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Freshwater mass balance and exchange of water masses with the open sea: the Mljet Lakes (Croatia, Adriatic Sea)

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Two karstic seawater lakes (Veliko – Big and Malo – Small Lake) located in the National Park Mljet on the Mljet Island in Croatia were investigated in this study. The Small and the Big Lake cover 0.25 and 1.45 km^2, respectively. The two lakes are connected to each other and to the sea by narrow channels. The connecting channel between the Big Lake and the sea is 12 m wide and 3 m deep. The connection to the Small Lake leads through another artificial channel (2.7 m wide and 0.8 m deep). The average salinity of the Big and the Small lake is 37.75 and 36.9, respectively, and the average salinity of the open sea is 38.5. While previous studies have been conducted due to the lakes' unique ecosystem and the karstic characteristics of the area, the main aim of this study was to determine the freshwater mass balance and exchange of water masses with the nearby sea.

Several measurement campaigns were performed between 2008 and 2015 when meteorological parameters as well as salinity, water temperature and water velocities in both lakes and the channels were observed. A perpetual year was determined using available meteorological data. The contribution of the surface runoff to both lakes was modelled using the hydrological rainfall-runoff HEC-HMS model. Curve number parameter was estimated using the CLC Corine Land cover and geomorphological maps. Evaporation from the lake was calculated using the Verburg, Kondo and Coare equations. We found that the annual evaporation approximately equals the annual rainfall to the lake surface (cca. 550-600 mm). From the hydrological model and the difference between precipitation and evaporation from the lake surface we calculated the annual net excess of freshwater between 0.5 10^6 and 0.7 10^6 m^3. The average salinity in both lakes is lower than the salinity in the sea; therefore, we hypothesize that the excess water should be discharged either through the channel between the Big Lake and the open sea or through underwater karstic sink holes. In order to determine the dynamics of discharge through the channel, we calculated the volume of incoming and outgoing water masses using measured velocity fields (ADCP) and sea surface elevations measured during the spring 2015 campaign. We calculated monthly net inflow exceeding 1.5 10^6 m^3. A comparison with previous measurements (October 2013) revealed similar water flow pattern. Moreover, during the spring 2015 measurements, when evaporation was relatively low, about one third of annual precipitation occurred. At the calculated inflow and precipitation rates salinity in the lakes would not increase significantly ($<$0.1 psu). However, the calculated inflow rate suggests that the water elevation increase in the lakes would exceed 1 m during the one month period. These results indicate strong subsurface connections between the lakes and the surrounding sea to regulate the water level in both lakes.

This hypothesis has to be tested using additional measurements in order to correctly identify possible outflows from the lakes, either through the complex subsurface karstic system or through the channel connecting the Lakes and the sea.