ABSTRACT

Ecosystem Carbon Cycles: Whole-Lake Fluxes Estimated with Multiple Isotopes

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Inorganic ^{13}C additions to lakes were used to: 1) determine the atmospheric flux of CO_2 isotopes in high pH lakes, 2) examine models of photosynthetic fractionation in planktonic algae, 3) estimate the relative contribution of algal and terrestrial sources of dissolved organic carbon (DOC), and 4) validate a combined bioenergetics/carbon model for *Chaoborus*.

Stable carbon isotope analysis has advanced the understanding of carbon flow in lake ecosystems. However, this approach is sometimes constrained by the limited range of carbon isotope signatures ($\delta^{13}C$) found in nature. To overcome some of these limitations, inorganic ^{13}C was added to the surface water of Paul and Peter lakes in 2001, and to Peter and Tuesday lakes in 2002. Peter Lake also received nutrient additions in 2002 to stimulate primary productivity. Photosynthetic uptake of added ^{13}C created algal isotope signatures that were distinct from those of terrestrial organic carbon. Addition of ^{13}C also caused a large increase in $\delta^{13}C$ of many other C pools. After the additions ended the $\delta^{13}C$ of these pools gradually

returned to background levels. Natural abundance $\delta^{13}C$ does not display such dynamics. The dynamic isotope signatures allowed us to estimate ecosystem and organism level carbon flux rates.

Increased algal productivity generally is considered to increase the $\delta^{13}C$ of dissolved inorganic carbon (DIC). However, increased productivity in Peter Lake caused conditions of low dissolved CO_2, high pH, and chemically enhanced diffusion of atmospheric CO_2 into the lake. Isotopic fractionation of CO_2 during the process of chemically enhanced diffusion created very negative $\delta^{13}C$-DIC (about -20‰).

An accurate estimate of algal $\delta^{13}C$, either by measurement or models, is necessary to evaluate the $\delta^{13}C$ of other organic carbon pools. Algal $\delta^{13}C$ is dependent on the source $\delta^{13}C$-DIC and photosynthetic fractionation. Existing models of photosynthetic fractionation did not accurately predict algal $\delta^{13}C$ in these study lakes. In addition, algal $\delta^{13}C$ may not be equivalent to particulate organic carbon $\delta^{13}C$ because of the presence of non-algal material, such as terrestrial detritus. Therefore, studies that require algal carbon signatures or estimates of photosynthetic fractionation should use models of photosynthetic fractionation cautiously, and instead, should directly estimate algal $\delta^{13}C$ by physical or chemical separation of algal carbon.

I used the distinct algal $\delta^{13}C$ to estimate the contribution of algal carbon to the dissolved organic carbon pool. The DOC isotope signature increased in all four whole-lake experiments due to the addition of ^{13}C labeled algal DOC. Between 5-40% of the dissolved organic carbon pool is of algal origin in the four lakes studied. Percentage of algal

contribution appears to be positively related to levels of primary productivity, and inversely related to water color, a potential indicator of terrestrial carbon loading.

Algal-fixed ^{13}C was also observed in herbivorous and predatory zooplankton. I constructed a bioenergetics model of *Chaoborus* spp. coupled with a carbon isotope mass balance model to predict dynamics in *Chaoborus* isotope ratios. The model reasonably reproduced the observed *Chaoborus* $\delta^{13}C$ dynamics. This model framework can be applied to organismal isotope studies where diet isotope signatures are dynamic or the consumer is not in equilibrium with the diet isotopic composition.