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SEASONAL DYNAMICS OF BIOGENS IN LAKE MARSZEWO; TROPHY STATE AND EUTROPHICATION RESISTANCE

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Summary. The aim of the study was presentation of seasonal nitrogen and phosphorus changes and the trophic state of the small lake Marszewo (Marszewskie Duże), located in the northern part of Poland. Water samples were collected and measured in monthly intervals from September 2007 until October 2008. Performed measurements showed that concentrations of phosphorus and nitrogen forms were varied and their translocations in lake waters were dependent on biological processes intensity, water circulation, and oxygen availability. The concentration of N_{tot} was in the range of 0.5–2.0 mg N dm^{-3}, and P_{tot} was from 0.05 to 0.55 mg P dm^{-3}. The maximum concentrations were observed in summer, in the bottom layer of the deepest station. The trophic condition of the lake was classified as mesoeutrophy. Low chlorophyll *a* content and relatively high visibility suggests that the lake is mesotrophic, but the high total phosphorus concentration during summer and the summer anoxia in the bottom layer indicate the beginning of eutrophy.

Key words: nitrogen, phosphorus, eutrophication, lake, trophy

INTRODUCTION

Lakes are very specific and susceptible to external changes ecosystems. Their dynamics of changes in time and intensity of transformations is closely associated with nitrogen and phosphorus concentrations [Kudelska *et al.* 1994] . Thus, knowledge of nutrient status is essential for the assessment of the present state of a lake ecosystem and to propose measures to prevent its degradation [Jarosiewicz and Witek 2009].

The aim of the study presented in this paper was to determine the vertical and seasonal biogens changes and the trophy level of the small and relatively shallow lake Marszewskie Duże.

STUDY AREA, MATERIAL AND METHODS

Studies were carried out in lake Marszewskie Duże (Marszewo) (54°30,5'; 16°42,6'), located in the northern part of Poland (West Pomeranian Lake District) (Fig. 1). The total surface area of the lake is about 18 ha, the volume of the lake amounts to about $11.6 \cdot 10^5$ m^3, the maximum depth is 20 m and average depth about 6.5 m [Jańczak 1996]. The direct catchment area of the lake is covered by arable fields and forest, however, probably the most intensive catchment pressure is associated with a camping base located near the lake.

The seasonal distribution of various phosphorus and nitrogen forms was measured in monthly intervals from September 2007 until October 2008 (except the period of ice cover). Measurements were conducted at 4 sites, arranged in the profile from the coast to the deepest central part of the lake. At each site water samples were collected from the surface (1 m under surface) and near-bottom layer, as well as from above and below the thermocline zone.

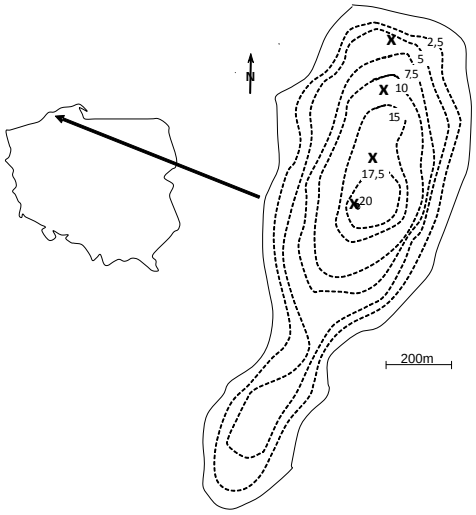

Fig. 1. Location of the study area, x – measurements points

Dissolved oxygen (HANNA HI9146), temperature and visibility (Secchi disc) were measured *in situ*. Concentrations of total phosphorus (P_{tot}), total mineral phosphorus (PO_4-P), total nitrogen (N_{tot}) nitrate nitrogen (NO_3-N) and ammonium nitrogen (NH_4-N) [Hermanowicz 1976] were determined in the laboratory by colorimetric methods, using spectrophotometer SP-830 plus Metertech. The determination of chlorophyll *a* was carried out in cold with 90% acetone. The trophic condition of the lake was evaluated according to the trophic state index method (TSI) [Carlson 1977]. The lake trophy was estimated using three indexes associated with visibility (TSI_{SD}), chlorophyll *a* concentration (TSI_{chl}) and total phosphorus concentration (TSI_{Ptot}) in the epilimnion during the summer.

RESULTS AND DISCUSSION

Performed measurements showed that lake Marszewo is a dimictic closed water body with thermal and chemical stratification during vegetative season. In summer, the epilimnion was about 5 m thick, with thermocline of maximum gradient of 5.9°C m^{-1}, and small hypolimnion (about 10% of total lake volume). The intensity of water mixing influenced the water oxygen saturation. Oxygen concentration in the epilimnion was high and amounted to about 100% during the whole period of measurements. In the hypolimnion, during summer stagnation, oxygen deficit was observed due to the degradation processes of the matter produced in the lake and deposited in the bottom. Anoxia appeared in this lake by the beginning of the summer season and lasted for 4 months. The autumn circulation well oxygenated bottom waters. It was observed, too, that water transparency (visibility of Secchi depth) of the lake was correlated with the vegetation cycle and amounted to from 2.3 m (vegetative season) to 4.3 m (winter).

