonging to 38 families and 12 orders, *viz.*, ephemeroptera, diptera, trichoptera, plecoptera, coleoptera, odonata, hemiptera, megaloptera, tricladida, plesiopora, rhychobdellida and pulmonata were recorded during the study period (Table 1), comprising 32 genera from riffles and 34 genera from pools.

Ephemeroptera, diptera, and trichoptera comprising 11, 8 and 8 genera, respectively were predominant orders among the macro-invertebrates followed by odonata, plecoptera, coleoptera, pulmonata, hemiptera, megaloptera, tricladida, plesiopora and rhynchobdellida comprising 5, 4, 4, 2, 1, 1, 1, 1 and 1 genera, respectively. Heptageniidae, baetidae and leptophlebidae were dominant families among ephemeropterans comprising 3, 2 and 2 genera followed by ephemeridae, ephemerellidae, caenidae and siphlonuridae each having single genus. Similarly, chironomidae, ceratopogonidae, tipulidae, psychodidae, tabanidae, culicidae, simuliidae and athericidae were families among dipterans having representation of single genus. Likewise, hydropsychidae, psychomyidae, polycentropodidae, hydroptilidae, leptoceridae and limnephilidae were families among trichopterans each having single genus, while glossosomatide was having 2 genera.

The generic richnes was lower (30 genera) at Site 2 (Vijaypur stream) than at Site 1 (Mardi stream) (38 genera) most probably due to urban influence upon the stream ecosystem. The total macro-invertbrate density at both the sites mostly observed major peak during the spring and fall during the summer season exhibiting an increasing trend from late summer till the spring season during the study period (Tables 2). The average total density during the spring peak was higher (967.42 m^{-2} in riffles and 652.10 m^{-2} in pools) at Site 1 and summer fall was lower (157.61 m^{-2} in riffles and 107.46 m^{-2} in pools) at Site 2. This peak was mainly contributed by the order ephemeroptera.

Table 1. Diversity of macro-invertebrates in the Mardi and the Vijaypur streams.

Taxa	Station	Distribution Sites 1	2
Order: Ephemeroptera			
Family: Ephemeridae			
Ephemera Linnaeus	R	+	+
	P	+	+
Family: Heptageniidae			
Heptagenia Walsh	R	+	+
	P	+	+
Rhithrogena Eaton	R	+	+
	P	+	+
Ecdyonurus sp.	R	+	+
	P	+	+
Family: Ephemerellidae			
Ephemerella Walsh	R	+	+
	P	+	+
Family: Baetidae			
Baetis Leach	R	+	+
	P	+	+
Centroptylum Westwood	R	-	+
	P	-	+
Family: Leptophlebidae			
Leptophlebia Eaton	R	+	+
	P	+	+
Habrophlebia Stephens	R	+	-
	P	+	-
Family: Caenidae			
Caenis Eaton	R	+	+
	P	+	+
Family: Siphlonuridae			
Siphlonurus Eaton	R	+	-
	P	+	-
Order: Diptera			
Family: Chironomidae			
Tendipes Meigen	R	+	+
	P	+	+
Family: Ceratopogonidae			
Culicoides Latreille	R	+	+
	P	+	+
Family: Tipulidae			
Antocha Osten Sacken	R	-	+
	P	-	+
Family: Psychodidae			
Psychoda Latreille	R	-	+
	P	-	+
Family: Tabanidae			
Tabanus Linnaeus	R	-	+
	P	-	+
Family: Culicidae			
Culex Linnaeus	R	-	-
	P	-	+
Family: Simuliidae			
Simulium Hagen	R	+	+
	P	+	+
Family: Leptidae (Athericidae)			
Atherix Meigen	R	-	-
	P	+	-
Order: Trichoptera			
Family: Hydropsychidae			
Hydropsyche Pictet	R	+	+
	P	+	+
Family: Psychomyidae			
Psychomyia Pictet	R	+	+
	P	+	+
Family: Glossosomatidae			
Glossosoma Curtis	R	+	-
	P	+	+
Agapetus Curtis	R	-	+
	P	-	+
Family: Polycentropodidae			
Polycentropus Curtis	R	+	-
	P	-	-
Family: Hydroptilidae			
Hydroptila Dalman	R	+	-
	P	+	-
Family: Leptoceridae			
Leptocerus Leach	R	+	-
	P	+	-

