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Phytoplankton assemblages as a criterion in the ecological classification of lakes in Finland

Liisa Lepistö[1)], Anna-Liisa Holopainen[2)], Heidi Vuoristo[1)] and Seppo Rekolainen[1)]

[1)] *Finnish Environment Institute, P.O. Box 140, FI-00251 Helsinki, Finland*
[2)] *Karelian Research Institute, University of Joensuu, P.O. Box 111, FI-80101 Joensuu, Finland; and North Karelian Environment Centre, P.O. Box 69, FI-80101 Joensuu, Finland*

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Implementation of the Water Framework Directive requires the formulation of lake types and classification of the lakes within each type using biological quality elements. In this study phytoplankton was used to test the lake typology of 32 non-impacted lakes belonging to eight of the ten lake types described in the preliminary Finnish typology. Phytoplankton did not accurately define these types, as only five lake groups were clustered in the DCA ordination analysis. The ecological status was preliminarily established for 23 impacted lakes using total phytoplankton biomass and the number of taxa. Impacted oligo-humic lakes were tentatively classified to a lower ecological status than in the general water quality classification carried out in the 1990s. Even more variation was observed when assessing the ecological status of humic impacted lakes. The number of taxa, on the other hand, appeared to overestimate the ecological status of the lakes, obviously due to the preliminary boundary classes used in this study.

Introduction

Key issues in the implementation of the Water Framework Directive (European Union 2000) for lakes are formulating lake types, and classifying the lakes within each type using biological quality elements, e.g. phytoplankton. The composition of a phytoplankton assemblage is known to depend not only on water quality, physical factors and lake basin size, but also on biological factors such as specific growth and loss rates among the algae, parasitism, predation and competition. Phytoplankton assemblages with short renewal times are not constant, partly due to their different developmental time scales (Hutchinson 1967, Reynolds 1984, Fee *et al.* 1992, Willén 2002). The occurrence of individual species may vary widely, so that the dominant species at different stages of succession will not always be the same (e.g. Lepistö 1999). Seasonally the mean population densities may vary over 2–9 orders of magnitude depending on the trophic state (Reynolds 1984, Holopainen *et al.* 2003). These complex interactions and rapid changes in phytoplankton biomass and species composition should be taken into account when assessing biological quality in lakes. Phytoplankton assemblages have not previously been included in the parameters when considering the general water quality classification in Finland (Vuoristo 1998), although even slight human impact affects the phytoplankton

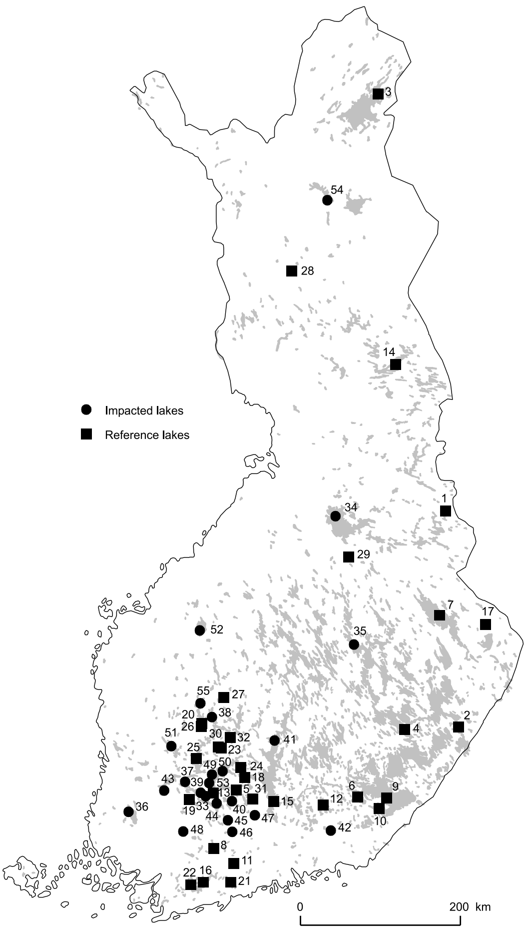

Fig. 1. The observation sites in July 2002. For further information about the lakes, *see* Tables 1 and 2. Reference lakes are indicated as squares and impacted lakes as dots.

species composition and biomass (Niinioja *et al.* 2000, Lepistö *et al.* 2004).