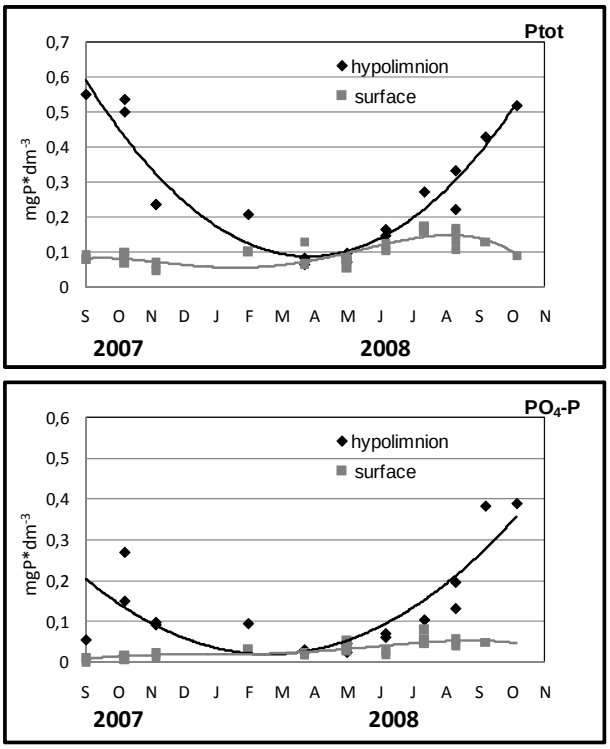

Fig. 2. Seasonal changes of phosphorus (mg P dm^{-3}) concentration in particular water layers in lake Marszewo

Concentrations of phosphorus and nitrogen forms were variable and their translocations in lake waters were dependent on: (i) biological processes inten-

sity, (ii) water circulation, and (iii) oxygen availability. The total phosphorus concentration during the measurement period was from about 0.05 to 0.55 mg P dm^{-3} (Fig. 2), but the biggest amounts were observed during the second part of the vegetative season in the anoxic bottom layer.

In the epilimnion the concentration of P_{tot} was more stable and, except for an increase in July–August period, amounted to about 0.08 ±0.02 mg P dm^{-3}.

A similar situation was observed in the case of total inorganic phosphorus (Fig. 2). From June the concentration of PO_4-P in hypolimnion increased to 0.27 mg P dm^{-3} in 2007 (and to 0.38 in 2008) until the late-autumn water circulation. In the surface layer it was about 0.03 mg P dm^{-3}. The increase of phosphorus concentration in water column was a consequence of worsening oxygen conditions in the bottom. The release of phosphorus from bottom sediments into the water takes place throughout the whole year, but under anoxic conditions the rate of release is significantly higher. The release of phosphorus from sediments is controlled by the existence of the aerobic surface-sediment layer, in which iron and other metals are oxidised into forms that have strong adsorbing capacities for phosphorus. Under reduced conditions this layer disappears, and phosphorus may be mobilszed [Jarosiewicz and Witek 2009].

The amount of total nitrogen was in the range from about 0.5 to almost 2.0 mg N dm^{-3} (Fig. 3).

The biggest concentrations were observed, as in the case of P_{tot}, in the second part of the vegetative season in the bottom layer, but opposed to P_{tot} changes total nitrogen concentration in the hypolimnion was more stable (1.42 ±0.19 mg N dm^{-3}). In the surface layer nitrogen concentration changed from 0.50 to 1.40 mg N dm^{-3} (mean of 0.84 mg N dm^{-3}), and the maximum was noted in spring. The spring increase can be attributed to intensive nitrogen fixation (the concentration of chlorophyll *a* amounted to about 11 mg chl. *a* m^{-3}). Also the concentration of mineral nitrogen forms was strongly connected with oxygen concentration changes in different layers of the lake. The most intensive changes and seasonal vertical stratification were observed in the case of ammonia nitrogen. Concentration of NH_4-N changed, depending on oxygen conditions, from 0.04 to 1.55 mg N dm^{-3} in near-bottom layer, whereas in the surface layer, during the whole measurements period, ammonium nitrogen concentration did not exceed 0.1 mg N (Fig. 3). Summer accumulation of NH_4-N in the bottom layer was associated with water stratification and oxygen deficit. In the hypolimnion, ammonium nitrogen appeared as a consequence of biological decomposition of organic matter and, because of stratification (thermocline between 6 and 11 m), could not penetrate to the higher lake layers. Moreover, by oxygen depletion the bacterial nitrification ceases and the release of NH_4 from sediments is higher. Seasonal changes of NO_3-N concentrations were almost the same in surface and bottom layers. From February to the beginning of summer the amounts of nitrate nitrogen were the highest (about 0.6 mg N dm^{-3}). On other measurement dates they were below 0.1 mg N dm^{-3}. The relation of NO_3–NH_4 was strictly associated with oxygen

