

RESEARCH ARTICLE

Seasonal variation of desmids diversity (zygnematales, zygnemaceae) from Jim Corbett National Park (JCNP), India

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Abstract The present paper is an exclusive contribution of the desmids flora of Jim Corbett National Park (JCNP), Uttarakhand, India. The study revealed 51 desmids taxa which included *Cosmarium* (29 taxa), *Closterium* (11 taxa), *Euastrum* (3 taxa), *Cylindrocystis* (2 taxa) and a single taxon of *Micrasterias, Pleurotaeium, Penium, Staurastrum, Heimansia* and *Netrium* were reported from the samples collected during January to December 2019 from JCNP. All these taxa have been recorded for the first time from the study area except two desmids - *Cosmarium monoliforme* and *Closterium monoliformum* reported earlier from our study site. Maximum desmids diversity occurred in winter season followed by monsoon, and minimum diversity were recorded in summer season. Physicochemical parameters revealed water bodies of the park were ideal habitat for desmids. The trophic status of water bodies of the park were classified as oligotrophic (O), oligotrophic - mesotrophic (OM) and mesotrophic (M). The present study helps in serving desmids as bio indicator of freshwater aquatic ecosystem.

Keywords: Desmids, diversity, Jim Corbett National Park, Physico-chemical parameters, trophic status.

Abbreviations: JCNP, Jim Corbett National Park, O, oligotrophic, (OM), oligotrophic-mesotrophic and (M), mesotrophic.

.Introduction

Desmids occur exclusively in the fresh water habitats. These are coccoid and have a striking morphology characterized by two symmetrical halves (semi-cells). They comprise both solitary and colonial taxa (Coesel and Krienitz 2007). Exploration of desmid flora around the world has been carried out by many workers such as Croasdale and Grönblad (1964) from Labrador, Claassen and Eicker (1985) from Transvaal, Gontcharov and Watanabe (1999) recorded rare desmids from Japan, Coesel (2002) from Netherlands, Dingley (2004) from Australia,

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Tomaszewicz and Hindák (2008) from Central Europe, Ngearnpat *et al.* (2008) from South Thailand, Coesel *et al.* (2017) reported desmid species from the southern Patagonian highlands, Argentina, Van *et al.* (2018) from Netherland and Şahin and Akar (2019) recorded 26 desmids from Artabel Lakes Nature Park, Gümüşhane, Turkey.

Though a good deal of work on desmids flora of Indian sub-continent has been done by a number of researchers since 1860, no extensive study has been carried out from JCNP Uttarakhand except Khare and Suseela (2004). Literature survey reveals that almost all parts of Indian subcontinent are covered by different algologists at different time in respect of desmids study except JCNP, Uttarakhand. Till date, a total of 1.326 species of desmids belonging to 26 genera (Gupta 2012) have been reported from various region of India. To mention a few, Wallich (1860), Iyengar and Bai (1941), Agarkar et al. (1979), Hedge and Bharati (1982), Sindhu and Pannikar (1995), Kant and Gupta (1998), Habib et al. (1998), Habib and Chaturvedi (2001), Misra et al. (2007, 2008), Shukla et al. (2008), Toppo and Suseela (2009), Suseela and Toppo (2010), Mallik and Kesari (2011), Das and Keshri (2013), Shahare et al. (2016), Raut and Bhardwaj (2017), Patil and

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Antibacterial activity of Cuscuta reflexa



Figure 1: Sampling sites of desmids in JCNP, Uttarakhand

Karande (2020) and Komal *et al.* (2021). There are only 346 algal species reported from Uttarakhand (Toppo *et al.* 2016), out of which only 25 taxa are desmids (Gupta 2012). Khare and Suseela (2004) reported only 2 desmids - *Cosmarium monoliforme* and *Closterium monoliformum* from JCNP. Our study has been specific addition of desmids flora to Uttarakhand.

Though desmids are reported from many parts of India, Jim Corbett National Park (JCNP), located in the foothills of the Himalayas, is lacking behind in the study of this particular desmid flora in spite of its rich biodiversity. The forest of the park has a unique composition of floristic elements of Himalayan flora. Although JCNP encompasses favorable ecological conditions for algal growth, the area has not been much explored yet. Therefore, the present investigation has been carried out. The aim of this research is to investigate the biodiversity



Figure 2: Distribution of desmids genera in JCNP, Uttarakhand

of desmids of JCNP for assessing health of freshwater aquatic ecosystem.

Materials and methods

Site description: The first and oldest National park of India comes mainly under two different districts - Nainital and Pauri, Uttarakhand. The land has a vast variety of geographical conditions with altitudes ranging from 400 m - 1,210 m above sea level. The Park (JCNP) is located between the following geographical coordinates: Latitude 29 25' N to 29'40' N and Longitude 78'5' E to 79'5' E, comprising an area of about 1,318.54 km² (Corbett:

Sampling Sites	Latitude	Longitude	Elevations	Sampling Sites Description
C1	29 60.9332' N	79 0 9.7035' E	571 m	Durga Devi (Transition Zone)
C2	29 3 7.3463' N	79 0 9.1032' E	741 m	Brys Caves Resort, Durga Devi (Transition Zone)
C3	29 Ø0.5733' N	79 1 0.1461' E	749 m	Durga Devi (Buffer Zone)
C4	29 29.770 ' N	78 4 5.607' E	976 m	Saddle Dam, Sona Nadi (Transition Zone)
C5	29 2 5.332' N	78 3 9.935' E	319 m	Jhirna (Buffer Zone)
C6	29 25.340' N	78 3 9.950' E	323 m	Jhirna (Transition Zone)
C7	29 3 1.651' N	79 0 5.964' E	462 m	Dhangarhi stream, Dhikala (Transition Zone)
C8	29 2 6.112' N	79 0 7.930' E	406 m	Ringorra Village, Bijrani (Transition Zone)
C9	29 25.285' N	79 00.064' E	319 m	Dhela stream, Dhela (Transition Zone)
C10	29 3 1.331' N	79 0 5.576' E	486 m	Dhikala (Buffer Zone)
C11	29 4 3.373' N	78 4 4.724' E	500 m	Kalagarh (Buffer Zone)
C12	29 29.770' N	78 4 5.607' E	984 m	Kalagarh (Transition Zone)
C13	29 3 3.276' N	79 06.681' E	512 m	Bhadrakot Mohan, Durga Devi (Transition Zone)

Table1: List of the sites of desmids samples collection showing latitude, longitude, elevations and place of the collection

S. No		Seasons Sampling sites in JCNP (C1 - C13)															
	desmids taxa		s	М	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
Class: Zy Order: Z	ygnematophyceae Tygnemetales		1	1										1	1	1	1
1	Cylindrocystis brebissonii (Ralfs)	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
2	Cylindrocystis crassa De Bary	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
3	Netrium digitus (Ehrenberg) Itzigs	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
4	Penium margaritaceum Brébisson	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
5	Closterium acerosum Ehrenberg ex Balfs	+	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-
6	Cl. braunii Reinsch	+	-	+	-	-	-	+	-	-	-	-	+	-	-	-	-
7	<i>Cl. calosporum</i> Wittrock	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
8	<i>Cl. ehrenbergii</i> Meneghini ex Ralfs	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+
9	<i>Cl. kuetzingii</i> Brébisson	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
10	<i>Cl. closterioides</i> (Ralfs) A. Louis & Peeters	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-
11	Cl.littorale F. Gay	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
12	<i>Cl. leibleinii</i> var. <i>Recurvatum</i> West & G. S. West	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
13	<i>Cl. lunula</i> var. <i>Massartii</i> (De Wildeman) Willi Krieger	+	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
14	<i>Cl. moniliferum</i> Ehrenberg ex Ralfs	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
15	Cl. parvulum Nägeli	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
16	Pleurotaenium trabecula Nägeli, C.	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
17	<i>Euastrum ansatum</i> Ehrenberg ex Ralfs	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
18	E. rostratum var. biculatum	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
19	<i>E. spinulosum</i> Delponte	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
20	Staurastrum punctulatum Brébisson	+		+	-	-	+	+	-	-	-	-	-	-	-	-	
21	Micrasterias radians W. B. Turner	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
22	<i>Heimansia pusilla</i> Hilse	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
23	Cosmarium awadhense B. N. Prasad & R.K. Mehrotra	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-
24	<i>C. calcareum</i> Wittrock	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
25	C. cucumis Corda ex Ralfs	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
26	<i>C. elongatum</i> (Raciborski) Teiling	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
27	C. granatum Brébisson ex Ralfs	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-

Table 2: Site wise and seasonal distributions of desmids taxa in JCNP, Uttarakhand

29	C. insigne Schmidle	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-
30	<i>C. javanicum</i> Nordstedt	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
31	C. leave Rabenhorst	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	+
32	<i>C. leave</i> var. <i>septentrionale</i> Wille	+	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-
33	C. lundellii Delponte	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
34	<i>C. nitidulum</i> De Notaris	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
35	<i>C. obsoletum</i> (Hantzsch) Reinsch	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
36	<i>C. pachydermum</i> P. Lundell	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
37	<i>C. perpastrum</i> W. B. Turner	-	-	+	-	+	-		-	-	-	-	-	-	-	-	-
38	<i>C. phaseolus</i> Brébisson ex Ralfs	+	-	-	-	+	-		-	-	-	-	-	-	-	-	-
39	<i>C. portblairii</i> B. N. Prasad & P. K. Misra	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-
40	<i>C. pseudoconnatum</i> Nordstedt	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
41	C. pseudopyramidatum var. oculatumn Willi Krieger	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
42	<i>C. punctatum</i> Nordstedt	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
43	<i>C. pyramidatum</i> Brébisson ex Ralfs	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+
44	<i>C. quadrum</i> P. Lundell	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
45	<i>C. quadrifarium</i> P. Lundell	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-
46	<i>C. quinarium</i> P. Lundell	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+
47	<i>C. speciosum</i> P. Lundell	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+
48	<i>C. subprotumidum</i> Nordstedt	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
49	<i>C. subspeciosum</i> <i>var. transiens</i> Messikommer	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
50	C. supraspeciosum Wolle	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
51	C. turpini Brébisson	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-





