
A SONG OF ICE & FIRE
TABLETOP MINIATURES GAME

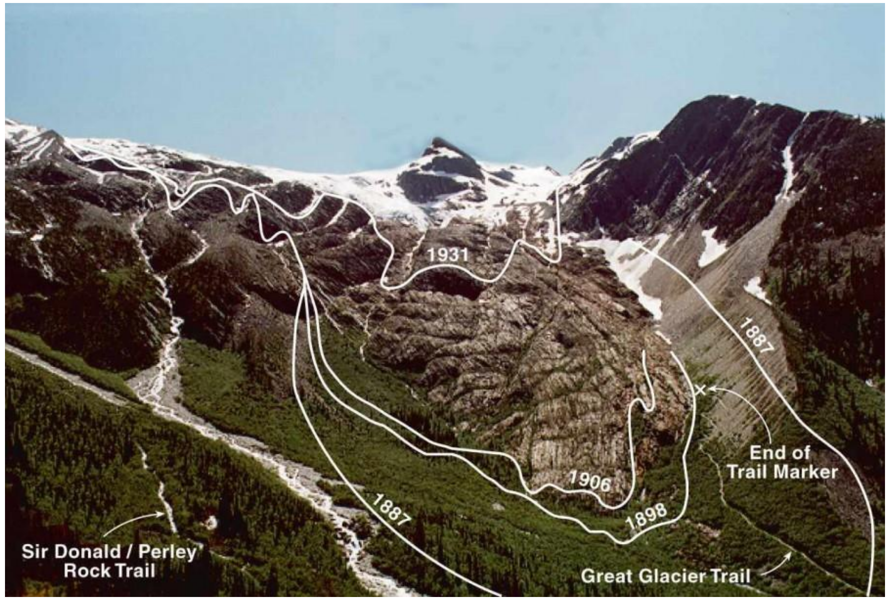



Photo Credit: Dr. Dan McCarthy, Brock University

# Climate change impacts on water quality and aquatic communities

Janice Brahney, Utah State University

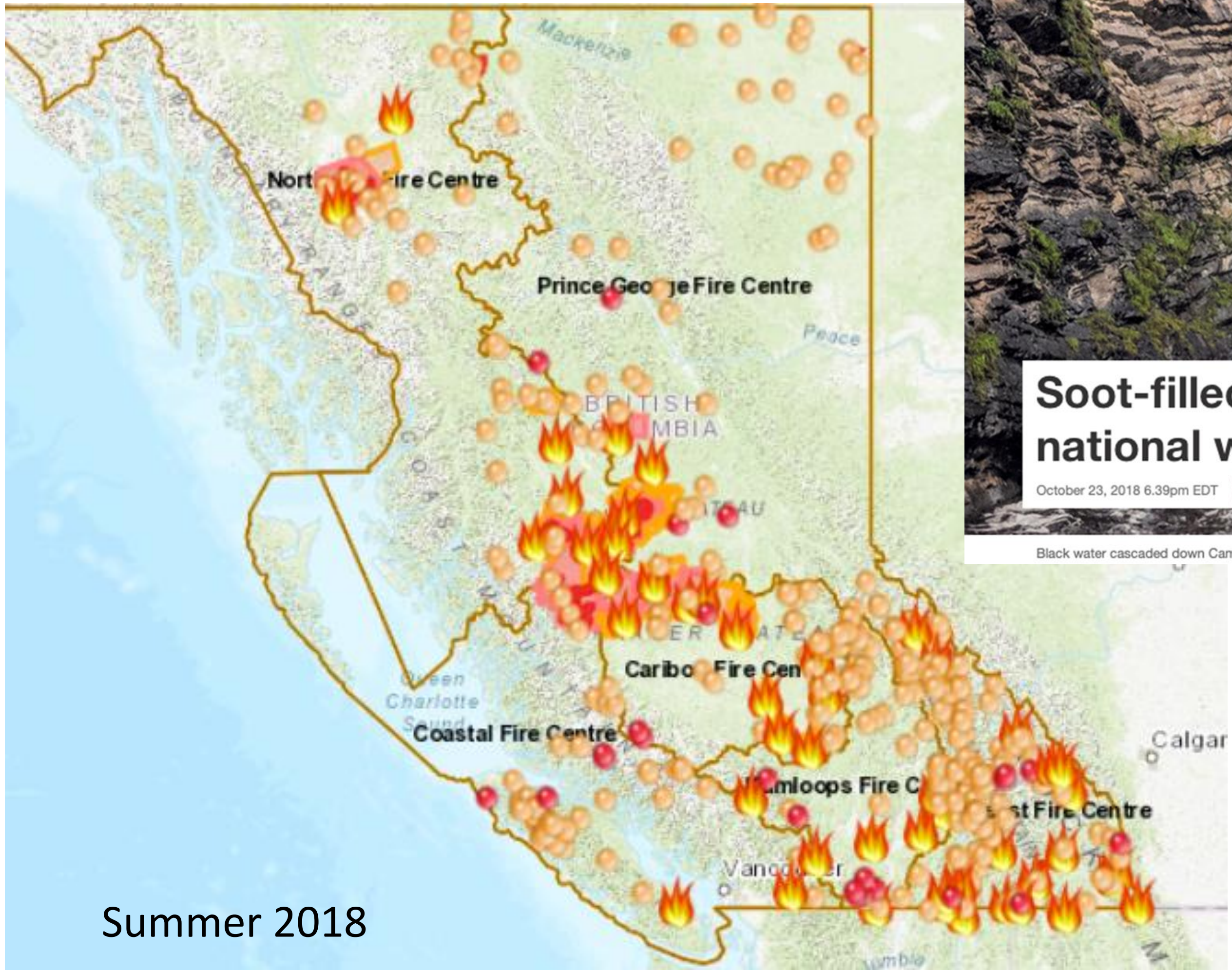
# The Great Climate Change Experiment

Emergent consequences of climate change

1. Habitat Changes/Community Reorganization
2. Wildfire
3. Glacier Loss

# Transition to Drier Climatic States Might not be Smooth

## Direct and Indirect effects on Water Quality



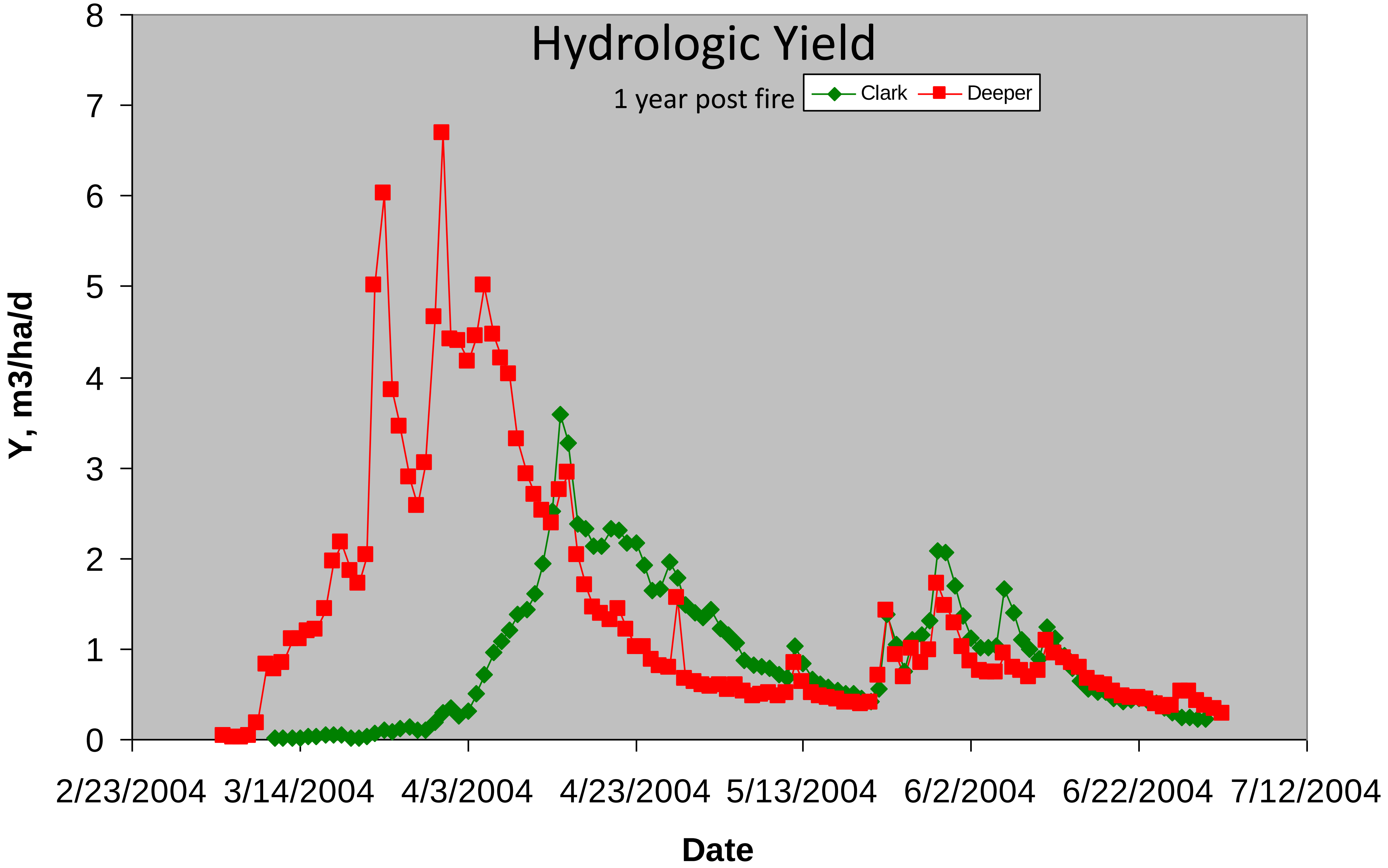

Summer 2018


Black water cascaded down Cameron Falls in Waterton Lakes National Park in Alberta after a 2018 wildfire denuded the landscape. (Kaleigh Watson), Author provided