The aim of this study was to evaluate the applicability of total phytoplankton biomass and the number of phytoplankton taxa in ecological classification, and to test the preliminary Finnish lake typology using phytoplankton assemblages. Furthermore, we considered how the phytoplankton total biomass and the number of taxa indicate the ecological status of impacted lakes.

Material and methods

Phytoplankton data sampled from a depth of 0–2 meters during one week in mid July 2002 from a total of 55 Finnish lakes (Fig. 1) was used in this study. Phytoplankton biomass and composition were estimated by microscopy using the Nordic variant of Utermöhl technique (Olrik *et al.* 1998). The complete set of lakes was divided into two parts: non-impacted lakes (i.e. reference lakes) with no or only minor anthropogenic alterations, and impacted lakes. The criteria of the division of the lakes were based on water quality, land use and point source loading data. The preliminary division was made by expert judgment in the Finnish Environment Institute.

The studied non-impacted lakes covered eight of ten lake types described in the preliminary Finnish typology B, which includes the following obligatory factors: altitude or latitude for differentiating lakes (e.g. northernmost Lapland), geology (nutrient richness, calcium, organic soil) and lake basin area. The preliminary Finnish lake types proposed by Pilke *et al.* (2002) are:

1. high mountain lakes,
2. naturally eutrophic lakes,
3. calcareous lakes,
4. small–moderately large (< 40 km^2), oligo-humic (< 30 mg l^{-1} Pt) lakes,
5. large (> 40 km^2), oligo-humic (< 30 mg l^{-1} Pt) lakes,
6. small (< 5 km^2), moderately humic (30–90 mg l^{-1} Pt) lakes,
7. moderately large (5–40 km^2), moderately humic (30–90 mg l^{-1} Pt) lakes,
8. large (> 40 km^2), moderately humic (30–90 mg l^{-1} Pt) lakes,
9. small (< 5 km^2), highly humic (> 90 mg l^{-1} Pt) lakes,
10. moderately large and large, highly humic (> 90 mg l^{-1} Pt) lakes.

An ordination of non-impacted lakes (Table 1) by detrended correspondence analysis (ter Braak 1987, 1990) was used to separate the lakes on the basis of the biomass of phytoplankton species. The medians of total biomass and number of taxa were estimated for each non-impacted lake group, and used as reference values. Taxa, which were observed only in a specific reference lake type, were nominated as type-specific taxa for the lake groups (Lepistö *et al.* 2004).

Table 1. Some characteristics of the studied non-impacted lakes. No. = the number of the observation site in Fig.1. Lake types: the preliminary Finnish B typology and lake groups clustered in the DCA ordination analysis (shown in Fig. 2). The general water quality classification is according to Vuoristo (1998). nd = not determined.

