

RESEARCH ARTICLE

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

Abhinav Sharma^{1,2}, Kiran Toppo¹ and Rajan Kumar Gupta²

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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 moniliforme* and *Closterium moniliformum* reported earlier from our study site. Maximum desmids diversity occurred in winter season followed by monsoon, and minimum diversity were recorded in summer season. Physico-chemical 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
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,

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

 Kiran Toppo¹
toppokiran@yahoo.co.in

¹ Algology Laboratory, Plant Diversity, Systematics and Herbarium, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226001, India

² Laboratory of Algal Research, Department of Botany, Institute of Science, Banaras Hindu University, Varanasi-221005, India

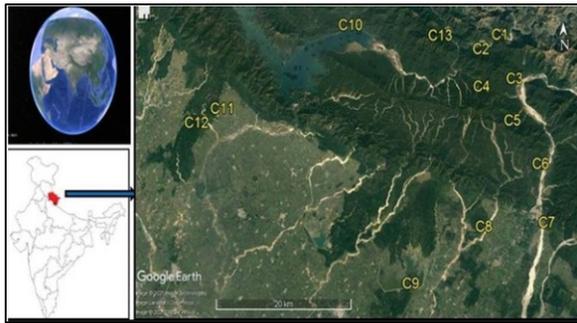


Figure 1: Sampling sites of desmids in JCNP, Uttarakhand

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 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

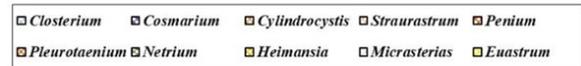


Figure 2: Distribution of desmids genera in JCNP, Uttarakhand

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

Materials and methods

Site description

Table 1: List of the sites of desmids samples collection showing latitude, longitude, elevations and place of the collection

Sampling Sites	Latitude	Longitude	Elevations	Sampling Sites Description
C1	29 80.9332' N	79 09.7035' E	571 m	Durga Devi (Transition Zone)
C2	29 97.3463' N	79 09.1032' E	741 m	Brys Caves Resort, Durga Devi (Transition Zone)
C3	29 80.5733' N	79 10.1461' E	749 m	Durga Devi (Buffer Zone)
C4	29 29.770' N	78 45.607' E	976 m	Saddle Dam, Sona Nadi (Transition Zone)
C5	29 25.332' N	78 59.935' E	319 m	Jhirna (Buffer Zone)
C6	29 25.340' N	78 59.950' E	323 m	Jhirna (Transition Zone)
C7	29 31.651' N	79 05.964' E	462 m	Dhangarhi stream, Dhikala (Transition Zone)
C8	29 26.112' N	79 07.930' 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 31.331' N	79 05.576' E	486 m	Dhikala (Buffer Zone)
C11	29 43.373' N	78 44.724' E	500 m	Kalagarh (Buffer Zone)
C12	29 29.770' N	78 45.607' E	984 m	Kalagarh (Transition Zone)
C13	29 33.276' N	79 06.681' E	512 m	Bhadrakot Mohan, Durga Devi (Transition Zone)

28	<i>C. hammeri</i> var. <i>homalodermum</i> (Nordstedt) West & G.S. West	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-
29	<i>C. insigne</i> Schmidle	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-
30	<i>C. javanicum</i> Nordstedt	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+
31	<i>C. leave</i> Rabenhorst	+	-	+	-	-	-	+	-	-	-	-	-	-	-	+
32	<i>C. leave</i> var. <i>septentrionale</i> Wille	+	-	-	-	-	-	-	-	-	+	-	-	+	-	-
33	<i>C. lundellii</i> 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	<i>C. pseudopyramidatum</i> var. <i>oculatum</i> 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> var. <i>transiens</i> Messikommer	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
50	<i>C. supra speciosum</i> Wille	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+
51	<i>C. turpini</i> Brébisson	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-

