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Composition, trophic categorization and biomonitoring potential of EPT complex in Giri River, Sirmour, Himachal Pradesh, India

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Abstract
Composition, trophic categorization and biomonitoring potential of Ephemeroptera, Plecoptera Trichoptera (EPT) complex was investigated in Giri River, Giripul, Sirmour district, Himachal Pradesh. The physico-chemical characteristics and EPT complex were carried out for three selected sites. Air and water temperature (°C), water current (m/s), pH, Total Dissolved Solid (mg/L), Free carbondioxide (ppm), Salinity (mg/L) and Dissolved Oxygen (mg/L) were also recorded. The larvae of these aquatic insects were collected by kick net sampling. The water temperature ranged from 19°C to 22°C. A total of 19 species belonging 6 families of Ephemeroptera, Plecoptera and Trichoptera complex were collected. Diversity indices showed that site I had maximum diversity and species richness. The values of Shannon-Weiner's index ranged from 2.706 to 2.845. The maximum percentage of the functional feeding groups of EPT was represented by Collectors, Gatherers, and Scrapers. On the basis of BMWP scores, the selected sampling sites harboured with good aquatic insect families and clean but slightly impacted ecosystem.

Keywords: complex, functional feeding groups, biomonitoring, diversity indices, Giri River

Introduction
Two thirds of the Earth is covered by water. On the earth, only three percent of the water on the surface is fresh. The remaining ninety seven percent resides in the ocean as salt water. Of the fresh water, sixty nine percent is in glaciers, thirty percent is underground and less than one percent is located in ponds, lakes, rivers, streams, dams and swamps (Praveen Chari & Vasantha Kumari 2019) [10]. Inland water covers less than 1 per cent of the earth surface and harbour 10 per cent of all known animal species of which 60 per cent is composed of aquatic insects. This diversity today numbers close to 1, 00, 000 described species (Balian *et al.* 2008) [19]. Aquatic insects spend one or more stages of their life cycles in the water with the majority living in water as eggs and larvae and moving in terrestrial habitats as adults. They play important ecological roles in both aquatic and terrestrial realms as primary consumers, detritivores, predators and pollinators. The fossil record suggests that all aquatic insects groups are the result of the invasion of freshwaters by terrestrial groups (Wootton 1988) [39]. Aquatic insects are important elements in the ecological dynamics of lotic environments (Hynes, 1970) [22] playing an important role in the cycle of materials and in trophic transfers (Cummins *et al.* 1989) [27]. The communities of aquatic insects are affected by several factors related to water quality, stream morphology, food availability and quality (Vannote *et al.* 1980; Richards *et al.* 1993; Diniz-Filho *et al.* 1998) [40, 11, 25]. It is important to understand how these communities are structured and to identify the main environmental factors that determine their composition and abundance in lotic environments, mainly because this provides information for biomonitoring and recovery of these environments when they are degraded (Peterson & Van Eeckhaute 1992; Richards *et al.* 1993; Zamora-Muñoz & Alba-Tercedor 1996) [38, 11, 24]. Among aquatic insects, Ephemeroptera, Plecoptera and Trichoptera (EPT), comprise rich assemblages in low and medium order stony cobble streams. These organisms are sensitive to environmental perturbations and occur in clean and well oxygenated waters. Therefore, EPT assemblages are frequently considered to be good indicators of water quality (Rosenberg & Resh 1993) [17]. In this context, the present study was attempted to investigate the composition, trophic categorization and biomonitoring potential of EPT complex in Giri River, Giripul, Sirmour, Himachal Pradesh.

Materials and Methods
Description of Study Area
The study was conducted in the three different sites of Giri River which flows through Giripul (30º53'30.78N; 77º12'37º.54E), Yashwant Nagar (30º43'26.75N; 77º21'47º.52E) and Badgala (30º53'08.81N; 77º12'22º.71E) (Plate 1). Giri River is a major water sources for Sirmour, Solan and surrounding areas. It located at the slope of Shivalik Mountains.

Sampling rationale
The physico-chemical characteristics and EPT complex were recorded from May to June 2018. During each sampling, three replicates were collected, pooled and considered as a single

collection. The mean values are provided for physico-chemical parameters.

