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Research Article

**PHYTOPLANKTON-NUTRIENT RELATIONSHIPS DURING THE  
EARLY SPRING AND THE LATE AUTUMN IN A SHALLOW AND  
POLLUTED RESERVOIR**

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**Abstract**

The reservoir where the studies were carried out was originated by modification of an old oxbow lake of the Vistula River. The most important sources of inflowing waters are industrial waters from "Puławy Fertilizer Factory". The highest variability of concentration, was  $\text{NH}_4^+\text{-N}$  and also  $\text{Cl}^-$ ,  $\text{N}_{\text{tot}}$ , and  $\text{PO}_4^{3-}$ . Some significant correlations between chemical properties of water and algae (especially green algae and diatoms) were found, which suggested that this phytoplankton was mainly responsible for the biogeochemical cycles in the shallow, strongly polluted reservoir. Another interesting phenomenon was the statistically positive correlation between the density of cyanobacteria and potassium, which suggested that it may play an important role in their abundance.

**INTRODUCTION**

Major efforts have been made to understand the dynamics of ecosystems by focusing on the chemical nature of organisms with respect to their environment and on the quantitative role of organisms in the major cycles of chemical elements. Both topics have become an important goal in ecological research (Cole 1983). The nutrients, as the abiotic part of ecosystems, can enter, leave,

and re-enter living systems repeatedly. Nutrients and minerals are continually recycled through biotic communities.

Autochthonous processes are significant in the cycles of nutrients in "closed" freshwater ecosystems (*e.g.* lakes). However, allochthonous nutrients play a more important role in reservoirs. Industrial waters, containing pollutants, can accelerate an increase in nutrient levels in reservoirs, and in this way modify their environments. In this case they enlarge a pool of macroelements, which are included into biogeochemical cycles. Autotrophic microorganisms, manufacturing macroelements in their own cells, introduce them into bio-cycles. Because planktonic algae are characterised by short life cycles, their dynamic growth respond quickly to changes in environment. They could be specific indicators of environmental change.

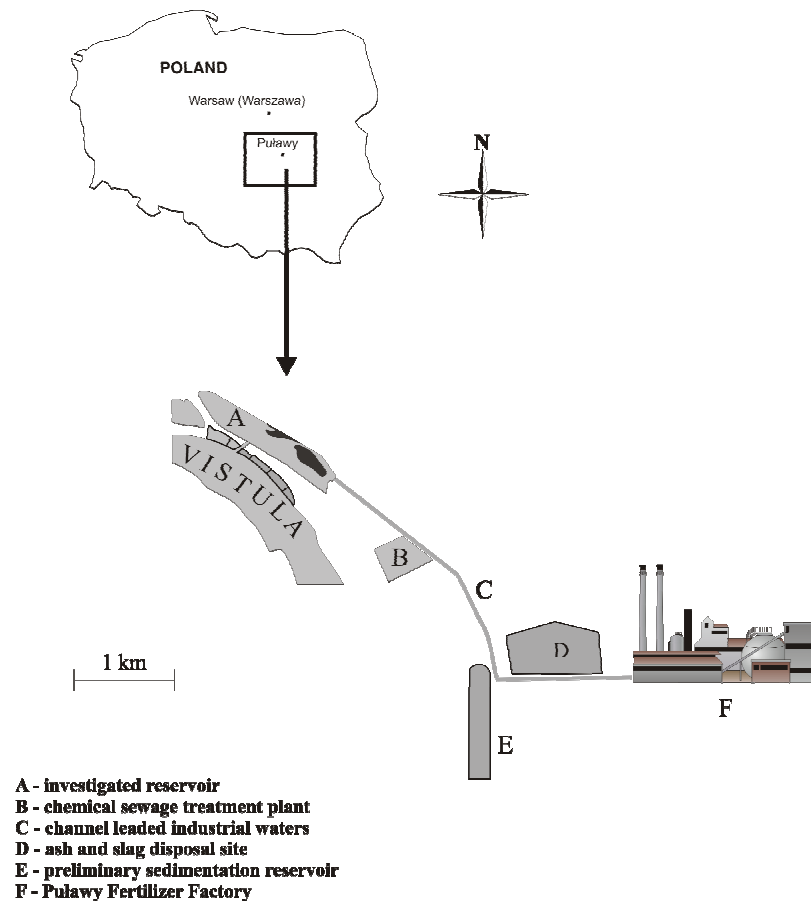
Particular groups of algae can respond differently to the same environmental factors, however each population shows its own response to change. This is the reason why the structure of phytoplankton, its density and contribution of particular species in relation to total biomass is variable. Every trophic system is characterized by specific seasonal change. The seasonal succession of phytoplankton, especially in lakes, is controlled by a combination of physical, chemical, and biological variables (Sommer *et al.* 1986). Reynolds (1984) defined three categories of agents affecting the dynamics of phytoplankton: (a) the autogenic succession due to the adaptation and response of species to highly stable physical conditions of the environment (thermal stratification), the depletion of nutrients, and the interaction between organisms (*i.e.* the feeding), (b) the allogenic direction, when changes in biocenosis are induced by permanent changes in the water column due to external physical disturbances (*i.e.* accidental water mixing, floods, storms), (c) the reversion (return) as a result of transient disturbances succeeded by the return of the system to its initial condition.

