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Ecological Study of Macroinvertebrate Communities in Three Limnocrene Freshwater Springs of Kashmir Himalaya

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ABSTRACT

Benthic macroinvertebrate communities during 2005-2006 were studied in three perennial limnocrene freshwater springs located in single ground water area in Kokergund Yaripora of District Kulgam (Kashmir).Though most of the invertebrate orders, as well as individual taxa, showed differences in relative abundance between habitat types, yet Tumbernag spring differed from other two springs in sustaining a different assemblage of macroinvertebrates. The macroinveretebrates were most abundant in Khudanag and least abundant in the Tumbernag.However, the taxonomic richness in the investigated springs was highest in Nagrad and lowest in Tumbernag. During the entire study, a total of 19 taxa belonging to Diptera (04), Trichoptera (03), Coleoptera (01), Megaloptera (01), Ephemeroptera (01), Amphipoda (1), Ostracoda (02), Oligochaeta (03), Hirudinae (01) and Mollusca (02) were encountered. Analysis of variance to the data showed that the taxa like *Chironomus* sp., *Limnodrilus* sp., *Tubufex tubifex*, *Branchiura sowerbyii*, *Erpobdella octoculata* and *Gammarus pulex* were found in all the four seasons without any significant variation among seasons. Certain taxa like *Rhyacophila* obscura and *Tabanus* sp. were absent in spring season while *Glossosoma* sp. was not recorded in summer season. However, no single taxa was restricted to a particular season. On the other hand, the taxa like *Simulium*, *Tabanus*, *Rhyacophila*, *Limnephilus* and *Glossosoma* were restricted to only one particular biotope. Most studied taxa showed differences in relative abundances between the seasons as well as between the spring biotopes.

Key words: Spring water, ecology, macroinvertebrates, Kashmir Himalaya

INTRODUCTION

The location of the springs at the interface between several distinct ecosystems creates a heterogeneous mosaic of aquatic, semi-aquatic and semi-terrestrial microhabitats, which has led many ecologists to suggest that springs are hot spots for aquatic biodiversity (Cantonati *et al.*, 2006; Scarsbrook *et al.*, 2007; Staudacher and Füreder, 2007).Habitat heterogeneity is usually higher in helocrene springs where water emerges in a swampy area, medium in rheocrene springs, where water emerges directly into a stream channel, and lower in limnocrene springs where water emerges into a pool(Lindegaard et al., 1998; Cantonati *et al*., 2006).A number of reviews have been published in 1990s (Williams *et al*., 1990; Ferrington, 1995; Botosaneanu, 1998), which has helped to understand the ecology of springs and the importance of some key factors controlling the composition and structure of their biological communities, especially benthic invertebrate assemblages. Classification of spring habitats into ecological typologies is central for spring management, conservation and monitoring (Barquín and Scarsbrook, 2007) and to improve our understanding of spring ecology (Glazier, 1991). Many ecologists have attempted to classify spring habitats using spring physical and chemical attributes (Roca 1990; Glazier, 1991; Hoffsten and Malmqvist, 2000), spring invertebrate communities(Glazier and Gooch, 1987; Roca and Castillo, 1993; Lindegaard *et al*., 1998;Hahn, 2000; Meyer *et al*., 2003; Ilmonen and Paasivirta, 2005) or both (Zollhöfer *et al*., 2000). Our knowledge of spring ecosystems in Kashmir valley lags far behind and only few preliminary reports on spring ecology are available (Qadri and Yousuf, 1979; Rashid, 1982; Yousuf *et al*., 1983; Qadri and Yousuf, 1988; Bhat and Yousuf, 2002; Latief *et al*., 2003; Pandit *et al*., 2001, 2002,2005 a &b,2007) and for this purpose baseline data on macroinvertebrates of three limnocrene springs in Kashmir Himalaya was carried out for formulating any conservation strategy.

STUDY AREA

The investigated springs are located in Kokergund Yaripora of Kulgam district and fall within the single large groundwater area. These springs are perennial and are situated around 33°44´ N latitude, 075°.01´ E longitude and at an altitude of about 1670±2 m(a.m.s.l.).These springs are surrounded by large trees comprising of *Populus*, *Ulmus*, *Acacia*, *Jugalanus*, *Platanus* etc. The springs are devoid of any macrophytic growth. All the three springs namely Nagrad,Tumbernag and Khudanag are alluvial type falling in sixth order classification based on discharge(Meinzer, 1923) with mean annual discharge of 0.401L/s, 0.172L/s and 0.299L/s respectively(Table 1). The area of spring was considered as the area of open water. The pristine naturalness of these springs has diminished because of anthropogenic modification such as concrete embankments for water storage which is used for various domestic purposes such as drinking water, irrigation, washing etc.

