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STUDIES ON THE DRIFTING BEHAVIORAL PATTERNS OF MACROZOOBENTHOS IN KYUNJA GAD, A MOUNTAIN STREAM FROM GARHWAL HIMALAYA, INDIA

Pankaj Bahuguna[1], Kumbhlesh Kamal Rana[2], Rajesh Rayal[2] and Hemant Kumar Joshi[3*]

[1]*Aquatic biodiversity Lab, Department of Zoology, B. D. Govt. P.G. College Jaiharikhal-246193, Uttarakhand, India.*
[2]*Department of Zoology, School of Basic and Applied Sciences, SGRR University, Patel Nagar, Dehradun, Uttarakhand, India.*
[3]*Department of Zoology, Government Degree College Chaubattakhal-246155, Pauri Garhwal, Uttarakhand, India.*

Corresponding Author Email id: drjoshihk2013@gmail.com

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Abstract: Macrozoobenthos displayed several interesting trends with regards to their occurrence and movement in the streams in response to various abiotic and biotic factors constituting the aquatic ecosystem. These are considered of great ecological significance in understanding the quality of the particular ecosystem. The present communication focused on understanding the spatial and temporal diel drifting patterns displayed by macrozoobenthos in different levels of stream orders at different duration round the clock. It was observed that there was a general preference of nocturnal and early evening hours of drifting. The drift by benthic species was performed mainly due to presence of predators, lack of proper food and breeding sites. The study revealed that highest diel drift density and diversity of macrozoobenthos was found in 3rd order in comparison to 2nd and 1st order of Kyunja Gad stream. Variations were also noted in the physico-chemical parameters of streams Kyunja Gad at different orders.

Key words: Macrozoobenthos, Diel Drifting Pattern, Kyunja Gad Mountain stream, Garhwal Himalaya, India

Introduction

Muller (1954) was the pioneer in describing downward transport of benthic invertebrates as drift. It is considered as common phenomenon in running water bodies (Brittian and Eikeland, 1988). Drift is considered to be an important feature of lotic ecosystem as it promotes dispersal and colonization of aquatic organisms (Towsend, 1989; Hughes, 1998).The drift is classified as catastrophic, behavioral, active, distributional and constant (Brittain and Eikeland, 1988). Invertebrate drift is thus defined as the downstream movement of benthic invertebrates in the water column that is generally found in or around the substratum of streams and rivers (Anderwald et al., 1991).

Earlier work on diel periodicity was conducted by Moon (1940) and Harker (1953). Studies on diel drift however, showed a notable trend after 1960, stimulated by the discovery of diel periodicity in many taxa in several parts of the world (Water 1972; Muller 1974). Two mechanisms are recognized for diel periodicity on the substratum namely (a). Diel positioning change and (b) Diel activity levels (Wiley and Kohler, 1984). Diel positioning changes of macrozoobenthos mainly referred to diel density changes in the top surface of the substratum. The reasons mainly accounted for various theories proposed for this mechanism regarding presence of those benthic animals on the top surfaces of the substratum mainly at night being Phototaxis, response to predation, foraging periodicity, and respiratory needs of animals (Hynes 1970; Waters 1972; Wiley and Kohler 1984).

In Garhwal region, the studies on benthic macroinvertebrates dynamics have been carried out by several researchers (Dobriyal et al., 2009; Katoch et.al.,2015; Balodi and Koshal (2015;, Koshal et al. (2017); Bahuguna et.al., 2019;), but drift studies are almost neglected. Majority of drifting studies till date have been conducted at relatively lower altitude and no published literature was found on the diel drifting behavioral patterns of the Indian central Himalayan water system flowing in different order levels. Therefore, the present study was undertaken to fill this lacuna in literature.

Material and Methods

Study area

The study was conducted in Kyunja Gad stream – a spring fed perennial tributary of Mandakini river from Garhwal Himalaya, India. It originates from Swami Kartik temple at an elevation of 1497 meter. Stream is narrow in upper course, widening towards its confluence with river Mandakini. Substratum of stream consists of boulders, cobbles, pebbles and tiny sand particles. Habitat heterogeneity (riffle, run, rapid, and pool) is a characteristic feature of the stream. Sampling sites were selected for Kyunja Gad stream in first order (origin of stream), second order (confluence of two first order streams create a 2^{nd} order stream) and third order (confluence of two second order streams forms a 3^{rd} order stream). Three sampling Sites: 1^{st} order stream (Spot K_1 - 30° 21.11'N and 78° 58.40' E) near Monkhal village, 2^{nd} order stream (Spot K_2 - 30° 25'20"N and 79° 07'38"E) Jayakandi village and 3^{rd} order stream (Spot K_3 - 30° 25' 08" N and 79° 03' 52" E) were studied at Chandrapuri market near the confluence of the stream with the river Mandakani (Fig.1).

Sampling Method

The drifting sampling method was followed as per Smock (1996). The drift nets described by Field-Dodgson (1965) having an internal diameter of 16.6 cm, a length of 1.7 m and 220 micron mesh size has been used. The nets were set for 3hours. As far as possible replicate samples were taken for riffle and runs for increased precision in estimates of total density and species diversity.

