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Phytoplankton Communities at Different Depths in Two Eutrophic and Two Oligotrophic Temperate Lakes at Higher Latitude During the Period of Ice Cover

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Summary. Phytoplankton communities at different depths and at different locations within each lake were studied during the period of ice cover (from January to March) in two eutrophic and two oligotrophic lakes in North-Eastern Sweden. Cryptophyceae, Dinophyceae and Euglenophyceae were dominant during the whole period of investigation in eutrophic environments. Bacillariophyceae, Chlorophyceae, Chrysophyceae and Cyanophyceae were only occasionally found both in eutrophic and oligotrophic lakes. Both in eutrophic and oligotrophic lakes diversity as well as abundance of phytoplankton were considerably higher immediately under ice than near the bottom. No differences in horizontal distribution of phytoplankton assemblages were detected within each lake. However, vertical differences were more profound. It is speculated that both light availability and increased ion concentration under the ice cover can be viewed as main factors determining phytoplankton communities.

Key words: ice cover, lake, phytoplankton, succession, trophic level.

INTRODUCTION

Lakes showing dimictic circulation patterns are common at temperate latitudes. The occurring stratification has profound effects on the whole complex of nutrient circulation in the water column thus leading to successions in phytoplankton communities (Trifonova 1993, Pierson and Weyhenmeyer 1994). It has been reported that lakes morphometry can play, besides nutrient contents, important role in distribution of phytoplankton populations (Agbeti *et al*. 1997). Although several reports dealt with development of phytoplankton under ice cover (e.g. Kelley 1997, Reitner *et al*. 1997), no comparative studies were performed in order to elucidate patterns in both spatial and temporal successions of planktonic algal communities under ice cover in lakes of different trophic level. Such factors as lake morphometry, light and nutrient availability can affect planktonic organisms under ice (Fritsen and Priscu 1999, Butler *et al*. 2000). The aim of our study was to investigate temporal and spatial patterns in development of phytoplankton communities under ice cover in two eutrophic and two oligotrophic temperate lakes in North-Eastern Sweden.

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MATERIALS AND METHODS

Two eutrophic and two oligotrophic lakes in Northeast Sweden (62°54' N) were sampled monthly during the period of ice-cover (January, February, March 2000). All four temperate lakes are shallow and show dimictic stratification patterns. Eutrophication was defined according to total phosphorus concentration (P_{tot}), where the lakes with P_{tot} less than 15 µg l^{-1} were considered as oligotrophic and above 25 µg l^{-1} as eutrophic, respectively (Swedish Environmental Protection Agency 1991). Four sampling stations were randomly chosen at a depth of 3 m within each lake in order to enable comparison of on both horizontal and vertical differences between phytoplankton communities. In order to perform water sampling holes in the ice were drilled. At each station sampling was done under ice and near bottom with the aid of a 1.5 l Ruttner water-bottle sampler with a built-in thermometer. For each sampling station and depth two PVC-bottles (500 ml, for qualitative and quantitative analyses) were filled. The samples for quantitative analyses were preserved in 1% Lugol's solution immediately after collection. Later in the laboratory, the preserved samples were left to stand for 24 h in order to achieve sedimentation of the algal cells. After sedimentation the samples were concentrated first to 50 ml by carefully removing 450 ml through plankton nets (3 µm mesh size). The remaining 50 ml were centrifuged for 20 s at 4000 rpm. The liquid phase was then immediately removed and the remaining pellet resuspended in approximately 10 drops of sample water with a Pasteur pipette. When the exact identification of species proved impossible from the preserved samples, fresh samples were used for assistance. The frequency of each species present in the fixed samples was determined according to relative units: 1 - occasional, 2 - rare, 3 - frequent, 4 - dominant (e.g. Kangas *et al*. 1993; Smolar *et al*. 1998; Danilov and Ekelund 1999, 2000).

Cluster analyses were performed on the base of species presence-absence matrices by using the Euclidean distance algorithm in the computer package Minitab 13.0 (Danilov and Ekelund 1999, 2000).

