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The influence of a long-term artificial aeration on the nitrogen compounds exchange between bottom sediments and water in Lake Długie

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Abstract

The study was conducted on a degraded Lake Długie in Olsztyn (surface area 26.8 ha, max depth 17.3 m) restored in 1987 – 2000 with the method of the artificial aeration with destratification. The aim of the study was to determine the influence of the applied method on the exchange of nitrogen compounds between the bottom sediments and overlying water. The results revealed that the applied method caused a decrease of nitrogen release from the bottom sediments and influenced the content of this component in the sediments. The observed changes may have been the effect of the intensification of the coupled nitrification-denitrification processes occurring in the aquatic conditions modified by the restoration.

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INTRODUCTION

Nitrogen transformations in the aquatic ecosystem are microbially mediated processes such as molecular nitrogen fixation, ammonification, nitrification and assimilative and dissimilative reduction of nitrates. The research of water reservoirs puts special attention to denitrification and its gaseous end-products N_2 and N_2O (Höhener and Gächter 1994, Rysgaard et al. 1994, Błaszczyk 1999, Tomaszek and Gruca-Rokosz 2004). A change of environmental conditions in lakes caused by restoration activities may have effect on the direction and intensity of nitrogen transformation which is very important with regard to the effectiveness of the restoration.

The aim of the study was to determine the influence of the multi-annual restoration of the lake with the artificial aeration method with destratification on the nitrogen compounds exchange across the sediment-water interface.

MATERIALS AND METHODS

The study was conducted in Lake Długie situated in Olsztyn, at 102.8 m above the sea level, in the Łyna–Pregoła drainage basin. The surface area of the lake is 26.8 ha (IRŚ 1958) (Fig. 1). The lake's drainage basin area is 114.6 ha. The lake has no inflows or surface outflows.

Aeration of Lake Długie with destratification was conducted in two phases; in phase I (Jul 1987 – Apr 1990) the deepest middle part of the lake was restored, in phase II (Aug 1991 – Nov 2000) the middle part and the northern bay were restored. In 1996 and 1999 aeration was switched off and the years are referred to as the reference years (Brzozowska, Gawrońska 2006).

The samples of the near-bottom water and the sediments were taken with Kajak core sampler from two sampling sites; the first was located in the non-aerated southern bay and the second in the deepest site of the lake, aerated since July 1987 (Fig. 1).

The sample of the near-bottom water was obtained by decantation of a 10-cm water layer over the bottom sediments. The top 10-cm layer of the undisturbed sediment core was taken and divided into two equal sections. In order to separate the interstitial water the sediments were centrifuged at 3,000 rpm for 20 min. Ammonium nitrogen, total nitrogen and organic nitrogen were analysed in the near-bottom water and in the interstitial water, in accordance with the methods by Hermanowicz et al. (1999).

The bottom sediments, after centrifugation of the interstitial water, were dried at room temperature and powdered in a porcelain mortar. The content of total nitrogen was determined in accordance with the methods by Januszkiewicz (1978).