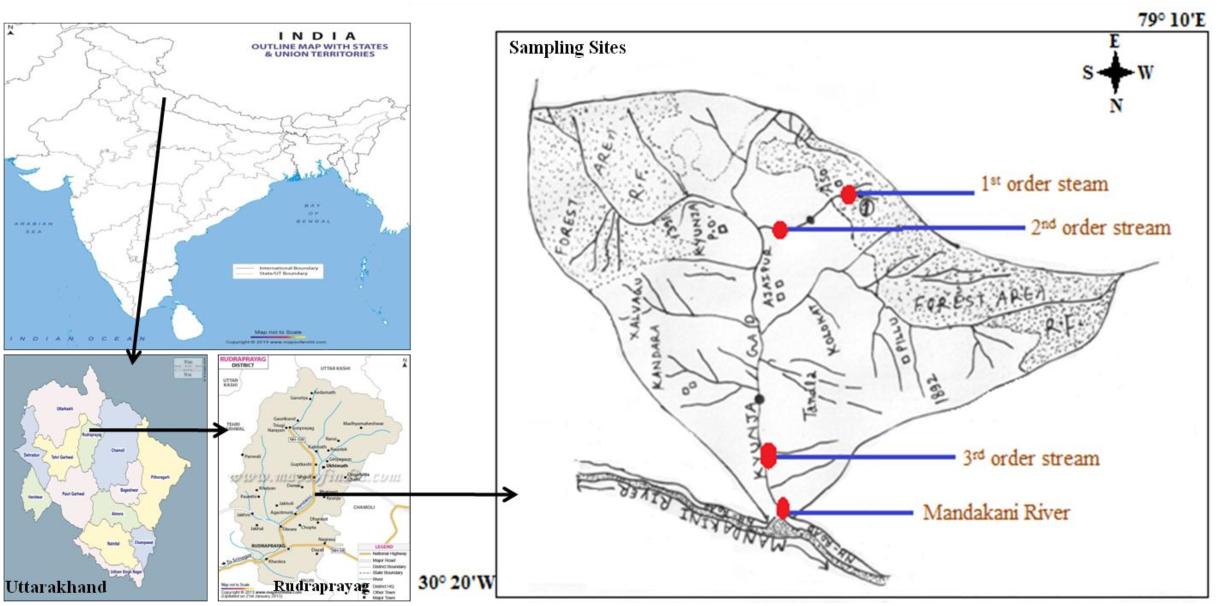

Figure 1: Sampling sites in Kyunja Gad.

The diel drift density of various macrozoobenthos was collected during different periods of the whole day at all the 3 spots (1^{st} order, 2^{nd} order and 3^{rd} order stream) and population has been expressed in individuals/100m^3/hours.

The drifting macrozoobenthos were preserved in 70% ethyl alcohol and brought to the laboratory for enumeration and identification using standard keys and monographs (Ward and Whipple, 1966; Needham and Needham, 1962; Tomka and Zurwerra, 1985 etc.). The identification was done to the lowest possible taxon. APHA (1976) protocols were used for the measurement of Physico-chemical conditions prevailing at 1st, 2nd and 3rd order streams during each collection period.

Results

Characteristics of Abiotic factors in Kyunja Gad Stream: Variations were noted in the physico-chemical parameters of different order streams of Kyunja Gad. Water temperature of the stream oscillated from 7.9 ± 1.1^0C to 15.8 ± 1.2^0C (1st Order Stream), 10.9 ± 2.1^0C to 22.2 ± 2.4^0C (2nd Order stream) and 15.8 ± 2.7^0C to 23.5 ± 3.1^0C (3rd O.S.). Similarly, current velocity ranged from 0.256 ± 0.021 m.s^{-1} to 0.656 ± 0.032 m.s^{-1} (1st O.S.), 0.264 ± 0.035 m.s^{-1} to 0.728 ± 0.097 m.s^{-1}(2ndO.S.) and 0.340 ± 0.051 to 0.875 ± 0.754 m.s^{-1} (3rd O.S.). Dissolved oxygen content varied from 7.4 ± 0.2 to 9.4 ± 1.6 mg.l^{-1} (1stO.S.), 7.2 ± 0.2 to 9.1 ± 0.7 mg.l^{-1} (2ndO.S.) and 7.0 ± 0.2 to 8.9 ± 0.5 mg.l^{-1} (3rd O.S.).

Diel drifting variation of macrozoobenthos in different order streams

A total of 2202 samples were collected throughout the study period collectively from all the three sites. Among all the three sites maximum specimens were obtained from 3rd order stream (1160 samples) followed by 2nd order stream (791samples) whereas least from 1st order stream (323samples). Along with the number of specimens collected, the species richness and species belonging to different orders of aquatic insect followed the similar trend with maximum being 40 species belonging to 9 orders, 32 species belonging to 8 orders and 17 species belonging to 6 insect orders respectively in 3rd, 2nd and 1st order Kyunja stream (Fig.2).

