

Investigating Algal Composition and its Ecology during Winter in Streams of Nagaland, North-Eastern India

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ABSTRACT

The present study was conducted in streams of Lumami, Zunheboto district, Nagaland to explore the types of algae prevalent in the waterbodies. This research aims at measuring a geographical area to invent the algal resources during the winter season. Three zones i.e. upstream, midstream and downstream were divided where samples comprising different species from several spots were collected. A total of 58 algal

taxa representing 10 families were identified with the maximum number of taxa recorded in class Bacillariophyceae while the most dominant algae found in the streams are the *Navicula* sp. and *Luticola* sp. which is also known as golden brown protists. As per the analysis the algae prefer low intensity of light and temperature with high DO. Further study on algae needs to be explored for the remaining seasons; this will enrich the biodiversity status and impart knowledge on the algal habitats in this region.

Keywords Lumami, Streams, Phycology, Physico-chemical parameters.

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INTRODUCTION

Alga is a diverse and widely distributed organism across different habitat and their occurrence differs seasonally (Suzuki and Takeuchi 2023). Microalgae including eukaryotic and prokaryotic cyanobacteria are photoautotrophic organisms, that can also thrive through heterotrophic, mixotrophic, and photoheterotrophic modes of existence (Xiao *et al.* 2020). Algal ecology involves a continuum of web-like interaction between the environments. It is also a primary carbon fixing organisms in the aquatic environment and thus an indispensable link for the ecosystem. They are abundant in streams and provide essential functions as primary producers at the intersection of the physical-chemical environment and the biological community (Lowe and LaLiberte 2017). In addition,

algae biomass contains a wide variety of compounds that can be applicable in the culinary, medicinal, and cosmetic sectors, as well as in biofuel production (Maltsev *et al.* 2017). Systems using immobilized algae are utilized for wastewater treatment, since they use their photosynthetic capabilities to generate valuable biomass while also treating wastewater (Mallick 2002).

Furthermore, algae exhibit sensitivity to nutrient contamination and species-specific optimal conditions. The tolerance of certain algae (e.g., diatoms) to specific environmental variables can be easily quantified (Liu *et al.* 2023). Therefore, algae have historically served as indicators of nutrient-related contamination in global streams and lakes. As such changes in physico-chemical factors and other anthropogenic activities threaten algae species (Chakraborty *et al.* 2022). Graca *et al.* (2002) mentioned that biodiversity has become a major conservation issue, yet algae are still a neglected subject due to its microscopic size or shortage of algal taxonomists and lack of funding for study. Different parts of India have different algal species depending on the place and their habitat. As far as the North–Eastern part of India is concerned, Das and Adhikary (2012) reported ninety-four algal species from different aquatic ecosystem of Nagaland. However, just a few research have been undertaken in Nagaland regarding the documentation of algal flora in lotic waters, particularly in the mountainous streams of Lumami. Due to the region distinct hilly terrain and its fast-flowing water current in remote areas far from human settlement, algal mats are rarely observed occurring in these streams. Numerous studies on algal distribution in various regions of India reveal the presence of many nameless and unidentified species, particularly at the regional level, where research and discoveries remain limited. This pioneering and preliminary work on freshwater algae in Lumami streams will be useful for future researchers for several purposes.

MATERIALS AND METHODS

Description of the study area

Nagaland, situated in the North-East region of India

occupying an area of 16,579 square kilometer. The average annual rainfall of the state ranges between 70 and 100 inches (1,800 and 2,500 mm). Heavy rainfall tends to usually occur during June to September and gradually reduces with the arrival of the winter months. The research was carried out in the streams of Khichighoki, Lumami, situated in the Zunheboto district of Nagaland. Annually, the area experiences a moderate temperature of 18 to 30°C with an average rainfall of 2000 mm. Geographically, the area stands at an altitude of 1874.22 meters above the sea level with a latitude of 26.216588° and longitude of 94.49844°. Winters are very cold (below 15 °C) but summers are moderately warm (14–28°C) while December and January form the coldest month of the season and at times the temperature drops down to 7°C. The types of vegetation include the Northern tropical wet evergreen forest, semi-deciduous, broad leaf and sub-tropical pine forests. Anthropogenic activities along the stretch of the streams include collection of fodder, periodic-seasonal hunting, gathering of firewood including wild flowers and vegetables.

