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Original Article

# Diversity of Phytoplankton of a sub-tropical reservoir of Mizoram, northeast India

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**Abstract:** Phytoplankton of Khawiva reservoir of Mizoram, northeast India (NEI) revealed a total of 55 species; nearly concurrent mean monthly richness and high community similarities (*vide* Sørensen index) during two years affirmed homogeneity in its species composition. Phytoplankton comprised dominant component (61.1±14.3%) of net plankton and recorded wider density variations. Chlorophyta influenced phytoplankton abundance with quantitative importance of *Staurastrum* spp. > *Xanthidium* spp. > *Cosmarium* spp. in particular. Bacillariophyta formed subdominant group; Cryptophyta and Cyanophyta showed limited importance; and Euglenophyta and Dinophyta recorded poor densities. Phytoplankton is characterized by moderate species diversity, high evenness and low dominance but with wide variations. Richness, abundance and species diversity followed no definite patterns of monthly variations during two years. Insignificant influence of individual abiotic factors on phytoplankton assemblages coupled with low cumulative influence of fifteen abiotic parameters (*vide* CCA) yielded little insight on overall role of abiotic parameters.

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## Introduction

Limnological studies in India began nearly one century ago and culminated in several investigations on reservoir ecology from different regions (Jana, 1998) and dealing with phytoplankton diversity. There is yet paucity of information on phytoplankton of sub-tropical environs of this country in general and from northeast India (NEI) in particular (Sharma, 2015). The related studies from NEI are limited to analysis of these primary producers and fish-food organisms of certain reservoirs of Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003), while other notable contributions related to certain floodplain lakes of this region (Sharma, 2004, 2010, 2012, 2015). The present study forms a part of first limnological endeavor undertaken by the authors from Mizoram state of NEI; the results on zooplankton diversity are published earlier by Sharma and Pachuau (2013). Nevertheless, this communication on phytoplankton diversity of Khawiva reservoir merits ecological value in view of the stated lacunae. The observations are made on monthly variations of phytoplankton assemblages of the sampled reservoir for a period of two years with emphasis on composition, richness, community similarities, abundance, species diversity, dominance and evenness. In addition, individual and cumulative influence of abiotic factors is analyzed to assess their limnological value vis-à-vis phytoplankton diversity.

## Materials and Methods

Our observations are based on limnology study (November, 2005-October, 2007) of Khawiva reservoir (22º35'N, 93º 47'E; area: about 10 ha; maximum depth: 40 m), Lunglei district, Mizoram state (Fig. 1A-C), NEI; located nearly 12 km from Lunglei town, it was commissioned in 1988 on Khawiva River with a capacity of generating 1050 kw power. This reservoir is surrounded by *Phyllanthus* sp., *Cyperus* sp., *Eupatorium* sp.,

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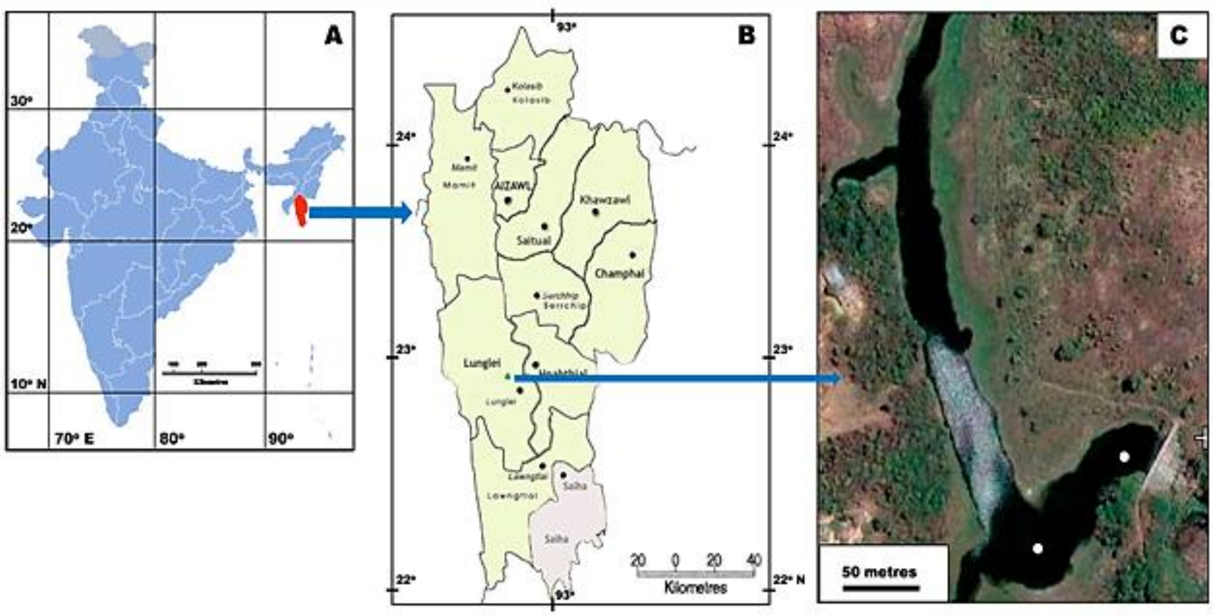


Figure 1. (A) Map of India showing Mizoram state (red color), (B) district map of Mizoram showing Lunglei district with location of Khawiva reservoir and (C) Khawiva reservoir (Google photo) with sampling station marked by dots.

