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Monitoring of algal taxa as bioindicator for assessing the health of the high altitude wetland, Dodi Tal, Garhwal Himalaya, India

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Abstract
The present study has been carried out on the algal taxa of high altitude wetland, Dodi Tal (3,075 above m.s.l), located in the western Himalaya, India. A total of 47 taxa belonging to 43 genera of phytoplankton were represented by four classes, *viz.*, Bacillariophyceae (20 genera), Chlorophyceae (16 genera), Cyanophyceae (4 genera) and Dinophyceae (3genera). The Palmer, Algal Genus and Species Pollution Index were employed to study the water quality of high altitude lake Dodi Tal. The total scores of S_1 and S_2 showed 10 indicating probable Lack of organic pollution while S_3 and S_4 showed moderate pollution due to tourist influx. Shannon wiener diversity index was recorded to be diversity index was recorded to be maximum (4.11) in summer and minimum (3.59) in monsoon, Thus, algal taxa can be considered as good bioindicator for assessing the health of the high altitude wetlands.

Keywords: Algal taxa, high altitude wetland, pollution index, evenness, Shannon wiener diversity

1. Introduction
High altitude wetlands are an important category of wetland found in the higher reaches of the Garhwal Himalaya. Algal communities do not respond only to natural changes into the lakes, but may also present variations as a consequence of human interventions affecting the water body, either directly or through activities carried on in the basin as a whole Ganai and Praveen [3] Algae are one of the most rapid bioindicator of water quality changes due to their short life spans, quick response to pollutants and easy to determine their numbers Plafkin *et al.* [11]. Ganai and Praveen [3] recorded phytoplankton (algal) species as indicators of water quality The high altitude lakes are mostly located in the higher reaches and are inaccessible. Environmental baseline data are fragmentary of these high altitude wetlands of Uttarakhand. No sincere effort has been made for studying these wetlands. Therefore, it was felt desirable to undertake study on the monitoring of algal taxa as bioindicator for assessment the health of high altitude wetland of Dodi Tal of Western Himalaya.

2. Materials and methods
2.1 study area
A high altitude wetland, Dodi Tal is very important freshwater ecosystem of the Garhwal Himalaya. It is located between latitude 30° 52'31.99 N and longitude 78° 31'12.47" E at an altitude of 3,075 m.asl in Uttarkashi district, Uttarakhand, India. It is large, somewhat triangular shaped lake with an approximate length of 248.22 m, width of 151.99 m and depth of 19.97m with a catchment area of about 3.0623 ha, Dodi Tal receives water from precipitation and melting of snow. (Fig. 1).

2.2 Collection of sample and Analysis
The present study on algal taxa was undertaken from November 2014-October 2015 four different sites (S_1, S_2, S_3 and S_4) For algal taxa, plankton net of mesh size 20 µm and immediately preserved in water sample bottle containing 4% formalin solution and identification was done with the help of inverted compound microscope Olympus CH 20*i*.For rating the water sample as high or low organically polluted, the Algal Genus Pollution Index (AGPI) of Palmer [11] was employed. Palmer [11] formulated the pollution index scale for assessment of organic pollution of the water bodies Enumeration of the algal taxa was done by

taking 1 ml of the sub- sample in the Sedgwick Rafter chamber counting its entire contents under microscope to obtain the statistical accuracy after their identification with the help of standard taxonomical works (Edmondson [2] APHA [1] Perscotte [13] Munshi *et al*. [9]). Shannon Wiener Diversity Indices: Species diversity index ($\overline{H}$) was calculated using the Shannon Wiener information function (Shannon and Weiner [15]. The evenness was calculated using Eveness index of Jaccard [5].