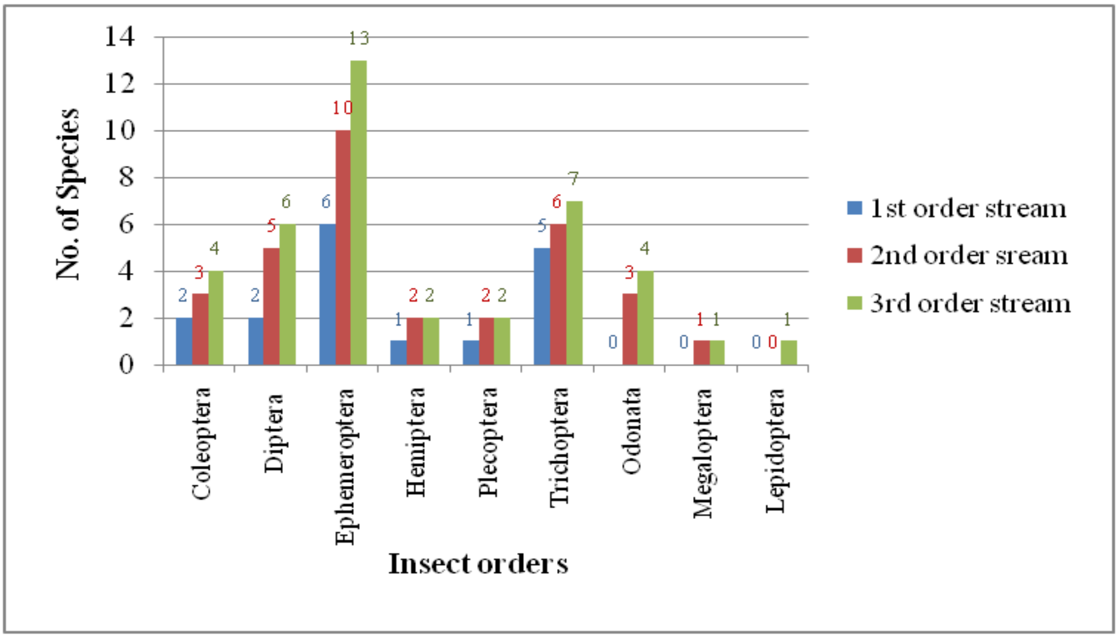

Figure 2: Graph showing different orders with number of species found in all three streams

Diel drifting behavioral patterns in different order streams

The study reveals that maximum diel drift density and diversity of macrozoobenthos was found in 3rd order stream in comparison to 2nd and 1st order. During the study fifteen (15) common species were recorded from all the sampling sites

they are *Psephenus tenulpes*, *Elmid (larva)*, *Simulium*, *Tipula*, *Caenis*, *Ecdyonurus*, *Ephemerella indica, Heptagenia, Heleocoris vicinus, Neoperla, Hydropsyche, Stenopsyche himalayana, Chimarra, Glossosoma caudatum and Rhyacophila similis.*

Sixteen (16) species were found common in 2nd and 3rd order stream namely *Hydrophilus, Atherix, Antocha, Chironomus, Ameletus, Atalophlebie, Baetis rhodani, Prosopistoma, Crinitella, Rhithrogeniella, Gerris, Argia, Zygonyx, Euphaea, Stenopsyche himvatika and Corydalus camutus*. *Isonychia* is the one only found in both 1st and 3rd order stream. Eight (8) species viz. *Berosus indicus, Hemerodromia, Platybaetis, Siphhlonurus, Progomphus, Isoperla, Chematopsycle,* and *Parapoynx* found only from 3rd order stream. Throughout the study a total number of 42 species were observed from 9 different orders.

In case of 1st order stream, it was noticed that *Simulium, Psephenus tenulpes, Baetis niger* and *Hydropsyche* was found maximum in number with total of 42, 37, 31 and 30 respectively (Table 1). In case of 2nd order stream it was noticed that *Baetis rhodani* (105), *Ameletus* (51), *Psephenus tenulpes* (46), *Caenis* (46), *Hydropsyche* (36) and *Heptagenia* (36) recorded maximum in number with total of 791 samples (Table 2). In case of 3rd order stream, it was observed that *Berosus indicus* (21), *Psephenus tenulpes* (81), *Simulium* (109), *Ameletus* (131), *Baetis rhodani* (87), *Caenis* (52), *Ecdyonurus* (95), *Euphaea* (24), *Neoperla* (32), *Hydropsyche* (48), *Stenopsyche himvatika* (44), *Stenopsyche himalayana* (27), *Chimarra* (39), *Parapoynx* (40) was found highest in total number during the whole diel drifting sampling work round the year (Table 3).