*Farmaria* sp., and *Centella* sp., and itself lacked any aquatic vegetation.

Water as well as qualitative and quantitative plankton samples was collected at monthly intervals at two sampling stations for a period of two years as per details of Sharma and Pachuau (2013). Water temperature, pH and specific conductivity were recorded using the field probes; rainfall data was collected from Lunglei meteorological station; Winkler's method was used for estimation of dissolved oxygen and APHA (1992) was followed to analyze the rest of the abiotic factors. The phytoplankton was identified following the works of Islam and Haroon (1980), Adoni et al. (1985) and Fritter and Manuel (1986). Quantitative enumeration of phytoplankton and its constituent taxa was done with a Sedgewick-Rafter counting cell and abundance was expressed as n/L. Phytoplankton community similarities, species diversity, dominance and evenness were calculated *vide* Sørensen, Shannon, Berger-Parker and Pileou indices, respectively (Ludwig and Reynolds, 1988; Magurran, 1988). ANOVA (two-way) was used to ascertain significance of temporal variations of different parameters; and SPSS (version 20.0) was used for the hierarchical cluster analysis. Pearson's correlation coefficients (r) were used to analyze ecological correlations amongst abiotic-vis-biotic attributes; *P*-values were calculated and significance was ascertained following Bonferroni corrections. XLSTAT (2012) was used for the canonical correspondence analysis to assess cumulative influence of fifteen abiotic factors namely rainfall, water temperature, specific conductivity, pH, dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, chloride, sulphate, phosphate, nitrate, silicate, dissolved organic matter and total dissolved solids on phytoplankton assemblages.

## Results

The variations in abiotic parameters (annual ranges and mean ±SD) of Khawiva reservoir observed during two years as well as during the study period are indicated in Table 1. Water temperature ranged between 22.1±4.0°C and total monthly rainfall ranged between 270.5±302.6 mm during the study period; specific conductivity, pH, dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, chloride and sulphate varied between 40.5±11.0 µS $cm^{-1}$, 6.64±0.31 mg $L^{-1}$, 7.7±1.6 mg $L^{-1}$, 11.5±3.0 mg $L^{-1}$, 31.6±4.7 mg $L^{-1}$, 30.0±8.0 mg $L^{-1}$, 7.9±3.5 mg $L^{-1}$ and 1.890±1.478 mg $L^{-1}$, while phosphate, nitrate, silicate and dissolved organic matter varied

Table 1. Temporal variations of abiotic parameters (Modified after Sharma and Pachuau, 2013).

| Parameters | First year | Second year | Study Period |
|---|---|---|---|
| | Range, Mean±SD | Range, Mean±SD | Range, Mean±SD |
| Rainfall (mm) | 0-890.0, 268.7±283.4 | 0-901.8, 272.4±320.7 | 0-901.8, 270.5±302.6 |
| Water temperature (°C) | 14.5-28.0, 22.4±4.0 | 14.0-27.0, 21.7±3.9 | 14.0-28.0, 22.1±4.0 |
| Specific conductivity (µS $cm^{-1}$) | 20.0-62.0, 42.8±13.5 | 28.0-50.0, 38.3±7.2 | 20.0-62.0, 40.5±11.0 |
| pH | 6.34-7.18, 6.81±0.24 | 5.86-6.83, 6.48±0.29 | 5.86-7.18, 6.64±0.31 |
| Dissolved oxygen (mg $L^{-1}$) | 5.6-10.4, 8.1±1.5 | 4.8-9.6, 7.2±1.6 | 4.8-10.4, 7.7±1.6 |
| Free carbon dioxide (mg $L^{-1}$) | 8.0-16.0, 12.8±2.6 | 6.0-14.0, 10.2±2.8 | 6.0-16.0, 11.5±3.0 |
| Total alkalinity (mg $L^{-1}$) | 24.0-40.0, 32.3±5.5 | 26.0-34.0, 30.8±3.6 | 24.0-40.0, 31.6±4.7 |
| Total hardness (mg $L^{-1}$) | 18.0-46.0, 30.3±9.5 | 22.0-38.0, 29.7±6.2 | 18.0-38.0, 30.0±8.0 |
| Chloride (mg $L^{-1}$) | 1.0-12.0, 9.2±3.6 | 4.0-11.0, 6.6±2.8 | 1.0-11.0, 7.9±3.5 |
| Sulphate (mg $L^{-1}$) | 0.714-2.584, 1.055±0.640 | 0.285-4.638, 2.725±1.601 | 0.285-4.638, 1.890±1.478 |
| Phosphate (mg $L^{-1}$) | 0.017-0.445, 0.079±0.115 | 0.017-0.221, 0.100±0.061 | 0.017-0.445, 0.089±0.093 |
| Nitrate (mg $L^{-1}$) | 0.074-0.392, 0.199±0.105 | 0.074-0.238, 0.171±0.065 | 0.074-0.392, 0.185±0.088 |
| Silicate (mg $L^{-1}$) | 0.037-1.384, 0.482±0.456 | 0.037-0.664, 0.353±0.221 | 0.037-1.384, 0.417±0.364 |
| Dissolved organic matter (mg $L^{-1}$) | 0.016-2.236, 0.413±0.797 | 0.025-0.452, 0.192±0.138 | 0.016-2.236, 0.302±0.582 |
| Total dissolved solids (mg $L^{-1}$) | 0.018-0.296, 0.191±0.221 | 0.075-0.347, 0.183±0.081 | 0.018-0.347, 0.187±0.166 |