3. Results and Discussion

3.1 Algal taxa community structure

A total of 47 taxa belonging to 43 genera of phytoplankton were represented by four classes, viz., Bacillariophyceae (20 genera), Chlorophyceae (16 genera), Cyanophyceae (4 genera) and Dinophyceae (3genera) Table. 2. The percentage compositions of these four families were Bacillariophyceae (47%), Chlorophyceae (37%), Cyanophyceae (9%), and Dinophyceae (7%) in high altitude wetland Dodi Tal. (Fig. 2). Similar finding has been reported phytoplankton (14) Bacillariophyceae, Chlorophyceae, Cyanophyceae and Dyanophyceae was recorded contributing 55%, 30%, 10% and 5% respectively in Kailash Lake, Kashmir Naik *et al*.[10]. Rawat and Sharma [14] reported 36 species of phytoplankton belonging to four groups, *viz*, Chlorophyceae, Bacillariophycea, Dinophyceae, Cyanophycea in Deoria Tal, Uttarakhand. Maximum density (1283 ind.l^{-1}), of algal taxa was recorded in April at S_4 and minimum (239 ind.l^{-1}) in January at S_2 and seasonally it was found to be maximum (1186±282.50 ind.l^{-1}) in autumn at S3 and minimum (381.5±58.5 ind.l^{-1}) in monsoon at S_1. The abundance of Bacillariophyceae in cold regions is due to the fact that they are able to grow in conditions of weak light and low temperature which are less suitable for other algae Loffler [8] in Mt Everest high altitude lake, Nepal. The density of Bacillariophyceae was found to be maximum (912 ind.l^{-1}) at S_1 and minimum (92 ind.l^{-1}) at S_4. The most dominant species were *Fragilaria sp., Navicula sp., Cyclotella sp., Synedra ulna*, *Nitzschia sp., Cymbella sp. Cladophora sp.,* in high altitude lake, Dodi Tal. Similar finding in Kailash Lake, Kashmir Naik *et al.,* [10]; Kumar *et al.,*[7] in Badrinath Ponds, Uttarakhand. Members of Bacillariophyceae can be used as bio-indicator for water quality evaluation, Stevenson and Pan [17]; Goma *et al.* [4]. *Synedra ulna* can produce both unwanted taste and odour problems in drinking waters and, when in large number, clog filters Palmer [11]. Chlorophyceae was also found to be an important contributor (35% -36%) of the phytoplankton community of Dodi Tal *Scenedesmus quadricauda, Closterium spp., Pandorina morum, Zygnema* spp., *Zygnema spp. Spirogyra spp.,*. were found to be the dominant species. *Scenedesmus quadricauda* abundant may impart unwanted odours to drinking waters (Palmer, 1969). The density of Chlorophyceae was found to be maximum (819 ind.l^{-1}) at S_3 and minimum (111 ind.l^{-1}) at S_2. Cyanophyceae was found to be contribute (9%) of the phytoplankton community of Dodi Tal. Cyanophyceae *Anabena sp.* and *Ocillatoria sp.* were also recorded in Dodi Tal. Similar species has been reported in Bhimtal, Uttarakhand by Jindal *et al.,*[6] in Rewalsar lake, Himachal Pradesh; Singh *et al.,* [16] in Chandra Tal, Suraj Tal, Deepak Tal and Sissu lake in Lahaul Spiti, Himachal Pradesh. In Palmer's pollution index of algal genera *Anabaena* was not considered as pollution tolerant. The density of Cyanophyceae was found to be maximum (39 ind.l^{-1}) at S_4 and minimum (3.00 ind.l^{-1}) at S_1. Dinophyceae was found to be contribute (6%) of the phytoplankton community of Dodi Tal. The density of Dinophyceae was found to be maximum (185 ind.l^{-1}) at S_4 and minimum (24 ind.l^{-1}) at S_1 (Fig. 2).

