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NITROGEN AND PHOSPHORUS COMPOUNDS IN LAKE PLUSZNE

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ZWIĄZKI AZOTOWE I FOSFOROWE W JEZIORZE PLUSZNYM

Badaniami objęto Jezioro Pluszne, jeden z największych (903,3 ha) i najgłębszych (52 m) zbiorników Pojezierza Olsztyńskiego. Jezioro to znajduje się około 6 km na wschód od Olsztynka, na 53°35'9"N i 20°24'5"E w dorzeczu Marózka – Łyna – Pregoła. W wodach Jeziora Plusznego fosfor ogólny zawierał się w przedziale od 0,014 mg P/dm^3 do 0,488 mg P/dm^3. Wyższe jego wartości notowano w naddennych warstwach wód. W strukturze fosforu ogólnego przez większą część okresu badawczego przeważała forma organiczna (występująca w wodach zbiornika w zakresie od 0,006 do 0,256 mg P/dm^3), co jest zjawiskiem typowym dla jezior eutroficznych. Zawartość azotu ogólnego w wodach Jeziora Plusznego wahała się w zakresie od 0,83 mg N/dm^3 do 3,73 mg N/dm^3. O ogólnej ilości związków azotowych w całej masie wód jeziora decydowała głównie forma organiczna stanowiąca od 60 do 99% jego składu (0,35 mg N/dm^3 do 2,79 mg N/dm^3). Koncentracje azotu mineralnego w tym akwenie zmieniały się od 0,058 mg N/dm^3 do 0,837 mg N/dm^3. Spośród mineralnych form azotu przez większą część roku najwyższe wartości osiągał azot azotanowy(V). Powodem postępującej eutrofizacji tego jeziora jest nadmierna rekreacja, coroczny wzrost liczby turystów i kąpiących się w jego wodach, rozwój ośrodków turystycznych na jego obrzeżach, a także wsi Pluski i Zielonawo. Ze względu na niepowtarzalne walory krajobrazowe i bogactwo przyrodnicze powinno ono podlegać ochronie, aby ingerencja człowieka nie wpływała na dalsze pogarszanie się stanu czystości jego wód.

Summary

The studies were carried out in Lake Pluszne which is one of the largest (903.3 ha) and deepest (52 m) lakes in the Olsztyńskie Lakeland. The lake can be found approximately 6 km east of the town of Olsztynek, at 53°35'9"N and 20°24'5"E, in the drainage basin of the Marózka – Łyna – Pregoła Rivers. Total phosphorus content in the waters of Lake Pluszne ranged from 0.014 mg P/dm^3 to 0.488 mg P/dm^3. Higher concentrations of total phosphorus were noted in the near bottom waters. In the whole study, the dominant form of total phosphorus was organic, which was measured in the range from 0.006 to 0.256 mg P/dm^3. Such phenomenon is typical for eutrophic lakes. Total nitrogen in Lake Pluszne waters oscillated between 0.83 mg N/dm^3 and 3.73 mg N/dm^3. The dominant organic form accounted for 60 to 99% (0.35 mg N/dm^3 to 2.79 mg N/dm^3) of the total nitrogen. The mineral nitrogen concentrations varied between 0.058 mg N/dm^3 and 0.837 mg N/dm^3 and for most of the year the highest content revealed the nitrate nitrogen(V). The reason for the ongoing eutrophication is the excessive recreation, annual growth of the number of tourists and swimmers, development of the leisure centers on the lake shores as well as of Pluski and Zielonawo villages. The unique landscape and richness of the natural environment in the lake's vicinity are the reasons for its protection that would prevent the water (quality) from further deterioration.

INTRODUCTION

It is commonly thought that the main driving element for eutrophication of lakes is phosphorus, while nitrogen and carbon only to a small extent provided that photosynthesis is intensive. These elements, next to potassium, sodium and microelements, are indispensable for the growth of plants and animals. Phosphorus compounds are responsible for transfer and storage of energy while nitrogen is the main component of proteins.

Nutrients in aquatic ecosystems are subject to various transformations known as matter circulation [1, 7]. One of the main processes is the uptake of the dissolved mineral forms of nitrogen and phosphorus by the primary producers for photosynthesis and the subsequent transformation with eventual re-introduction to the circulation. Additionally, nutrients in the form of organic compounds, suspensions or complexes with iron, aluminium and calcium, settle and accumulate in the bottom deposits.

Because of the key role nitrogen and phosphorus play in lakes eutrophication, studies of the trophic condition focus on the concentration and seasonal variability of these elements in the water.

