

Spatio-temporal changes of littoral macrophytes along hydrological conditions in Yliki, a Greek lake

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Introduction

Human-induced changes in hydrological conditions seem to be among the main factors affecting ecological relationships in lakes (Zhao et al., 2021). Water level fluctuation (WLF), which is often attributed to anthropogenic activities and its amplitude variations can have an impact on aquatic plant communities by altering several key environmental factors (Hill et al., 1998, Zhao et al., 2021). These fluctuations influence water depth, underwater irradiance, water quality, and dissolved oxygen levels, all of which play crucial roles in the growth and survival of macrophytes (Li et al., 2017). The interplay of these factors can significantly change the growing conditions for several macrophyte species over time. To overcome this, macrophytes have evolved to adjust gradually to periodic WLF over time, as part of their long-term evolutionary process (Zhao et al., 2021).

The aims of the study are to present the results of WLF over time in Lake Yliki, study its aquatic plant community and explore the effect of WLFs on macrophytes.

Materials and methods

Lake Yliki is a natural lake, located in the district of Viotia, Greece. It is integrated into the water supply system of Athens to address the increased water consumption demands due to the population growth in the Attica region. The Athens Water Supply and Sewerage Company (EYDAP) provided recordings of lake's Yliki water level (a.m.s.l) at a monthly time step, from 1/1/2007 to 31/12/2023.

Macrophyte samplings were conducted in 20 transects located along the lake perimeter, up to the maximum colonization depth of macrophytes during years 2014, 2017, 2020 and 2023, following the methodology described in Zervas et al. (2018). Macrophyte diversity and taxonomic metrics were calculated for each sampling campaign and depth range. The direct relationship between life forms of macrophytes and environmental data (WLF, lake size and mean depth) was explored by Redundancy analysis (RDA) using plots with type II scaling, focusing on the response variables. All statistical analyses were performed in R environment version 4.4.1 (R Core Team, 2024).

Results and concluding remarks

The inter-annual fluctuation of the lake's water level is shown in Figure 1. The fluctuating amplitude during the years of sampling (2014-2023) was 10.77m, with the maximum value recorded at 1/3/2019 (79.47m) and the minimum at 1/11/2017 (68.7m).

Macrophyte taxa richness showed a decreasing trend in median values with increasing sampling depth (Figure 2), which was confirmed by the statistically significant difference of average taxa richness across different sampling depths ($F(3) = 3.754$, $p < 0.05$). A Tukey post-hoc test revealed statistically significant differences between sampling depths 0-1m and 3-4m ($p\text{-value} < 0.05$). Lower taxa richness in the sampling depth 0-1m, seemed to coincide with years with large water level fluctuations.

In the RDA ordination analysis, among different macrophyte life forms, Helophytes and Ceratophyllids, with one representative *Ceratophyllum demersum*, appeared to be the most sensitive to the effects of water level changes. The first two axes of the RDA explained 96.51% of the variance of macrophytes (eigenvalues $\lambda_1 = 17.70$, 86.21% and $\lambda_2 = 2.11$, 10.30% respectively). However, the total variance of the RDA model was 20.54.

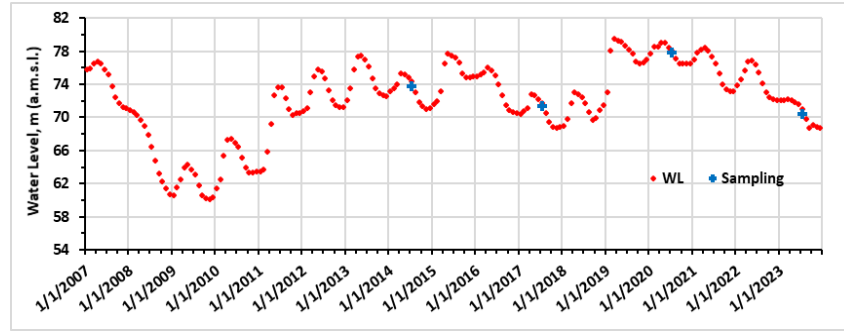


Figure 1. WLF of Lake Yliki during 1/1/2007 – 31/12/2023 with noted sampling dates of macrophytes.

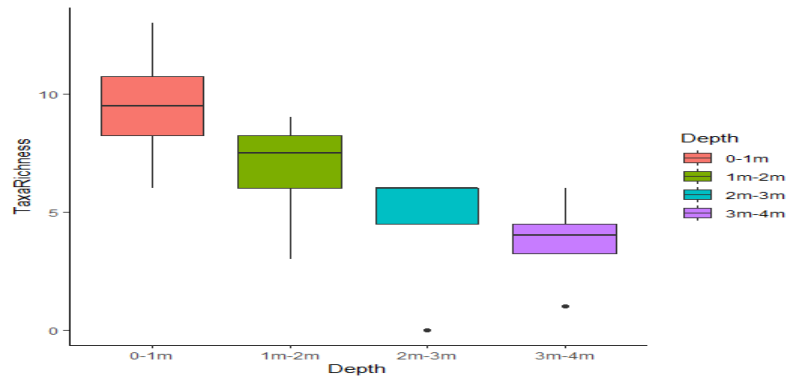


Figure 2. Box and whisker plots of taxa richness of the four different group categories of sampling depth. In the box plots, the central line represents the median; the lower and upper box limits correspond to the 25th and 75th percentiles and the upper (lower) whiskers extend to 1.5 (–1.5) times the interquartile range, respectively.

The interplay of frequency and amplitude of water level fluctuations determines the severity of their effects (Zhao et al., 2021). Although macrophytes have evolved mechanisms to cope with intermediate water-level changes, large fluctuations can lead to adverse effects on their growth and survival. The enrichment of the dataset would provide a more comprehensive view of how WLF affect macrophytes.

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