The investigations were carried out in a small reservoir that is permanently supplied with an industrial effluent containing pollutants. In contrast to large reservoirs, wide variability and unpredictability characterize smaller ones. The aim of this study was to determine the relationship between the development of planktonic algae and the chemical composition (biogeochemical cycle) of a shallow, polluted reservoir.

### **Study area**

The reservoir we investigated is located in southeastern Poland, Europe (21°54'E, 51°28'N, near the town of Puławy). The reservoir is an industrial water collector of the Fertilizer Factory and was formed in the late 1960s from an ox-bow lake of the Vistula River by its technical modification. The

maximum area amounts to about 28 ha but changes depending on the water level. The mean depth averages 1 m and the capacity is about  $279 \times 10^3 \text{ m}^3$ . The waters inflowing to the reservoir have different origins. There are natural ground water inflows, influxes from neighbouring ox-bow lakes of the Vistula River, industrial water discharged from biological and chemical sewage treatment plants of the “Puławy Fertilizer Factory”, heated water from a thermoelectric power station, cooling water with a high concentration of salts, leachates from an ash and slag disposal site, and municipal sewages of the town of Puławy. All water sources are introduced into the channel where they are mixed, and then they flow into the reservoir (Fig. 1). The nearest point of sewage discharge is situated about 1 km from the reservoir.



**Fig. 1.** Localization of the investigated reservoir.

## MATERIAL AND METHODS

Samples for analyses were collected from the surface layer of water at four sites on the reservoir (Fig. 2). Samples were taken every month from February to April, from October to December 2000, and in April 2001. Two sampling sites (1, 3) were located where the reservoir was stagnant and the other two sites (2, 4) in zones of fast water flow (inflow to reservoir and outflow to the Vistula River).

Samples for quantitative analyses of algae were preserved with Lugol's and concentrated by sedimentation (Starmach 1955). Phytoplankton density was calculated according to Lund *et al.* (1958). Non-fixing samples for taxonomic analyses were taken, too.

The chemical analysis of water was according to Hermanowicz *et al.* (1999). Flame photometry was used to determine  $K^+$ ,  $Na^+$ ,  $Ca^{++}$  and the AAS method for  $Mg^{++}$ . A colorimetric method was used for soluble  $PO_4^{-3}$  (blue molybdate - phosphate complex).  $NH_4^+-N$  was analysed according to the method by Nessler and  $NO_3^- -N$  as a colour compound with phenyldisulphonic acid. Chloride anions were determined by the argentometric method (titration with  $AgNO_3$ ). Total nitrogen was given as a sum of Kjeldahl nitrogen forms plus  $NO_3^- -N$ .

The program Statistica 5.0 was used to determine the correlation coefficients and ARSTAT (Agricultural University in Lublin) for multifactor variance analysis.

