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Studies of high altitude algae from some water bodies of Dzükou valley, Eastern Himalaya

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ABSTRACT

The present study was carried out at Dzükou valley, a high altitude region of Nagaland, Northeast India. Algal diversity was evaluated from 3 depression springs and 2 rivers. A total of 62 algal taxa belonging to 41 genera and 8 classes were recorded. The class Baccillariophyceae (37 species) was the most dominant while the genus *Eunotia* (8 species) represented the maximum genera. Biodiversity indices such as Shannon–Wiener index (H2), Simpson's diversity index (D) and Margalef richness (R) shows maximum diversity and richness in Depression Spring 2 followed by Depression Spring 1, Depression Spring 3, River 1 and River 2. Pielou's index (J) depicted the highest evenness value from River 1. Palmer's pollution index of all the sites was found to be d"10 thus indicating no organic pollution. This study will provide a preliminary screening for algal community thriving at high altitude of Nagaland and coherently aids to the biodiversity richness of the Indo-Burma hotspot.

Key words: *Algae, High altitude, Dzükou, Nagaland.*

Introduction

Algae are widely distributed in nature since it can adapt to different types of environment; majority of the algae are aquatic where they form the basis of food chain. Algae can be considered as one of the most important organisms on planet. Chapman (2013) discussed the importance of algae from the ancient times to the future prospect of algae, highlighting their present use and their importance for our Ecosystem like its photosynthetic abilities, as source of pharmaceutical and nutritional human and animal food, bio-fertilizer, industrial uses etc. Das *et al.* (2002) stated that algae can be used as indicator of environmental change and ecosystem's health due to their many attributes like their ubiquitous distributions, their sensitivity to wide range of pollutants and their short life cycle. Nagaland, a northeastern state situated in the Indo Burma Biodiversity hotspot of India has rich biodiversity including algae which are understudied. Dzükou valley is not influence by humans settlements however, it is one of the top tourist attraction spots in Nagaland because of the lush green natural scenery, the rivers flowing through the valley, the dwarf bamboos in the valley and surrounding hillocks, the caves and the seasonal flowers such as the Dzükou Lily "*Lilium mackliniae*" which is endemic to Eastern Himalaya. Mao and Gogoi (2010) in their work revealed that about 6% of the plants recorded from this valley were endemic to the area or eastern Himalaya. So far, no work has been done on the algal taxa of this region and considering the importance of algae in science and the limited work available on studies of algae in high altitude region of India, the present study was taken up to explore the algae of Dzükou Valley. The findings will highlight the importance of algal diversity of this region, im-

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part a deeper sense of knowledge in its ecological structure and also contributes to phycological studies for researchers.

Materials and Methods

Study area

Nagaland is surrounded by Assam in the northwest, Manipur in the south, Arunachal Pradesh and Myanmar in the east. It is located between 25°62 N to 27°42 N Latitude and 93°202 E to 95°152 E Longitude with an annual average rainfall of 1,800 to 2,500 mm. The maximum temperature from 21 °C to 36°C in summer and 21°C to below 0 °C in winter. Dzükou valley is located between 25°31′0 ′′N to 25°35′0" N and 94°03′0"8 to 94°05′0"E with an area of about 27 sq. km and an elevation ranging from 2400 m- 2994 m. The area receives an average annual rainfall of 2000-2500 mm. The valley is dominated by variety of small shrubs, dwarf bamboos, herbs and is devoid of big trees. Water bodies in the valley include two main rivers, few small rivers and perennial springs.

Collection and identification of samples

Triplicate samples were collected from 2 rivers and 3 depression springs during spring season and overall species richness was taken into consideration for the present study. Filamentous algae were collected by hand and twig. Phytoplanktons were directly collected into sample bottles and occasionally algae were collected by squeezing aquatic plants and submerged leaves. Submerged rock surfaces were scrappedwith forceps or brush and washed into sample bottles. The collected samples were fixed in 4% formalin and stored at 4^0C in the refrigerator for further studies. Photomicrographs of the algal specimens were taken using Motic microscope BA-210 and identified consulting standard literatures and publications of Prescott (1591), Desikachary (1959); John *et al.* (2002); Taylor *et al.* (2007) and internet sources. Systematic of taxa were arranged according to Algae Base website (Guiry and Guiry, 2021). The voucher specimens were than deposited in the Department of Botany, Nagaland University, Lumami campus.

Diversity indices

Biodiversity indices were calculated following the postulated method of Shannon-Wiener Index by Shannon (1963); Simpson's Diversity Index (1949), Evenness index by Pielou's (1969); Margalef's richness index (1958) and Palmer's pollution tolerance index (1969).