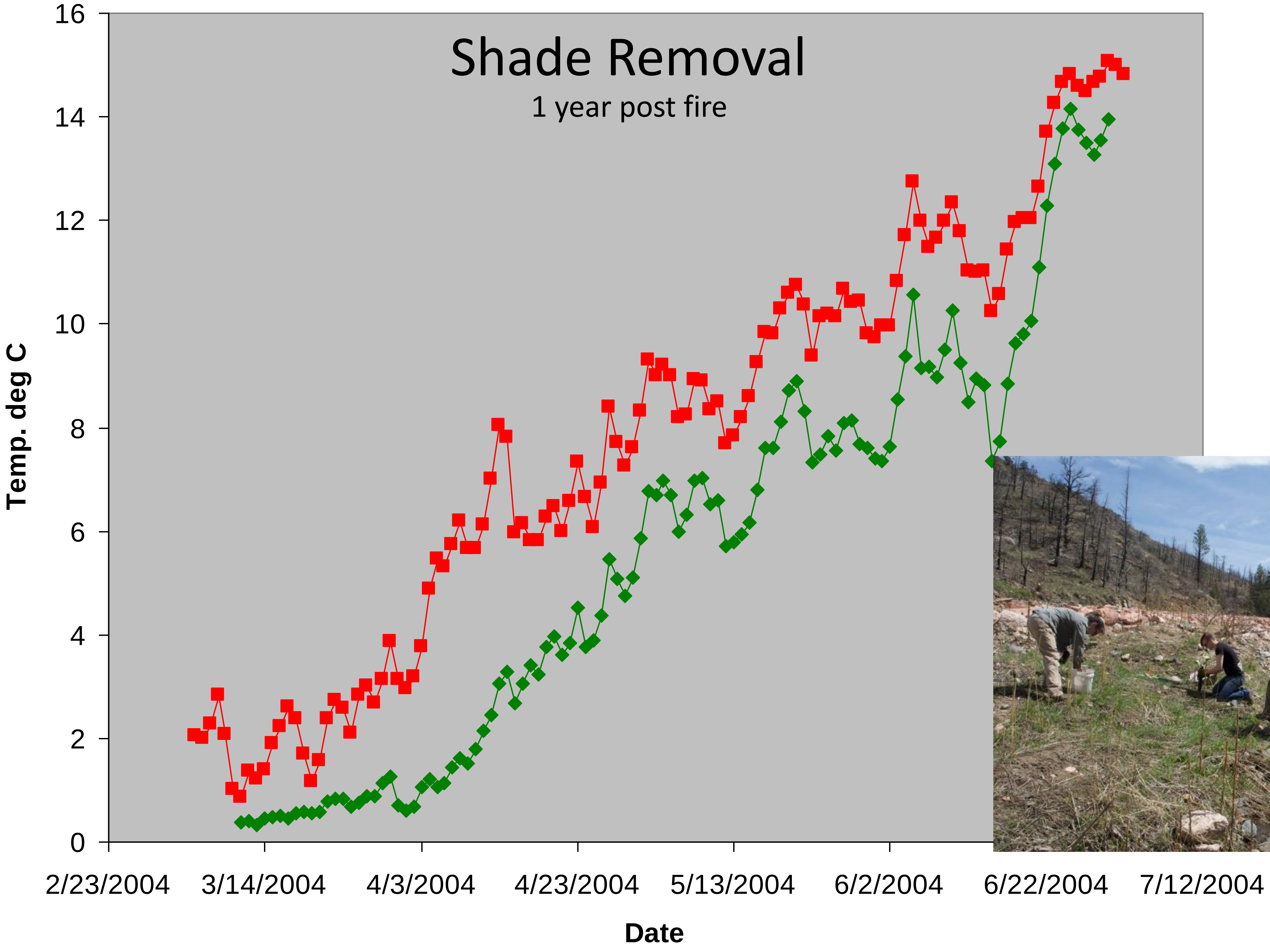
**The Wettest Place in North America Is Burning**

Extreme drought is causing Canada's only rainforest to dry up, and now it's on fire.

# Wildfire as Experiment Okanagan Mountain Park



Hydrologic Yield
1 year post fire
Clark
Deeper
Y, m3/ha/d
0
1
2
3
4
5
6
7
8
2/23/2004
3/14/2004
4/3/2004
4/23/2004
5/13/2004
6/2/2004
6/22/2004
7/12/2004
Date

# Increased flow can bring substantial amounts of sediments from the burned landscape


Shade Removal
1 year post fire
16
14
12
10
8
6
4
2
0
Temp. deg C
2/23/2004
3/14/2004
4/3/2004
4/23/2004
5/13/2004
6/2/2004
6/22/2004
7/12/2004
Date