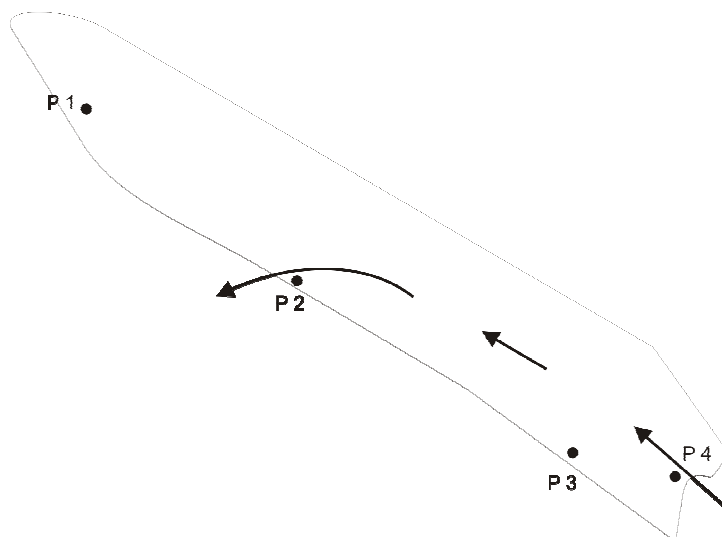


Fig. 2. Sampling points P1-P4.

**Table 1**

Some chemical properties of water.

Parameter	Minimum	Maximum	Average ( $\bar{x}$ )	SD	V*
pH	6.9	8.1	7.5	-	-
Conductivity [ $\mu\text{S}/\text{cm}$ ]	320	1245	700	348	0.50
[ $\text{mg l}^{-1}$ ]					
Na <sup>+</sup>	41.4	108.2	77.0	20.0	0.26
K <sup>+</sup>	6.0	13.9	8.7	2.6	0.29
Ca <sup>++</sup>	57.1	122.2	78.2	19.2	0.25
Mg <sup>++</sup>	3.2	15.6	10.9	3.8	0.35
NH <sub>4</sub> <sup>+</sup> -N	0.06	5.2	0.8	1.3	1.56
NO <sub>3</sub> <sup>-</sup> -N	1.5	9.0	3.8	1.6	0.41
N <sub>tot.</sub>	2.8	29.5	13.1	7.0	0.67
PO <sub>4</sub> <sup>-3</sup>	0.09	1.9	0.6	0.4	0.53
Cl <sup>-</sup>	80.0	212.0	171.8	50.5	0.71

\*V – coefficient of variation;  $V = \frac{SD}{\bar{x}}$

## RESULTS

### Water chemistry

Chemical element concentrations, pH and EC varied during the sampling period (Table 1). The highest concentrations were Na<sup>+</sup>, Cl<sup>-</sup>, and Ca<sup>++</sup>. Sodium and calcium, on the contrary were the most stable constituents among the chemical elements (see the coefficients of variation in Table 1). Water with salts concentrated by evaporation from the cooling towers was mixed with other industrial waters and introduced without purification to the reservoir. Other sources of Na<sup>+</sup> and Ca<sup>++</sup> were leachates from an ash and slag disposal site. The highest change of concentration, although in a narrow range of values, was NH<sub>4</sub><sup>+</sup>-N, and subsequently for Cl<sup>-</sup>, N<sub>tot.</sub>, and PO<sub>4</sub><sup>-3</sup>. All the investigated parameters showed statistically significant differences and only sodium was different between sampling sites of the reservoir (Table 2).

**Table 2**

Variance analysis - statistical significant differences of water parameters.

Parameter	Factor	Fo	P(F>Fo)	P
pH	term	3.793	0.0128	*
EC	term	373.621	0.0000	**
Na <sup>+</sup>	term	908.400	0.0000	**
Na <sup>+</sup>	point	3.600	0.0338	*
K <sup>+</sup>	term	186.729	0.0000	**
Ca <sup>++</sup>	term	984.195	0.0000	**
Mg <sup>++</sup>	term	243.382	0.0000	**
NH <sub>4</sub> <sup>+</sup> -N	term	22.146	0.0000	**
NO <sub>3</sub> <sup>-</sup> -N	term	6.872	0.0006	**
N <sub>tot.</sub>	term	32.253	0.0000	**
PO <sub>4</sub> <sup>-3</sup>	term	44.668	0.0000	**
Cl <sup>-</sup>	term	150.680	0.0000	**