Lake and municipality	No.	Lake types (Finnish B typology)	Lake groups* (DCA ordination)	Lake basin (km^2)	Mean depth (m)	P_{tot} (µg l^{-1})	N_{tot} (µg l^{-1})	Water colour (mg l^{-1} Pt)	pH	Phytopl. (bm. mg l^{-1})	Taxa number	General water quality classification
Änätti Kuhmo	1	7	I	23.7	9.9	8	280	50	6.9	0.95	56	good
Karjalan Pyhäjärvi/Kitee	2	5	I	206.8	8.0	6	240	10	7.6	0.25	70	excellent
Inarijärvi Inari	3	5	I	1040.3	14.3	4	150	10	7.2	0.15	61	excellent
Iso-Haukivesi Rantasalmi	4	5	I	562.3	11.5	8	490	35	7.2	0.40	61	excellent
Kukkia Luopioinen	5	5	I	43.4	6.6	9	360	20	7.3	0.62	82	excellent
Kuolimo Suomenniemi	6	5	I	79.1	8.5	4	320	20	7.2	0.44	61	excellent
Pielinen Lieksa	7	8	I	900.0	12.9	8	370	40	7.3	0.21	63	good
Punelia Loppi	8	7	I	8.2	6.0	8	350	40	7.2	0.59	70	good
Saimaa, Ilkons. Taipalsaari	9	5	I	382.0	11.2	6	380	25	7.1	0.37	61	good
Saimaa, Riutan.Taipalsaari	10	5	I	45.8	12.0	15	380	20	7.3	0.98	78	good
Sääksjärvi Nurmijärvi	11	4	I	2.6	3.1	8	360	8	6.9	0.89	51	excellent
Vuohijärvi Jaala	12	5	I	86.2	11.3	5	380	15	7.2	0.27	58	excellent
Mallasvesi Pälkäne	13	5	I	55.7	7.4	11	390	15	7.4	0.66	74	excellent
Yli-Kitka Kuusamo	14	8	I	237.3	4.6	11	250	10	7.4	0.25	60	excellent
Päijänne Asikkala	15	5	I	76.7	16.9	6	550	25	7.4	0.51	53	excellent
Hormajärvi Lohja	16	4	II	5.0	6.9	12	300	10	7.3	0.24	42	good
Iso-Hietajärvi Lieksa	17	4	II	0.8	3.6	5	210	20	6.8	0.12	43	nd
Iso-Löytäne Längelmäki	18	4	II	8.8	7.2	5	370	15	7.3	0.51	69	excellent
Iso-Arajärvi Vesilahti	19	6	II	2.3	5.5	13	370	40	7.0	0.48	56	excellent
Iso-Helvetinjärvi Ruovesi	20	6	II	0.5	0.5	7	340	60	6.1	0.35	34	nd
Kattilajärvi Espoo	21	4	II	0.3	3.3	5	230	15	6.5	0.58	38	nd
Puujärvi Karjalohja	22	4	II	6.4	8.5	9	390	15	7.4	0.52	68	excellent
Siikajärvi Orivesi	23	4	II	0.9	5.9	7	490	25	6.1	0.68	40	nd
Vehkajärvi Kuhmalahti	24	4	II	25.9	5.4	8	370	15	7.0	0.33	61	excellent
Näsijärvi Ylöjärvi	25	8	II	210.2	13.3	13	500	45	7.1	0.51	55	good
Haukkajärvi Ruovesi	26	6	III	2.6	4.2	10	480	100	5.8	0.67	53	excellent
Pihlajavesi Keuruu	27	10	III	20.7	5.0	23	570	120	6.2	0.95	47	good
Unarinjärvi Sodankylä	28	10	III	28.8	6.1	24	380	110	6.8	1.17	81	good
Lika-Pyöree Sonkajärvi	29	2	IV	1.9	0.8	37	510	160	5.8	0.73	39	nd
Kalliojärvi Juupajoki	30	9	IV	0.2	13.0	28	540	160	6.2	6.86	55	nd
Valkea-Kotinen Lammi	31	nd	V	0.04	2.6	14	440	100	5.5	0.30	12	nd
Iso-Hanhijärvi Orivesi	32	9	V	0.3	12.0	16	380	160	5.3	0.88	30	nd

* I = Oligo-humic large lakes, II = Oligo-humic moderately large lakes, III = Humic moderately large lakes, IV = Highly humic lakes, IV = Acidic, highly humic lakes.

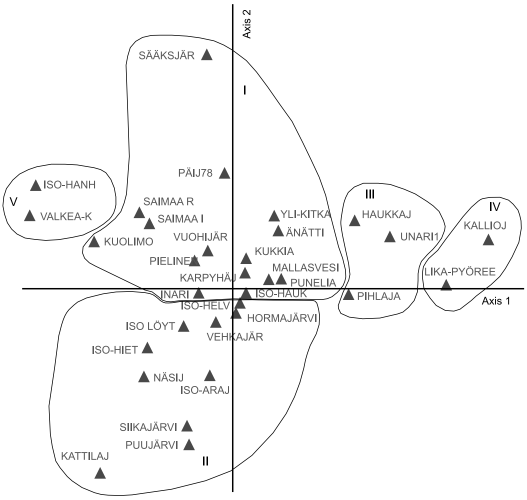

Fig. 2. Detrended correspondence analysis (DCA) of the reference lakes based on the biomass of phytoplankton species in July 2002. Eigenvalue: axis 1 = 0.55, axis 2 = 0.31. (I) = oligo-humic large lakes, (II) = oligo-humic moderately large lakes, (III) = humic moderately large lakes, (IV) = highly humic lakes, (V) = acidic, highly humic lakes.

