Composition and mobilization of particulate organic matter from retrogressive thaw slump impacted streams

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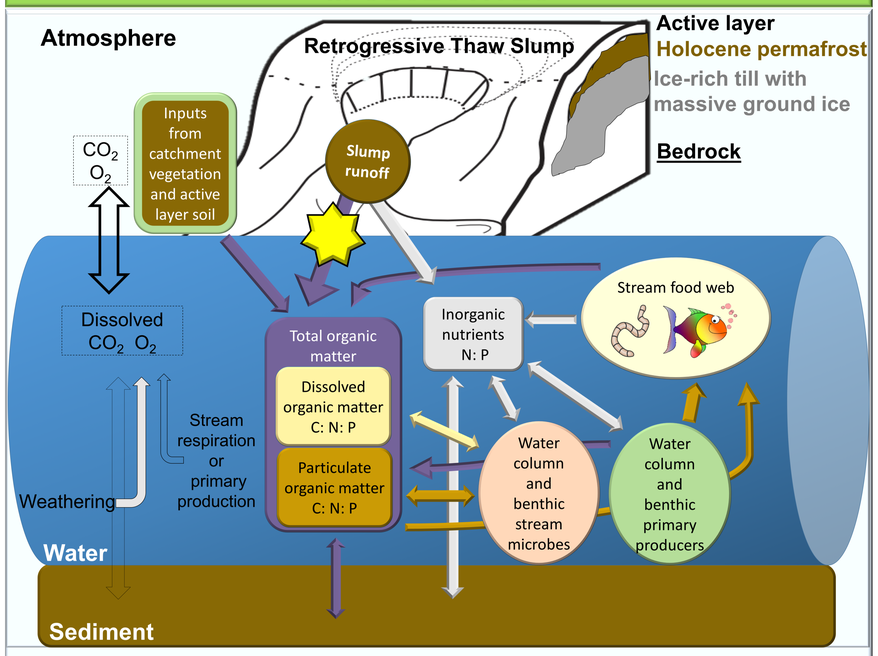
I. BACKGROUND

The source and composition of organic matter can play an important role in metabolism in aquatic systems. Although thermokarst processes are thought to mobilize significant quantities of particulate organic matter (POM), and its organic carbon component (POC), to aquatic systems (1), we know little about its composition and fate, despite permafrost-origin dissolved organic carbon (DOC) having been shown to be easily degraded to CO_2 (2-4).

In the western Canadian Arctic, a warming and wetting climate has intensified thaw slumping (5). These features thaw large volumes of glacigenic sediments and can increase total suspended sediment flux in streams by orders of magnitude (6). While these high sediment concentrations have been shown to have negative impacts on stream biota (7) the alteration of organic matter pools, especially POM pools, and its impact on aquatic ecosystems has not been addressed.

II. OBJECTIVES



A How do thaw slumps alter organic carbon **delivery** to streams and how does this effect differ in the dissolved vs. particulate phases?

B How do thaw slumps alter the **composition** of organic matter in streams and how does this effect differ in the dissolved vs. particulate phase?

III. METHODS

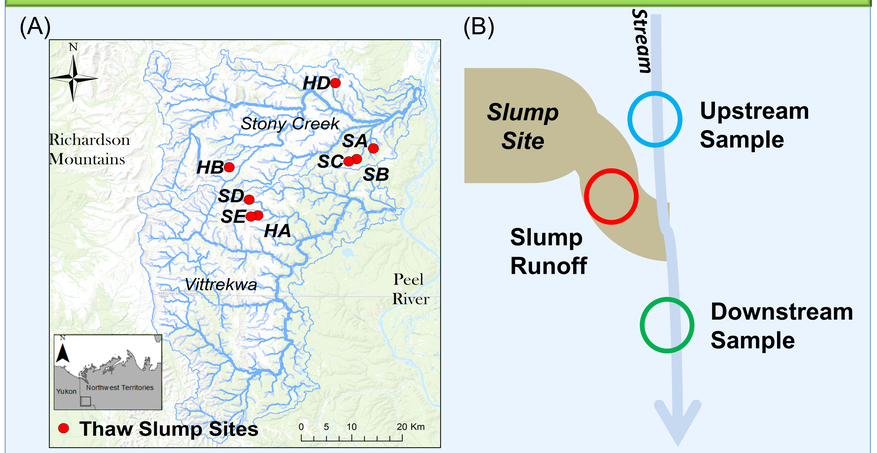


Fig. 1. A) Thaw slump sites, Peel Plateau, NWT. B) Sampling schematic. Whole water samples were obtained upstream, from, and downstream of slump runoff. Samples were collected 1-2 times from each thaw slump from June to August in 2015.

IV. RESULTS

A1

Large thaw slumps, or those well connected to streams, increase organic carbon yields in streams by orders of magnitude, primarily driven by increases in POC. Impacted streams switch from being DOC dominated systems to POC dominated systems. This also reflects changes in the partitioning of organic matter pools.

