Phytoplankton as Indicator of Water Quality in Lake Durowskie, Wągrowiec Poland

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1. Aims

Our analysis aims to address the following questions.

- What is the state of the physical and chemical parameters in the lake?
- What types of phytoplankton predominates in the pelagic zone?
- Which are the periphytic species present?

2. Methods

Sites: Samples were taken from Struga Gołaniecka (inflow and outflow) and in the lake, at aerators 1 and 2, 2 opposite beaches and 2 deep water sites.

Table 1. Basic morphometric data of Durowskie Lake and its catchment area

Parameters	
surface	143.7 ha
volume	11,322,900 m^3
max depth	14.6 m
mean depth	7.9 m
main tributary	Struga Gołaniecka
surface of the whole catchment area	236.1 km^2
surface of the direct catchment area	1,581.3 ha
share of agricultural area	58.26%
share of forests	33.52%
urban area	8.25%

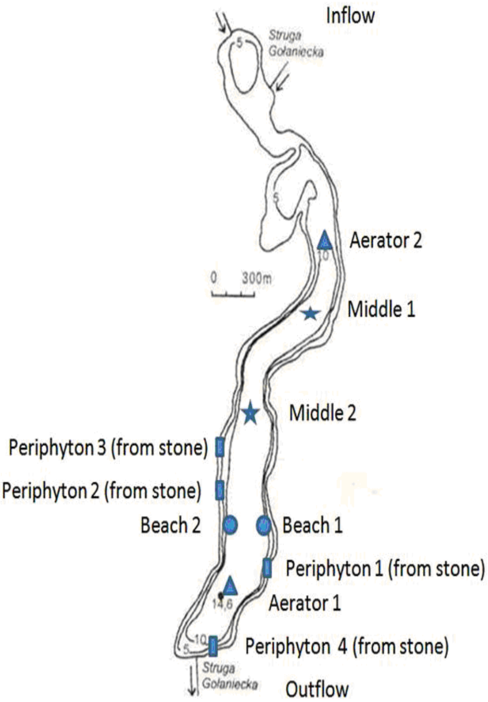

Fig. 1. Sampling sites in and around Lake Durowskie

Water parameters measured were: pH, conductivity, temperature, oxygen content, nitrate and phosphate concentration at vertical profile at depth intervals of 1m starting from the surface (0m) to the bottom of the lake. Samples of water were collected at each site using plankton net for qualitative species identification and a 100mL sample for quantitative analysis of species abundance. Lugos solution was added to each samples to preserve and fix the phytoplanktons. Periphytic samples were also collected from lake edges by using a brush and preserved by adding H_2O_2 into the bottled samples. Diatom samples were prepared for identification according to the procedures described by Battarbee (1986). Also, 500mL samples were taken and filtered onto Whatman paper for chlorophyll *a* analysis. Chlorophyll *a* concentration was determined fluorometrically according to the procedures described by Strickland and Parsons (1972). These physical data for 2009 were compared with those of 2008.

Phytoplankton count: We identified and quantified the phytoplantkton in 100 cells counting chamber of $0.0125mm^3$ each. The species abundance and community composition in the sample was estimated from these cells. Phytoplankton biovolume was estimated from cell numbers and specific volumes. We then calculated mixed trophic index of phytoplankton using the formula: Q= (Cyanophyceae+ Chlorococcales+Centriceae+Euglenophyta) /Desmidiales

$Q<2,5$ oligotrophic lake, $Q>2,5$ eutrophic lake

3. Results and discussion

3.1. State of the physical and chemical parameters in Lake Durowskie

All sites within the lake are eutrophic or even hypertrophic based on chlorophyll *a*, Secchi-disc transparency and trophic state index calculations (table 1).

Table 1. Trophic state

Parameter		Trophic state						Reference
	Standard range	Aerator 1	Aerator 2	Beach 1	Beach 2	Middle 1	Middle 2	
Secchi disc (SD)/ m	Oligotrophic >5 Mesotrophic 5-3 Eutrophic <3	0,9-1,1 (mean=1,034)	1,07-1,4 (mean=1,204)	1-1,1 (mean=1,05)	1,05-1,25 (mean=1,15)	1.15	1.2	Chapra and Dobson, 1981
Chl *a* /µg/l	Oligotrophic <2.9 Mesotrophic 2.9-5.6 Eutrophic >5.6	19.9	15.44	16.69	-	11.23	10.26	Chapra and Dobson, 1981
TSI (SD)*	Oligotrophic <40 Mesotrophic 40-45 Meso-Eutrophic 45-50 Eutrophic 51-85 Hypertrophic >90	59.98	59.91	59.98	59.93	59.93	59.91	Carlson, 1977
TSI (Chl mg/l)**	Ultraoligotrophic <0.5 Oligotrophic 0.5-1 Mesotrofic 2.5-8.0 Eutrophic 8.0-25 Hypertrophic >25	68.94	66.45	67.21		63.33	62.44	Zdanowskim, 1991

Note: * Trophic State Index based on secchi disc (TSI SD) = 10 (6 – lnSD/ln2)

