The oxygen-18 isotope approach for measuring aquatic metabolism in high productivity waters

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ABSTRACT: We examined the utility of $\delta^{18}O_2$ measurements in estimating gross primary production (P), community respiration (R), and net metabolism (P : R) through diel cycles in a productive agricultural stream located in the midwestern U.S.A. Large diel swings in O_2 (±200 µmol L^{-1}) were accompanied by large diel variation in $\delta^{18}O_2$ (±10‰). Simultaneous gas transfer measurements and laboratory-derived isotopic fractionation factors for O_2 during respiration (α_r) were used in conjunction with the diel monitoring of O_2 and $\delta^{18}O_2$ to calculate P, R, and P :R using three independent isotope-based methods. These estimates were compared to each other and against the traditional ❬❭open-channel diel O_2-change❬❭ technique that lacked $\delta^{18}O_2$. A principal advantage of the $\delta^{18}O_2$ measurements was quantification of diel variation in R, which increased by up to 30% during the day, and the diel pattern in R was variable and not necessarily predictable from assumed temperature effects on R. The P, R, and P :R estimates calculated using the isotope-based approaches showed high sensitivity to the assumed system fractionation factor (α_r). The optimum modeled ar values (0.986-0.989) were roughly consistent with the laboratory-derived values, but larger (i.e., less fractionation) than α_r values typically reported for enzyme-limited respiration in open water environments. Because of large diel variation in O_2, P :R could not be estimated by directly applying the typical steady-state solution to the O_2 and ^{18}O-O_2 mass balance equations in the absence of gas transfer data. Instead, our results indicate that a modified steady-state solution (the daily mean value approach) could be used with time-averaged O_2 and $\delta^{18}O_2$ measurements to calculate P :R independent of gas transfer. This approach was applicable under specifically defined, net heterotrophic conditions. The diel cycle of increasing daytime R and decreasing nighttime R was only partially explained by temperature variation, but could be consistent with the diel production/consumption of labile dissolved organic carbon from photosynthesis.

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