Sample collection and water analysis

Samples of algal species were collected from eight locations, consisting of three stations: Upstream, midstream, and downstream. The methods involving scooping, scraping and scrubbing various damp and submerged substrates were implied to sample the algae during the months of December 2023 and January 2024. Macroalgae were gathered using forceps and for benthic algae, the stone containing the algae were randomly selected and the samples were scrubbed from the surface of the stone with the help of a painting brush. Algae samples were preserved in 4% formaldehyde solution in air-tight bottles at room temperature. After collecting the surface water samples from the sampling stations, they were analyzed for Light intensity, Water temperature, pH, Total Dissolved Solid (TDS), Dissolved Oxygen (DO), Total Hardness, Calcium Hardness, Magnesium Hardness, Electrical Conductivity (EC), Chloride and Total alkalinity. The water physico-chemical parameters were analyzed following standard protocols of APHA (2005). Triplicate assessments for the parameters were tested, and their arithmetic mean range value was considered for the study.

Observation and identification

Photomicrographs of the algal specimens were taken with a Motic microscope BA-210 and identified using standard literature and publications by Prescott (1962), Desikachary (1959), John *et al.* (2002), Taylor *et al.* (2007), and internet sources. Taxa were organized systematically using the Algae Base website (Guiry and Guiry 2021). The voucher specimens were then stored in the Department of Botany at Nagaland University's Lumami Campus.

RESULTS AND DISCUSSION

The algal taxa documented from the streams of Lumami comprise 58 species across 10 families, as detailed in Table 1. Observations indicate that the majority of algae identified in the current study's streams are similar, with Bacillariophyceae prevailing in both

Table 1. Occurrence of algal taxa recorded along the Lumami stream from 8 stations.

Sl. No.	Algal taxa	1	2	3	4	5	6	7	8	
1	Bacillariophyceae									
1	<i>Achnanthes minutissima</i>	-	-	-	-	-	+	-	-	
2	<i>Amphora pediculus</i>	-	+	-	-	-	-	-	-	
3	<i>Aulacosira</i> sp.	-	-	-	-	-	+	+	-	
4	<i>Caloneis amphisbaena</i>	-	-	+	-	-	-	-	-	
5	<i>Cocconeis</i> sp.	-	+	-	-	+	-	+	-	
6	<i>Cyclotella</i> sp.	-	-	-	-	+	-	-	-	
7	<i>Cymbella neoleptoceros</i>	-	-	-	-	+	-	+	-	
8	<i>Diatoma vulgare</i>	-	-	-	-	+	-	-	-	
9	<i>Diploneis</i> sp.	-	+	-	+	+	-	-	-	
10	<i>Encyonema vulgare</i>	+	-	-	-	-	-	-	-	
11	<i>Epithemia sorex</i>	-	-	-	-	+	-	-	-	
12	<i>Eunotia implicate</i>	-	-	-	-	+	-	-	-	
13	<i>Gomphonema minutum</i>	-	+	-	+	-	-	-	-	
14	<i>Grammatophora</i> sp.	+	-	-	-	-	-	-	-	
15	<i>Gyrosigma acuminatum</i>	+	+	-	-	+	+	+	-	
16	<i>Haslea ostrearia</i>	+	-	-	-	-	-	-	-	
17	<i>Luticola mutica</i>	+	+	-	-	-	-	-	+	
18	<i>Luticola nivalis</i>	+	-	-	-	-	-	-	-	
19	<i>Melosira varians</i>	-	+	-	+	+	-	+	-	
20	<i>Melosira undulata</i>	-	-	-	-	-	+	-	-	
21	<i>Meridion</i> sp.	-	-	-	-	+	-	-	-	
22	<i>Navicula lanceolata</i>	+	+	+	+	+	+	+	+	
23	<i>Navicula rhyncephala</i>	-	-	-	-	+	-	+	-	
24	<i>Navicula straitula</i>	-	-	-	-	+	-	-	-	
25	<i>Navicula tripunctata</i>	-	-	-	-	-	+	-	-	
26	<i>Navicula radiosa</i>	-	-	-	-	-	+	+	-	
27	<i>Neidium</i> sp.	-	-	+	-	-	-	+	-	
28	<i>Nitzschia minuta</i>	-	-	+	+	+	-	-	-	

Table 1. Continued.

