VOLUME 10 ISSUE 1 2024

ISSN 2454 – 3055

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 10, No. 1, 1077-1085 (2024)

International Journal of Zoological Investigations

Contents available at Journals Home Page: www.ijzi.net

Editor-in-Chief: Prof. Ajai Kumar Srivastav

Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Diversity and Spatial-Temporal Distribution of Hydrachnidia Fauna in Laster Gad, a Spring-Fed Stream of Garhwal Himalaya, Uttarakhand, India

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Received: 28th November, 2023; **Accepted:** 22nd February, 2024; **Published online:** 28th June, 2024

https://doi.org/10.33745/ijzi.2024.v10i01.111

Abstract: The current study was conducted to determine the diversity and distribution of Hydrachnidia fauna in the Laster Gad stream of the Garhwal Himalaya, Uttarakhand, India from July 2018 to June 2020. Two sampling sites in the Laster Gad stream were selected for the collection of water mites and for the analysis of water parameters. During the present study, Hydrachnidia fauna is represented by 6 families, with the Torrenticolidae emerging as the most dominant family. A total of 2538 Hydrachnidia samples were collected, and the maximum diversity of Hydrachnidia was reported at the upstream site (L-1). Winter months (December and January) were the most conducive months for Hydrachnidia abundance at all locations. Shannon-Wiener index (3.19), and Margalef index (5.25) were highest at L-2. Pielou's evenness index (0.81), and the Berger-Parker index was highest (0.19), at L-1. The Bray-Curtis dissimilarity shows a 15% compositional difference between L-1 and L-2 spots. Canonical Correspondence Analysis (CCA) was used to identify the critical environmental factors that affect Hydrachnidia abundance.

Keywords: Canonical Correspondence Analysis, Hydrachnidia, Seasonal pattern, Taxonomic diversity, Torrenticolidae

Citation: Negi Shailza, Dobriyal A.K., Bahuguna Pankaj and Negi Arjun Singh: Diversity and spatial-temporal distribution of Hydrachnidia fauna in Laster Gad, a spring-fed stream of Garhwal Himalaya, Uttarakhand, India. Intern. J. Zool. Invest. 10(1): 1077-1085, 2024.

https://doi.org/10.33745/ijzi.2024.v10i01.111

Introduction

Hydrachnidia, also known as water mites are one of the most threatened taxonomic groups because of their sensitivity to the quantitative and qualitative alteration of aquatic habitats. Hydrachnidia successful diversification in freshwater habitats was most likely aided by