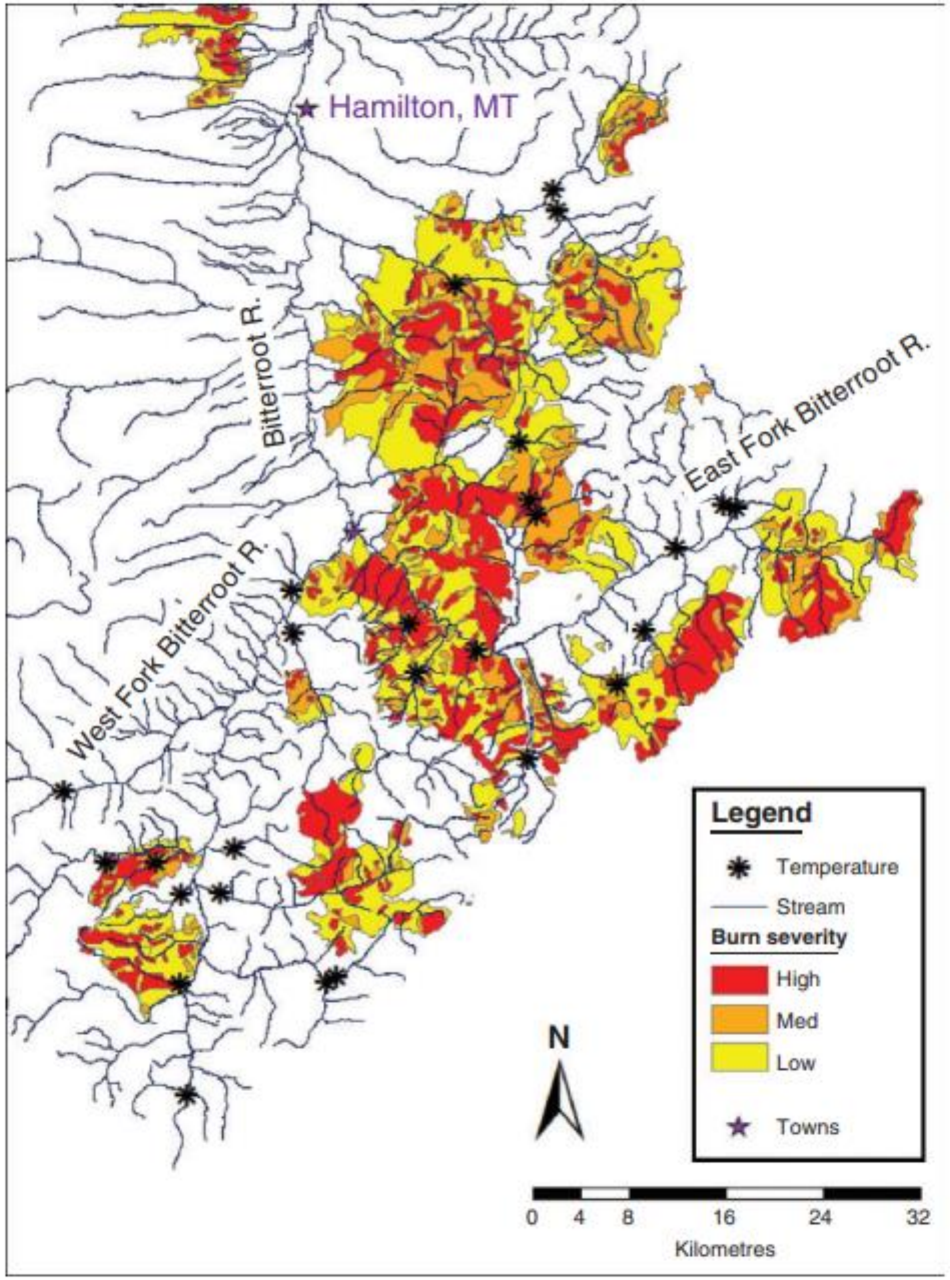
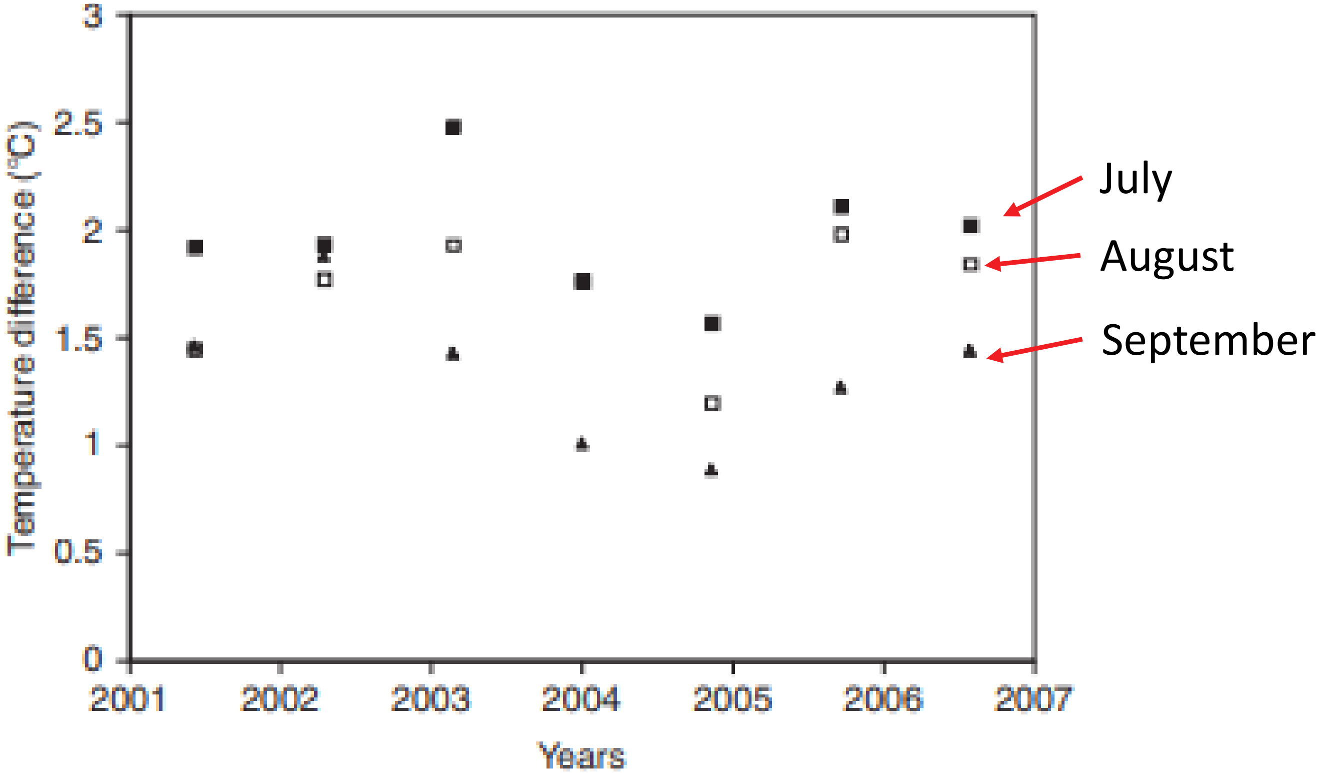