Sl. No.	Algal taxa	1	2	3	4	5	6	7	8	
29	<i>Pinnularia borealis</i>	+	+	+	-	+	-	+	-	
30	<i>Rhopalodia constricta</i>	-	-	-	+	+	-	-	+	
31	<i>Rhopalodia gibba</i>	-	-	-	-	+	-	-	-	
32	<i>Stauroneis smithii</i>	+	-	-	-	-	-	-	-	
33	<i>Surirella striatula</i>	+	+	+	+	+	-	-	+	
34	<i>Surirella splendida</i>	-	+	+	+	+	-	+	-	
35	<i>Synedra minuscula</i>	+	+	+	+	+	-	-	-	
36	<i>Tabellaria flocculosa</i>	-	+	-	-	-	-	-	-	
37	<i>Tabellaria fenestrata</i>	-	+	-	-	-	-	-	-	
2	Cyanophyceae									
1	<i>Aphanizomenon gracile</i>	+	-	-	-	-	-	-	-	
2	<i>Aulosira laxa</i>	-	-	-	-	-	-	+	-	
3	<i>Chroococcus giganteus</i>	+	-	-	-	-	-	-	-	
4	<i>Microcaleus</i> sp.	+	-	-	-	-	-	-	-	
5	<i>Oscillatoria limosa</i>	+	-	-	-	-	-	-	+	
6	<i>Oscillatoria borneli</i>	+	-	-	-	-	-	-	-	
7	<i>Phormidium uncinatum</i>	-	-	+	-	-	-	-	+	
8	<i>Phormidium retzii</i>	+	-	-	-	-	-	-	-	
3	Chlorophyceae									
1	<i>Netrium naegelii</i>	+	-	+	-	-	-	-	-	
2	<i>Oedogonium</i> sp.	-	+	-	-	-	-	-	-	
3	<i>Spirogyra alternata</i>	-	-	-	-	+	-	-	-	
4	<i>Ulothrix cylindrica</i>	-	-	-	-	+	-	-	-	
4	Zygnematophyceae									
1	<i>Closterium venus</i>	-	+	+	-	+	-	-	+	
2	<i>Mesotaenium endlicherianum</i>	-	-	-	-	-	-	+	-	
3	<i>Mougeotia</i> sp.	-	-	-	-	-	+	-	-	
4	<i>Pleurotaenium ehrenbergii</i>	-	-	-	-	-	+	-	-	
5	Chromadorea/Nematoda									
1	<i>Ancylostoma duodenale</i>	+	-	-	-	-	-	-	-	
2	<i>Enterobius vermicularis</i>	+	-	-	-	-	-	-	-	
6	Charophyceae									
1	<i>Chara nucule</i>	-	+	-	-	-	+	-	-	
7	Dinophyceae									
1	<i>Ceratium hirundinella</i>	-	-	-	-	-	+	-	-	
8	Eugleninae									
1	<i>Euglena</i> sp.	-	-	-	+	-	-	-	-	
9	Monogononta/ Rotifera									
1	<i>Cephalodella gibba</i>	+	-	-	-	-	-	-	-	
10	Raphidophyceae/ Ochrophyta									
1	<i>Gonyostomum</i> sp.	+	-	-	-	-	-	-	-	
	Other life form									
	<i>Fungi conidia</i>	-	+	-	-	-	-	-	-	
	<i>Homolozone</i>	-	-	-	-	-	-	+	-	

the findings of Kuotsu *et al.* (2022) in the streams of Dziikou Valley, Nagaland, and in the present study, arranged in a descending order as follows: Bacillar-

iophyceae (37) > Cyanophyceae (6) > Chlorophyceae (4) and Zygnematophyceae (4) > Nematoda (2) > Charophyceae (1), Dinophyceae (1), Eugleninae (1), Rotifera (1) Raphidophyceae (1).

Brief description of the identified algae:

Bacillariophyceae

Achnanthes minutissima

Achnanthes frustules are heterovalvar. The raphe valve generally possesses an inner region of thickened silica referred to as a fascia. The rapheless valve is devoid of a center section, and the sternum may be positioned adjacent to the valve edge.

Amphora pediculus

The valves display uniformity with respect to the transapical axis but asymmetry concerning the apical axis. The valve mantle has greater depth across the dorsal margin compared to the ventral margin. Consequently, the frustule possesses a wedge-like morphology, like a segment of an orange.

***Aulacosiera* sp.**

Aulacosiera cells form a cylindrical chain that connects the adjacent sibling's cell and the spine around the valve face. Separation cells are embedded in the filament, and the frequency of the separation valve determines the filament length. However, some species lack separation valves and instead have linking valves that can be easily separated.