3.2 Palmer's pollution index

Palmer [11] first made the list of algae genera and species which indicate organic pollution. According to Palmer, scores of 20 or more are indication of high organic pollution. The pollution tolerant genera belonging to four groups of algae from four sites of Dodi Tal was recorded (Table 2). By using Palmer's index of pollution for rating of water samples as high, moderate and low organically polluted at four sites of Dodi Tal were tested. The total score of Algal Genus Pollution Index (AGPI) of sites $S2< S1<<S_3< S_4$ were calculated to be 10, 7, 11 and12 respectively (Table 2 and Fig. 3). The total score of Algal species Pollution Index of sites $S2< S1<<S_3< S_4$ were calculated to be 10, 4, 13 and 13 respectively (Table 3 and Fig 3). The total scores of S_1 and S_2 showed 10 indicating probable Lack of organic pollution while S_3 and S_4 showed moderate pollution due to tourist influx according to Palmer [11] (Table 1-3), *Oscillatoria* was found to be the most active participant in all sites which may be the good indicator of contaminated water the similar observation recorded by Palmer [11].*Scenedesmus*, *Navicula*, *Nitzschia*, *Synedra* and *Melosira* were recorded repeatedly and consider as indicators of pollution in view of the results of Palmer pollution index.

3.3 Shannon Wiener index

Wilhm and Dorris [18] set diversity index <1 for highly polluted, 1-3 for moderately polluted and >4 for unpolluted water bodies. the Shannon-Weiner diversity index in the present study ranged between 3.27-4.34 in the high altitude wetland, Dodi Tal, Seasonally diversity index was recorded to be maximum (4.11) in summer and minimum (3.59) in monsoon. Therefore, this water body comes in diversity index (>4) means clean water. Table. 4. So here we found the water of the high altitude wetland, Dodi Tal is clean and potable.

3.4 Jaccard's Eveness index

The data on Jaccard's eveness calculated for algal taxa dwelling in the high altitude wetland, Dodi Tal Table. It was recorded to be maximum (0.150) at S_2 and minimum (0.092) at S_1 and S_3. Seasonally, Jaccard's eveness was found to be maximum (0.139) in monsoon season at S_2 and minimum (0.099) in autumn and summer seasons at S_3 and S_4 during the year of the study (Table 5).

4. Conclusion

Over all pollution indexes was showed that all sites of the lake water showed confirms low organic pollution and Palmer (1969) suggested that algae are reliable indicators of water pollution as it was justify in present study. Diversity change of algal communities (Palmer algal genus and species index) can be used to compare and classify the water quality of High altitude wetland Dodi Tal of Uttarakhand. We recommend that a sustainable management plan should be formulated and implemented in order to preserve Dodi Tal's diverse ecosystem.

Table 1: Algal genus pollution index (Palmer, 1969).

Genus	Pollution Index	Species	Pollution index
Anacystis	1	*Ankistrodesmus falcatus*	3
Ankistrodesmus	2	*Arthrospirajenneri*	2
Chlamydomonas	4	*Chlorella vulgaris*	2
Chlorella	3	*Cyclotellameneghiniana*	2
Closterium	1	*Euglena gracilis*	1
Cyclotella	1	*Euglena viridis*	6
Euglena	5	*Gomphonema parvulum*	1
Gomphonema	1	*Melosira varians*	2
Lepocinclis	1	*Navicula crptocaphala*	1
Melosira	1	*Nitzschia acicularis*	1
Micractinium	1	*Nitzschia palea*	5
Navicula	3	*Oscillatoria chlorine*	2
Nitzschia	3	*Oscillatoria limosa*	4
Oscillatoria	5	*Oscillatoria princeps*	1
Pandorina	1	*Oscillatoria putrid*	1
Phacus	2	*Oscillatoriatenuis*	4
Phormidium	1	*Pandorina morum*	3
Scenedesmus	4	*Scenedesmus quadricauda*	4
Stigeoclonium	2	*Stigeocloniumtenue*	3
Synedra	2	*Synedra ulna*	3

Following numerical values for pollution classification of Palmer (1969), 0-10= Lack of organic pollution 10-15= Moderate pollution 15-20= Probable high organic pollution 20 or more = Confirms high organic pollution

Table 2: Pollution index of Algal genera according to Palmer, (1969) at four sites of high altitude wetland Dodi Tal of Garhwal Himalaya 2014 - 2015.