Figure 3: Seasonal distribution of desmids in JCNP, Uttarakhand

Figure 4: Distribution of desmids taxa across sampling sites, JCNP, Uttarakhand

Water parameter Season C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 pH Wintr 0.058 0.025 0.008 0.026 0.0016 0.015 0.02 0.015 0.021 </th <th></th> <th></th> <th colspan="10">No. of sampling sites in Jim Corbett National Park</th> <th></th>			No. of sampling sites in Jim Corbett National Park												
parameter Season C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 pH 0058 0.22 0.032 0.035 0.038 0.025 0.036 0.015 0.02 0.012 0.05 0.231 0.025 0.025 0.021 0.015 0.022 0.010 0.015 0.022 0.010 0.015 0.022 0.010 0.025 0.013 0.025 0.013 0.025 0.013 0.025 0.013 0.025 0.013 0.025 0.013 0.025 0.013 0.025 0.013 0.025 0.013 0.025 0.013 0.025 0.033 0.015 0.046 0.025 0.033 0.025 0.033 0.015 0.026 0.033 0.015 0.026 0.033 0.015 0.046 0.025 0.033 0.025 0.033 0.031 0.025 0.033 0.031 0.025 0.033 0.031 0.031 0.031	Water														
Winter 7.43 ± 8.12 ± 7.07 ± 8.03 ± 7.87 ± 8.04 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.83 ± 7.74 ± 7.84 ± 7.83 ± 7.84 ± 7.82 ± 7.83 ± 7.74 ± 7.96 ± 7.86 ± 7.12 ± 7.83 ± 7.74 ± 7.96 ± 7.86 ± 7.17 ± 7.25 ± 7.76 ± 8.33 ± 7.94 ± 7.14 ± 7.96 ± 7.82 ± 7.04 ± 7.06 ± 8.14 ± 8.16 ± 7.77 ± 7.52 ± 7.76 ± 8.33 ± 7.94 ± 8.14 ± 8.10 ± 0.01 ± 0.02 ± 0.01 ±<	parameter	Season	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
pH 0.058 0.022 0.035 0.035 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.016 0.025 0.015 0.025 0		Winter	7.43 ±	8.12 ±	7.07 ±	8.03 ±	8.34 ±	8.37±	$8.05 \pm$	7.70 ±	8.12±	7.87 ±	8.34 ±	8.03±	7.82 ±
pH Summer 0.10± 0.07± 0.23± 0.23± 0.24± 0.25± 0.24± 0.025 0.024 0.014 0.025 0.024 0.014 0.025 0.024 0.015 0.014 0.025 0.024 0.015 0.012 0.004 0.015 0.002 0.014 0.025 0.036 0.21± 0.036 0.02± 0.035 0.036 0.22± 0.035 0.036 0.21± 0.022 0.035 0.036 0.035 0.036 0.02± 0.036 0.02± 0.036 0.02± 0.036 0.02± 0.036 0.02± 0.036 0.02± 0.035 0.02± 0.035 0.02± 0.035 0.02± 0.035 0.02± 0.035 0.02± 0.03± 0.02± 0.03± <th0< th=""><th></th><th>··· meer</th><th>0.058</th><th>0.225</th><th>0.032</th><th>0.058</th><th>0.038</th><th>0.026</th><th>0.036</th><th>0.015</th><th>0.02</th><th>0.012</th><th>0.05</th><th>0.231</th><th>0.025</th></th0<>		··· meer	0.058	0.225	0.032	0.058	0.038	0.026	0.036	0.015	0.02	0.012	0.05	0.231	0.025
Monsoon 0.025 0.026 0.016	pН	Summer	7.10 ± 0.100	7.67±	$6.93 \pm$ 0.230	$7.5/\pm$ 0.321	7.8 ±	7.82 ± 0.026	$7.43 \pm$ 0.026	7.26 ±	7.35 ±	7.74 ± 0.006	7.96 ±	7.86 ±	7.12 ±
Monsoon 0.057 0.251 0.025 0.031 0.025 0.151 0.251 0.021 0.015 0.023 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.015 0.025 0.036 2.015 0.026 1.015 0.022 0.015 0.025 0.036 2.015 2.036 0.416 0.022 0.031 2.015 0.025 0.036 2.036 0.416 0.022 0.023 0.036 4.0331 0.036 4.0331 0.025 0.036 4.0331 0.025 0.036 4.0331 0.024 4.0331 0.024 4.0331 0.036 4.0331 0.036 4.0331 0.036 4.0371 0.265 0.11 0.041 0.031 0.034 4.037 0.026 0.036 4.037 0.026 0.036 4.0331 0.034 1.033 1.024 1.014 1.014 1.014 1.014			7.16+	7.97 +	7.04 +	7.96 +	8 14 +	8.16+	7 77 +	7 52 +	7.83+	7.76 +	8 33 +	7 94+	7 47 +
		Monsoon	0.057	0.251	0.026	0.142	0.02	0.035	0.031	0.025	0.153	0.251	0.032	0.015	0.058
EC (µScm ¹) Winter 0.473 ± 0.611 ± 0.571 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.361 ± 0.32 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.321 ± 0.331		XX/*	$90.87 \pm$	188.83	352.67	321.03	$318.4 \pm$	200.26	$121.8 \pm$	$207.4 \pm$	200.53	$305.47 \pm$	644.23	$300.26 \pm$	81.3 ±
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		winter	0.473	± 0.611	± 0.577	± 0.551	0.361	± 0.306	0.721	0.2	± 0.306	0.416	± 0.252	0.306	0.265
	EC (uScm ⁻¹)	Summer	$96.4 \pm$	$198.4 \pm$	395.93	381.43	399.33	389.37	$197.6 \pm$	$434.3 \pm$	390.73	400.2 ±	680.37	$415.33 \pm$	$88.73 \pm$
	EC (µScm ⁻¹)	Summer	0.361	0.361	± 0.115	± 0.404	± 0.306	± 0.351	0.361	0.3	± 0.115	0.2	± 0.321	0.152	0.208
		Monsoon	91.7±	190.96	$367.3 \pm$	328.63	321.06	297.76	$210.2 \pm$	$415.3 \pm$	$320.3 \pm$	350.36±	650.43	326.4 ±	86.17±
			0.1 77.52 ±	± 0.757	0.265	± 0.709	± 0.839	± 0.737	0.346	0.416 50.0±	0.3 182.6 ±	0.635	$\pm 0.3/9$	0.361	0.153
TDS (mgL-)		Winter	0.451	0.950	0.2	+0.252	+0.153	+ 0.208	0.265	0.1	0.1	0.611	0.2	98.5 ±	0 321
$ TDS (ngL^-) \\ \hline Salinity % 0 \\ $			86 37 +	188.23	144.5 +	191.8 +	$1525 \pm$	201.67	201 57	$230.9 \pm$	140.3 +	242.33 +	311.3 +	110.4 +	43.5+
Monson 80.13 ± 60.63 ± 191.33 122.43 103.27 112.76 200.2 ± 103.37 112.457 ± 41.73 Salinity (%) 0.22 ± 0.51 ± 0.07 ± 0.22 ± 0.51 ± 0.07 ± 0.22 ± 0.15 ± 0.07 ± 0.11 ± 0.06 ± 0.005 0.005 0.006 0.005 0.006 0.005 0.006 0.005 0.006 0.005 0.006 0.005 0.006	TDS (mgL ⁻¹)	Summer	0.635	± 0.252	0.361	0.721	0.2	± 0.153	± 0.208	0.529	0.265	0.351	0.3	0.2	0.5
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		Monsoon	$80.13 \pm$	$60.63 \pm$	191.33	$124.8 \pm$	125.43	103.27	112.76	$200.2 \pm$	195.27	$108.63 \pm$	$313.3 \pm$	$124.57 \pm$	$41.73 \pm$
			0.231	0.777	± 0.306	0.1	± 0.493	± 0.666	± 0.608	0.346	± 0.208	0.153	0.265	0.208	0.058
		Winter	$0.22 \pm$	$0.51 \pm$	$0.07 \pm$	$0.22 \pm$	$0.15 \pm$	$0.17 \pm$	$0.11 \pm$	$0.05 \pm$	0.13	$0.31 \pm$	0.35	$0.10 \pm$	$0.04 \pm$
Salinity (%) Summer 0.19± 0.19± 0.18± 0.18± 0.14± 0.16± 0.17± 0.20± 0.27± 0.026 0.001 0.033 0.013 0.013 0.012 0.014 0.012 0.014 0.015 0.011 0.015 0.015 0.015 0.015 0.015 0.015 0.015	Salinity (%)	Summer Monsoon	0.006	0.015	0.005	0.006	0.01	0.006	0.012	0.006	±0.005	0.005	±0.01	0.006	0.006
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			$0.19 \pm$	$0.19 \pm$	$0.18 \pm$	$0.18 \pm$	$0.14 \pm$	$0.16 \pm$	$0.17 \pm$	$0.20 \pm$	$0.11 \pm$	0.26 ±	$0.27 \pm$	0.05	$0.18 \pm$
			0.006	0.005	0.006	0.006	0.005	0.000	0.006	0.000	0.000	0.006	0.000	±0.006	0.015
Winter 10.70± 11.23± 7.86± 8.13± 9.97± 0.80± 0.00± 0.01± 0.0± <			0.04 ±	0.04 ±	$0.03 \pm$ 0.006	0.11 ± 0.012	$0.08 \pm$ 0.006	0.09 ±	$0.14 \pm$ 0.006	0.21 ±	0.08 ±	0.24 ±	0.23 ±	0.00 ±	0.04 ±
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			$10.70 \pm$	$11.23 \pm$	7.96±	8.13 ±	9.97 ±	9.86±	9.83 ±	9.36±	8.16±	8.71 ±	9.35 ±	8.46 ±	8.93 ±
		Winter	0.095	0.153	0.012	0.015	0.015	0.098	0.01	0.02	0.032	0.015	0.01	0.053	0.113
	Dissolved	C	$9.83 \pm$	$10.12 \pm$	7.11 ±	7.91	$6.92 \pm$	$6.82 \pm$	$7.36 \pm$	$6.57 \pm$	7.14 ±	7.05 ±	$8.18 \pm$	8.02 ±	$6.04 \pm$
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	(mgL ⁻¹)	Monsoon	0.006	0.021	0.015	± 0.01	0.006	0.015	0.01	0.03	0.118	0.012	0.068	0.031	0.015
	(ingl.)		10.33 ±	10.58 ±	7.63 ±	8.03 ±	7.71 ±	7.78 ±	7.46 ±	7.47 ±	7.23 ±	7.94 ±	8.45 ±	8.15 ±	7.51 ±
Winter $0.173 \pm 0.53 \pm 16.07 \pm 20.64 \pm 21.4 \pm 14.7 \pm 14.7 \pm 14.83 \pm 22.07 \pm 20.13 \pm 15.43 \pm 18.23 \pm 15.47 \pm 15.47 \pm 17.47 \pm 14.83 \pm 12.07 \pm 20.13 \pm 17.43 \pm 18.23 \pm 15.47 \pm 15.47 \pm 17.47 \pm 14.83 \pm 12.07 \pm 20.13 \pm 17.43 \pm 18.23 \pm 15.47 \pm 17.47 \pm 14.83 \pm 17.47 \pm 14.83 \pm 17.47 \pm 14.83 \pm 17.47 \pm 14.83 \pm 17.47 \pm 1$	-		0.025	0.02	0.025	0.057	0.058	0.072	0.025	0.023	0.58	0.01	0.05	0.015	0.015
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		Winter	$21./3 \pm$	$13./3 \pm$	$15.33 \pm$	$16.0/\pm$	$20.64 \pm$	$21.4 \pm$ 0.520	14./±	$14.83 \pm$	$22.07 \pm$ 0.115	$20.13 \pm$	$15.43 \pm$	$18.23 \pm$	$15.4/\pm$ 0.152
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Temperature		20.13 +	26.7 +	22 17 +	28.03 +	$30.71 \pm$	30.9 +	27.37 +	25 53 +	33.13.+	35.1+	$23.17 \pm$	29.23 +	29.67 +
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	(E)	Summer	0.153	0.173	0.289	0.058	0.01	0.1	0.635	0.503	0.231	0.173	0.289	0.252	0.866
Monsoon 0.153 0.208 0.115 0.208 0.577 0.265 0.153 0.050 0.115 0.153 0.173 0.1 0.416 Nitrate Nitrogen (mgL ⁻¹) 1.15 ± 1.41 ± 1.44 ± 0.53 ± 0.63 ± 0.74 ± 0.55 ± 2.17 ± 0.57 ± 0.69 ± 0.81 ± 0.51 ± 0.32 ± 0.020 0.010 0.04 0.006 0.061 0.006 0.081 0.015 0.023 0.021 0.01 0.04 0.006 0.061 0.006 0.081 0.015 0.023 0.021 0.01 0.024 0.021 0.01 0.024 0.021 0.01 0.015 0.015 0.02 0.01 0.021 0.01 0.015 0.015 0.02 0.01 0.015 0.02 0.01 0.015 0.02 0.01 0.015 0.02 0.01 0.015 0.02 0.01 0.015 0.02 0.01 0.015 0.026 0.01 0.015 0.026 0.01 0.015 0.026	(-)		29.13 ±	$20.23 \pm$	$21.07 \pm$	$27.23 \pm$	$26.67 \pm$	$28.3 \pm$	$26.13 \pm$	$24.75 \pm$	$31.77 \pm$	34.23 ±	19.9 ±	27.1 ±	$26.47 \pm$
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		Monsoon	0.153	0.208	0.115	0.208	0.577	0.265	0.153	0.050	0.115	0.153	0.173	0.1	0.416
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		Winter	$1.15 \pm$	1.41 ±	$1.44 \pm$	$0.53 \pm$	$0.63 \pm$	$0.74 \pm$	$0.5 \pm$	2.17 ±	$0.57 \pm$	$0.69 \pm$	$0.81 \pm$	0.51 ±	$0.32 \pm$
		winter	0.15	0.01	0.032	0.015	0.01	0.04	0.006	0.061	0.006	0.081	0.015	0.023	0.021
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Nitrate	Summer	$1.54 \pm$	$1.61 \pm$	$1.64 \pm$	$1.07 \pm$	$1.5 \pm$	$1.63 \pm$	$1.23 \pm$	$2.53 \pm$	1.2 ±	$1.42 \pm$	$1.62 \pm$	$1.17 \pm$	$1.13 \pm$
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	(mgI ⁻¹)		0.069	0.017	0.012	0.064	0.1	0.01	0.058	0.031	0.015	0.015	0.02	0.01	0.155
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	(mgr.)	Monsoon	$1.2 \pm$ 0.265	1.31 ± 0.012	1.39 ± 0.015	0.33 ± 0.042	0.82 ± 0.021	1.1 ± 0.1	0.31 ±	+0.92	0.30 ±	1.4 ± 0.1	$1.2 \pm$ 0.087	$0.93 \pm$ 0.044	0.02 ± 0.015
			0.54 ±	0.62±	0.65±	$0.73 \pm$	0.10±	0.14 ±	0.18±	$0.18 \pm$	0.17±	0.51 ±	0.53 ±	0.52 ±	0.61±
	Soluble R.	Winter	0.006	0.021	0.031	0.015	0.006	0.015	0.015	0.006	0.01	0.015	0.026	0.01	0.01
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		C	$1.14 \pm$	$1.37 \pm$	1.1 ±	1.51 ±	0.53 ±	$0.6 \pm$	0.71 ±	$0.83 \pm$	$0.95 \pm$	0.92 ±	$0.81 \pm$	0.90 ±	$1.03 \pm$
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	(mgI ⁻¹)	Summer	0.51	0.351	0.1	0.015	0.031	0.006	0.012	0.015	0.95	0.01	0.01	0.006	0.061
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	(ingl.)	Monsoon	0.92 ±	0.95 ±	0.85 ±	0.93 ±	0.12	0.21 ±	0.35 ±	0.41 ±	0.42 ±	0.69 ±	0.79 ±	0.82 ±	0.76 ±
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			0.01	0.045	0.031	0.020	±0.01	0.021	0.006	0.015	0.015	0.01	0.012	0.021	0.015
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		Winter	0.23 ±	$0.41 \pm$	$0.33 \pm$	$0.15 \pm$	0.14 ±	$0.44 \pm$	$0.22 \pm$	$0.34 \pm$	0.31 ±	$0.46 \pm$	$0.33 \pm$	0.39 ±	0.50 ±
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Ammonium		0.01	0.03	0.03	0.006	0.015	0.025	0.006	0.006	0.01	0.000	0.015	0.006	0.006
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Nitrogen	Summer	0.42 ±	0.48±	0.48 ±	0.22 ± 0.02	0.19 ± 0.006	$0.34 \pm$ 0.006	0.17 ± 0.006	0.52 ±	0.30 ±	0.012	0.40 ±	0.49 ±	0.40 ±
Monsoon 0.01 0.03 0.025 0.006 0.02 0.02 0.02 0.01 0.01 0.015 0.006 0.02 0.016	(mgL ⁻¹)		0.32 ±	0.31 +	0.24 ±	0.10.+	0.24 ±	0.25 +	0.15 ±	0.17 +	0.13 ±	$0.34 \pm$	0.48 ±	0.56 ±	0.34 +
		Monsoon	0.01	0.03	0.025	0.006	0.02	0.02	0.02	0.01	0.01	0.015	0.006	0.02	0.006

