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Diversity, distribution, and seasonal abundance of Ephemeroptera in streams of Meghalaya State, India

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Abstract

Diversity, distribution, seasonal changes in density and relative abundance of Ephemeroptera nymphs were studied in five stations on three streams in and around Shillong, Meghalaya state, North-eastern India. Seventeen species belonging to eight genera and five families were recorded. Diversity (Shannon's index) was governed by the heterogeneity of the substratum which in turn was influenced by catchment disturbances (quarrying, logging, and entry of sewage). Seasonal changes in density were governed by the spate-frequency regime of the streams. Relative abundance showed dominance of one or two species at impacted stations, while in less disturbed ones, a more equitable distribution of species was observed.

Introduction

Ecological studies on lotic Ephemeroptera from India and other South Asian countries are far from adequate (Hora, 1923, 1930; Ali, 1968a, 1968b, 1969; Gupta & Michael, 1981, 1983; Gupta, 1984; Ao *et al.*, 1984). This paper deals with the diversity, distribution and relative abundance of Ephemeroptera nymphs and the factors governing their ecology in a few Meghalaya streams. As the streams experience varying degrees of human impact on their catchments, Shannon index values were calculated for their Ephemeroptera communities. This index was chosen because of its wide acceptance (Cairns & Dickson, 1971; Wilhm, 1972; Godfrey, 1978; Roy, 1985), and because it could be utilized for any community irrespective of its species-abundance distribution patterns (Pielou, 1969).

Description of study area

Our five collecting stations are located on three different streams, viz., Umkhrah, Umshirpi and Umshing. All of them flow through the city of Shillong or its outskirts (lat. 25° 34′ N; long. 91° 52′ E). These streams are tributaries to the Umiam river, one of the major rivers draining the north slope of the Shillong plateau (Fig. 1). While the Umkhrah and Umshirpi flow at an altitude of about 1500 m at the study sites, the Umshing flows at about 1200 m. Vegetation near the collecting stations on the Umkhrah and Umshirpi consists of *Pinus kesiya*, *Eupatorium* spp., *Bambusa* sp., *Lantana* sp., and *Polygonum* sp. on the stream margins. Besides these plants, stream Umshing also has an abundance of *Rhododendron* sp. on the hills flanking the study site, and a more extensive growth of *Polygonum* spp. and a few

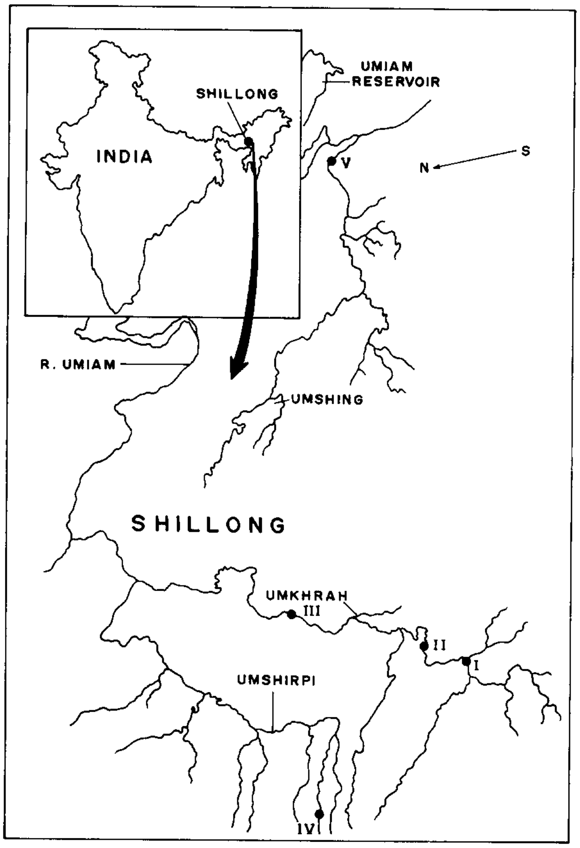


Fig. 1. Study area showing streams and sampling stations.

species of grasses on the margins, forming a dense weed bed.