Table1.General characteristics of three limnocrene freshwater springs in Kokergund Yaripora, Kulgam

S.No	Parameter	NAGRAD	TUMBERNAG	KHUDANAG
1	Altitude	1665m	1667m	1667m
2	Lat. & Long.	33°44´N;075°.01´E	33°44´N;075°.01´E	33°44´N;075°.01´E
3	Mean annual discharge L/S	0.401	0.172	0.299
4	Spring order	6	6	6
5	*Spring type I. (Meinzer, 1923)*			
	(a) Hydraulic characteristics	Gravity-Contact type	Gravity-Contact type	Gravity-Contact type
	(b)Topography	Pool type	Pool type	Pool type
	(c)Permenance	Perrenial	Perrenial	Perrenial
	(d)Character of opening	Filtration type	Filtration type	Filtration type
	Spring type II. Thieneman (1924)	Limnocrene	Limnocrene	Limnocrene
6	Spring area(1-5)*	3	1	2
7	Naturalness(0-3)**	2	2	2
8	Substrate composition	Pebble, gravel, sand, less organic matter	Gravel with less sand	Gravel, sand, mud, organic matter

*Classes of spring area are: 1=<5m^2, 2= 5-10m^2, 3= 10-20m^2, 4=20-40m^2 and 5= 40-100m^2
**Spring naturalness are: 1= severe pressure/ damage from humans in spring or vicinity, 2= minor pressure/ damage in or near the spring, 3= almost or totally undisturbed spring in its surrounding.

MATERIAL AND METHODS

The field study was carried out during 2005-06 and the benthic samples were taken in summer (June), autumn (September), winter (December) and spring (March) with the help of D-net having 0.2mm mesh size. The organisms were collected while disturbing the substratum by kicking or forcing ahead the net (Hoffsten and Malmqvist, 2000).

Table 2. Seasonal variations in invertebrates (ind/m²) in three limnocrene freshwater springs														
Class/Order/ Taxa	Summer (June)			Autumn (September)			Winter (December)			Spring (March_			ANOVA Seasons P Value	ANOVA Siters P Value
	Nagrad	Tumber-nag	Khuda-nag	Nagrad	Tumber-nag	Khuda-nag	Nagrad	Tumbernag	Khuda-nag	Nagrad	Tumber-nag	Khuda-nag		
Mollusca														
Lymnea sp.	4	0	0	3	0	1	3	0	0	6	0	0	0.962	0.000
Corbicula sp.	3	0	1	4	0	0	4	0	0	8	0	1	0.852	0.001
Annelida														
Branchiura sowerbyii	25	12	280	40	16	456	35	21	396	35	15	180	0.921	0.000
Limnodrillus sp.	15	8	300	10	6	280	10	8	130	18	5	300	0.000	0.952
Tubifex tubifex	150	6	200	140	8	240	70	5	130	180	8	280	0.792	0.000
Arthropoda *Erpobdella octoculata*	20	12	30	32	20	45	8	2	56	25	18	60	0.782	0.003
Gammarus pulex	40	32	200	45	30	180	60	40	250	32	8	120	0.860	0.000
Illyocypris sp.	10		5	15	0	0	5	0	2	3	0	0	0.731	0.017
Cyclocypris sp.	15	0	2	10	0	0	6	0	1	1	0	4	0.810	0.027
Baetis rhodani	5	0	6	11	0	16	3	0	15	3	0	10	0.752	0.003
Rhyacophila obscura	2	0	0	6	0	0	3	0	0	0	0	0	0.686	0.037
Limnephilus sp.	0	0	6	0	0	21	0	0	14	0	0	20	0.909	0.001
Glossosoma sp.	0	0	0	0	0	3	0	0	3	0	0	0	0.596	0.100
Elmidae sp.	0	0	3	2	0	5	2	0	6	0	0	12	0.843	0.007
Corydalus sp.	1	0	2	2	2	1	3	0	2	2	0	0	0.633	0.127
Tipula sp.	3	0	2	4	0	5	2	0	2	1	0	2	0.532	0.014
Chironomus sp.	100	30	200	80	25	130	100	125	80	40	15	62	0.407	0.192
Simulium sp.	3	0	0	1	0	1	2	0	0	1	0	0	0.908	0.007
Tabanus sp.	1	0	0	1	0	0	1	0	0	0	0	0	0.802	0.007
Total	397	100	1237	406	107	1384	317	201	187	355	69	1051		

The samples were also taken 5by sweeping the top substrate of half a square meter once or twice ahead of D-net(Ilmonen and Paasivirta, 2005).The organisms were sorted out and the material was sieved through a sieve(mesh size 500µm) and preserved in 4% formalin and 70% alcohol depending upon the type of organisms to be preserved. The soft-bodied organisms were preserved in 70% alcohol while the shelled organisms like molluscs in 4% formalin (Borror *et al*., 1976). The identification of specimens was done with the help of standard taxonomical works (Edmondson,1959; Borror *et al*., 1976; Pennak, 1978;Ward,1992;Engblom and Lingdell, 1999; Yildiz and Balik, 2005; Rossetti *et al*., 2006).

