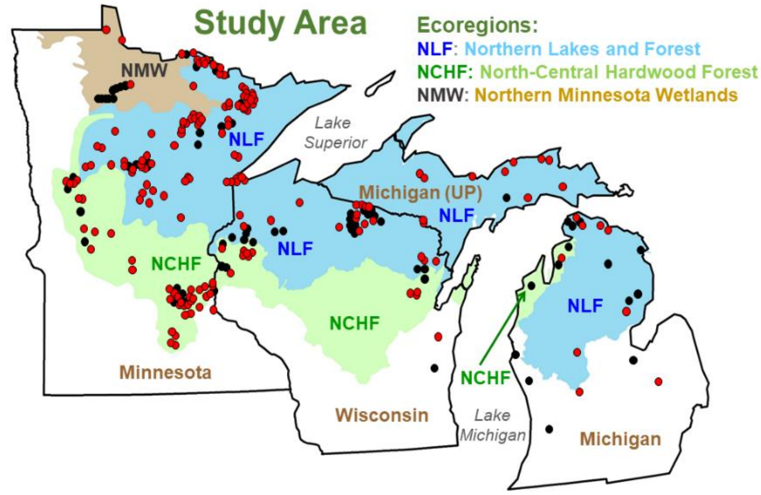
CDOM: Field-based studies

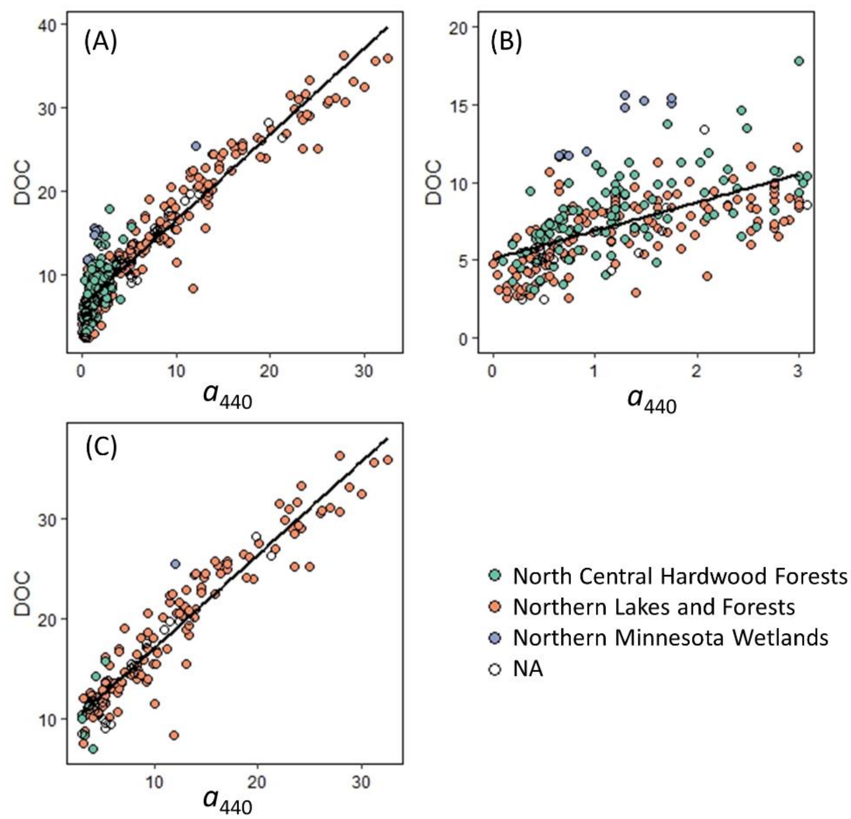
In addition to mapping CDOM by remote sensing, we have used our field data (see map at the right for 2014-2017 sampling sites), coupled with lab measurements and experiments, to address three important questions related to the role of CDOM in aquatic ecosystems: (1) can CDOM be used to predict DOC concentrations; (2) what is the role of iron in causing the color we attribute to dissolved organic matter; and (3) to what extent does CDOM affect water clarity as measured by Secchi depth? Here we present findings from recently published papers on these topics.



Sampling locations for our ground-based CDOM studies. Red circles denote sites where iron was measured in addition to DOC, CDOM, SD, chlorophyll and other water quality parameters that were measured at all sites