Stations I, II and III are on stream Umkhrah. At I and III catchment disturbances are considerable: stone-sand quarries on the hills nearby and stone-sand collection spots on the stream beds. The banks are almost completely denuded and have plots of cultivated land strewn among abandoned pastureland. Urban buildup is moderate at station I, but more extensive at station III. Station II, which is located in a gorge between stations I and III, has ample forest cover. Disturbances are in the form of washing and laundering activities. The average width and depth of the stream at these three stations are similar, 2.5 to 4.0 m and 20 to 27 cm, respectively.

Station IV on the headwaters of Umshirpi stream has an intact forest cover with little catchment disturbance. The mean width and depth are 1.5 m and 18 cm respectively.

At Station V on the Umshing stream conditions similar to those of station IV exist. Mean width and depth are 5 m and 32 cm, respectively.

Material and methods

Several physical and chemical features of the stream water were measured. Dissolved oxygen by Winkler's method; free carbon dioxide, total alkalinity and dissolved nitrate after Golterman *et al.*, 1969; pH and conductivity with a pH and conductivity meter, respectively. Air and water temperatures were also measured. Current velocity was measured by a float and a stopwatch, while mineral substratum particles were measured directly as well as by mechanical sieving and categorizing (Hynes, 1970).

Ephemeroptera nymphs were collected by holding a net downstream while an unit area of 900 cm^2 was disturbed upstream. Three such samples were taken monthly at each station. The coefficient of association between stations was calculated (Bishop, 1973) with the following formula: $I = 2j/(a + b)$, where I = coefficient of association between stations A and B, a = number of species in A, b = number of species in B, and j = number of species common to A and B. The Shannon index of diversity ($\overline{H}$) was calculated by using the following formula:

$$\overline{H} = \sum_{i=1}^{s} (ni/N) \log_2 (ni/N),$$

where N is the total number of individuals, ni is the number of individuals in the ith species and the information content or diversity is expressed as number of bits (Zar, 1974). The greatest possible value of $\overline{H}$, $\overline{H}$ max was calculated as: $\overline{H}$ max = $\log_2 s$, when s is the number of species. The evenness or equitability index (J) was calculated as: $J = \overline{H}/\overline{H}$ max (Zar, 1974).

Results and discussion

Physical and chemical variables: Air temperature, rainfall and water temperature (Table 1, Table 2) showed a fairly wide seasonal variation. Though the highest rainfall was recorded in June, spates were more frequent in May, August and September, as rainfall was less evenly distributed during the latter months. Dissolved oxygen, free carbon dioxide, total alkalinity, pH and conductivity did not show marked seasonal or stationwise variations. This probably reflects a typical tropical-subtropical situation (Bishop, 1973). Temperature fluctuations were due to altitude (1200 to 1500 m above msl). Nitrate concentrations were somewhat higher in stations I, II and III (Table 2), due to entry of domestic sewage. Another point of difference among stations was the degree of silt-sand deposition and the degree of heterogeneity of their mineral substratum. Stations I and III were heavily silted with only fist-sized pebbles and smaller gravel on their beds. Station II was also silted, but with cobbles and boulders among pebbles and gravel. Stations IV and V were not silted and had a heterogeneous mineral substratum. The low substratum heterogeneity and heavy siltation in stations I and III was due to collection of boulders and cobbles from the stream bed and washing-off of sand from quarries and denuded slopes. Station II, though not directly impacted, received sand and nitrate from station I. Thus, catchment disturbances mostly ushered in changes in the physical environment by a reduced

Table 1. Rainfall and air temperature in the study area.

Month	Year	Rainfall cm	Mean max. air temp. (°C)	Mean min. air temp. (°C)
January	1978	00.0	13.4	4.5
February	–	17.7	15.2	6.8
March	–	34.9	21.3	10.3
April	–	84.4	24.7	14.0
May	–	208.3	25.0	16.6
June	–	460.1	26.4	17.2
July	–	245.2	26.8	17.3
August	–	193.0	27.1	18.3
September	–	246.4	23.1	16.6
October	–	50.6	22.4	15.2
November	–	20.4	18.5	10.3
December	–	00.0	17.8	7.4

Table 2. Ranges of some physical and chemical variables in the stations.