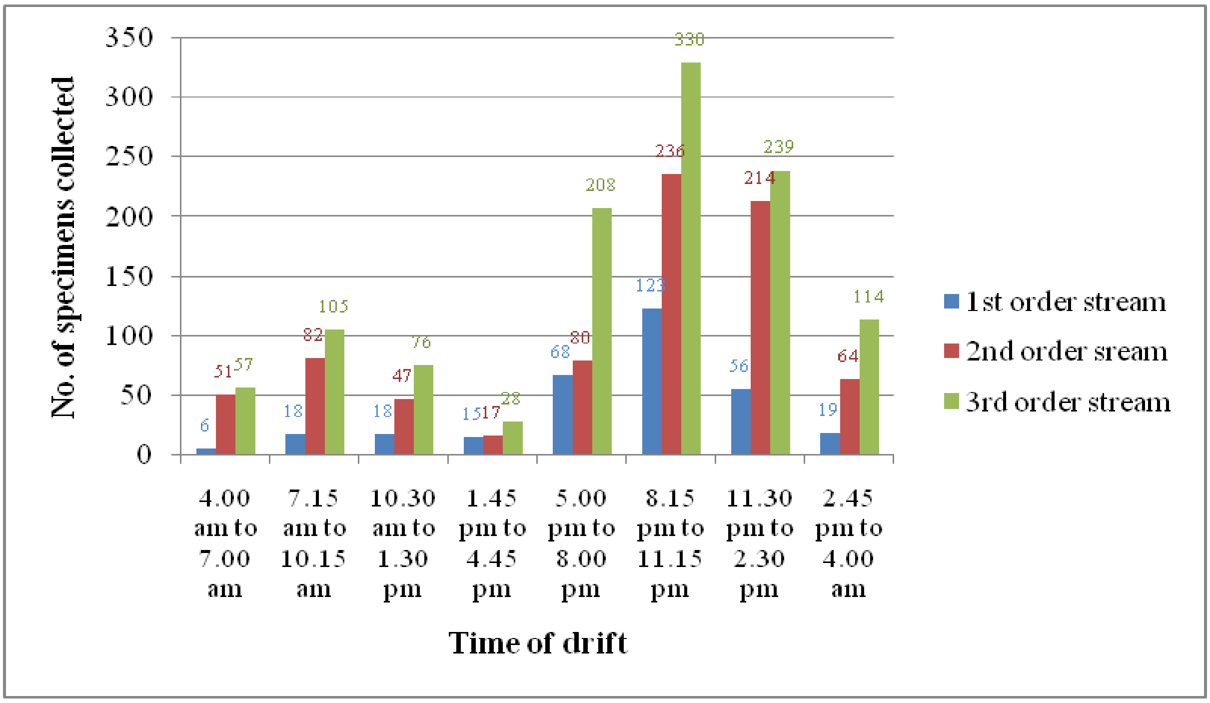

Figure 3: Graph showing diel drift of macrozoobenthos in all three streams.

Table 1: Diel drift value of macrozoobenthos observed in 1st order stream Kyunja Gad during October 2017 to September 2018

S.N	**Periodicity**	**Diurnal drift**				**Nocturnal drift**				**Total no. of diel drift indivi-dual**
	Sampling Time	4.00am to 7.00am	7.15am to 10.15am	10.30am to 1.30pm	1.45pm to 4.45pm	5.00pm to 8.00pm	8.15pm to 11.15pm	11.30pm to 2.30am	2.45am to 4.00am	
Order	**Name of the Genus/ species**	Early morning	Late morning	Day Period	Day Period	Early evening	Night period	Night period	Night period	
Coleoptera										
1	*Psephenus tenulpes*	0	0	0	0	10	19	5	3	**37**
2	*Elmid(larva)*	0	0	0	0	0	9	5	0	**14**
Diptera										
3	*Simulium*	0	0	0	0	7	21	9	5	**42**
4	*Tipula*	1	2	6	5	2	4	1	1	**22**
Ephemeroptera										
5	*Baetis niger*	0	0	0	0	8	14	6	3	**31**
6	*Caenis*	0	0	0	0	7	9	2	0	**18**
7	*Ecdyonurus*	0	0	0	0	3	3	5	1	**12**
8	*Ephemerella indica*	1	2	1	1	1	1	2	1	**10**
9	*Heptagenia*	0	0	0	0	7	8	5	2	**22**
10	*Isonychia*	1	5	6	2	0	0	0	0	**14**
Hemiptera										
11	*Heleocoris vicinus*	1	2	2	2	3	2	2	1	**15**
Plecoptera										
12	*Neoperla*	0	2	1	1	0	2	2	0	**08**
Trichoptera										
13	*Hydropsyche*	0	0	0	0	8	17	5	0	**30**
14	*Stenopsyche himalayana*	1	3	2	2	0	3	2	1	**14**
15	*Chimarra*	0	0	0	0	6	7	3	1	**17**
16	*Glossosoma caudatum*	0	0	0	0	5	3	1	0	**09**
17	*Rhyacophila similis*	1	2	0	2	1	1	1	0	**08**
Total		**6**	**8**	**18**	**15**	**68**	**123**	**56**	**119**	**323**

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Table 2: Diel drift value of macrozoobenthos observed in 2nd order stream Kyunja Gad during October 2017 to September 2018