Impacted lakes were grouped according to water color using 60 mg l^{-1} Pt as a limit value and lake area with a limit value of 40 km^2. These limits corresponded to the water color and lake area of the non-impacted lake groups clustered by DCA ordination analysis (Tables 1 and 2). Three groups of impacted lakes were formed, as no data was available from impacted highly humic or highly humic acidic lakes. The ecological quality ratios (EQR) for 23 impacted lakes were estimated by dividing the reference values (calculated as medians for each non-impacted lake group) with the observed values from the impacted lakes. The ecological status was assessed using the scale presented in the REFCOND Guide (2003), where EQR ratios of 1–0.8 for high, 0.8–0.6 for good, 0.6–0.4 for moderate, 0.4–0.2 for poor, and < 0.2 for bad ecological status were proposed as boundaries between classes. The preliminary definition of ecological status was compared to the general water quality classification of Finnish lakes. The classification into excellent, good, satisfactory, passable and poor is based on physico-chemical data. In this classification humic compounds have a deteriorating influence on the water quality (Vuoristo 1998).

Results and discussion

Non-impacted lakes clustered by phytoplankton

On the basis of phytoplankton assemblages the non-impacted lakes were clustered into five distinct groups in the DCA ordination analysis (Fig. 2). Oligo-humic large lakes (group I) and moderately large lakes (group II) were grouped according to the basin size of lakes along the axis 2. There was a partial overlapping of the groups. These lake groups were characterized by water color from 8 to 60 mg l^{-1} Pt, and were composed mainly of the preliminary lake types 5 and 4 (cf. Table 1). Humic moderately large lakes (group III, water color 100–120 mg l^{-1} Pt) formed a separate group on the axis 1 between oligo-humic lakes and two other lakes, one highly humic and the other naturally eutrophic (group IV, water color 160 mg l^{-1} Pt). Two acidic, highly humic lakes were grouped at the opposite end (group V, water color 100–160 mg l^{-1} Pt).

Water quality

In the oligo-humic large and moderately large non-impacted lakes the total phosphorus concentration mainly indicated oligotrophic conditions, according to the limits given by OECD (1982), and varied from 4 to 15 $\mu g\ l^{-1}$. In humic lakes the concentrations were higher, from 10 to 24 $\mu g\ l^{-1}$, due to the humic substances as recorded by Arvola (1984) and Salonen *et al.* (2002). In highly humic lakes the total phosphorus concentrations were 28 and 37 $\mu g\ l^{-1}$, and in acidic lakes 14 and 16 $\mu g\ l^{-1}$ (Table 1).

In oligo-humic impacted lakes the total phosphorus concentration varied from 10 to 52 $\mu g\ l^{-1}$, indicating mesotrophy in general, according to the limits given by OECD (1982). In humic lakes the range was from 13 to 50 $\mu g\ l^{-1}$ (Table 2).

Phytoplankton abundance

In the oligo-humic large and moderately large non-impacted lakes phytoplankton biomass indicated oligotrophy, in some lakes oligo-

Table 2. Some characteristics of the studied impacted lakes. No. = the number of the observation site in Fig. 1. Lake types: the preliminary Finnish B typology and impacted lakes grouped according to water color and lake area, pressures: eutr. = loaded by point sources, reg. = water level regulation. The preliminary definition of the ecological status is based on the total biomass and total number of taxa. The general water quality classification is according to Vuoristo (1998).