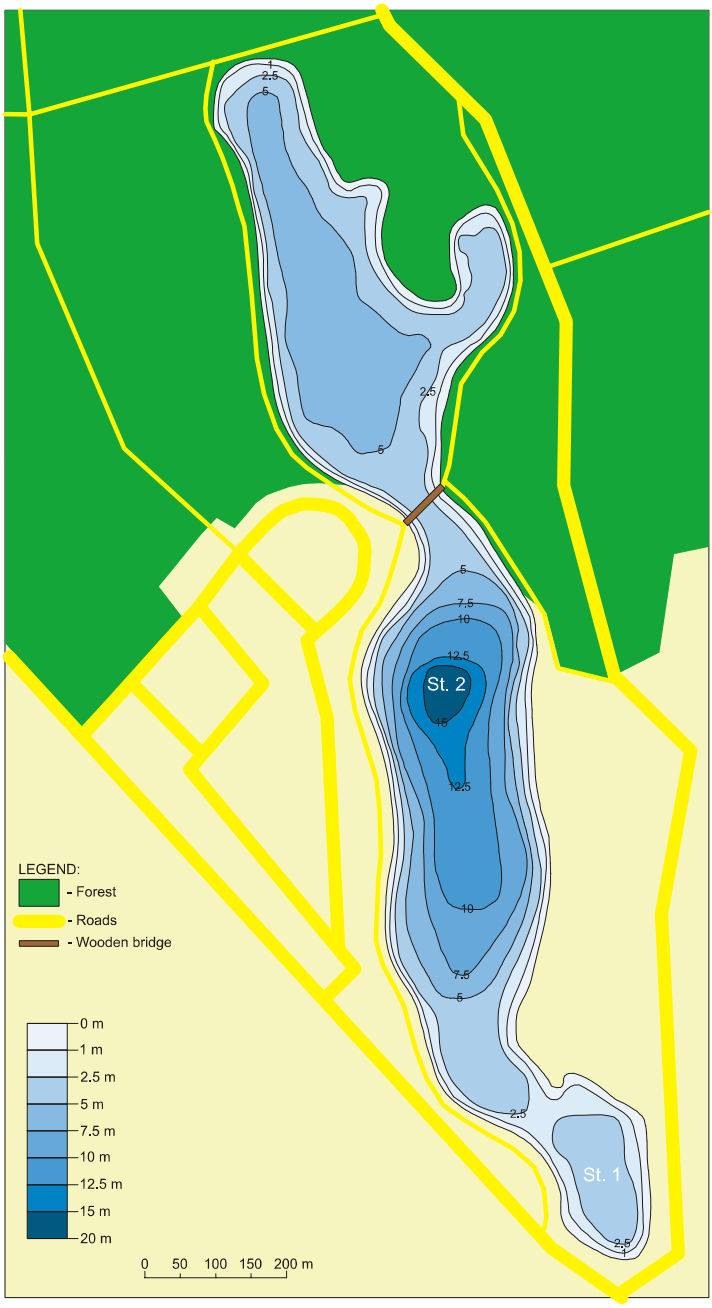

Fig. 1. Localization of the bottom sediments sampling stations in Lake Długie.

RESULTS AND DISCUSSION

The multi-annual use of Lake Długie as a sewage receiver had caused its extreme degradation. The catastrophic condition of the lake was among others displayed by the very high content of nitrogen compounds in the examined layers of water and bottom sediments (Fig. 2, 3 and 4), by far exceeding the values typical for eutrophic lakes. The dominant form of nitrogen in the near-bottom water was organic one whereas in the interstitial water – ammonium form. The high concentrations of ammonium nitrogen in the near-bottom waters (on average from approx. 10 mgN dm^{-3} at station 1 to 16 mgN dm^{-3} on station 2) and in the interstitial waters of Lake Długie (on average over 70 mgN dm^{-3} at station 2) (Fig. 2) measured in 1987 were the effect of the ammonification of organic matter in the anaerobic conditions. The long-term oxygen deficits near the bottom, occurring in the lake before the restoration, favoured accumulation of ammonium nitrogen in both interstitial water and lake water.

The artificial aeration with destratification initiated in 1987 stimulated temperature elevation in the near-bottom waters and improvement of the oxygen conditions in the hypolimnion (Grochowska, Gawrońska 2004). High temperature in the near-bottom water accelerates mineralization processes of organic matter, especially the microbially driven transformations of nitrogen compounds (Cerco 1989, Gelda et al. 2000).

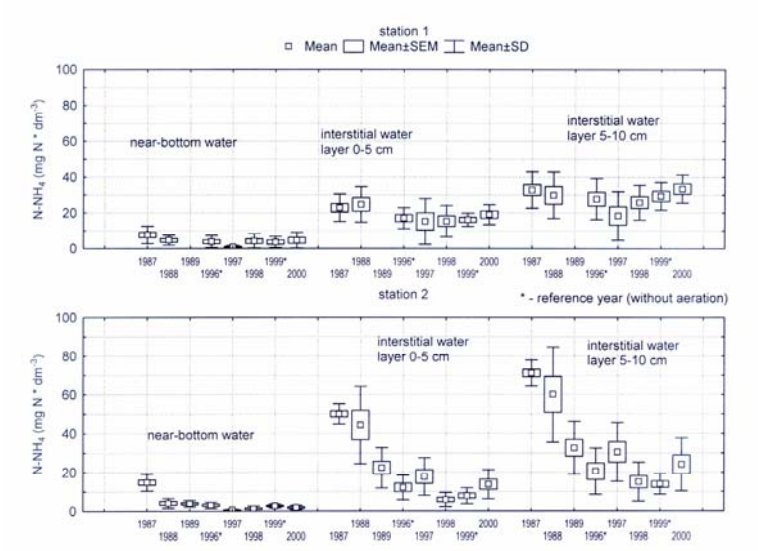

Fig. 2. Mean amounts of ammonium nitrogen in the near-bottom water and interstitial water of Lake Długie.

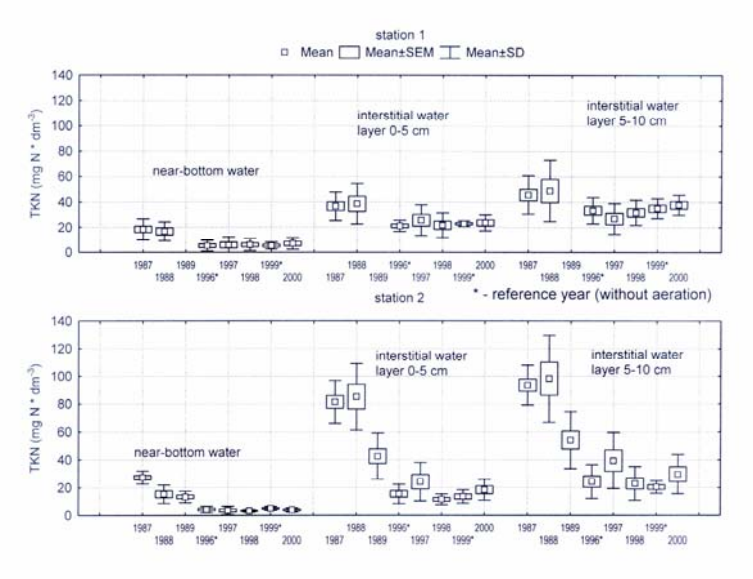

Fig. 3. Mean amounts of total Kjeldahl nitrogen in the near-bottom water and interstitial water of Lake Długie.

