Consequences of ecohydrological responses upon spatio-temporal variability of dissolved organic carbon characteristics in Boreal Plain shallow lakes

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EXTENDED ABSTRACT

The consequences of terrestrial ecosystem-hydrology interactions (hereafter 'ecohydrological responses') upon the variability of DOC (dissolved organic carbon) characteristics in Boreal Plain (BP) shallow lakes is largely unknown and difficult to forecast. Source water quality can deteriorate as a result of ecohydrological responses, creating water treatment issues for drinking water providers in terms of cost and distribution demands. The BP region is characterized by a sub-humid climate and thick heterogeneous glacial surficial geology, comprising three major landforms that differ in water storage capacity and transmissivity: fine-grained hummocky disintegration moraines, fine-grained low relief clay plains, and coarse-grained outwash areas. The surficial geology is overlain by landcovers that include a series of shallow lakes interspersed with extensive peatlands and pockets of forestlands with isolated depressions. Each landcover has a different threshold storage capacity, due to their relief, soil and vegetation properties. Forestlands, shallow lakes and isolated depressions typically exhibit large threshold storages. Forestlands have deeper, better drained soils to promote forest growth, increased actual evapotranspiration (AET) creating a large demand for soil moisture and deeper water tables that respond slowly to precipitation events, requiring a series of extended wet periods to reach their threshold storage and generate runoff. Shallow lakes and isolated depressions are typically characterized by depression storage and exhibit AET rates that exceed PET due to direct exposure to solar radiation and lack of soil or vegetative covering. Conversely, peatlands generate runoff more frequently due to soil layering and a shallow confining layer that results in a low threshold storage (detention storage) that responds rapidly to precipitation events and promotes surface saturation, as well as reduced AET rates as a result of shading and shallow water tables. A combination of landcovers, surficial geology and a sub-humid climate creates dynamic hydrologic connectivity in the BP, whereby subtle changes between precipitation and evapotranspiration causes storage of different landcovers to fluctuate between a positive and negative water balance, thereby causing terrestrial-aquatic linkages to switch on or off. The hydrologic connectivity of a watershed can have dramatic downstream effects regarding landscape carbon cycling and water quality by determining the magnitude, timing and composition of DOC entering shallow lakes. In this study, we hypothesize that DOC characteristics of BP shallow lakes will show temporal variability in absolute concentration, magnitude and timing of DOC response between different landforms (surficial geology), landscape positions (topographically high or low), and landcover organizations (proportion of landcovers and % peatland connectivity to shallow lake) within a watershed. The spatio-temporal variability in BP shallow lake DOC characteristics resulting from ecohydrological responses is currently poorly understood with previous studies examining shorter timescales and overlooking interactions between climate, landform and landcover organisation.

In this study, a landscape scale annual synoptic survey of DOC characteristics (DOC, absorbance & Specific Ultra-Violet Absorbance (SUVA)), oxygen/hydrogen isotopes, geochemistry and water quality (turbidity, phosphorus, nitrogen and chlorophyll a) of 34 shallow lakes and representative end-members source areas was undertaken at Utikuma Region Study Area (URSA) annually from 2012 to 2017. These analyses enable assessment of the temporal variability in shallow lake DOC characteristics, water residence time (isotopes and geochemistry) and water quality across the BP. A combination of climate data, watershed characteristics (including landcover organization, landscape position and landform texture) and end-member analyses from respective allochthonous DOC sources was used to define potential surface and subsurface connections to shallow lakes and broadly identify the climate and watershed characteristics required to trigger a response in DOC characteristics of a shallow lake. Preliminary results show that absolute DOC concentration varies spatially, whereby shallow lakes in coarse-grained outwash (CO) have the lowest absolute DOC concentrations followed by fine-grained hummocky disintegration moraines (HM) and fine-grained low relief clay plains (CP) shallow lakes, respectively (Fig.1a). SUVA follows the same spatial trend, however temporal variability is larger, indicating the influence of within-lake processing of DOC (Fig.1b). Additional results show hysteresis between DOC characteristics and climate, suggesting time lags between an ecohydrological response to climate and consequences to DOC characteristics of a shallow lake. Identifying the variability in DOC characteristics (quality and quantity) of shallow lakes and developing a conceptual model to understand spatio-temporal variability in response to ecohydrological processes is critical for watershed managers and drinking water providers to anticipate and mitigate problematic consequences of ecohydrological responses within shallow lakes.

