Stable carbon and nitrogen isotopes as tracers of eutrophication process in mountain lakes

P. Vreca

"Jožef Stefan" Institute, Jamova 39, 1000 Ljubljana, Slovenia

Stable carbon and nitrogen isotope investigations have proven to be a powerful tool in studies related to C and N cycles in aquatic environments. Organic matter produced and sedimented at the lakes bottom represents a time-averaged integration of processes affecting stable isotopic composition. The use of stable isotopes of bulk sedimentary organic matter (SOM) to study past environmental conditions is based on the assumptions that SOM originates from primary production in the water column and that the isotopic ratios reflect those of organic matter produced in the water column (Schelske and Hodell, 1991). If these assumptions are valid, then the stable isotopic composition of sediments should be a function of nutrient-driven productivity or trophic state in lake (Gu et al., 1996).

In the Julian Alps in NW Slovenia there are 14 small postglacial mountain lakes. All lakes are situated in the area of the Triglav National Park where human impact is limited by law. Lakes are situated at different altitudes, have different size, maximum depth and different trophic state. For the purpose of this study we investigated four lakes: Zgornje Krisko jezero, Jezero v Ledvicah, Krnsko jezero and Jezero na Planini pri Jezeru. The first two are oligotrophic and are situated above tree level while the other two are eutrophic and are situated just below tree level. In order to investigate the applicability of C and N stable isotope signatures in SOM to trace changes in lake trophic state sediment cores were taken from the deepest basin of the lake and sectioned into 1 cm segments. Dry sediment samples were used for determination of the stable isotopic composition of organic carbon ($\delta^{13}C_{org}$) and nitrogen ($\delta^{15}N$) that was performed on a Europa 20-20 continuous-flow mass spectrometer with an ANCA-SL preparation module. Ranges of $\delta^{13}C_{org}$ and $\delta^{15}N$ values are summarized in the Table below.

Lake	$\delta^{13}C$ [‰]	$\delta^{15}N$ [‰]
Zgornje Krisko jezero	-19.8 to -15.2	-1.0 to +0.9
Jezero v Ledvicah	-26.3 to -22.4	-3.0 to +1.6
Krnsko jezero	-31.5 to -24.9	-1.2 to +2.4
Jezero na Planini pri Jezeru	-36.0 to -29.6	+1.3 to +2.9

$\delta^{13}C_{org}$ values decrease with depth of the sediment in Zgornje Kriško jezero while in other three lakes the isotopic composition of organic carbon increases with depth. Isotopic composition of nitrogen increases with depth in all four lakes. Higher $\delta^{13}C_{org}$ values are associated with lower $\delta^{15}N$ values and are characteristic for oligotrophic lakes, while lower $\delta^{13}C_{org}$ values are associated with higher $\delta^{15}N$ values that are characteristic for eutrophic lakes. Very low $\delta^{13}C_{org}$ values in eutrophic lakes are related to the presence of methanotrophic organisms that consume ^{13}C-depleted methane during synthesis of microbial biomass in water column and consequent sedimentation of this ^{13}C-depleted biomass at the bottom of the lake. Lower $\delta^{15}N$ values in oligotrophic lakes can be attributed to the primary source of nitrogen. Above tree level nitrate deposition or atmospheric N_2 comprise the primary source for dissolved lake nitrate, which is available to aquatic plants and phytoplankton and consequently $\delta^{15}N$ values of the lacustrine biomass is close to 0‰ or negative (Mayer and Schwark, 1999). In contrast, terrestrial input of organic matter into the lake contributes material with more positive nitrogen isotopic

composition. This is evident in both eutrophic lakes that are situated below tree level and where SOM is a mixture of terrestrial and aquatic organic matter.

References

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