RESULTS AND DISCUSSION

The lists of phytoplankton species identified during the period of investigation are shown in Tables 1 and 2. Cryptophyceae were present all the time in all four lakes, *Rhodomonas lacustris* being abundant both in eutrophic and oligotrophic environments. *Cryptomonas erosa* and *C. reflexa* were abundant in eutrophic lakes where they formed the main part of abundance at all depths, while *C. marssonii* only occasionally occurred in oligotrophic lakes. *C. reflexa* was rarely found immediately under ice in oligotrophic environments. Two species of Dinophyceae as well as almost all species of Euglenophyceae occurred entirely in eutrophic lakes. While Dinophyceae were abundant at all depths, *Phacus caudatus*, *P. suecicum* and *Trachelomonas planktonica* (Euglenophyceae) were restricted to water layer immediately below the ice cover. *T. volvocinopsis* formed a considerable part of abundance at all depths in eutrophic lakes, while *T. volvocina* was only occasionally found near bottom in oligotrophic lakes. Only occasional presence of Bacillariophyceae and Chrysophyceae could be reported, Chlorophyceae reached their highest species diversity in eutrophic lakes, although the abundance of species identified was extremely low (occasional founds) in all four lakes studied (Tables 1 and 2).

In the present study autotrophic species contributed to the main part of plankton cell numbers as it has been shown by other investigators (e.g. Padisak *et al*. 1998). It has been reported earlier that Chrysophyceae and Cryptophyceae are most often dominant under ice cover (Spaulding *et al*. 1994, Agbeti and Smol 1995). Our study showed only Cryptophyceae being dominant during the whole period of investigation in eutrophic environments at any depths sampled. Thereby, the densities of Cryptophyceae were much higher immediately under ice cover compared to deeper water layers. Nonetheless, Cryptophyceae dominated also near the bottom. The appearance of *T. volvocinopsis* as codominant can be explained by the ability of it and of Cryptophyceae to heterotrophic nutrition and thus survival in conditions of insufficient light intensity (van den Hoek *et al*. 1995). The dominance of *R. lacustris* in oligotrophic lakes agrees well with predominant presence of small flagellates under ice cover reported earlier (Tulonen *et al*. 1994, Agbeti and Smol 1995, Kelley 1997, Reitner *et al*. 1997). Phytoplankton abundance in oligotrophic environments was considerably lower than under eutrophic conditions. This can be explained by general availability of nutrients (Tulonen *et al*. 1994).

No horizontal differences between phytoplankton communities at the same depth could be revealed in any of the lakes investigated. This phenomenon coincides with results reported by Spaulding *et al*. (1993) and disagrees with those reported by Goldman *et al*. (1996). This fact, however, can be explained by relatively small sizes of the lakes investigated in the present study thus limiting horizontal variability of habitats within lakes. Therefore, we can conclude that the lakes investigated showed highly homogeneous phytoplankton assemblages at the same depths. However, vertical variation within the water column could be detected in all four lakes (Fig. 1). Thereby, although some phytoplankton species did occur both in eutrophic and oligotrophic environments, they occurred with temporal shift during the period of investigation - a phenomenon reported earlier (Spaulding *et al*. 1993, Reitner *et al*. 1997, Padisak *et al*. 1998). Oligotrophic lakes always showed a cluster clearly

Table 1. Phytoplankton species found during the period of ice cover (from January to March) in two eutrophic temperate lakes in the Northeastern Sweden (62°54’ N): u.c. - immediately under the ice cover, n.b. - near bottom (*ca* 3 m)

Group	**J**		**F**		**M**	
	u.c.	n.b.	u.c.	n.b.	u.c.	n.b.
CHLOROPHYCEAE						
Chlamydomonas sp.	1			1	1	
Crucigeniella rectangularis (Nägeli) Komarek		1				
Dictyosphaerium pulchellum Wood					1	
Didymocystis bicellularis (Chodat) Komarek	2	3	2	1	4	4
Scenedesmus quadricauda (Turpin) Brebisson		1	1			
CRYPTOPHYCEAE						
Cryptomonas erosa Ehrenberg	4	1	4	1	4	2
Cryptomonas reflexa Skuja	2		4	1	4	2
Rhodomonas lacustris Pasher et Ruttner	4	3	3		2	
DINOPHYCEAE						
Gymnodinium lantzschii Utermöhl	1	2			1	
Peridinium willei Huitfeld-Kaas					2	1
EUGLENOPHYCEAE						
Phacus caudatus Hübner		1				1
Phacus suecicum Lemmermann					1	
Trachelomonas planktonica Swirenko	1					
Trachelomonas volvocinopsis Swirenko	4	1	3	1	3	1

Table 2. Phytoplankton species found during the period of ice cover (from January to March) in two oligotrophic temperate lakes in the Northeastern Sweden (62°54’ N): u.c. - immediately under the ice cover, n.b. - near bottom (3 m)