S.No.	**Periodicity**	**Diurnal drift**				**Nocturnal drift**				**Total no. of diel drift indivi-dual**
	Sampling Time	4.00am to 7.00am	7.15am to 10.15am	10.30am to 1.30pm	1.45pm to 4.45pm	5.00pm to 8.00pm	8.15pm to 11.15pm	11.30pm to 2.30am	2.45am to 4.00am	
Order	**Name of the Genus/ species**	Early morning	Late morning	Day Period	Day Period	Early evening	Night period	Night Period	Night period	
Coleoptera 1	*Elmid(larva)*	0	0	0	0	3	4	1	1	**09**
2	*Hydrophilus*	1	2	3	1	0	0	0	0	**07**
3	*Psephenus tenulpes*	0	0	0	0	10	17	14	5	**46**
Diptera 4	*Atherix*	0	1	3	4	1	2	2	2	**15**
5	*Antocha*	2	2	2	1	1	2	1	1	**12**
6	*Tipula*	0	0	0	0	0	11	7	2	**20**
7	*Simulium*	6	13	0	0	0	15	12	0	**46**
8	*Chironomus*	13	16	7	3	0	0	0	0	**39**
Ephemeroptera 9	*Ameletus*	0	0	0	0	18	21	12	0	**51**
10	*Atalophlebie*	2	4	2	1	1	4	3	1	**20**
11	*Baetis rhodani*	0	0	0	0	18	29	37	21	**105**
12	*Caenis*	0	0	0	0	3	22	17	4	**46**
13	*Ecdyonurus*	0	0	0	0	5	10	9	4	**28**
14	*Ephemerella indica*	1	4	5	2	1	4	5	1	**23**
15	*Heptagenia*	0	0	0	0	4	15	16	2	**37**
16	*Prosopistoma*	2	3	2	0	0	3	2	1	**13**
17	*Crinitella*	7	8	0	0	0	0	0	0	**15**
18	*Rhithrogeniella*	0	0	0	0	0	6	7	1	**14**
Hemiptera 19	*Gerris*	1	2	1	1	1	2	1	1	**10**
20	*Heleocoris vicinus*	2	2	3	0	0	0	0	0	**07**
Odonata 21	*Argia*	2	1	3	1	3	2	3	1	**16**
22	*Zygonyx*	0	2	1	1	0	2	2	1	**09**
23	*Euphaea*	0	0	0	0	0	9	7	6	**22**
Plecoptera 24	*Neoperla*	1	2	3	0	1	3	2	0	**12**
25	*Nemoura*	0	0	0	0	0	1	2	0	**03**
Trichoptera 26	*Hydropsyche*	0	0	0	0	0	14	19	3	**36**
27	*Stenopsyche himvatika*	2	3	2	1	1	5	5	0	**19**
28	*Stenopsyche himalayana*	6	14	7	0	0	0	0	0	**25**
29	*Chimarra*	0	0	0	0	5	14	13	2	**34**
30	*Glossosoma caudatum*	0	0	0	0	0	8	7	0	**15**
31	*Rhyacophila similis*	0	0	0	0	2	8	5	3	**18**
Megaloptera 32	*Corydalus camutus*	3	3	3	1	2	3	3	1	**19**
Total		**51**	**82**	**47**	**17**	**80**	**236**	**214**	**64**	**791**

Table 3: Diel drift value of macrozoobenthos observed in 3rd order stream Kyunja Gad during October 2017 to September 2018

S.No.		Periodicity	Diurnal drift				Nocturnal drift				Total no. of diel drift indivi-dual
		Sampling Time	4.00am to 7.00am	7.15am to 10.15am	10.30am to 1.30pm	1.45pm to 4.45pm	5.00pm to 8.00pm	8.15pm to 11.15pm	11.30pm to 2.30am	2.45am to 4.00am	
Order		**Name of the Genus/ species**	Early morning	Late morning	Day Period	Day Period	Early evening	Night period	Night period	Night period	
Coleoptera	1	*Berosus indicus*	3	2	4	2	2	5	1	2	**21**
	2	*Elmid(larva)*	0	0	0	0	3	5	1	1	**10**
	3	*Hydrophilus*	2	4	4	0	0	0	0	0	**10**
	4	*Psephenus tenulpes*	0	0	0	0	16	31	25	9	**81**
Diptera	5	*Atherix*	0	2	3	0	1	3	2	2	**13**
	6	*Antocha*	1	0	2	1	1	2	1	1	**09**
	7	*Tipula*	0	0	0	0	2	6	8	2	**18**
	8	*Simulium*	10	24	18	8	9	14	17	9	**109**
	9	*Chironomus*	5	8	6	0	0	0	0	0	**19**
	10	*Hemerodromia*	0	0	0	0	1	5	3	0	**09**
Ephemeroptera	11	*Ameletus*	0	0	0	0	32	41	38	20	**131**
	12	*Atalophlebie*	2	3	2	2	3	4	2	1	**19**
	13	*Baetis rhodani*	0	0	0	0	11	33	24	19	**87**
	14	*Caenis*	0	0	0	0	19	14	16	3	**52**
	15	*Ecdyonurus*	0	0	0	0	23	35	24	13	**95**
	16	*Ephemerella indica*	3	4	2	2	2	3	2	1	**19**
	17	*Heptagenia*	0	0	0	0	3	7	5	2	**17**
	18	*Prosopistoma*	1	3	1	1	2	2	1	1	**12**
	19	*Isonychia*	3	5	3	0	0	0	0	0	**11**
	20	*Platybaetis*	2	5	0	0	0	0	0	0	**07**
	21	*Crinitella*	2	4	0	0	0	0	0	0	**06**
	22	*Rhithrogeniella*	0	0	0	0	5	4	1	1	**11**
	23	*Siphhlonurus*	5	7	0	0	0	0	0	0	**12**

Cont….