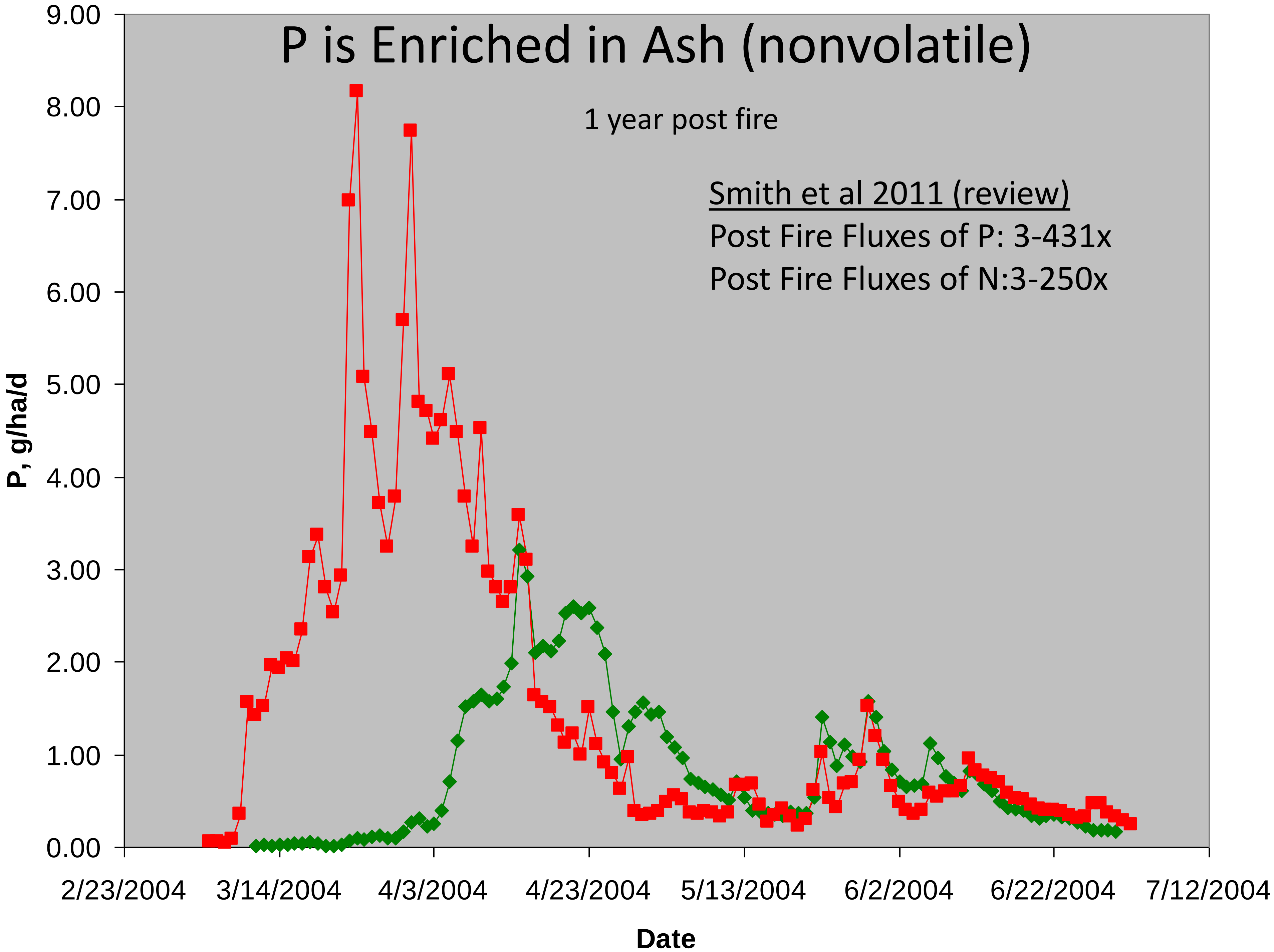

**Fig. 1.** Temperature logger sites (asterisks) and 2000 burn severity in the southern Bitterroot River basin, Montana. Red, orange and yellow indicate areas of high, medium and low burn severity. White indicates areas that did not burn.