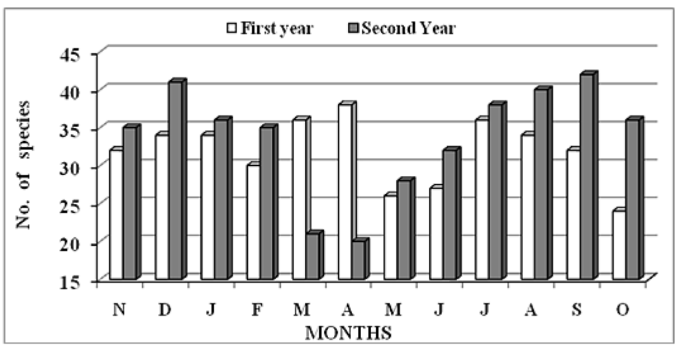


Figure 2. Monthly variations in species richness of phytoplankton.

between 0.089±0.093 mg $L^{-1}$, 0.185±0.088 mg $L^{-1}$, 0.417± 0.364 mg $L^{-1}$, and 0.302±0.582 mg $L^{-1}$ during the study period, respectively. ANOVA registered significant annual variations of pH ($F_{1, 23}$=7.553, $P$=0.019) and sulphate ($F_{1, 23}$=9.465, $P$=0.011), while specific conductivity ($F_{11, 23}$=3.589, $P$=0.022) and hardness ($F_{11, 23}$=3.238, $P$=0.032) recorded significant monthly variations.

The richness and density variations (ranges and mean ±SD) of phytoplankton are presented in Table 2. We observed 55 species of phytoplankton; the monthly richness (Fig. 2) ranged between 24-38 and 20-41 species, and community similarities varied between 51.7-84.4% and 50.0-95.8%. Chlorophyta, the diverse group, is represented by 22±4 and 23±6 species during two years, respectively. The hierarchical cluster analyses, based on Sørensen's community similarities, are presented in Figures 3-4. The phytoplankton density varied between 132-1199 (369±253 n/L) and it comprised 61.1±14.3% of net plankton; Chlorophyta exhibited wide density variations (57-1087, 239±238 n/L) and it formed between 59.5±21.9% of total phytoplankton during the study period; Bacillariophyta (71±62 n/L), Cyanophyta (24±52 n/L) and Cryptophyta (26±44 n/L) comprised 21.2±15.2%, 8.1±17.7% and 6.1±6.9% of phytoplankton abundance, respectively in this study while Euglenophyta (9±19 n/L) and Dinophyta ((1±1 n/L) depicted poor abundance. The species diversity (1.693-3.399, 2.607±0.451), dominance (0.080-0.649, 0.265±0.151) and evenness (0.472-0.921, 0.760±0.119) recorded wide variations. The monthly variations of abundance of phytoplankton, Chlorophyta and Bacillariophyta, and that of species diversity are presented in Figures 5-8, respectively. This study indicated quantitative importance of *Staurastrum* spp. (100±142 n/L), *Xanthidium* spp. (73±83 n/L) and *Cosmarium* spp. (32±30 n/L); *Staurastrum inflexum* (36±42 n/L), *S. nonanum* (23±57 n/L), *S. kurzianum* (13±16 n/L), *S. chaetoceras* (11±20 n/L), *Oscillatoria* sp. (23±52 n/L), *Frustulia* sp. (22±17 n/L) and *Navicula* sp. (19±23 n/L) are important individual taxa.