Table 3: Seasonal variation in physico-chemical parameters of water bodies (Mean \pm SD) at thirteen sampling sitesof Jim Corbett National Park, Uttarakhand

520.82 km²; Sonanadi Wildlife Sanctuary: 301.18 km² and Reserve Forests: 496.54 km²) (Khanna *et al*. 2017) (Figure 1).

C13).

Sampling of Desmids

Sample collection and preservation

One twenty five algal samples were collected during January to December 2019 (winter, summer and monsoon season) from 13 sampling sites encompassing various habitats such as rivers, streams, ditches, canals, dams, and spring water bodies from Jim Corbett National Park (JCNP) as depicted in Table-1 as C1-C13 and Figure 1 (C1Desmids samples were collected using standard methods (Squeeze sampling) prescribed by Coesel (1998), Coesel and Meesters (2007) - Submerged aquatic plants of streams, rivers were collected by hand and gently squeezed to remove excess water (squeezing). The excess water from the aquatic vegetation was squeezed very hard by thumb pointing downwards. Excess water was allowed to run along the thumb and final water drips were

	Trophi	c status	
Sites	Winter	Summer	Monsoon
C1	OM	OM	OM
C2	OM	М	OM
C3	OM	М	OM
C4	ОМ	OM	OM
C5	OM	OM	OM
C6	OM	М	OM
C7	О	OM	OM
C8	0	М	OM
С9	OM	OM	OM
C10	OM	М	OM
C11	OM	М	OM
C12	OM	OM	OM
C13	OM	OM	OM

Table 4: Trophic status of water bodies of Jim Corbett

 National Park, Uttarakhand

Abbreviations: O - oligotrophic, OM - oligotrophicmesotrophic and M - mesotrophic

collected into the 50 ml sterilized Tarson plastic bottles with tight seal cap. Sample number, date of collection, locality, name of the collector, and time of collection was noted down on the sample container as well as on notebook for furnishing a complete collection process. Algal samples were kept in 50 ml pre-rinsed sterilized Tarson specimen bottles and kept cool in icebox and transported to the laboratory for analysis which was performed within 48 hours after collection. The collected samples were preserved in 8% Formaldehyde solution and deposited at the Lucknow Garden (LWG) Herbarium, CSIR-National Botanical Research Institute, Lucknow, India. Similarly, all water samples were collected in triplicates. At each sampling site, about 300 ml water samples for water parameter analyses were taken at 0.5 m depth, placed in pre-cleaned polyethylene bottles. Water samples were filtered using Whatman Filter paper (pore size $2.5 \,\mu\text{m}$) in the laboratory and preserved by adding 0.15 % (v/v) of conc. HNO, and stored in a refrigerator (4C).

Analysis of water parameters

The Physico-chemical parameters such as temperature, salinity, pH, dissolved oxygen (DO), electrical conductivity (EC) and total dissolved solids (TDS) were measured at the sampling site (Table 3) with multi-parameter Analyser (HQ 40d multi, HATCH). Nutrients such as nitrate-nitrogen (NO_3N) , ammonium nitrogen (NH_4^+-N) , and soluble reactive phosphorous (SRP) were analysed using the multi-parameter instrument LOVIBOND Xd7500.

Trophic status evaluation

The key parameters (electrical conductivity, nitrate-nitrogen, dissolved oxygen, ammoniumnitrogen, and soluble reactive phosphorus) were evaluated for development of trophic status of water bodies according to the Applied Algal Research Laboratory Physical and Chemical score (AARL-PC) score formulated by Leelahakriengkrai and Peerapornpisal (2011).

Morphological Identification

Microscopic observation of desmid samples was carried out by Leica DM 500 research microscope connected with a computer having a digital image analyser and software LAS EZ 1.8.0 taken with attached camera LEICA EC-3. The identification of the desmid was authenticated based upon standard keys given by Turner (1892), Fritsch (1935), Scott and Prescott (1961), Tiffany and Britton (1951), Prescott (1966), Prasad and Misra (1992), Yamagishi and Kanetsuma (1990), Coesel (1993).

Results

Desmids taxa have been classified according to Guiry (2013). Descriptions of each taxon are presented along with synonyms, locality (collection site), phenology of organism, voucher number and ecological conditions (habitat with environmental parameters).

Systematic Enumeration of Desmids

Class: Zygnematophyceae

Order: Zygnemetales

Family: Mesotaeniaceae

Genus: Cylindrocystis Meneghini De Bary

1. *Cylindrocystis brebissonii* (Ralfs) De Bary (Plate1, Figure 22) Scott and Prescott (1961), pg. 8, Plate 1, Figure 3





(Synonyms: Homotypic: *Penium brebissonii* (Ralfs) De Bary; Heterotypic: *Cylindrocystis brebissonii* var. *curvata* Rabanus, *Cylindrocystis brebissonii* var. *minor* West & G. S. West, *Cosmarium brebissonii* var. *majus* Huber-Pestalozzi, *Cylindrocystis brebissonii f. curvata* (Rabanus) Kossinskaja)

Cells 67-72 µm long, 14-15µm in diameter

Locality: Ringora village, Bijrani (Transition zone) Phenology: Winter season

Voucher number: LWG 002213

Ecological conditions: Stream water with slightly alkaline pH (7.70), conductivity (207.4 μ Scm⁻¹), TDS (50.9 mgL⁻¹), water temp. (14.83 °C), salinity

(0.05 %), DO (9.36 mgL⁻¹), NO₃⁻N (2.17 mgL⁻¹), SRP (0.18 mgL⁻¹) and NH₄⁺-N (0.34 mgL⁻¹).

2. *Cylindrocystis crassa* **De Bary** (Plate 1, Figure 29)

Scott and Prescott (1961), pg. 8, Plate 1, Figure 4 Cells 21 μ m long, 11 μ m in diameter Locality: Kalagarh (Buffer zone) Phenology: Winter season Voucher number: LWG 002213 Ecological conditions: Stream water characterized with slightly alkaline pH (8.34), conductivity (644.23 μ Scm⁻¹), TDS (303.2 mgL⁻¹), water temp. (15.43 °C), salinity (0.35 %), DO (9.35 mgL⁻¹), NO₃⁻¹ N (0.69 mgL⁻¹), SRP (0.51 mgL⁻¹) and NH₄⁺-N (0.46 mgL^{-1}).

Genus: Netrium (Nägeli) Itzigsohn & Rothe

3. *Netrium digitus* (Brébisson **ex Ralfs) Itzigsohn** & **Rothe** (Plate 2, Figure 16)

Prasad and Misra (1992), pg. 90, Plate 15, Figure 1

(Synonym: Homotypic: *Penium digitus* Brébisson ex Ralfs; Heterotypic: *Closterium digitus* Ehrenberg)

Cells 262 μ m long, 45 μ m in diameter, apex 18-19 μ m.

Locality: Saddle dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002951

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

Class: Zygnematophyceae Order: Desmidiales Family: Peniaceae Genus: Penium Brébisson ex Ralfs

4. *Penium margaritaceum* **Brébisson** (Plate 2, Figures 2, 3 and 8)

Tiffany and Britton (1951), pg. 176, Plate 51, Figure 540

(Synonyms: Heterotypic: *Penium margaritaceum* var. *punctatum* Ralfs, *Closterium margaritaceum* Ehrenberg)

Cells 40-68 μ m long 12-13 μ m in diameter

Locality: Saddle Dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002852 and 002853

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃⁻N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

Note: Size of the cells is slightly less than previous reported by Tiffany and Britton (1951).