Stream characteristics
The stream characteristics like stream order, nature of the eco-region, substrate and organic composition and other physico-chemical parameters were done. Stream characteristics were evaluated qualitatively by visual observation following description adopted by Nagendran (2002) [29].

Substrate Index
Substrates were classified by using the following criteria: <0.5 mm for mud/silt, 0.5-2 mm for sand, 2-64 mm for gravel, 65-256 mm for cobbles, and >256 mm for boulders (Jowett *et al*., 1991). For statistical analysis, substrate composition was converted to a substrate index
as explained below, following (Suren 1996) [4]:
Substrate Index = (0.07x % boulder) + (0.06 x % cobble) + (0.05x % gravel) + (0.04x % sand) + (0.03x % mud/ silt)

Chemical Analysis
Sampling and analytical procedures followed the methods of American Public Health Association (APHA 2005) [6]. Total dissolved solid (TDS), Free Carbon dioxide, Salinity and Dissolved oxygen (DO) were analyzed by using Water Analyzer Kit (Systronics Make, Model No. 371). pH of water was determined with the help of digital pH meter (Elico, India).

Aquatic insect sampling
The larvae of aquatic insect species were collected by kick net (mesh size; 0.5 to1.0 mm) sampling (Balasubramanian *et al.* 1992). The duration of each kick net operation was 2 minutes. The substratum *viz*., bed rocks, boulders and cobbles was vigorously disturbed strictly restricted to one m^2 area. All specimens from the net surface were carefully collected without any morphological damage using fine forceps or brush and preserved in 85% Ethyl alcohol immediately. The collected samples were brought to laboratory and identified upto genus and species level by using published taxonomical literature pertaining to of the North Western Himalaya, India (Eaton (1892) [3]; Chopra (1927) [7]; Hafiz (1937) [21]; Kapur & Kripalani (1961); Kaul & Dubey (1970); Dubey (1970, 1971) [8, 33]; Waltz & Mc Cafferty (1987) [37]; Braasch (2006) [15]; Sivarama krishnan *et al*. 2009; Selvakumar *et al*. 2012; Kubendran *et al.* 2014; 2015) [26, 12, 46].

Diversity indices
The richness and density of the EPT complex were summarized. The diversity indices such as Shannon-Wiener diversity index, Simpson diversity index, species richness index of Margalef, evenness of index Pielou and others were calculated. Principal Component Analysis was performed to find relationship between the faunal changes and physico-chemical variables. Calculations were done by using package PAST software.

Functional feeding groups
Classification of aquatic insects into functional feeding groups was done by following description of Merritt and Cummins (1984). Trophic categorization was based on the general category of functional feeding groups of aquatic insects.

Calculation of BMWP scores
BMWP score may be otherwise known as TSS (Total Site Score). Families of aquatic insects were tabulated separately for each station. Each family was ascribed the suitable score (10-1) depending on its sensitivity to pollution as prescribed by BMWP score system. Scores of indicator families were just added to arrive at BMWP or TSS (Armitage *et al*. 1983).

Average Score per Taxon (ASPT)
ASPT value was obtained from TSS by dividing it with total number of families recorded as follows.
ASPT = Total Site Score / Total number of families.