	Station I	Station II	Station III	Station IV	Station V
Water temperature °C	9–24	9–24	9.5–25	8.5–23	11–26
Current Velocity cm sec^{-1}	35–50	50–80	40–65	50–80	5–100
pH	5.8–6.6	5.9–6.3	5.7–6.5	5.7–6.3	5.9–6.4
Conductivity $\mu S\ cm^{-1}$	37.7–46.2	26.25–57.75	37.75–53.15	23.1–60.9	31.92–57.75
Dissolved Oxygen $mg\ l^{-1}$	7.2–8.4	7.2–9.6	7.2–8.2	8.0–9.0	7.2–9.8
Free Carbondioxide $mg\ l^{-1}$	2.2–4.8	2.2–4.0	2.3–4.0	2.2–4.8	2.0–4.0
Total alkalinity $mg\ l^{-1}$	20–44	18–44	36–44	14–44	21.4–48
Nitrate $mg\ l^{-1}$	0.35–0.56	0.4–0.55	0.43–0.58	0.06–0.17	0.22–0.24

substratum heterogeneity, sand deposition and loss of vegetation. The chemical environment was not markedly altered except for a rise in nitrate.

Species composition and diversity of Ephemeroptera: Seventeen species of Ephemeroptera belonging to eight genera, viz., *Baetis* (4 spp.), *Pseudocloeon* (2 spp.), *Ecdyonurus* (1 sp.), *Epeorus* (2 spp.), *Isca* (2 spp.), *Nathanella/Notophlebia* (2 spp.), *Caenis* (1 sp.), and *Ephemerella* (3 spp.) were recorded in the five stations. Of these, eight (*Baetis*, *Ecdyonurus*, *Isca* and *Caenis*) could be distinguished at the species level during all stages of their life history, while in the remaining nine species, species level distinctions could be made at the mature nymphal stages only. Each of these species groups is, therefore, treated as one operational taxonomic unit or OTU (Clifford, 1978) for calculation of Shannon index values, as well as for population estimates. Station V has thirteen species, station IV eight, station II five, and stations I and III have three each (Table 7). The coefficient of association between successive stations (Table 3) reveals that stations I, II and III could be classed together, although station II showed a fairly high coefficient of association with station IV. Station V was distinct from all others, and station IV from I, III and V.

The total number of individuals collected at each station every month (N), the number of species (S), Shannon index values ($\overline{H}$), and evenness index values (J) are presented in Table 4. Diversity and evenness were highest and most uniform in station V, followed by IV, II, III and I. A Duncan's multiple range test of significance (at $p = 0.05$) between the means of sample diversity ($\overline{H}$) (Table 5) reveals that stations I and III were not significantly different from each other, but different from the other stations. Station II was different from IV and V, while station IV was different from V.

Based on the number of species, coefficients of association, and diversity index values, the

Table 3. Association table and coefficients of association of the number of species of Ephemeroptera at the stations. Whole numbers denote the number of species common between successive stations; fractions denote the coefficients of association (after Bishop, 1973).

	I	II	III	IV	V
I	3	3	2	2	3
II	0.75	5	3	4	4
III	0.67	0.75	3	2	3
IV	0.36	0.62	0.36	8	4
V	0.38	0.44	0.38	0.38	13

Table 4. Total number of individuals (N), number of species (S), diversity ($\overline{H}$), and evenness (J) values for different months in the stations.

		Station I				Station II				Station III				Station IV				Station V			
Month/Year		N	S	$\overline{H}$	J	N	S	$\overline{H}$	J	N	S	$\overline{H}$	J	N	S	$\overline{H}$	J	N	S	$\overline{H}$	J
Jan	1978	159	3	1.13	0.71	276	5	1.67	0.72	125	3	0.71	0.45	100	7	1.73	0.62	256	8	2.71	0.90
Feb	-	130	3	0.92	0.58	354	4	1.44	0.72	67	3	1.07	0.67	144	5	1.69	0.73	325	8	2.73	0.91
Mar	-	109	3	0.65	0.41	466	5	1.82	0.78	193	2	0.55	0.55	192	6	1.67	0.65	228	8	2.76	0.92
April	-	180	3	0.91	0.57	210	4	1.44	0.72	202	2	0.46	0.46	206	7	1.73	0.62	157	9	2.66	0.84
May	-	21	3	0.90	0.56	49	4	1.33	0.66	31	2	0.87	0.87	73	6	2.14	0.83	130	7	1.89	0.67
June	-	85	2	0.42	0.42	337	5	1.59	0.68	26	3	1.39	0.87	98	5	1.89	0.81	157	6	1.65	0.64
July	-	91	2	0.39	0.39	154	5	1.57	0.68	50	3	0.90	0.56	96	5	1.80	0.78	147	7	1.95	0.69
Aug	-	58	2	0.77	0.77	106	3	1.21	0.76	27	2	0.77	0.77	120	5	1.67	0.72	150	6	1.70	0.66
Sept	-	50	3	1.01	0.64	91	4	1.21	0.60	21	3	1.05	0.66	66	5	1.47	0.73	98	7	2.22	0.79
Oct	-	168	3	0.79	0.50	250	4	1.59	0.79	112	3	0.85	0.54	188	7	2.32	0.83	254	8	2.71	0.90
Nov	-	300	3	0.97	0.61	355	5	1.60	0.69	181	3	0.75	0.47	245	6	1.89	0.73	431	8	2.76	0.92
Dec	-	106	3	0.58	0.37	170	4	1.36	0.68	103	2	0.55	0.55	114	6	1.95	0.75	213	8	2.32	0.77