** Trophic State Index based on chlorophyll (TSI Chl) = 10 [6- (2.04-0.68lnChl)/ln2]

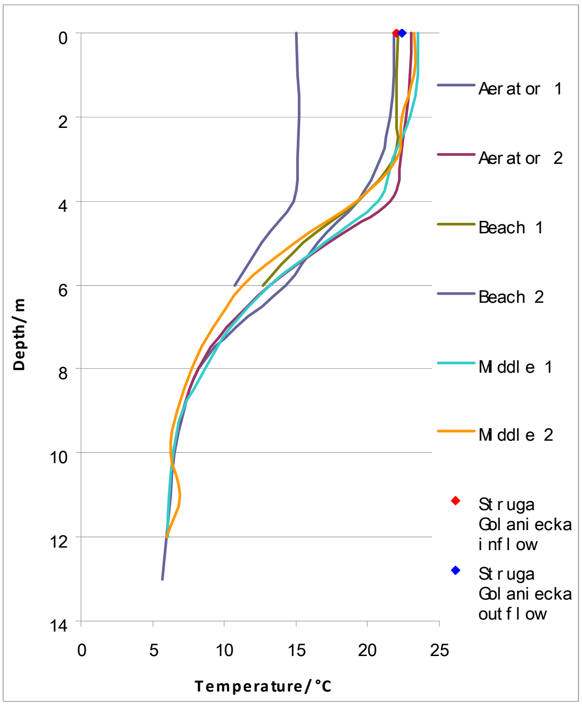

Fig. 2. Vertical stratification of temperature at 6 sampling sites

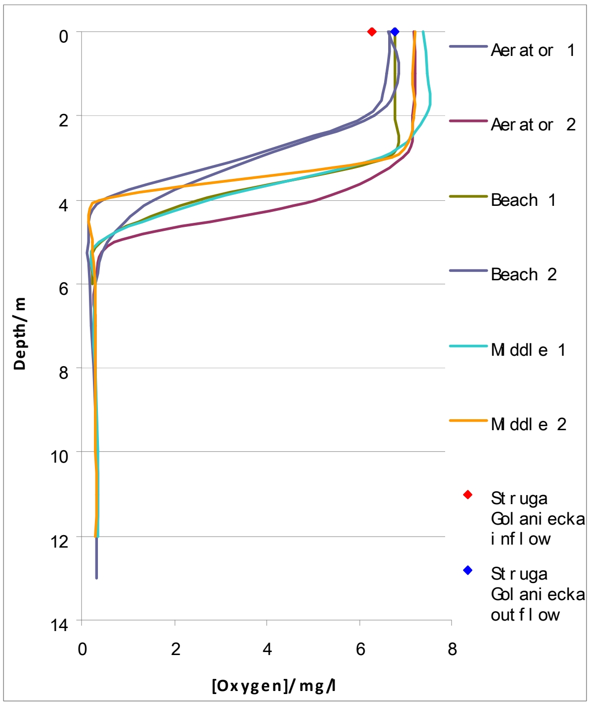

Fig. 3. Vertical distribution of dissolved oxygen at 6 sampling sites

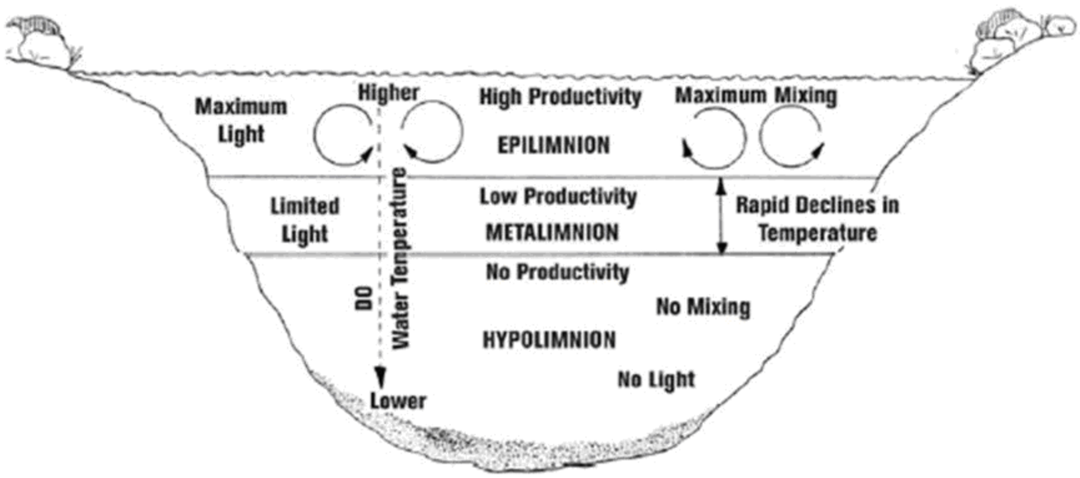

Fig. 4. Thermal stratification in a lake (Kolbe 2005)

The patterns of temperature in the vertical profile (see fig. 4 for thermal stratification) of the sampling sites were similar to those of dissolved oxygen (figs. 2 and 3). Across the lake, the epilimnion layer (0-4m depth on average) has an average temperature around 20˚C. Oxygen content is between 6-8mg/l (60-80% O_2) at depth up to 2m and decreased sharply between the depth of 2 and 5m. All 6 measured sites are highly anoxic by 5m depth but aerator 1 and middle

2 sites are highly anoxic by 4m depth. At depths of 4m to 8m from surface, the temperature decreased dramatically, from 20˚C to 5˚C, indicating the metalimnion, or thermocline which is characterized by anoxic conditions. The hypolimnion (>8m depth) was characterized by highly anoxic condition (0.16mg/l – 0.3mg/l O_2; 1.66 - 2.9% O_2). Struga Gołaniecka is a shallow river with less than 1m depth at the outflow and inflow sites, and their physical parameters lie within the range of the rest of the lake at surface level (figs. 2-3,5-6).