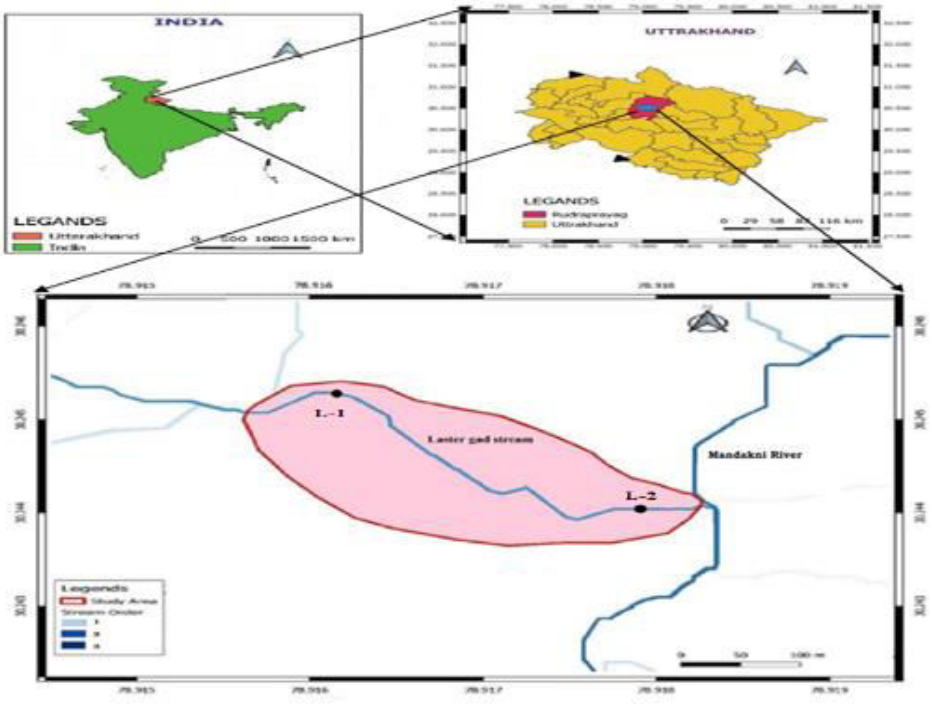

Fig. 1: Map of Laster gad stream showing both sampling sites (L-1 and L-2).

various factors, including swimming abilities and bright coloration. Although Hydrachnidia play a significant role in habitats yet they are taxonomically and functionally underestimated (Di Sabatino *et al.*, 2002). The reason for this is not only a lack of expertise but also the difficulty in identifying Hydrachnidia due to their small size, whereas fish and freshwater macroinvertebrates are regularly researched to determine water quality, Hydrachnidia are often overlooked (Jackson and Fureder, 2006).

Extensive work on the taxonomy of Hydrachnidia from Garhwal Himalaya has been done by many researchers (Kumar and Dobriyal, 1992; Kumar *et al.,* 2006; Pesic *et al.,* 2007a, b, 2009a, b, 2012, 2019a, b, 2020a, b; Pesic and Panesar, 2008, 2009; Bahuguna *et al.,* 2019; Negi *et al.,* 2021a). Many studies have taken consideration of the diel drifting pattern of aquatic mites in the past few years (Bahuguna *et al.,* 2019; Bahuguna and Dobriyal, 2020; and Negi *et al.,* 2021b). The objective of the present study was to observe and assess the occurrence of Hydrachnidia in the Laster gad stream of Garhwal

Materials and Methods

The present study was conducted on the Laster gad stream, which is a major tributary of the Mandakini River. Two sampling spots were selected, Spot L-1 (30°21'04"N, 78°57'59"E) situated upstream at an altitude of 729 m asl and spot L-2 (30°21'6"N, 78°58'21"E) situated downstream at an altitude of 711m asl (Fig. 1). The sampling was carried out on monthly basis from July 2018 to June 2020. The ecological parameters were estimated by following standard methods (Welch, 1948; APHA, 2012). Mites samples were fixed in Koenike fluid for further investigation. For identification purposes, standard identification keys by Cook (1967, 1974), Gerecke (2007), Kumar *et al.* (1992, 2006, 2007), and Pesic *et al.* (2019a, b, 2020a, b) were applied.

Using PAST software version 4.03, all statistical analysis, including CCA, Shannon-Wiener diversity index, Pielou's evenness index, Berger-Parker dominance index, Margalef species richness index, and Bray-Curtis dissimilarity index, were carried out.

Table 1: Monthly average variation of physico-chemical parameters of the Laster gad stream at spot L-1 and L-2 during 2018-20