Table 5. Results of a Duncan's Multiple-Range Test among mean diversity ($\overline{H}$) values at stations.

Mean diversity station	I: 0.7867	minimum critical differences:
	III: 0.8267	$r = 2$: 0.2334
	II: 1.4858	$r = 3$: 0.245
	IV: 1.8291	$r = 4$: 0.2532
	V: 2.3383	$r = 5$: 0.2581

stations could be classified as follows: station V in the most diverse and even category, followed by IV; station II was intermediate, while stations III and I belonged to the least diverse category. This ordering confirms the one based on catchment and instream disturbances. Disturbances in the study area resulted in increased siltation, reduction of substratum heterogeneity, elimination of shelter and shade for the nymphs, and increased severity of spates. Evidence that all these act to depress benthic diversity through elimination of more sensitive taxa is overwhelming (Ali, 1968a, 1968b, 1969; Hynes, 1970; Brusven & Prather, 1974; Hart & Brusven, 1976; Egglishaw, 1980; Boles, 1981), and the outcome of the present study is in line with these findings.

Seasonal changes in density: Seasonal changes in the density of Ephemeroptera nymphs at different stations are depicted in Figure 2. There were two major population buildups: February–April, and October–November. While the timing of the spring peak showed variation among stations, the autumn peak occurred in all of them. Different cohorts of Ephemeroptera at different stations experienced uneven retardation of growth during winter due to microhabitat differences in temperature and food supply. Consequently, the spring peak was not sharp and showed stationwise variations in its occurrence. Thereafter, during May to September, density aspects were mostly governed by spates. The general absence of spates from October onwards enabled uninterrupted recolonization and a November peak in all stations. Thus spates lent a certain degree of seasonality to these systems that would otherwise remain largely non-seasonal except for winter. The seasonal abundance patterns of benthic insect communities in subtropical and tropical running water systems are known to be related to their spate-frequency regime (Ali, 1969; Bishop, 1973; Turcotte & Harper, 1982), and the Shillong streams are found to more or less follow this pattern. However, the impact of temperature is also felt in these systems because of