The aim of the present studies was to determine the degree of Lake Pluszne eutrophication on the basis of the content of nutrients (nitrogen and phosphorus).

MATERIAL AND METHOD

The studies were conducted in Lake Pluszne which is one of the largest (903.3 ha) and deepest (52 m) (Tab. 1) reservoirs in the Olsztyńskie Lakeland. The lake is situated approximately 6 km east of the town of Olsztynek (Fig. 1), at 53°35'9"N and 20°24'5"E, in the Marózka – Łyna – Pregoła Rivers drainage basin.

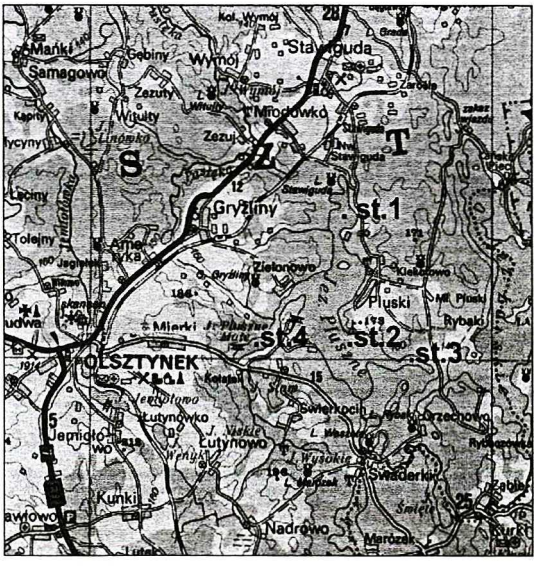

Fig. 1. The map of research area

Table 1. Detailed morphometric properties and the coefficient characteristic for Lake Pluszne [11]

Parameter	Value
Water table area [ha]	903.3
Maximum depth [m]	52.0
Mean depth [m]	14.9
Relative depth	0.0173
Depth index	0.29
Volume [thousand m^3]	134913.7
Maximum length [km]	8.75
Maximum width [km]	1.9
Elongation	4.3
Shoreline of the lake bowl [km]	30.25
Development of shoreline	2.84

The shape of the lake is irregular. A few sections can be distinguished: the northern – elongated, with the max. depth of 18 m, the middle – comprising the actual lake with the max. depth of 52 m, the eastern – very small, with the max. depth of 19.5 m and connected by a narrow inlet to the rest of the lake, and the south-western – a long and very narrow bay with the deepest spot at 16 m [11].

Lake Pluszne has one island with the area of 4.3 ha located on the latitude of the Pluski village and a few in-lake shallow spots in the middle section overgrown with reeds [20].

The south-western section of the lake receives water from a stream flowing out from the lake complex Staw – Niskie – Wysokie. Outflow from the lake which carries water to Lake Poplusz is localized at the south-eastern shore (Fig. 1).

The watershed is the area of 54.56 km^2 out of which 61.2% are large forests, 22.9% fields, 11.5% meadows, and as little as 1.1% the built-up land and 3.3% lakes [13].

On the eastern shore of Lake Pluszne lies Pluski village and on the western, near the inlet to the south-western bay, Zielonowo village. Both villages and the south-western lake edges are characteristic for extensive tourist and leisure building development (summer cottages, camping sites, leisure centers).

Examinations of the phosphorus and nitrogen compounds content in Lake Pluszne were conducted from 17 March 2005 when the lake was covered with 30-cm thick ice, until 7 November 2005. Four sampling stations were set over the deepest sites in each selected section of the lake' i.e., in the northern bay (St. 1) at 18 m depth, in the middle section (St. 2) at 52 m, in the eastern bay (St. 3) at 19.5 m, and in the south-western bay (St. 4) at 16 m.

Water for analyses was taken on each sampling site from 1 m under the surface and 0.5 m above the bottom. The content of individual forms of phosphorus and nitrogen was determined in accordance with the methods by Hermanowicz *et al.* [9].

RESULTS AND DISCUSSION

In Lake Pluszne waters total phosphorus oscillated between 0.014 mg P/dm^3 and 0.488 mg P/dm^3 (Fig. 2, 3). Higher concentrations were noted in the near bottom waters.

For most of the experiment total phosphorus was dominated by the organic form (occurring in the waters in the range from 0.006 to 0.256 mg P/dm^3) (Fig. 2, 3) which according to Lossow [12] and Zdanowski *et al.* [21] is typical for eutrophic lakes.

