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Title:
Why Are Small Lakes Brown? A Framework for Assessing Watershed Carbon Loading and In-lake Processing for a Northern Lake District

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Background/Questions/Methods

There is a growing recognition that lakes are of consequence for the global carbon cycle. In north temperate and boreal landscapes, small lakes have been found to have particularly high rates of C cycling and higher mean dissolved organic carbon (DOC) concentrations, color, and pCO_2 relative to large lakes. The reasons for these differences are not known, but are likely related to variation in C loading rates from the watershed, variation in within-lake C processing rates, or both. The goal of this study was to explore alternative hypotheses to explain the observation that lake DOC concentration is inversely related to lake area, using a set of 168 lakes in the Northern Highlands Lake District (NHLD) of Wisconsin/Michigan. The central question is, which of the hypotheses most plausibly explain the observed relationship? We used a combination of approaches: First, measured lake DOC concentrations were related to GIS-derived landscape characteristics using multivariate and multiple linear regression techniques. Second, a simple equilibrium model of lake DOC as a function of OC load and processing rates was developed, and used to generate hypothetical relationships among landscape characteristics and lake DOC, which were then compared to observed relationships. Finally, plausibility of each of the alternate hypotheses was evaluated.

Results/Conclusions

Lake DOC concentration was positively correlated with wetland proportion in watershed, and negatively correlated with lake area. Variation in OC loading, rather than variation in processing rates, emerged as the most likely explanation for the observed relationship between lake size and DOC in this region. A few promising refined hypotheses emerged from our analysis. These include: 1. Small lakes are found in a different landscape context than large lakes, in particular in this region many of the tiniest lakes are ponds isolated in peat bogs, thus surrounded by a rich source of organic carbon. 2. Because of variation in perimeter:area ratio, the input of leaf litter from riparian forests makes a substantial contribution to the C budget of small lakes, but not large lakes. Our model predicts that with areas of less than about 1 ha (close to the median for the region), lakes on average receive more OC inputs from tree leaf litter than from wetlands. This challenges the oft-cited assumption that wetland DOC is typically the main source of DOC for northern surface waters. This study suggests that both watershed-wide characteristics and riparian characteristics can contribute substantially to DOC load and lake C dynamics, emphasizing the importance of a spatially-aware approach to terrestrial-aquatic carbon linkages.