Dissolved organic matter in the Mackenzie River Delta: Changes in quantity and quality during the ice-free season.

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Introduction

Arctic floodplains, located at the interface between large north-flowing circumpolar rivers and the Arctic Ocean, are important but poorly understood sites of carbon and organic matter cycling. Recent work has found that three to seven times more carbon is cycled through these ecosystems than is ultimately discharged to the Arctic Ocean (*1*). This indicates a potential for extensive processing and transformation of carbon and dissolved organic matter (DOM) during periods of floodplain storage. To date, however, most studies investigating discharge from large circumpolar rivers have treated the river as a pipe funnelling water, carbon, and DOM from continents to the ocean, largely unaltered during transport, with sampling sites located upstream from large, lake-rich floodplains.

Objectives & Hypotheses

Our objective was to establish baseline carbon and DOM data for the open-water season in the Mackenzie River and Delta, against which future changes resulting from anticipated warmer, wetter conditions in the region (*2*) can be assessed. Our specific hypotheses were:

1. DOM quantity and quality would differ between the two delta inflow rivers (the Mackenzie and Peel).
2. DOM quantity and quality in the Mackenzie River would be greatest during the freshet.
3. DOM would be extensively processed during storage in floodplain lakes.

Study Site & Methods

The Mackenzie River Delta is located in the northwestern Canadian Arctic. It is the second largest Arctic floodplain, contains more than 45,000 shallow lakes (*3*), and is remarkably biodiverse and productive relative to the surrounding tundra landscape (*4*).

Delta floodplain lakes are differentially flooded each year during the spring freshet. The flooding frequency and duration for an individual lake is determined by its elevation above the nearest delta channel. Lakes at the same elevation as the channel are flooded for longer periods than those at higher elevations, which may only flood for short periods or during years with particularly high peak floods (*5, 6*). This creates gradients of dissolved carbon and organic matter in delta lakes (Figure 1).

From 2007 to 2010, various sites in the delta were sampled, including inflow rivers, downstream delta sites, and a set of six differentially-flooded lakes in the east-central delta near the town of Inuvik (Figure 2). Samples were taken during the ice-free seasons, starting in the high discharge freshet period (May) and continuing through to summer base flows (August/September).

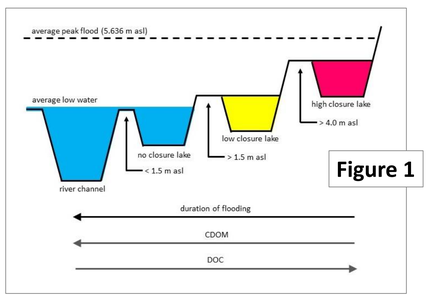


Figure 1

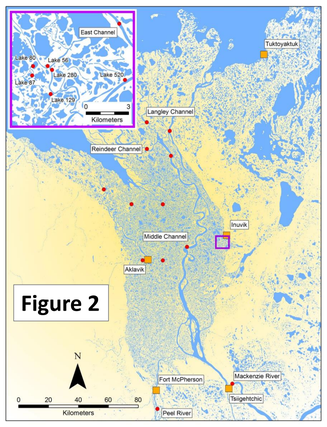


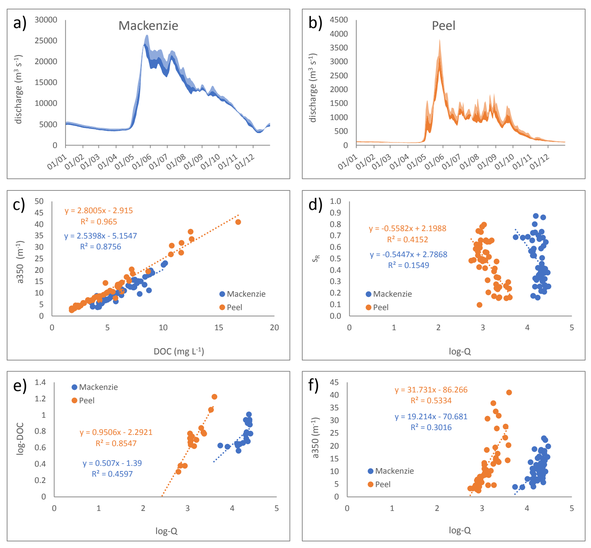
Figure 2

Photo to left – the Mackenzie Delta during the open-water season. Courtesy of JA Krauls, patternity.org.

Dissolved organic carbon (DOC) concentrations were measured using high-temperature catalytic oxidation. Several absorbance-based analyses were used to assess our hypotheses, including absorbance at 350 nm (a350, a proxy for the quantity of chromophoric DOM, or CDOM), specific ultraviolet absorbance ($SUVA_{254}$, with greater values indicating greater average aromaticity and molecular weight of the DOM pool), and the ratio of spectral slopes (s_R, with lower values indicating fresher, or less degraded, DOM).

Results & Discussion

Hypothesis 1: Annual hydrographs (a, b) show that Peel River discharge (Q) is an order of magnitude lower than Mackenzie Q, with flashier discharge later in the ice-free season. DOC and CDOM levels (a350) are closely correlated in both rivers (c). For both, DOM quality parameters (d) are less strongly correlated to Q than are quantity parameters (e, f), although in all cases the correlation is significantly stronger ($p < 0.05$) for the Peel than for the Mackenzie. The Peel also shows a greater range in DOM quantities than the Mackenzie (c, e, f), with far greater maximums (Peel DOC_{max} = 16.8 mg L^{-1} and $CDOM_{max}$ = 40.99 m^{-1}, Mackenzie DOC_{max} = 10.2 mg L^{-1} and $CDOM_{max}$ = 23.03 m^{-1}).