Results and Discussion

A detailed study on the morphological characters i.e. cell size, shape, ornamentation, striae and raphe morphology, arrangement of the chloroplast, number and arrangement of pyrenoids were studied for identification of materials. List of algal taxa and their distribution is given in Table 1.

Enumeration of algal species from Dzükou valley

A total of 62 algal taxa belonging to 41 genera and 7 classes were recorded. Baccillariophyceae (37) was the most dominant class which was followed by Chlorophyceae (6), Cyanophyceae (6), Zygnematophyceae (5), Xanthophyceae (2), Euglenophyceae (2) and Coscinodiscophyceae (1). Maximum representation of the algal genera belongs to *Eunotia* (8 species), *Pinnularia* (5 species) and *Gomphonema* (3 species).

In DS1, 23 algae species belonging to 19 genera were recorded. This site was dominated by the genera Eunotia (4). An absolute total of 4866 individuals were estimated from 1ml of the sample and the highest number of individual was *Pectinodesmus holtmanii* (1240/ml) followed by *Tribonema affine* (680/ml) and *Eunotia bilunaris* (506/ml). From DS2, 26 algal species belonging to 18 genera were recorded. Genera *Eunotia* (6) also dominated this site. Total number of individuals calculated in 1ml is 3233 and the highest number of individual is *Lepocinclis fusiformis* (606/ml) followed by *Micros pora pacyderma* (353/ml) and *Eunotia bilunaris* (326/ml). DS3 had a total of 17 algae species belonging to 13 genera. This site was also dominated by Eunotia (4). Total number of individuals calculated is 3000 and the maximum number of individual is *Navicula* sp. (1240/ml) followed by *Tribonema affine* (333/ml) and *Caloneis acuta* (326/ml). A total of 15 algae species belonging to 13 genera and 4 classes were recorded from STR1 where the dominant genus were Fragilaria (2) and Gomphonema (2). *Cymbellan eoleptoceros* (266/ml) has the highest number of individual followed by *Gomphonema pumilum* (253/ml) and *Melosira varians* (213/ml). At STR 2, 14 algae species belonging to 12 genera were recorded. The dominant genus was *Gomphonema* (3/ml).

Table 1. DistributionofalgalspeciesindifferentwaterbodiesofDziikou valley

Algal Taxa	Class	DS1	DS2	DS3	STR1	STR2
Aphanocapsa grevillei	Cyanophyceae	-	+	-	-	-
Cyanothece aeruginosa		-	+	-	-	-
Gleocapsa novacekii		-	+	-	-	-
Gloeocapsa nigrescens		-	-	+	-	-
Oscillatoria sp.		-	-	-	-	+
Stigonema tomentosum		-	+	-	-	-
Achnanthes minutissima	Baccillariophyceae	+	-	-	-	-
Achnanthidium nanum		-	-	-	+	-
Achnanthidium neotropicum		-	+	-	-	-
Brebissonia lanceolata		-	-	+	-	+
Caloneis acuta		-	-	+	-	-
Caloneis strelnikovae		+	-	+	-	-
Cymbella neoleptoceros		-	-	-	+	-
Cymbopleura amphicephala		+	-	-	-	-
Diatoma vulgaris		-	+	+	-	-
Encyonema sublungebertulotii		-	-	-	+	-
Encyonemavulgare		-	-	-	-	+
Epithemiasorex		-	+	-	-	-
Eunotiabilunaris		+	+	-	-	-
Eunotia epithemioides		-	+	-	+	+
Eunotia implicate		+	-	-	-	-
Eunotianaegelii		+	-	-	-	-
Eunotiaparatridentula		+	+	+	-	-
Eunotiaserra		-	+	+	-	-
Eunotiatridentula		-	+	+	-	-
Eunotia novaecaledonica		-	+	+	-	-
Fragilariacapucina		-	-	-	+	+
Fragilariarumpens		-	+	+	+	-
Gomphoneispseudo-okunoi		-	-	-	+	-
Gomphonemagracile		+	-	-	+	+
Gomphonemaminutum		-	-	-	-	+
Gomphonema pumilum		-	-	-	+	+
Hannaea inaequidentata		-	-	-	+	-
Navicula sp.		+	-	+	+	+
Odontidium hyemale		-	-	+	-	-
Odontidium mesodon		+	-	+	-	+
Pinnularia appendiculata		-	+	-	-	-
Pinnularia borealis		+	+	-	-	-
Pinnularia subgibba		-	+	-	-	+
Pinnularia viridiformis		-	+	+	-	-
Pinnularia viridis		+	-	-	+	-
Rhopalodia gibba		-	+	+	-	-
Surirellaroba		-	-	-	-	+
Melosira varians	Coscinodiscophyceae	-	-	-	+	-
Tribonema affine	Xanthophyceae	+	-	+	-	-
Tribonema viride		-	+	-	-	-
Coelastrum pseidomicropopum	Chlorophyceae	+	-	-	-	-
Eudorina elegans						
Microspora pachyderma		+	+	-	-	-
Microspora tumidula		-	+	-	-	-
Pectinodesmus holtmannii		+	-	-	-	-
Pediastrum tetras		+	-	-	-	-
Scenedesmus acunae		+	-	-	-	-