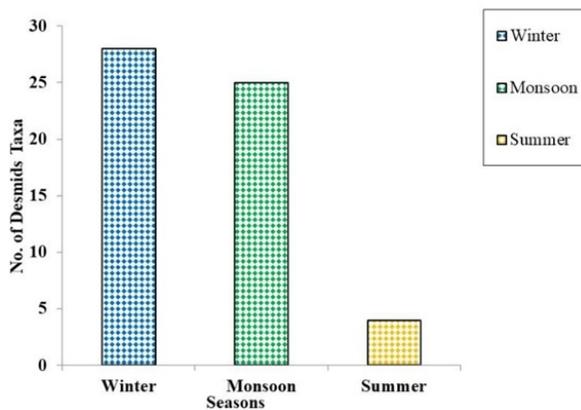


Figure 3: Seasonal distribution of desmids in JCNP, Uttarakhand

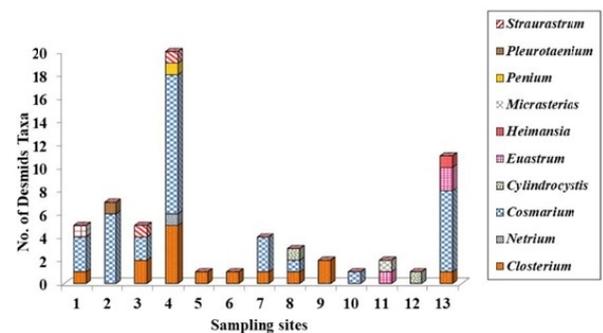


Figure 4: Distribution of desmids taxa across sampling sites, JCNP, Uttarakhand

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

		No. of sampling sites in Jim Corbett National Park												
Water parameter	Season	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
pH	Winter	7.43 ± 0.058	8.12 ± 0.225	7.07 ± 0.032	8.03 ± 0.058	8.34 ± 0.038	8.37 ± 0.026	8.05 ± 0.036	7.70 ± 0.015	8.12 ± 0.02	7.87 ± 0.012	8.34 ± 0.05	8.03 ± 0.231	7.82 ± 0.025
	Summer	7.10 ± 0.100	7.67 ± 0.115	6.93 ± 0.230	7.57 ± 0.321	7.8 ± 0.01	7.82 ± 0.026	7.43 ± 0.026	7.26 ± 0.051	7.35 ± 0.042	7.74 ± 0.006	7.96 ± 0.02	7.86 ± 0.01	7.12 ± 0.015
	Monsoon	7.16 ± 0.057	7.97 ± 0.251	7.04 ± 0.026	7.96 ± 0.142	8.14 ± 0.02	8.16 ± 0.035	7.77 ± 0.031	7.52 ± 0.025	7.83 ± 0.153	7.76 ± 0.251	8.33 ± 0.032	7.94 ± 0.015	7.47 ± 0.058
EC (µS _{cm} ⁻¹)	Winter	90.87 ± 0.473	188.83 ± 0.611	352.67 ± 0.577	321.03 ± 0.551	318.4 ± 0.361	200.26 ± 0.306	121.8 ± 0.721	207.4 ± 0.2	200.53 ± 0.306	305.47 ± 0.416	644.23 ± 0.252	300.26 ± 0.306	81.3 ± 0.265
	Summer	96.4 ± 0.361	198.4 ± 0.361	395.93 ± 0.115	381.43 ± 0.404	399.33 ± 0.306	389.37 ± 0.351	197.6 ± 0.361	434.3 ± 0.3	390.73 ± 0.115	400.2 ± 0.2	680.37 ± 0.321	415.33 ± 0.152	88.73 ± 0.208
	Monsoon	91.7 ± 0.1	190.96 ± 0.757	367.3 ± 0.265	328.63 ± 0.709	321.06 ± 0.839	297.76 ± 0.737	210.2 ± 0.346	415.3 ± 0.416	320.3 ± 0.3	350.36 ± 0.635	650.43 ± 0.379	326.4 ± 0.361	86.17 ± 0.153
TDS (mgL ⁻¹)	Winter	77.53 ± 0.451	55.03 ± 0.950	117.6 ± 0.2	103.23 ± 0.252	110.17 ± 0.153	102.57 ± 0.208	105.4 ± 0.265	50.9 ± 0.1	182.6 ± 0.1	104.53 ± 0.611	303.2 ± 0.2	98.5 ± 0.1	40.37 ± 0.321
	Summer	86.37 ± 0.635	188.23 ± 0.252	144.5 ± 0.361	191.8 ± 0.721	152.5 ± 0.2	201.67 ± 0.153	201.57 ± 0.208	230.9 ± 0.529	140.3 ± 0.265	242.33 ± 0.351	311.3 ± 0.3	110.4 ± 0.2	43.5 ± 0.5
	Monsoon	80.13 ± 0.231	60.63 ± 0.777	191.33 ± 0.306	124.8 ± 0.1	125.43 ± 0.493	103.27 ± 0.666	112.76 ± 0.608	200.2 ± 0.346	195.27 ± 0.208	108.63 ± 0.153	313.3 ± 0.265	124.57 ± 0.208	41.73 ± 0.058
Salinity (%)	Winter	0.22 ± 0.006	0.51 ± 0.015	0.07 ± 0.005	0.22 ± 0.006	0.15 ± 0.01	0.17 ± 0.006	0.11 ± 0.012	0.05 ± 0.006	0.13 ± 0.006	0.31 ± 0.005	0.35 ± 0.005	0.10 ± 0.006	0.04 ± 0.006
	Summer	0.19 ± 0.006	0.19 ± 0.005	0.18 ± 0.006	0.18 ± 0.006	0.14 ± 0.005	0.16 ± 0.006	0.17 ± 0.006	0.20 ± 0.006	0.11 ± 0.006	0.26 ± 0.006	0.27 ± 0.006	0.05 ± 0.006	0.18 ± 0.015
	Monsoon	0.04 ± 0.006	0.04 ± 0.006	0.05 ± 0.006	0.11 ± 0.012	0.08 ± 0.006	0.09 ± 0.006	0.14 ± 0.006	0.21 ± 0.0	0.08 ± 0.01	0.24 ± 0.006	0.25 ± 0.006	0.06 ± 0.006	0.04 ± 0.006
