ECOLOGICAL STATUS AND TRENDS OF LAKE KASTORIA: TEN YEARS OF BIOLOGICAL MONITORING

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Abstract

Lake Kastoria, in northwestern Greece, is a shallow lake, impacted mainly by pollution. The objectives of the research are to assess the ecological status and trends of Lake Kastoria during the ten-year operation of biological monitoring and to present the classification of its ecological status, according to the WFD provisions. The biological quality elements of phytoplankton, aquatic macrophytes and littoral zoobenthos were monitored during 2012-2021 and three national assessment systems (i.e., HeLPhy-phytoplankton, HeLM-aquatic macrophytes and HeLLBI-littoral zoobenthos) were used in order to classify the ecological status of the lake. Phytoplankton biovolume values varied considerably during the first monitoring period (2012-2015); while lower variations were recorded during the second monitoring period (2016-2021). Lake Kastoria is classified as Moderate according to HeLPhy and HeLLBI assessment systems and Good according to HeLM. Overall, it is classified as Moderate. HeLM and HeLLBI indicated some improvement in the littoral zone of the lake in 2018-2021 compared to the previous periods. However, the status of the pelagic zone of Lake Kastoria remained relatively stable, in moderate status during the 10 years. Nutrient inputs from the lake catchment, causing eutrophication, should be further controlled in order to improve the lake ecosystem's status.

Keywords: WFD, EQR, HeLPhy, HeLM, HeLLBI.

1. Introduction

Most lakes suffer from degradation in the last decades, causing decline in their water quality, due to anthropogenic pressures (Reid *et al.*, 2019). The need to monitor their status and trends, in order to design effective management measures and to reduce those impacts are now being highlighted worldwide. The national monitoring network for lakes, in the context of the Water Framework Directive (WFD) (EU, 2000), became operational in 2012 with the Joint Ministerial Decision 140384/2011 (JMD, 2011). Lake Kastoria, in northwestern Greece, is a shallow urban lake, situated by the town of Kastoria. It belongs to the Natura 2000 network as a Special Area for Conservation according to the Habitats Directive and as a Special Protection Area according to the Birds Directive (codes GR1320001 and GR1320003, respectively). In the 2nd round of the River Basin Management Plan of Western Macedonia (RBMP, 2017), eutrophication from point and non-point sources has been identified as a significant pressure to Lake Kastoria. Therefore, the lake is subject to operational monitoring (JMD, 2011). The lake has been designated as a heavily modified water body, according to WFD (EU, 2000), due to hydromorphological modifications (code GR000900030073H). The objectives of this research are to assess the status and trends of Lake Kastoria during the ten-year operation of biological monitoring and to present the classification of its ecological status, according to the WFD provisions.

2. Material and Methods

According to WFD (EU, 2000), samplings for phytoplankton analysis are carried out annually and samplings for aquatic macrophytes and zoobenthos analyses, every three years. In Lake Kastoria, water sam-

plings for phytoplankton analysis took place during the warm period (June – October) of each year from 2012 to 2021. All samples were collected from the deepest part of the pelagic zone, from the euphotic zone of the water column (2.5 × Secchi disk depth), using a Nansen type sampler, according to the Hellenic Lake Phytoplankton (HeLPhy) assessment system (Tsiaoussi *et al.*, 2017). Phytoplankton samples were preserved with lugol's solution. Thirty-two phytoplankton samples were analysed. Quantitative analysis was performed using the Utermöhl sedimentation method (ELOT EN 15204:2006) and phytoplankton biovolume was estimated based on ELOT EN 16695:2015. Chlorophyll a concentrations were determined according to standard methods (10200 H, APHA, 2017). Regarding aquatic macrophytes sampling process, the belt transect-mapping method was applied and sampling within each transect followed the Hellenic Lake Macrophyte (HeLM) monitoring and assessment system (Zervas *et. al.*, 2018). To apply this method, full surveys of twenty permanent transects per lake were undertaken during the vegetative period, in 2014, 2017 and 2020, corresponding to the triennia 2013-2015, 2016-2018 and 2019-2021 respectively. The abundance, frequency and depth distribution data of all taxa encountered were recorded. Additionally, the maximum colonization depth of species per lake was measured annually. Regarding benthic macroinvertebrates, sampling and analysis followed the specifications of the Hellenic Lake Littoral Benthos (HeLLBI) assessment method (Mavromati *et al.*, 2021). In particular, samplings were undertaken using the three-minute kick/sweep method with standard hand net (500 μm mesh size) at the littoral zone of the lake (up to 1.2 m depth of water). Five selected sites were sampled during spring 2017 and 2021, corresponding to the triennia 2016-2018 and 2019-2021 respectively. Samples were sieved on site and sorting, identification and counting were carried out in the lab (Mavromati *et al.*, 2021). The Ecological Quality Ratios (EQRs) for each Biological Quality Element (BQE) were calculated according to the respective WFD compliant national assessment methods (EC, 2018). The overall ecological status classification for Lake Kastoria was determined with the application of the one-out-all-out principle, i.e. by the lowest of the values for the biological monitoring results of BQEs (EU, 2000).