### Algal analysis

Diatoms (especially centrics) and green algae (*Chlorococcales*) were the most abundant phytoplankton during autumn in the whole reservoir. At sites where the water was stagnant, there were also numerous euglenophytes and cyanobacteria. During spring, the most abundant phytoplankton at sites 1, 3, and 4 was diatoms. They were small centrics diatoms living as single cells or joined in chains. However, at site 2 the most numerous phytoplankters were euglenophytes. Among centrics species: *A. ambigua*, *A. subarctica*, *A. granulata*, *Cyclotella meneghiniana*, *C. atomus*, *C. radiosa*, *Stephanodiscus binderanus*, *S. hantzschii*, *S. minutulus*, *Thalassiosira* cf. *guillardii*, were noted very often.

Green algae were represented, e.g. *Actinastrum hantzschii*, *Dictyosphaerium pulchellum*, *Micractinium pusillum*, *Pediastrum biradiatum*, *P. boryanum*, *P. duplex*, *Scenedesmus acuminatus*, *S. cf. intermedius* (= *Desmodesmus intermedius*) *S. opoliensis* (= *Desmodesmus opoliensis*). Among euglenophytes the most abundant were: *Euglena acus*, *E. deses* fo *intermedia*, *E. geniculata* and among cyanobacteria *Oscillatoria tenuis*, *Woronichinia compacta* (full list of algal species is in appendix).

Most of the recognized algal species were recorded as common, cosmopolitan, and present in eutrophic, polluted and brackish waters. Some of them were characteristic of water rich in organic pollutants.

**Table 3**

Significant coefficients of correlation between algae density and water parameters.

Parameter	Total algae density		Density of diatoms		Density of green-algae	
	Correlation coefficients	Level of significance	Correlation coefficients	Level of significance	Correlation coefficients	Level of significance
pH	0.751	0.032	0.754	0.031	0.712	0.048
EC	0.883	0.004	0.839	0.009	0.808	0.015
Na <sup>+</sup>	0.890	0.003	0.848	0.008	0.836	0.010
Ca <sup>++</sup>	0.899	0.002	0.907	0.002	0.861	0.006
N <sub>tot</sub>	0.918	0.001	0.904	0.002	0.864	0.006
PO <sub>4</sub> <sup>-3</sup>	0.791	0.019	-	-	0.737	0.037
Cl <sup>-</sup>	-0.926	0.001	-0.935	0.001	-0.905	0.002
Density of cyanoprokaryotes						
K <sup>+</sup>	0.809	0.015				

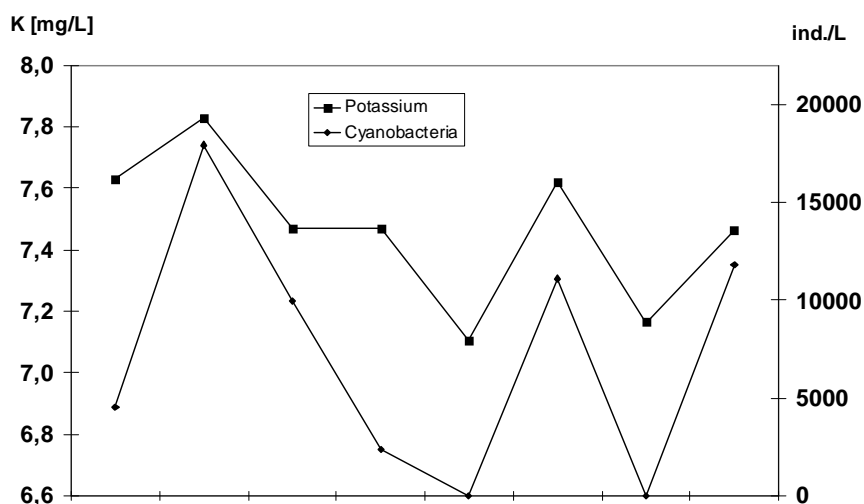
The phytoplankton density did not show statistically significant differences between sampling sites, ( $F_0=38.017$ ;  $P(F>F_0)=0.0086$ ), which meant that differences in chemical parameters between sampling sites did not influence the development of algae.