Dissolved Oxygen (mgL ⁻¹)	Winter	10.70 ± 0.095	11.23 ± 0.153	7.96 ± 0.012	8.13 ± 0.015	9.97 ± 0.015	9.86 ± 0.098	9.83 ± 0.01	9.36 ± 0.02	8.16 ± 0.032	8.71 ± 0.015	9.35 ± 0.01	8.46 ± 0.053	8.93 ± 0.113
	Summer	9.83 ± 0.006	10.12 ± 0.021	7.11 ± 0.015	7.91 ± 0.01	6.92 ± 0.006	6.82 ± 0.015	7.36 ± 0.01	6.57 ± 0.03	7.14 ± 0.118	7.05 ± 0.012	8.18 ± 0.068	8.02 ± 0.031	6.04 ± 0.015
	Monsoon	10.33 ± 0.025	10.58 ± 0.02	7.63 ± 0.025	8.03 ± 0.057	7.71 ± 0.058	7.78 ± 0.072	7.46 ± 0.025	7.47 ± 0.023	7.23 ± 0.58	7.94 ± 0.01	8.45 ± 0.05	8.15 ± 0.015	7.51 ± 0.015
Temperature (°C)	Winter	21.73 ± 0.462	13.73 ± 0.115	15.33 ± 0.306	16.07 ± 0.115	20.64 ± 0.053	21.4 ± 0.529	14.7 ± 0.1	14.83 ± 0.025	22.07 ± 0.115	20.13 ± 0.231	15.43 ± 0.208	18.23 ± 0.208	15.47 ± 0.153
	Summer	29.13 ± 0.153	26.7 ± 0.173	22.17 ± 0.289	28.03 ± 0.058	30.71 ± 0.01	30.9 ± 0.1	27.37 ± 0.635	25.53 ± 0.503	33.13 ± 0.231	35.1 ± 0.173	23.17 ± 0.289	29.23 ± 0.252	29.67 ± 0.866
	Monsoon	29.13 ± 0.153	20.23 ± 0.208	21.07 ± 0.115	27.23 ± 0.208	26.67 ± 0.577	28.3 ± 0.265	26.13 ± 0.153	24.75 ± 0.050	31.77 ± 0.115	34.23 ± 0.153	19.9 ± 0.173	27.1 ± 0.1	26.47 ± 0.416
Nitrate Nitrogen (mgL ⁻¹)	Winter	1.15 ± 0.15	1.41 ± 0.01	1.44 ± 0.032	0.53 ± 0.015	0.63 ± 0.01	0.74 ± 0.04	0.5 ± 0.006	2.17 ± 0.061	0.57 ± 0.006	0.69 ± 0.081	0.81 ± 0.015	0.51 ± 0.023	0.32 ± 0.021
	Summer	1.54 ± 0.069	1.61 ± 0.017	1.64 ± 0.012	1.07 ± 0.064	1.5 ± 0.1	1.63 ± 0.01	1.23 ± 0.058	2.53 ± 0.031	1.2 ± 0.015	1.42 ± 0.015	1.62 ± 0.02	1.17 ± 0.01	1.13 ± 0.153
	Monsoon	1.2 ± 0.265	1.51 ± 0.012	1.59 ± 0.015	0.55 ± 0.042	0.82 ± 0.021	1.1 ± 0.1	0.51 ± 0.01	0.92 ± 0.015	0.50 ± 0.006	1.4 ± 0.1	1.2 ± 0.087	0.95 ± 0.044	0.62 ± 0.015
Soluble R. Phosphorous (mgL ⁻¹)	Winter	0.54 ± 0.006	0.62 ± 0.021	0.65 ± 0.031	0.73 ± 0.015	0.10 ± 0.006	0.14 ± 0.015	0.18 ± 0.015	0.18 ± 0.006	0.17 ± 0.01	0.51 ± 0.015	0.53 ± 0.026	0.52 ± 0.01	0.61 ± 0.01
	Summer	1.14 ± 0.51	1.37 ± 0.351	1.1 ± 0.1	1.51 ± 0.015	0.53 ± 0.031	0.6 ± 0.006	0.71 ± 0.012	0.83 ± 0.015	0.95 ± 0.95	0.92 ± 0.01	0.81 ± 0.01	0.90 ± 0.006	1.03 ± 0.061
	Monsoon	0.92 ± 0.01	0.95 ± 0.045	0.85 ± 0.031	0.93 ± 0.020	0.12 ± 0.01	0.21 ± 0.021	0.35 ± 0.006	0.41 ± 0.015	0.42 ± 0.015	0.69 ± 0.01	0.79 ± 0.012	0.82 ± 0.021	0.76 ± 0.015
Ammonium Nitrogen (mgL ⁻¹)	Winter	0.23 ± 0.01	0.41 ± 0.03	0.33 ± 0.03	0.15 ± 0.006	0.14 ± 0.015	0.44 ± 0.025	0.22 ± 0.006	0.34 ± 0.006	0.31 ± 0.01	0.46 ± 0.006	0.33 ± 0.015	0.39 ± 0.006	0.50 ± 0.006
	Summer	0.42 ± 0.01	0.48 ± 0.035	0.48 ± 0.04	0.22 ± 0.02	0.19 ± 0.006	0.54 ± 0.006	0.17 ± 0.006	0.32 ± 0.02	0.36 ± 0.025	0.51 ± 0.012	0.46 ± 0.02	0.49 ± 0.01	0.46 ± 0.012
	Monsoon	0.32 ± 0.01	0.31 ± 0.03	0.24 ± 0.025	0.10 ± 0.006	0.24 ± 0.02	0.25 ± 0.02	0.15 ± 0.02	0.17 ± 0.01	0.13 ± 0.01	0.34 ± 0.015	0.48 ± 0.006	0.56 ± 0.02	0.34 ± 0.006