Class: Zygnematophyceae Order: Desmidiales Family: Closteriaceae Genus: *Closterium* Nitzsch ex Ralfs

5. Closterium acerosum Ehrenberg ex Ralfs

(Plate 2, Figure 14)

Prasad and Misra (1992), pg. 97, Plate 16, Figure 15 (Synonym: *Vibrio acerosum* Schrank, *Closterium sigmoideum* Lagerheim & Nordstedt in Wittrock & Nordstedt)

Cells 333-335 μm long, center 47-48 μm in diameter, apex 3-4 μm in diameter

Locality: Durga devi (Transition zone) and Jhirna (Transition zone)

Phenology: Winter season

Voucher number: LWG 002977, 002969 and 002813

Ecological conditions: (i) Durga devi (Transition zone) - Spring stream water with slightly alkaline pH (7.43), low conductivity (90.87 μ Scm⁻¹), low TDS (77.53 mgL⁻¹), water temp. (21.73 °C), salinity (0.22 %), high DO (10.70 mgL⁻¹), NO₃N (1.15 mgL⁻¹), SRP(0.54 mgL⁻¹) and NH₄⁺-N (0.23 mgL⁻¹). (ii) Jhirna (Transition zone): Moderately flowing small water canal in the form of small freshwater ditch made purposely to supply drinking water to the village people and wildlife. This water is alkaline pH (8.37), EC (200.26 μ Scm⁻¹), TDS (102.57 mgL⁻¹), water temp. (21.4 °C), salinity (0.17 %), DO (9.86 mgL⁻¹), NO₃N (0.74 mgL⁻¹), SRP (0.14 mgL⁻¹) and NH₄⁺-N (0.44 mgL⁻¹).

6. Cl. braunii Reinsch (Plate 2, Figure 11)

Scott and Prescott (1961), pg.10, Plate 1, Figure 22 Cells 678 μ m long, center 32 μ m, apex 14 μ m Locality: Saddle dam, Sona Nadi (Transition zone) and Dhela stream, Dhela (Transition zone) Phenology: Monsoon and winter season Voucher number: LWG 002952 and 002843 Ecological conditions: (i) Saddle Dam, Sona Nadi (Transition zone): River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃ N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

(ii) Dhela stream, Dhela (Transition zone): Moderately shallow flowing stream water characterized by slightly alkaline pH (8.12), conductivity (200.53 μ Scm⁻¹), TDS (182.6 mgL⁻¹), water temp. (22.07 °C), salinity (0.13 %), DO (8.16 mgL⁻¹), NO₃ N (0.57 mgL⁻¹), SRP (0.17 mgL⁻¹) and NH₄⁺-N (0.31 mgL⁻¹).

7. *C. calosporum* Wittrock (Plate 2, Figure 13) Scott and Prescott (1961), pg.10, Plate 1, Figure 20 Cells 72-91 μm long, center 11 μm, apex 2 - 4 μm Locality: Saddle dam, Sona Nadi (Transition zone)

Phenology: Monsoon season

Voucher number: LWG 002954

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

8. *Cl. ehrenbergii* Meneghini ex Ralfs (Plate 2, Figure 9)

Scott and Prescott (1961), pg.11, Plate 2, Figure 22 (Synonym: *Closterium gigas* F. Gay)

Cells 420-428 μ m long, center 69-83 μ m, apex 15 μ m

Locality: Bhadrakot Mohan, Durga Devi (Transition zone)

Phenology: Summer season

Voucher number: LWG 002985

Ecological conditions: Fast flowing stream water characterized with pH (7.12), conductivity (88.73 μ S cm⁻¹), TDS (43.5 mgL⁻¹), salinity (0.18%), low dissolved oxygen (6.04 mgL⁻¹), water temperature (29.67 °C), NO₃ N (1.13 mgL⁻¹), SRP (1.03 mgL⁻¹) and NH₄⁺-N (0.46 mgL⁻¹).

9. C. kuetzingii Brébisson (Plate 2, Figure 7)

Scott and Prescott (1961), pg.11, Plate 2, Figure 2 (Synonym: Heterotypic: *Closterium kuetzingii* var. *onchyosporum* West & G. S. West, *Closterium kuetzingii* var. *laeve* Krieger)

Cells 322-350µm long, center 23-24 µm, apex 3 µm Locality: Durga devi (Buffer zone)

Phenology: Winter season

Voucher number: LWG 002978

Ecological conditions: Spring water stream characterized with pH (7.07), conductivity (352.67 μ S cm⁻¹), TDS (117.6 mgL⁻¹), salinity (0.07%), low dissolved oxygen (7.96 mgL⁻¹), water temperature (15.33 °C), NO₃ N (1.44 mgL⁻¹), SRP (0.65 mgL⁻¹) and NH₄⁺-N (0.33 mgL⁻¹).

10. *Cl. closterioides* (Ralfs) A. Louis & Peeters (Plate 2, Figure 1)

Prasad and Misra (1992), pg. 110, Plate 17, Figure 16

(Synonym: *Closterium libellula* Focke ex Nordstedt)

Cells 139-142 μ m long, center 24-27 μ m, apex 10 μ m

Locality: Jhirna (Buffer zone)

Phenology: Monsoon season

Voucher number: LWG 002852

Ecological conditions: Stream water with pH (8.13), conductivity ($321.06 \ \mu S \ cm^{-1}$), TDS ($125.43 \ mgL^{-1}$), salinity (0.08%), dissolved oxygen (7.71 mgL⁻¹), water temperature ($26.67 \ C$), NO₃⁻N ($0.82 \ mgL^{-1}$), SRP ($0.12 \ mgL^{-1}$) and NH₄⁺-N ($0.24 \ mgL^{-1}$).

11. C. littorale F. Gay (Plate 2, Figure 15)

Prasad and Misra (1992), pg.111, Plate 17, Figure 9 Cells 148-150 μ m long, center 22-23 μ m, apex 3-4 μ m

Locality: Dhangarhi stream, Dhikala (Transition zone) and Ringora village, Bijrani (Transition zone)

Phenology: Winter season

Voucher number: LWG 002813

Ecological conditions: (i) Dhangarhi stream, Dhikala (Transition zone): Transparent, clean, moderately flowing stream water with alkaline pH (8.05), conductivity (121.8 μ Scm⁻¹), TDS (105.4 mgL⁻¹), water temp. (14.7 °C), salinity (0.11 %), DO (9.83 mgL⁻¹), NO₃⁻N (0.5 mgL⁻¹), SRP (0.18 mgL⁻¹) and NH₄⁺-N (0.22 mgL⁻¹).

(ii) Ringora village, Bijrani (Transition zone): Spring water with fast flow alkaline pH (7.70), conductivity (207.4 μ Scm⁻¹), TDS (50.9 mgL⁻¹), water temp. (14.83 °C), salinity (0.05%), DO (9.36 mgL⁻¹), NO₃⁻N (2.17 mgL⁻¹), SRP (0.18 mgL⁻¹) and NH₄⁺-N (0.34 mgL⁻¹).

12. *C. leibleinii* var. *recurvatum* West & G. S. West (Plate 2, Figures. 4 and 5)

Prasad and Misra (1992), pg.110, Plate 17, Figure 16

Cells 190-198 μm long, center 31-33 μm , apex 6-7 μm

Locality: Saddle Dam, Sona Nadi (Transition zone) Phenology: Winter season

Voucher number: LWG 002791 and 002790

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

13. *C. lunula* var. *massartii* (De Wildeman) Willi Krieger (Plate 2, Figure 10)

Scott and Prescott (1961), pg.112, Plate 15, Figure

5-8

(Basionym: Closterium massartii De Wildeman)

Cells 690-712 μm long, center 91-100 μm , apex 12-13 μm

Locality: Durga devi (Buffer zone) and Dhela stream, Dhela (Transition zone)

Phenology: Winter season

Voucher number: LWG 002978 and 002803

Ecological conditions: (i) Durga devi (Buffer zone): Spring water stream characterized with pH (7.07), conductivity (352.67 μ S cm⁻¹), TDS (117.6 mgL⁻¹), salinity (0.07%), low dissolved oxygen (7.96 mgL⁻¹), water temp. (15.33 °C), NO₃'N (1.44 mgL⁻¹), SRP (0.65 mgL⁻¹) and NH₄⁺-N (0.33 mgL⁻¹). (ii) Dhela stream, Dhela (Transition zone): Spring water stream characterized with pH (8.12), conductivity (200.53 μ S cm⁻¹), TDS (182.6 mgL⁻¹), salinity (0.13%), low dissolved oxygen (8.16 mgL⁻¹), water temp. (22.07 °C), NO₃'N (0.57 mgL⁻¹), SRP (0.17 mgL⁻¹) and NH₄⁺-N (0.31 mgL⁻¹).

14. *C. moniliferum* Ehrenberg ex Ralfs (Plate 2, Figure 17)

Prasad and Misra (1992), pg.113, Plate 17, Figure 5 Cells 209-222 µm long, 34-35 µm in diameter, lateral apex 8-9

(Synonym: Heterotypic: *Lunulina monilifera* Bory)

Locality: Saddle Dam, Sona Nadi (Transition Zone)

Phenology: Monsoon season

Voucher number: LWG 002852

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃⁻¹ N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

15. C. parvulum Nägeli (Plate 2, Figure 12)

Prasad and Misra (1992), pg.114, Plate 16, Figure 17

Cells 121-124µm long, center 14-17µm, apex 2-3µm

Locality: Saddle Dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002853

Ecological conditions: River water with alkaline pH (7.96), conductivity ($328.63 \ \mu$ Scm⁻¹), TDS ($124.8 \ mgL^{-1}$), water temp. ($16.07 \ ^{\circ}$ C), salinity ($0.18 \ ^{\circ}$), DO ($8.03 \ mgL^{-1}$), NO₃⁻N ($0.55 \ mgL^{-1}$), SRP

(0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹). Class: Zygnematophyceae Order: Desmidiales Family: Desmidiaceae Genus: *Pleurotaenium* Nägeli

16. *Pleurotaenium trabecula* Nägeli (Plate 2, Figure 6)

Scott and Prescott (1961), pg.18, Plate 3, Figure 4 (Synonym: Heterotypic: *Docidium ehrenbergii* var. [delpontei] f. *constricta* Playfair, *Closterium trabecula* Ehrenberg, *Docidium trabecula* (Ehrenberg) Reinsch, *Pleurotaenium trabecular* f. *granulatum* G. S. West) Cells 422-510 µm long, 27-31 µm in diameter, Isthmus 21-24 µm.

Locality: Brys Caves Resort, Durga devi (Transition zone)

Phenology: Winter season

Voucher number: LWG 002240

Ecological conditions: Stream water with alkaline pH (8.12), conductivity (188.83 μ Scm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73 °C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃⁻N (1.41 mgL⁻¹), SRP (0.62 mgL⁻¹) and NH₄⁺-N (0.41 mgL⁻¹).

Genus: Euastrum Ehrenberg ex Ralfs

17. *Euastrum ansatum* Ehrenberg ex Ralfs (Plate 2, Figure 20)

Scott and Prescott (1961), pg. 22, Plate 9, Figure 1 (Synonym: Homotypic: *Cosmarium ansatum* (Ehrenberg ex Ralfs) Rabenhorst; Heterotypic: *Euastrum rotundum* Playfair; *Euastrum ansatum* var. *dideltiforme* Ducellier, *Euastrum ansatum* var. *c o m m u n e* D u c elli e r, *C o s m a r i u m pseudopyramidatum* var. *ansatum* Krieger & Gerloff, *Euastrum ansatum f. dideltiforme* (Ducellier) G. H. Tomaszwicz & W. W. Kowalski) Cells 87-89 µm long, 40-41µm in diameter,

Cells 87-89 μ m long, 40-41 μ m in diameter, Isthmus 14 μ m.

Locality: Kalagarh (Buffer zone)

Phenology: Winter season

Voucher number: LWG 002214

Ecological conditions: Stream water with alkaline pH (8.34), conductivity (644.23 μ Scm⁻¹), TDS (303.2 mgL⁻¹), water temp. (15.43 °C), salinity (0.35%), DO (9.35 mgL⁻¹), NO₃⁻N (0.81 mgL⁻¹), SRP(0.53 mgL⁻¹) and NH₄⁺-N (0.33 mgL⁻¹).