Results and Discussion
Physico-chemical characteristics, Total Site Score (TSS) and Average Score Per Taxon (ASPT) as per BMWP score system for three selected sampling sites of Giri River, Giripul, Sirmour district, Himachal Pradesh from May 2018 to June 2018 were given in Table 1. All three study sites are third order stream. The ecoregion are mixed deciduous forest. The altitude of the site I and site III is 1600 (m.a.s.l). The appearance was slightly brown. The substrate index ranged from 5.0 in site III to 5.55 in site II which represent heterogenous nature of substrate. The water temperature ranged from 19°C to 22°C. The water temperature was high in the site III (22°C). The lowest water temperature was observed in the site I (19°C). Jaswal *et al.* (2017) [2] reported the ranges of water temperature from minimum 8°C to maximum 26°C in the year 2013 to 2015 in a torrential hill stream of mid Himalaya, Sirmour, Himachal Pradesh, India. The average width of river was 7.5 m. The depth of river ranged 35 to 65 cm at sampling sites. The average range of total solid was 195 mg/L. The lowest value of total dissolved solid found in site I (75 ±7.1 mg/L). The high total dissolved solid noticed in site III (165±16.7 mg/L). The maximum value of TDS was recorded under suburban land use, whereas, minimum TDS was observed under forest land use systems by Anchal Rana *et al.* (2016). This might be due to increased anthropogenic activities in urban land uses, which might have increased the dumping of waste materials and other household waste water effluents and ultimately increased TDS of surface water sources in addition to rainy seasons. The pH ranged from 7.2 to 7.6. It showed slightly alkalinity. The dissolved oxygen ranged from 10 to 11.4 mg/L. The minimum dissolved oxygen (10mg/L) was found in site II. The maximum dissolved oxygen (11.4 mg/L) was found in site I. Indu & Rani (2012) [42] recorded 7 to14.27 mg/L range of dissolved oxygen in the five snow-fed northern tributaries of Beas drainage system of Western Himalaya, India. The present study revealed that free carbondioxide ranged from 2 to 3 ppm. Joshi (1991) [14] observed range of 2.0 to 4.5ppm free carbon dioxide in sheerkhad stream of Sarkaghat region of Himachal Pradesh. During the study, a total of 19 species from 6 families of Ephemeroptera, Plecoptera and Trichoptera complex were recorded and the community of taxa differed among sampling sites. Site I had 279 numbers of individuals and the minimum number of individuals (164) was noticed in site III (Table & Plate 2). Singh *et al.* (2016) [16] reported a total of 12 genera from 9 families and largest contribution by Trichoptera, Ephemeroptera, Diptera, Coleoptera, Hemiptera during December 2013 to May 2014 from the Giri river. Jindal *et al.* (2020) [36] reported total 30 species of macroinvertebrates belonging to Plecoptera, Coleoptera,

Ephemeroptera and Trichoptera from Binwa stream of the Dhauladhar range, in district Kangra, Himachal Pradesh, India. The larvae of these insects also act as bioindicators of water pollution (NCDEHNR 1997; Mohan 2004; Chauhan & Verma, 2016) [31, 28, 1]. Diversity indices showed that site I had maximum diversity and species richness (Table 3). The values of Shannon-Weiner's index ranged from 2.706 to 2.845. The high value of simpson diversity index was observed in site I (0.9375) and low value of index was found in site III (0.9235). Diversity indices were chosen because of its wide acceptance and it could be utilized for any community irrespective of its species abundance and distribution patterns (Pielou EC 1969) [18]. Turkmen & Kazanci (2010) [20] reported that the values of Simpson diversity index ranged between 0.66 and 0.94 at Yedigoller National Park, Turkey. The maximum percentage of the functional feeding groups of EPT from Giri River, Giripul was represented by Collectors, Gatherers, and Scrapers (Table 4). Collector-gatherer-scrapers dominated by *Notophlebia jobi*, *Caenis sp*, *Baetis sp* and *Hydropsyche sp* from Kurangani stream of Western Ghats, South India (Rathinakumar *et al*. 2014a) [46]. The biological monitoring working party score (BMWP) provides single values, at the family level, representative of the organism's tolerance to pollution. The greater their tolerances towards pollution, the lower the BMWP score. Table 5 showed BMWP scores for families of taxa in the selected sampling sites of Giri River, Giripul, Sirmour district, Himachal Pradesh. BMWP scores in site I and site II was 54 whereas 44 in site III. The aquatic insect family with BMWP score ranged from 6 to 10. The present study revealed that selected Giri River, Giripul, Sirmour district harboured with good aquatic insect families. Nasirian (2014) [30] evaluated the water quality and organic pollution of Shadegan and Hawr Al Azim wetlands by biological indices using insects. The results of the biological monitoring working party index indicated that the environment of Shadegan and Hawr Al Azim wetlands are polluted due to the abundance of family insects with BMWP scores higher than medium (>5) was low BMWP classes, scores, categories adapted from Armitage *et al.* (1983) [34] and Alba-Tercedor (1996) [24] above 150 BWMP score indicated very clean water whereas <15 is heavily polluted. The range 61–100 interpreted as clean but slightly impacted ecosystem. According to the PCA ordination (Figure 1), the results implied that species like *Druella submontana, Ecdyonurus dispargratificus* and *Iron suspicatus* associated with community of sampling site I. The most influencing factor was the stream depth in species richness of sampling site II. Rathinakumar *et al.* (2014b) [46] observed similar results in mayfly species richness of sampling site Sorimuthu Ayyanar temple stream. *Acentrella (Liebebiella) vera*, *Tyloperla barog* and *Choroterpes kaegies* influenced the EPT complex community in sampling site II.