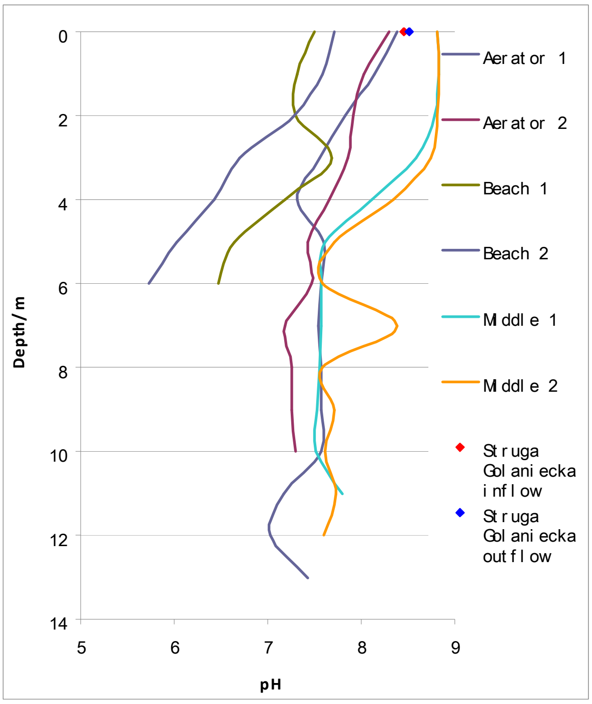

Fig. 5. Vertical distribution of pH at 6 sampling sites

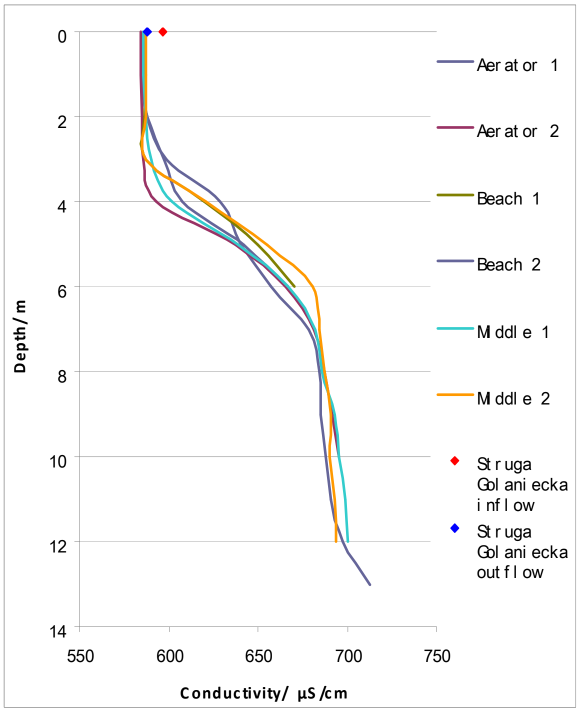

Fig. 6. Vertical distribution of conductivity at 6 sampling sites

The pH remained between the range of 6 and 8 at aerator 1, aerator 2, beach 1, middle 1 and middle 2 but at beach 2, the pH changed significantly, from pH 7 at surface to pH 5 at the bottom layer of 6m depth (fig. 5). This stratification of pH from the epilimnion to hypolimnion layer is likely the effect of a greater abundance of algae at the surface which removed carbon dioxide in the epilimnion layer. Previous study in the area by Messyasz (2000) reported that high concentration of calcium (>78.5mg Ca/L) resulted in the high buffering capacity of the water. Our conductivity measurements indicate that conductivity is high, between 584µS/cm and 758 µS/cm across all sites on the lake; with general pattern of increasing conductivity from epilimnion to hypolimnion (fig. 6), suggesting that greater amount of suspended organic matter at the lower layers due to the lack of aerobic decomposition of organic matter.

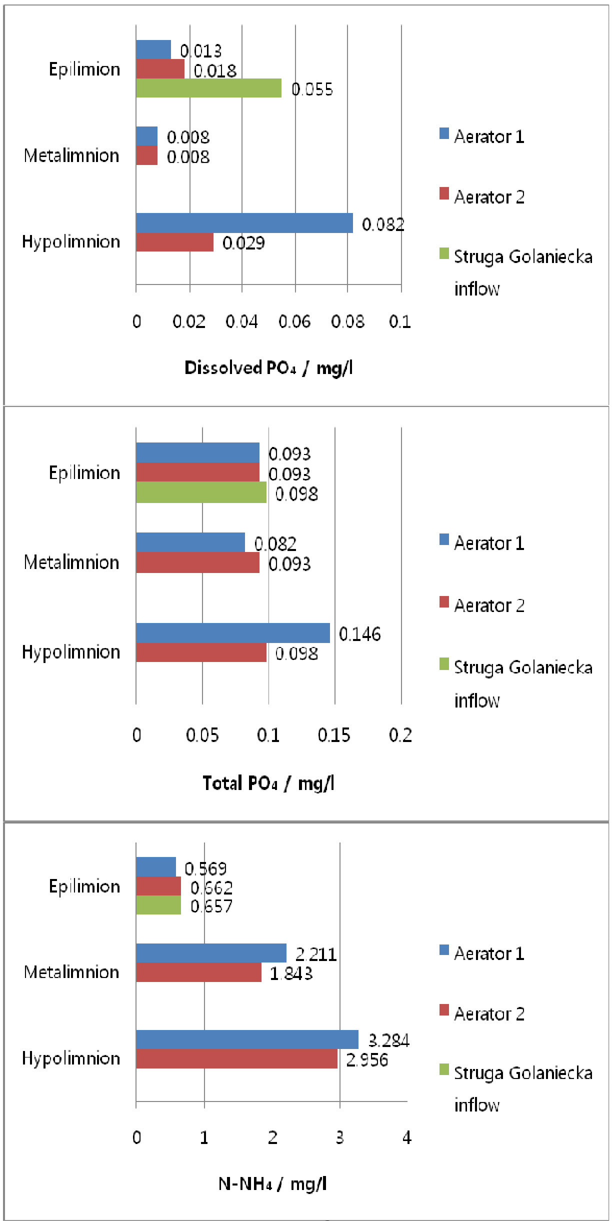

Fig. 7. Dissolved and total PO_4^{3-} and NH_4^+ concentration variation at aerators 1and 2 and Struga Gołaniecka inflow

The concentration of dissolved and total PO_4^{3-} is high at Struga Gołaniecka, suggesting that it is contributing to PO_4^{3-} load in the lake (fig. 7). The dissolved PO_4^{3-} concentration at aerator 1 is higher than at aerator 2 in the hypolimnion; likely due to the combined effects of better oxygenation at aerator 2 due to shallower depth while aerator 1 has deeper depth and poorer oxygenation at the lower layer. The total PO_4^{3-} at epilimnion is high at both aerator 1 and 2 but the dissolved PO_4^{3-} only contribute approximately 14% of the total PO_4^{3-}, corresponding to the presence of great amount of algae biomass in the epilimnion layer. At the hypolimnion layer, higher dissolved PO_4^{3-} concentration reflected the anoxic condition that did not favour biomass growth (44-70% of total PO_4^{3-} in dissolved form). The trend at all 3 sites showed increase in concentration of NH_4^+ from epilimnion to hypolimnnion, corresponding to the decrease in phytoplankton with increasing depth. As no NO_3^- or NO_2^- was found at aerator 1 or aerator 2 from epilimnion to hypolimnion layer, anaerobic decomposition of sediment layer is likely an important contributor to hypolimnion NH_4^+.

The observations of the physical parameters above suggest that the aerators are not very effective at oxygenating the hypolimnion layer during summer time. We have observed that the aerator rotation based on 5 day-average was 11.2 rotations per minute at aerator 1 and 9.2 rotations per minute at aerator 2, which may not generate sufficient energy to mix the water column sufficiently to aerate the metalimnion and hypolimnion.