Bacillariophyceae	Order	Family	Pollution Index (Palmer1969)	S1	S2	S3	S4
Achananthes Sp.	Pennales	*Acanthaceae*	-	-	+	+	+
Amphora spp.	Pennales	*Naviculaceae*	-	-	-	+	+
Asterionella spp.			-	-	+	+	+
Bacillaria spp.							
Cyclotella spp.	Centrales	*Coscinodiscaceae*	1	+(1)	+(1)	+(1)	+(1)
Frustulia spp.			-	+	+	+	+
Gomphonema spp.	Pennales	*Naviculaceae*	1	-	+(1)	-	+(1)
Melosira spp.	Centrales	*Coscinodiscaceae*	1	+(1)	+(1)	+(1)	+(1)
Navicula spp.	Pennales	*Naviculaceae*	3	+ (3)	+(3)	+(3)	+(3)
Chlorophyceae							
Cosmarium spp.	Zygnamatales	*Mesotaeniaceae*	-	+	-	+	+
Closterium spp.	Zygnamatales	*Mesotaeniaceae*	1	-	+(1)	+(1)	+(1)
Mougeotia Spp.	Zygnematales	*zygnemataceae*	-	+	+	+	+
Oocystis spp.	-	*Occystaceae*	-	-	-	+	-
Pediastrum spp.	-	*Hydrodictyaceae*	-	+	-	+	+
Spirogyra spp.	Zygnematales	*zygnemataceae*	-	+	+	+	+
Staurastrum spp.	Zygnamatales	*Mesotaeniaceae*	-	+	-	+	-
Zygnema spp.	Zygnematales	*zygnemataceae*	-	+	+	+	+
Cyanophyceae							
Anabaena sp.	-	-		+	-	+	+
Lyngbya sp.	-	-	-	+	-	+	+
Oscillatoria sp.	-	*Cyanophyceae*	5	+(5)	-	+(5)	+(5)
Spirulina sp.	-	*Cyanophyceae*	-	+	-	-	-
Dinophyceae							
Ceratium spp.	Peridiniales	*Ceratiaceae*	-	+	+	-	+
Asterocystis spp.	-	-		-	-	-	+
Total Score				10	7	11	12

Key: + = present - = absent

Table 3: Pollution index of Algal species according to Palmer, (1969) at four sites of high Altitude wetland Dodi Tal of Garhwal Himalaya 2014 - 2015.

Bacillariophyceae	Order	Family	Pollution Index (Palmer1969)	S1	S2	S3	S4
Closteriopsis longissima Lemmermann 1899			-	-	-	+	+
Cocconeis placentula Ehrenberg 1838	Pennales	*Acanthaceae*	-	+	+	+	+
Cymbella bengalensis Grun, 1875.	Pennales	*Naviculaceae*	-	+	+	+	+
Cymbella cistuala ((Ehrenberg) O.Kirchner, 1878	Pennales	*Naviculaceae*	-	-	-	+	+
Diatoma vulgaris Bory 1824			-	+	-	+	+
fragilaria capucina Desmazières 1830	Pennales	*Fragilariaceae*	-	+	+	+	+
Nitzschia recta Hantzsch ex Rabenhorst 1862	Pennales	*Epithemiaceae*	-	+	-	+	+
Synedra ulna Ehrenberg 1832	Pennales	*Fragilariaceae*	3	+(3)	-	+(3)	+(3)
Synedra acus Kützing 1844			-				
Tabellaria fenestrata (Lyngbye) Kützing 1844	-	-	-	+	+	+	+
Tabellaria flocculosa (Roth) Kützing 1844	-	-	-	+	+	+	+
Chlorophyceae							
Actinastrum hantzschii Lagerheim 1882	-	*Scenedesmaceae*	-	+	-	+	-
Ankistrodesmus falcatus (Corda) Ralfs 1848	-	*Oocystaceae*	3	-	-	+(3)	+(3)
Cladophora glomerata (Linnaeus) Kützing 1843	Sphaeropleales	*Sphaeropleaceae*	-	+	-	+	-
Pandorina morum (O.F.Müller) Bory 1824	Volvocales	*Volvocaceae*	3	+ (3)	-	+(3)	+(3)
Scenedesmus quadricauda Brébisson & Godey 1835	-	*Scenedesmaceae*	4	+(4)	+(4)	+(4)	+(4)
Ulothrix zonata (F.Weber & Mohr) Kützing 1833	Ulotrichales	*Ulotrichales*	-	+	+	+	+
Ulothrix tenerrima Kützing 1843	Ulotrichales	*Ulotrichales*	-	+	-	+	+
Volvox aureas Ehrenberg 1832	Volvocales	*Volvocaceae*	-	+	-	+	+
Xanthidium antilopaeum Kützing 1849	Zygnamatales	*Mesotaeniaceae*	-	+	-	+	-
Dinophyceae							
Peridinium cinctum (O.F.Müller) Ehrenberg 1832	Peridiniales	*Peridiniaceae*	-	-	-	+	+
Total Score				10	4	13	13