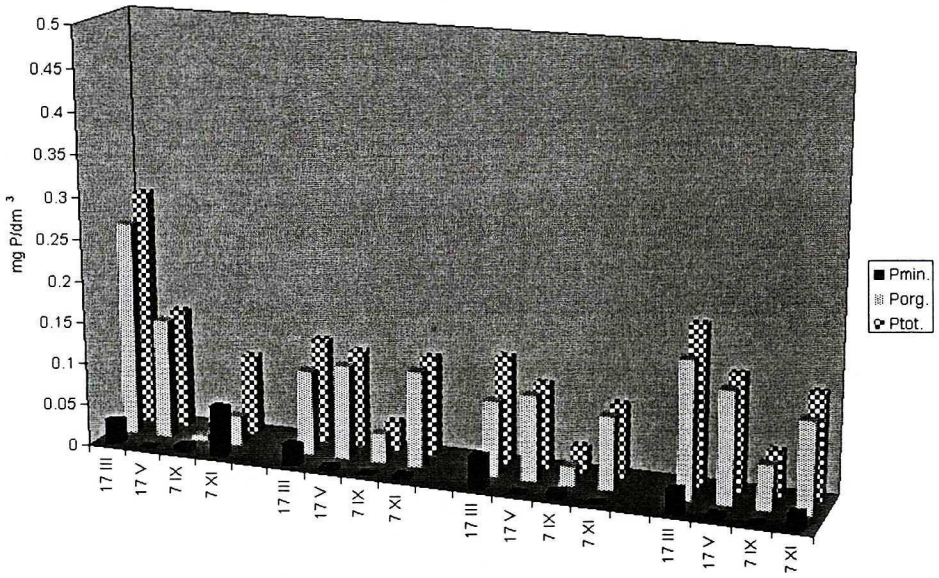

Fig. 2. Content of the phosphorus compounds in the surface water layers of Lake Pluszne

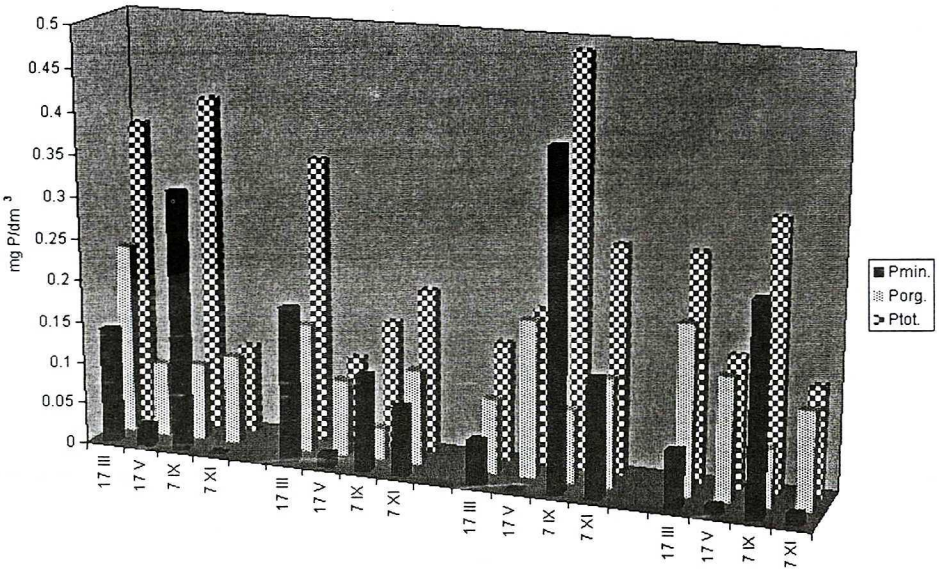

Fig. 3. Content of the phosphorus compounds in the near-bottom waters of Lake Pluszne