# Effects of wildfire on stream temperatures in the Bitterroot River Basin, Montana

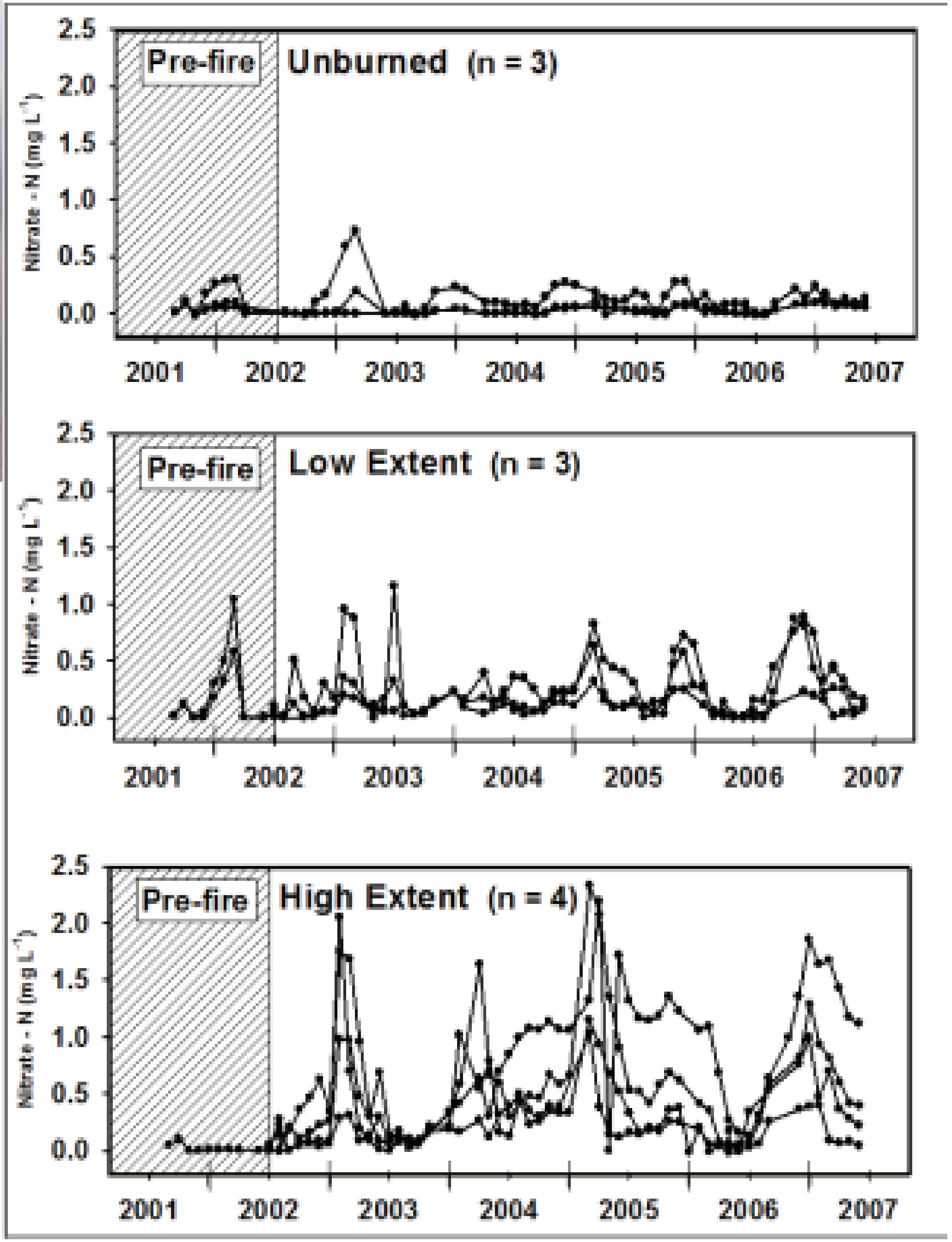

*Shad K. Mahlum[A], Lisa A. Eby[A,E], Michael K. Young[B], Chris G. Clancy[C] and Mike Jakober[D]*