Caloneis amphisbaena

The shape of valves is oval to elliptical-lanceolate, featuring capitate apices. The central axial region is extensive and enlarged, leading to a substantial lanceolate rhombic center zone. The middle section exhibits moderate asymmetry between the two sides of the axial area. The raphe is linear and centrally positioned. The closer raphe ends exhibit slight enlargement. The distal terminal of the raphe are bent in a uniform direction. Mostly striae stretch throughout the valve, becoming parallel and convergent at the

termini. The two longitudinal lines run parallel to the raphe, segmenting the striae into approximately thirds.

***Cocconeis* sp.**

The valves are oblong to linear-elliptical and slightly flattened. The raphe valve comprises a slender axial region and a small round or oval center portion. The raphe is symmetrical and thread-like. Striae radiate from both raphe and rapheless valves.

***Cyclotella* sp.**

Cyclotella is a tiny diatom with cells measuring 3-5 μm in diameter. With a short, drum-shaped valves. The circular valve face features rows of areolae emanating from a prominent center region wrapped with warts, spines, or granules.

Cymbella neoleptoceros

Cymbella valves are slightly too strongly asymmetric to the apical axis. The valves show symmetry concerning the transapical axis. The ends of the raphe fissures deviate towards the dorsal aspect, serving as a valuable diagnostic characteristic. At both terminals apical pore fields are present.

Diatoma vulgaris

Cells form zigzag colonies. Frustules have a rectangular shape in the girdle viewpoint. The valves are elliptical to elliptical-lanceolate with broadly rounded subrostrate ends, measuring 8-12 μm in width and 15-60 μm in length. Transapical ribs have a measurement range of 6-10 μm . Uniseriate striae, numbering 45-50 per 10 μm , comprise small poroid areolae. The axial region is elongated and exceedingly thin. Each valve apex contains one rimoportula. Apical pore fields are present at both apices.

***Diploneis* sp.**

The frustules have an elliptic to panduriform morphology, characterized by bluntly round apices. Each valve possesses two longitudinal canals: One on each side of the raphe. The canals are situated within the silica cell wall and connect to the exterior via pores,

although there are no apertures leading to the inner part of the cell.

Encyonema vulgare

Encyonema has distinct morphological characteristics such as valve and apex shape, as well as striae density. It ranges in length from 180-215 μm and breadth from 67-87 μm .

Epithemia sorex

The structure shows an eccentric raphe system situated at the ventral border. Every raphe branch is oriented towards the dorsal border. The adjacent raphe slits exhibit enlarged ends externally, whereas internal slit remains continuous across the center nodule. The length ranges from 27-85 μm , width 10.4-12.4 μm , striae 12-13 in 10 μm , and costae 2-4 in 10 μm .

Eunotia implicate

Valves exhibit a linear form with a straight ventral margin and a subtly arcuate dorsal margin, widest at the center and progressively diminishing towards the ends, which are frequently somewhat ventrally reflexed. They are 15-54 μm in length and 2-2.6 μm in width at its broadest point.

Gomphonema minutum

Each valve is identical and contains a raphe (the genus is biraphid). Valves feature asymmetry, having one pointed end and the other either bluntly rounded (club-shaped), lobed (violin-shaped), or pointy, but still slightly asymmetric. The specimen measures 12-19 μm in length, 8-11 μm in width, and 11-14 μm in striae.

Grammatophora sp.

Valvocopula with undulating septa, chloroplast lobes within the valve and septa, and apical pore fields with small spines. Transverse areolae fine, poroid, in a linear or quincunx pattern, with two rimoportulae.

Gyrosigma acuminatum

Valves feature a central slit known as a raphe, which allows the diatom to move. Gyrosigma's valves and

raphe have a sigmoid shape. The striations are both parallel and perpendicular to the raphe, measuring 55-85 μm long and 8.5-12.5 μm wide.

Haslea ostrearia

The strain produces blue 'marenin' pigment and contain small colorless flagellates measuring 37-43 μm in length and 6-7 μm wide.

Luticola mutica

Luticola valves have a larger central area and a distinct stigma. The striae are clearly punctate. The proximal raphe termini are a little deflected unilaterally. The distal raphe ends deviate toward the same side as the proximal raphe ends, with measurements ranging from 10.7 to 20.5 μm in length and 4.5 to 6.5 μm in breadth.