Family: Limnephilidae			
Limnephilus Leach	R	+	-
	P	-	-
Order: Plecoptera			
Family: Perlidae			
Neoperla Needham	R	+	+
	P	+	-
Family: Perlodidae			
Isoperla Banks	R	+	-
	P	-	-
Family: Nemouridae			
Nemoura Pictet	R	+	-
	P	+	-
Protonemura sp.	R	+	-
	P	+	-
Order: Coleoptera			
Family: Psephenidae			
Psephenus Haldeman	R	+	+
	P	+	+
Ectopria Leconte	R	-	+
	P	-	+
Family: Elmidae			
Heterlimnius Hinton	R	+	+
	P	+	+
Family: Dytiscidae			
Dytiscus Linnaeus	R	-	-
	P	+	-
Order : Odonata			
Family: Gomphidae			
Ophiogomphus Selys	R	-	-
	P	+	+
Octogomphus Selys	R	+	-
	P	+	-
Dromogomphus Selys	R	-	-
	P	+	-
Family: Agrionidae			
Argia Rambur	R	+	-
	P	+	-
Family: Libellulidae			
Sympetrum Newman	R	-	-
	P	+	-
Order : Hemiptera			
Family: Corixidae			
Corixa sp.	R	-	-
	P	+	-
Order: Megaloptera			
Family: Corydalidae			
Corydalus Latreille	R	+	+
	P	-	+
Order: Tricladida			
Family: Planaridae			
Planaria Girard	R	+	+
	P	+	+
Order: Plesiopora			
Family: Tubificidae			
Tubifex Muller	R	-	-
	P	+	+
Order: Rhynchobdellida			
Family: Glossiphonidae			
Hemiclepsis marginata Moore	R	-	-
	P	-	+
Order: Pulmonata			
Family: Planorbidae			
Gyraulus convexiculus Hutton	R	+	-
	P	+	-
Family: Lymnaeidae			
Lymnaea andersoniana Preston	R	-	-
	P	-	+

Abbreviations:

R = Riffle, P = Pool, 1 = Mardi khola, 2 = Vijayapur khola, (+) = Present and (-) = Absent.

Table 2. Seasonal average values of density and percentage of macro-invertebrates in Mardi and Vijaypur streams (no. m^{-2}).

Taxa	Site	Station	Season							
			Autumn		Winter		Spring		Summer	
			No.	%	No.	%	No.	%	No.	%
Ephemeroptera	1	R	447.90	67.57	691.56	82.13	472.97	48.88	211.39	68.61
		P	247.23	56.10	422.81	80.82	322.47	49.45	114.64	65.30
	2	R	222.15	65.26	347.57	75.78	247.23	45.69	96.72	61.36
		P	118.22	38.37	222.15	58.49	154.06	28.66	32.23	29.99
Trichoptera	1	R	96.73	14.59	60.89	7.29	182.73	18.88	46.56	15.11
		P	35.82	8.12	17.91	3.42	64.50	9.89	3.58	2.03
	2	R	39.41	11.57	32.24	7.02	75.24	13.90	7.16	4.54
		P	14.33	4.65	21.49	5.65	50.16	9.33	3.58	3.33
Diptera	1	R	28.66	4.32	21.50	2.55	64.50	6.66	14.33	4.65
		P	60.90	13.82	35.83	6.84	96.74	14.83	28.66	16.32
	2	R	71.66	21.05	57.33	12.50	139.73	25.82	46.57	29.54
		P	128.99	41.86	107.48	28.30	218.56	40.66	53.74	50.00
Plecoptera	1	R	32.24	4.86	35.83	4.25	114.66	11.85	14.33	4.64
		P	21.49	4.87	3.58	0.68	14.33	2.19	10.75	6.12
	2	R	-	-	-	-	-	-	3.58	2.27
		P	-	-	-	-	-	-	-	-
Coleoptera	1	R	25.08	3.78	17.91	2.12	50.16	5.18	14.32	4.64
		P	14.32	3.24	10.74	2.05	43.00	6.59	-	-
	2	R	-	-	10.75	2.34	34.41	7.28	-	-
		P	-	-	3.58	0.94	25.08	4.66	-	-
Odonata	1	R	10.74	1.62	7.16	0.85	25.08	2.59	-	-
		P	35.82	8.12	21.49	4.10	46.57	7.14	10.75	6.12
	2	R	-	-	-	-	-	-	-	-
		P	3.58	1.16	-	-	7.16	1.33	3.50	3.33
Hemiptera	1	R	-	-	-	-	-	-	-	-
		P	-	-	3.58	0.68	14.33	2.19	-	-
	2	R	-	-	-	-	-	-	-	-
		P	-	-	-	-	-	-	-	-
Megaloptera	1	R	10.75	1.62	3.58	0.42	25.08	2.59	3.58	1.16
		P	-	-	-	-	-	-	-	-
	2	R	3.58	1.05	7.16	1.56	14.33	2.64	-	-
		P	3.58	1.16	3.58	0.94	10.75	2.00	-	-