Table 1: Physio-chemical characteristics, Total Site Score (TSS) and Average Score Per Taxon (ASPT) as per BMWP score system for three selected sampling sites of Giri River, Giripul, Sirmour, Himachal Pradesh.

S. No.	Physico-chemical characteristics	Site I	Site II	Site III
1.	Stream Order	III	III	III
2.	Altitude (m.a.s.l)	~ 1600	~ 1605	~1600
3.	Eco-region	Mixed deciduous forest	Mixed deciduous forest	Mixed deciduous forest
4.	Canopy cover	Open	open	Open
5.	Odour	Odourless	Odourless	Odourless
6.	Colour	Slightly brown	Slightly brown	Slightly brown
7.	Substrate (%)			
	a. Bed Rock	-	-	-
	b. Boulders	20	25	5
	c. Cobbles	40	40	50
	d. Pebbles	10	15	5
	e. Gravel	20	10	25
	f. Sand	10	5	10
	g. Silt	0	5	5
	Substrate index	5.4	5.55	5
8.	Organic deposition			
	a. Coarse particulate Organic matter (CPOM)	Presence	Presence	Presence
	b. Fine particulate Organic matter (FPOM)	Presence	Presence	Presence
9.	Width (m)	8.7 ± 1.0	6.6 ± 1.0	7.2 ± 1.0
10.	Depth (cm)	35 ± 0.47	65 ± 0.25	45 ± 0.84
11.	Air temperature (ºC)	23 ± 1.0	27 ± 0.76	28 ± 1.52
12.	Water temperature (º C)	19 ± 1.52	20 ± 1.0	22 ± 0.76
13.	Water current (sec/m)	5.5 ± 1.0	5.7 ± 2.0	7.1 ± 1.0
14.	pH	7.5 ± 0.15	7.6 ± 0.158	7.2 ± 0.1
15.	Dissolved oxygen (mg/L)	11.4 ± 0.21	10 ± 0.1	11.2 ± 0.1
16.	Free carbon dioxide (ppm)	3.0 ± 1.0	3.0 ± 1.0	2.0 ± 1.0
17.	Salinity (mg/L)	0.41 ± 0.01	0.39 ±4.5	0.41 ± 0.01
18.	Total solids (mg/L)	130±14.8	170± 18.3	285±21.5
19.	Total dissolved solids (mg/L)	75 ±7.1	139±12.96	165±16.7
20.	Total suspended solids (mg/L)	55 ±3.5	31 ± 2.6	120 ± 15.0
21.	TSS	54	54	44
22.	ASPT	9	9	7.3

Table 2: Ephemeroptera, Plecoptera and Trichoptera collected for three selected sampling sites of Giri River, Giripul, Sirmour, Himachal Pradesh.

Order	Family	Species Name	Site I	Site II	Site III
Ephemeroptera	Baetidae	*Acentrella (Liebebiella) vera*	22	15	5
		Baetiella spathae	17	11	7
		Baetiella marginata	18	5	5
		Labiobaetis jacobusi	30	14	12
		Labiobaetis soldani	11	4	10
		Nigrobaetis paramakalayani	11	18	17
	Heptageniidae	*Epeorus psi*	25	14	11
		Iron suspicatus	16	2	2
		Epeorus petersi	14	16	16
		Ecdyonurus dispargratificus	16	4	6
	Leptophlebidae	*Choroterpes(ch.) kaegies*	16	14	11
		Choroterpes (Ch.) nigella	11	18	22
	Ephemerellidae	*Druella submontana*	15	4	11
		Crinitella lacuna	12	9	6
		Torleya coheri	18	14	15
		Torleya nepalica	8	5	1
Plecoptera	Perlidae	*Tyloperla barog*	11	7	4
		Marthamea bayae	6	2	2
Trichoptera	Stenosychidae	*Stenopsyche kodaikanalensis*	2	1	1
Total			279	177	164

Table 3: The diversity indices for EPT collected for three selected sampling sites of Giri River, Giripul, Sirmour, Himachal Pradesh