Luticola nivalis

Smaller specimens have linear-elliptic shells with pronounced triangular edges (\pm). Raphe branches have thread fencing and weakly one-sided bent central pores. The axial artery is moderately narrow, linear or slightly lanceolate in the middle, and the central artery forms a transverse band that extends almost to the edges, with a punctiform isolated stigma on the side away from the central pores. Valve dimensions are 12-14 μm in length, 5-13 μm in breadth, and 17-20 (24)/10 μm in stria density.

Melosira varians

It grows colonially, with uniformly structured valve walls, no costae or septae, and no visible spines under a light microscope. Cells are pill-shaped, cylindrical to spherical, and yellow-brown in color. Cells are 11-30 μm long and 17-70 μm wide. Cells form elongated chains through the interconnection of mucus pads.

Melosira undulata

Cells are cylindrical and form chains. Frustules range in diameter from 6 to 30 μm and have a mantle height of 5-15 μm . The valve surface exhibits slight convexity and is lined with tiny spines. The mantle

is covered with minute grains. The frustule possesses a loculate architecture. Rimoportulae are distributed throughout the valve face and mantle, with a single row located along the mantle edge.

***Meridion* sp.**

Frustules form fan-shaped colonies that are clavate in the girdle view. The valves are linear-clavate and asymmetrical about the transapical axis. Costae are present and extend transversely over the valves. In numerous specimens displayed here, the costae are only located near the headpole and absent near the footpole. A narrow sternum runs along the length of the valve. A single rimoportula is found near the headpole. The length ranged from 17 to 80 μm and the width was 3-4 μm .

Navicula lanceolata

Navicula is a yellow-brown algae with longitudinal symmetry and linear or oval-shaped valves. Some pennate diatoms have a raphe, which allows them to be mobile. Diatoms' silica cell wall is hard and porous, measuring 32-130 μm in length and 7-21 μm in width.

Navicula rhyncephala

The valves are lanceolate, with elongate-protracted, rounded apices. The axial region is constricted and linear prior to expanding into an irregularly rounded to circular center zone. The central area is formed by shortened striae that are wider apart than elsewhere on the valve. The raphe is positioned laterally and exhibits a small arch, featuring larger proximal ends. Striae are distinctly lineate, radiating from the center, becoming parallel, and subsequently converging at the end. The length range is 48-53 μm , the width is 9-10 μm , and the striae are 10 μm (8-9 at the center, 11-12 towards the apices).

Navicula straitula

The valves have a lanceolate morphology, characterized by obtusely rounded termini that vary from short and cuneate in smaller specimens to elongated and prolonged in larger specimens. The axial region

constricts before expanding into a varied rhombic to transversely elliptical central part. The raphe is positioned laterally, including proximal ends that are almost linear, expanded, and marginally deviated towards the primary side. Striae radiate prominently from the center of larger valves, becoming parallel at distinct Voigt discontinuities and ultimately converging near the apices. The striae are more broadly and unevenly distributed near the center of the valve. The areolae are quite coarse, numbering 20-22 within a 10 μm range. The length ranges from 32-60 μm , width from 8.1-10.4 μm , and striae are 10 μm .

Navicula tripunctata

The length range is 77.6-86.9 μm , the width range is 14.7-15.4 μm , and the striae are 10 μm (9-9.5 in the valve center, 11-12 at both ends).

Navicula radiosa

The valves are narrow, lanceolate, and have sharply rounded ends. The axial area is narrow and linear. The central area is rhombic. The raphe is straight, with proximal ends that hook into the secondary side. The transapical striae are strongly radiating, bent in the valve center, and converging near the poles. The lineolae number is 28-32 in 10 μm , the length is 52-105 μm , the width is 8.8-11.2 μm , and the striae are 9-11 μm .

***Neidium* sp.**

The valves range from elliptical lanceolate to elliptical, with apices that are acute to rounded. The size ranges from 18 to 52 μm in length and 10.5 to 17 μm in breadth.

Nitzschia minuta

Cells are usually long, straight, and narrow, but they can also be ovoid or slightly sigmoid. They generally exist alone, but may can establish stellate colonies or inhabit mucilage tubes. Cells generally possess two plastids, situated at opposite poles of the cell. The valve has parallel sides and cuneate poles that protrude into slightly capitate ends. It measures 22-23 μm long and 3 μm wide.