3. Results

The mean annual (mean value of the warm season) total phytoplankton biovolume values in Lake Kastoria for the period 2012-2021 are shown in Figure 1. In particular, high variations were recorded during the first monitoring period (2012-2015); the highest phytoplankton values were measured in 2014, and the lowest in the following year (2015). During the second monitoring period (2016-2021), lower variations in phytoplankton biovolume values were recorded. The mean annual total phytoplankton biovolume ranged from 7.3 mm^3/L in 2015 to 24.8 mm^3/L in 2020, with the exception of 2014. Specifically, in the last warm months of 2014, exceptionally high phytoplankton biovolume values were measured, due to an extensive bloom of cyanobacteria in the lake; thus, the mean total phytoplankton biovolume of the whole warm season was calculated to 83.8 mm^3/L. The organisms that contributed mostly to total phytoplankton biovolume values, with the exception of 2015, were cyanobacteria, ranging from 64.9% to 100% of total biovolume in 2018 and 2013 respectively.

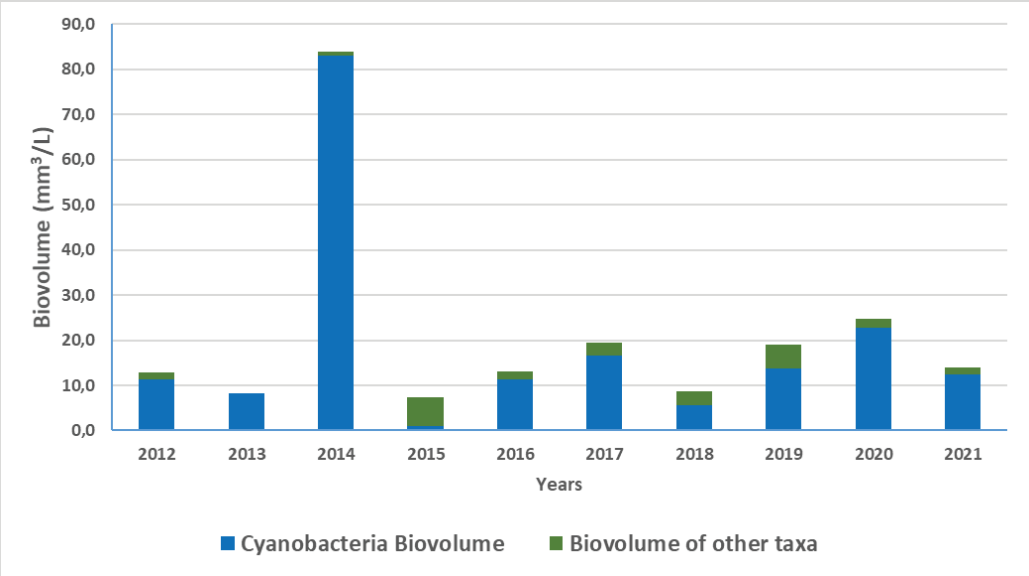

Fig. 1: Values of mean annual phytoplankton biovolume, in Lake Kastoria (2012-2021).

The annual values of the EQRs of the Hellenic Lake Phytoplankton (HeLPhy) assessment system for phytoplankton, in Lake Kastoria, for ten years (period 2012-2021) are shown in Figure 2. The mean EQR was 0.45, thus, the ecological quality of the lake was assessed as Moderate during the last decade. In particular, during the first monitoring period (2012-2015), the mean value of the EQR was 0.47 (± 0.19), ranging from 0.24 (in 2014) to 0.71 (in 2015) and during the second monitoring period it was 0.44 (± 0.03), ranging between 0.40 and 0.49.