18. *Euastrum rostratum* var. *biculatum* A. M. Scott & Prescott (Plate 1, Figure 26)

Scott and Prescott (1961). pg. 36, Plate 11, Figures 8,9

Cells 48-50 μ m long, 31-32 μ m in diameter, Isthmus 10 μ m

Locality: Bhadrakot Mohan, Durga devi (Transition zone)

Phenology: Winter season

Voucher number: LWG 002986

Ecological conditions: Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃ N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

19. *Euastrum spinulosum* **Delponte** (Plate 1, Figure 15)

Scott and Prescott (1961). pg. 40, Plate 10, Figure 3 Cells 55 μ m long, 47 μ m in diameter, Isthmus 113 μ m

Locality: Bhadrakot Mohan, Durga Devi (Transition Zone)

Phenology: Winter season

Voucher number: LWG 002961

Ecological conditions: Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃ N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

20. *Staurastrum punctulatum* **Brébisson** (Plate 2, Figures 23, 24 and 25)

Scott and Prescott (1961). Pg. 104, Plate 52, Figure 14

(Synonyms: Homotypic: Cosmoastrum punctulatum (Brébisson) Palamar-Mordvintseva, Staurodesmus punctulatus (Brébisson) Akin & R. L. Meyer)

Cells 24-30 µm long, 22-28 µm broad

Locality: Durga devi (Buffer zone) and Saddle Dam, Sona Nadi (Transition zone)

Phenology: Winter and monsoon season

Voucher number: LWG 002863

Ecological conditions: (i) Durga devi (buffer zone) - spring water stream characterized with pH (7.07), conductivity (352.67 μ S cm⁻¹), TDS (117.6 mgL⁻¹), salinity (0.07%), low dissolved oxygen (7.96 mgL⁻¹)

¹), water temp. (15.33 °C), NO₃-N (1.44 mgL⁻¹), SRP (0.65 mgL⁻¹) and NH₄⁺-N (0.33 mgL⁻¹).

(ii) Saddle Dam, Sona Nadi (Transition zone): River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃⁻¹ N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

Genus: Micrasterias C. Agardh ex Ralfs

21. *Micrasterias radians* **W.B. Turner** (Plate 1, Figure 32)

Scott and Prescott (1961). Pg. 51, Plate 23, Figure 1 (Synonym: Homotypic: *Micrasterias cruxmelitensis* var. *radians* (W. B. Turner) Coesel & M. Dingley)

Cells 115-117 μ m long, 102-103 μ m in diameter, Isthmus 18-20 μ m

Locality: Kalagarh, (Transition zone)

Phenology: Winter season

Voucher number: LWG 002214

Ecological conditions: Water stream characterized with pH (8.03), conductivity (300.26 μ S cm⁻¹), TDS (98.5 mgL⁻¹), salinity (0.10%), low dissolved oxygen (8.46 mgL⁻¹), water temp. (18.23 °C), NO₃ N (0.51 mgL⁻¹), SRP (0.52 mgL⁻¹) and NH₄⁺-N (0.39 mgL⁻¹).

Genus: Heimansia Coesel

22. Heimansia pusilla Hilse (Plate 1, Figure 20)

Coesel (1993), pg. 106, Plate 1, Figures 1-3

(Synonym: Homotypic: Cosmocladium pusillum L. Hilse; Heterotypic: Euastrum pusillum Brébisson, Cosmarium pusillum (Brébisson) W. Archer)

Cells 5-8 μm long, 10-12 μm in diameter, Isthmus 14-24 μm

Locality: Bhadrakot Mohan, Durga devi (Transition zone)

Phenology: Winter season

Voucher number: LWG 002986

Note: Heimansia pusilla is a rare desmid.

Ecological conditions: Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃ N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺N (0.50 mgL⁻¹).

Genus: Cosmarium Corda ex Ralfs

23.*Cosmarium awadhense* B. N. Prasad & R. K. Mehrotra (Plate 1, Figure 7)

Prasad and Misra (1992), pg. 114, Plate 16, Figure 17

Cells 16 μ m long, 13 μ m in diameter

Locality: Brys Caves Resort, Durga devi

(Transition zone)

Phenology: Monsoon season

Voucher number: LWG 002192

Ecological conditions: Stream water with alkaline pH (8.12), conductivity (188.83 μ Scm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73 °C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃⁻N (1.41 mgL⁻¹), SRP(0.62 mgL⁻¹) and NH₄⁺N (0.41 mgL⁻¹).

24. C. calcareum Wittrock (Plate 2, Figure 18)

Prasad and Misra (1992), pg.156, Plate 24, figures 15, 18

(Synonym: Homotypic: Ursinella calcarea (Wittrock)Kuntze)

Cells 7-15 μ m long, 10-14 μ m in diameter, Isthmus 2-3 μ m

Locality: Saddle dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002852

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃ N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄ ⁺N (0.10 mgL⁻¹).

25. C. cucumis Corda ex Ralfs (Plate 1, Figure 4)

Tiffany and Britton (1952), pg. 185, Plate 53, Figure 581

(Synonym: Homotypic: Cosmaridium cucumis (Corda ex Ralfs) F. Gay, Calocylindrus cucumis (Corda ex Ralfs) Istvanfy; Heterotypic: Pleurotaeniopsis cucumis (Ralfs) Lagerheim)

Cells 34-35 µm long, 19-20 µm in diameter, Isthmus 15-16µm

Locality: Dhangarhi stream, Dhikala (Transition zone)

Phenology: Winter season

Voucher number: LWG 002194

Ecological conditions: Transparent, clean, moderately flowing stream water with alkaline pH (8.05), conductivity (121.8 μ Scm⁻¹), TDS (105.4 mgL⁻¹), water temp. (14.7 °C), salinity (0.11 %), DO (9.83 mgL⁻¹), NO₃⁻N (0.5 mgL⁻¹), SRP (0.18 mgL⁻¹) and NH₄⁺N (0.22 mgL⁻¹).

26. C. elongatum Raciborski Teiling (Plate 1)

Turner (1892), pg. 58, Plate 8, Figure 46 Cells 92-94 μm long, 39-42 μm in diameter, isthmus 33-35 μm Locality: Durga devi (Buffer Zone) Phenology: Winter season

Voucher number: LWG 002192

Ecological conditions: Spring water stream characterized with pH (7.07), conductivity (352.67 μ S cm⁻¹), TDS (117.6 mgL⁻¹), salinity (0.07%), low dissolved oxygen (7.96 mgL⁻¹), water temp. (15.33 °C), NO₃⁻-N (1.44 mgL⁻¹), SRP (0.65 mgL⁻¹) and NH₄⁺N (0.33 mgL⁻¹).

27. *C. granatum* Brébisson ex Ralfs (Plate 1, Figure 21)

Prasad and Misra (1992), pg. 160, Plate 21, Figure 20

(Synonym: *Euastrum granatum* (Brébisson ex Ralfs) F. Gay, *Cosmarium granatum* f. *pentagonum* Raciborski)

Cells 11-21 μ m long, 14-15 μ m in diameter, Isthmus 4-5 μ m

Locality: Saddle dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002907

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺N (0.10 mgL⁻¹).

28. C. hammeri var. homalodermum (Nordstedt) West & G. S. West (Plate 1, Figure 31)

Prasad and Misra (1992), pg.161, Plate 21, Figure 4 (Synonym: Homotypic: Cosmarium homalodermum Nordstedt; Basionym: Cosmarium homalodermum Nordstedt)

Cells 50-53 μm long, 30-33 μm in diameter, Isthmus 10-11 μm

Locality: Ringora village, Bijrani (Transition zone) Phenology: Winter season

Voucher number: LWG 002980

Ecological conditions: Spring water with fast flow, alkaline pH (7.70), conductivity (207.4 μ Scm⁻¹), TDS (50.9 mgL⁻¹), water temp. (14.83 °C), salinity (0.05%), DO (9.36 mgL⁻¹), NO₃N (2.17 mgL⁻¹), SRP (0.18 mgL⁻¹) and NH₄⁺-N (0.34 mgL⁻¹).

29. C. insigne Schmidle (Plate 1, Figure 14)

Turner (1892), pg. 58, Plate 8, Figure 46 (Synonym: *Cosmarium pseudoinsigne* Prescott) Cells 380 long, 32-36 µm in diameter, Isthmus 10-11 µm Locality: Dhangathi stream Dhikala (Transition

Locality: Dhangarhi stream, Dhikala (Transition zone)

Phenology: Summer season

Voucher number: LWG 002950

Ecological conditions: Transparent, clean, moderately flowing stream water with alkaline pH (8.05), conductivity (121.8 μ Scm⁻¹), TDS (105.4 mgL⁻¹), water temp. (14.7 °C), salinity (0.11 %), DO (9.83 mgL⁻¹), NO₃⁻N (0.5 mgL⁻¹), SRP (0.18 mgL⁻¹) and NH₄⁺-N (0.22 mgL⁻¹).

30. C. javanicum Nordstedt (Plate 1, Figure 28)

Bordoloi (1983), pg. 120, Figures 1-3.

(Synonym: Homotypic: *Pleurotaeniopsis javanicum* (Nordstedt) De Toni; Heterotypic: *Cosmarium maculatum* W. B. Turner)

Cells 108 µm long and 82 µm broad; Isthmus 35 µm Locality: Bhadrakot Mohan, Durga devi (Transition zone)

Phenology: Winter season

Voucher number: LWG 002981

Ecological conditions: Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

31. *C. laeve* **Rabenhorst** (Plate 1, Figure 19)

Yamagishi and Kanetsuma (1990), pg. 48, Plate 7, Figure 15

(Synonym: Euastrum laeve (Rabenhorst) F. Gay, Euastrum leiodermum F. Gay, Cosmarium laeve var. hispanicum Lewin, Cosmarium portuense J. Sampaio)

Cells 40 long, 32-36 μ m in diameter, Isthmus 10-11 μ m

Locality: Bhadrakot Mohan, Durga devi (Transition zone) and Saddle Dam, Sona Nadi (Transition zone)

Phenology: Winter and Monsoon Season

Voucher number: LWG 002986 and 002908

Ecological conditions: (i) Bhadrakot Mohan, Durga devi (Transition zone): Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

(ii) Saddle Dam, Sona Nadi (Transition zone): River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃⁻¹ N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

32. *C. laeve* var. *septentrionale* Wille (Plate 1, Figure 30)

Scott and Prescott (1961), pg. 60, Plate 32, Figure 1,2.

Cells 38 µm long, 24µm in diameter, Isthmus 9 µm Locality: Dhangarhi stream, Dhikala (Transition zone) and Dhikala (Buffer zone)

Phenology: Winter season

Voucher number: LWG 002846

Ecological conditions: (i) Dhangarhi stream, Dhikala (Transition zone): Transparent, clean, moderately flowing stream water with alkaline pH (8.05), conductivity (121.8 μ Scm⁻¹), TDS (105.4 mgL⁻¹), water temp. (14.7 °C), salinity (0.11 %), DO (9.83 mgL⁻¹), NO₃⁻N (0.5 mgL⁻¹), SRP (0.18 mgL⁻¹) and NH₄⁺-N (0.22 mgL⁻¹).

(ii) Dhikala (Buffer zone): Clean, moderately flowing stream water with alkaline pH (7.87), conductivity ($305.47 \ \mu Scm^{-1}$), TDS ($104.53 \ mgL^{-1}$), water temp. ($20.13 \ ^{\circ}$ C), salinity ($0.31 \ ^{\circ}$), DO ($8.71 \ mgL^{-1}$), NO₃⁻N ($0.69 \ mgL^{-1}$), SRP ($0.51 \ mgL^{-1}$) and NH₄⁺-N ($0.46 \ mgL^{-1}$).