Our results lacked significant influence of any individual abiotic parameter on richness and abundance of phytoplankton as well as on abundance of the Chlorophyta, Bacillariophyta and Cyanophyta

Table 2. Variations (range, average and SD) of phytoplankton.

| | Nov. 2005-Oct. 2006 | | Nov. 2006-Oct. 2007 | | Study Period | |
|---|---|---|---|---|---|---|
| **Richness** | Phytoplankton > Zooplankton | | | | | |
| Phytoplankton | 55 species: 24-38 | 32±4 | 55 species: 20-41 | 34±7 | 55 species: 20-41 | 33±6 |
| % similarity | 51.7-84.4 | | 50.0-95.8 | | | |
| Chlorophyta | 40 species: 15-27 | 22±4 | 40 species: 11-30 | 23±6 | 40 species: 22-30 | 22±5 |
| **Abundance** | Phytoplankton > Zooplankton | | | | | |
| Net Plankton n/L | 254-1344 | 589±296 | 276-1077 | 550±234 | 254-1344 | 570±267 |
| Phytoplankton n/L | 132-1199 | 430±288 | 138-836 | 308±265 | 132-1199 | 369±253 |
| % composition | 41.3-89.2 | 68.8±12.7 | 39.1-77.6 | 53.4±11.3 | 39.1-89.3 | 61.1±14.3 |
| Species diversity | 1.922-3.086 | 2.534±0.314 | 1.693-3.399 | 2.680±0.546 | 1.693-3.399 | 2.607±0.451 |
| Dominance | 0.144-0.590 | 0.285±0.127 | 0.080-0.649 | 0.245±0.127 | 0.080-0.649 | 0.265±0.151 |
| Evenness | 0.545-0.919 | 0.756±0.107 | 0.472-0.921 | 0.764±0.130 | 0.472-0.921 | 0.760±0.119 |
| **Different groups** | Chlorophyta > Bacillariophyta > Cyanophyta > Cryptophyta > Euglenophyta > Dinophyta | | | | | |
| Chlorophyta n/L | 83-1087 | 306±265 | 57-739 | 171±184 | 57-1087 | 239±238 |
| % composition | 37.7-93.3 | 67.5±19.7 | 17.3-88.3 | 51.5±21.1 | 17.3-93.3 | 59.5±21.9 |
| Bacillariophyta n/L | 6-313 | 83±83 | 27-101 | 58±24 | 6-313 | 71±62 |
| % composition | 2.1-59.8 | 20.1±19.4 | 8.8-38.5 | 22.4±9.1 | 2.1-59.8 | 21.2±15.2 |
| Cyanophyta n/L | 0-54 | 6±15 | 2-192 | 42±68 | 0-192 | 24±52 |
| % composition | 0-23.8 | 2.5±6.4 | 0-73.5 | 13.7±22.9 | 0-73.5 | 8.1±17.7 |
| Cryptophyta n/L | 1-192 | 31±51 | 1-130 | 21±34 | 1-192 | 26±44 |
| % composition | 0.7-25.8 | 6.2±6.9 | 0.7-23.5 | 6.1±6.9 | 0.7-25.8 | 6.1±6.9 |
| Euglenophyta n/L | 0-21 | 2±6 | 3-96 | 16±25 | 0-96 | 9±19 |
| % composition | 0-9.2 | 1.0±2.5 | 0.3-33.9 | 7.0±9.0 | 0-33.9 | 4.0±7.8 |
| Dinophyta n/L | 0-6 | 1±2 | 0-2 | 0±1 | 0 - 6 | 1±1 |
| % composition | 0-2.6 | 0.5±0.9 | 0-0.9 | 0.2±0.3 | 0-2.6 | 0.4±0.7 |
| **Important genera** (n/L) | | | | | | |
| *Staurastrum* spp. | 11-663 | 108±175 | 27-367 | 92±97 | 11-663 | 100±142 |
| *Xanthidium* spp. | 1-290 | 12±88 | 0-215 | 35±56 | 0-290 | 73±83 |
| *Cosmarium* spp. | 14-106 | 43±31 | 3-88 | 20±25 | 3-106 | 32±30 |
| **Important species** (n/L) | | | | | | |
| *Staurastrum inflexum* | 2-186 | 45±49 | 1-100 | 26±32 | 1-192 | 36±42 |
| *S. nonanum* | 0-257 | 27±71 | 3-96 | 16±25 | 0-257 | 23±57 |
| *S. kurzianum* | 0-65 | 10±18 | 2-45 | 16 ±13 | 0-65 | 13±16 |
| *S. chaetoceras* | 0-7 | 2±2 | 2-80 | 20±24 | 0-80 | 11±20 |
| *Oscillatoria* sp. | 0-44 | 5±12 | 0-192 | 41±68 | 0-192 | 23±52 |
| *Frustulia* sp. | 1-76 | 21±21 | 9-47 | 23±11 | 1-76 | 22±17 |
| *Navicula* sp. | 1-100 | 23±30 | 4-30 | 15±8 | 1-100 | 19±23 |