Mineral phosphorus in Lake Pluszne oscillated between 0.000 and 0.401 mg P/dm^3. Gawrońska [6] reports that in lakes with moderate trophic conditions phosphorus circulation is largely regulated by phytoplankton. The results obtained in Lake Pluszne confirm such thesis. In the surface water layers during the growing season (17 May and 7 September) phosphates were undetectable or occurred in trace amounts (Fig. 2, 3). The reason was the intensive production processes and algal uptake for photosynthesis. Moreover, the evidence is the values of other parameters, e.g. pH above 8.3, absence of free carbon dioxide, super oxygenation of the water (approx. 120% saturation) (17 May and 7 September). The near-bottom water was much richer in mineral phosphorus; the highest concentrations were determined in the peak of the summer stagnation (from 0.116 mg P/dm^3 (St. 2) to 0.401 mg P/dm^3 (St. 3)) (Fig. 3). Such phenomenon is related to internal feeding of the near-bottom layers with phosphates from detritus decay or from the sediment release in anaerobic conditions [5]. Gawrońska [7] and Tandyrak [19] share the opinion that circulation of phosphorus compounds in the lake is linked with iron transformations, although phosphates also bind with aluminium, manganese or calcium and precipitation in the bottom sediments in the form of insoluble phosphates. Phosphates bind with iron only when Fe/P ratio is higher then 1.8 or even 3.0 [3]. In Lake Pluszne this situation was not possible because iron was not detected in the lake waters. At oxygen deficits phosphorus is again released to the water. In the summer (7 September) in Lake Pluszne the near-bottom waters were anoxic [8] and phosphates increased.

According to the trophic status classification by Hillbricht-Ilkowska and Wiśniewski [10] which refers to the water transparency and total phosphorus abundance, Lake Pluszne is eutrophic whereas the division proposed by Patalas [17] puts the lake in the group of phosphorus-rich of the "poly" type.

Nitrogen is another very important element in eutrophication. In the waters of Lake Pluszne total nitrogen occurred in the amounts from 0.83 mg N/dm^3 to 3.73 mg N/dm^3 (Figs 4 and 5). Nitrogen compounds in the whole water mass were dominated by the organic form comprising from 60 to 99% (0.35 mg N/dm^3 to 2.79 mg N/dm^3). Like in the case of phosphorus, such regularity is typical for eutrophic lakes [12, 21].

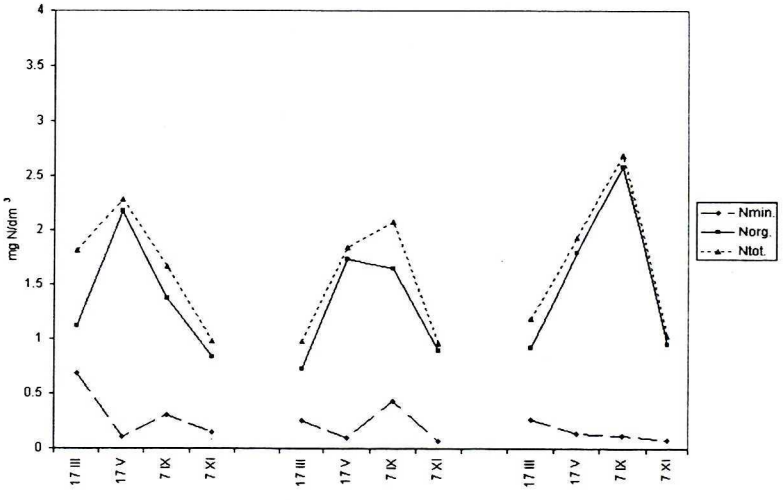

Fig. 4. Content of the nitrogen compounds in the surface water layers of Lake Pluszne

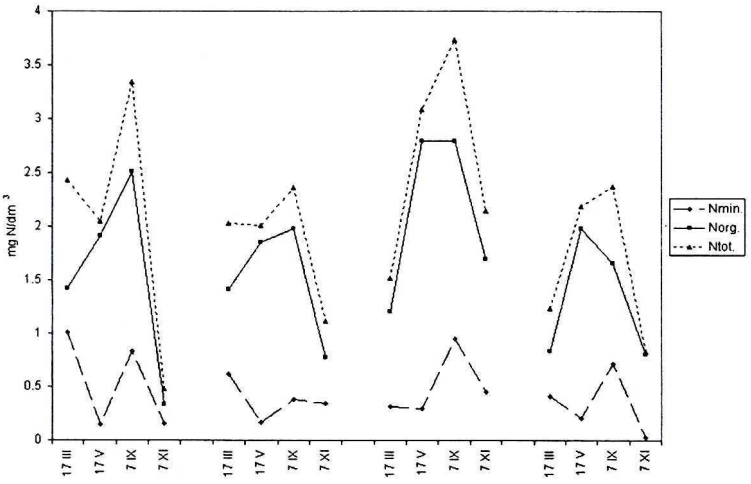

Fig. 5. Content of the nitrogen compounds in the near-bottom waters of Lake Pluszne