Parameters	Site	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
WT (°C)	L-1	17.9 ±0.8	17.3 ±0.2	16.4 ±0.3	13.6 ±0.3	10.9 ±0.3	10.4 ±0.2	9.3 ±0.2	10.1 ±0.2	11.4 ±0.3	12.7 ±0.2	14.8 ±0.1	15.9 ±0.1
	L-2	18.3 ±0.2	17.2 ±0.2	17.1 ±0.4	14.2 ±0.1	11.6 ±0.3	10.9 ±0.2	9.6 ±0.2	10.1 ±0.2	11.4 ±0.3	13.1 ±0.2	15.2 ±0.1	17.3 ±0.1
CV (m/sec)	L-1	0.55 ±0.06	0.51 ±0.03	0.40 ±0.03	0.34 ±0.02	0.30 ±0.02	0.29 ±0.02	0.24 ±0.01	0.26 ±0.02	0.29 ±0.03	0.33 ±0.02	0.35 ±0.03	0.37 ±0.03
	L-2	0.46 ±0.01	0.39 ±0.03	0.31 ±0.02	0.29 ±0.01	0.27 ±0.02	0.25 ±0.01	0.23 ±0.01	0.25 ±0.03	0.26 ±0.04	0.29 ±0.01	0.31 ±0.02	0.34 ±0.03
pH	L-1	7.2 ±0.1	7.4 ±0.3	7.5 ±0.2	7.4 ±0.6	7.5 ±0.2	7.7 ±0.3	7.6 ±0.2	7.5 ±0.1	7.4 ±0.1	7.5 ±0.4	7.4 ±0.1	7.5 ±0.2
	L-2	7.1 ±0.3	7.3 ±0.2	7.2 ±0.1	7.3 ±0.2	7.5 ±0.3	7.6 ±0.3	7.5 ±0.2	7.4 ±0.1	7.2 ±0.2	7.2 ±0.1	7.3 ±0.1	7.4 ±0.1
DO (mg/l)	L-1	7.2 ±0.1	7.5 ±0.1	8.1 ±0.1	8.3 ±0.2	8.5 ±0.3	8.6 ±0.2	8.6 ±0.2	8.0 ±0.2	7.9 ±0.3	7.7 ±0.2	7.9 ±0.2	7.5 ±0.2
	L-2	6.9 ±0.2	7.2 ±0.2	7.6 ±0.2	7.8 ±0.1	7.9 ±0.2	8.0 ±0.2	8.1 ±0.3	7.5 ±0.2	7.5 ±0.2	7.1 ±0.2	7.3 ±0.2	7.2 ±0.1
TA (mg/l)	L-1	79.9 ±1.1	80.2 ±1.4	81.6 ±1.0	83.3 ±1.3	85.9 ±1.7	88.8 ±1.4	94.5 ±1.4	92.4 ±1.2	91.2 ±1.8	90.7 ±1.6	90.8 ±0.9	89.4 ±1.2
	L-2	72.7 ±0.8	74.8 ±0.9	77.3 ±1	79.2 ±0.9	80.8 ±1.4	83.7 ±1.3	91.9 ±1.3	90.1 ±0.4	94.5 ±0.5	95.7 ±0.4	85.4 ±0.6	81.3 ±0.8
TH (mg/l)	L-1	80.1 ±0.7	88.9 ±0.9	90.2 ±1.4	99.8 ±1.5	105.2 ±1.7	110.8 ±1.4	117.1 ±5.2	104.9 ±1.8	101.2 ±1.3	99.7 ±0.9	95.4 ±0.2	91.3 ±2.1
	L-2	83.6 ±1.2	82.4 ±1.8	84.5 ±1.3	86.3 ±2.4	92.2 ±3.2	104.1 ±0.8	105 ±8.4	100.2 ±3.2	96.7 ±2.5	90.5 ±2.1	86.7 ±3.7	83.2 ±2.4
F.CO_2 (mg/l)	L-1	0.12 ±0.11	0.16 ±0.05	-	-	-	-	-	-	-	-	-	-
	L-2	0.11 ±0.01	0.15 ±0.07	-	-	-	-	-	-	-	-	-	-