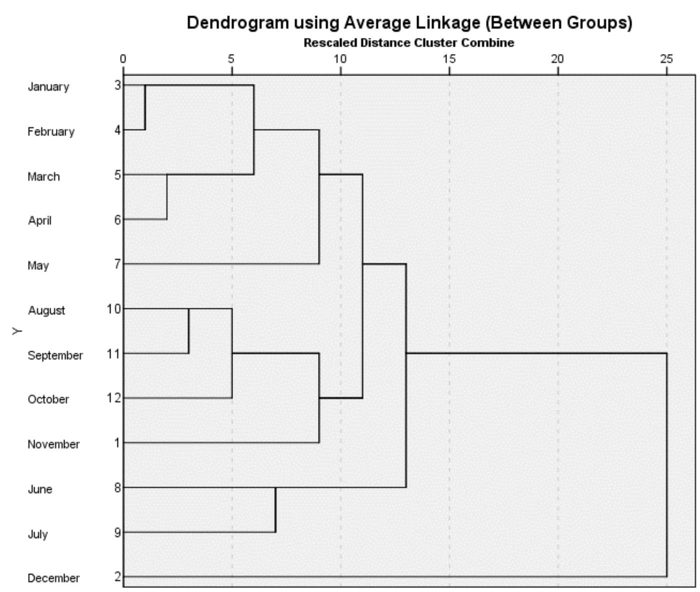


Figure 3. Hierarchical cluster analysis of phytoplankton (First year).

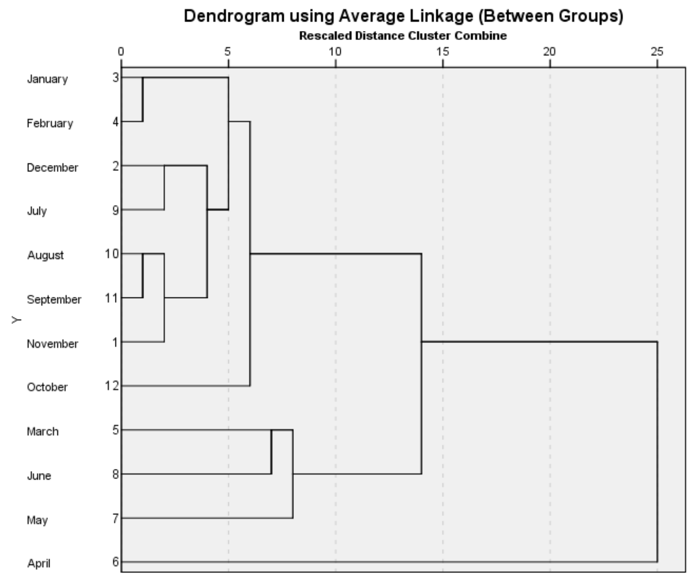


Figure 4. Hierarchical cluster analysis of phytoplankton (Second year).

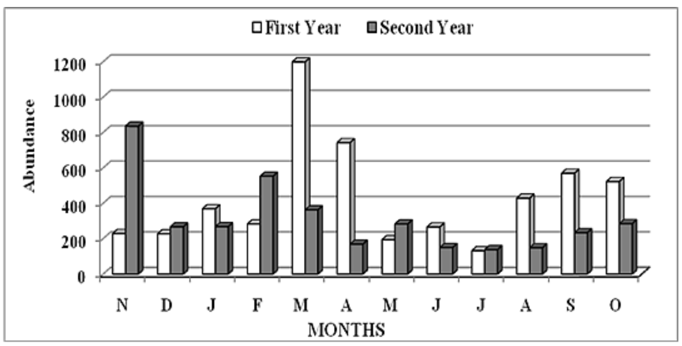


Figure 5. Monthly variations in abundance (n/L) of phytoplankton.

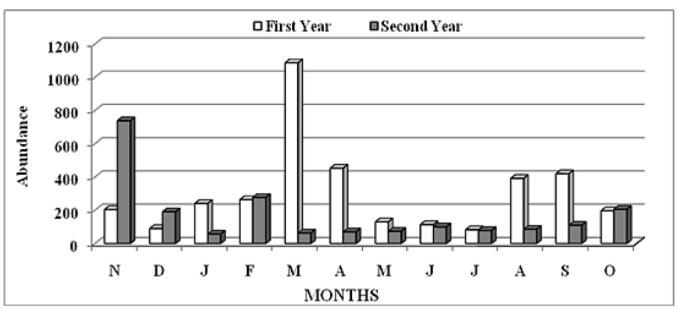


Figure 6. Monthly variations in abundance (n/L) of Chlorophyta.

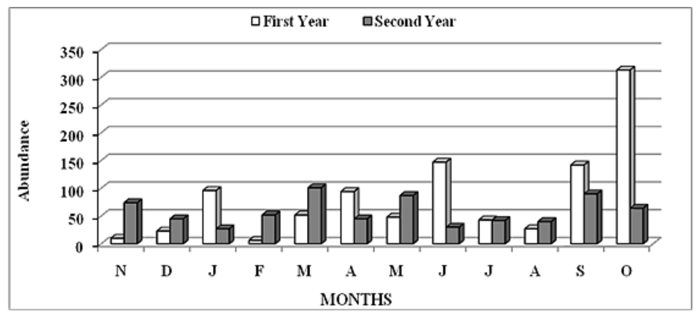


Figure 7. Monthly variations in abundance (n/L) of Bacillariophyta.