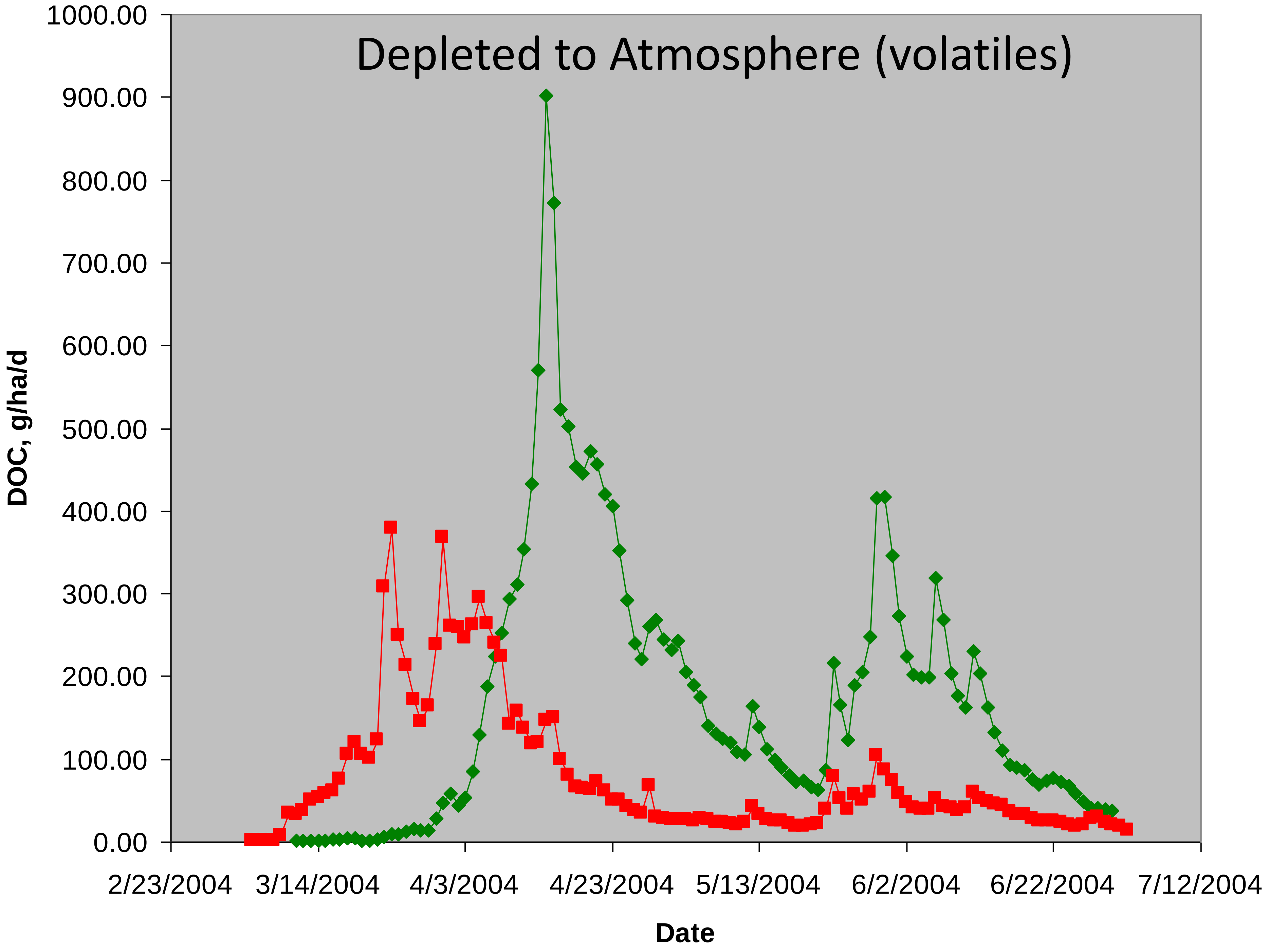

**- 1.4 – 2.2 ˚C warmer – no change after 7 years**



P is Enriched in Ash (nonvolatile)
1 year post fire
Smith et al 2011 (review)
Post Fire Fluxes of P: 3-431x
Post Fire Fluxes of N:3-250x
P, g/ha/d
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2/23/2004
3/14/2004
4/3/2004
4/23/2004
5/13/2004
6/2/2004
6/22/2004
7/12/2004
Date