Table 2. Comparison of 2008 and 2009 physical and chemical parameters

Year	**2008**	**2009**	**Trophic State***
Date	20th, July	20th, July	
Place	Aerator 1	Aerator 1	
Secchi disc (SD) transparency	0.9m	1m	Eutrophic
TSI (SD)	60.05	60.00	Eutrophic
Weather	Cloudy, rainy, huge rain on 19th	Cloudy with intermittent sun, windy	

* refer to table 1 for details on standard range and reference

We also compared the physical and chemical condition of Lake Durowskie based on data available from 2008 at aerator 1. The condition at aerator 1 remained eutrophic with a decline observed with respect to oxygenation. However, this single sample comparison is insufficient for any conclusions, particularly as heavy rain was observed the night before sampling in 2008 and this may have contributed to higher dissolved oxygen at the site. Additionally, 2 dominant species of cyanobacteria found at the site -*Limnothrix* sp. and *Planktothrix* sp. – are sensitive to flushing and as such, the abundance of cyanobacteria is lower after rain, which allows dissolved oxygen content to recover. Conductivity differences were also explanable by the anoxic condition at the hypolimnion while pH variation between 2008 and 2009 at depth up to 4m is explainable by rain forcing algae into the deeper parts of the lake and photosynthetic activities of these algae increased alkalinity at those depths although we expect that this effect is moderated by acid leached into the lake from the surrounding pine forest (fig. 8). The NH_4^+ concentration is higher at the metalimnion and hypolimnion layers in 2009 compared to 2008, corresponding with the poorer oxygen condition in those layers in 2009 compared to 2008 (fig. 9). The dissolved PO_4^{3-} concentration is significantly higher in 2008 compared to 2009 (T=6.2806, p= 0.0244, d.f.=4; fig. 10). This higher phosphate condition correspond to the higher algae biomass in 2008 compared to 2009 (fig. 11). The significant decrease in PO_4^{3-} in 2009 indicated that chemical intervantion which has begun in spring 2009 is successful at sedimenting PO_4^{3-}.