Table 1. *Continued ...*

Algal Taxa	Class	DS1	DS2	DS3	STR1	STR2
Tetradesmus dimorphus		+	+	-	-	-
Glaucocystis sp.	Glaucophyceae	+	-	-	-	-
Closterium parvulum	Zygnematophyceae	-	-	-	-	+
Cosmarium blytii		+	-	-	+	-
Docidium undulatum		-	-	-	-	+
Hyalotheca dissiliens		+	-	-	-	-
Spirogyra sp.		-	+	+	+	-
Lepocinclis fusiformis	Euglenophyceae	-	+	-	-	-
Phacus caudatus		-	+	-	-	-

+=Present,-=Absent

Encyonema vulgare (2593/ml) has the maximum number of individual while *Docidium undulatum* and *Surirella roba* (6/ml each) has the minimum. In all the sites, the class Baccillariophyceae contributed the highest percentage of algal taxa. Percentage of Baccillariophyceae in DS1 (52%) and DS2 (57%) constituted approximately half of the algal taxa while DS3, STR1 and STR2, contributed 82%, 80 % and 78 % respectively. This result was found to be similar with Dalkiran *et al.* (2021) who found Baccillariophyceae to be dominant in high altitude regions of Turkey. In India, some of the high altitude algal studies recorded Cyanophyceae (Toppo *et al.*, 2016); Baccillariophyceae (Das and Adhikary, 2012) and Chlorophyceae (Kant and Gupta, 1998) as highly dominant. The present study also shows such dominance and distribution of algae which suggest that altitude can influence the composition and growth of similar algal taxa irrespective of the region. *Navicula* sp. was the most widely distributed species reported from four sites while *Eunotia epithemioides, Eunotia paratridentula, Fragillaria rumpens* and *Spirogyra* sp. were reported from three sites.

Diversity indices of algae

The diversity indices are calculated to study the diversity and abundance of species in different habitats for comparison and also to assess ecosystem health and ecological processes (Naidu and Kumar, 2016). To show algal diversity and its richness, Shannon–Wiener diversity index (H2), Simpson's dominance index (D), Margelaf richness (R) and Pielou's evenness index (J2) were calculated and the

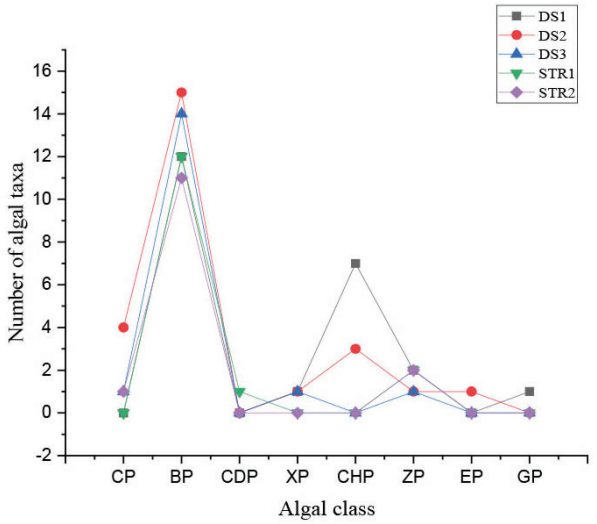

Fig. 1. Overall compositional pattern of the different a lgal classes at the sampling sites. Note: CP: Cyanophyceae; Bp: Bacillariophyceae; C DP: Coscinodiscophyceae; XP: Xanthophyceae; CHP: Chlorophyceae; ZP: Zygnematophyceae; EP: Euglenophyceae; GP: Glaucophyceae

Table 2. Diversity indices of different sampling sites

Sites	Shannon-Wiener Index	Simpson's Diversity Index	Margalef's Richness Index	Pielou's Evenness Index
DS1	1.08	0.88	3.33	0.34
DS2	1.16	0.91	4.04	0.36
DS3	0.88	0.79	2.62	0.31
STR1	1.03	0.90	2.55	0.38
STR2	0.72	0.73	1.92	0.27

result are given in Table 2. Shannon–Wiener index was maximum in DS1 (1.16) and minimum in STR2 (0.72). The result was comparatively lower than Singh and Sharma (2018) wetland of Garhwal Himalaya. Simpson's diversity index ranges from 0.73 (STR2) - 0.91 (DS1). The result was in conformity with Suresh *et al.* (2010) from the high altitude of Western and Eastern Ghats.