The total density of phytoplankton showed strong significant correlations with some water parameters. Most statistical correlations were positive and only chloride had a negative correlation (Table 3). Only the density of diatoms and green algae was strongly correlated with a majority of the physico-chemical parameters. The density of diatoms showed positive correlations with pH, conductivity, Na<sup>+</sup>, Ca<sup>++</sup>, total nitrogen but a negative correlation with Cl<sup>-</sup>. They did not show correlations with PO<sub>4</sub><sup>-3</sup>. The density of green-algae showed positive correlations with pH, conductivity, Na<sup>+</sup>, Ca<sup>++</sup>, total nitrogen, PO<sub>4</sub><sup>-3</sup> and a negative correlation with Cl<sup>-</sup>.

Cyanobacteria had a significant positive correlation with K<sup>+</sup> (Fig. 3). Euglenophytes did not show significant correlations with the investigated parameters.

## DISCUSSION

The large variability of the measured chemical parameters was due to the heterogeneity of industrial water and the number of pollutant sources. The domination of Na<sup>+</sup>, Cl<sup>-</sup>, and Ca<sup>++</sup> was a reflection of the industrial effluents from the "Puławy Fertilizer Factory". In spite of the constant loading of particular chemical constituents, their variable concentrations over time suggested that discharges of contaminants were dynamic and contributed different portions to



**Fig. 3.** Correlation between density of cyanobacteria and K concentration.

the water inflow. Thus, the reservoir was very dynamic and an unstable environment for living organisms. Additionally, the time of total water exchange was very short (from hours to days) which can have unexpected effects on phytoplankton.

Thus, the reservoir is very homogenous in respect of chemical composition of water but simultaneously strongly diversified in the time. It testifies to very good mixing of water within the precincts of object and rapid water exchange.

Biochemical cycles of particular nutrients are connected with each other because biomass of all organisms is composed of the same components. The fundamental composition of organisms is the atomic ratio C:N:P=106:16:1. In lakes polluted by sewage the optimal ratio of N:P is variable and ranges from 17:1 to 10:1, but when the ratio of N:P is <10 or >17 then N or P are limiting, respectively (Wojciechowski 1987). Permanent influx of phosphorus and nitrogen from the outside of the reservoir meant that both nutrients were available throughout the year. Absorption of nutrients by planktonic algae was possible during the entire growth period.

A strong positive correlation between the density of algae and phosphate suggested that P might be the factor which limited the growth of algae, especially the *Chlorococcales* (the greens showed a strong positive correlation with phosphate). This relationship demonstrates the essential role of planktonic assemblages, especially *Chlorococcales*, in the cycling of phosphorus in the

small and high polluted reservoir. The numerous presences of some species of green algae, e.g. *Desmodesmus opoliensis*, were correlated with the availability of nutrients. It has been reported that polymorphism of *Desmodesmus* (formerly *Scenedesmus*) in freshwater ecosystems might be coincident with seasonal environmental changes (Trainor 1998). Some species are able to produce a "succession" of phenotypes or morphs. *Desmodesmus* can form morphs with colonies with long spines and multiple bristles. Presence of spines and bristles may indicate an increase in nutrient uptake (Trainor 1993). The rate of phosphate uptake by living organisms is rapid, so the cycling of phosphorus is rapid as well. The complete cycle of P in lakes ranges from 5 to 10 days, in ponds from 2.5 to 10.5 days, and in the epilimnion of lakes only a few minutes (Wojciechowski 1987). Cells of algae very easily lose P (Lean and Nalewajko 1976). Ten minutes after the death of algal cells, the inorganic phosphorus is released. After 30 minutes 12% is released, and after 24 hours 50-60% of the total phosphorus is transformed into phosphates (Pliński 1999). However, phosphates are consumed by living organisms very quickly. Replacement can occur in 10 minutes. The bio-circulation of phosphorus is the fastest of the chemical elements. The fast cycle of phosphorus was responsible for the numerous presence of minute species, which belong to "r" strategists.