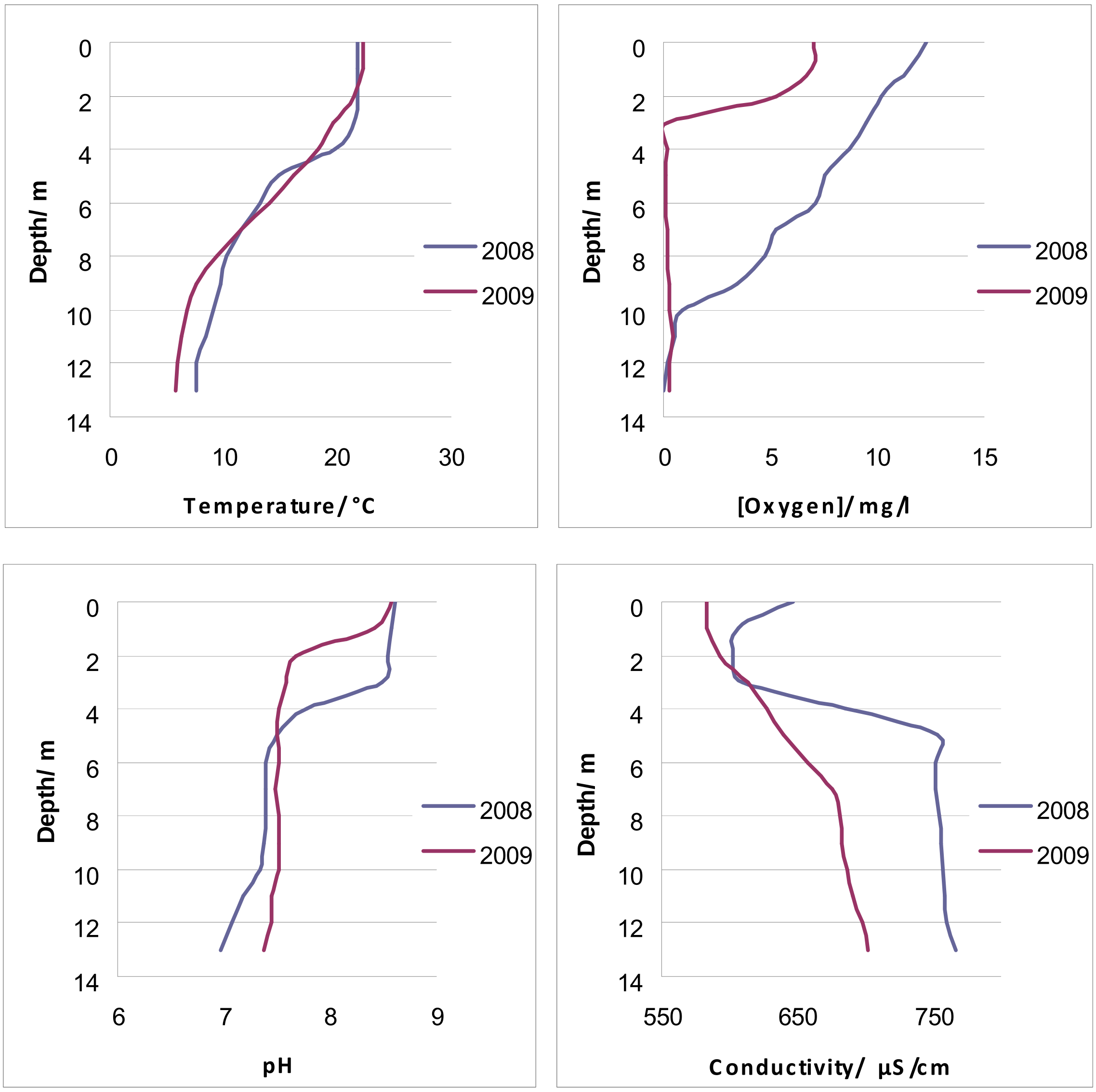

Fig. 8. Comparison of physical parameters for year 2008 and 2009

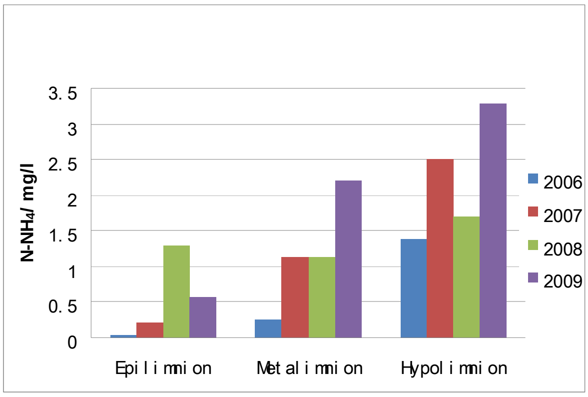

Fig. 9. [NH_4^+] variation between 2006 – 2009

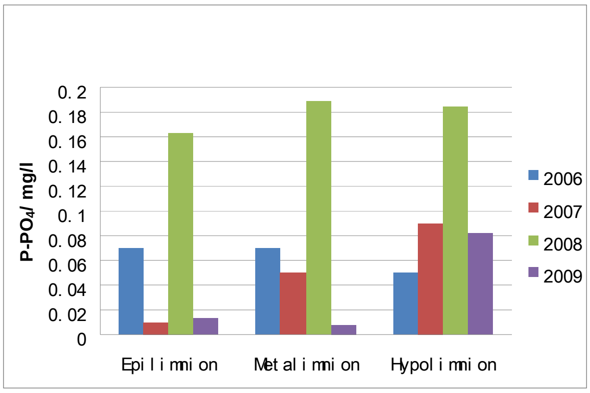

Fig. 10. [PO_4^{3-}] dissolved variation between 2006-2009

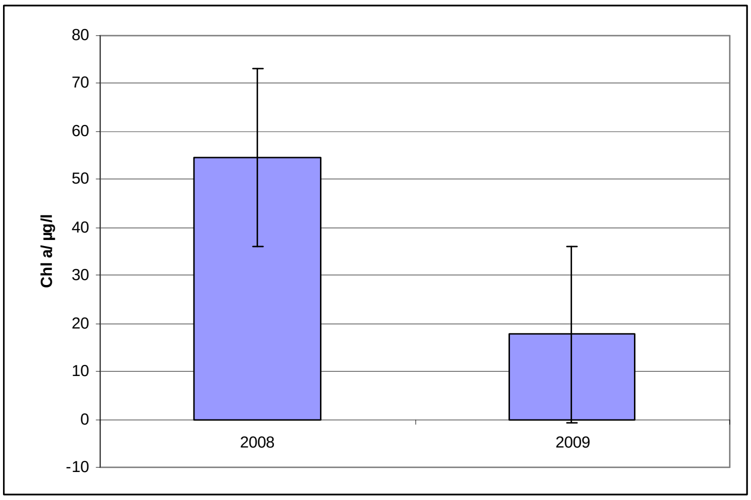

Fig. 11. Comparing algae biomass using surrogate indicator chlorophyll *a*

These changes observed from 2008 to 2009 further indicated that the aerator has not managed to improve the physical parameters at the local site, particularly in relation to oxygen content but PO_4^{3-} and algae biomass conditions have improved at aerator 1 due to chemical intervention.

3. 2. Phytoplankton community in the pelagic zone

We found 73 species of phytoplanktons from 7 groups in Lake Durowskie (table 3; fig 12; refer to annex 1 for species list). Cyanoprokaryota and Dinophyceae contribute most to the species diversity in the lake followed by Bacillariophyceae (fig. 12) but based on overall abundance and biovolume, Cyanoprokaryota is the dominant group in Lake Durowskie (fig. 13). The highest phytoplankton count ($1.541*10^{12}$cells/l) and the highest phytoplankton biovolume were on beach

1 (2.58 mg/l). The lowest phytoplankton count ($2.782*10^9$) was at aerator 2 but the lowest phytoplankton biovolume was found at aerator 1 (41.472mg/l). We observed the domination of 2 species of Cyanoprokaryota, which are *Planktrothrix agardhii* and *Aphanizomenon flos-aquae* (both in terms of quantity and biovolume) at aerator 2 and beach 1. *A. flos-aquae* particularly thrives under high NH_4^+ content, which is the current state of the lake. Although Dinophyceae *Ceratium hirundinella* dominates aerator 1 by biovolume (due to their high biovolume per cell), Cyanoprokaryota is the dominant species by abundance (fig. 13; refer to annex 4 for species list & annex 5 for characteristics of these species).

Table 3. Species discovered in Lake Durowskie according to group

Group	Number of species
Cyanoprokaryota	18
Bacillariophyceae	12
Chlorophyceae	19
Cryptophyceae	6
Dinophyceae	4
Euglenophyceae	3
Chrysophyceae	5

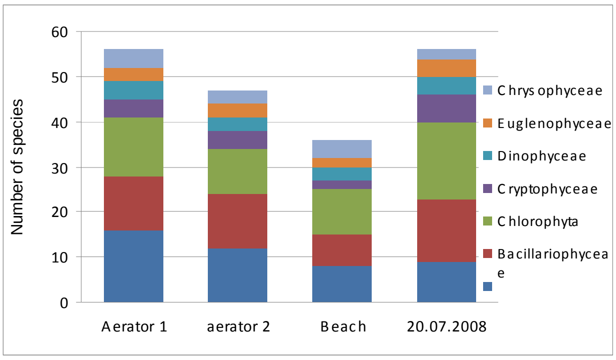

Fig. 12. Number of phytoplankton species at each site

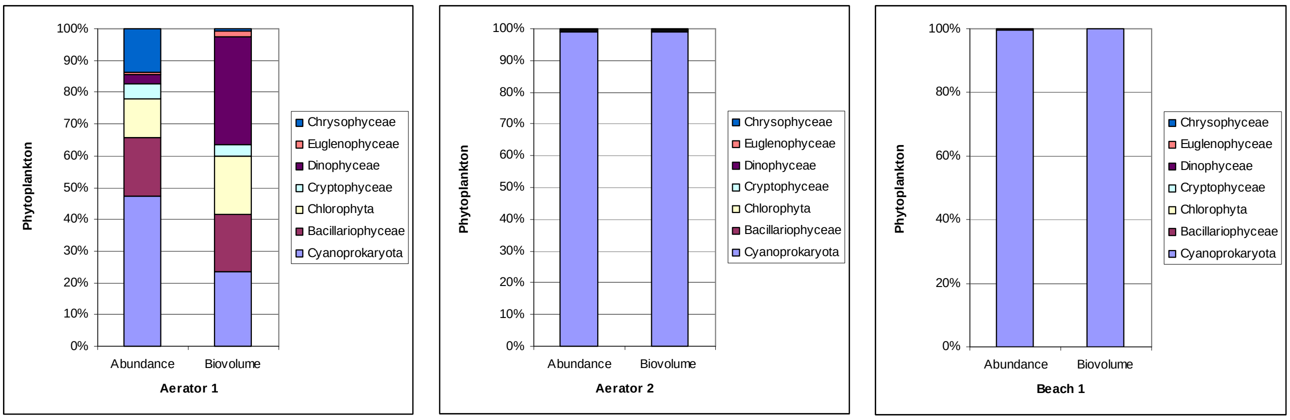

Fig. 13. Quantity and biovolume of algae at aerator 1, aerator 2 and beach 1

Table 4. Mixed Trophic Index of Phytoplankton

Station	Mixed trophic index	Trophic state	Standard scale	Reference
Aerator 1	16	Eutrophic	> 3	Round, 1981
Aerator 2	26	Eutrophic	> 3	Round, 1981
Beach	9	Eutrophic	> 3	Round, 1981
2008	9.67	Eutrophic	> 3	Round, 1981

According Round's scale (1981) for phytoplankton, Durowskie Lake is eutrophic. We also compared the results of 2009 to that of 2008 and observed a greater Cyanoprokaryota biovolume near Aerator 1 in 2008 (fig. 14). *Limnothrix redekei* (Cyanoprokaryota) was the dominant species in 2008 at aerator 1 and is replaced by *Ceratium hirundinella* (Dinophyceae) in 2009. Chlorophyta increased their participation in the total biovolume in 2009 compared to 2008 although Cyanoprokaryota remained as overall the dominant group in both years. This agreed with the general anoxic conditions of the metalimnion and hypolimnion layers which are unfavourable to most phytoplanktons but tolerable to Cyanoprokaryota. The species composition in both years is comparable (fig. 12).