Lake and municipality	No.	Lake types (Finnish B typology)	Lake types according to water color and lake area*	Pressure	Basin (km^2)	Mean depth (m)	P_{tot} (µg l^{-1})	N_{tot} (µg l^{-1})	Water colour (mg l^{-1} Pt)	pH	Phytopl. (bm, mg l^{-1})	Number of taxa	Ecological status/bm.	Ecological status/ taxa no.	Geneneral water quality classification
Längelmävesi Kangasala	33	5	I	eutr.	133.0	11.4	12	400	25	7.4	1.25	77	poor	high	good
Oulujärvi Niskans. Vaala	34	8	I	reg.	329.1	5.9	20	660	40	7.2	0.87	76	moderate	high	good
Porttipahta Sodankylä	54	8	I	reg.	151.3	4.5	14	310	45	7.1	0.73	44	good	high	satisfactory
Pyhäjärvi Eura	36	5	I	eutr.	155.2	5.4	24	440	20	8.0	0.96	82	moderate	good	good
Pyhäjärvi Nokia	37	8	I	eutr.	67.9	9.4	35	670	40	7.8	3.53	98	bad	good	satisfactory
Vanaja Valkeakoski	39	5	I	eutr.	46.9	4.9	17	450	15	7.3	3.07	84	bad	good	satisfactory
Vanajanselkä Valkeakoski	40	8	I	eutr.	102.9	5.8	27	1200	60	7.7	3.60	59	bad	high	satisfactory
Päijänne Korpilahti	41	5	I	eutr.	863.3	18.0	12	530	30	7.3	0.58	48	high	high	good
Haukkajärvi Valkeala	42	7	II	eutr.	13.2	6.1	11	600	45	7.3	0.58	80	high	good	good
Houhajärvi Vammala	43	6	II	eutr.	3.7	2.3	30	690	40	7.2	5.71	76	bad	good	satisfactory
Iso-Roine Hauho	44	4	II	eutr.	30.9	14.4	10	410	25	7.6	0.81	79	good	good	excellent
Katumajärvi Hämeelinna	45	4	II	eutr.	3.8	4.6	28	540	35	7.7	1.51	81	poor	good	good
Rehtijärvi Jokioinen	48	6	II	eutr.	0.4	6.1	39	810	60	8.9	4.07	62	bad	high	satisfactory
Mäyhäjärvi Lempäälä	53	9	II	eutr.	2.1	2.6	52	1400	50	10.0	3.49	42	bad	high	satisfactory
Roine Kangasala	49	4	II	eutr.	40.4	–	12	330	20	7.5	0.86	72	good	good	good
Vesijärvi Kangasala	50	4	II	eutr.	39.5	8.8	11	370	20	7.3	0.98	71	moderate	good	good
Pääjärvi Hämeenkoski	47	7	III	eutr.	13.4	14.8	13	1400	65	7.3	1.24	59	high	high	good
Kyrösjärvi Ikaalinen	51	10	III	eutr.	96.1	10.3	20	840	100	6.9	3.64	58	poor	high	good
Lappajärvi Lappajärvi	52	8	III	eutr.	145.5	7.4	26	1000	80	7.2	3.34	69	poor	high	satisfactory
Northern Kallavesi	35	8	III	eutr.	162.0	10.7	29	770	70	7.2	1.67	53	good	high	satisfactory
Kernaalanjärvi Janakkala	46	6	III	eutr.	4.5	2.9	50	640	90	7.6	3.63	82	poor	good	satisfactory
Tarjannevesi Virrat	38	8	III	eutr.	54.9	13.8	16	600	80	6.9	0.80	60	high	high	good
Toisvesi Virrat	55	10	III	eutr.	29.4	18.6	16	770	110	6.6	0.36	60	high	high	good

* I = Oligo-humic large lakes, II = Oligo-humic moderately large lakes, III = Humic moderately large lakes.