Because the reservoir we studied is shallow, the cycle of phosphorus was different than in stratified reservoirs. Weak solubility of orthophosphates in the warm, oxygenated epilimnion of deep reservoirs causes the settling into the hypolimnion and eventually in the sediments, where it might be absorbed by clay minerals or precipitate as insoluble compounds of iron, calcium and aluminium. Re-entry of phosphorus from the sediments is rather slow and release from the iron compounds is possible only under anaerobic conditions, which occur at the bottom of many reservoirs. Phosphates can return to the upper layers during the spring and autumn overturn or during floods. In polymictic reservoirs phosphate might return from the sediment to the water column more often, but at the same time, every circulation causes oxygenation of surface sediment layers and stops the release of available forms of phosphorus. In the reservoir we investigated there was a permanent influx of phosphates, which was constantly available for uptake by algae. We don't know if phosphorus which originates outside the shallow reservoir plays a more important role for the planktonic assemblages than phosphorus "returning" from the sediments. Maybe yes because it is present and available during the whole year, however this problem needs more careful studies. The differences in the P cycle in the investigated reservoir and deeper reservoirs might be connected with the lower release from the sediments. Many algae, especially cyanobacteria, are able to undergo "luxury consumption" of phosphorus during

periods when its concentration is disproportional and high in comparison to other nutrients, culminating in P accumulating as a reserve in the cells, and using P during periods of deficits but here the deficits do not exist.

A large portion of phosphorus retention is taken by calcium ions if they are co-precipitated with phosphate chemically stable, insoluble compounds, hydroxyapatites, in sediments. Also precipitation of calcium carbonate, within biological decalcification of water, is able to decrease the concentration of phosphates during the co-precipitation process (Koschel *et al.* 1983, Koschel 1997). Calcium can also stimulate the development of algae. In alkaline water with a high concentration of  $\text{Ca}^{++}$  the cyanobacteria have optimal conditions for growth. There were no statistically significant correlations between cyanobacteria and calcium concentration in the reservoir. However, such a relationship was observed between calcium concentrations and the density of diatoms and green algae. The ecological role of calcium in the regulation of species composition and their abundance is rather relatively minor or it is unclear (Reynolds 1984).

Nitrate is an important growth stimulating nutrient for algae. Algae (other than cyanobacteria) are not able to fix atmospheric nitrogen, and have a preference for the uptake of nitrate-nitrogen, nitrite-nitrogen or ammonium ions. The largest demand for fixed nitrogen was demonstrated by the green-algae, followed by cyanobacteria and it was lowest for diatoms. In alkaline water ammonium-nitrogen is taken up rapidly by algae and in acid water it is nitrate-nitrogen. Many algae (*e.g.* green algae) can also use urea, as the source of nitrogen.

The seasonal variability of nitrogen availability in aquatic ecosystems is very closely connected with seasonal growth of phytoplankton. In the temperate zone, seas and freshwater reservoirs, the concentration of nitrates decreases after the spring bloom. In summer, the plankton is a little smaller, which results in a renewal of nitrogen reserves and utilized later during the autumn diatom bloom. In winter, when phytoplankton is very low, the reserves of dissolved nitrate increase. During the spring overturn, the diatoms will take advantage of the nitrate present in the water column. There is not such seasonality in the reservoir of "Puławy Fertilizer Factory" because the influx of nitrogen is continuous. Interestingly, there is no significant correlation between algae and nitrate- or ammonium-nitrogen. However, there was a significant correlation between the density of algae and total nitrogen. A possible relationship between phytoplankton and nitrogen might have the following explanation. Regular supply of nitrate-nitrogen stimulates the growth and development of diatoms, and a limited supply of ammonium-nitrogen could affect the growth and development of green-algae. The absence of seasonality causes perturbation in

the annual cycle of algae, which is present in non-polluted reservoirs. Thus, when diatoms and green-algae “normally” appear they develop in parallel. We believe that both forms of nitrogen are fixed in parallel, that is nitrate-nitrogen by diatoms and nitrate-nitrogen and ammonium-nitrogen by green-algae. In this case both forms of nitrogen are incorporated parallel into the bio-cycles irrespective of the season. The increase in concentration of nitrate- and ammonia-nitrogen (from spring and summer) in the “naturally” functioning reservoirs is accompanied by the development and dominance of diatom or green algae assemblages. However, only *Bacillariophyceae* were grouped in the area of high  $\text{NO}_3^-$ -N values. *Chlorophyceae* frequently manifested dependence on  $\text{NH}_4^+$ -N (Wilk-Woźniak and Kosiński 2001).