Tricladida	1	R	7.16	1.08	3.58	0.42	25.08	2.59	3.58	1.16
		P	7.16	1.62	-	-	14.33	2.19	-	-
	2	R	3.58	1.05	3.58	0.78	25.08	4.63	3.58	2.27
		P	3.58	1.16	3.58	0.94	10.75	2.00	-	-
Plesiopora	1	R	-	-	-	-	-	-	-	-
		P	10.75	2.42	3.58	0.68	21.50	3.29	7.16	4.07
	2	R	-	-	-	-	-	-	-	-
		P	17.91	5.81	10.75	2.83	25.08	4.66	10.75	10.00
Rhynchobdellida	1	R	-	-	-	-	-	-	-	-
		P	-	-	-	-	-	-	-	-
	2	R	-	-	-	-	-	-	-	-
		P	7.16	2.32	3.58	0.94	14.33	2.66	-	-
Pulmonata	1	R	3.58	0.54	-	-	7.16	0.74	-	-
		P	7.16	1.62	3.58	0.68	14.33	2.19	-	-
	2	R	-	-	-	-	-	-	-	-
		P	10.75	3.48	3.58	0.94	21.50	4.00	3.58	3.33
Total	1	R	662.84	99.99	842.01	99.99	967.42	99.99	308.09	99.99
		P	440.65	99.99	523.10	99.99	652.10	99.99	175.54	99.99
	2	R	340.38	99.99	458.63	99.99	541.02	99.99	157.61	99.99
		P	308.10	99.99	379.77	99.99	537.43	99.99	107.46	99.99

Abbreviations: R = Riffle, P = Pool.

The average density (and percentage) of various taxa of macro-invertebrates are presented in Table 2, which shows that, ephemeroptera was higher comprising 691.56 m^{-2} (82.13%) from riffles and 422.81 m^{-2} (80.82%) from pools at Site 1 (Mardi stream) in winter, followed by trichoptera comprising 182.73 m^{-2} (18.88%) from riffles and 64.50 m^{-2} (9.89%) from pools at Site 1 in spring; and diptera comprising 139.73 m^{-2} (25.82%) from riffles and 218.56 m^{-2} (40.66%) from pools at Site 2 (Vijaypur stream) in spring season. Likewise, those of plecoptera were higher comprising 114.66 m^{-2} (11.85%) from riffles and 14.33 m^{-2} (2.19%) from pools at Site 1; coleopteran comprising 50.16 m^{-2} (5.18%) from riffles and 43.00 m^{-2} (6.59%) from pools at Site 1 and odonata comprising 25.08 m^{-2} (2.59%) from riffles and 46.57 m^{-2} (7.14%) from pools at Site 1 in spring season. Similarly, those of tricladida were higher comprising 25.08 m^{-2} (2.59%) from riffles and 14.33 m^{-2} (2.19%) from pools at Site 1; megaloptera comprising 25.08 m^{-2} (2.59%) from rifles at Site 1 and 10.75 m^{-2} (2%) from pools at Site 2; plesiopora comprising the whole (25.08 m^{-2}, 4.66%) from the pools; and pulmonata comprising the whole (21.50 m^{-2}, 4.00%) from the pools at Site 2 in spring season. Likewise, those of hemiptera were higher comprising the whole (14.33 m^{-2}, 2.19%) from pools at Site 1 and rhynchobdellida comprising the whole (14.33 m^{-2}, 2.66%) from pools at Site 2 in spring season.