Indices	Site I	Site II	Site I
Taxa	19	19	19
Dominance	0.06252	0.07249	0.07652
Shannon	2.845	2.735	2.706
Simpson	0.9375	0.9275	0.9235
Evenness	0.9049	0.811	0.7875
Menhinick	1.138	1.428	1.484
Margalef	3.196	3.477	3.53
Equitability	0.9661	0.9288	0.9189
Fisher_alpha	4.613	5.397	5.559
Berger-Parker	0.1075	0.1017	0.1341

Table 4: Percentage of the Functional Feeding groups of EPT collected for three selected sampling sites of Giri River, Giripul, Sirmour, Himachal Pradesh.

Order	Family	Species name	Functional feeding groups
Ephemeroptera	Baetidae	*Acentrella (Liebebiella) vera*	Collector Gatherer Scraper
		Baetiella spathae	Collector Gatherer Scraper
		Baetiella marginata	Collector Gatherer Scraper
		Labiobaetis jacobusi	Collector Gatherer Scraper
		Labiobaetis soldani	Collector Gatherer Scraper
		Nigrobaetis paramakalayani	Collector Gatherer Scraper
	Heptageniidae	*Epeorus psi*	Collector Gatherer Scraper
		Iron suspicatus	Collector Gatherer Scraper
		Epeorus petersi	Collector Gatherer Scraper
		Ecdyonurus dispargratificus	Collector Gatherer Scraper
	Leptophlebidae	*Choroterpes kaegies*	Collector Gatherer Scraper
		Choroterpes nigella	Collector Gatherer Scraper
	Ephemerellidae	*Druella submontana*	Collector Gatherer
		Crinitella lacuna	Collector Gatherer
		Torleya coheri	Collector Gatherer
		Torleya nepalica	Collector Gatherer
Plecoptera	Perlidae	*Tyloperla barog*	Predator, Engulfer
		Marthamea bayae	Predator, Engulfer
Trichoptera	Stenosychidae	*Stenopsyche kodaikanalensis*	Collector Filterer

Table 5: BMWP scores for families of taxa for three selected sampling sites of Giri River, Giripul, Sirmour, Himachal Pradesh.

Family	Site I	Site II	Site III
Baetidae	8	8	8
Leptophlebidae	10	10	10
Heptageniidae	10	10	10
Ephemerellidae	10	10	10
Perlidae	10	10	0
Stenosychidae	6	6	6
Total	54	54	44

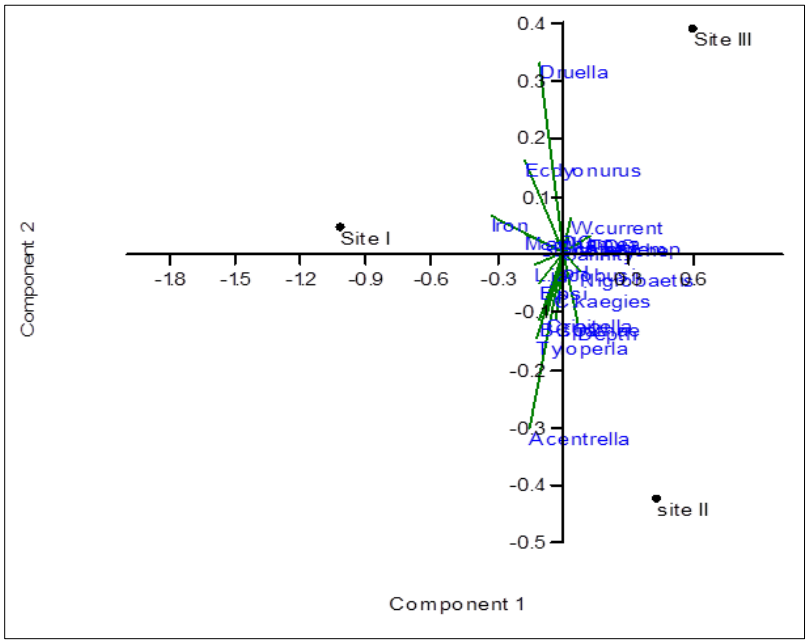

Fig 1: Biplot ordination based on physico-chemical parameters and abundance of EPT taxa of Giri River, Giripul, Sirmour, Himachal Pradesh by Principal component analysis.