Results and Discussion

The average (mean±SD) data of physico-chemical parameters recorded at two sampling sites of the Laster gad stream is presented in Table 1. During the present study, the maximum water temperature was recorded at L-2 (18.3 ±0.2 °C) and the minimum at L-1 (9.3 ±0.2 °C). The water temperature was low during the winter months and high during the summer. A similar trend was observed by Bahuguna and Negi (2018) in Kyunja gad. Throughout the two years, Laster Gad Stream's velocity was fairly good, with the highest value at L-1 (0.55 ±0.06 m/sec) whereas the lowest velocity was recorded at L-2 (0.23 ±0.01 m/sec). In the present study, during the monsoon season, water velocity was reported high in both the spring-fed stream. The pH fluctuated between 7.2±0.1 to 7.7±0.3 at L-1, and 7.1±0.3 to 7.6±0.3 at L-2, which showed a natural alkaline nature of the stream indicating unpolluted water. The highest values of dissolved oxygen were observed at L-1 (8.6 ±0.2 mg/l) and the lowest at L-2 (6.9 ±0.2 mg/l). Although the DO level was moderate throughout the study, there was a slight decrease in the summer months due to higher temperatures and faster decomposition rates. Negi *et al.* (2021a) made a similar observation in the Khankra Gad stream of the Garhwal Himalaya. Free CO_2 was only observed during July and August. The total alkalinity ranged from 79.9 ±1.1 mg/l to 94.5 ±1.4 mg/l at L-1, and 72.7 ±0.8 mg/l to 95.7 ±0.4 mg/l at L-2. During the winter months, alkalinity was at its highest, while during the monsoon season, it was at its lowest. Similar findings have been reported by Negi *et al.* (2021b). The total hardness

Table 2: Monthly average variation of density and diversity of water mites (units/m^2) in Laster gad at L-1 spot during 2018-20

Family/Genus/Species	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
F–Torrenticolidae												
Torrenticola uttarakhandensis	+	+	+	+	+	+	+	+	+	+	+	+
Torrenticola chatterjeei	-	+	-	-	+	-	+	-	+	-	+	-
Torrenticola rangareddyi	-	+	-	+	-	+	-	+	-	+	-	+
Torrenticola turkestanica	-	-	+	-	+	+	+	-	-	+	+	-
Torrenticola wonchoeli	+	+	+	+	+	+	+	+	+	+	+	-
Torrenticola nana	-	-	+	-	-	+	+	+	+	+	+	+
Torrenticola kumari	-	-	+	-	-	+	+	+	+	+	+	-
Torrenticola semisuta	-	-	+	+	-	-	+	+	+	-	-	+
Torrenticola muranyii	-	-	+	-	+	+	+	-	+	-	+	-
Monatractides oxystomus	-	+	-	+	+	+	+	+	+	-	-	-
Monatractides garhwaliensis	+	+	+	+	+	+	+	+	+	+	+	+
Monatractides kontschani	+	-	-	+	+	+	+	+	-	+	-	+
F – Sperchontidae												
Sperchon indicus	+	+	+	+	+	+	+	+	+	+	+	+
Sperchon garhwalensis	+	+	+	+	+	+	+	+	+	+	+	+
Sperchon plumifer	+	+	+	+	+	+	+	+	+	+	+	+
Sperchonopsis verrucosa	+	+	+	+	+	+	+	+	+	+	+	+
F- **Hygrobatidae**												
Atractides indicus	+	+	+	+	+	+	+	+	+	+	+	+
Atractides Garhwali	+	+	+	+	+	+	+	-	-	+	-	+
Atractides incertus	+	+	+	+	+	+	+	+	+	+	+	+
Hygrobates dobriyali	+	+	+	+	+	+	+	+	+	+	+	+
F- Aturidae Thor												
Kongsbergia rucira	-	+	+	+	+	+	+	+	-	-	+	+
Kongsbergia himalayaensis	+	+	+	+	+	+	+	+	+	-	-	-
F- Feltriidae												
Feltria gereckei	+	-	-	+	+	+	+	+	+	+	+	-
Feltria indica	-	+	+	+	+	+	+	-	+	-	+	+
Total density (units/m^2)	**36 ±18.3**	**54 ±24.1**	**66 ±22.6**	**90 ±25.4**	**119 ±36.7**	**155 ±42.4**	**204 ±48.1**	**106 ±29.4**	**92 ±21.2**	**75 ±21.2**	**64 ±24.1**	**47 ±19.8**