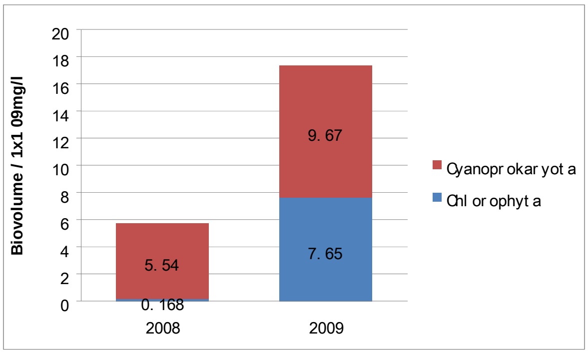

Fig. 14. Cyanoprokaryota and Chlorophyta biovolume comparison between 2008 and 2009

Based on these observations of phytoplankton diversity and abundance, Cyanoprokaryota is still dominant at the lake but aerator 1 has experienced a slight increase in green algae and dinoflagelletes in 2009 compared to 2008.

3.3. Periphytic species presence

A total of 20 epilithic diatom species was found at the 4 sites where periphytons were sampled (refer to annex 3), but only two dominant species are described here. *Encyonema minutum* is dominant at sites 1 and 2 while *Achnanthes lanceolata* is dominant at sites 3 and 4 (figs. 15 and 16). *Achnanthes lanceolata* indicates eutrophic conditions while *Encyonema minutum* is a ubiquitous species.

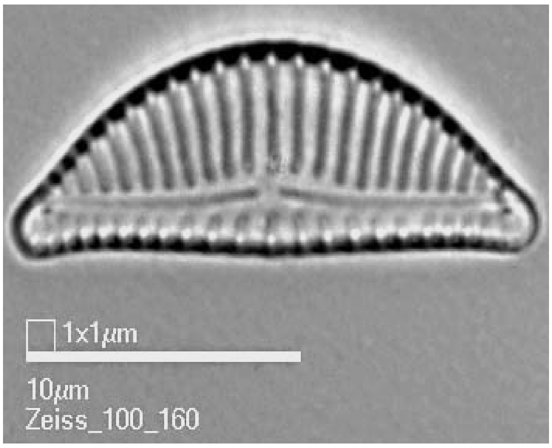

Fig. 15. Dominant species ***Encyonema minutum*** at periphyton sites 1 and 2

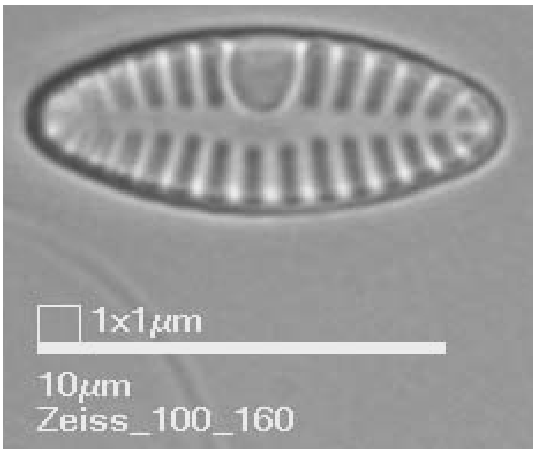

Fig. 16. Dominant species - ***Achnanthes lanceolata*** at periphyton sites 3 and 4

Based on the diatom species found, the water quality index was calculated using the Multimetric Diatom Index. The results indicated that the water quality at all sites is moderate (fig.17).

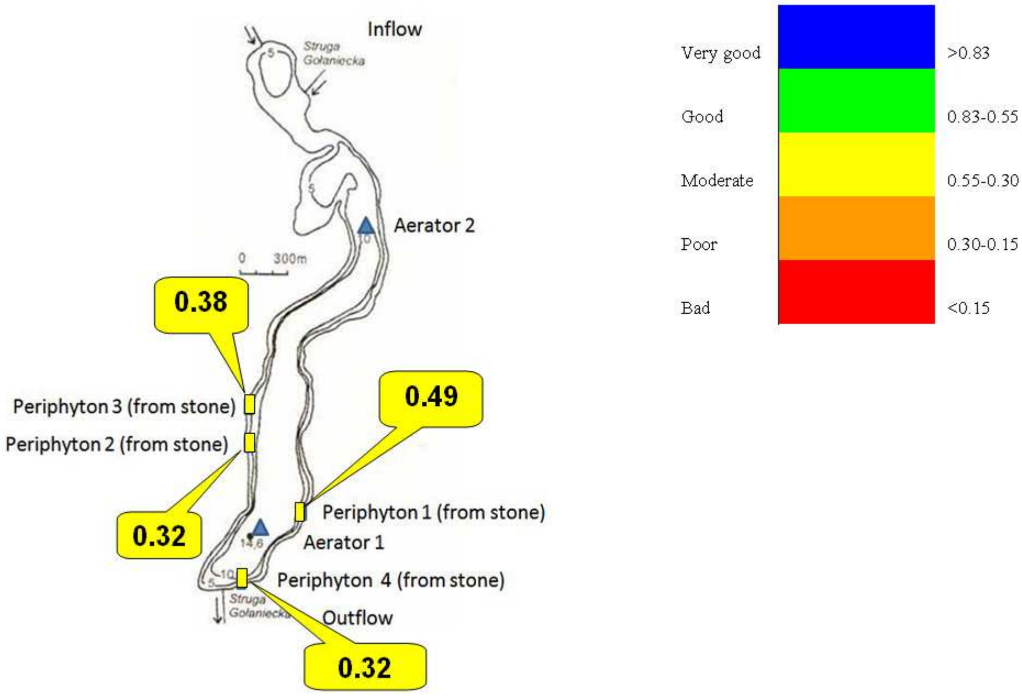

Fig. 17. Comparison of periphyton diatoms using epilithic diatom index at 4 sites

4. Conclusion

The lake is still eutrophic based on physical, chemical and phytoplankton parameters. The combined observations of the physical parameters at the 6 lake sites suggest that the aerators are not very effective at oxygenating the hypolimnion layer during summer time as the wind is insufficient in the area to generate enough energy to aerate the lake. The comparison findings further indicated that the aerator has not managed to improve the physical parameters even at a local scale, particularly in relation to oxygen content but PO_4^{3-} and algae biomass conditions have declined at aerator 1 due to effective chemical intervention. Cyanoprokaryota is still dominant at the lake but aerator 1 has experienced a slight increase in green algae and dinoflagelletes in 2009 compared to 2008. Finally, water quality based on diatom analysis indicated that water quality is moderate. The tentative results suggest that in general, there are no significant observable changes up to now since the introduction of aerator 1. The effects of biomanipulation on phytoplankton abundance are also not visible within the limits of this analysis.