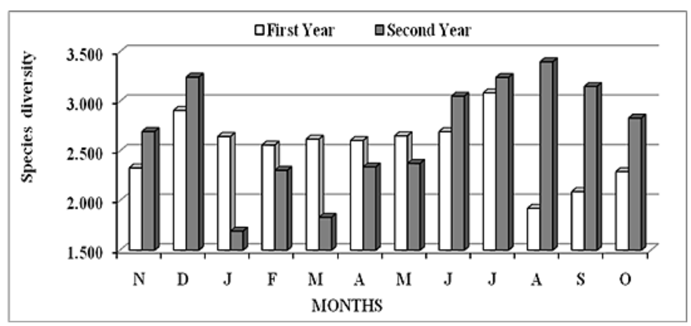


Figure 8. Monthly variations in species diversity of phytoplankton.

during the study period. The canonical correspondence analysis (CCA) with fifteen abiotic factors explained 57.6% of cumulative variance of phytoplankton assemblages along axis 1 and 2 (Fig. 9).

## Discussion

The sub-tropical Khawiva reservoir is characterized by 'soft, slightly acidic-circum neutral and well-oxygenated waters with distinctly low specific conductivity, low free $CO_2$ throughout the study period, low chloride content, and low concentration of nutrients and other abiotic factors (Sharma and Pachuau, 2013). Of these, pH and sulphate recorded significant annual variations (*vide* ANOVA) while specific conductivity and hardness recorded significant monthly variations thus indicating limited temporal variations during this study.

Fifty-five species of phytoplankton, belonging to six groups, observed from Khawiva reservoir

