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Long-term ecological modeling of a subalpine lake subject to anthropogenic changes and restoration via hypolimnetic withdrawal

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After a period of strong anthropogenic eutrophication, in the past 40 years the subalpine Lake Caldonazzo, northern Italy, shifted from eutrophic to mesotrophic thanks to the introduction of in-lake restoration operations, such as hypolimnetic aeration and withdrawal, but the improvement in lake's water quality slowed down in the last decade. In order to understand the underlying dynamics, the ecological behaviour of the lake was reconstructed through a one-dimensional coupled hydrodynamic and ecological numerical approach (GLM-AED2), with a main focus on phosphorus dynamics. Five-year long simulations (2013-2018) properly reproduced measured phosphorus (total phosphorus and orthophosphate), nitrogen (ammonium and nitrate), dissolved oxygen and chlorophyll concentration. Surface dynamics were found to depend on phytoplankton photosynthetic activity, which is responsible of high dissolved oxygen and phosphorus concentration in the epilimnion. Two algal species, diatoms and greens, were taken into account to reproduce spring and summer blooms, with silica (for diatoms) and clorophyll (for both) concentrations being used as proxy for the correct representation of phytoplankton biomass. The internal load caused by the sediment release of phosphorus played a leading role in the increase of hypolimnetic nutrient concentration and anoxia, together with the phytoplankton respiration and sedimentation processes and the degradation of organic matter in dissolved and particulate form.

The effects of the existing hypolimnetic withdrawal were evaluated by assuming its activation from mid-May to the end of October at the operating depth of 37 m. The removal of phosphorus- and ammonia-rich and anoxic water from the bottom of the lake produced a decrease of the average concentration of total phosphorus and nitrogen, as expected, with a significant reduction of algal blooms. As a design solution for fastening the improvement of lake status, a scenario was simulated with the hypolimnetic withdrawal at a lower depth (45 m, close to the bottom of the lake). Simulation results suggest that this choice could significantly improve the removal process. For both cases, the non-linear changes in all other quantities (i.e. thermal structure, dissolved oxygen, organic matter and dissolved inorganic carbon concentrations) were evaluated, suggesting that a coupled modelling approach can provide useful suggestions for lake restoration in terms of operational depth and timing of withdrawal operations.