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

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 (C1-C13).

Table 4: Trophic status of water bodies of Jim Corbett National Park, Uttarakhand

Sites	Trophic status		
	Winter	Summer	Monsoon
C1	OM	OM	OM
C2	OM	M	OM
C3	OM	M	OM
C4	OM	OM	OM
C5	OM	OM	OM
C6	OM	M	OM
C7	O	OM	OM
C8	O	M	OM
C9	OM	OM	OM
C10	OM	M	OM
C11	OM	M	OM
C12	OM	OM	OM
C13	OM	OM	OM

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

Sampling of desmids

Desmids 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 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 μm) in the laboratory and preserved

by adding 0.15 % (v/v) of conc. HNO_3 and stored in a refrigerator (4°C).

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 ($\text{NO}_3\text{-N}$), ammonium nitrogen ($\text{NH}_4^+\text{-N}$), 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, ammonium-nitrogen, 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 (Plate 1, 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, 14-15 µm 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 µScm⁻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 µm long, 11 µm 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 µScm⁻¹), TDS (303.2 mgL⁻¹), water temp. (15.43 °C), salinity (0.35 %), DO (9.35 mgL⁻¹), NO₃⁻-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 µm long, 45 µm in diameter, apex 18-19 µm.

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 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 NH₄⁺-N (0.10 mgL⁻¹).