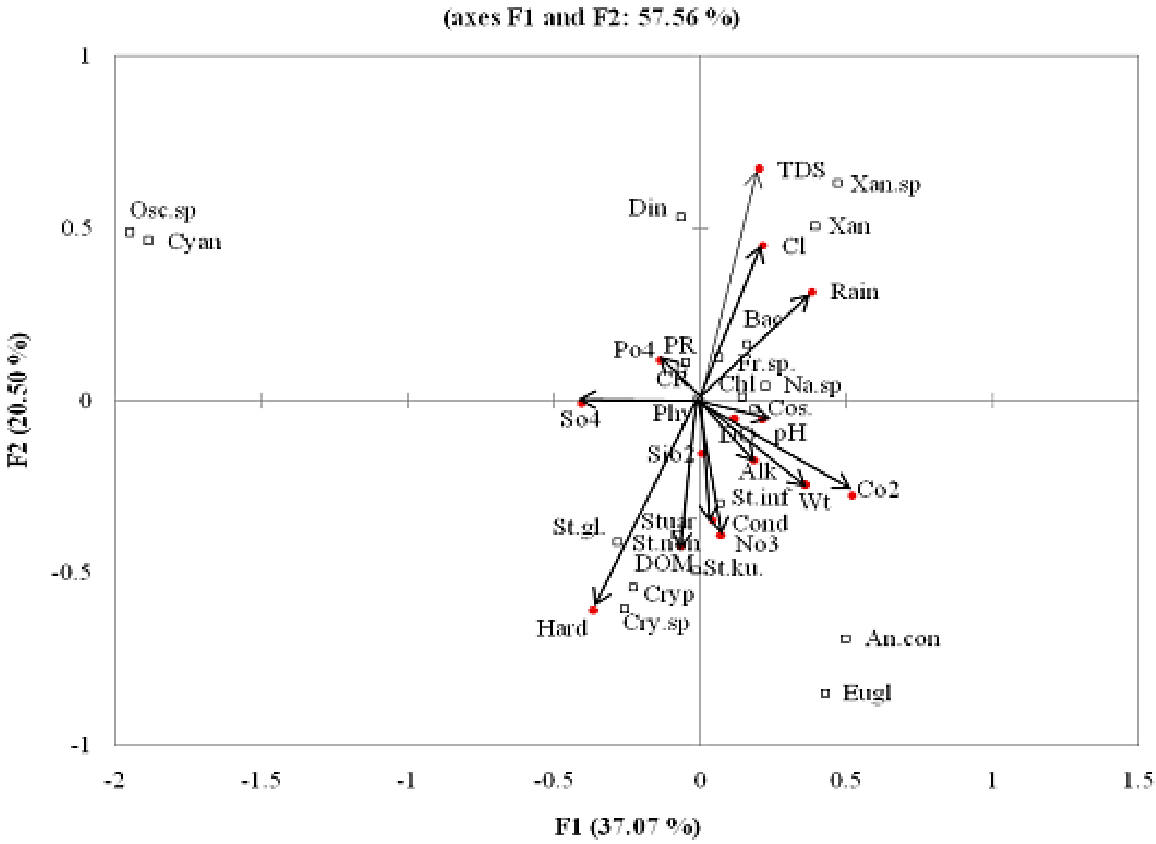


Figure 9. CCA ordination biplot of phytoplankton and abiotic factors of Khawiva reservoir. **Abbreviations**: **Abiotic:** Alk (alkalinity), Co2 (free carbon dioxide), Cl (Chloride), Cond (conductivity), DO (dissolved oxygen), DOM (dissolved oxygen matter), pH (hydrogen-ion concentration), No3 (nitrate), $PO_4$ (phosphate), Rain (rainfall), Sio2 (silicate), So4 (sulphate), TDS (Total dissolved solids), Trans (transparency) and Wt (water temperature). **Biotic:** An.con (*Anthrodesmus convergens*), CR (Chlorophyta richness), PR (Phytoplankton richness), Bac (Bacillariophyta), Chl (Chlorophyta), Cryp (Cryptophyta), Cry.sp (*Cryptomonas* sp.), (Cyan (Cyanophyta), Eugl (Euglenophyta), Phy (phytoplankton), Stuar (*Staurastrum*), St.gl (*S. gladiosum* ), St.inf (*S. inflexum* ), St.ku. (*S. kurzianum*), St.non (*S. nonanum*), Cos. (*Cosmarium*), Na.sp (*Navicula* sp), Fr.sp. (*Frustulia* sp), Xan (*Xanthidium*), *Xan* sp (*Xanthidium* sp), Osc.sp (*Oscillatoria* sp).

exhibited fairly diverse nature of these primary producers compared with the richness known from sub-tropical reservoirs of Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003) and with the reports from Kashmir (Zutshi et al., 1980), Bihar (Baruah et al., 1993; Sanjer and Sharma, 1995) and Assam (Sharma, 2004). On the other hand, it broadly compared with the results from two floodplain lakes of NEI (Sharma, 2012, 2015). The richness indicated no definite pattern of annual variations but exhibited peaks during April (first year) and September (second year) while lowest richness is observed during October (first year) and April (second year). The occurrence of all phytoplankton species during both years asserted homogeneity in their overall composition; this generalization is also supported by high community similarities during two years with values between 60-80% in majority of instances (88.0%) in the matrix during first year while 58% instances affirmed the stated range in the following year. Peak phytoplankton similarity is observed concurrently between January-February communities in both years. The hierarchical cluster analysis showed differences in clusters groupings during two years with high associations during January-February and most divergence in December during first year. High affinities are observed between January-February, August-September and December-July phytoplankton while divergence is noted in April in the following year.

The most diverse Chlorophyta largely contributed to phytoplankton richness and thus mainly influenced phytoplankton similarities; these features agreed with the reports from NEI (Sharma, 1995, 2009, 2010, 2012, 2015; Sharma and Lyngdoh, 2003). The slightly acidic-circum neutral soft waters with low ionic concentrations exhibited high desmid richness (Payne, 1986) while Karikal (1995) observed that soft waters with low nutrients favored the growth of desmids. These remarks hold true for de-mineralized soft waters of Khawiva reservoir with *Staurastrum* (11 species) > *Cosmarium* (10 species) > *Micrasterias* (4 species). The importance of desmid richness concurred with those from reservoirs of Meghalaya indicating identical characteristics (Sharma, 1995; Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003) and also with the reports of Sharma (2009, 2010, 2012, 2015) from NEI.

Phytoplankton recorded wider density variations with more difference during first year; it registered insignificant monthly and annual differences (vide ANOVA). It formed main component of net plankton and significantly influenced their density (r = 0.946) during the study with >50.0% of abundance of the former throughout first year except in December while their contribution is >50.0% in the months of November, February and August through October during second year. In general, quantitative importance of phytoplankton in Khawiva reservoir concurred with the results (Sharma, 1995; Das et al., 1996, Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003) from certain reservoirs of Meghalaya state of NEI and also with the reports from the floodplains of Kashmir (Kaul and Pandit, 1982), Bihar (Rai and Dutta-Munshi, 1982; Sinha et al., 1994; Sanjer and Sharma, 1995), Assam (Yadava et al., 1987) and Kerala (Krishnan et al., 1999). On the contrary, our results differed from phytoplankton sub-dominance reported by (Sharma, 2004, 2009, 2010). The present study showed no definite annual pattern of abundance while peak density is noticed in May (summer) and November (autumn) during two years, respectively; the former concurred with the report of Sharma (2015) but differed from winter peaks reported by Yadava et al. (1987), Wanganeo and Wanganeo (1991), Sharma and Lyngdoh (2003) and Sharma (2009).

The Chlorophyta, dominant component, significantly influenced phytoplankton abundance (r=0.935) and contributed to its peaks during two years. The green algae registered insignificant monthly and annual density differences during the study; they exhibited annual peaks during March and November during two years, respectively. The average densities of this group are high than the reports from sub-tropical environs of Meghalaya (Sharma, 1995; Das et al., 1996; Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003) as well as than the results of Yadava et al. (1987) and Sharma (2004, 2009). The Chlorophyta is characterized by high abundance of *Staurastrum* spp. >*Xanthidium* spp. >*Cosmarium* spp.; the first two genera in particular largely influenced density variations of the former and contributed to Chlorophyta peak abundance. In general, quantitative significance of desmids agreed with the reports of Sharma (1995, 2009, 2010) and Sharma and Lyngdoh (2003). Rao and Govind (1964) recorded desmid maxima in summer and winter while Doddagauder (1989), Karikal (1995) and Hulyal and Kaliwal (2009) reported their winter peaks. Our results did not affirm any such generalizations but indicated peak in autumn (November) during the second year. *Staurastrum* spp. and *Cosmarium* spp. registered concurrent peaks in March but *Xanthidium* spp. showed peak density in September during first year. *Staurastrum inflexum* > *S. nonanum* > *S. kurzianum* > *S. chaetoceras* are notable desmid species.