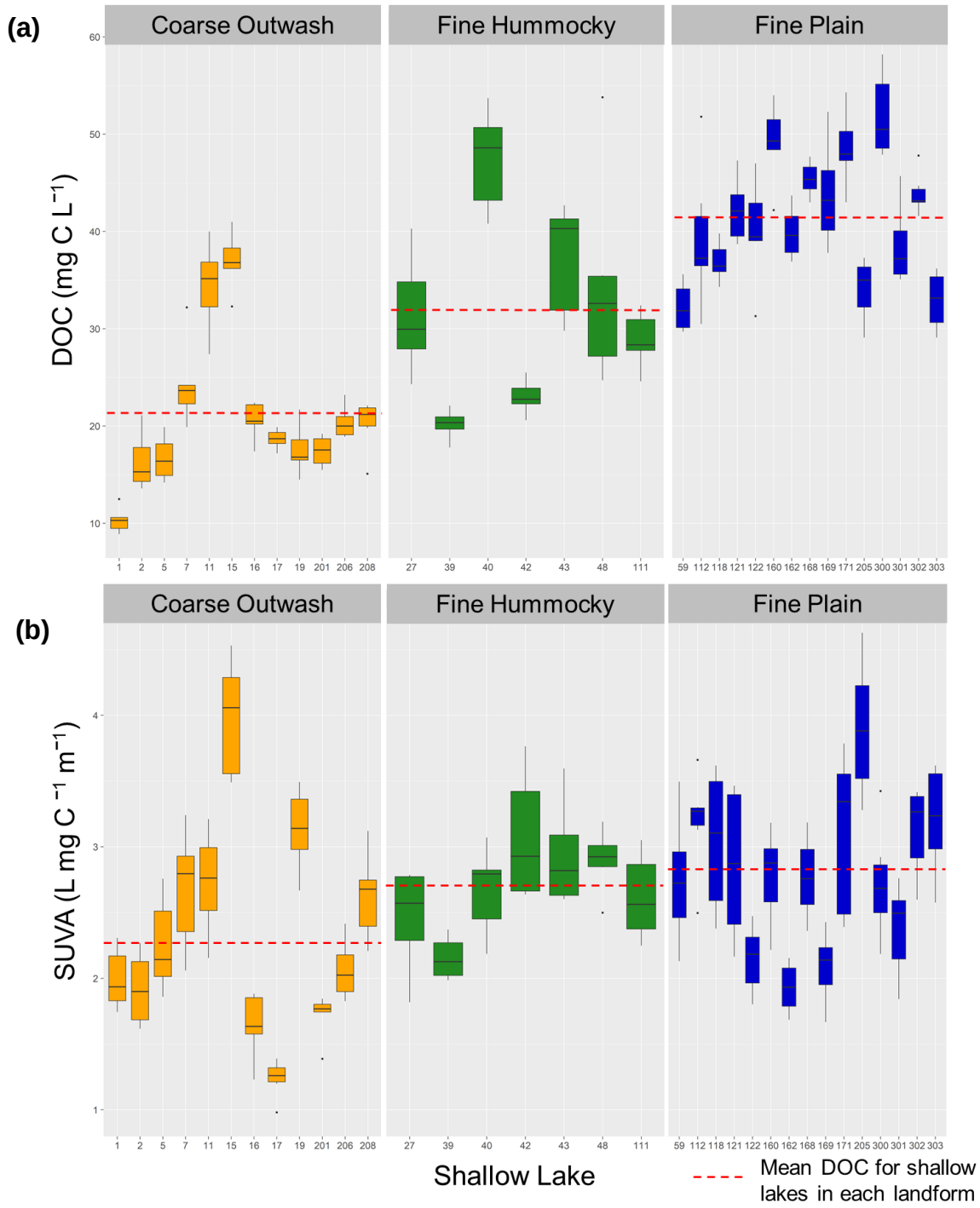

Figure1. Spatio-temporal variability in (a) DOC and (b) SUVA across 34 shallow lakes in the URSA transect from 2012 - 2017. Coarse Outwash shallow lakes (orange) show the lowest DOC and SUVA values, followed by fine hummocky (green) and fine plain (blue) respectively. The mean DOC and SUVA values for shallow lakes within a surficial geology category is indicated by a red dashed line. Mean DOC between surficial geologies is larger than mean SUVA indicating more spatial variability in DOC; however the temporal variability is greater in SUVA values, indicating the occurrence of within-lake processing of DOC.