Class: Zygnematophyceae

Order: Desmidiiales

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 µm long 12-13 µm 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 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 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: Desmidiiales

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



Plate 1. (Photomicrographs. 1-32) 1. *Cosmarium pyramidatum* Brébisson ex Ralfs, 2. *C. pseudopyramidatum* var. *oculatum* Willi Krieger, 3. *Actinotaenium elongatum* (Raciborski) Teiling, 4. *C. cucumis* Corda ex Ralfs, 5. *C. supraspeciosum* Wolle, 6. *C. quadrum* P. Lundell 7. *C. awadhense* B.N. Prasad & R.K. Mehrotra, 8. *C. punctatum* Borgesen, 9. *C. quadrifarium* P. Lundell, 10. *C. perpastum* W.B. Turner, 11. *C. speciosum* P. Lundell, 12. *C. pachydermum* P. Lundell, 13. *C. pseudoconnatum* Nordstedt, 14. *C. insigne* Schmidle, 15. *Euastrum spinulosum* Delponte, 16. *C. quinarium* P. Lundell, 17. *C. nitidulum* De Notaris, 18. *C. calcarium* Wittrock, 19. *C. laeve* Rabenhorst, 20. *Heimans iapusilla* Hilse, 21. *C. granatum* Brébisson ex Ralfs, 22. *Cylandrocystis brebissonii* (Ralfs) De Bary, 23. *C. punctatum* Nordstedt, 24. *C. subprotumidum* Nordstedt, 25. *C. phaseolus* Brébisson ex Ralfs 26. *Euastrum rostratum* var. *biculatum* A.M. Scott & Prescott, 27. *C. lundellii* Delponte, 28. *Cylandrocystis crassa* De Bary, 29. *C. laeve* var. *septentrionale* Wille, 30. *C. hammeri* var. *homalodermum* (Nordstedt) West & G.S. West, 31. *Micrasterias radians* W.B. Turner 32. *C. javanicum* Nordstedt. Scale bar: Photomicrographs, 1-34=10µm (63X)



Plate 2. (Photomicrographs. 1-25) 1. *Closterium libellula* Focke ex Nordstedt, 2-3 & 8. *Penium margaritaceum* Brebisson, 4 & 5. *Closterium libellula* var. *recurvatum* West & G.S. West, 6. *Pleurotaenium trabecular* Nägeli, 7. *Closterium kuetzingii* Brebisson, 9. *C. ehrenbergii* Meneghini ex Ralfs, 10. *C. lundula* var. *massartii* (De Wildeman) Willi, 11. *C. braunii* Reinsch, 12. *C. parvulum* Nageli, 13. *C. calosporum* Wittrock, 14. *C. acerosum* Ehrenberg ex Ralfs, 15. *C. littorale* F. Gay, 16. *Netrium digitus* (Ehrenberg) Itzigs, 17. *C. moniliforme* Ehrenberg ex Ralfs, 18. *Cosmarium turpini* urpini, 19. *C. portblairii* Prasad et Misra, 20. *Euastrum ansatum* Ehrenberg ex Ralfs, 21. *C. obsoletum* (Hantzsch) Reinsch, 22. *C. subspeciosum* var. *transiens* Messikommer, 23-25. *Staurastrum punctulatum* Breb. in Ralfs.

Scale bar: Photomicrographs, 1-17 = 10 μm (40X); 18-25 = 10 μm (63X)

zone) - Spring stream water with slightly alkaline pH (7.43), low conductivity (90.87 μScm^{-1}), low TDS (77.53 mgL^{-1}), water temp. (21.73 °C), salinity (0.22 %), high DO (10.70 mgL^{-1}), $\text{NO}_3\text{-N}$ (1.15 mgL^{-1}), SRP (0.54 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 μScm^{-1}), TDS (102.57 mgL^{-1}), water temp. (21.4 °C), salinity (0.17 %), DO (9.86 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.74 mgL^{-1}), SRP (0.14 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.44 mgL^{-1}).

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

Scott and Prescott (1961), pg.10, Plate 1, Figure 22
Cells 678 μm long, center 32 μm , apex 14 μm
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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 μScm^{-1}), TDS (182.6 mgL^{-1}), water temp. (22.07 °C), salinity (0.13 %), DO (8.16 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.57 mgL^{-1}), SRP (0.17 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.31 mgL^{-1}).