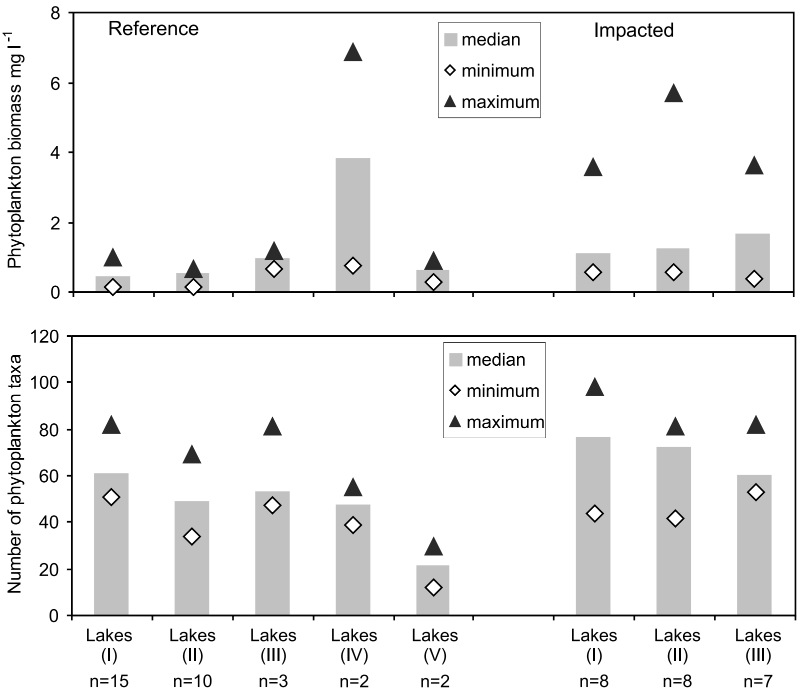

Fig. 3. The median, minimum and maximum total phytoplankton biomass and number of taxa in reference and impacted lakes. Impacted lakes are grouped according to water color and lake area. (I) = oligo-humic large lakes, (II) = oligo-humic moderately large lakes, (III) = humic moderately large lakes, (IV) = highly humic lakes, (V) = acidic, highly humic lakes.

mesotrophy (Table 1), according to the limits (< 0.50 mg l^{-1} for oligotrophy and 0.51–1.00 mg l^{-1} for oligo-mesotrophy), presented by Heinonen (1980). The median biomass was 0.44 mg l^{-1} in large oligo-humic non-impacted lakes and 1.12 mg l^{-1} in large impacted lakes. The median number of taxa was 61 (maximum 82) in non-impacted lakes and 76 (maximum 98) in impacted lakes. In moderately large non-impacted lakes the median biomass was 0.5 mg l^{-1} and in impacted lakes 1.24 mg l^{-1}. The median number of taxa was 49 (maximum 69) in non-impacted lakes and 74 (maximum 81) in impacted lakes (Tables 1–2 and Fig. 3). Eutrophication of the oligo-humic lakes was indicated not only by increase in biomass but also by increase in the number of taxa.

In humic non-impacted lakes the median biomass was 0.95 mg l^{-1} and in impacted lakes almost two times higher, 1.67 mg l^{-1}. The median numbers of taxa 53 and 60 did not differ as clearly (Fig. 3). Two of the study lakes were highly humic, with wide variation of biomass values, and two were acidic, with similar biomass values. As in the case of humic lakes the difference in the number of taxa was not marked in these four highly humic lakes (Table 1 and Fig. 3).

Although the median biomass in impacted lakes was approximately two times higher than in non-impacted lakes, most of the impacted oligo-humic and humic lakes were classified as oligo-mesotrophic or mesotrophic, according to the limits presented by Heinonen (1980). In fact, based on phytoplankton biomass 55 of our study lakes fell into the two best quality classes of the Swedish environment quality classification (Naturvårdsverket 1999).

In this study the sampling was restricted to one week only, and thus the natural fluctuation in phytoplankton communities might have caused uncertainty in the results. The intra-annual fluctuation of phytoplankton biomass in large oligo-humic and nutrient poor Finnish lakes seemed to be twofold during May–June, and is at its lowest in July (e.g. Lepistö 1999). The seasonal variation of phytoplankton biomass is at its lowest in mid-July during strong stratification, according to Heinonen (1982). However, along with the increasing humus or nutrient concentration the fluctuation is more pronounced (Lepistö 1999, Salonen *et al.* 2002). Furthermore, the seasonal succession of phytoplankton is influenced by weather conditions and e.g. the location of the lakes (Hutchinson 1967, Round 1981). Thus, the long geographical distance between the lakes obviously causes some additional differences due to the seasonality in the development of phytoplankton.