RESULTS AND DISCUSSION

In all 19 taxa of invertebrates, insect as well as non-insect fauna, belonging to Diptera (04), Trichoptera (03), Coleoptera (01), Megaloptera (01), Ephemeroptera (01), Amphipoda (1), Ostracoda (02), Oligochaeta (03), Hirudinae (01) and Mollusca (02) were recorded from three springs. Nagrad and Khudanag registered more taxa (17 and 16) than Tumbernag (07). Diptera among the insects and Annelida among noninsect fauna were the best represented groups with four and three taxa respectively. *Chironomus* sp., *Limnodrilus* sp. , *Tubifex tubifex, Branchiura sowerbyii, Erpobdella octoculata* and *Gammarus pulex* were found in all the three springs throughout the sampling period without any significant variation among seasons (F-1.09, P-0.407,df-3; F-0.11, P-0.952,df-3; F-0.35.p-0.792,df-3; F-0.16,P-0.921, df-3; F-0.36,P-0.782,df-3; F-0.25, P-0.860,df-3) for the above species respectively. Seasonal distribution of taxa was not prominent as no single taxa was restricted to any particular season.However, *Rhyacophila obscura and Tabanus* sp. were absent in spring season while *Glossosoma* was absent in both the summer and spring seasons. The forms like *Simulium* sp. *Tabanus* sp. and *Rhyacophila* sp. having variance values (F-9.21,p-0.007,df-2; F-9.0,P-O.O7,df-2; F-4.84,P-0.037,df-2) were restricted to Nagrad spring while as *Limnephilus* sp. and Glossosoma sp.(F-19.55,P-0.001,df-2;F-3.0,P-0.100,df-2). were confined to Khudanag spring.

Among the spring invertebrates, *Chironomus* sp, *Tubifex tubifex,Limnodrilus, Erpobdella octoculata, Gammarus pulex* and *Branchiura sowerbyii* were the most dominant forms, being present in all the three springs .However, species like *Simulium* sp., Tabanus sp, *Lymnaea* sp. *Corbicula* sp., *Rhyacophila obscura* and *Glossosoma* sp. were least represented as only few individuals were encountered. Seasonal variation of benthic fauna reveals the maximum growth and abundance of spring invertebrates to be in the autumn at Nagrad(406 ind./m^2) and Khudanag (1384 ind/m^2) and winter at Tumbernag (201 ind/m^2). Among the sites the maximum mean seasonal population was obtained at Khudanag(1156 ind/m^2) followed by Nagrad (369 ind/m^2) and decreasing to a minimum of 119 ind./m^2 at Tumbernag.

All the three limnocrene freshwater springs are located in similar geologic strata and the differences between them in substrate composition are largely the result of local environmental factor, being an element of manipulation as well (Table 1.). These included the minor variations in current speed which affected the fine sediment transport with settlement besides being a source of allochthonous material especially leaf litter in Nagrad and Khudanag springs. In case of Tumbernag the bed has been modified by the addition of sand which accumulated between and on stones, as a result of which the range of habitats available to benthos was reduced(Marrshall and Winterbourn, 1979). Average number of invertebrate taxa collected per spring was 10 oscillating between 7 and 19 taxa. This number (7-19) is slightly lesser than the average invertebrate taxa collected from springs in the Pyrenees(6-30; Roca and Castillo, 1993) or in karstic regions of Poland(6-25; Dumnicka *et al*. 2007) and Slovenia(8-26; Mori and Brancelj, 2006). Large spring size and high discharge has been shown to increase the invertebrate number of taxa elsewhewre (Cantonati et al. 2006) and we believe this may be the case in our study because Nagrad spring has larger size and higher mean annual discharge than Khudanag and double that of the Tumbernag spring(Table1).Lower invertebrate diversity in spring habitats when compared to similar nearby runoff-fed streams has been reported elsewhere (Ward and Dufford, 1979; Anderson and Anderson, 1995).However, very slightly lower invertebrate diversity(16) in nearby runoff-fed stream(Saeskoon) against 19 in the studied springs has been reported(Bhat and Pandit, 2006).The lower invertebrate diversity in spring habitats of Cantabria, Spain in comparison to nearby runoff- fed streams has been attributed to the result of the intereaction between factors such as glaciation,flow constancy and predation(Barquin and Death, 2004).Predation by amphipods like *Gammarus pulex* may be important factor reducing the invertebrate diversity in the studied springs as has been reported elsewhere(Glazier, 1991; Barquin and Death, 2004;Zollhöefer et al., 2000).