Highest Margalef richness index was observed in DS1 (3.33) and lowest in STR2 (1.92) which was similar with Pandey *et al.* (1995) at Schirmacher Oasis, Antarctica. The Pielou's evenness ratio was quite low in all the sampling sites depicting a more selective dominant of particular species like *Eunotia bilunaris*, *Pinnularia borealis*, *Lepocinclis fusiformis*, *Cymbella neoleptoceros*, *Navicula* sp., *Encyonema vulgare* and *Gomphonema pumilum* compared to the other species present in the same habitat. The reference values of Palmer's pollution index are 0-10, 10–15, 15-20 and 20 and above which indicate no evidence of organic pollution, moderate pollution, probable high organic pollution and high organic pollution respectively (Palmer, 1969). The study shows the presence of 9 pollution tolerant genera and their numerical values were calculated and pollution index was found in the ranges of 3 to 10 with the minimum value exhibited in DS3 and Maximum in STR2. Moreover the result shows a value of d"10 from the five sampling sites which indicates that the water bodies have negligible or no organic pollution (Table 3). Bacillariophyceae or Diatoms was the most abundant and diverse class of algae as they are widely distributed in all the sites. Padhi *et al.* (2010) in their studies revealed that Diatoms usually grow better in unpolluted waters. The dominance of diatoms in all the study sites can indicate the good water quality. Since Dzükou is situated in a mountainous terrain with very little anthropogenic influences, the water status could be suitable for the growth of such algal species. It should also be noted that Euglenoids and Cyanophytes are known to grow in polluted water (Murulidhara and Murthy, 2018). However, only 2 species of Euglenoids was found from DS2 and 6 Cyanophytes was recorded in STR2 and DS2. Among the 6 Cyanophytes, only 1 species i.e., *Oscillatoria* sp. is known to tolerate organic pollution (Palmer, 1969). The negligible presence of such species also indicated the good water quality status of Dzükou Valley.

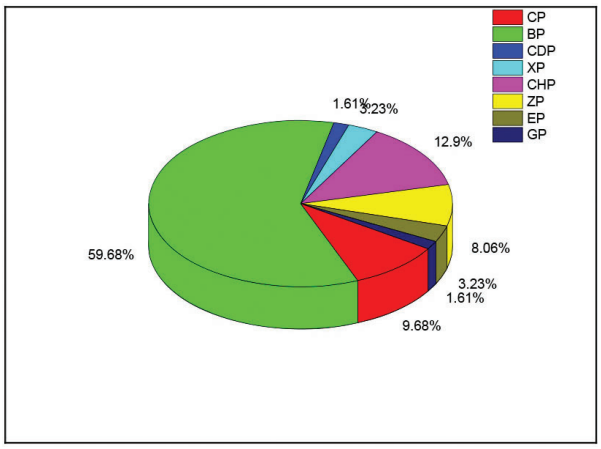

Fig. 2. Total number of algal taxa belonging to various classes from each sampling sites. Note: CP: Cyanophyceae; Bp: Bacillariophyceae; CD P: Coscinodiscophyceae; XP: Xanthophyceae; CHP: Chlorophyceae; ZP: Zygnematophyceae; EP: Euglenophyceae; GP: Glaucophyceae

Conclusion

The quantitative phycological study at Dzükou valley has prominently depicted the algal composition and richness of the region. DS2 contributed the highest diversity and species richness while STR2 has the

Table 3. List of pollution tolerant genera from the study sites following algal genus Pollution Index of Palmer (1969)

AlgalGenera	Pollutionindex	DS1	DS2	DS3	STR1	STR2
Gomphonema	1	+	-	-	+	+
Navicula	3	+	-	+	+	+
Melosira	1	-	-	-	+	-
Scenedesmus	4	+	+	-	-	-
Closterium	1	-	-	-	-	+
Lepocinclis	1	-	+	-	-	-
Phacua	2	-	+	-	-	-
Oscillatoria	5	-	-	-	-	+
Total Score		8	7	3	5	10

lowest diversity. The total species (62 species), high dissimilarity between each sampling sites and the low species evenness ratio represents a diverse dynamic distribution of algae. Apart from tourist visiting the valley and forest fire which are the main threat to the biodiversity, this region has no human settlement hence has very less anthropogenic influences. The unique biodiversity of Dzükou valley makes this study an utmost importance to understand algal composition and sustain its ecological structure for preserving a spatial habitat. With regard to the significance of algae in science and its contribution to the biodiversity status, the documented database from this study can be a primary source for supporting enthusiastic researchers and environmentalists exploring the Indo-Burma biodiversity hotspot region to promote the use of the algal records of this area as part of conserving biological diversity.

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Conflict of Interest

The Authors declare no conflict of interest.

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