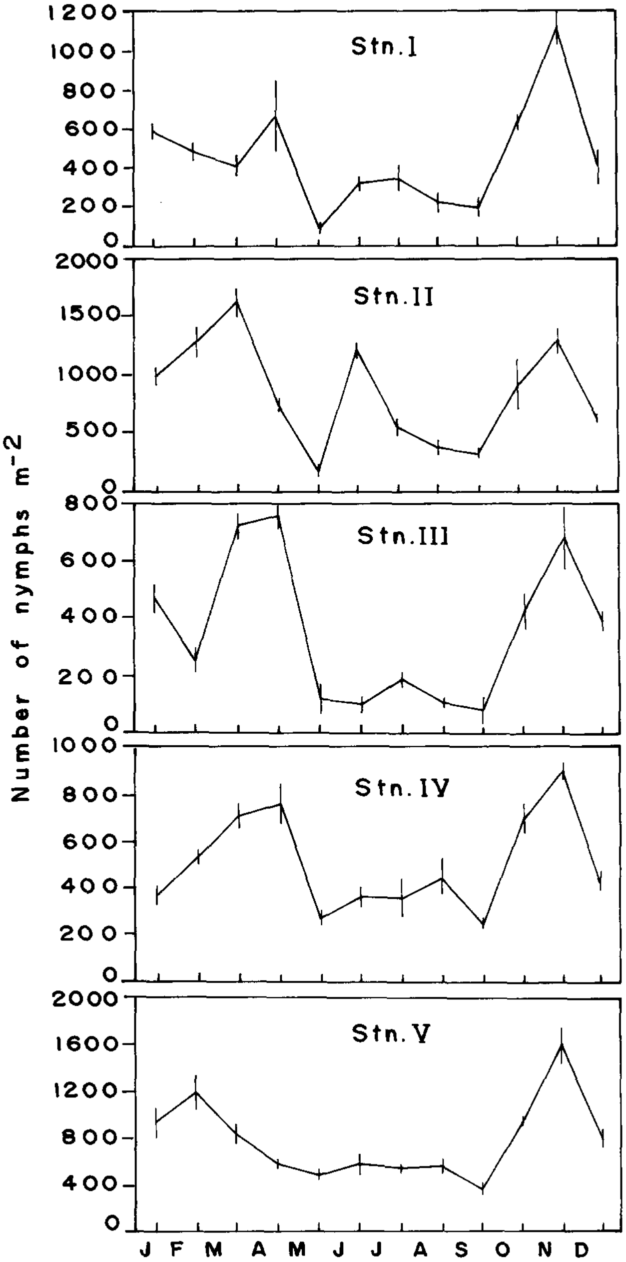
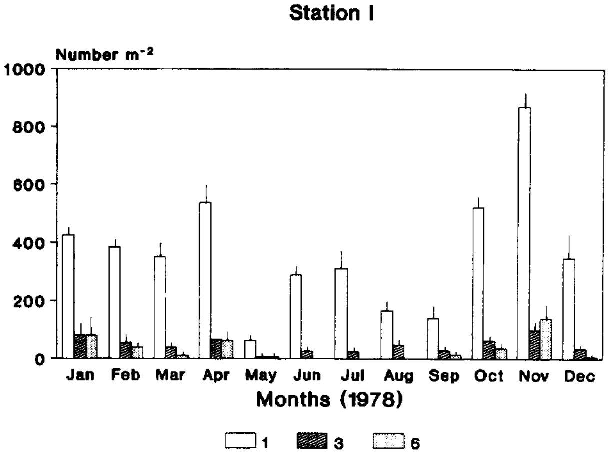
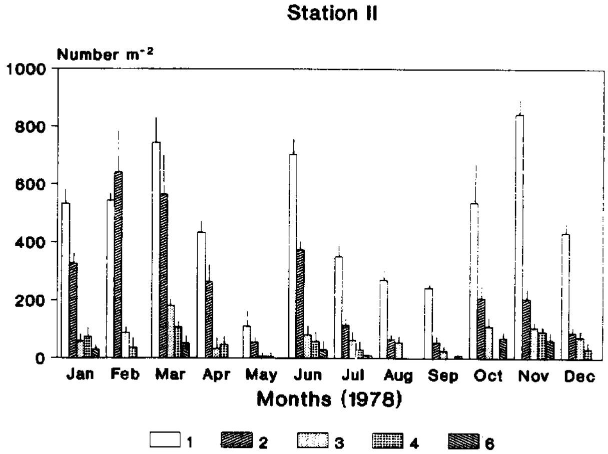


Fig. 2. Seasonal abundance of Ephemeroptera nymphs at the stations.





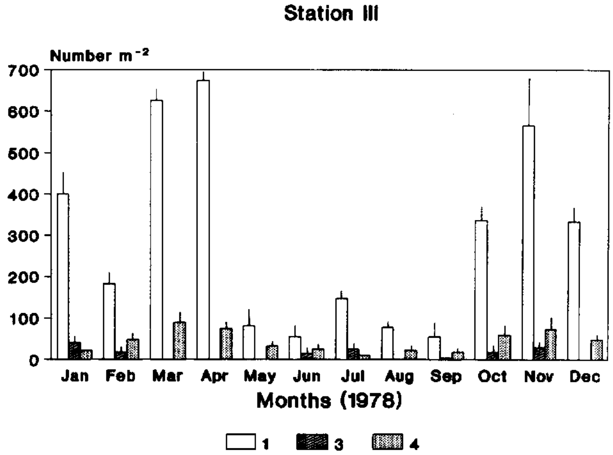


Fig. 3. Relative abundance of Ephemeroptera species and species-complexes at the stations. 1: *Baetis* sp. A, 2: *Baetis* sp. B, 3: *Baetis* sp. C, 4: *Baetis* sp. D, 5: *Pseudocloeon* spp., 6: *Caenis* sp., 7: *Ecdyonurus* sp., 8: *Epeorus* spp., 9: *Isca* sp. A, 10: *Isca* sp. B, 11: *Nathanella*/*Notophlebia* spp., 12: *Ephemerella* spp. Vertical bars in Fig. 2 and Fig. 3 represent Standard Deviation from the mean value.