When considering the ecological classification of large and moderately large oligo-humic lakes on the basis of phytoplankton biomass and the number of taxa, the restricted data of this study could be sufficient. However, the data of humic lakes gives only a preliminary estimate of the studied metrics. It is important to notice that our data represents the July values and should not be applied as such to the results of other months, especially when considering the EQR ratios. An even more important aspect is that the EQR ratios are based on phytoplankton data from lakes in pristine or good ecological status (REFCOND Guide 2003). This data is analyzed with standard methods and with high-quality identification. When classifying the ecological status of impacted lakes using phytoplankton, the data must be comparable to the data used in setting of reference conditions.

Typical phytoplankton taxa

In large oligo-humic non-impacted lakes the cyanobacteria *Merismopedia warmingiana*, the dinoflagellate *Peridinium umbonatum* and the chrysomonads *Dinobryon borgei*, *D. crenulatum* and *D. suecicum* were typical. However, diatoms *Aulacoseira granulata* v. *angustissima*, *Rhizosolenia eriensis* and *Stephanodiscus* sp., and the desmid *Closterium gracile* dominated in oligo-humic impacted lakes. In the case of oligo-humic moderately large non-impacted lakes the cyanobacteria *Radiocystis geminata* and *Rhabdoderma lineare* and chrysomonads *Dinobryon crenulatum* and *D. borgei* were typical. In impacted moderately large lakes e.g. the cyanobacterium *Aphanocapsa holsatica*, and the diatoms *Acanthoceras zachariasii*, *Aulacoseira ambigua*, and *A. italica* v. *tenuissima* were typical (Table 3). The observed taxa in non-impacted lakes were in accordance with earlier observations from oligotrophic lakes (e.g. Hutchinson 1967, Rosenström and Lepistö 1996), and taxa typical for the oligo-humic lakes were mainly those also presented as indicators of oligotrophy e.g. by Heinonen (1980) and Brettum (1989).

Typical for non-impacted humic lakes were the chrysomonads *Bicosoeca* spp., *Dinobryon divergens* and the diatom *Aulacoseira ambigua*, and for impacted lakes the cyanobacteria *Aphanothece minutissima* and *Woronichinia naegeliana*, and the diatom *Rhizosolenia eriensis*. In highly humic lakes *Dinobryon bavaricum* and *Gonyostomum semen* (Raphidophyceae), and in acidic lakes also the small dinoflagellates *Gymnodinium* sp. and *Peridinium umbonatum*, were typical (Table 3). These flagellated taxa are capable of vertical migration, and are benefited in small humic boreal lakes (Lepistö and Rosenström 1998, Salonen *et al*. 2002)

An exercise to classify the ecological status of impacted lakes using phytoplankton metrics

The EQR ratio classified the ecological status of four of eight oligo-humic large impacted lakes as bad or poor, two as moderate and two as high or good on the basis of the total biomass (Table 2). However, when using the EQR ratio of total number of taxa, five lakes had high and three good ecological status. One of these lakes having good (by biomass) and high (by number of taxa) ecological status was a man-made lake Porttipahta in which regulation of the water level is reflected in the abundance of diatoms in the overall phytoplankton biomass (Lepistö and Pietiläinen 1996).

The EQR ratio of the total biomass classified the ecological status of three of eight oligo-humic moderately large impacted lakes as high or good, one as moderate and four as poor or bad. The EQR ratio of number of taxa indicated high ecological status for two and good for six lakes. Three of the seven humic lakes had poor and four high or good ecological status on the basis of the total biomass and six had high and one good ecological status on the basis of the number of taxa (Table 2).

Phytoplankton biomass and the number of taxa classified one of the observation sites in Lake Päijänne, considered to be impacted, into high ecological status, which is in agreement with the low total phosphorus concentration. Similarly, in the case of the northern man-made

Table 3. Typical phytoplankton species in the non-impacted and impacted lake groups.