Mineral nitrogen in the lake varied between 0.058 mg N/dm^3 and 0.837 mg N/dm^3 (Tab. 2). Most of the year, nitrate nitrogen(V) was recorded for the highest values of all the mineral forms of nitrogen; the maximum in all the bays was measured in the winter (from 0.246 mg N/dm^3 (St. 2) to 0.679 mg N/dm^3 (St. 1)) (Tab. 2). One reason might be the intensive nitrification favored by good oxygenation of the water [7] as well as low content of iron and absence of manganese (toxic to the nitrifying bacteria even in low concentrations) [22]. Moreover, during winter this compound is less utilized for (stagnating) primary production. Spodniewska [18] comes up with the hypothesis that the basic form of nitrogen used up by phytoplankton is the nitrate nitrogen (V) although plants may assimilate the ammonium form. The results of the Pluszne examinations revealed that algae preferred the ammonium nitrogen. It was confirmed by the fact that in the growing season ammonium nitrogen in the surface waters – used up by the phytoplankton for photosynthesis – was not detected, additionally confirmed by the water super oxygenation, high pH and absence of CO_2. At the same time, the whole growing season nitrate nitrogen(V) was detected (Tab. 2).

Table 2. Content of the mineral forms of nitrogen in Lake Pluszne waters in 2005

Nitrogen [mg N/dm^3]		Ammonium				Nitrite				Nitrate			
		III	V	IX	XI	III	V	IX	XI	III	V	IX	XI
St. 1	surface	0.000	0.000	0.000	0.065	0.007	0.000	0.003	0.000	0.679	0.103	0.298	0.080
	bottom	0.433	0.053	0.731	0.074	0.016	0.002	0.014	0.000	0.563	0.088	0.089	0.080
St. 2	surface	0.000	0.000	0.000	0.012	0.005	0.000	0.005	0.006	0.246	0.097	0.429	0.050
	bottom	0.428	0.052	0.110	0.228	0.017	0.001	0.026	0.098	0.175	0.109	0.242	0.018
St. 3	surface	0.000	0.000	0.000	0.049	0.005	0.000	0.005	0.006	0.261	0.139	0.109	0.021
	bottom	0.000	0.175	0.833	0.400	0.004	0.017	0.009	0.000	0.306	0.103	0.106	0.047
St. 4	surface	0.241	0.000	0.000	0.000	0.005	0.000	0.005	0.000	0.291	0.254	0.053	0.012
	bottom	0.133	0.090	0.621	0.000	0.004	0.003	0.007	0.000	0.272	0.115	0.086	0.027

In the summer (7 September), in the near bottom waters the amounts of ammonium nitrogen were as high as 0.833 mg N/dm^3 (Tab. 2). The reason was ammonification which is a process of ammonium release to water. The favorable conditions were the anoxic conditions and elevated temperature. Intensive degradation of organic matter was accompanied by carbon dioxide increase to 55 mg CO_2/dm^3 and water pH reduction to 7.30.

Nitrate nitrogen (III) which is the transitional form occurring in nitrification and denitrification, is usually detected in lake waters in low amounts. This thesis was confirmed by the results obtained in Lake Pluszne; in the whole study this form of the mineral nitrogen occurred in traces (Tab. 2).

Taking into consideration the obtained results and the 3rd degree of the lake's stability, Lake Pluszne may be classified with regard to mineral nitrogen abundance as the "poly" type [17].

CONCLUSION

1. Lake Pluszne belongs to rarely examined reservoirs. First mention regarding its trophic status appeared in the 1920s (Olszewski 1951) [14] when it was classified as little eutrophic thus α-mezotrophic. The following studies were conducted in 1951 by Olszewski and Paschalski (1959) [15] who qualified the lake to the same group. In the 1970s and 1980s [2, 4, 16], the lake was assessed as a reservoir with a very high water quality.
2. As shown by the present study, concentrations of nitrogen, phosphorus ("poly type") and organic compounds (BZT_5) increased (from 3 to 7 mg O_2/dm^3) and the water transparency diminished (from 5 to 2 m). In the summer (7 September), the oxygen properties of the lake were represented with a clinograde curve (oxygen content in epilimnion oscillated around 13 mg O_2/dm^3, in the metalimnion, the amount of this gas noticeably decreased and the water deeper than 12 m was oxygen-deficient), typical for eutrophic lakes [8].
3. The reason for the water quality deterioration is excessive recreation, the annual increase of the number of tourists and swimmers, development of the on-shore leisure centers and of Pluski and Zielonawo villages. Such circumstances pose a threat to the lake's water quality.

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