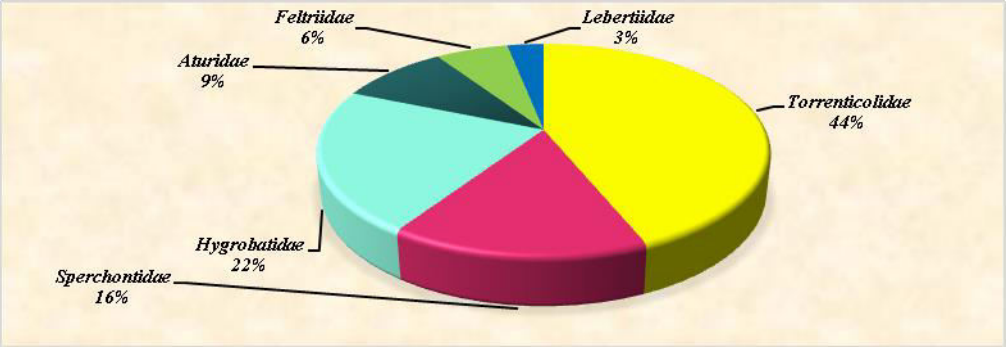

Fig. 2: Family wise percentage distribution of water mites in Laster gad during 2018-20.

Table 3: Monthly average variation of density and diversity of water mites (units/m^2) in Laster gad at L-2 spot during 2018-20

Family/Genus/Species	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
F –Torrenticolidae												
Torrenticola uttarakhandensis	+	+	+	+	+	+	+	+	+	+	+	+
Torrenticola wonchoeli	-	+	+	+	+	+	+	+	+	+	+	+
Torrenticola chatterjeei	+	-	+	+	+	+	+	+	+	-	+	-
Torrenticola rangareddyi	+	+	-	+	-	+	+	+	+	+	+	+
Torrenticola turkestanica	+		+	+	-	+	+	+	+	+	+	+
Torrenticola muranyii	+	+		+	+	+	+	+	+	-	+	+
Torrenticola nana	-	+	+	+	+	+	+	+	+	-	+	-
Torrenticola kumari	-	-	+	+	-	+	+	+	-	+	+	-
Torrenticola tetraporella	+	-	+	+	-	+	+	+	-	-	-	+
Monatractides oxystomus	-	-	-	+		+	+	+	+	-	+	-
Monatractides kontschani	+	+	+	+	+	+	+	-	-	+	-	+
Monatractides tuzovskyi	+	-	+	-	+	-	+	+	+	-	-	+
Monatractides garhwaliensis	-	-	-	-	+	+	+	+	+	+	+	-
F– Sperchontidae												
Sperchon indicus	+	+	+	+	+	+	+	+	+	+	+	+
Sperchon garhwalensis	+	+	+	+	+	+	+	+	+	+	+	+
Sperchon plumifer	+	+	+	+	+	+	+	+	+	+	+	+
Sperchon ootacamundis	-	-	+	+	+	+	+	+	+	+	+	+
Sperchonopsis verrucosa	+	+	+	+	+	+	+	+	+	+	+	+
F- Hygrobatidae												
Atractides garhwali	+	+	+	+	+	+	+	+	+	+	+	+
Atractides indicus	+	+	+	+	+	+	+	+	+	+	+	+
Atractides yukii	-	+	+	+	+	+	+	+	+	+	-	-
Atractides incertus	-	-	-	+	+	+	+	+	+	+	-	+
Atractides ootacamundis	+	-	-	-	+	+	+	+	-	-	-	-
Hygrobates dobriyali	-	+	+	-	+	+	+	+	+	-	-	-
Hygrobates fluviatilis	-	-	-	+	-	+	+	-	-	+	+	-
F – Aturidae												
Kongsbergia rucira	+	+	+	+	+	+	+	+	+	+	+	+
Kongsbergia indica	+	+	+	+	+	+	+	+	+	+	+	+
Kongsbergia himalayaensis	+	+	+	+	+	+	+	+	+	+	+	+
F – Feltriidae												
Feltria gereckei	-	+	-	+	+	+	+	-	-	+	-	+
Feltria indica	+	-	+	-	-	+	+	+	+	-	+	-
F – Lebertiidae												
Lebertia spp.	-	+	-	+	+	+	+	+	+	-	-	-
Total density (units/m^2)	**31 ±9.8**	**51 ±18.3**	**69 ±18.4**	**106 ±24.1**	**145 ±43.8**	**215 ±51.9**	**306 ±60.8**	**172 ±38.2**	**131 ±29.6**	**93 ±21.2**	**63 ±19.7**	**48 ±19.7**

