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Long- and short-term changes of the macrophyte vegetation in strongly stratified hypertrophic Lake Verevi

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Abstract

The aim of study was to bring out changes in the macrophyte vegetation, caused by eutrophication, short-term lowering of the water level and the following restoration of equilibrium in L. Verevi. Also biomass and N and P content of shoots of main submergent species were studied in 1999–2001, to follow the temporal and specific differences. Due to strong eutrophication, the type of the lake changed from a *Myriophyllum-Potamogeton*-Charophyta lake to a *Ceratophyllum-Lemna trisulca* lake in 1984–1988, obviously owing to the formation of loose organic-rich sediment. Water lowering by 0.7 m during summer months of 1998 facilitated mineralization of sediments, as a consequence of which a mass development of *Ranunculus circinatus* and a temporary increase in the abundance and biomass of other nutrient-demanding species took place during following years. Our data suggest differences in nutrient supply and release of submerged species and the need for more species-related approach to this group. The problem of nutrient supply of unrooted plants at the time of stratification arises. Regarding the increase of biomass of *Ceratophyllum demersum* in second half of summer, we suppose that one part of nutrients for this growth may derive from freshly decayed filamentous algae or vascular plants.

Introduction

The small strongly stratified L. Verevi (12.6 ha, hard-water, more particularly characterized in Ott et al., 2005) has been rich in macrophytes at least during the last century. Emergent and submerged species dominate, while scattered stands of floating-leaved and floating plants are frequent and large filamentous algae occur abundantly. Macrovegetation has occupied 35–50% of the lake's area in different years. Over 50 macrophyte species have been recorded, among them 30 species of hydrophytes. The diverse bottom of the littoral zone (sand, gyttja, calcareous gyttja and dy) supports a diverse vegetation. Hard water favours high productivity of macroalgae, *Potamogeton* spp., *Elodea canadensis*, *Chara* spp. and other macrophytes which have high or intermediate extraction capacity of HCO_3^- (Madsen & Sand-Jensen, 1991) as the source of carbon. Supply from sediments is the advantage for rooted macrophytes over the phytoplankton in a situation where nutrients are scarce in water during the stratification period. However, also unrooted *Ceratophyllum* and large filamentous algae are abundant in such lakes and their nutrient supply is poorly studied. Changes in the opulent macrovegetation as the habitat, feeding and hiding area, are important for the biota of the littoral as well as for nutrient dynamics of whole lake (Diehl & Kornijów, 1998; Scheffer & Jeppesen, 1998; Feldman, 2001). Covering densely a large area, the submerged macrovegetation is a particularly essential integral component of the lacustrine ecosystem (Structuring Role, 1998).

The species composition of the macrovegetation probably determines the specific features of matter circulation, at least in the littoral zone. The aim of our study was to bring out long- and short-term changes in the macrovegetation and their possible reasons. An attempt was made to associate these changes with nutritional differences between the species.

Materials and methods

Three sets of literature and unpublished data, at three time levels, were available for our purposes:

(1) changes in the species composition in the 20th century;
(2) phenomena followed to the 0.7 m water lowering in summer months in 1998;
(3) seasonality in the biomass and nutrient content of macrophytes, studied in the most recent years.

To find out long-term changes, species abundance estimates according to Braun-Blanquet scale (1964) for the years 1929, 1957, 1988 and 2003 (Riikoja, 1940; Eesti järved, 1968; Mäemets Aime, 1991; our data), and vegetation distribution schemes (for 1957 compiled by H. Tuvikene, for 1988 compiled by A. Mäemets) were used. From the newest data 2003 was chosen, regarding the state as least influenced by the water lowering in 1998. Short-term changes resulting from water lowering were followed in 1998–2003 on the basis of: (1) a yearly description (1998–2003) and mapping (1998–2001) the vegetation in July when the species composition, abundances and depth limits were registered; (2) sampling of the shoots of main submerged plants with SCUBA (ducking equipment) from 33 quadrats (0.5 × 0.5 m) in midsummer 1999, 2000 and 2001 (Fig. 1). Five samples of filamentous algae taken in June 2000 and July 2001 included only their floating (not attached) part. For observation of seasonal changes in biomass and nutrient content, altogether 11 samples were taken from the same stands at the beginning of June and in mid-July in 2000. In 2001, four samples after every 2 weeks (total 20) between 24.05 and 21.07 were taken from stands in transition area between the wide southern part and the narrow northern part of the lake (Fig. 1) (*Ceratophyllum demersum* and *Potamogeton friesii* at the western shore, *Fontinalis antipyretica* and *Ranunculus circinatus* at the eastern shore). All above-ground part of plants (both for the dominating and other species) were collected, and their air-dry weight (= air-dry biomass = ADW) was determined without the crumbling (by drying) part of calcareous precipitate. The content of total phosphorus and total nitrogen in the plants was determined from a 2 g mixture (flowers, leaves and shoots) at the Laboratory of Plant Biochemistry of Faculty of Agronomy of EAU). Phosphorus (P) in plant tissues was analysed by Kjeldahl digest, stannous chloride method. Nitrogen (N) in tissues was analysed after H_2SO_4 (+Se) digest with gas-diffusion method. The amounts of nutrients per surface unit of stand area were calculated multiplying their concentration by biomass.

Data on weather conditions were obtained from the Tõravere Meteorological Station located at a distance of 5 km of the lake. Data on hydrochemistry and plankton were drawn from the database of the Võrtsjärv Limnological Station of the Institute of Zoology and Botany of EAU. The analysis of variance (Nonparametrics – Kruskal–Wallis ANOVA) ($\alpha = 0.05$) was performed with Statistica 5.5 to test the significance of differences in biomass and nutrient content of plant samples.

Results

Long-term changes

Long-term changes are mostly related to abundance; species composition has been more stable (Table 1). However, three recently important species, *Lemna trisulca*, *Potamogeton friesii* and *P. pectinatus*, were not mentioned before 1980s (*Potamogeton* spp. were not identified to the species in 1929). *Myriophyllum spicatum*, being opulent in 1929 (Riikoja, 1940), is absent today, as well as *Stratiotes aloides*. The decline of *Schoenoplectus lacustris* and *Equisetum fluviatile* was marked already in 1957, as well as the increasing abundance of *Potamogeton natans*. The most remarkable is the replacement of the dominating charophytes by *Ceratophyllum demersum* in the 1980s (Fig. 2). Both Charophyta and *Ceratophyllum* occurred opulently during 4–5 years (Mäemets Aime, 1991);