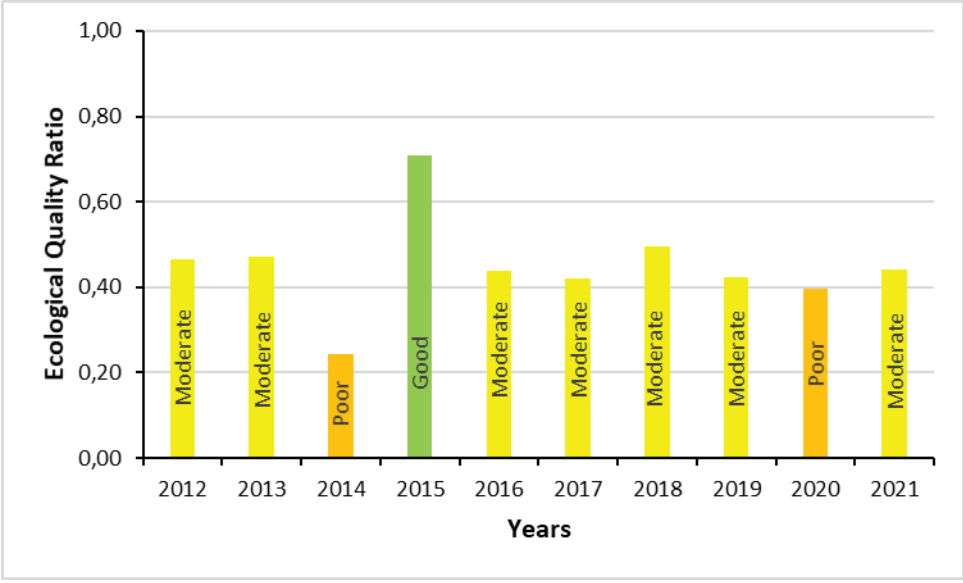

Fig. 2: Annual EQR values of the HeLPhy assessment system in Lake Kastoria (2012-2021).

The EQR values of each of the three assessment systems; HeLPhy, HeLM and HeLLBI in Lake Kastoria, for the three triennia (period 2013-2021) are shown in Fig. 3. The mean EQR value of the HeLPhy assessment system for phytoplankton was 0.45 (± 0.03), indicating the Moderate ecological quality of the lake. The mean EQR value of the HeLM assessment system for aquatic macrophytes was 0.71 (± 0.06), evaluating the lake as Good, throughout the examined period. Notably, an increase in these values has been observed in the period 2019-2021 compared to the previous two triennia (2013-2015, 2016-2018). The mean EQR value of the HeLLBI assessment system for littoral zoobenthos was 0.52 (± 0.07), classifying the lake as Moderate. An increase in the EQR values of HeLLBI has been observed in the period 2019-2021 compared to the period 2016-2018. All three assessment systems were constructed to respond to the

pressure of eutrophication, whereas HeLLBI also responds to morphological modifications (Tsiaoussi *et al.*, 2017; Zervas *et al.*, 2018; Mavromati *et al.*, 2021).

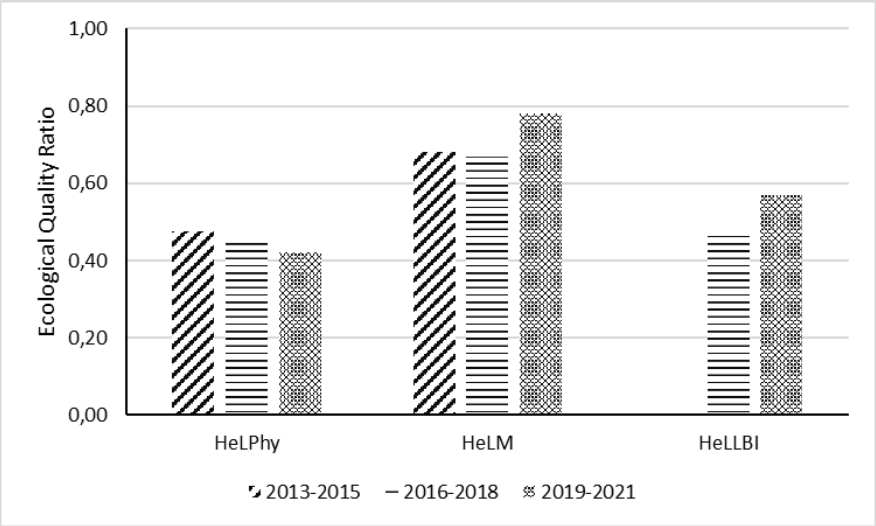

Fig. 3: EQR values of the HeLPhy, HeLM and HeLLBI assessment systems in Lake Kastoria.

4. Discussion/Conclusion

Based on the results from the National Monitoring Project, and with the application of the one-out-all-out principle (EU, 2000), Lake Kastoria is classified overall as Moderate, during both the first and the second monitoring periods. The HeLM assessement system classified the lake consistently as Good, unlike the other two assessment systems (HeLPhy and HeLLBI). Results from aquatic macrophytes and zoobenthos suggest that there has been an improvement in the biological quality of the littoral zone in the period 2018-2021, compared to the previous years. Results from phytoplankton show that the pelagic zone of the lake is at moderate status, with no signs of improvement throughout the decade. Human activities have been affecting the lake, which is a recipient of urban wastewater and fertilizers from agricultural areas. Although some actions are underway, such as the reconstruction of certain sewage pumping stations of the town, more actions that minimize nutrient loading from all pollution sources of the lake catchment are necessary, in order to reduce eutrophication and to improve the overall status of the lake ecosystem. Biological monitoring should continue in the future, in order to document changes in the state and trends of the lake, and thus evaluate the effectiveness of management measures applied.

5. Acknowledgements

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