Table 4: Monthly and Seasonally variation in diversity index (Shannon-Wiener, 1964) for Algal taxa of high altitude wetland, Dodi T, Garhwal Himalaya for the period November 2014-October 2015

Sites	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
2014-2015												
S1	4.21	3.71	3.27	NA	NA	4.07	4.14	3.98	3.46	3.73	3.89	4.26
S2	4.21	3.74	3.31	NA	NA	4.08	4.14	3.99	3.49	3.71	3.89	4.27
S3	4.23	3.71	3.41	NA	NA	4.15	4.15	4.03	3.59	3.75	3.86	4.26
S4	4.24	3.74	3.44	NA	NA	4.14	4.15	4.04	3.62	3.79	3.91	4.28
$\bar{x}$ Diversity Index	4.22	3.73	3.36	NA	NA	4.11	4.15	4.01	3.54	3.75	3.89	4.27

Sites	Winter	Spring	Summer	Monsoon	Autumn
2014-2015					
S1	3.73	NA	4.07	3.59	4.08
S2	3.75	NA	4.07	3.60	4.08
S3	3.78	NA	4.11	3.67	4.06
S4	3.81	NA	4.11	3.67	4.06
$\bar{x}$ Diversity Index	3.77	NA	4.09	3.63	4.07

Table 5: Monthly and Seasonally variation in Jaccard evenness calculated for Algal taxa of high altitude wetland, Dodi Tal, Garhwal Himalaya for the period November 2014-October 2015

Sites	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
2014-2015												
S1	0.097	0.127	0.148	NA	NA	0.094	0.098	0.104	0.144	0.128	0.114	0.092
S2	0.097	0.124	0.150	NA	NA	0.094	0.100	0.105	0.145	0.132	0.114	0.094
S3	0.096	0.127	0.142	NA	NA	0.094	0.101	0.103	0.143	0.133	0.107	0.092
S4	0.096	0.124	0.143	NA	NA	0.094	0.101	0.103	0.144	0.130	0.105	0.093
$\bar{x}$ Jaccard evenness	0.097	0.126	0.146	NA	NA	0.094	0.100	0.104	0.144	0.131	0.110	0.093

Sites	Winter	Spring	Summer	Monsoon	Autumn
2014-2015					
S1	0.124	NA	0.099	0.136	0.103
S2	0.124	NA	0.100	0.139	0.104
S3	0.122	NA	0.099	0.138	0.100
S4	0.121	NA	0.099	0.137	0.099
$\bar{x}$ Jaccard evenness	0.123	NA	0.099	0.137	0.101