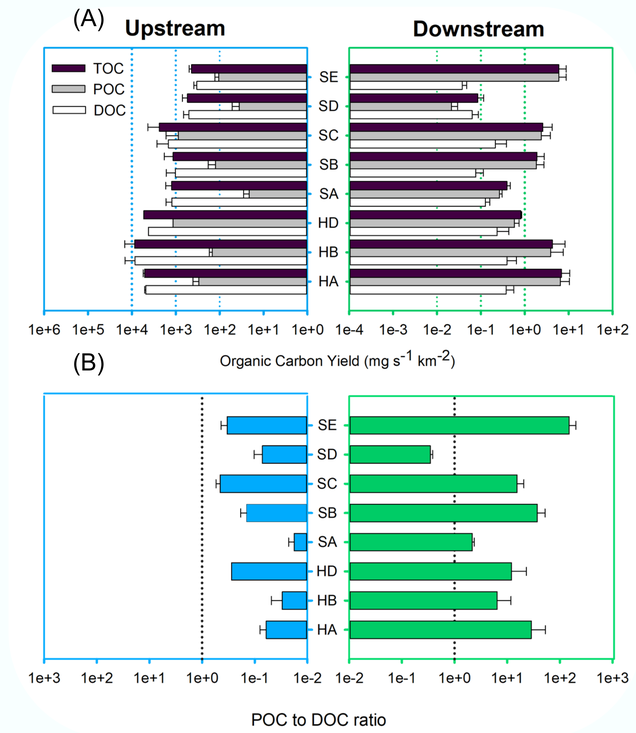


Fig. 2. A) Total (TOC), particulate (POC) and dissolved (DOC) organic carbon instantaneous yield (mg s^{-1} km^{-2}) and B) POC to DOC ratio upstream and downstream of thaw slump sites. *Error bars indicate standard error of the mean of samples obtained from June to August (n=2 HA-HD; n=3 SA – SE).*

B1

Impacted streams have an older $PO^{14}C$ age similar to slump runoff suggesting significant mobilization of permafrost POM

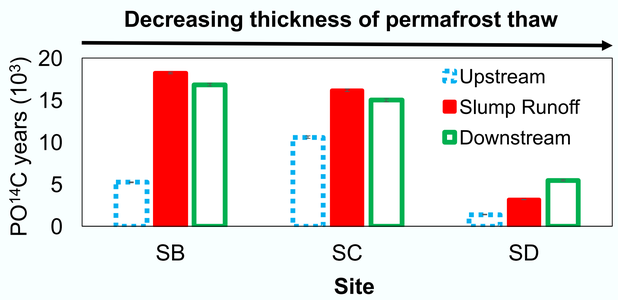
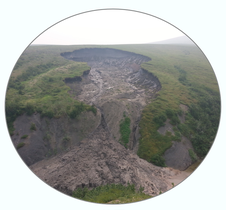


Fig. 3. Radiocarbon age (^{14}C age; Yrs BP 1950) of POC upstream, from, and downstream of the runoff of three active thaw slumps. *Error bars represent 1σ confidence limits.*

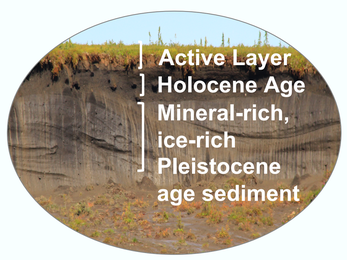
SB
Large Active Slump
Subarctic boreal forest

SA
Mostly Stable Slump
Subarctic boreal forest

SD
Small Shallow Slump
Dwarf shrub tundra



SE
Newly Formed Active Slump
eroding bedrock
Dwarf shrub tundra



SC Headwall

B2

Thaw slump runoff contains dissolved organic matter (DOM) richer in nutrients relative to DOM in un-impacted streams. However, DOM mobilized by thaw slumps does little to alter the DOM pool downstream.

Thaw slump runoff contains particulate organic matter (POM) that is depleted in nutrients relative to POM in un-impacted streams. POM mobilized by thaw slumps substantially alters the POM pool present downstream.