In the present study large populations of *Gammarus pulex* showed codominance with certain oligochaetes like *Limnodrillus* sp., *Tubifex tubifex*, *Erpobdella octoculata* and *Branchiura sowerbyii* and Dipterans like Chironomus sp.However,Oligochaeta and Diptera dominated the fauna more prominently in the Nagrad and Khudanag and less prominently in Tumbernag spring.The presence of fine sediments with their high organic content and abundance of microbial colonization sites might be expected to provide favourable conditions for burrowing oligochaetes as the fine sediments fill the interstices between larger bed materials, decrease turbulence and reduce the number of dead spaces near the surface, (Lopez and Levinton, 1978).The authors believe that the physical heterogeinity of the substrate is reduced as is being reflected by a reduction in species richness. In contrast, springs charecterised by pebble,gravel sand leaf litter(Nagrad) and gravel,sand,mud,organic detritus(Khudanag) relatively maintain fairly high level of physical diversity,support populations of richer fauna which include amphipods like *Gammarus pulex* and insect larvae. Marshall and Winterbourn (1979) have shown that growth and productivity of Tubufex tubifex is greater in fine than coarse sediments and at nutrient enriched as opposed to non-enriched sites. In general, oligochaete communitiues have been observed in soft depositing substrates rather than stony beds. However, exception is the study of Lafont(1977) who found that Naididae,Lumbriculidae and Tubificidae made up 48, 23 and 22% of oligochaete fauna in stony substrates of running waters where as Tubificidae accounted for 92% of worms in soft sediments and still waters. Amphipoda like Gammarus pulex demonstrated numerically after *Chironomus , Tubifex tubifex,Limnodrilus* and *Branchiura sowerbyii* in these studied springs were subdominants also been obtained by Barquin and Death(2004).The results of this study are well in concordance with the previous studies carried out in other biogeographical areas depicting the differences in the macroinvertebrate assemblages between different spring types especially with respect to flow conditions and substrate characteristics. Our results confirm that substrate composition plays an important role for macroinvertebrate assemblages as it has been widely documented in literature (Bonettini and Cantonati, 1996;Hahn, 2000;Ilmonen and Paasivirta,2005).The present study reveals that the springs like Nagrad and Khudanag, with good percentage of leaf litter in substrate composition, harbour relatively fairly high diversity and density of *Gammarus pulex*, a fact also revealed by Cumminus *et al*. (1973) and Pandit *et al*.(1978).

The population density varied greatly and reached upto 1384 ind/m^2 in Khudanag spring in autumn followed by 406 ind/m^2 in Nagrad in autumn and 201 ind/m^2 in Tumbernag in winter.The higher invertebrate densities in spring habitats seems to be a globally recognized pattern (Barquin and Death, 2006).The mean annual density of invertebrates at Nagrad (369),Tumbernag(119) and Khudanag(1190) and their density ranges from317-406,69-201 and 957-1384 at three respective sites are lower than the invertebrate density reported elsewhere(Cantabrian springs- 6313-28615 ind/m^2; Barquin and Death, 2009; Karstic springs of Switzerland- (2250-14225 ind/m^2 ; Fumetti *et al*., 2007) and Austrian alpine springs-(3880-9750 ind/m^2; Staudacher and Fureder, 2007), helocrene springs in Denmark(>70000 ind/m^2; Lindegaard and Thorup, 1975; Thorup and Lindegaard,1977), Alluvial springs in Switzerland(>200000 ind/m^2; Zollohöefer,2000).The invertebrate density pattern in the springs under study may be related to the proportion of leaf litter deposited, being higher in Khudanag than in Nagrad, Tumbernag spring being devoid of any significant amount of leaf litter. It may also be opined that spring area is also believed to have some effect on invertebrate density pattern as also suggested by Cantonati *et al*. (2006). Most invertebrate orders as well as individual taxa showed marked differences in their relative abundances between the habitat types, although the most common taxa were represented in all springs except in Tumbernag. This result is in concordance with a study of a single spring in Denmark with variable benthic substrate types and flow conditions (Thorup and Lindegaard, 1977).The study reveals that discharge is one governing factor determining both the substrate composition and the macrozoobenthic assemblages in springs. The springs are also linked because of the influence of the substrate on macroinvertebrate assemblages.

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