Another interesting, statistically significant correlation is the relationship between cyanobacteria and  $\text{K}^+$ . Some investigators have shown the demand for potassium by blue-greens, e.g. *Oscillatoria rubescens* needs 10 mg/L of  $\text{K}^+$  for optimal growth (Staub 1961). In this reservoir *Oscillatoria tenuis* was noted, which suggested relations with some chemical parameters similar to *O. rubescens*.

A significant negative correlation between the density of algae, especially diatoms and green algae, was  $\text{Cl}^-$  and it was probably a salinity factor. However, a high concentration of chlorides does not have an effect on the abundance of euglenophytes, such as *Euglena deses*, which is resistant to an elevated salt content. The presence of brackish water diatoms is also unaffected by a high salt content.

The large and permanent influx of nutrients is an important stress factor because the variability is huge and unpredictable. That is the reason why in this reservoir phytoplankton is the dominant species as represented by the “r” strategy. They are tolerant to a very rapidly changing environment. The algal cells are small and numerous, reproduce quickly and have a short generation time. In the reservoir we investigated, nutrients incorporated by algae into their cells are recycled into bio-cycles faster and in greater amounts than in other reservoirs.

The statistical correlations demonstrated that in shallow, polymictic reservoirs which are heavily polluted by allochthonous substances such as diatoms and green algae can make significant contributions to the bio-cycling of nutrients.

Future investigations should be undertaken to study relationships between the appearance and development of particular algal species and the different forms of nitrogen. This would document the importance of the nitrogen cycle for certain dominant species.

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## Appendix

List of algal species found during the spring and autumn investigations.