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Hemiptera	24	*Gerris*	2	1	3	1	1	3	1	1	**13**
	25	*Heleocoris vicinus*	1	4	3	0	0	0	0	0	**08**
Odonata	26	*Argia*	1	2	1	1	1	2	1	0	**09**
	27	*Zygonyx*	1	1	1	1	1	1	1	1	**08**
	28	*Euphaea*	0	0	0	0	7	10	4	3	**24**
	29	*Progomphus*	0	0	0	0	2	3	2	0	**07**
Plecoptera	30	*Neoperla*	3	5	5	3	4	6	4	2	**32**
	31	*Isoperla*	0	0	0	0	3	3	7	1	**14**
Trichoptera	32	*Hydropsyche*	0	0	0	0	15	22	10	1	**48**
	33	*Stenopsyche himvatika*	3	8	7	4	5	7	8	2	**44**
	34	*Stenopsyche himalayana*	6	11	9	1	0	0	0	0	**27**
	35	*Chimarra*	0	0	0	0	10	19	8	2	**39**
	36	*Glossosoma caudatum*	0	0	0	0	6	7	7	4	**20**
	37	*Rhyacophila similis*	0	0	0	0	4	9	3	1	**18**
	38	*Chematopsycle*	1	2	2	1	1	2	1	0	**10**
Megaloptera	39	*Corydalus camutus*	0	0	0	0	6	8	2	2	**18**
Lepidoptera	40	*Parapoynx*	0	0	0	0	8	15	11	6	**40**
Total			**57**	**105**	**76**	**28**	**209**	**331**	**241**	**113**	**1157**

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Maximum drift was noticed during the night phase in all the streams while minimum was seen in day time. In 1st order stream 10 out of total 17 species exhibited nocturnal drift i (5.00 pm to 8.00 pm and 8:15 pm to 11:15pm) while only one species *Isonychia* drifted in a incessant pattern throughout day time. Rest species *Tipula*, *Ephemerella indica*, *Heleocoris vicinus*, *Neoperla*, *Stenopsyche himalayana and Rhyacophila similis* followed irregular patterns throughout the 24 hours with no special affinity for any specific day or night hours. (Table 1). The maximum drift (123 individuals/100m^3/3hours) was observed in night period around 5.0pm to 8.0pm and 8:15pm to 11:15pm and in 1st order stream. Minimum (06 individuals/100m^3/3hours) were recorded during early morning hours around 4:0am to 7:0am. In case 2nd order stream, lowest drift number (17individuals/100m^3/3hours) was recorded during day time between 1:45pm to 4:45pm (Table 2 and Fig.3) and highest drift number (236 and 214individuals/100m^3/3hours) in night period (8:15pm to 11:15pm and 11.30pm to 2.30am). In the 2nd order stream 15 out of total 32 species exhibited continuous night drift and 12 species had irregular pattern of drift (Table 2). There were five species *Hydrophilus*, *Chironomus*, *Crinitella*, *Heleocoris vicinus* and *Stenopsyche himalayana* which were seen following a continuous pattern of diurnal drift indicating that they are found only at day time.

During investigation of 3rd order stream, it was observed that 19 species out 40 showed array of continuous nocturnal drift and 13 species displayed discontinuous pattern of movement during both day and night time. Concurrently only 8 species *Hydrophilus*, *Chironomus*, *Isonychia*, *Platybaetis*, *Crinitella*, *Siphhlonurus*, *Heleocoris vicinus* and *Stenopsyche himalayana* demonstrated continuous diurnal drift pattern (Table 3). Minimum drift number (28individuals/100m^3/3hours) was recorded during day period between 1:45pm to 4:45pm (Table 3 and Fig.3) and peak drift number (331 and 214 individuals/100m^3/3hours) was noticed in night period of 8:15pm to 11:15pm and 11.30pm to 2.30pm at this spot.

Discussion

Significant drift pattern of macrozoobenthos was recorded in the present study which varied in different levels of stream order due to their geomorphological characteristics. In the first order stream only 10 species were observed performing diel drift (order-Coleoptera-*Psephenus tenulpes* and *Elmid(larva);*order-Diptera-*Simulium;* order-Ephemeroptera-*Baetis niger*, *Caenis*, *Ecdyonurus* and *Heptagenia;* order-Trichoptera-*Hydropsyche*, *Chimarra*, *Glossosoma caudatum*) while the number increased to 15 in second order (order-Coleoptera-*Elmid (larva)* and *Psephenus tenulpes;* order-Diptera-*Tipula;* order-Ephemeroptera-*Ameletus*, *Baetis rhodani*, *Caenis*, *Ecdyonurus*, *Heptagenia* and *Rhithrogeniella;* order-Odonata-*Euphaea*, *Nemoura*, order-Trichoptera-*Hydropsyche*, *Chimarra*, *Glossosoma caudatum* and *Rhyacophila similis*) and 19 in 3rd order (order- Coleoptera- *Elmid (larva)* and *Psephenus tenulpes;* order-Diptera-*Tipula and Hemerodromia;* order-Ephemeroptera-*Ameletus*, *Baetis rhodani*, *Caenis*, *Ecdyonurus*, *Heptagenia sulphurea* and *Rhithrogeniella;* order-Odonata-*Euphaea* and *Progomphus;* order-Plecoptera-*Isoperla;* order-Trichoptera-*Hydropsyche*, *Chimarra*, *Glossosoma caudatum* and *Rhyacophila similis;* order- Megaloptera-*Corydalus camutus and* order-Lepidoptera-*Parapoynx*).