The dominant genera were, *Heptagenia*, *Rhithrogena* and *Baetis* among ephemeropterans; *Hydropsyche*, *Psychomyia* and *Glossosoma* among trichopterans; *Tendipes*, *Culicoides* and *Simulium* among dipterans, *Neoperla* and *Nemoura* among plecopterans; *Psephenus* and *Heterlimmius* among coleopterans and *Ophiogomphus* and

Octogomphus among odonates. Only a single genus recorded were- *Corixa*, *Corydalus*, *Planaria*, *Tubifex* and *Hemiclepsis* under the taxa hemiptera, megaloptera, tricladida, plesiopora and rhychobdellida, respectively. *Gyraulus* was dominant among pulmonates.

DISCUSSION

Generally, the ephemeroptera have been reported to be the dominant order among the macro-invertebrates in hill-streams having natural environmental conditions, followed by trichoptera, plecoptera, diptera, coleoptera, odonata, hemiptera, oligochaeta, megaloptera, etc. Likewise, heptageniidae, baetidae, leptophlebidae, ephemerellidae and caenidae; chironomidae, ceratopogonidae and simuliidae and hydropsychidae, psychomyidae and limnephilidae were dominant representative families belonging to ephemeroptera, diptera and trichoptera respectively. Aquatic insects, their learvae or nymphs constitute more than 85% of which ephemeroptera, trichoptera, diptera and plecoptera contributed major bulk of the total faunal composition in mid-land streams or rivers (Ormerod *et al.* 1994, Vaidya 2002, Sharma *et al.* 2004, Pokharel 2011-12). Similar pattern of composition and order/family dominance of macro-invertebrates was observed in the present work, which could be due to complex physio-hydrological characteristics and zoogeographical factors.

There was increasing trend of taxa richness at upstream to downstream sites, maximum richness at the transition between montane and valley sites, a significant decrease in taxa richness at the valley sites and a decline of both habitat stability and diversity at the urban sites (Carter *et al*. 1996, Useeglio-P and Besel 2002, Sharma *et al.* 2004). In the present study, the habitat stability as well as taxa richness were reduced at the urban influenced site, which could be attributed to the diverse physiography with stream-bed/bank heterogeneity along-with various abiotic and biotic factors including the human activities.

Higher taxa richness and population density were observed during autumn/winter and lower during summer/monsoon season in various lotic water-bodies (Sunder 1997, Brewin *et al.* 2000, Sharma *et al.* 2004). Similar temporal variations including higher values in spring/winter season were observed in the present study, which could be due to seasonal climatic conditions which markedly change the hydrological regime, abiotic characteristics and biotic communities.

Higher population density and taxa richness of riffle-dominant taxa (mainly ephemeroptera, trichoptera and plecoptera) were reported at riffle stations in comparison to those at pool stations where pool-dominant taxa (mainly diptera, odonata, coleoptera, and oligochaeta) counted higher (Payne and Miller 1991, Sunder 1997, Carter and Fend 2001). Similar trend of population density and taxa richness were observed in the present study, which could be attributed to heterogeneity of substrata, velocity of water and climatic regime.

The above mentioned activities probably influenced the ecological components particularly at Site 2, having lower taxa richness and density, which reflects the perturbation of the stream ecosystem due to urbanization, industrialization and application of inorganic fertilizers and pesticides in the agricultural lands and needs regular ecological monitoring and measures to control further deterioration.

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