Table 6. Results of a Least Square Difference Test among mean nymphal densities at different stations and over different months (all values log(x + 1) transformed for ANOVA).

Mean densities: At various stations:	Over different months:	Least Square Difference (LSD) values:
III: 1.4	May: 1.25	For stations: 0.12
I: 1.54	Sep : 1.31	For months : 0.18
IV: 1.63	Aug : 1.44	
V: 1.82	July : 1.54	
II: 1.83	June: 1.55	
	Dec : 1.66	
	Jan : 1.76	
	Feb : 1.77	
	Oct : 1.8	
	Apr : 1.81	
	Mar: 1.85	
	Nov: 2.04	

altitude. As a result, there is no population buildup during winter in spite of the absence of spates.

Statistical analysis: A two-way ANOVA of log(x + 1) transformed density values revealed significant density differences among stations and months ($F_{4,44} = 20.5$ for stations; $F_{11,44} = 13.0$ for months; $P = 0.001$ in both) (Table 6). Stations II and V differed significantly from the others, but not from each other. Again, I and IV differed from III. November differed from all other months, and so did the monsoon months of May-September, except that June and July did not differ from December, confirming the observation that spates significantly depressed density.

Relative abundance of species: The number of individuals of Ephemeroptera nymphs collected during January to December 1978 is depicted in Fig. 3, while the ranges of their relative abundance are shown in Table 7. *Baetis* sp.A was the most