Similar observations were reported by Moon (1940); Elliott (1968) and Bailey (1981). Casey (1987) reported that a diel periodicity for *Drunella coloradensis* and *Baetis* nymphs was found at proportionally greater densities on the top of the substratum in the dark than in the light period.

Elliott (2002) reported that the mechanism of invertebrate drift often leads to an increase in upstream movements and in downstream dispersal. Most streams invertebrate increase their activity at night. It is generally observed that the highest density occurs just after sunset and another one (slightly lower) before sunrise (Waters 1972; Brittain and Eikeland 1988; Allan 1995). High nocturnal densities of prey on top of the substratum is chiefly escape from the a visually feeding predator active during day hours moreover, nocturnal decrease in dissolved oxygen in the substratum may cause a migration from the bottom surfaces of the substratum to more exposed surfaces at night (Wiley and Kohler 1980).

Some benthic insects were also observed performing daylight drifts in Kyunja Gad Stream. One species (*Isonychia*) in first order stream, five (*Hydrophilus, Chironomus, Crinitella, Heleocoris vicinus* and *Stenopsyche himalayana*) in second order stream and eight species (*Hydrophilus, Chironomus, Isonychia, Platybaetis, Crinitella, Siphhlonurus, Heleocoris vicinus* and *Stenopsyche himalayana*) in third order stream were observed performing specific day light drift. Several studies that employed direct observations on running water streams macrozoobenthos have demonstrated density increases in the day light (Graesser and Lake 1984; Statzner and Mogel 1984, 1985; Allan et.al. 1986).

The species like *Tipula, Ephemerella indica, Heleocoris vicinus, Neoperla, Stenopsyche himalayana Rhyacophila similis, Atherix, Antocha, Simulium, Atalophlebie, Prosopistoma, Gerris, Argia, Zygonyx, Neoperla, Stenopsyche himvatika, Corydalus camutus, Berosus indicus and Chematopsyche* showed indefinite pattern of drift in all the 3 sites studied. Irregular drift pattern is reported by many limnologists working on macro zoobenthos. Incident light has been shown to be key role in the management of drift behavioral patterns. (Water 1972; Muller 1974; Casey 1987).

Day-night alterations in the spatial distribution of insects in a stony stream were studied by Elliott (2002). The nocturnal activities of mayfly *Baetis* was interpreted by Kohler (1985) mainly through the foraging activities which was however opposed by Wilzbach (1990). When animals are abundant enough to outbalance the capacity of their microhabitat, density-dependent drift is observed. However, population densities are maintained below this level due to physical perturbation and predation (Bishop and Hynes 1969; Ciborowski 1983). Hay et al. (2008) reported the influence of limited food availability on the drifting behaviour of Macrozoobenthos. Statzner et.al, (1985) noted that abundance of food, predators and intra-specific density are the most important biotic factors affecting the drift of a taxon. Fish predation and invertebrate drift (odonata) relation was also reported by Bahuguna et al. (2019).

Conclusion

The study emphasizes on the fact that drift is a very important behavior of benthic insects at larval and nymphal stage which is performed specifically by different species during either night hours or day light hours or may be irregular depending upon eco-physiological requirements.

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References

Allan JD (1995) *Stream ecology. Structure and function of running waters*. Chapman & Hall London: 1-388.

Allan JD Flecker AS and McClintock NL (1986) Diel epibenthic activity of mayfly nymphs and it nonconcordance with behavioural drift. *Limnol. Oceanogr.*31: 1057-1065.

Anderwald PH, Konar HM and Humpesch UH (1991) Continuous drift samples of macroinvertebrates in a large river, the Danube in Austria. *Freshw. Biol.* 25: 461-476.

APHA (1976) *Standard methods for the examination of water and waste waters.* APHA, AWWA and WPCF, New York. 1-1193.

Bahuguna P, Joshi HK and Kumar K (2019) A report on drifting behaviour of odonata (aquatic insects) in Kyunja Gad, a spring fed tributary of river Mandakani, Chamoli Garhwal, Uttarakhand. *J. Mountain Res.* 14(2): 63-67.

Bailey PCE (1981). Diel activity patterns in nymphs of an Australian mayfly Atalophlebioides sp. (Ephemeroptera: Leptophlebiidae). *Aust. J. Mar. Freshwat. Res*. 32:121-131.

Balodi VP and Koshal Kumar (2015) Macro-Zoobenthic study in relation to physico Chemical parameters of Khoh River in Uttarakhand. *Int. J. of Sci. Res.* Vol.4 (6) 171-173.

Bishop JE and Hynes HBN (1969). Downstream drift of the invertebrate fauna in a stream ecosystem. *Arch. Hydrobiol.* 66:56-90.

Brittain JE and Eikeland TJ (1988) Invertebrate drift-a review. Hydrobiologia, 166(1): 77-93.