7. *Cl. 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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 °C), salinity (0.18 %), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 μm long, center 69-83 μm , apex 15 μm

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 $\mu\text{S cm}^{-1}$), TDS (43.5 mgL^{-1}), salinity (0.18%), low dissolved oxygen (6.04 mgL^{-1}), water temperature (29.67 °C), $\text{NO}_3\text{-N}$ (1.13 mgL^{-1}), SRP (1.03 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.46 mgL^{-1}).

9. *Cl. 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 322-350 μm 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 $\mu\text{S cm}^{-1}$), TDS (117.6 mgL^{-1}), salinity (0.07%), low dissolved oxygen (7.96 mgL^{-1}), water temperature (15.33 °C), $\text{NO}_3\text{-N}$ (1.44 mgL^{-1}), SRP (0.65 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 μm long, center 24-27 μm , apex 10 μm

Locality: Jhirna (Buffer zone)

Phenology: Monsoon season

Voucher number: LWG 002852

Ecological conditions: Stream water with pH (8.13), conductivity (321.06 $\mu\text{S cm}^{-1}$), TDS (125.43 mgL^{-1}), salinity (0.08%), dissolved oxygen (7.71 mgL^{-1}), water temperature (26.67 °C), $\text{NO}_3\text{-N}$ (0.82 mgL^{-1}), SRP (0.12 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.24 mgL^{-1}).

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

Prasad and Misra (1992), pg.111, Plate 17, Figure 9

Cells 148-150 μm long, center 22-23 μm , apex 3-4 μm

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 μScm^{-1}), TDS (105.4 mgL^{-1}), water temp. (14.7 $^{\circ}\text{C}$), salinity (0.11%), DO (9.83 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.5 mgL^{-1}), SRP (0.18 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.22 mgL^{-1}).

(ii) Ringora village, Bijrani (Transition zone): Spring water with fast flow alkaline pH (7.70), conductivity (207.4 μScm^{-1}), TDS (50.9 mgL^{-1}), water temp. (14.83 $^{\circ}\text{C}$), salinity (0.05%), DO (9.36 mgL^{-1}), $\text{NO}_3\text{-N}$ (2.17 mgL^{-1}), SRP (0.18 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.34 mgL^{-1}).

12. *Cl. 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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 $^{\circ}\text{C}$), salinity (0.18%), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.10 mgL^{-1}).

13. *Cl. 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 $\mu\text{S cm}^{-1}$), TDS (117.6 mgL^{-1}), salinity (0.07%), low dissolved oxygen

(7.96 mgL^{-1}), water temp. (15.33 $^{\circ}\text{C}$), $\text{NO}_3\text{-N}$ (1.44 mgL^{-1}), SRP (0.65 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.33 mgL^{-1}).

(ii) Dhela stream, Dhela (Transition zone): Spring water stream characterized with pH (8.12), conductivity (200.53 $\mu\text{S cm}^{-1}$), TDS (182.6 mgL^{-1}), salinity (0.13%), low dissolved oxygen (8.16 mgL^{-1}), water temp. (22.07 $^{\circ}\text{C}$), $\text{NO}_3\text{-N}$ (0.57 mgL^{-1}), SRP (0.17 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.31 mgL^{-1}).

14. *Cl. 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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 $^{\circ}\text{C}$), salinity (0.18%), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.10 mgL^{-1}).

15. *Cl. parvulum* Nägeli (Plate 2, Figure 12)

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

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

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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 $^{\circ}\text{C}$), salinity (0.18%), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.10 mgL^{-1}).

Class: Zygnematophyceae

Order: Desmidiiales

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 μScm^{-1}), TDS (55.03 mgL^{-1}), water temp. (13.73 $^{\circ}\text{C}$), salinity (0.51%), DO (11.23 mgL^{-1}), NO_3N (1.41 mgL^{-1}), SRP (0.62 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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* Duce'llier, *Euastrum ansatum* var. *commune* Duce'llier, *Cosmarium pseudopyramidatum* var. *ansatum* Krieger & Gerloff, *Euastrum ansatum* f. *dideltiforme* (Duce'llier) G. H. Tomaszewicz & W. W. Kowalski) Cells 87-89 μm long, 40-41 μm in diameter, Isthmus 14 μm .