The Bacillariophyta comprised 21.2±15.2% of phytoplankton abundance and recorded relatively high abundance during first year. The diatoms followed oscillating but different annual patterns and peak densities during October and March during two years, respectively not concurrent with phytoplankton peaks. Our results recorded higher diatom abundance than the results of Sharma (1995, 2009, 2010), Das et al. (1996), Sharma and Lyngdoh (2003) and Sharma and Lyngskor (2003). *Frustulia* sp. and *Navicula* sp. are important diatoms in this study. The Cyanophyta > Cryptophyta showed importance during certain months. The former recorded relatively high abundance during second year and January through March in particular with peak density in March attributed to *Oscillatoria* sp. Cryptophyta occurred in low densities except for peaks during April and February during two years, respectively attributed to *Cryptomonas* sp. Euglenophyta > Dinophyta recorded poor densities; the former showed peak density in March during second year.

The phytoplankton species diversity (1.693-3.399; 2.607±0.451) recorded relatively wider variations during second year. High values (>3.0) are observed only during July during first year, and during December and August during second year while low diversity (below 2.0) is observed in August (first year) and during January and March in the following year. The diversity followed multi-modal and bimodal patterns during two years respectively, and ANOVA registered its insignificant annual and monthly variations. Khawiva reservoir indicated higher phytoplankton diversity than the reservoirs of Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003). An equitable abundance of majority of species resulted in general higher phytoplankton evenness (0.760±0.119) during the study except in August-September during first year and in January-March during second year. It is positively correlated with species diversity (r=0.843, $P$<0.0001), thereby, indicating that periods of high diversity correspond with high equitability. The evenness followed oscillating annual variations. This study indicated relatively wide variations in dominance (0.080-0.649) indicating period of very low dominance to certain months. On the other hand, *Xanthidium* sp. mainly resulted in high dominance in August during first year while its peak value in January during second year is attributed to abundance of *Oscillatoria* sp. and *Xanthidium* sp. The dominance is inversely corrected with species diversity (R=-0.839, $P$<0.0001) and evenness (r=-0.868, $P$<0.0001). In general, high evenness and low dominance affirmed the previous reports from sub-tropical reservoirs of Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003) and also concurred with reports from various ecosystems of NEI (Sharma, 1995, 2004, 2009, 2010, 2012, 2015).

This study lacked significant influence of any individual abiotic parameter on phytoplankton richness and abundance as well as on abundance of Chlorophyta, Bacillariophyta and Cyanophyta. This interesting feature is concurrent with the report of Sharma (2009) but differed from importance of various abiotic factors reported by Sharma and Lyngskor (2003), Sharma and Lyngdoh (2003) and Sharma (2010). Our results explained lower (57.6%) cumulative variance of fifteen abiotic factors along first two axes (*vide* the canonical correspondence analysis) on phytoplankton assemblages; and recorded importance of hardness, DOM, rainfall, chloride and phosphate. *Staurastrum, S. gladiosum, S. kurzianum, S. nonanum,* and Chrysophyta abundance are influenced by hardness and dissolved organic matter. *S. inflexum* density is influenced by conductivity and nitrate; pH influenced *Cosmarium* abundance; richness of phytoplankton and Chlorophyta and phytoplankton abundance is influenced by phosphate; high rainfall influence abundance of Chlorophyta, *Frustulia* sp. and *Navicula* sp. while high rainfall and chloride influenced Bacillariophyta abundance. In general, this study thus yielded little insight on overall importance of abiotic parameters on variations phytoplankton taxa.

## Conclusions

The fairly rich phytoplankton of Khawiva reservoir indicated homogeneity in its composition. High richness of Chlorophyta and diverse nature of desmids with *Staurastrum* > *Cosmarium* > *Micrasterias* are interesting. Phytoplankton and its dominant component Chlorophyta indicated wider density variations; Bacillariophyta showed sub-dominance; and Cryptophyta and Cyanophyta exhibited limited importance; *Staurastrum* >

*Xanthidium* are quantitatively important genera while *S. inflexum* > *S. nonanum* > *S. kurzianum* > *S. chaetoceras*> *Oscillatoria* sp. > *Frustulia* sp. > *Navicula* sp. are notable individual taxa. Richness and abundance followed no definite pattern of monthly variations. Phytoplankton indicated moderate species diversity, high equitability and low dominance. With lack of significant influence of abiotic factors and CCA with 15 abiotic factors explaining low cumulative phytoplankton variance, this study yielded little insight on overall role of abiotic parameters. The results thus suggested importance of biotic factors associated with microhabitat variations.

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