33. *C. lundellii* **Delponte** (Plate 1, Figure 27)

Scott and Prescott (1961), pg. 60, Plate 25, Figure 6 Cells 64 μ m long, 67 μ m in diameter, Isthmus 30 μ m

Locality: Saddle Dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002910

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃⁻N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

34. C. nitidulum De Notaris (Plate 1, Figure 17)

Prasad and Misra (1992), pg. 168, Plate 22, Figures 17 and 21

(Synonym: Homotypic: *Euastrum nitidulum* (De Notaris) F. Gay)

Cells 30-33 μ m long, 23-24 μ m in diameter, Isthmus 3-4 μ m

Locality: Saddle dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002910

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18

%), DO (8.03 mgL⁻¹), NO₃⁻N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

35. *C. obsoletum* (Hantzsch) Reinsch (Plate 2, Figure 21)

Prasad and Misra (1992), pg. 170, Plate 22, Figures 12 and 16

(Synonym: Homotypic: Arthrodesmus obsoletus Hantzsch in Rabenhorst, Staurodesmus obsoletus (Hantzsch) Teiling, Pachyphorium obsoletum (Hantzsch) Palamar-Mordvintseva; Basionym: Arthrodesmus obsoletus Hantzsch)

Cells 47-50 μ m long, 42-44 μ m in diameter, Isthmus 21-24 μ m

Locality: Saddle dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002908

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹),

TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃ N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

36. *C. pachydermum* **P. Lundell** (Plate 1, Figures 12)

Scott and Prescott (1961), Pg. 64, Plate 31, Figure 14

Cells 22-25 μm long, 18-21 μm in diameter, Isthmus 5-8 μm

Locality: Saddle dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 0029007

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃⁻N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

37. *C. perpastrum* **W.B. Turner** (Plate 1, Figure 10)

Turner (1892), pg. 48, Plate 7, Figure 23

Cells 64-65µm long, 37-38µm in diameter, Isthmus 26-27µm

Locality: Brys Caves Resort, Durga Devi (Transition zone)

Phenology: Monsoon season

Voucher number: LWG 002896

Ecological conditions: Stream water with alkaline pH (8.12), conductivity (188.83 μ Scm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73 °C), salinity

(0.51%), DO (11.23 mgL⁻¹), NO₃⁻N (1.41 mgL⁻¹), SRP (0.62 mgL⁻¹) and NH₄⁺-N (0.41 mgL⁻¹).

38. *C. phaseolus* Brébisson ex Ralfs (Plate 1, Figure 34)

Scott and Prescott (1961), pg. 65, Plate 31, Figure 17

(Synonym: Homotypic: *Euastrum phaseolus* (Brébisson) F. Gay)

Cells 70 μ m long, 48 μ m in diameter, Isthmus 15 μ m

Locality: Brys caves, Durga devi (Transition zone) Phenology: Winter season

Voucher number: LWG 002993

Ecological conditions: Stream water with alkaline pH (8.12), conductivity (188.83 μ Scm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73 °C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃⁻N (1.41 mgL⁻¹), SRP (0.62 mgL⁻¹) and NH₄⁺-N (0.41 mgL⁻¹).

39. *C. portblairii* **B. N. Prasad & P. K. Misra** (Plate 2, Figure 19)

Prasad and Misra (1984), pg. 154, Plate 1, Figure 2; Plate 2, Figure 3

Cells 110-114 μ m long, 69-72 μ m in diameter, Isthmus 59-60 μ m

Locality: Durga devi (Buffer zone) and Saddle Dam, Sona Nadi (Transition zone)

Phenology: Winter and monsoon season

Voucher number: LWG 002986 and 002910 Ecological conditions: (i) Durga devi (Buffer zone): Spring water stream characterized with pH (7.07), conductivity (352.67 μ S cm⁻¹), TDS (117.6 mgL⁻¹), salinity (0.07%), low dissolved oxygen (7.96 mgL⁻¹), water temp. (15.33 °C), NO₃ N (1.44 mgL⁻¹), SRP (0.65 mgL⁻¹) and NH₄⁺-N (0.33 mgL⁻¹). (ii) Saddle Dam, Sona Nadi (Transition zone): River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃⁻ N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

40. *C. pseudoconnatum* Nordstedt (Plate 1, Figure 13)

Scott and Prescott (1961), pg. 66, Plate 25, Figure 4 (Synonym: Homotypic: *Calocylindrus pseudoconnatus* (Nordstedt) Wolle; Heterotypic: *Pleurotaeniopsis pseudoconnata* (Nordstedt) Lagerheim) Cells 65 μ m long, 49-54 μ m in diameter, Isthmus 45-49 μ m

Locality: Saddle dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002907

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

41. *C. pseudopyramidatum* var. *oculatumn* Willi Krieger (Plate 1, Figure 2)

Scott and Prescott (1961), pg. 67, Plate 27, Figures 2-3

(Synonym: Homotypic Synonym: Euastrum pseudopyramidatum (P. Lundell) F. Gay)

Cells 58-64 μm long, 35-38 μm in diameter, Isthmus 24-25 $\mu m.$

Locality: Bhadrakot Mohan, Durga devi (Transition zone)

Phenology: Winter season

Voucher number: LWG 002760 and 002770

Ecological conditions: Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃⁻N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

42. *C. punctatum* **Nordstedt** (Plate1, Figures 8 and 23)

Prasad and Misra (1992), pg. 176, Plate 23, Figures 21

Cells 27-30 μ m long, 14-24 μ m in diameter, Isthmus 3-5 μ m

Locality: Bhadrakot Mohan, Durga devi (Transition zone)

Phenology: Winter season

Voucher number: LWG 002984

Ecological conditions: Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

43. *C. pyramidatum* **Brébisson ex Ralfs** (Plate1, Figures 1)

Prasad and Misra (1992), pg. 177, Plate 22, Figure 18

Cells 54-63 μ m long, 32-36 μ m in diameter, Isthmus 10-12 μ m

Locality: Bhadrakot Mohan, Durga devi (Transition zone) Phenology: Summer season

Voucher number: LWG 002213

Ecological conditions: Stream water with alkaline

pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃ N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

44. *C. quadrum* P. Lundell (Plate 1, Figure 6)

Prasad and Misra (1992), pg.178, Plate 23, Figures 1 and 2

Cells 30-33 μm long, 28-29 μm in diameter, Isthmus 9-10 μm

Locality: Saddle Dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002909

Ecological conditions: Saddle Dam, Sona nadi (Transition zone) river water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃⁻N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

45. *C. quadrifarium* **P. Lundell** (Plate 1, Figure 9) Scott and Prescott (1961), pg. 67, Plate 30, Figure 10

Cells 42 μ m long, 33 μ m in diameter, Isthmus 16 μ m

Locality: Brys Caves Resort, Durga Devi (Transition zone)

Phenology: Monsoon season

Voucher number: LWG 002906

Ecological conditions: Stream water with alkaline pH (8.12), conductivity (188.83 μ Scm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73 °C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃⁻N (1.41 mgL⁻¹), SRP (0.62 mgL⁻¹) and NH₄⁺-N (0.41 mgL⁻¹).

46. C. quinarium P. Lundell (Plate 1, Figure 16)

Prasad and Misra (1992), pg. 179, Plate 24, Figure 17

Cells 20-21 μ m long, 14-16 μ m in diameter, Isthmus 5-6 μ m

Locality: Bhadrakot Mohan and Brys Caves Resort, Durga devi (Transition zone)

Phenology: Winter and monsoon season

Voucher number: LWG 002884 and 002906

Ecological conditions: (i) Bhadrakot Mohan, Durga devi (Transition zone): Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

(ii) Brys Caves Resort, Durga devi (Transition zone): Stream water with alkaline pH (8.12), conductivity (188.83 μ Scm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73 °C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃ N (1.41 mgL⁻¹), SRP (0.62 mgL⁻¹) and NH₄⁺-N (0.41 mgL⁻¹).

47. C. speciosum P. Lundell (Plate 1, Figure 11)

Tiffany and Britton (1951), pg. 191, Plate 53, Figure 584

(Synonym: *Euastrum speciosum* (P. Lundell) F. Gay, *Dysphinctium speciosum* (P. Lundell) Hansgirg)

Cells 90-95 μ m long, 65-70 μ m in diameter, Isthmus 9-10 μ m

Locality: Saddle Dam, Sona Nadi (Transition zone) Phenology: Monsoon season

Voucher number: LWG 002910

Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 μ Scm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH₄⁺-N (0.10 mgL⁻¹).

48. *C. subprotumidum* **Nordstedt** (Plate 1, Figure 33)

Prescott (1966), pg. 22, Plate 3, Figure 29

Cells 32 µm long, 24 µm in diameter, Isthmus 6 µm Locality: Brys Caves Resort, Durga devi (Transition zone)

Phenology: Monsoon season

Voucher number: LWG 002992 Ecological conditions: Stream water with alkaline pH (8.12), conductivity (188.83 μ Scm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73 °C), salinity

(0.51%), DO (11.23 mgL⁻¹), NO₃^{-N} (1.41 mgL⁻¹), SRP (0.62 mgL⁻¹) and NH₄⁺-N (0.41 mgL⁻¹).

49. *C. subspeciosum var. transiens* Messikommer (Plate 2, Figure 22)

Lenzenweger (1994), pg. 151, Plate 64, Figure 9 Cells 32-33 µm long 26-67 µm in diameter, Isthmus 9.5-10 µm

Locality: Bhadrakot Mohan, Durga devi (Transition zone) Phenology: Winter season Voucher number: LWG 002986

Ecological conditions: Stream water with alkaline pH (7.82), conductivity (81.3 μ Scm⁻¹), TDS (40.37 mgL⁻¹), water temp. (15.47 °C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

50. C. supraspeciosum Wolle (Plate1, Figure 5)

Tiffany and Britton (1951), pg. 188, Plate 54, Figure 598

Cells 89-91 μm long, 63-65 μm in diameter, Isthmus 8-9 μm

Locality: Bhadrakot Mohan, Durga devi (Transition zone)

Phenology: Winter season

Voucher number: LWG 002986

Ecological conditions: Stream water with alkaline pH (7.82), conductivity (81.3μ Scm⁻¹),

TDS (40.37 mgL⁻¹), water temp. (15.47 $^{\circ}$ C), salinity (0.04%), DO (8.93 mgL⁻¹), NO₃N (0.32 mgL⁻¹), SRP (0.61 mgL⁻¹) and NH₄⁺-N (0.50 mgL⁻¹).

51. C. turpini Brébisson (Plate 2, Figure 18)

Tiffany and Britton (1951), pg. 191, Plate 54, Figure 593 Synonym: Ursinella turpinii (Brébisson) Kuntze) Cells 60-70 µm long, 50-55 µm in diameter, Isthmus 14-15 µm Locality: Saddle Dam, Sona Nadi (Transition zone) Phenology: Monsoon season Voucher number: LWG 002851 Ecological conditions: River water with alkaline pH (7.96), conductivity (328.63 µScm⁻¹), TDS (124.8 mgL⁻¹), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL⁻¹), NO₃'N (0.55 mgL⁻¹), SRP (0.93 mgL⁻¹) and NH,⁺-N (0.10 mgL⁻¹).

In our study, the most diverse genus was *Cosmarium* (57%) followed by *Closterium* (21%), *Euastrum* (6%), *Cylindrocystis* (4%) and remaining genera with 2% as shown in Figure 2. Seasonal variation in desmids was reported in the following trend: Winter (28 taxa) > Monsoon (25 taxa) > Summer (3 taxa) (Figure 3). Distribution of desmids taxa viz-a-viz seasons and sites are described in Table 3 and distribution of desmids taxa across sampling sites is described in Figure 4.

Environmental parameters: pH of water bodies in JCNP ranged between 7.07 to 8.37 in the winter season; 6.93-7.96 in the summer season and

monsoon season with a pH 7.04-8.33 (Table 3). Conductivity of water bodies was reported highest in the summer season while lowest conductivity was reported in the winter season. In our result, among all 13 sampling sites, we found TDS in the range with minimum concentration 50.9 ± 0.1 from site C8 and maximum concentration 303.2 ± 0.2 mgL^{-1} from site C11 in the winter season. TDS in the monsoon season range between $[41.73 \pm 0.058]$ mgL^{-1}] to [313.30 ± 0.265 mgL^{-1}] from site C13 and C11 respectively. Water bodies of the park were recorded with low salinity in all 3 seasons with very slight variations among different sites and seasons. Compared to winter and monsoon season, salinity was higher in the summer which may due to more evaporation. Among all the sites, winter seasons was found favourable for water bodies with higher concentration of dissolved oxygen (DO) recorded with highest concentration from site C2 (11.23 \pm 0.153 mgL^{-1}) to lowest DO observed at site C3 (7.96) $\pm 0.012 \text{ mgL}^{-1}$). Dissolved oxygen in the summer season varied between 6.04 \pm 0.015 to 10.12 \pm 0.021 mgL^{-1} at site C13 and C2 respectively. In the monsoon season, DO was recorded in the following minimum concentration (7.23 ± 0.58) from site C2 to maximum (10.58 \pm 0.02) mgL⁻¹ from C9. Water temperature varied between 13.73 ± 0.115 °C in the winter season from site C2 to 22.07 ± 0.115 °C from site C9. In the summer season, water temperature reached to maximum temperature which was recorded from site C9 while lowest temperature was recorded as 22.17 ± 0.289 °C from site C3. Monsoon season, water temperature varied in the range 19.9 \pm 0.173 °C from site C11 to 34.23 \pm 0.153 °C from site C10.