Locality: Kalagarh (Buffer zone)

Phenology: Winter season

Voucher number: LWG 002214

Ecological conditions: Stream water with alkaline pH (8.34), conductivity (644.23 μScm^{-1}), TDS (303.2 mgL^{-1}), water temp. (15.43 $^{\circ}\text{C}$), salinity (0.35%), DO (9.35 mgL^{-1}), NO_3N (0.81 mgL^{-1}), SRP (0.53 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 μm long, 31-32 μm in diameter, Isthmus 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 μScm^{-1}), TDS (40.37

mgL^{-1}), water temp. (15.47 $^{\circ}\text{C}$), salinity (0.04%), DO (8.93 mgL^{-1}), NO_3N (0.32 mgL^{-1}), SRP (0.61 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.50 mgL^{-1}).

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

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

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 μScm^{-1}), TDS (40.37 mgL^{-1}), water temp. (15.47 $^{\circ}\text{C}$), salinity (0.04%), DO (8.93 mgL^{-1}), NO_3N (0.32 mgL^{-1}), SRP (0.61 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.50 mgL^{-1}).

Genus: *Staurastrum* Meyen ex Ralfs

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 $\mu\text{S cm}^{-1}$), TDS (117.6 mgL^{-1}), salinity (0.07%), low dissolved oxygen (7.96 mgL^{-1}), water temp. (15.33 $^{\circ}\text{C}$), $\text{NO}_3\text{-N}$ (1.44 mgL^{-1}), SRP (0.65 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.33 mgL^{-1}).

(ii) Saddle Dam, Sona Nadi (Transition zone): River water with alkaline pH (7.96), conductivity (328.63 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 $^{\circ}\text{C}$), salinity (0.18%), DO (8.03 mgL^{-1}), NO_3N (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 crux-melitensis* var. *radians* (W. B. Turner) Coesel & M. Dingley)

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

Locality: Kalagarh, (Transition zone)

Phenology: Winter season

Voucher number: LWG 002214

Ecological conditions: Water stream characterized with pH (8.03), conductivity ($300.26 \mu\text{S cm}^{-1}$), TDS (98.5 mgL^{-1}), salinity (0.10%), low dissolved oxygen (8.46 mgL^{-1}), water temp. (18.23°C), $\text{NO}_3^- \text{N}$ (0.51 mgL^{-1}), SRP (0.52 mgL^{-1}) and $\text{NH}_4^+ \text{N}$ (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 ($81.3 \mu\text{Scm}^{-1}$), TDS (40.37 mgL^{-1}), water temp. (15.47°C), salinity (0.04%), DO (8.93 mgL^{-1}), $\text{NO}_3^- \text{N}$ (0.32 mgL^{-1}), SRP (0.61 mgL^{-1}) and $\text{NH}_4^+ \text{N}$ (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 μm long, 13 μm 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 ($188.83 \mu\text{Scm}^{-1}$), TDS (55.03 mgL^{-1}), water temp. (13.73°C), salinity

(0.51%), DO (11.23 mgL^{-1}), $\text{NO}_3^- \text{N}$ (1.41 mgL^{-1}), SRP (0.62 mgL^{-1}) and $\text{NH}_4^+ \text{N}$ (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 μm long, 10-14 μm in diameter, Isthmus 2-3 μm

Locality: Saddle dam, Sona Nadi (Transition zone)

Phenology: Monsoon season

Voucher number: LWG 002852

Ecological conditions: River water with alkaline pH (7.96), conductivity ($328.63 \mu\text{Scm}^{-1}$), TDS (124.8 mgL^{-1}), water temp. (16.07°C), salinity (0.18 %), DO (8.03 mgL^{-1}), $\text{NO}_3^- \text{N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+ \text{N}$ (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 15-16 μm

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 ($121.8 \mu\text{Scm}^{-1}$), TDS (105.4 mgL^{-1}), water temp. (14.7°C), salinity (0.11 %), DO (9.83 mgL^{-1}), $\text{NO}_3^- \text{N}$ (0.5 mgL^{-1}), SRP (0.18 mgL^{-1}) and $\text{NH}_4^+ \text{N}$ (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 ($352.67 \mu\text{S cm}^{-1}$), 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 µm long, 14-15 µm in diameter, Isthmus 4-5 µm

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 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 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 µScm⁻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).

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: 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 µScm⁻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 µScm⁻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).

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 µm in diameter, Isthmus 10-11 µm

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 µScm⁻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).

(ii) Saddle Dam, Sona Nadi (Transition zone): 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 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, 24 μm 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 μScm^{-1}), TDS (105.4 mgL^{-1}), water temp. (14.7 $^{\circ}\text{C}$), salinity (0.11 %), DO (9.83 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.5 mgL^{-1}), SRP (0.18 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.22 mgL^{-1}).