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Annex 1. List of phytoplanktons found in pelagic zone

Cyanoprokaryota		**Cryptophyceae**
Anabaena flos-aquae	*Fragilaria crotonensis*	*Cryptomonas erosa*
Aphanizomenon flos-aquae	*Fragilaria ulna*	*Cryptomonas gracilis*
Aphanizomenon isatschenkoi	*Fragilaria ulna var. angustissima*	*Cryptomonas marssonii*
Aphanocapsa grevillei	*Navicula cincta*	*Cryptomonas opata*
Aphanocapsa incerta	*Placoneis gastrum*	*Rhodomonas globosa*
Cyanogranis ferruginea	*Asterionella formosa*	*Rhodomonas minuta*
Gloeocapsa minuta	**Chlorophyta**	**Dinophyceae**
Gloeocapsa turgida	*Ankistrodesmus falcatus*	Ceratium hirundinella
Limnothrix lauterbornii	*Characium angustum*	Peridiniopsis berolinense
Limnothrix redekei	*Chlamydomonas globosa*	Peridiniopsis cuningtoni
Lyngbya hieronymusii	*Chlamydomonas reinhardtii*	Peridinium cinctum
Lyngbya limnetica	*Coelastrum reticulatum*	**Euglenophyceae**
Oscillatoria gracilis	*Cosmarium exiguum*	*Colacium vesiculosum*
Oscillatoria limnetica	*Cosmarium regnellii*	*Euglena pisciformis*
Oscillatoria pseudogeminata	*Dictyosphaerium pulchellum*	*Phacus orbicularis*
Phormidium granulatum	*Monoraphidium contortum*	**Chrysophyceae**
Phormidium tenue	*Monoraphidium komarkovae*	*Erkenia subaequciliata*
Planktothrix agardhii	*Pteromonas angulosa*	*Dinobryon divergens*
Spirulina major	*Monoraphidium minutum*	*Dinobryon cysts*
Bacillariophyceae	*Oocystis lacustris*	*Dinobryon elegantissimum*
Amphora ovalis	*Scenedesmus longispina*	*Dinobryon bavaricum*
Cyclotella atomus	*Scenedesmus maxima*	
Fragilaria construens	*Scenedesmus quadricauda*	
Cyclotella meneghiniana	*Tetraedron minimum*	
Cyclotella operculata	*Tetraedron triangulare*	
Cyclotella radiosa	*Treubaria schmidlei*	

Annex 2. Species composition and quantity of organisms.

Volume	Species	Aerator 1		Aerator 2		Beach	
		count [cells/l]	biovolume [mg/l]	count [cells/l]	biovolume [mg/l]	count [cells/l]	biovolume [mg/l]
	Cyanoprokaryota						
1256	*Anabaena flos-aquae*		0	120000	0.151		0
1962,5	*Aphanizomenon flos-aquae*	9526666	1.869	935280500	1.83	9,18212E+11	1,80
491	*Aphanizomenon isatschenkoi*		0		0	360000	0.177
165	*Aphanocapsa grevillei*	112000	0.018	184000	0.03		0
165	*Aphanocapsa incerta*	480000	0.079		0		0
130	*Cyanogranis ferruginea*	112000	0.015	1040000	0.135		0
165	*Gloeocapsa minuta*	112000	0.018		0		0
165	*Gloeocapsa turgida*	112000	0.018		0		0
314	*Limnothrix lauterbornii*	1505000	0.473	237037500	74,43	120000	0.038
314	*Limnothrix redekei*		0	11920000	3.743	11520000	3.617
5273	*Lyngbya hieronymusii*	540000	2.847	80000	0.422		0
177	*Lyngbya limnetica*	2022666667	0.358	2930000	0.519		0
314	*Oscillatoria gracilis*	560000	0.176	120000	0.038	120000	0.038
314	*Oscillatoria limnetica*	3702000	1.162	2400000	0.754	4512000	1.417
314	*Oscillatoria pseudogeminata*	90000	0.028		0		0
490	*Phormidium granulatum*	1105333,333	0.542	271359	1.32	120000	0.059
490	*Phormidium tenue*	112000	0.055		0		0
1256	*Planktothrix agardhii*	1570000	1.972	986745000	1.23	6,20169E+11	7,78
314	*Spirulina major*	112000	0.035		0		0
SUM		1319966667	9.667	2449216333	3.28	1,5384E+12	2,58
	Bacillariophyceae		0		0		0
5024	*Amphora ovalis*	56000	0.281	120000	0.603	120000	0.603
200	*Cyclotella atomus*	112000	0.022	80000	0.016		0
2270	*Cyclotella meneghiniana*	30000	0.068	320000	0.726		0