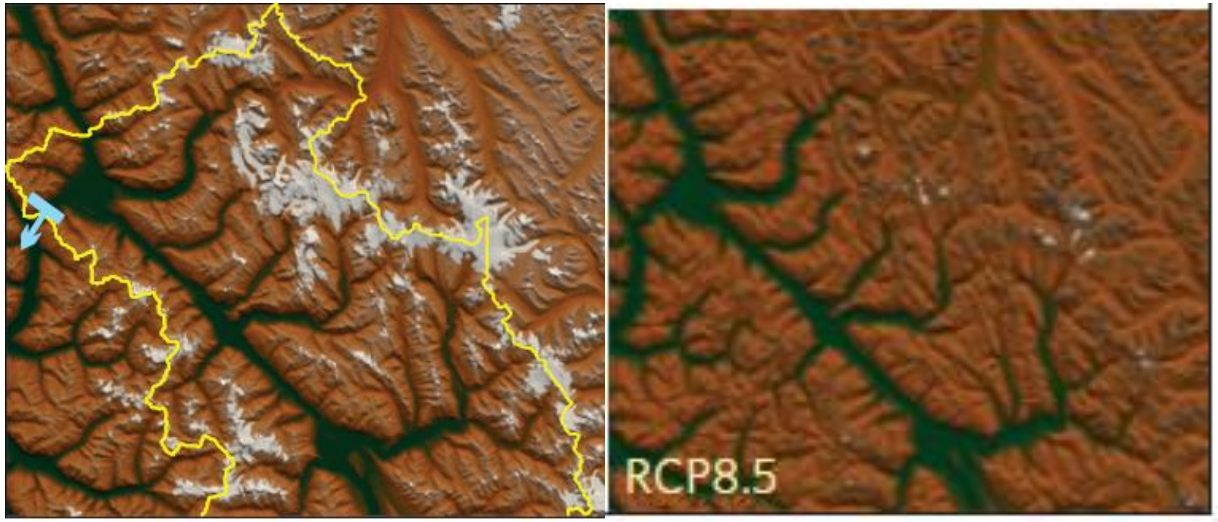



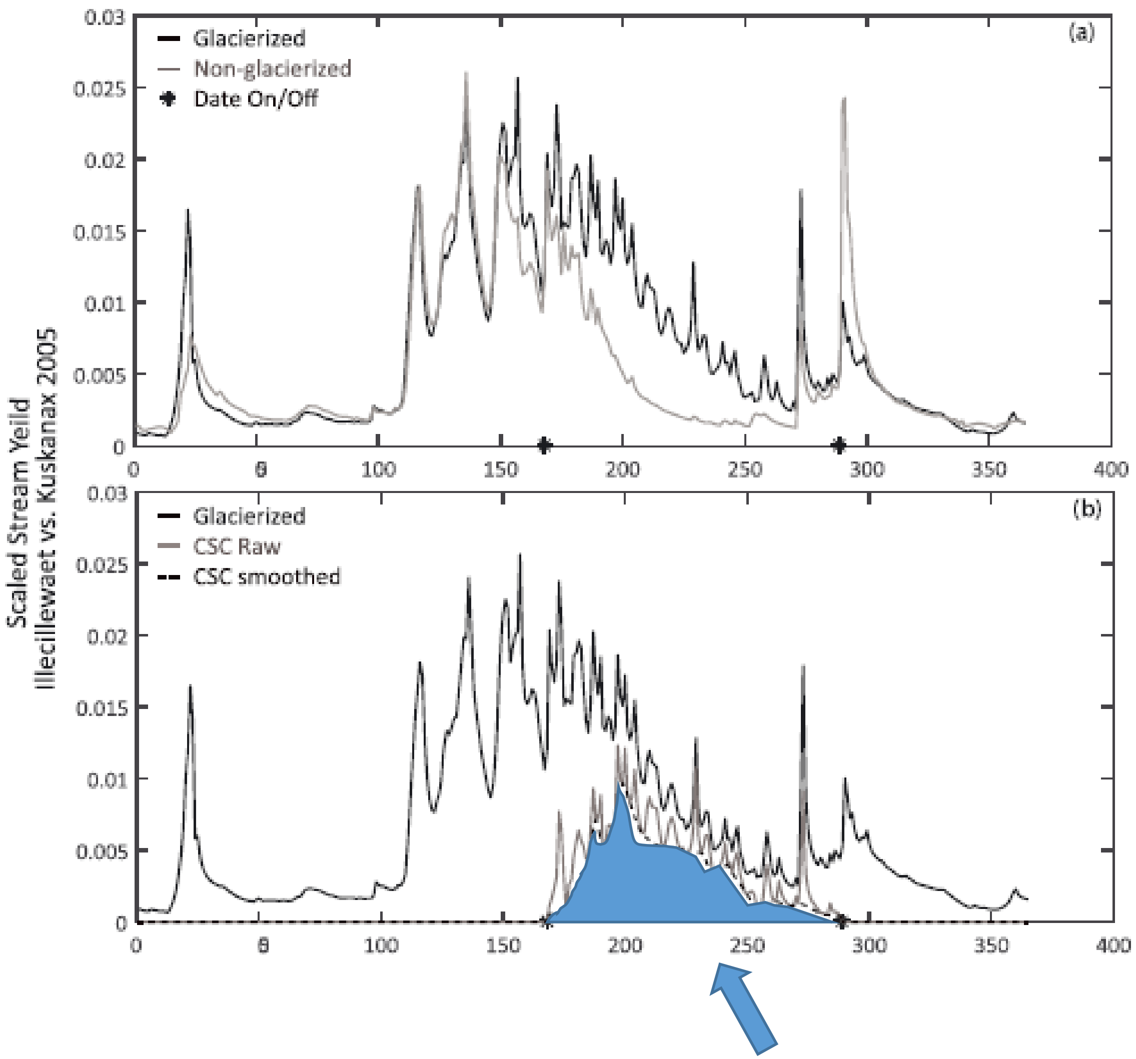

- **Nutrient concentrations remained elevated through the study period (5 years)**
- **Varied by catchment slope – lower slopes showed effects longer (Hauer et al. 1998)**


Depleted to Atmosphere (volatiles)