Nitrate-nitrogen, soluble reactive phosphorous and ammonium nitrogen concentration was highest in the summer season followed by monsoon and least concentration in the winter season (Table 3).

Trophic status of the park

The overall trophic status of the park is classified mainly under "oligotrophic", "oligo-mesotrophic" and "mesotrophic". Trophic status of the park was found to be similar in all the sampling sites as "oligo-mesotrophic" in monsoon season depicting clean-moderate water quality. However, some sampling sites such as site C2, C3, C6, C8, C10 and C11 in the summer season were classified as "mesotrophic" depicting moderate water quality (Table 4). Only site C7 and C8 in winter season are represented by "oligotrophic" status i.e. clean water quality, while remaining sites had "oligomesotrophic" status in the winter season. The study of Venkateshwarlu (1983) found that the dominance of desmids specifies the oligotrophic quality of the water body. This finding is probably related with our study because of geographical proximity of the preserved area of Corbett National Park.

As far as the sampling sites are concerned (Figure 4), site C4 is recorded with maximum diversity with total 5 genera reported i.e. *Netrium*, *Penium*, *Closterium*, *Straurastrum* and *Cosmarium*. Site C5 and C6 are reported with one genus (*Closterium*) and site C10 is reported with only *Cosmarium* genus. Thus, we can say that site C4 is a favourable site for desmids diversity.

Discussions

Floristic compositions

The taxonomic survey and morphotaxonomic identification of fresh water desmids samples resulted in altogether 51 taxa pertaining to 10 genera - *Closterium*, *Netrium*, *Cosmarium*, *Cylindrocystis*, *Euastrum*, *Heimansia*, *Micrasterias*, *Penium*, *Pleurotaenium* and *Straurastrum* under four families; Mesotaeniaceae, Peniaceae, Closteriaceae and Desmidiaceae (Plates 1 and 2). Family Desmidiaceae is dominated with 37 taxa under 7 genera, followed by Closteriaceae with 11 taxa and one genera, Mesotaeniaceae with 3 taxa and 2 genera and Peniaceae with single taxon under one genera. All these taxa are first report for JCNP except 2 desmid (Khare and Suseela 2004).

Species composition and distribution

Highest diversity of desmids has been recorded in winter season with 20 taxa (site C4). The most species rich genera was *Cosmarium* (29 taxa), followed by *Closterium* (11 taxa), *Euastrum* (3 taxa), *Cylindrocystis* (2 taxa) and *Staurastrum* (2 taxa). While genera with one taxon were *Heimansia*, *Micrasterias*, *Penium*, *Pleurotaenium*, *Netrium* and *Staurastrum*. Most abundant distribution of desmids in winter season and monsoon season was *Cosmarium*. Second most abundant was *Closterium* distributed in site C1,

C3-C9 and C13. Though Cosmarium and Closterium were found in all 3 seasons, but most of the desmids taxa were found in winter season while least number of taxa was found in summer season. Genus Cosmarium (3 taxa i.e. C. leave, C. portblairii and C. quinarium) and a single taxon of Straurastrum and Closterium are reported to be common in both winter and monsoon season (Table 2). While remaining taxa are season specific. Euastrum, Micrasterias and Heimansia were recorded in winter season from site C11 and C13. similarly exclusive diversity of Cylindrocystis were recorded in winter season (Figure 4). Clean water of the park is the reason for fairly dominant desmids diversity. These water bodies of the Park need conservation which will not only protect natural habitats supporting algal biodiversity but also be a good source of algal biomass for experimental and economic research.

The seasonal variations change the physico-chemical parameters of water which in turn changes the occurrence and diversity of algal species (Barman et al. 2015). The present study indicates that seasonal variation influenced the desmids diversity in a studied locality and maximum desmids species diversity occurred in the winter season followed by monsoon and the least diversity was recorded in the summer season. Patil and Karande (2020) reported the slightly alkaline pH with a low concentration of nitrate, phosphate, total alkalinity, and total dissolved solids (TDS) indicating that these parameters might be favourable for the acceleration of desmids in the winter season, whereas the higher concentration of total alkalinity, total hardness, and total dissolved solids were reported in summer season indicating hard water due to which diversity of desmids was found to be decreased in the summer season. Our observations also revealed the same.

Water temperature

The water temperature is directly correlated with atmospheric temperature. The factors influencing surface water temperature includes intensity of solar radiations, evaporation and fresh water influx which favours growth and distribution of aquatic community (Deepa *et al.* 2016). Water temperature in summer is high due to low water level, high temperature and clear atmosphere (Salve and Hiware 2008). Similar higher temperature was reported in our study in the summer season. This is further supported with the study of Pandey and Pandey (1980) that water temperature (20 - 30 °C) favours desmids growth. Winter season was favourable for desmids diversity in our study within the range (20-30 °C).

pН

pH is related with the presence of CO_2 , H_2CO_3 and HCO_3 in water body. It was observed that pH level showed that water is neutral to slightly alkaline. Gonzalves and Joshi (1946) and Zafar (1967) have recorded thicker population of desmids in moderately alkaline waters. This is due to geographical habitat of the park.

Electrical conductivity (EC)

Electrical conductivity (EC) determines the amount of ionic matter in water body. Low electrical conductivity indicates pristine or background conditions (Sallam *et al.* 2018). In our sampling sites, there were great variations in conductivity values, this is due to different sampling sites had different water sources and geological conditions.

Total Dissolved Solids (TDS)

TDS indicates hardness and buffering capacity of water. Because of high concentration of TDS at site C11 (Table 3), only few desmids species were observed and site C13 with low TDS was found to have high desmids diversity in winter season. Patil and Karande (2020) reported that maximum density of desmids in Kas lake in winter season (January) with slightly alkaline pH, low concentration of nitrate, phosphate, total alkalinity and TDS.

Dissolved oxygen (DO)

Dissolved oxygen indicates biological health of rivers exhibiting large fluctuations over a wide range of spatial and temporal scales. It depends upon water temperature and undergoes changes due to fluctuating hydro-meteorological conditions (Rajwa *et al.* 2014). Kalwale and Savale (2012) reported that DO indicates good water quality if the concentration is 7 mgL^{-1} at $30 \degree$ C.

Nitrate nitrogen, soluble reactive phosphorus and ammonium nitrogen

Site C8 had the highest concentration of nitrate-N in summer season, while the lowest value was found at site C13 during winter season. Inaotombi and Gupta (2014) observed respective concentration of NO₃-N (0.06 to 0.84 mgL^{-1} ; 0.04 to 0.66 mgL^{-1} ; PO₄³⁻ (0.02 to 0.14 mgL⁻¹; 0.01 to 0.16 mgL^{-1}) and NH_4 -N (0 to 0.65 mgL⁻¹; 0 and 0.56 mgL⁻¹ ¹) in eastern and western basin of Sattal lake, Uttarakhand. Highest nitrate-N was observed at site C8 during summer season due to decay of vegetation around spring water body. Desmids have found to be negatively correlated with nitrate and PO_4^{3-} concentration (Bidarulmunir *et al.* 2012). The main natural sources of nitrate in water bodies such as rivers are decaying vegetation of leguminous plants, oxidation of human and animal excreta (Khan et al. 2016). Phosphate in rivers is usually due to agricultural runoff and detergents for washing clothes. Similar sources have been observed at many sites of Jim Corbett National Park.

Distributions of desmids at generic level w.r.t. sites and seasons

In our diversity exploration across the three seasons, we found all together 10 genera of desmids. Some of these genera were season specific such as Cylindrocystis, Euastrum, Pluerotaenium, Micrasterias and Heimansia, which were found exclusively in winter season. Ecological distribution of genus Cylindrocystis suggest that it favours winter season for its growth. It was reported from the park (site C8 and C11). There is report of this genus from Gangtok, Sikkim with pH of water body as 6.5 and 17° C as water temperature (Das and Keshri 2018). Cylindrocystis has been reported as oligo-mesotrophic species (Coesel and Meesters 2007). Euastrum was reported in winter season from site C11 and C13. It is also been reported from Badrinath, Uttarakhand from 2 ponds noted with the following characteristics with pH (7.9, 8.1); conductivity $(650, 660) \,\mu\text{Scm}^{-1}; \text{TDS}(470, 510) \,\text{mgL}^{-1}; \text{DO}(8.4,$ 8.8) mgL⁻¹; water temperature 18 °C; Nitrate (0.38, (0.43) mgL⁻¹ and ortho-phosphate (0.049, 0.056) mgL⁻¹ (Kumar et al. 2012). Similarly, monsoon

specific genera include Penium and Netrium both being recorded from site C4. Netrium is an elongate form of desmids and prefer to have an advantage in effective photosynthesis over sub-spherical taxa owing to more favourable surface: volume ratio (Coesel 1982). Genus Straurastrum was common in both winter and monsoon season. Straurastrum prefers weakly mineralized water (Negro et al. 2003). Site C3 and C4 are also reported to have weakly mineralized water, thus have favoured the latter desmid. Genera Closterium and Cosmarium were very common and found in all seasons. Pleurotaenium trabecula is a placoderm (truedesmids) (Domozych et al. 2007). It is also reported from site C2 of the park. Nassar et al. (2015) reported Pleurotaenium from Eastern coast of Suez Gulf, Egypt in the winter season with an average pH (7.6 to 8.3); dissolved oxygen (4.63 mgL⁻¹); water temperature (18.16 °C); phosphate (0.15 mgL^{-1}) ; nitrate (0.52 mgL^{-1}) and ammonia (2.60 mgL^{-1}) . Site C2 is also recorded with weakly alkaline pH and low temperature in the winter season that is favourable for Pleurotaenium. In our study, Micrasterias was recorded from site C12 during winter season and absent in other seasons. It may be due to favourable seasonal conditions and environmental characteristics attributed for its appearance (Table 3). One of the widely distributed genera in our study was Cosmarium with the highest diversity, followed by *Closterium*. Genus Cosmarium is found in freshwater ecosystem with slightly acidic, basic or eutrophic water. It is reported by Stamenković and Cvijan (2006) that Cosmarium and Closterium are dominant taxa. Some desmids species prefers nutrient rich environments such as Cosmarium, Closterium and Staurastrum and they reach a length of several tens of micro meters and undergo one division per 24 hours. On the other hand, nutrient-poor habitats are the province of more spectacular species such as Micrasterias and Euastrum (Coesel 1983). Heimansia pusilla is a rare desmid (Coesel and Kooijman 1994). It is reported in the winter season from site C13. Thus, Jim Corbett National Park is a rich assemblage of desmids and can be considered a suitable site for bio monitoring of water pollution.

Conclusion

A combined composition and ecological distribution study during three different seasons

from 13 freshwater stream segments in Jim Corbett National Park resulted in the following conclusions: Fifty one species of desmids belonging to 10 genera were identified, showing a fairly rich diversity of desmids. Therefore, desmids flora of these water bodies can be regarded as 'models' that will be of great significance in providing baseline data for future bio monitoring and assessing the effects of anthropogenic pollution. The present trophic status of the water bodies of the park depicted as "oligotrophic", "mesotrophic" and "oligotrophic-mesotrophic". This trophic status data will serve as ideal tool for water management in Corbett National Park.