(ii) Dhikala (Buffer zone): Clean, moderately flowing stream water with alkaline pH (7.87), conductivity (305.47 μScm^{-1}), TDS (104.53 mgL^{-1}), water temp. (20.13 $^{\circ}\text{C}$), salinity (0.31 %), DO (8.71 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.69 mgL^{-1}), SRP (0.51 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.46 mgL^{-1}).

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

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

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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 $^{\circ}\text{C}$), salinity (0.18 %), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 μm long, 23-24 μm in diameter, Isthmus 3-4 μm

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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 $^{\circ}\text{C}$), salinity (0.18 %), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 μm long, 42-44 μm in diameter, Isthmus 21-24 μm

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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 $^{\circ}\text{C}$), salinity (0.18 %), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 μScm^{-1}), TDS (124.8 mgL^{-1}), water temp. (16.07 $^{\circ}\text{C}$), salinity (0.18 %), DO (8.03 mgL^{-1}), $\text{NO}_3\text{-N}$ (0.55 mgL^{-1}), SRP (0.93 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (0.10 mgL^{-1}).

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

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

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

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 μScm^{-1}), TDS (55.03 mgL^{-1}), water temp. (13.73 $^{\circ}\text{C}$), salinity (0.51%), DO (11.23 mgL^{-1}), $\text{NO}_3\text{-N}$ (1.41 mgL^{-1}), SRP (0.62 mgL^{-1}) and $\text{NH}_4^+\text{-N}$ (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 µm long, 48 µm in diameter, Isthmus 15µm

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 µScm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73°C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃N (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 µm long, 69-72 µm in diameter, Isthmus 59-60 µm

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 µS cm⁻¹), TDS (117.6 mgL⁻¹), salinity (0.07%), low dissolved oxygen (7.96 mgL⁻¹), water temp. (15.33°C), NO₃N (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 µScm⁻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).

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

Scott and Prescott (1961), pg. 66, Plate 25, Figure 4 (Synonym: Homotypic: *Calocyldrurus pseudoconnatus* (Nordstedt) Wolle; Heterotypic: *Pleurotaeniopsis pseudoconnata* (Nordstedt) Lagerheim)

Cells 65 µm long, 49-54 µm in diameter, Isthmus 45-49 µm

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 µScm⁻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. *oculatum* 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 µm.

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 µScm⁻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).

42. *C. punctatum* Nordstedt (Plate 1, Figures 8 and 23)

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

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

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 µScm⁻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 (Plate 1, Figures 1)

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

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

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 µScm⁻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).

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 µScm⁻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).

45. *C. quadrifarium* P. Lundell (Plate 1, Figure 9)

Scott and Prescott (1961), pg. 67, Plate 30, Figure 10

Cells 42 µm long, 33 µm in diameter, Isthmus 16 µm

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 µScm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73°C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃N (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 µm long, 14-16 µm in diameter, Isthmus 5-6 µm

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 µScm⁻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 µScm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73°C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃N (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 µm long, 65-70 µm in diameter, Isthmus 9-10 µm

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 µScm⁻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 µScm⁻¹), TDS (55.03 mgL⁻¹), water temp. (13.73°C), salinity (0.51%), DO (11.23 mgL⁻¹), NO₃N (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 µScm⁻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 (Plate 1, 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 (81.3 μScm⁻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).

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 NH₄⁺-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 ± 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 ± 0.153 mgL⁻¹) to lowest DO observed at site C3 (7.96 ± 0.012 mgL⁻¹). Dissolved oxygen in the summer season varied between 6.04 ± 0.015 to 10.12 ± 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 ± 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 ± 0.173 °C from site C11 to 34.23 ± 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 “oligo-

mesotrophic" 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*, *Staurastrum* 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 *Staurastrum* 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 desmids (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 *Staurastrum* 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).

pH

pH is related with the presence of CO₂, H₂CO₃ and HCO₃⁻ 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 °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 NH₄-N (0 to 0.65 mgL⁻¹; 0 and 0.56 mgL⁻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 PO₄³⁻ 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) μScm⁻¹; TDS (470, 510) mgL⁻¹; 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 *Staurastrum* was common in both winter and monsoon season. *Staurastrum* 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 (true-desmids) (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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