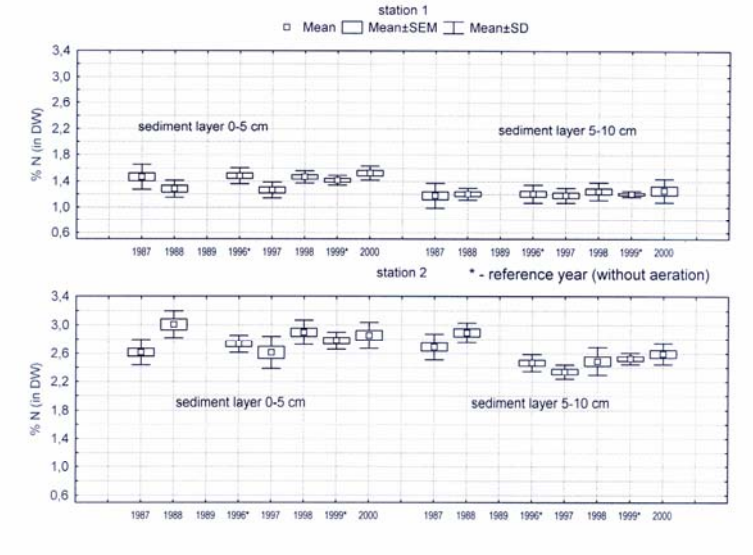

Fig. 4. Mean amounts of nitrogen in the bottom sediments of Lake Długie.

The lake's restoration with the destratification method caused a very high decrease of the ammonium and total nitrogen in the aerated station 2 (by approx. 90% in the near-bottom waters and by approx. 70% in the interstitial water). In the non-aerated station 1 the changes were much more moderate (Fig. 2 and 3). The influence of the restoration was observable in the whole examined 10-cm layer of the sediments.

Many authors (Cerco 1989; Rysgaard et al. 1994; Tomaszek, Gruca-Rokosz 2004) report that even in aerobic near-bottom waters is possible the formation of so-called anaerobic micro-niches in the upper sediment layer where denitrification may occur. The high contents of organic matter in the bottom sediments of Lake Długie (30-50% d.w. – Brzozowska, Gawrońska 2006) and improvement of the aerobic conditions near the bottom during the aeration undoubtedly favoured intensification of the nitrification-denitrification processes in the lake. The results of the laboratory analyses concerning the influence of the aeration on the nitrogen compounds transformations (Brzozowska et al. 2001) and the revealed reduction of the nitrogen content in the lake (Grochowska, Gawrońska 2004) during the restoration point at denitrification as the main reason for nitrogen losses which is confirmed also by other authors (Gawrońska 1994; Höhener, Gächter 1994).

The sediments of Lake Długie contained high amounts of total nitrogen (>3% N). In the non-aerated station 1 the values were approximately two times lower (Fig. 4). At the start of the restoration total nitrogen increased, most possibly due to the augmented sedimentation during the artificial destratification (Fig. 4). Such phenomenon was observed also by Gawrońska (1994) in the aerated Lake Starodworskie. However, in the following years of the restoration the amounts of nitrogen in the bottom sediments of the aerated basin decreased (Fig. 4). The lowest values of the whole analysed period were noted in 1997. The reasons may have been the elevated temperature in the near-bottom waters, the good oxygen conditions favouring mineralization, and the lower *in situ* production compared to the preceding years. The increase of nitrogen content in the sediments, observed in 1998–2000, may have been related to the reduced input of mineral substances caused by the storm waters diversion.

Switching off the aeration in the reference years (1996 and 1999) deteriorated oxygen conditions near the bottom in the deepest site of the lake and was the reason for a small total nitrogen increase in the near-bottom waters caused mainly by the ammonium nitrogen (Fig. 2 and 3). However, the noted concentrations were at the level similar to that observed in the second phase of the restoration.

The results of the study reveal that the multi-annual aeration with destratification applied in Lake Długie reduced the amounts of nitrogen

compounds in both the near-bottom waters and two examined layers of the interstitial waters. The noted changes confirm the thesis that nitrogen removal from the waters of artificially aerated lakes with the destratification method occurs by intensification of the coupled nitrification-denitrification processes but also as a result of the enhanced sedimentation of suspensions driven by the absent thermal gradient.

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