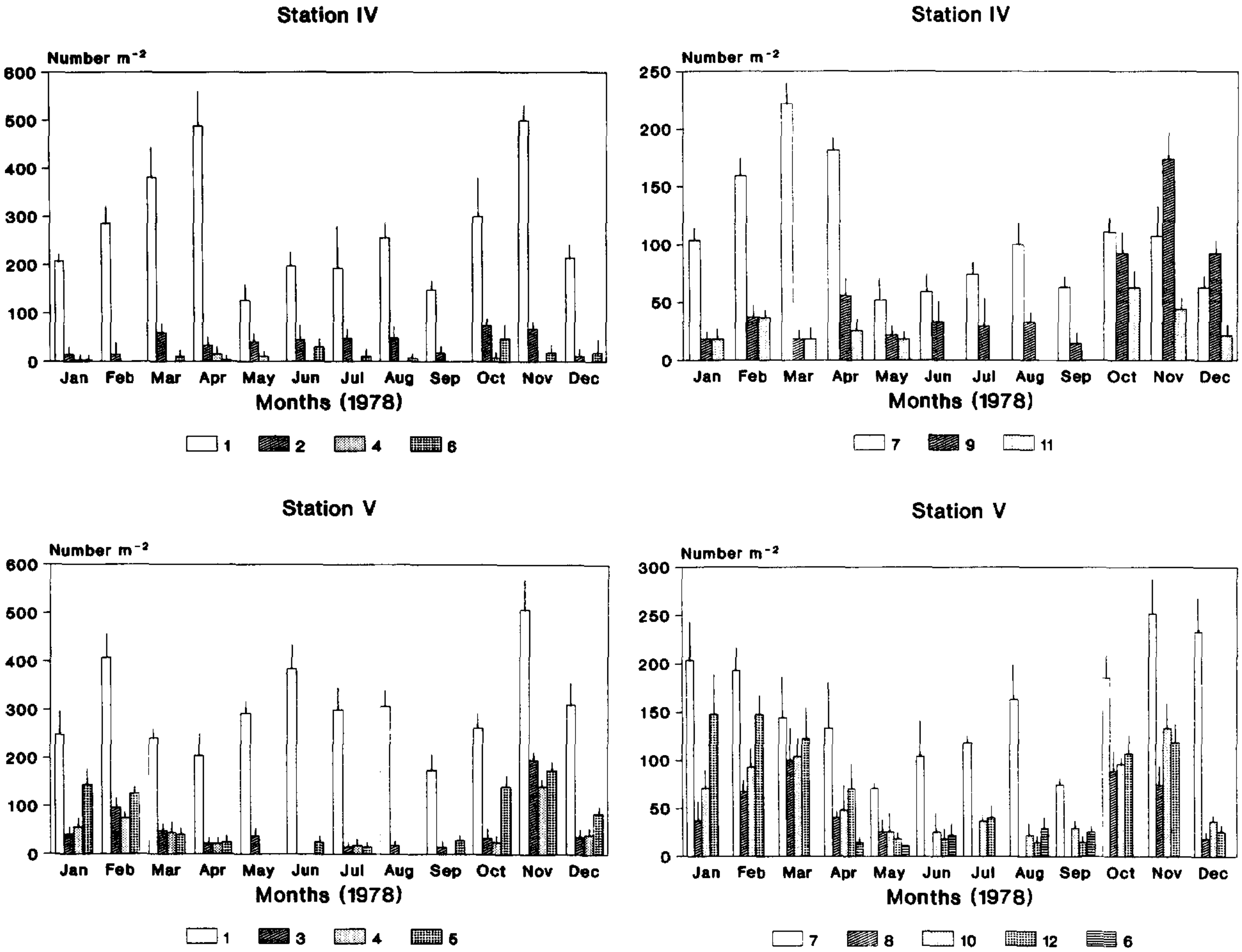


Table 7. Ranges of percentage abundance of various Ephemeroptera species and species groups at the stations.

Species and Species-complexes	Ranges of abundance in percentage				
	Station I	Station II	Station III	Station IV	Station V
Baetis sp. A	72.4–92.3	41.5–72.5	71.0–90.1	43.1–60.6	26.2–66.2
B. sp. B	–	14.1–48.9	–	2.6–13.6	–
B. sp. C	7.7–22.4	4.1–14.1	4.4–15.4	–	2.7–12.3
B. sp. D	–	2.8–7.2	4.8–29.0	1.0–4.1	2.8–8.8
Pseudocloeon spp.	–	–	–	–	2.7–15.2
Caenis sp.	1.9–13.8	2.0–7.6	–	0.5–8.2	2.3–7.1
Ecdyonurus sp.	–	–	–	11.9–31.3	14.6–29.6
Epeorus spp.	–	–	–	–	2.3–11.8
Isca sp. A	–	–	–	2.6–21.9	–
Isca sp. B	–	–	–	–	4.0–12.3
Nathanella/ *Notophlebia* spp.	–	–	–	2.6–9.0	–
Ephemerella spp.	–	–	–	–	2.8–15.6

ubiquitous species at all stations. However, in the more impacted stations I and III, the abundance pattern revealed a dominance of this species over the others, while elsewhere there was a more equitable distribution of species. Certain species of *Baetis* can withstand stresses such as induced by silt and sand deposition, logging, organic pollution, and acid mine drainage (Hynes, 1960; Chutter, 1969; Wielgosz, 1979; Scullion & Edwards, 1980), and *Baetis* sp.A is apparently such a form. Other species, particularly in the families Leptophlebiidae, Heptageniidae, Ephemerellidae, and the baetid genus *Pseudocloeon*, appear to be limited by disturbances, and were found in the least impacted stations IV and V.

Conclusions

Although synergic influences of other factors cannot be ruled out, catchment disturbance was the dominant factor controlling the diversity and distribution of Ephemeroptera in the streams. Furthermore, most structural aspects of the community were governed by physical factors such as the degree of heterogeneity and stability of the substratum and the frequency of spates. This is significant because the physical regime of the streams in this region is subject to alterations by logging, quarrying and mining. These, rather than industrial pollution, constitute the major source of pollution in this region of India, a situation which also prevails in most South and South-East Asian countries (Bishop, 1973).

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References

Ali, S. R., 1968a. Bottom fauna of the streams and rivers of Hazara district after summer rains. Pak. J. Sci. Ind. Res. 11: 208–211.

Ali, S. R., 1968b. Bottom fauna of the streams of Kohat district Kurram agency after winter rains. Pak. J. Sci. Ind. Res. 11: 449–454.

