# Two decades of change in emergent macrophyte expansion in two large shallow northern temperate lakes on a retrospective series of satellite images

Jaan Liira [1], Urmas Peterson [2,3], Tõnu Feldmann [4] and Helle Mäemets [4]

[1] Institute of Ecology and Earth Sciences, Tartu University, Lai 40, Tartu, Estonia,
E-mail: jaan.liira@ut.ee;
[2] Tartu Observatory, Tõravere 61602, Tartumaa, Estonia, E-mail: urpe@aai.ee;
[3] Institute of Forestry and Rural Engineering, Estonian University of Life Sciences, Kreutzwaldi 5, Tartu 51014, Estonia
[4] Centre for Limnology, Estonian University of Life Sciences, Rannu vald 61101, Estonia,
E-mail: feld@ut.ee, helle.maemets@emu.ee

Many large lakes in northern Europe have undergone an improvement of conditions after the decrease of agricultural land use intensity during the last two to three decades. However, recent habitat and lake level studies have demonstrated continuously increasing shore overgrowth by aquatic macrophytes, mostly by common reed, despite the favorable development in water quality. Consequently there is a growing interest in the factors that control macrophyte development and the changing extent of the macrophyte patches in large lakes. With inadequate retrospective field data the actual long-term changes of emergent macrophyte communities in large lakes is difficult to evaluate. Retrospective satellite images make it possible to go back in time even though no field data are available.

We made use of the more than 20-year archive of medium resolution Landsat TM and ETM+ data supplemented by SPOT and Aster satellite images to examine the change in coastal vegetation of two large shallow lakes Lake Peipsi (3550 square kilometers), the fourth largest in Europe and Lake Võrtsjärv (270 square kilometers), the second largest lake in the Baltic countries. We addressed the following questions. Is there a measurable change in the cover of emergent macrophytes that could be consistently monitored with medium spatial resolution satellite images? What are the main driving factors of the horizontal extension of emergent macrophyte vegetation in such large shallow lake environment? What are the main patterns of change of the width of the reed belt along the shore reaches of a large shallow lake?

The reflectance characteristics of aquatic macrophytes as well as density are known to alter seasonally. Satellite images used were acquired between the middle of July and the beginning of September, corresponding to the period of maximum aquatic macrophyte vegetation abundance.
A classification into two categories: aquatic macrophyte vegetation and open water or lake bottom was performed. We used Normalized Difference Vegetation Index (NDVI) to decrease the dependence of the signatures of macrophyte patches on water or lake bottom background signals. Visual aerial photograph interpretation results and ground-based GPS-measurements were used to estimate the accuracy of emergent macrophyte patch boundary delineation. Multivariate linear modeling analysis was used to test the driving factors of horizontal expansion of coastal reed belt. In the model we included the soil, landscape and lake morphometric factors that on prior published knowledge could affect the emergent aquatic vegetation in large shallow northern temperate lakes.

The satellite images revealed the dynamic changes in the coastal reed areas within the last 22 years. Results of the mixed model analysis show that the horizontal extension of the reed belt has large inter-regional variation that is affected by large and small inflows and by anthropogenic activities.