Pinnularia borealis

It consists of a linear valve with rounded and broad ends and parallel margins measuring 0.135 to 0.2 mm in length and 0.02 to 0.03 mm in width. Striae are almost parallel or slightly radiant, with a very distinct band that runs about one-third the length of the striae. The area is narrow, but the length can reach up to 300 μm .

Rhopalodia constricta

Frustules exhibit strong dorsiventral symmetry. The raphe is situated on the dorsal aspect of each valve within the shallow keel. The valve faces are almost flat, with each frustule resembling half of an orange. The central ends of the raphe are elongated.

Rhopalodia gibba

In girdle view, the valves are linear, with apices bent towards the ventral margin. The central valve is inflated, often leaving a visible "notch" on the dorsal margin. The raphe is situated in a canal along the dorsal border, terminating at the proximal raphe ends. Costae are prominent and distributed across the valve surface. Between each costa, there are two to three rows of single punctuate striae. Costae number 5-8 in 10 μm have a length range of 75-205 μm and a width range of 8-11 μm , with striae ranging from 12 to 16.

Stauroneis smithii

Naviculoid and mostly solitary cells with two chloroplasts, one on each side of the cell opposite the cingulum. The valves vary from nearly linear to lanceolate to elliptic-lanceolate. A prominent transverse fascia known as a "stauros" dominates the central area. The length ranges from 34.1 to 58.0 μm , with a valve width of 8.0-12.0 μm .

Surirella striatula

The wings are 75-250 μm long, 40-60 μm wide, and have 12-25 ribs per 100 μm .

Surirella splendida

Frustules are isolated, regular, broadly lanceolate to

narrowly oval, featuring a median raphe. The valve exhibits a widely rounded base and tapers towards the tip, showing coarse, short, parallel transverse costae and fine striations. The valve measures 43-45 μm long and 15 μm broad at the base.

Synedra minuscula

Individual cells possess an extended, filamentous morphology. In valve view, the cells have a linear configuration, with each extremity slightly swollen. Striations may be visible radiating outward from the center. Valve dimensions are 75-100 μm long, 9-15 μm wide, with 9-10 μm striae and narrow linear valves.

Tabellaria flocculosa

The colonies are cuboids in shape, with frustules (siliceous cell walls) attached at the corners to form a zigzag shape. Dimensions: 39-83 μm in length, 2-6 μm in width, and 14-19 μm in striae.

Tabellaria fenestrata

The valves are linear, with medial inflation that is the same width or slightly wider than the distinctly capitate apices. The striae are parallel and alternating. The axial area is narrow and linear. Striae reach the central valve, and the girdle bands are open with regular septa. There are four girdle bands per frustule. Each valve contains one rimoportula, which is usually located in or near the medial inflation. Rudimentary septa are absent, as are marginal spines. The cells are joined in colonies to form a long straight chain. The frustules are rectangular in girdle view, with lengths ranging from 39.0-83.0 μm and widths ranging from 2.1-6.9 μm .

Cyanophyceae***Aphanizomenon gracile***

It tends to form trichome fascicles composed primarily of vegetative cells. The vegetative cells of *Aphanizomenon* are cylindrical and elongated. Each cell is made of hyaline. 5-7 μm long, 4 μm wide.

Aulosira laxa

Uniseriate trichomes are enclosed in firm individual sheaths and can occur singly or in clusters, but never in mats. Occasional heterocysts appear at regular intervals along the trichome and are marginally larger than vegetative cells.

Chroococcus giganteus

Colonies typically consist of two or four cells, with division stadia in between. Round single cells with a width of 40-52 μm are rare.

Microcoleus sp.

Unbranched, untapered trichomes with no heterocysts are structured in parallel array bounded by a shared broad sheath. Individual trichomes move back and forth over one another. Trichomes are found in sheaths and colonies, with a width of 5-10 μm .

Oscillatoria limosa

Filaments are motile and form thin mats that cover sediment and other submerged surfaces. The bright blue and blue-green mats resemble spilt paint, with 9 μm wide filaments and 2.5 μm long cells.

Oscillatoria borneli

The filamentous blue-green algae's cell width ranges from 57.60 μm to 69.05 μm .

Phormidium uncinatum

Each of the cells are squarish and connect end to end (*Oscillatoria* cells are thinner). The ends of their filaments are rounded. Width-spans of 3-4.5 and 3-4.8 μm are nearly identical.