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References

Agarkar MS, Agarkar DS and Dixit R 1979 Desmids from Bhandhavgarh, M.P. *Hydrobiologia* **65** 213-223.

Barman D, Deka SJ and Barman B 2015 Seasonal diversity and habitat characteristics of Algae of wetlands in the West Garo hills, Meghalaya, India. *Res. J. Recent Sci* **4** 274-279.

Bharati SG and Hedge GR 1982 Desmids of Karnataka state and Goa. Part 1. *Phykos* **21** 143-149.

Bidarulmunir AA, WO, WM, AS Ruddin and Manisah T 2012 Distribution of Desmids and Dinoflagellates in Littoral Zones of Pedu Reservoir, Kedah Darul Aman. In: International Environment and Health Conference Pp 163-171.

Bordoloi RPM 1983 On some abnormal and asymmetric desmids from Assam. *Phykos* **22** 120-124.

Claassen MI and Eicker A 1985 Some species of

Cosmarium (Chlorophyta, Desmidiaceae) from the Transvaal. *S. Afr. J. Bot* **51** 199-207.

Coesel P and Kooijman-Van Blokland H 1994 Distribution and seasonality of desmids in the Maarsseveen Lakes area. *Neth. J. Aquat. Ecol.* **28**(1) 19-24.

Coesel PF and Meesters KJ 2007 Desmids of the lowlands: Mesotaeniaceae and Desmidiaceae of the European lowlands. BRILL.

Coesel PFM 1982 Structural Characteristics and Adaptations of Desmid Communities. *J. Ecol.* **70**(1) 163-177.

Coesel PFM 1983 The significance of desmids as indicators of the trophic status of freshwaters. *Schweiz*. *Z. Hydrol* **45** 388-393.

Coesel PFM 1993 Taxonomic notes on Dutch Desmids II. *Cryptogam.*, *Algol* **14** 105-114.

Coesel PFM 1998 Sieralgen en Natuurwaarden-Handleiding ter bepaling van natuurwaarden van stlstaande, zoete wateren, op basis van het desmidiaceeenbestand.

Coesel PFM 2002 New intriguing desmid taxa from the Netherlands. *Arch. Hydrobiol* **142** 69-79.

Coesel PFM and Krienitz L 2007 Diversity and geographic distribution of desmids and other coccoid green algae. *Biodivers. Conserv* **17** 381-392.

Coesel PFM, Porcel EMS, Van Geest A and Izaguirre I 2017 Remarkable desmid species from the southern Patagonian highlands. *Fottea, Olomouc* **17**(1) 89-95.

Croasdale H and Grönblad R 1964 Desmids of Labrador 1. Desmids of the south eastern coastal area. *Trans Am Microsc Soc* **83**(2) 142-212.

Das D and Keshri JP 2013 Desmids of Khechiperi Lake, Sikkim Eastern Himalaya. *Algol Stud* **143** 27-41.

Deepa P, Raveen R, Venkatesan P, Arivoli S and Samuel T 2016 Seasonal variations of physicochemical parameters of Korattur lake, Chennai, Tamil Nadu, India. *Int. J. Chem. Stud* **4** 116-123.

Dingley M 2004 Some new, rare and interesting Desmids from Australia. *Algol Stud* **112** 25-47.

Domozych DS, Elliott L, Kiemle SN and Gretz MR 2007 *Pleurotaenium trabecula*, a desmid of wetland biofilms: the extracellular matrix and adhesion mechanisms 1. *J. Phycol.* **43**(5) 1022-1038.

Fritsch FE 1935 The structure and reproduction of the

Algae. Vol. 1, Cambridge Univ. Press, Cambridge, London.

Gontcharov AA and Watanabe MM 1999 Rare and new desmids (Desmidiaceae, Chlorophyta) from Japan. *Phycol Res* **47** 233-240.

Gonzalves EA and Joshi DB 1946 Freshwater algae near Bombay. I. The seasonal Succession of the algae in a tank at Bandra. *J. Bomb. Nat. Hist. Soc* **46** 154-176.

Guiry MD 2013 Taxonomy and nomenclature of the Conjugatophyceae (= Zygnematophyceae). *Algae* **28**(1) 1-29.

Gupta RK 2012 *A Checklist of Chlorophyceae, Xanthophyceae, Chrysophyceae and Euglenophyceae* II. Botanical Survey of India, Kolkata.

Habib I and Chaturvedi UK 2001 Contribution to the knowledge of desmid of Kumaon in Himalaya. *J. Indian Bot. Soc* **80** 177-182.

Habib I, Ansari AR, Mehrotra DK and Chaturvedi UK 1998 Some desmids from foot hills zone of Kumaon Himalaya. *Nature Biosphere* **3** 36-40.

Inaotombi S and Gupta PK 2014 Water quality of a Central Himalayan lake, Lake Sattal, Uttarakhand. *J. Ecophysiol. Occup. Hlth* **14** 83-102.

Iyengar MOP and Bai V 1941 Desmids from Kodaicanal, South India. *J. Indian Bot. Soc* **20** 73-103.

Kalwale AM and Savale PA 2012 Determination of physico-chemical parameters of Deoli Bhorus dam water. *Adv. Appl. Sci. Res* **3** 273-279.

Kant S and Gupta P 1998 Algal flora of Ladakh. Additional Series, *J. Econ. Taxon. Bot* **15** 341.

Khan MYA, Gani KM and Chakrapani GM 2016 Assessment of surface water quality and its spatial variation. A case study of Ramganga River, Ganga Basin, India. *Arab. J. Geosci* **9**(1) 1-9.

Khanna AC, Sawhney KK and Vashist SR 2017 *Uttarakhand "The Abode of Gods"*. Nest and Wings, Malviya Nagar, New Delhi.

Khare R and Suseela MR 2004 Fresh Water Algal Flora of Corbett Tiger Reserve, Uttaranchal, India. *Annals of Forestry* **12** 233-242.

Komal, Khattar JIS, Singh DP and Singh Y 2021 New records of desmids from Ropar wetland (a Ramsar Site) of Punjab, India. *Plant Sci. Today* **8**(4) 885-896.

Kumar, P, Wanganeo, A, Sonaullah, F and Wanganeo, R 2012 Limnological study on two high altitude Himalayan Ponds, Badrinath, Uttarakhand. *Int. J. Ecosyst.* **2**(5) 103-111.

Mallik P and Kesari JP 2011 Contribution to the Desmid flora of India, Genus *Cylindrocystis Meneghini* from West Bengal. *Bionature* **31** 55-59.

MD Guiry in Guiry, MD and Guiry GM 2021 *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 14 May 2021.

Misra PK, Shukla M and Prakash J 2008 Some fresh water algae from Eastern Uttar Pradesh. *Indian Hydrobiology* **11** 121-132.

Misra PK, Shukla M, Misra P and Prakash J 2007 Some desmids from Chilwa Lake, Gorakhpur, Uttar Pradesh. *J. Appl. Biosci* **33** 80-83.

Nassar, MZ, El-Din, NGS and Gharib SM 2015 Phytoplankton variability in relation to some environmental factors in the eastern coast of Suez Gulf, Egypt. *Environ. Monit. Assess.* **187**(10) 1-18.

Ngearnpat N and Peerapornpisal Y 2007 Application of desmid diversity in assessing the water quality of 12 freshwater resources in Thailand. *J. Appl. Phycol* **19** 667-674.

Ngearnpat N, Coesel PF and Peerapornpisal Y 2008 Diversity of desmids in three Thai peat swamps. *Biologia* **63** 901-906.

Pandey UC and Pandey DC 1980 Desmids of Allahabad I. *J. Indian Bot. Soc* **59** 246-250.

Patil SV and Karande VC 2020 Diversity of Desmids from some water bodies of Satara district, Maharashtra (India). *Res J Chem Environ* **24** 44-50.

Prasad BN and Misra PK 1984 Some taxa of genus *Closterium* Nitzs. New to Indian flora. *J. Indian Bot. Soc* **63** 451-452.

Prasad BN and Misra PK 1985 Some taxa of *Cosmarium Corda* ex Ralfs new to Indian Desmid flora. *J. Indian Bot. Soc* **64** 343-347.

Prescott GW 1966 *Algae of the Panama Canal and its Tributaries-II.* Conjugales. *Phykos* **5** 1-49.

Rajwa-Kuligiewicz, A, Bialik, RJ and Rowinski PM 2015 Dissolved oxygen and water temperature dynamics in lowland rivers over various timescales. *J. Hydrol. Hydromech.* **63**(4) 353.

Raut L and Bhardwaj AK 2017 A study of Closterium in

Tapti pond of Multai, district Betul, M.P. India. *Int. J. Botany Stud* **2** 118-120.

Şahin B and Akar B 2019 New desmid records from high mountain lakes in Artabel Lakes Nature Park, Gümüşhane, Turkey. *Turk J Botany* **43** 570-583.

Sallam GA and Elsayed EA 2018 Estimating relations between temperature, relative humidity as independent variables and selected water quality parameters in Lake Manzala, *Ain Shams Eng. J. Ain Shams Eng J***9** 1-14.

Salve VB and Hiware CJ 2008 Study on water quality of Wanparakalpa reservoir Nagpur, Near Parli Vaijnath, District Beed. Marathwada region. *J. Aqua. Biol* **21** 113-117.

Scott AM and GW Prescott 1961 Indonesian Desmids. *Hydrobiologia* **17**: 132.

Shahare PC and Cherian KJ 2016 Desmid flora of Chulband river, Gondia district, Maharashtra, (India). *Int. J. Res. Biosci. agric. technol* **4**41-44.

Shukla SK, Shukla CP and Misra PK 2008 Desmids (Chlorophyceae, Conjugales, Desmidiaceae) from foot hills of western Himalaya, India. *Algae* **23** 1-14.

Sindhu P and Panikkar MVN 1995 Desmids flora of Quilon, Kerala. *J Econ Taxon Bot* **19** 245-259.

Stamenković M and Cvijan M 2008 Desmid flora (Chlorophyta, Zygnematophyceae) of the Danube in the province of vojvodina (northern serbia). *Arch. Biol. Sci.* **60**(2) 181-199.

Suseela MR and Toppo K 2010 Occurrence of rare Desmids and their addition to Indian algal flora. *J. Indian Bot. Soc* **89** 320-323.

Tiffany LH and Britton ME 1952 Monograph on The

algae of Illinois. The University of Chicago press, Chicago.

Tomaszewicz GH and Hindák F 2008 Some rare desmids (Zygnematophyceae) from Central Europe. *Biologia* **63** 289-293.

Toppo K and Suseela MR 2009 *Cosmarium* diversity of Mani Pokhar pond of Jashpur district in Chhattisgarh State, India. *Ann. For. Res.* **17**(1)117-124.

Toppo, K, Mandotra, SK, Nayaka, S and Suseela MR 2016 Algal diversity of high altitude zones in Govind Wild Life Sanctuary, Uttarakhand, India. *J. Indian Bot.* **95** (3 and 4) 283-287.

Turner WB 1892 *The freshwater algae of East India*. Stockholm, Sweden.

Van Westen MC and Coesel PF 2018 Taxonomic notes on desmids from the Netherlands II, with a description of six new species. *Phytotaxa* **385** 1-12.

Venkateshwarlu V 1983 Ecology of desmids *I Staurastrum tetracerum*, Ralfs. *Indian J. Bot.* **6** 68-73.

Wallich GC 1860 Desmidiaceae of Lower Bengal. *Ann. mag. nat. hist* **3** 273-285.

Yamagishi T and Kanetsuma Y 1990 Fresh water algae of Papua New Guinea (4). Some Euglenoid Flagellates & Desmids. *Bull. Natl. Mus. Nat. Sci., Ser. B, Bot* **16** 41-59.

Zafar AR 1967 On the ecology of algae in certain fish ponds of Hyderabad, India III. The periodicity. *Hydrobiologia* **30** 96-112.