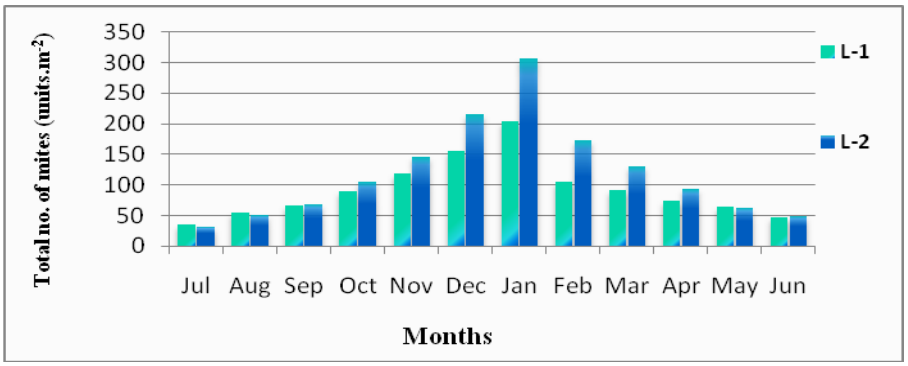

Fig. 3: Bar graph showing monthly average variation of density of water mites (units/m^2) in Laster gad at L-1 and L-2 during 2018-20.

Table 4: Richness, diversity, evenness and similarity indices for the water mite communities in Laster stream at L-1 and L-2 during 2018-20

Month	H'		J'		D		M	
		L-2	L-1	L-2	L-1	L-2	L-1	L-2
Jul	2.56	2.42	0.81	0.75	0.19	0.18	4.18	4.07
Aug	2.71	2.61	0.78	0.71	0.16	0.17	4.51	4.57
Sep	2.6	2.58	0.74	0.7	0.15	0.15	4.05	4.25
Oct	2.68	2.89	0.77	0.72	0.13	0.12	4.01	5.14
Nov	2.81	2.83	0.79	0.74	0.12	0.12	4.18	4.42
Dec	2.82	3.01	0.76	0.67	0.13	0.12	4.16	5.4
Jan	2.93	3.19	0.81	0.78	0.12	0.09	4.13	5.25
Feb	2.65	3.03	0.75	0.74	0.17	0.11	3.86	5.24
Mar	2.6	2.87	0.71	0.77	0.17	0.11	3.98	4.51
Apr	2.52	2.76	0.73	0.79	0.16	0.12	3.71	4.19
May	2.68	2.62	0.81	0.68	0.12	0.14	4.08	4.58
Jun	2.53	2.64	0.78	0.78	0.17	0.16	3.89	4.39

H': Shannon-wiener diversity index, **J':** Pielou's evenness index
d: Berger-Parker dominance index, **M:** Margalef species richness index

