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Nitrogen dynamics in the steeply stratified, temperate Lake Verevi, Estonia

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Abstract

The dynamics of different nitrogen compounds and nitrification in diverse habitats of a stratified Lake Verevi (Estonia) was investigated in 2000–2001. Also planktonic N_2-fixation (N_2fix) was measured in August of the observed years. The nitrogen that accumulated in the hypolimnion was trapped in the non-mixed layer during most of the vegetation period causing a concentration of an order of magnitude higher than in the epilimnion. The ammonium level remained low in the epilimnion (maximum 577 mgN m^{-3}, average 115 mgN m^{-3}) in spite of high concentrations in the hypolimnion (maximum 12223 mgN m^{-3}, average 4807 mgN m^{-3}). The concentrations of NO_2^- and NO_3^- remained on a low level both in the epilimnion (average 0.94 and 9.09 mgN m^{-3}, respectively) and hypolimnion (average 0.47 and 5.05 mgN m^{-3}, respectively). N_2fix and nitrification ranged from 0.30 to 2.80 mgN m^{-3} day^{-1} and 6.0 to 107 mgN m^{-3} day^{-1}, respectively; the most intensive processes occurred in 07.08.00 at depths of 2 and 5 m, accordingly. The role of N_2fix in the total nitrogen budget of Lake Verevi (in August 2000 and 2001) was negligible while episodically in the nitrogen-depleted epilimnion the N_2fix could substantially contribute to the pool of mineral nitrogen. Nitrification was unable to influence nitrogen dynamics in the epilimnion while some temporary coupling with ammonium dynamics in the hypolimnion was documented.

Introduction

Nitrogen (N) is one of the main building blocks for the production of organic matter on the planet Earth and it is required in greatest quantities (Stolp, 1996; Williams et al., 2002). N, as many other elements in the world, is involved in cyclical transformations. Non-biological transformations have little importance in the nitrogen cycle by contrast with biological transformations, which are primarily controlled by microorganisms (Gorlenko et al., 1977; Sprent, 1987; Stolp, 1996; Voytek et al., 1999). A nitrogen cycle consists of four main components: molecular nitrogen (N_2) fixation (N_2fix), mineralization of organic N (ammonification), nitrification, and denitrification.

Only prokaryotes are capable of N_2fix. In aquatic ecosystems cyanobacteria appear responsible for most of the planktonic N_2fix while heterotrophic bacteria are most important N_2 fixers in lake sediments. The fixation of N_2 by microorganisms is the only process in nature that counteracts the nitrogen losses from the environment by denitrification. The central compound of the nitrogen cycle is ammonium (NH_4^+) which is released into the water by zooplankon and represents the main decomposition product of urea of other animals like fish. In anaerobic hypolimnion where animals are scarce, ammonium is formed at amino-acid degradation of proteins carried out by ammonificating bacteria, occurring in the water column and sediments (Gorlenko et al., 1977;

Howarth et al., 1988a; Stolp, 1996). Nitrification is a two-step oxidation of NH_4^+ through nitrite (NO_2^-) to nitrate (NO_3^-), carried out mainly by chemolithoautotrophic bacteria in aerobic conditions. The most important and intensive site in lakes for nitrification are aerobic sediments while planktonic nitrification could be also significant. Denitrification is an anaerobic heterotrophic process, which shares many of the same substrates and intermediates as nitrification. Denitrification leads to gaseous nitrogen (N_2, N_2O) losses counteracting N_2fix (Gorlenko et al., 1977; Hall, 1982; Henriksen et al., 1993; Stolp, 1996; Voytek et al., 1999). In stratified lakes phytoplankton takes up epilimnetic mineral nitrogen and transports it to the hypolimnion via sedimentation. N may accumulate in the hypolimnion during stratification period while in the epilimnion N deficiency may occur if resupply from the inflows is limited (Scheffer, 1998).

The aim of the present study was to investigate the dynamics of different nitrogen compounds as well as the rates of N_2-fixation and nitrification in diverse habitats of a stratified partly meromictic lake. The main processes of transformations (Fig. 1) were followed on the background of the dynamics of the physico-chemical stratification regime.

Materials and methods

Lake Verevi (0.126 km^2, mean depth 3.6 m, maximum depth 11 m) is a small stratified hypertrophic (see Ott et al., the present issue) lake in South Estonia. The lake is characterized by strong stratification from April to September and an anoxic hypolimnion. The main N_2fix cyanobacterium in Lake Verevi during the years 2000 and 2001 was *Aphanizomenon klebahnii* (Elenkin) Pechar *et* Kalina (Kangro et al., the present issue).

The water samples for nitrogen determination were collected from April to December 2000 and from March to August 2001. In the year 2000 eight and in 2001 three to eight vertical samples were taken at different depths of the epi-, meta- and hypolimnion. The water from the surface layer (0.5 m) was taken directly into the bottle, for other depths a Masterflex pump was used (for details see Zingel, the present issue). Total nitrogen (TN), NH_4^+, NO_2^- and NO_3^- was analysed at the laboratory of Võrtsjärv Limnological Station using the methods described by Grasshoff et al. (1983). For more detailed description of TN determination see Ott et al. (present issue). Ammonium was determined (detection error ± 5.5%) with indophenol blue method (Hansen & Koroleff, 1999). Nitrate was reduced to nitrite, and sulphanil-amide and

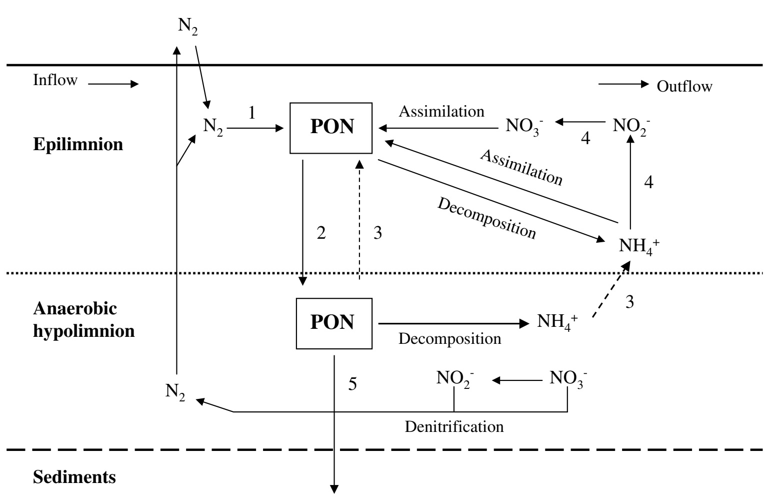

Figure 1. Conceptual scheme of the main processes of the nitrogen cycle in a stratified lake according to Lampert and Sommer (1997): 1 – planktic molecular nitrogen fixation (N_2fix); 2 – a part of the PON (particular organic nitrogen) sinks to the hypolimnion; 3 – due to water mixing some PON is carried from hypolimnion to epilimnion; 4 – in epilimnion ammonium (NH_4^+) is subject to nitrification; 5 – a part of PON is switched off from nitrogen cycle due to sedimentation.