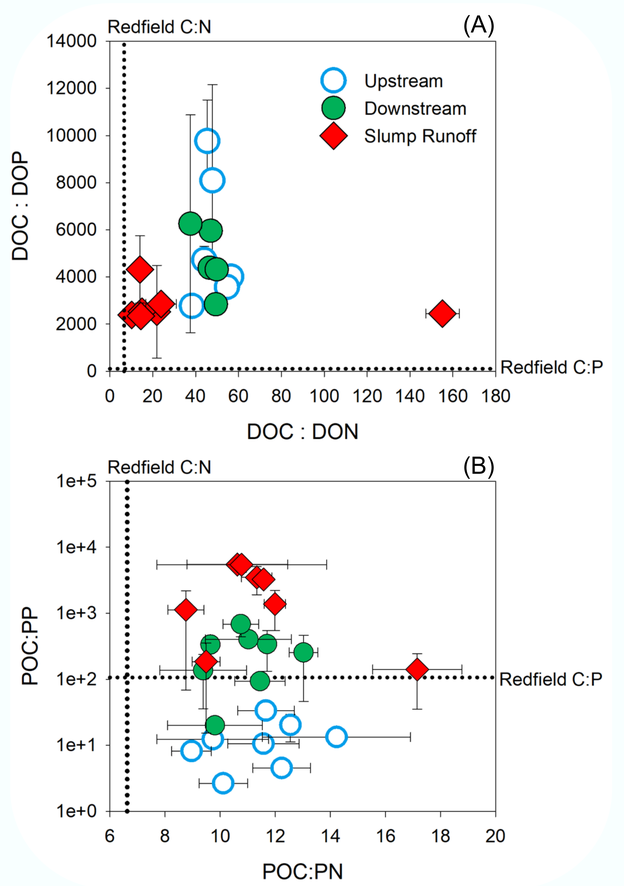


Fig. 4. C: P vs C: N of A) dissolved and B) particulate organic matter upstream, from, and downstream of slump runoff. *Error bars indicate standard error of the mean of samples obtained from June to August (n=2 HA – HD; n=3 SA – SE). Note: Some sampling points for Fig 5A are missing due to dissolved phosphorus values being near the detection limit.*

VI. CONCLUSIONS & FUTURE DIRECTIONS

Thaw slumps increase total organic carbon and organic matter delivery to streams by orders of magnitude. However, this increase in delivery is primarily due to increases in the particulate phase. Thaw-slump-mobilized POM is depleted in nutrients compared to POM present in un-impacted streams and may be a poorer quality food source to stream organisms. This, along with extreme loading of particulate material in streams, may have adverse impacts on stream biota both in adjacent aquatic systems and downstream environments.

Ongoing and Future Research Directions

- Is POC mobilized by thaw slumps readily biodegradable?
- How does the impact of thaw slumps differ in different watershed units?
- To what degree is POC mobilized by thaw slumps available for transport downstream and how does it alter watershed organic matter flux?

Questions/Comments?
E-mail me at shakil@ualberta.ca!
I'm always happy to chat about my research!

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SUPPLEMENTARY METHODS

Whole water samples and discharge measurements (current meter, area-velocity method) were obtained upstream, downstream, and from RTS outflows and from eight RTS sites (Fig. 1). Samples were collected in HDPE bottles (pre-leached for 24 hours with 10% HCl). Samples for dissolved analyses were allowed to settle for 24 hours prior to filtration through a pre-combusted GF/F filter. For particulate analyses, a separate bottle was collected and shaken thoroughly before a known volume of sample water was filtered through pre-weighed and pre-combusted GF/F filter (diameter = 47mm) within 24 hours of collection. Filters were stored frozen until shipment to the U of A. Filter samples were dried at 60°C and weighed to determine total suspended sediment concentration (mg L^{-1}). Samples for POC were fumigated for 24 hours at 60°C with 12M HCl. Fumigated samples for POC were packed into tin capsules and analyzed by an elemental analyzer interfaced to a continuous flow isotope ratio mass spectrometer (IRMS, UC DAVIS Stable Isotope Facility) along with paired non-acidified samples for particulate nitrogen (PN) analysis. Particulate phosphorus samples were analyzed using the ash-hydrolysis method following (8). DOC concentration was determined as non-purgeable organic carbon (NPOC) from the best three of five injections, with a coefficient of variation <2% or similar, on a Shimadzu TOC-V analyzer. Dissolved inorganic nitrogen samples were analyzed for ammonia and nitrate/nitrite via colorimetry at the University of Alberta, Biogeochemical Analysis Laboratory (BASL) following modified versions of Standard Methods (SM) 4500-NH3-B,H and US EPA 353.2 respectively. Total dissolved nitrogen (TDN) samples were analyzed via colorimetry at BASL following SM 4500N-B. Soluble reactive phosphorus samples were analyzed via colorimetry using a molybdate-ascorbic acid method modified from (9), on a Genesys 10 UV-VIS scanning spectrophotometer (quartz cell with a light path length of 50 mm) at the Aurora Research Institute laboratory. Total dissolved phosphorus (TDP) was analyzed via colorimetry at BASL following SM 4500 P-B. Dissolved organic nitrogen (DON) and phosphorus (DOP) were then calculated as total dissolved pools (TDN and TDP respectively) minus their respective inorganic pools (DIN and SRP respectively). All calculations were made using molar concentrations.
Watershed areas, delineated using Canadian CDED CDEM and NHN stream network datasets using ArcGIS, were combined with discharge and concentration data to calculated instantaneous fluxes (Fig. 2a).
Fumigated samples for $PO^{14}C$ were sent to A.E. Lalonde AMS Laboratory where radiocarbon analyses were performed on a 3MV accelerator mass spectrometer (AMS) by High Voltage Engineering. Measurements were normalized with respect to the reference material Oxalic II (F14C=1.34) and ages are calculated using the Libby 14C half-life of 5568 years. Samples for dissolved organic carbon (DOC) were measured on a Shimdazu TOC-V analyzer.

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