Table 5: Bray- Curtis dissimilarity index between L-1 and L-2 during 2018-20

Between Spots	Bray-Curtis dissimilarity	%
L-1 and L-2	0.15	15%

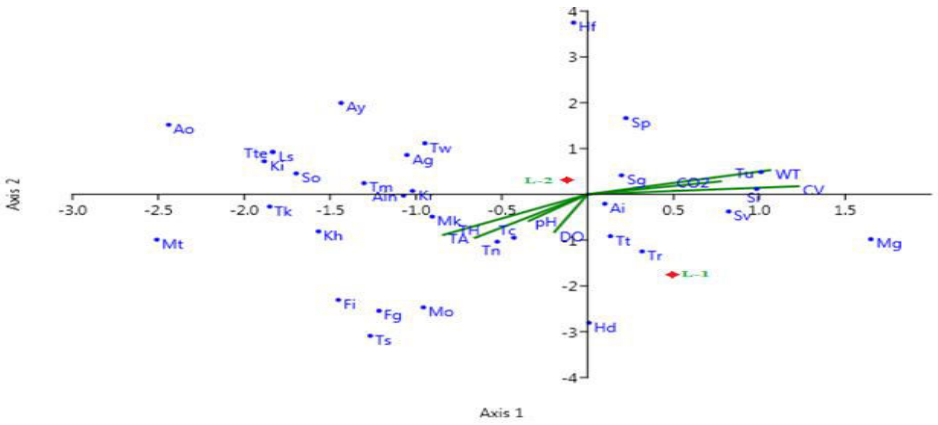

Fig. 4: Canonical Correspondence Analysis (CCA) plot showing the effect of biochemical parameters on the abundance of drifting water mite community of Laster gad during 2018-20.

ranged from 80.1 ±0.7 mg/l to 117.1 ±5.2 mg/l at L-1 and 82.4.7 ±1.8 mg/l to 105 ±8.4 mg/l at L-2.

A total of 2538 Hydrachnidia samples were collected via a comprehensive study over the Laster gad stream during the two-year research period of 2018-20. The Hydrachnidia dwelling in the Laster gad stream were represented by the six families, of all the families, the Torrenticolidae family (44%), had the largest number of species, while lowest in Lebertiidae family (3%) (Fig. 2). The average density of the Hydrachnidia ranged from 36-204 units/m^2 at L-1, at L-2 31-306 units/m^2 (Fig. 3). The density of Hydrachnidia was highest in January and lowest in July throughout the two-year research period (Tables 2, 3). The high abundance of Hydrachnidia during the winter months may be due to the diversity of biota (periphyton and benthos populations) and low current velocity. Shannon-Wiener index was highest (3.19) and lowest (2.42) at L-2 (Table 4). Pielou's evenness index ranged from 0.7 at L-2 to 0.81 at L-1, and the Berger-Parker index was highest (0.19) at L-1, and lowest (0.09) at L-2, whereas the Margalef index was highest at L-2 (5.25) and lowest (3.71) at L-1 (Table 4). The Bray-Curtis dissimilarity shows a 15% compositional difference between L-1 and L-2 spots (Table 5). The spot L-2 had the greatest diversity of Hydrachnidia, which might be attributed to the substratum heterogeneity, which includes cobbles, pebbles, and sand, as well as high-quality debris, which serves as food and shelter for them.

According to Hammen and Smit (1996) and Smit and Hammen (2000), Hydrachnidia assemblages are influenced by biochemical factors such as pH, oxygen content, current velocity, and others. Canonical Correspondence Analysis (CCA) was conducted to determine the environmental factors which are the main drivers of Hydrachnidia abundance (Fig. 4). Water temperature and free CO_2 was the most important driver for Hydrachnidia's abundance at L-2 and total alkalinity, pH, current velocity, total hardness, and dissolved oxygen at L-1. Smit and Hammen (1992 a, b) worked on the impact of biochemical parameters on the composition of Hydrachnidia species in coastal zones in the Netherlands and northern France, came to the same conclusion. In the current study, water temperature and pH were shown to have a significant correlation with a few mite species but not with others.

Conclusion

The present investigation shows that there is sufficient diversity and abundance of Hydrachnidia in the Laster gad. The present study revealed the dominance of different species in different seasons indicating temporal niche separation. Different biochemical parameters of Laster gad displayed seasonal variations at both sites. The findings of this study will form baseline information for further in-depth studies of aquatic mite ecology in Garhwal Himalaya.

Acknowledgements

First author (S.N.) expresses her gratitude to her parents for their constant guidance and support throughout the research process. The authors thank Prof. A.K Dobriyal, Head, Department of Zoology, Pauri Campus, H.N.B Garhwal University for providing laboratory facilities. The authors are thankful for the financial support received from the Science and Engineering Research Board (S.E.R.B) under major project No. ECR/ 2016/001291.

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