Casey RJ (1987) Diel periodicity in density of Ephemeroptera nymphs on stream substrata and the relationship with drift and selected abiotic factors. *Can. J. Zool.* 65: 2945-2952.

Ciborowski JJK (1983) Influence of current velocity, density and detritus on drift of two mayfly species (Ephemeroptera). *Can. J. Zool* 61: 119-125.

Dobriyal AK, Balodi VP, Joshi HK, Thapliyal A, Bahuguna P, Uniyal SP and Kotnala C B 2009. Substratum heterogeneity and indicator macro-zoobenthos of the Eastern Nayar, Garhwal, Central Himalaya. *J. Mountain Res.* 4: 130-135

Elliott JM (1968) The daily activity patterns of mayfly nymphs (Ephemeroptera). *J. Zool.* 155: 201-221.

Elliott JM (2002) Time spent in the drift by downstream-dispersing invertebrates in a Lake District Stream. *Freshw. Biol.* 71: 112-122.

Field and Dodgson MS (1985) A simple and efficientdriftsampler. *New. Zeal. J. mar. Fresh.* 19: 167- 172.

Graesse A and Lake PS (1984) Diel changes in the benthos of stones and of drift in a Southern Australian upland stream. *Hydrobiolo.* 111:153-160.

Harker J E (1953). The diurnal rhythm of activity of mayfly nymphs. *J. Ex. Biol.* 30: 525-533.

Hay C H, Franti T G, Marx D B, Peters E J and Hesse L W (2008). Macroinvertebrate drift density in relation to abiotic factors in the Missouri River. *Hydrobiologia* 598: 175-189.

Hughes N F (1998). A model of habitat selection by drift-feeding stream salmonids at different scales. *Ecology*, 79(1): 281-294.

Hynes HBN (1970) *The Ecology of Running Waters.* Liverpool Univ. Press, U.K., 555 pp.

Katoch PD, Balodi VP, Thapliyal A, Koshal Kumar, Md. Rashid, Md. Sagir and Dobriyal AK (2015) Population structure and diversity analysis of benthic Ephemeropterans in Western Nayar river during 2014-15, *J. Mountain Res.*, 10: 55-66.

Koshal Kumar, Rana JS, Rana AR and Kotnala, CB (2017) Checklist of Benthic Macroinvertebrate Communities of Stream Rawasan In Garhwal Region (Central Himalaya), Uttarakhand (India). *J. Mountain. Res* 12: 91-95.

Kohler SL (1985) Identification of stream drift mechanisms: An experimental and observational approach. *Ecology* 66 (6): 1749-1761.

Moon HP (1940) An investigation of the movements of fresh-water invertebrate faunas. *J. Anim. Ecol.* 9: 76-83.

Muller K (1954) Investigations on the organic drift in north Swedish streams. *Rep. Inst. Freshwat. Res. Drottningholm* 35: 133-148.

Muller K (1974) Stream drift as a chronobiological phenomenon in running water ecosystems. *Annu Rev Ecol Systemat* 5: 309-323.

Needham I G and Needham P R (1962). *A guide to the study of freshwater biology. San Francisco Holden Day Inc.* 108 PP.

SmockL A (1996). Macroinvertebrate movements: Drift, colonization and emergence. *In Hauer, F. R. and G. A. Lamberti(eds.), Methods in stream ecology, Academic Press, New York*.

Statzner B and Mogel R (1984) No relationship between the substrate surface densities and drift of the stream caddis fly Micrasema longulum (Brachycentridae: Trichoptera). *Proceeding of the 4th International Symposium on Trichoptera, Clemson, South Carolina*, 1983. Edited by J. C. Morse. Dr.W. Junk by Publishers, The Hague: 383-389.

Statzner B, Elouard, JM and Dejoux C (1985) Field experiments on the relationship between drift and benthic densities of aquatic insects in tropical streams (Ivory Coast). II. *Cheumatopsyche falcifera* (Trichoptera: Hydropsychidae). *J. Anim. Ecol*. 55:93-110.

Tomka I and Zurwerra A (1985) Key to the genera of the Heptageniidae (Ephemroptera) of the Holarctic, Oriental and Ethiopian region. *Em. Ber. Luzern.* 14: 113- 126.

Townsend CR (1989) The patch dynamics concept of stream community ecology. *J. N. Am. Benthol. Soc.* 8(1): 36-50.

Ward HB and Whipple GV (1966*) Freshwater Biology* (ed. W.T. Edmondson). *Wiley and sons. Inc.* New York 1203 pp.

Waters TF (1972) *The drift of stream insects.* Annual Review Entomology17: 253-272.

Wiley MJ and Kohler SL (1980) Positioning changes of mayflies nymphs due to behavioural regulation of oxygen consumption. *Can. J. Zool.* 58: 618-622.

Wiley MJ, and Kohler SL (1984) Behavioral adaptations of aquatic insects. In: *The ecology of aquatic insects.* Edited by V. H. Resh and D.M. Rosenberg. Frederich A. Praeger Inc., New York pp. 101-133.

Wilzbach MA (1990) Nonconcordance of drift and benthic activity in Baetis. *Limnol. Oceanogr.* 35(4): 945-952.

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