Ali, S. R., 1969. Effects of rains on the bottom fauna of the streams of Rawalpindi and Wah. Pak. J. Forest. 19: 227–234.

Ao, M., J. R. B. Alfred & A. Gupta, 1984. Studies on some lotic systems in the North-eastern hill region of India. Limnologica (Berlin) 15: 135–141.

Bishop, J. E., 1973. Limnology of a small Malayan river Sungai Gombak. Dr W. Junk, The Hague, 485 pp.

Boles, G. L., 1981. Macroinvertebrate colonization of replacement substrate below a hypolimnial release reservoir. Hydrobiologia 78: 133–146.

Brusven, M. A. & K. V. Prather, 1974. Influence of stream sediments on distribution of macrobenthos. J. Ent. Soc. Brit. Columbia. 71: 25–32.

Cairns, J., Jr. & K. L. Dickson, 1971. A simple method for the biological assessment of the effects of waste discharges on aquatic bottom-dwelling organisms. J. Wat. Pollut. Cont. Fed. 43 : 755–772.

Chutter, F. M., 1969. The effects of silt and sand on the invertebrate fauna of streams and rivers. Hydrobiologia 34: 57–76.

Clifford, H. F., 1978. Descriptive phenology and seasonality of a Canadian brown-water stream. Hydrobiologia 58: 213–231.

Egglishaw, H. J., 1980. Benthic invertebrates of streams on the Alburz Mountain range near Tehran. Hydrobiologia 69: 49–55.

Godfrey, P. J., 1978. Diversity as a measure of benthic macro-invertebrate community response to water pollution. Hydrobiologia 57: 111–122.

Golterman, H. L., R. S. Clymo & M. A. Ohnstad, 1969. Methods for physical and chemical analysis of fresh waters. Blackwell, Oxford, Melbourne. 213 pp.

Gupta, A. & R. G. Michael, 1981. Population ecology and feeding propensities of two co-existing species of Baetidae (Insecta: Ephemeroptera). Proc. Symp. Ecol. Anim. Popul. zool. Surv. India Pt. 2: 95–104.

Gupta, A. & R. G. Michael, 1983. Seasonal differences and relative abundance among populations of benthic aquatic insects in a moderately high altitude stream. Proc. Wkshp. High Alt. Ent. & Wildl. Ecol. zool. Surv. India: 21–28.

Gupta, A., 1984. Observations on human interferences in some running water systems of Meghalaya. p. 61–68. In: Jaswal, I. J. S. (ed.) Status of ecology. Punjab Publishing House, Patiala. 106 pp.

Hart, D. S. & M. A. Brusven, 1976. Comparison of benthic insect communities in six small Idaho batholith streams. Melanderia 23: 1–18.

Hora, S. L., 1923. Observations on the fauna of certain torrential streams in the Khasi hills. Rec. Ind. Mus. 25: 579–600.

Hora, S. L., 1930. Ecology, bionomics and evolution of the torrential fauna, with special reference to the organs of attachment. Phil. Trans. r. Soc. B 218: 171–282.

Hynes, H. B. N., 1960. The biology of polluted waters. Liverpool University Press, Liverpool. 202 pp.

Hynes, H. B. N., 1970. The ecology of running waters. Liverpool University Press, Liverpool. 655 pp.

Pielou, E. C., 1969. An introduction to mathematical ecology. Wiley, New york. 286 pp.

Roy, S. P., 1985. Investigations on the population dynamics and species diversity of nymphal odonates in a freshwater tropical shallow wetland. Proc. First Indian Symp. Odonatol.: 185–191.

Scullion, J. & R. W. Edwards, 1980. The effects of coal industry pollutants on the macroinvertebrate fauna of a small river in the South Wales coalfield. Freshwat. Biol. 10: 141–162.

Turcotte, P. & P. P. Harper, 1982. The macroinvertebrate fauna of a small Andean stream. Freshwat. Biol. 12: 411–419.

Wielgosz, S., 1979. The effect of wastes from the town of Olsztyn on invertebrate communities in the bottom of the River Tyna. Acta Hydrobiologica 21: 149–165.

Wilhm, J., 1972. Graphic and mathematical analyses of biotic communities in polluted streams. Ann. Rev. Ent. 17: 223–252.

Zar, J. H., 1974. Biostatistical analysis. Prentice-Hall Inc., N.J. 620 pp.