254	*Cyclotella operculata*	86000	0.002	80000	0.02		0
1250	*Cyclotella radiosa*	436000	0.545	960000	1.2	732000	0.915
1450	*Fragilaria construens*	56000	0.081	120000	0.174	120000	0.174
1100	*Fragilaria crotonensis*	56000	0.062	120000	0.132	1884000	2.072
1360	*Fragilaria ulna*	3228666667	4.391	4460000	6.066	3035030000	4,13
2340	*Fragilaria ulna var. angustissima*	830000	1.942	900000	2.106	1272000	2.976
750	*Navicula cincta*	112000	0.084	120000	0.09	120000	0.09
750	*Placoneis gastrum*	60000	0.045		0		0
409	*Asterionella formosa*	60000	0.025		0		0
SUM		5122666667	7.568	7280000	11.133	3039278000	4,13
	Chlorophyta		0		0		0
1105	*Ankistrodesmus falcatus*		0		0	120000	0.133
960	*Characium angustum*	86000	0.083		0		0
267	*Chlamydomonas globosa*	112000	0.029	80000	0.021	10720000	2.862
540	*Chlamydomonas reinhardtii*	183000	0.099	800000	0.432		0
3791	*Coelastrum reticulatum*	30000	0.114		0		0
3791	*Cosmarium exiguum*	90000	0.341		0	216000	0.819
162	*Cosmarium regnellii*	168000	0.027	360000	0.058	120000	0.019
4822	*Dictyosphaerium pulchellum*	1020000	4.918		0		0
176	*Monoraphidium contortum*		0		0	1068000	0.188
3860	*Monoraphidium komarkovae*		0		0	120000	0.463
728	*Pteromonas angulosa*	560000	0.408	720000	0.524		0
100	*Monoraphidium minutum*		0	360000	0.036		0
2554	*Oocystis lacustris*	562000	1.435		0		0
490	*Scenedesmus longispina*		0	80000	0.039		0
490	*Scenedesmus maxima*	224000	0.110	160000	0.078		0
490	*Scenedesmus quadricauda*	1133333333	0.056	120000	0.059	156000	0.076
111	*Tetraedron minimum*	122000	0.014	6832000	0.758	288000	0.032
120	*Tetraedron triangulare*	112000	0.013	6776000	0.813	120000	0.014
940	*Treubaria schmidlei*	0	0		0	144000	0.135

SUM		3382333333	7.647	16288000	2.784	13072000	4.742
	Cryptophyceae				0		0
1620	*Cryptomonas erosa*	336000	0.544	560000	0.907		0
1540	*Cryptomonas gracilis*		0	80000	0.123		0
1270	*Cryptomonas marssonii*	60000	0.076		0		0
1994	*Cryptomonas opata*	112000	0.223	80000	0.160		0
706	*Rhodomonas globosa*		0		0	120000	0.085
706	*Rhodomonas minuta*	814000	0.575	160000	0.113	2304000	1.627
SUM		1322000	1.419	880000	2.784	2424000	1.711
	Dinophyceae		0		0		0
46740	Ceratium hirundinella	131000	6.123		0		0
9200	Peridiniopsis berolinense	66000	0.607	120000	1.104	240000	2.208
9000	Peridiniopsis cuningtoni	360000	3.240	220000	1.98	372000	3.348
21840	Peridinium cinctum	192000	4.193	500000	10.92	96000	2.097
SUM		749000	14.163	840000	14.004	708000	7.653
	Euglenophyceae		0		0		0
1766	*Colacium vesiculosum*	112000	0.198	160000	0.283		0
3926	*Euglena pisciformis*	56000	0.220	120000	0.471	96000	0.377
4006	*Phacus orbicularis*	56000	0.224	120000	0.481	120000	0.481
SUM		224000	0.642	400000	1.234	216000	0.858
	Chrysophyceae		0		0		0
65	*Erkenia subaequiciliata*	3002000	0.195	2400000	0.156	18048000	1.173
183	*Dinobryon divergens*	570000	0.104	520000	0.095	192000	0.035
310	*Dinobryon cysts*	168000	0.052	120000	0.037	120000	0.037
183	*Dinobryon elegantissimum*	80000	0.015		0		0
1115	*Dinobryon bavaricum*		0		0	1512000	1.686
SUM		3820000	0.366	3040000	0.288	19872000	2.931
total sum		2781966667	41.472	2477944333	3,32	1,54147E+12	2,58

Annex 3. List of diatom species found in periphyton analysis

Species name
Achnanthes clevei
Achnanthes lanceolata
Amphora ovalis
Cocconeis pediculus
Cocconeis placentula
Cyclotella radiosa
Cyclotella stelligera
Cymbella affinis
Cymbella sinuata(Reimeria)
Diatoma vulgare
Encyonema minutum
Fragilaria crotonensis
Gomphonema gracile
Gomphonema olivaceum
Navicula capitata
Navicula lanceolata
Nitzschia recta
Synedra acus
Synedra ulna(Fragilaria)
Tabellaria flocculosa

Annex 4. Dominant and subdominant species of phytoplankton in Lake Durowskie

Site		Aerator 1	Aerator 2	Beach	Comparing with 2008
By quantity of each species	**Dominantes**				
	Aphanizomenon flos-aquae		37,70%	59,57%	
	Erkenia subaequciliata	10,79%			
	Fragilaria ulna	11,60%			
	Limnothrix redekei				
	Phormidium granulatum		10,95%		
	Planktothrix agardhii		39,82%	40,23%	
	Subdominantes				
	Lyngbya limnetica	7,27%			
	Limnothrix lauterbornii		9,57%		
By biovolume	**Dominantes**				
	Aphanizomenon flos-aquae		55,30%	69,70%	
	Ceratium hirundinella	14,80%			
	Dictyosphaerium	11,90%			

	pulchellum				
	Fragilaria ulna	10,60%			
	Planktothrix agardhii		37,30%	30,13%	
	Limnothrix redekei				47,30%
	Subdominantes				
	Lyngbya hieronymusii	6,87%			
	Peridiniopsis elpatiewskyi				6,60%
	Pseudanabaena limnetica				5,27%

Annex 5. Characteristic of dominants in Durowskie Lake based on functional groups of phytoplankton by Reynolds (1997)

***Aphanizomenon flos-aquae* - codon H_1**

- Habitat: dinitrogen – fixing Nostocaleans
- Tolerances: low carbon
- Sensitivities: low phosphorus
- Can’t occur below 8^0C
- Can occur in low concentration of nitrogen, silica and carbon

***Planktrothrix agardhii* – codon S_1**

- Habitat: turbid, mixed layers, enriched , exposed and generally shallow lakes at most latitudes
- Sensitivities: flushing
- Can occur below 8^0C
- Doesn’t like low concentration of phosphorus and nitrogen.
- Can occur in low concentration of silica and carbon.

***Limnothrix redekei* – codon S_1**

- Dominant species only in sample from last year
- Habitat: turbid mixed layers
- No sensitivities
- Can occur below 8^0C
- Doesn’t like low concentration of phosphorus and nitrogen

- Tolerates low concentrate of silica and carbon.

***Ceratium hirundinella* – codon L_M**

- Habitat: summer epilimnion in eutrophic lakes
- Actually it's rather eutrophic and may be associated equally with Cyanoprokaryota
- Tolerances: very low carbon
- Sensitivities: mixing
- Doesn't occur below 8^0C
- Doesn't like low concentration of phosphorus and nitrogen
- Can occur in low concentration of silica and carbon.