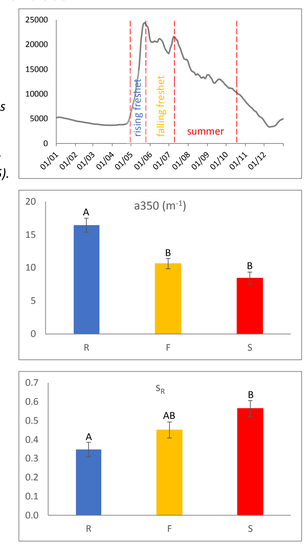


Hypothesis 2: Mackenzie River DOM quantity and quality parameters showed significant differences amongst hydrologically-defined seasons (top graph).

DOM quantity parameters (middle row; DOC and CDOM, expressed as a350) were significantly greater ($p < 0.05$) during the rising freshet (R) period of the hydrograph than during either the falling freshet (F) or the summer (S) seasons. DOM quality parameters (bottom row) indicate a more bioavailable character later in the ice-free season, with significantly lower average molecular weight and aromaticity of the DOM pool, and a less terrigenous character.

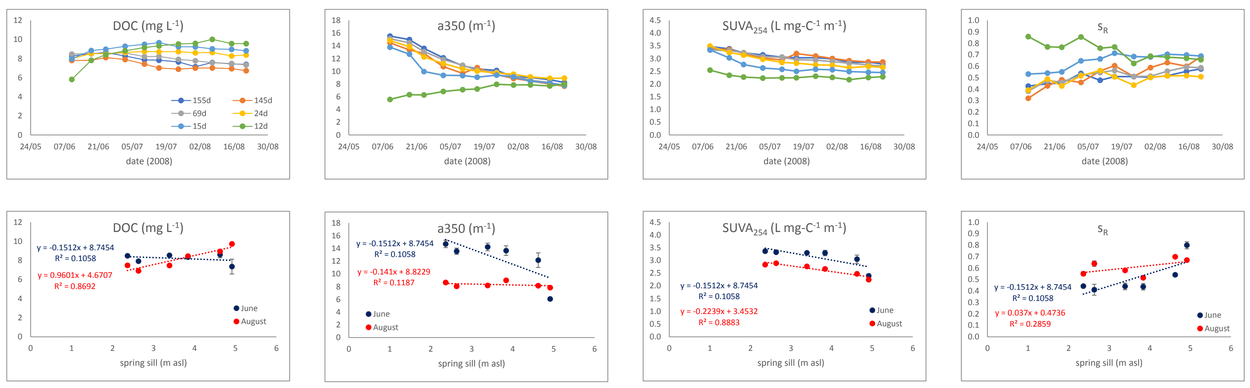
To right – Mackenzie hydrograph showing divisions into hydrological seasons.

For each graph below, means accompanied by the same letter are not significantly different ($p < 0.05$).



Hypothesis 3: DOM in floodplain lakes was extensively processed over the ice-free season. Time series of DOM quantity and quality parameters (top row) show a progressive loss of DOC and CDOM (a350) in most lakes, regardless of channel connection time (shown in legend), along with decreases in average aromaticity and molecular weight (↓ $SUVA_{254}$) and an increasingly degraded character (↑ s_R).

Lakes also showed different relationships between sill elevation and DOM parameters at the start (June) versus the end (August) of the ice-free season (bottom row). Changes in CDOM levels (a350) and DOM quality parameters point towards extensive photobleaching in high sill elevation lakes, and the influence of CDOM-depleted and pre-processed river water inputs in low sill elevation lakes.



Conclusions

- DOM quantity differed between the Mackenzie and Peel Rivers, with greater ranges seen in the Peel. This is likely due to different river hydrologies, basin permafrost extents (75% Mackenzie, 100% Peel), and basin topographies (predominantly lowland Mackenzie, mountainous Peel).
- Quantities of DOM in the Mackenzie River were significantly greater during the rising freshet than in any other season. However, DOM was more bioavailable (less aromatic and lower average molecular weight) during the summer.
- DOM is extensively altered during storage in floodplain lakes. Quantities generally decline, while the remaining DOM becomes more bioavailable.
- The quantity and quality of DOM in downstream delta habitats, and of DOM eventually discharged to the Beaufort Sea, may differ substantially from that carried in inflow rivers due to processing on the delta floodplain during the ice-free season.

References

1. JC Rowland, J Muss, E Shelef, S Stauffer, NA Sutfin. Quantifying the export of floodplain soil carbon to Arctic rivers by bank erosion. GSA Annual Meeting, Denver, USA. 25 September (2016)
2. Y Dibike, T Prowse, B Bonsal, H O'Neil. Int. J. Climatol. 37: 3247-3263 (2017)
3. CA Emmerton, LFW Lesack, P Marsh. Water Resour. Res. 43: W05419 (2007)
4. MM Squires et al. Ecosystems 12: 853-872 (2009)
5. LFW Lesack, P Marsh. Water Resour. Res. 46: W12504 (2010)
6. P Marsh, M Hey. Geogr. Ann. Ser. A, Phys. Geogr. 76: 221-234 (1994)

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