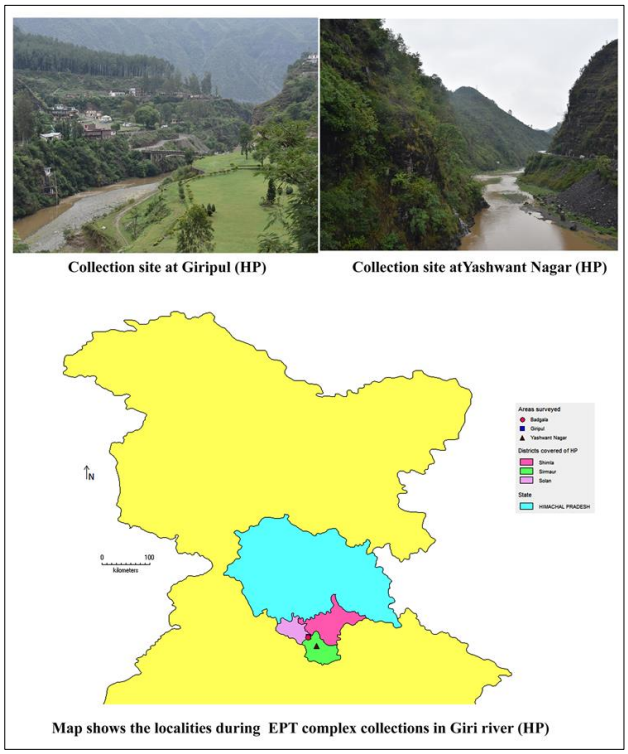

Plate 1: EPT complex collection sites and locality map of Giri River (HP)

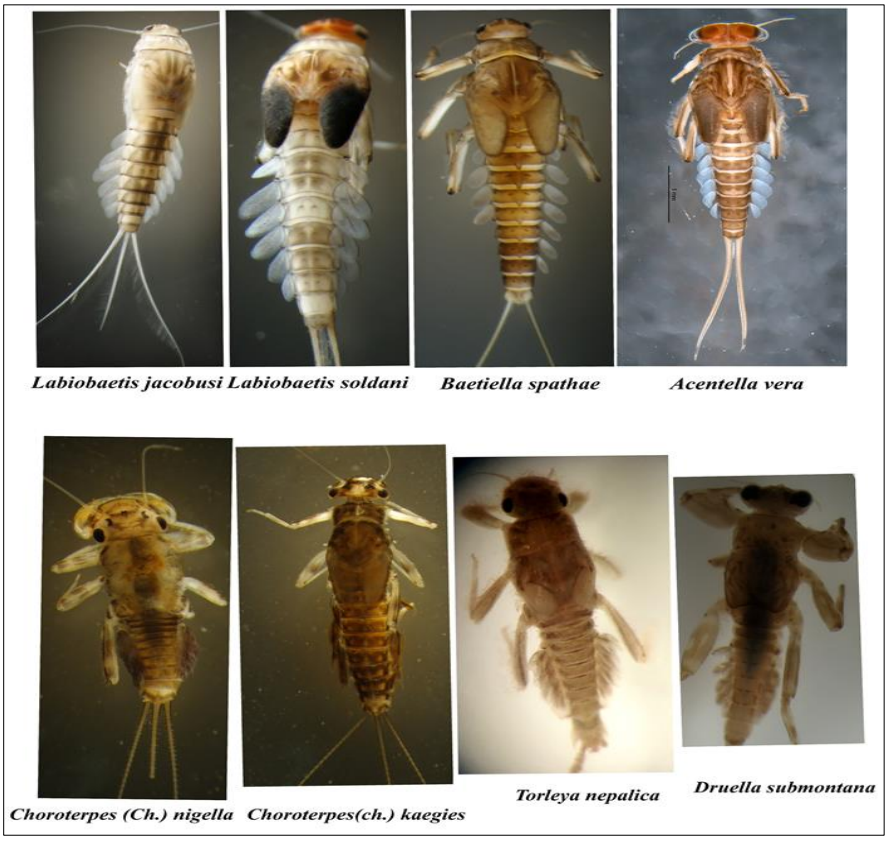

Plate 2: Some Ephemeroptera species collected from Giri River Himachal Pradesh

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