Phormidium retzii

The thallus is bright blue green, the filaments are straight, the sheath is diffuent, the trichome is bright to dark blue green, and the cells are 2.8-3.8 μm long, isodiametric, slightly longer than wide, and have an attenuated apical cell that is obtuse-rounded

or truncate. The trichome is predominantly uncontracted, with slight constriction at the ungranulated crosswalls, and is not tapered at the ends. Their cells do not constitute calyptras.

Chlorophyceae***Netrium naegelii***

Cells are solitary, medium-sized to large (35-430 μm long), elongated-cylindrical, elliptic, or fusiform (length 2-9 times width), and straight with rounded or truncated ends.

Oedogonium sp.

The filaments are non-branched, often connected, and devoid of bristles. Cells are cylindrical, often a little wider at the anterior end, and possess one or more annular caps just beneath the cross wall, each encompassing a parietal, reticulate chloroplast and many pyrenoids. The cell dimensions vary from 20 to 73 μm , with a stalk length of 13 to 23 μm .

Spirogyra alternata

Multicellular filaments are formed when unicellular green algae connect end to end. Their bodies are distinguished by multicellular filaments that are found beneath a mucilaginous sheath. The width ranges from 10 to 100 μm , while the length can reach several centimeters.

Ulothrix cylindrica

A non-branching thread-like green alga present in both freshwater and saltwater environments. Its cells are often equidimensional and it flourishes in the frigid temperatures of spring and winter. They attach to surfaces by an improved holdfast cell. It measures 6-12 μm in length and 8-12 μm in breadth.

Zygnematophyceae***Closterium venus***

The cells are crescent-shaped or elongated, and they lack spines. Some are exceedingly linear and needle-like, while others are significantly broader with curved endpoints. The peripheral edges of the

cell are often tapered and can be either pointed or rounded. Each semi-cell possesses a solitary axial, ridged chloroplast that contains a minimum of one pyrenoid. Lengths range from 25 to 400 μm , and widths from 2.5 to 8 μm .

Mesotaenium endlicherianum

Cells are either solitary or aggregated within a gelatinous matrix with a simple or layered structure. Cells are small to medium in size (10-123 μm long), straight or slightly curved, long or short cylindrical, and have broadly rounded ends. Each cell, axial plate, or band (rarely parietal) contains one or two chloroplasts, with each chloroplast storing one or two pyrenoids. The nucleus is located at the center of the chloroplast band or between two chloroplasts.

***Mougeotia* sp.**

They are unbranched, filamentous charophytes with long cylindrical cells. A single ribbon-like green chloroplast, including a series of circular pyrenoids, runs the middle of the cell; it is often twisted, allowing visibility from many different angles. Purple cell sap may be present in certain habitats. *Mougeotia* cells measure 60-185 μm in length and 19-30 μm in diameter. They contain 4-9 pyrenoids and a multitude of granules on the central membrane of cysts.

Pleurotaenium ehrenbergii

Long, cylindrical, bilaterally and symmetrical unicells with blunt ends. When the two semi cells meet, a ring-like thickening appears in the center. Cell body medium measures 220-739 μm long and 15-45 μm wide.

Chromadorea/Nematoda

Ancylostoma duodenale

The flexure at the frontal end gives the worm an S-shaped appearance. The worm is pinkish white. Adult male hookworms range in length from 8 to 11 mm, while adult females range from 10 to 13 mm.

Enterobius vermicularis

Adults appear as elongated whitish tubes with pointed tails. They have three lips around the anterior mouth and a large esophageal bulb. Adult male *Enterobius* can measure up to 2.5 mm long and 0.1-0.2 mm wide.

Charophyceae

Chara nucule

The nucule is oval, with a short stalk. It, like the globule, develops at the node of primary laterals just above the globule in homothallic species. It consists of one central cell, one stalk, and one large egg on top. Oogonium (nucule) can measure up to 0.5 mm in length and 0.35 mm in width.

Dinophyceae

Ceratium hirundinella

They possess a pellicle, structure composed of cell membrane and vesicles; these vesicles are cross-linked cellulose that constitute the plates. The pellicle comprises two structures: The epicone and the hypocone, situated above and below the transverse groove, or cingulum. Two rows of plates encircle the epicone and hypocone in a distinctive design that can be transmitted to offspring. *C. hirundinella* is 33-40 μm wide and 65-80 μm long, but can reach over 400 μm .