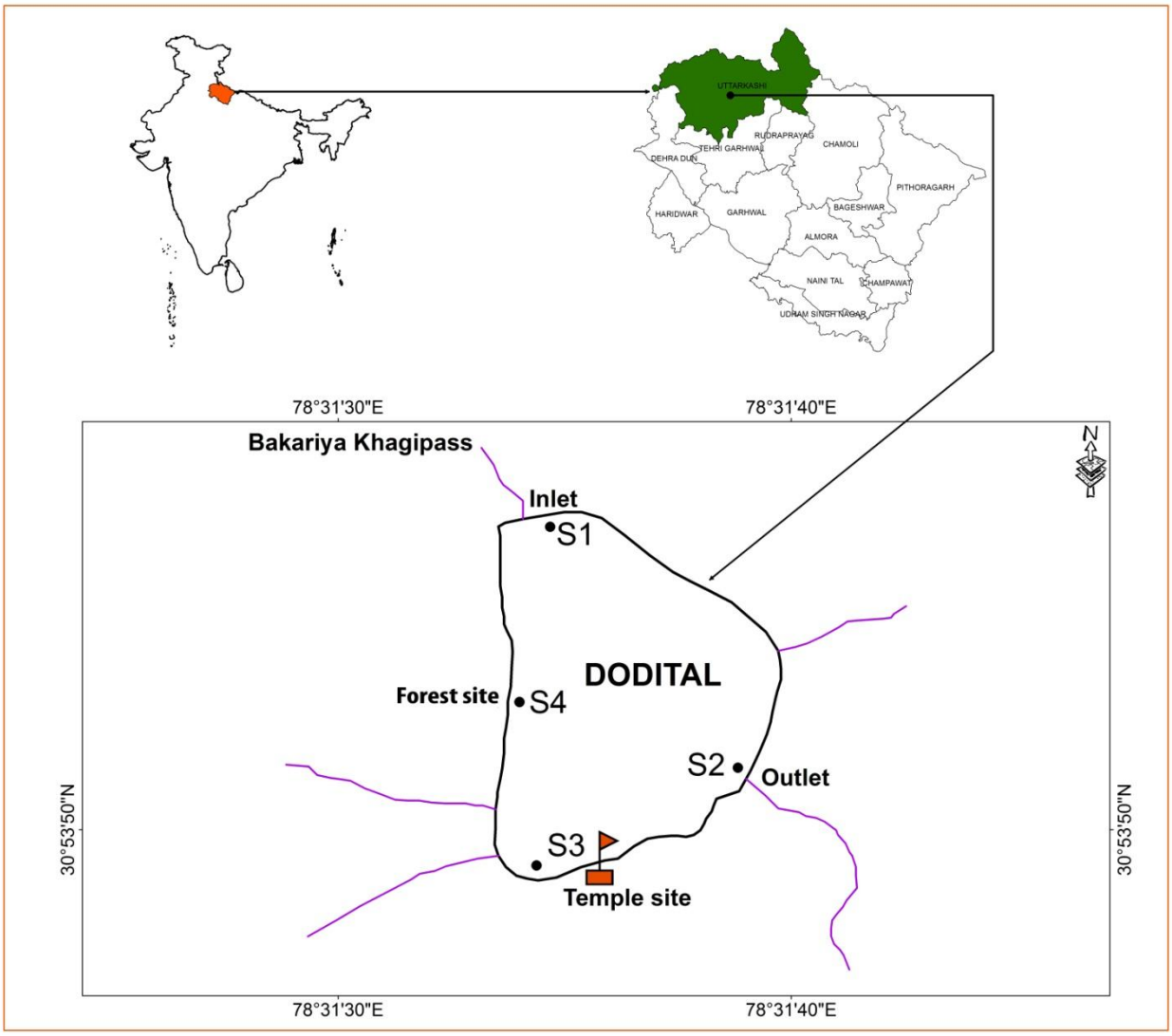

Fig 1: Location map of high altitude wetland Dodi Tal with sampling sites (S1, S2, S3, S4)