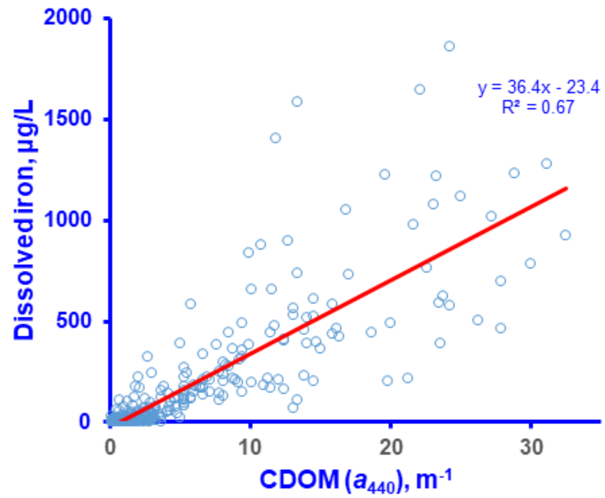
1. DOC-CDOM relationships

DOC (measured in m/L) and CDOM (measured as a_{440}) are strongly correlated across the lakes of the Upper Great Lakes states (Figure (A) at right), but the DOC-a_{440} relationship is much weaker in low colored lakes, i.e., $a_{440} < 3\ m^{-1}$ (Figure (B)), likely because low-colored organic matter from human sources (e.g., wastewater effluent, urban runoff) contributes varying amounts to the DOC pool but not to the CDOM pool. The relationship is especially strong in visibly stained lakes, i.e., lakes with $a_{440} > \sim 3\ m^{-1}$ (C), with an R^2 value of 0.90. Data in these figures are largely from the three ecoregions in the northern, central, and eastern parts of the state shown in the map at the top of the page: Northern Lakes and Forests (NLF), North Central Hardwood Forests (NCHF) and Northern Minnesota Wetlands (NMW).



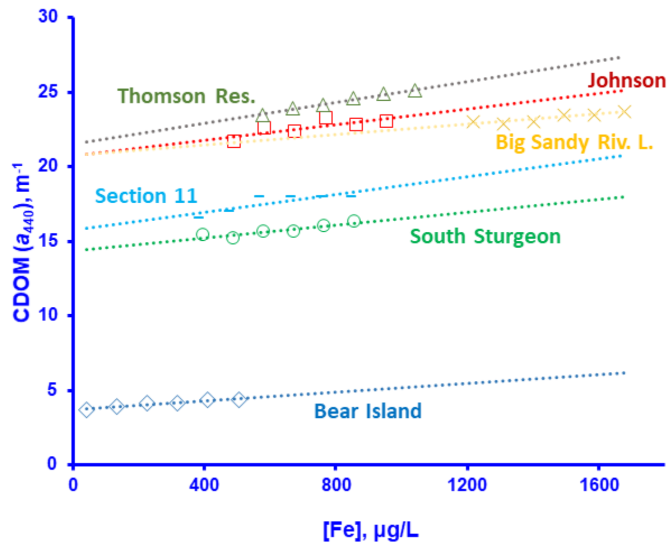
Easily measured CDOM thus can be used as a surrogate (predictor) of DOC in lakes that are visibly colored, but caution should be used in estimating DOC from CDOM in low-color lakes. Further details on CDOM relationships with DOC and other properties of DOM can be found in Griffin et al., *Water Research* 144: 719 (2018).

2. CDOM and Iron



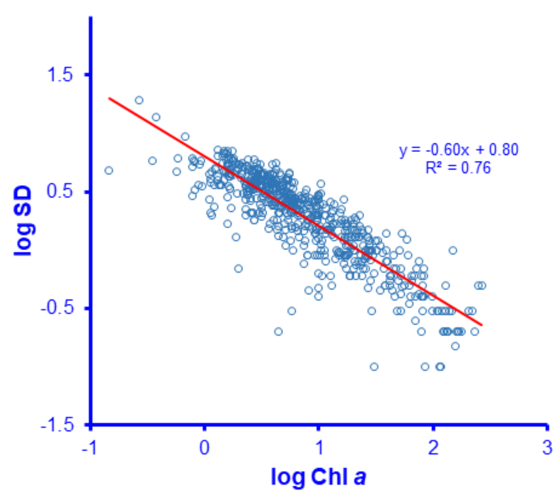
CDOM levels and dissolved iron (Fe) concentrations are moderately associated with each other in Minnesota lakes (see figure at right) and elsewhere. In fact, anecdotal data suggest that many lake homeowners and lake users attribute the brown color of lakes to high Fe concentrations. Scandinavian scientists have concluded that increasing concentrations of dissolved Fe could explain the "browning" phenomenon (increases in brown color) commonly found in Scandinavian lakes and northeastern North America in recent decades.

Analysis of our field data, coupled with laboratory experiments in which we added controlled amounts of dissolved Fe to several Minnesota lakes with varying CDOM levels, led us to conclude, however, that dissolved Fe is not a major factor affecting apparent CDOM levels (i.e., a_{440}) in lakes of Minnesota and the surrounding region.