Group	**J**		**F**		**M**	
	u.c.	n.b.	u.c.	n.b.	u.c.	n.b.
BACILLARIOPHYCEAE						
Navicula spp.		1		1		
Tabellaria fenestrata (Lyngbye) Kützing			1		1	
CHLOROPHYCEAE						
Chlamydocapsa ampla (Kütz.) Fott	1					
Chlamydomonas sp.					1	1
CRYPTOPHYCEAE						
Cryptomonas marssonii Skuja	2	1				
Cryptomonas reflexa Skuja					2	1
Rhodomonas lacustris Pasher et Ruttner	2	1	1	1	2	1
CYANOPHYCEAE						
Anabaena sp.			1			
DINOPHYCEAE						
Peridinium willei Huitfeld-Kaas					1	
EUGLENOPHYCEAE						
Trachelomonas volvocina Ehrenberg			1			
Trachelomonas volvocinopsis Swirenko				1		

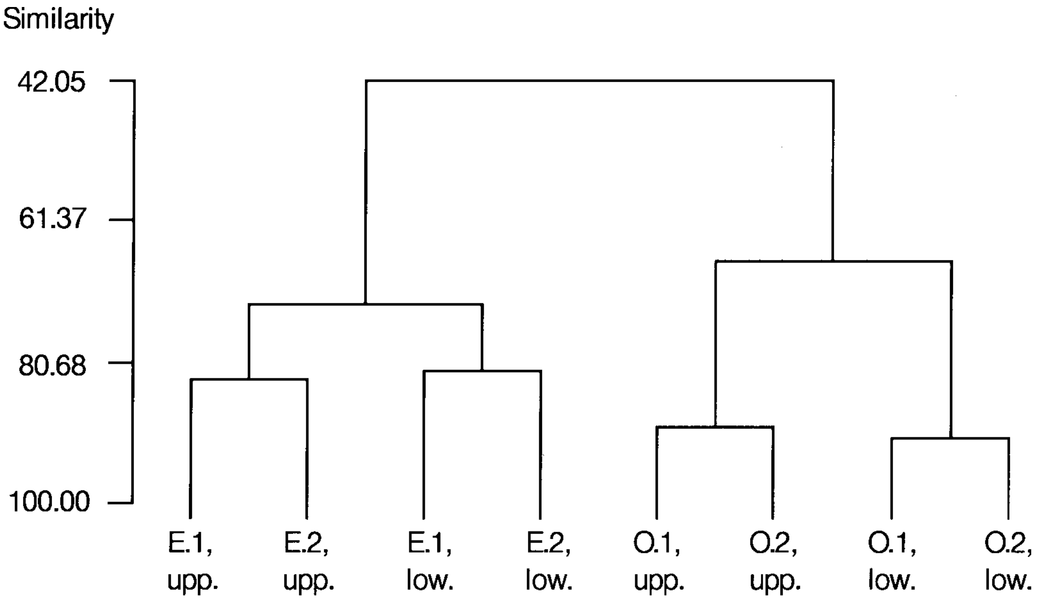

Fig. 1. Clustering analyses of sampling stations based on presence-absence phytoplankton data sampled during the period of ice cover (from January to March) in two eutrophic and two oligotrophic lakes in North-Eastern Sweden: O.1, O.2 - oligotrophic lakes, E.1., E.2 - eutrophic lakes, upp. - immediately under the ice cover, low. - near the bottom

separated from that built by eutrophic lakes. Phytoplankton communities at the same depths were highly homogeneous in oligotrophic lakes, on the one hand, and in eutrophic lakes, on the other hand. We can conclude that the lakes of the same trophic status exhibited highly similar phytoplankton assemblages at similar depths under the ice cover. Contrary to results reported by Agbeti *et al.* (1997), the morphometry of lakes did not seemed to play an important role with only depth being the determinative factor. A possible explanation to this phenomenon could be the limited light availability at higher depths (Tulonen *et al.* 1994). However, vertical differences shown by higher phytoplankton diversities immediately below the ice cover became obvious in our study. These results correspond to those reported earlier in the literature (Lizotte *et al.* 1996, Ventela *et al.* 1998). A possible explanation of this fact could be both differences in light availability at different depths and increased ions concentrations (excluded from the lower surface of ice) below the ice cover (Spaulding *et al.* 1993, Tulonen *et al.* 1994).

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