I. Oligo-humic large lakes	II. Oligo-humic moderately large lakes	III. Humic moderately large lakes	IV. Highly humic lakes	V. Acidic lakes
Non-impacted (*n* = 15)	**Non impacted** (*n* = 10)	**Non-impacted** (*n* = 3)	**Non-impacted** (*n* = 2)	**Non-impacted** (*n* = 2)
Merismopedia warmingiana Lagerheim	*Radiocystis geminata* Skuja	*Bicosoeca* sp.	*Gymnodinium* sp.	*Gymnodinium* sp.
Dinobryon borgei Lemmermann	*Rhabdoderma lineare* Schmidle & Lauterborn	*Dinobryon divergens* Imhof	*Dinobryon bavaricum* Imhof	*Dinobryon bavaricum* Imhof
D. crenulatum W. & G.S.West	*Dinobryon borgei* Lemmermann	*Aulacoseira ambigua* (Grun.) Simonsen	*Gonyostomum semen* (Ehr.) Diesing	*Monochrysis* sp.
D. suecicum Lemmermann	*D. crenulatum* W. & G.S.West	*Tetraedriella jovetii* (Bour.) Bourrelly		*Peridinium umbonatum* Stein
Kephyrion spp.	*Kephyrion boreale* Skuja			*Gonyostomum semen* (Ehr.) Diesing
Kephyrion ovale (Lack.) Huber-Pestalozzi	*Gloeobotrys limnetica* (G.M. Sm.) Pasche			
Peridinium umbonatum Stein				
Impacted (*n* = 8)	**Impacted** (*n* = 8)	**Impacted** (*n* = 7)		
A. granulata v. *angustissima* (O.M.) Simonsen	*Aphanocapsa holsatica* (Lemm.) Cronb.& Kom.	*Aphanothece minutissima* Kom.-Legn. & Cronberg		
Rhizosolenia eriensis H.L. Smith	*Acanthoceras zachariasii* (Brun) Simonsen	*Rhizosolenia eriensis* H.L. Smith		
Stephanodiscus sp.	*A. ambigua* (Grun.) Simonsen	*Woronichinia naegeliana* (Unger) Elenkin		
Closterium gracile Brébisson	*A. italica* v. *tenuissima* (Grun.) Simonsen			
Bicosoeca sp.				

reservoir Porttipahta with strong water level regulation, phytoplankton classified the ecological status to a higher level despite its state as a heavily modified water body. On the other hand, in the case of total phytoplankton biomass, the ecological classification of the impacted lakes generally assessed their ecological status to a lower level (Table 2) than did the water quality classification presented by Vuoristo (1998). This classification is based on physico-chemical data, and furthermore, it does not take into consideration the intrinsic water quality differences between lake types. Direct comparisons between classifications based on water quality and ecological parameters are therefore not relevant.

Concluding remarks

Phytoplankton did not accurately define the preliminarily described eight lake types in this rather limited material, as only five lake groups were formed on the basis of phytoplankton assemblages. Our results indicate that phytoplankton assemblages alone grouped the non-impacted lakes according to their humic concentration and pH and that the size of the basin in the case of oligo-humic lakes was rather significant. Phytoplankton biomass appears to classify the oligo-humic impacted lakes to lower ecological status than the general water quality classification due to the different criteria used. This might depend also on the preliminary EQR ratios used in this study. The differences between the two classification methods were particularly evident in the case of the humic impacted lakes and the man-made reservoir. More data is needed for considering the role of phytoplankton metrics in the classification criteria, especially for humic lakes, which are typical to boreal areas. In order to obtain representative, comparable and reliable results for decision-making, frequent sampling accompanied by high-quality standard identification is needed. Another subject of great interest for debate is how to select suitable reference lakes and reference values.

Although the restricted data in this study might be sufficient when considering the ecological classification of large and moderate large oligo-humic lakes, the data of humic lakes gives only a preliminary estimate of the studied metrics. It is also important to notice that data represents only the July values and should not be applied as such to the other months, especially when considering the EQR ratios. However, it should be stressed that the data pertaining to reference conditions is used to establish the reference value in the EQR-based classification system. This data is analyzed with standard methods and with high-quality identification. When classifying the ecological status of impacted lakes using phytoplankton, the high level of quality assurance must be guaranteed in the analyses.

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