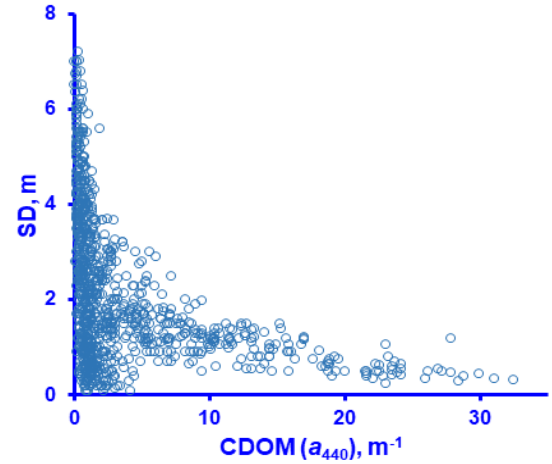
Adding dissolved Fe to lake waters (see figure at right) increased a_{440} only by very small amounts (average of only 0.24 m^{-1} per 100 µg/L of added Fe). Extrapolating the best-fit lines of a_{440} vs. added Fe back to zero ambient Fe showed that most of each lake's ambient a_{440} remained. Overall, DOM accounted for ~ 92 ± 5% of measured a_{440} for our lakes, and dissolved Fe accounted for the rest. For further information on this topic and other effects of Fe on DOM optical properties, see Brezonik, Finlay et al. *PLOS ONE* 14(2): e0211979 (2019).

3. CDOM effects on Secchi depth (SD)

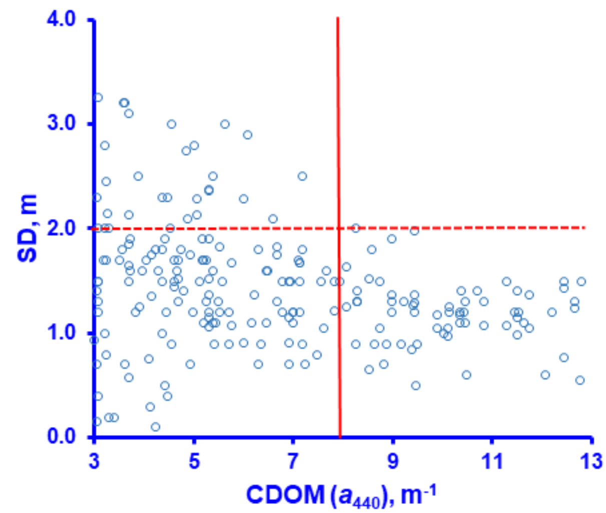


In most lakes, SD is controlled by algal density, commonly measured as chlorophyll *a* concentration. The strong relationship in the log-log plot at the right of SD vs. chlorophyll for low-color lakes in the Upper Great Lakes states (lakes with $a_{440} < 3$ m^{-1}) suggests that chlorophyll (algal density) is a primary controlling factor for SD in these lakes. The outliers below the best-fit line suggest that other factors aside from algal density affect SD levels in some lakes.

In highly colored lakes, CDOM is the main controlling factor for SD, and SD may not be a good indicator of trophic state (i.e., algal density) in highly colored lakes. An indication that this is the case is seen in the plot at the right for a large number of lakes across the Upper Great Lakes States. SD values have a wide range in low-color lakes (a_{440} < ~3 m^{-1}), largely reflecting how much chlorophyll is present, but all high colored lakes have low SD because of the light-absorbing properties of CDOM.



Using a data set of 1460 samples from our 2014-2017 ground-based sampling program and monitoring data from the Minnesota Pollution Control Agency for 2015-2017, we found that no lake with CDOM (a_{440}) > 8 m^{-1} had a SD > 2 m (see plot below right). Further statistical analyses showed that CDOM starts to affect SD at a_{440} > ~4 m^{-1}. A SD of 2 m is Minnesota's water quality standard indicative of trophic state impairment for warm/cool-water lakes in the NLF ecoregion. For more details on this subject, see Brezonik, Bouchard, et al. *Ecological Applications* e01871 (2019).



References

Brezonik, P. L., J. C. Finlay, C. G. Griffin, W. A. Arnold, E. H. Boardman, N. Germolus, R. M. Hozalski, and L. G. Olmanson. 2019. Iron influence on dissolved color in lakes of the Upper Great Lakes States. *PLoS ONE* 14(2): e0211979. https://doi.org/10.1371/journal.pone.0211979

Brezonik, P. L., R. W. Bouchard, Jr., J. C. Finlay, C. G. Griffin, L. G. Olmanson, J. P. Anderson, W. A. Arnold, and R. M. Hozalski. 2019. Color, chlorophyll a, and suspended solids effects on Secchi depth in lakes: implications for trophic state assessment. *Ecological Applications* 29(3):e01871. https://doi.org/10.1002/eap.1871

Griffin, C. G., J. C. Finlay, P. L. Brezonik, L. G. Olmanson, and R. M. Hozalski. 2018 Limitations on using CDOM as a proxy for DOC in temperate lakes. *Water Research* 144: 719-727. https://doi.org/10.1016/j.watres.2018.08.007