SPRING	AUTUMN
<p>CYANOBACTERIA <i>Oscillatoria tenuis</i> Agardh</p> <p>CHRYSOPHYTES <i>Synura uvella</i> Ehr. emend. Korš.</p> <p>BACILLARIOPHYCEAE <i>Amphora ovalis</i> (Kütz.) Kütz. <i>Anomooneis sphaerophora</i> (Ehr.) Pfitz. <i>Asterionella formosa</i> Hass. <i>Aulacoseira ambigua</i> (Grun.) Simon <i>A. granulata</i> (Ehr.) Ralfs (Ehr.) Simonsen <i>A. subarctica</i> (O. Müll.) Haworth <i>Caloneis amphibia</i> (Bory) Cl. <i>Cyclostephanos dubius</i> (Fricke) Round <i>C. invisitatus</i> (Hohn) Theriot, Stoermer &amp; Håkansson, <i>Cyclotella atomus</i> <i>Cyclotella meneghiniana</i> Kütz. <i>C. pseudostelligera</i> <i>C. radiosa</i> <i>C. stelligera</i> Cl. et Grun. (in Van Heurck) <i>Cymatopleura solea</i> (Bréb.) W. Sm. <i>Diatoma tenuis</i> Ag. <i>Diatoma vulgare</i> Bory <i>Fragilaria ulna</i> var. <i>acus</i> (Kütz.) Lange-Bertalot <i>Melosira varians</i> Ag. <i>Nitzschia acicularis</i> (Kütz.) W.Sm. <i>N. sigmoidea</i> (Nitzsch) W. Sm. <i>Rhoicosphenia abbreviata</i> (C. Ag.) Lange-Bertalot <i>Stauroneis phoenicentron</i> Ehr. <i>Stephanodiscus alpinus</i> Hust. <i>S. binderanus</i> (Kütz.) Krieger <i>S. hantzschii</i> Grun. (in Cl. &amp; Grunow) <i>S. minutulus</i> (Kütz.) Cl. &amp; Möller <i>Thalassiosira guillardii</i> Hasle <i>T. pseudonana</i> Hasle &amp; Heimdal <i>T. weissflogii</i> (Grun.) Fryxell &amp; Hasle</p> <p>EUGLENOPHYTA <i>Euglena acus</i> Ehr. <i>E. deses</i> fo. <i>intermedia</i> Klebs <i>E. ehrenbergii</i> Klebs <i>E. geniculata</i> Duj. em. Schmitz <i>E. spirogyra</i> Ehr. <i>E. viridis</i> Ehr. <i>Phacus curvicauda</i> Swir. <i>Trachelomonas planctonica</i> Swir.</p> <p>CHLOROPHYCEAE <i>Crucigenia tetrapedia</i> (Kirchn.) W. &amp; G.S. West <i>Dictyosphaerium pulchellum</i> Wood 1872 <i>Pediastrum boryanum</i> (Turp.) Menegh. <i>Pediastrum tetras</i> (Ehr.) Ralfs <i>Scenedesmus acuminatus</i> (Lagerh.) Chod. (Lagerh.) Chod. <i>Scenedesmus obtusus</i> Meyen <i>Scenedesmus opoliensis</i> Richt. 1896 (<i>Desmodesmus opoliensis</i> (P. Richt) Hegew. comb. nova) <i>Scenedesmus quadricauda</i> Turp. (Bréb.) sensu Chod.</p> <p>CONJUGATOPHYCEAE <i>Closterium moniliferum</i> (Bory) Ehr. ex Ralfs</p>	<p>CYANOBACTERIA <i>Anabaena planctonica</i> Brunth. <i>Aphanothece</i> sp. <i>Microcystis aeruginosa</i> (Kütz.) Kütz. <i>M. wesenbergii</i> (Kom.) Kom. in Kondr. <i>Woronichinia compacta</i> (Lemm.) Kom. et Hindák</p> <p>BACILLARIOPHYCEAE <i>Anomooneis sphaerophora</i> (Ehr.) Pfitz. <i>Asterionella formosa</i> Hass. <i>Aulacoseira ambigua</i> (Grun.) Simon <i>A. granulata</i> (Ehr.) Ralfs (Ehr.) Simonsen <i>A. subarctica</i> (O. Müll.) Haworth <i>Cyclostephanos dubius</i> (Fricke) Round <i>C. invisitatus</i> (Hohn) Theriot, Stoermer &amp; Håkansson, <i>Cyclotella meneghiniana</i> Kütz. <i>C. stelligera</i> Cl. et Grun. (in Van Heurck) <i>Cymatopleura solea</i> (Bréb.) W. Sm. <i>Fragilaria crottonensis</i> Kitt. <i>Fragilaria ulna</i> var. <i>acus</i> (Kütz.) Lange-Bertalot <i>Melosira varians</i> Ag. <i>Nitzschia sigmoidea</i> (Nitzsch) W. Sm. <i>Stauroneis phoenicentron</i> Ehr. <i>Stephanodiscus alpinus</i> Hust. <i>S. binderanus</i> (Kütz.) Krieger <i>S. hantzschii</i> Grun. (in Cl. &amp; Grunow) <i>S. minutulus</i> (Kütz.) Cl. &amp; Möller <i>Thalassiosira guillardii</i> Hasle <i>T. pseudonana</i> Hasle &amp; Heimdal <i>T. weissflogii</i> (Grun.) Fryxell &amp; Hasle</p> <p>EUGLENOPHYTA <i>Euglena deses</i> fo. <i>intermedia</i> Klebs <i>E. spirogyra</i> Ehr. <i>E. viridis</i> Ehr.</p> <p>CHLOROPHYCEAE <i>Actinastrum hantzschii</i> Lagerh. <i>Crucigenia tetrapedia</i> (Kirchn.) W. &amp; G.S. West <i>Dictyosphaerium ehrenbergianum</i> Näg. <i>Microactinium pusillum</i> Fres. <i>Pediastrum biradiatum</i> Meyen <i>P. boryanum</i> (Turp.) Menegh. <i>P. duplex</i> Meyen <i>Lagerheimia citriformis</i> (Snow) Collins <i>Scenedesmus acuminatus</i> (Lagerh.) Chod. (Lagerh.) Chod. <i>Scenedesmus intermedius</i> (<i>Desmodesmus intermedius</i>) <i>Scenedesmus opoliensis</i> Richt. 1896 (<i>Desmodesmus opoliensis</i> (P. Richt) Hegew. comb. nova) <i>Scenedesmus quadricauda</i> Turp. (Bréb.) sensu Chod. <i>Tetraedron caudatum</i> (Corda) Hansg.</p>