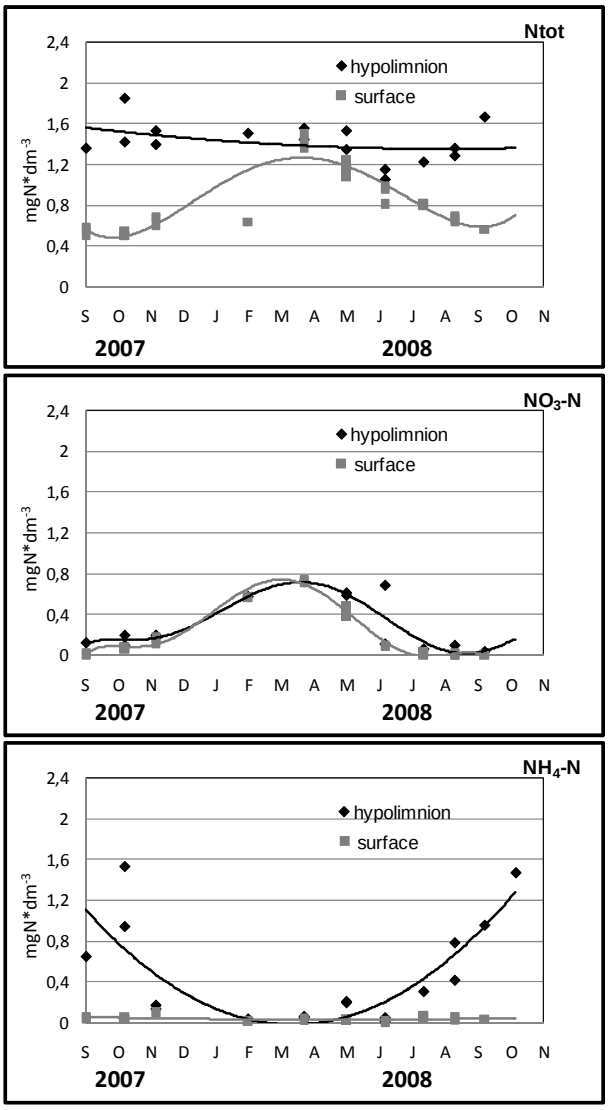

Fig. 3. Seasonal changes of nitrogen (mg N dm^{-3}) concentration in particular water layers in lake Marszewo

resources. In spring, when water was well oxygenated, nitrate nitrogen form dominated, during stratification – ammonium nitrogen.

Performed measurements permit to determine the current trophy level of lake Marszewo. The trophic condition of the lake was classified as mesoeutrophic. Low chlorophyll *a* content (about 6.3 µg dm^{-3} TSI_{chl} – 49) and relatively high visibility (TSI_{SD} – 48) suggest that lake is mesotrophic, but the high total phosphorus concentration during summer (TSI_{Ptot} – 77) and the summer anoxia

in the bottom layer indicate the beginning of eutrophy. Moreover, the natural lake resistance to outside influence, evaluated according to Kudelska *et al*. [1994], is between classes II and III. Weak resistance of lake Marszewo is associated with the small proportion of lake volume and shoreline length (0.56) and small hypolimnion volume in comparison with the total lake volume, all of which create favourable conditions for eutrophication.

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SEZONOWA DYNAMIKA ZMIAN STĘŻENIA SUBSTANCJI BIOGENICZNYCH W TONI WODNEJ JEZIORA MARSZEWO; POZIOM TROFII ZBIORNIKA ORAZ JEGO PODATNOŚĆ NA EUTROFIZACJĘ

Streszczenie. Celem niniejszej pracy było przedstawienie sezonowych zmian stężenia azotu i fosforu oraz określenie poziomu trofii jeziora Marszewo (Marszewskie Duże), zlokalizowanego w północnej Polsce. Analiza wody odbywała się od września 2007 do października 2008 r., w miesięcznych odstępach. Przeprowadzone analizy wykazały sezonową zmienność stężenia poszczególnych form azotu i fosforu, która uzależniona była od intensywności zachodzących procesów biologicznych, cyrkulacji wody i dostępności tlenu. Stężenie azotu całkowitego wynosiło od 0,5 do prawie 2 mg $N \cdot dm^{-3}$, a fosforu od 0,05 do 0,55 mg $P\ dm^{-3}$, przy czym najwyższe obserwowano latem, w strefie przydennej. Obliczone warunku troficzne jeziora wskazują na jego mezoeutrofię. Niskie stężenie chlorofilu *a* i relatywnie wysoka przejrzystość wód sugerują, że jezioro jest mezotroficzne, ale wysokie stężenie P_{tot} latem i występowanie deficytów tlenowych przy dnie wskazują na rozpoczynającą się eutrofię.

Słowa kluczowe: azot, fosfor, eutrofizacja, jezioro, trofia