Eugleninae

***Euglena* sp.**

The cell is elongated and measures 15-500 μm . Its color is mostly green due to chlorophyll pigment. Certain species of *Euglena* carry carotenoid pigments, imparting a characteristic red colour. *Euglena* is a unicellular organism possessing a singular nucleus.

Monogononta/ Rotifera

Cephalodella gibba

The body is elongated, relatively slender, prismatic,

and slightly compressed laterally. The body length is 80 μm , and the width is 53-57 μm .

Raphidophyceae/ Ochrophyta

Gonyostomum sp.

It contains numerous mucocysts, which discharge when collected in a plankton net, making the net and its contents gummy. Size ranges from 36 to 92 μm .

The ecology of water bodies, and the physical and chemical parameters of water, have a significant impact on algae distribution along streams (Das and Semy 2023). Temperature, dissolved oxygen, and salinity have a strong influence on algae diversity and abundance, as do nutrients (Natij *et al.* 2014). According to Farid *et al.* (2012), algae development is not consistent year-round, but rather peaks when light and temperature conditions are favorable. Light is crucial for the synthesis of several organic compounds, including chlorophyll, carotenoid, and xanthophyll in algae. As observed in the study, the habitat light Intensity ranges from 1075-1673 LUX. The result is presented in Table 2. Temperature is an important growth-determining factor for organisms including algae. Water temperature of the streams ranges from 18.24-18.28°C as such the stream algae can be classified as thermophiles which according to Varshney *et al.* (2018) are algae growing at temperatures >50 °C. Acidic or non-acidic habitats that occur naturally support a varied array of microorganisms, including algae, which can endure and, in certain instances, flourish at pH levels that would be detrimental to most microorganisms (Souza-Egipsy *et al.* 2011). pH was found in between 6.14-7.05, indicating a moderate acidic to basic condition of the habitat. High TDS, conductivity, alkalinity can also permit a high volume of algae bloom which effects the cycle of photosynthesis (Semy and Singh 2021). The algae were pre-dominant in conditions where TDS was 156.66-163.33 mg/l, conductivity was 108.43-273.00 $\mu\text{S/cm}$, and total Alkalinity was 88.00-95.33 mg/l. The principal source of oxygen in a pond is derived by microscopic algae (phytoplankton) or submerged vegetation. In sunlight, these organisms generate oxygen via photosynthesis and discharge it into the pond water. DO range between 7.11-7.65 mg/l, indicating a

Table 2. Ecological preferences of the algae during winter season in stream.

Parameter	Ranges
Light intensity (LUX)	1075-1673
Temperature (°C)	18.24-18.28
pH	6.14-7.05
TDS (mg/L)	156.66-163.33
DO (mg/L)	7.11-7.65
Total hardness (mg/L)	88.00-95.33
Calcium hardness (mg/L)	25.11-27.79
Magnesium hardness (mg/L)	8.77-9.0
Conductivity ($\mu\text{S/cm}$)	108.43-273.00
Chloride (mg/L)	30.76-45.44
Total alkalinity (mg/L)	88.00-95.33

sufficient supply of oxygen for algal development in the streams. The sampled water has a total hardness of 88.00-95.33 mg/l, Calcium hardness of 25.11-27.79 mg/l, Magnesium hardness of 8.77-9.0 mg/l and Chloride of 30.76-45.44 mg/l. Water hardness induced by calcium and magnesium affects the growth of algae (Charles *et al.* 2002) which may alter the diversity, richness and evenness of aquatic algae.

CONCLUSION

The quantitative phycological study in the stream of Lumami village, Zunheboto district, Nagaland, has prominently depicted the algal composition and its richness in the region. The class bacillariophyceae contributed the highest diversity with 37 species from the overall observation. The physico-chemical properties of water in the algal habitat significantly influence algal growth and are essential for their survival. Apart from cultivation and forest fire, which are the main threat to the biodiversity, this region is not much inhabited by human settlement hence has negligible anthropogenic influences. While looking at the negative impact, this area is seen to be disturbed by fishing or other recreational activities. The unique biodiversity of the stream makes this study an utmost importance to understand algal composition and sustain its ecological structure for preserving a spatial habitat. Hence, the significance of algae in science and its contribution to the biodiversity status, the documented database 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. The result from the study indicates that algal constitution in this area is rich and is applicable for further research and studies at different seasons of the year.

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