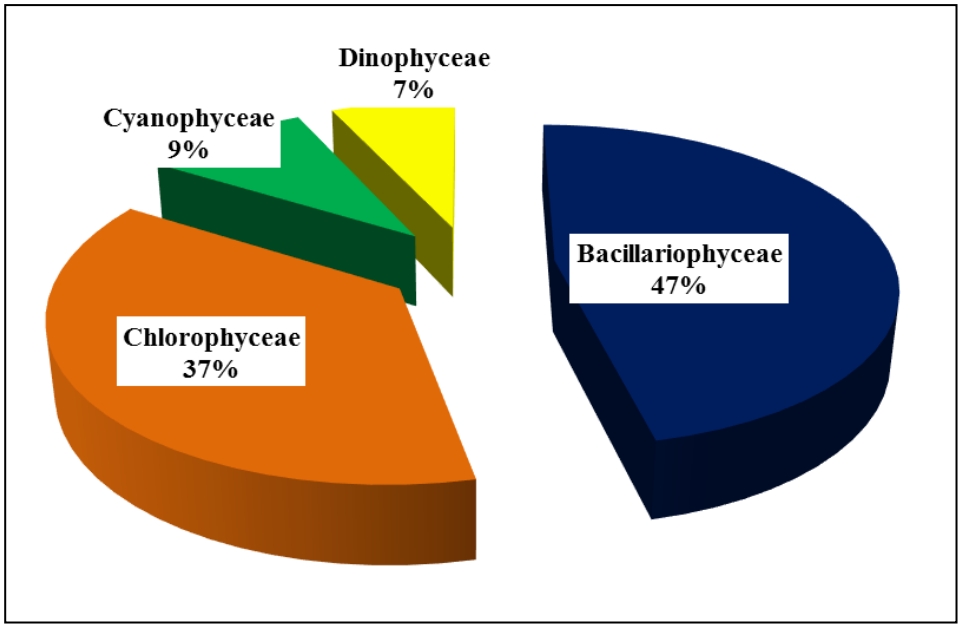

Fig 2: Percentage composition of algal taxa in Dodi Tal, Garhwal Himalaya (November 2014-October 2015)

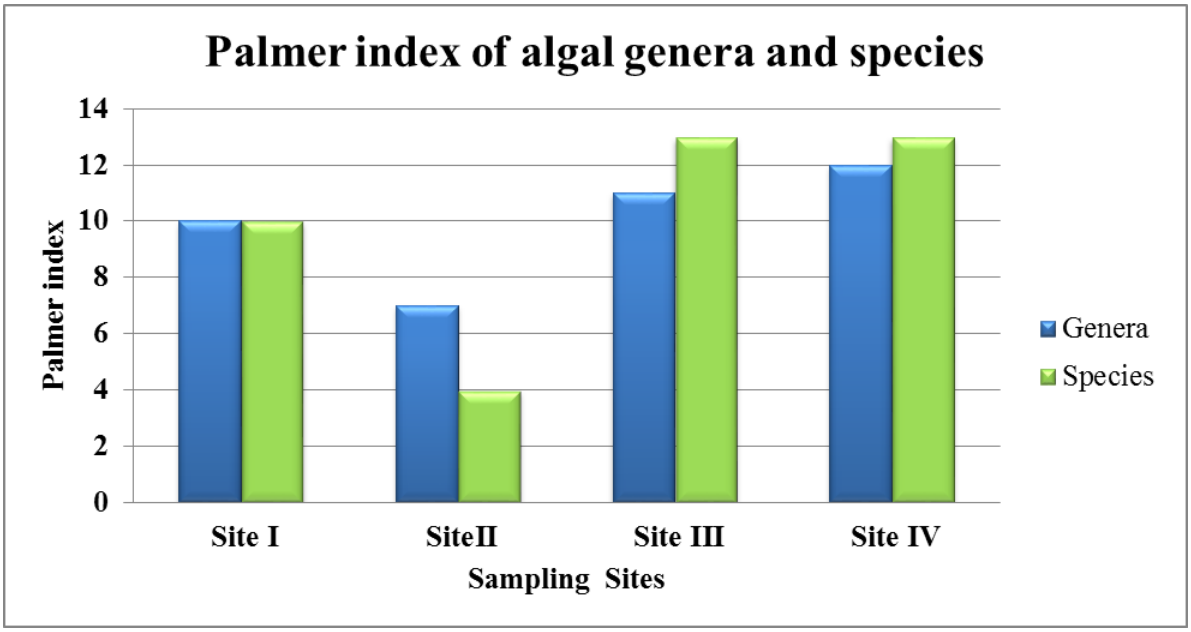

Fig 3: Pollution index score of algal genera and species at selected sampling sites of Dodi Tal for the period of November 2014-Octobar 2015

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