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General description of partly meromictic hypertrophic Lake Verevi, its ecological status, changes during the past eight decades, and restoration problems

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Abstract

The present study describes generally the ecosystem of Lake Verevi while more detailed approaches are presented in the same issue. The main task of the article is to estimate long-term changes and find the best method for the restoration of good ecological status. Lake Verevi (surface 12.6 ha, mean depth 3.6 m, maximum depth 11 m, drainage area 1.1 km^2, water exchange 0.63-times per year) is a hypertrophic hard-water lake located in town Elva (6400 inhabitants). Long-term complex limnological investigations have taken place since 1929. The lake has been contaminated by irregular discharge of urban wastewaters from oxidation ponds since 1978, flood from streets, and infiltrated waters from the surrounding farms. The so-called spring meromixis occurred due to extremely warm springs in recent years. The index value of buffer capacity of Lake Verevi calculated from natural conditions is on the medium level. Water properties were analysed according to the requirements of the EU Water Framework Directive. According to the classification, water quality as a long-term average of surface layers is moderate-good, but the water quality of bottom layers is bad. Values in deeper layers usually exceed 20–30 times the calculated reference values by Vighi and Chiaudani's model. Naturally, at the beginning of the 20th century the limnological type of the lake was moderately eutrophic. During the 1980s and 1990s the ecosystem was out of balance by abiotic characteristics as well as by plankton indicators. Rapid fluctuations of species composition and abundance can be found in recent years. Seasonal variations are considerable and species composition differs remarkably also in the water column. The dominating macrophyte species vary from year to year. Since the annual amount of precipitation from the atmosphere onto the lake surface is several times higher, the impact of swimmers could be considered irrelevant. Some restoration methods were discussed. The first step, stopping external pollution, was completed by damming the inlet. Drainage (siphoning) of the hypolimnetic water is discussed. Secondary pollution occurs because Fe:P values are below the threshold. The authors propose to use phosphorus precipitation and hypolimnetic aeration instead of siphoning.

Introduction

Physically and chemically stratified lakes have a special ecosystem structure. Vertical gradients of environmental parameters became a limnological issue as early as in the study by Hutchinson (1938). The investigation of vertical distribution of biota developed from the descriptive stage through the investigation of ecological processes into a stage dealing with the ecological holistic approach to

lake management (Ripl, 1976; Faafeng & Nilssen, 1981; Wolter, 1994; Lindenschmidt & Chorus, 1997). Refining and prediction of functioning of an ecosystem and the ecological status of stratified lakes is complicated for many reasons. One of the most important factors is the occurrence of many microhabitats for biota and their irregular interactions. Sometimes complexity of investigation seems unrealistic and smaller compartments need to be used (Pipp & Rott, 1995). Long-term data sets (since 1929) and the availability of complex data with references to the other articles about the same issue (hydrochemical and hydrophysical, sediments, bacterioplankton, phytoplankton, protozoa, metazooplankton, epiphyton, meio- and macrozoobenthos, macrophytes, fishes) serve as the basis of this study. The influence of wind and also of inflow in recent years is minimal, although usually core factors for the functioning of the ecosystem. To some extent these conditions make it easier to predict the functioning of the whole ecosystem. The present study describes generally the ecosystem of Lake Verevi, while more detailed approaches are presented in the same issue. The main task of the article is to estimate long-term changes and to find the best method for restoration.

Site description

Lake Verevi is located in a small town of Elva (6400 inhabitants). Tartu, the second city in Estonia, is at a distance of 25 km. The relatively young town (ca. 115 years-old) is suitable for leisure with a landscape of a hilly pine forest and several small lakes. Small wooden private houses and summer cottages without special industry dominate. Elva has been attracting for tourists and holidaymakers. One of the best swimming pools and beach halls in Estonia was built here in 1929.

The lake has an elongated shape in the north–south direction with the deepest and widest part near the southern end (Fig. 1). By origin Lake Verevi is a kettle lake formed by the melting of a buried ice block from the decaying glacier (Mäemets & Ennok, 1991). The drainage basin represents a hydrologically complex landscape – from the south and the south-east the lake is surrounded by sandy hills and dunes covered with pine forests. The densely populated eastern shore slopes steeply towards the lake. The area to the west is wetland and covered by quagmires and swamps.

Lake Verevi is a small and relatively deep lake (Table 1) with low water exchange (Loopmann, 1984). The high value of relative depth (the ratio of maximum depth as a percentage of the mean diameter of the lake on the surface; Wetzel, 1983) supports the idea that the water column does not mix easily. The lake is thermally sharply stratified and strong gradients of chemical substances occur during summer. Usually, the lake is dimictic, water mixing in spring has been incomplete in recent years even at homothermal conditions, which adds some temporal meromictic features to the lake (Nõges & Kangro, 2005; Ott et al., 2005). The metalimnion is progressively eroded during summer and autumn and a complete mixing usually takes place in November. The lake has up to 10 small inflows, but only three of them (Fig. 1; inflows 1, 4, and 5) are nearly permanent. Inflows 4 and 5 start from two spring-fed lakelets, Linajärv and Jaanijärv located in the northern part of the watershed. The main part of the annual inflow comes irregularly from inlet 10, which has been closed totally since 2002. Lake Verevi receives also a significant part of water as hardly measurable sub-surface run-off (Mäemets & Ennok, 1991). Small ditches and bottom springs in the narrow northern part form the bulk of the inflowing water. The lake has been contaminated by irregular discharge of urban wastewaters from oxidation ponds since 1978, flood from streets, and infiltrated waters from the surrounding farms. The outflow of the lake is located on the western shore (Fig. 1, N 7), and it flows into the Kavilda river valley. In dry years, the outflow becomes discontinuous. The ice-free period lasts mainly between April and November.

Materials and methods

Lake Verevi has been studied extensively over a long period, between 1929 and 2001 (in 1929, 1957, 1984, 1985, 1986, 1988, 1989, 1991 and each year between 1993 and 2001). The first data are available in the literature (Riikoja, 1930, 1940; Eesti Järved, 1968). Plankton and hydrochemical samples have been gathered mainly from the deepest