DOC, g/ha/d
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
2/23/2004
3/14/2004
4/3/2004
4/23/2004
5/13/2004
6/2/2004
6/22/2004
7/12/2004
Date

# ICE

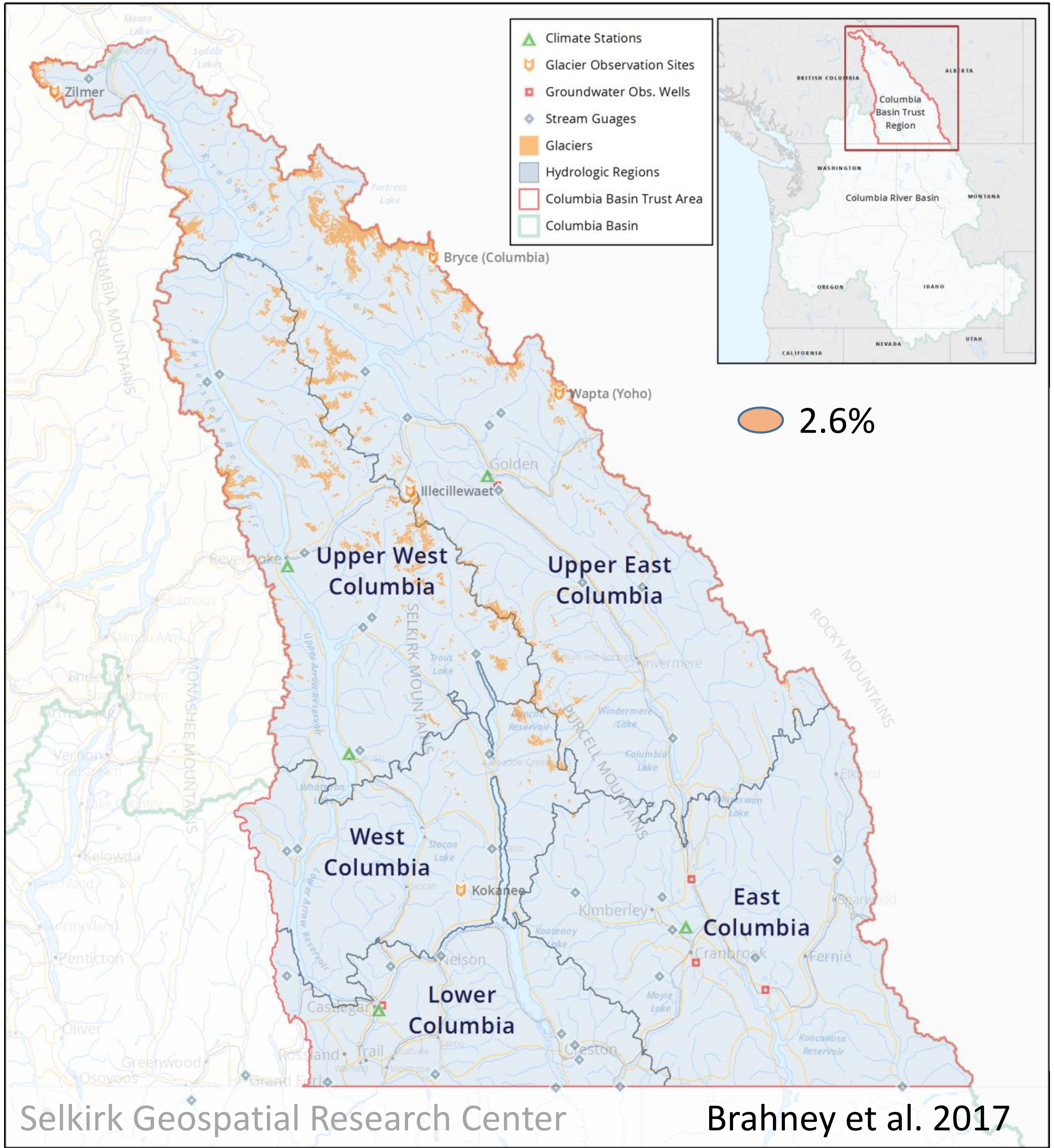

Clark et al. 2015




Important late summer

Brahney et al. 2017, Hyd. Proc.

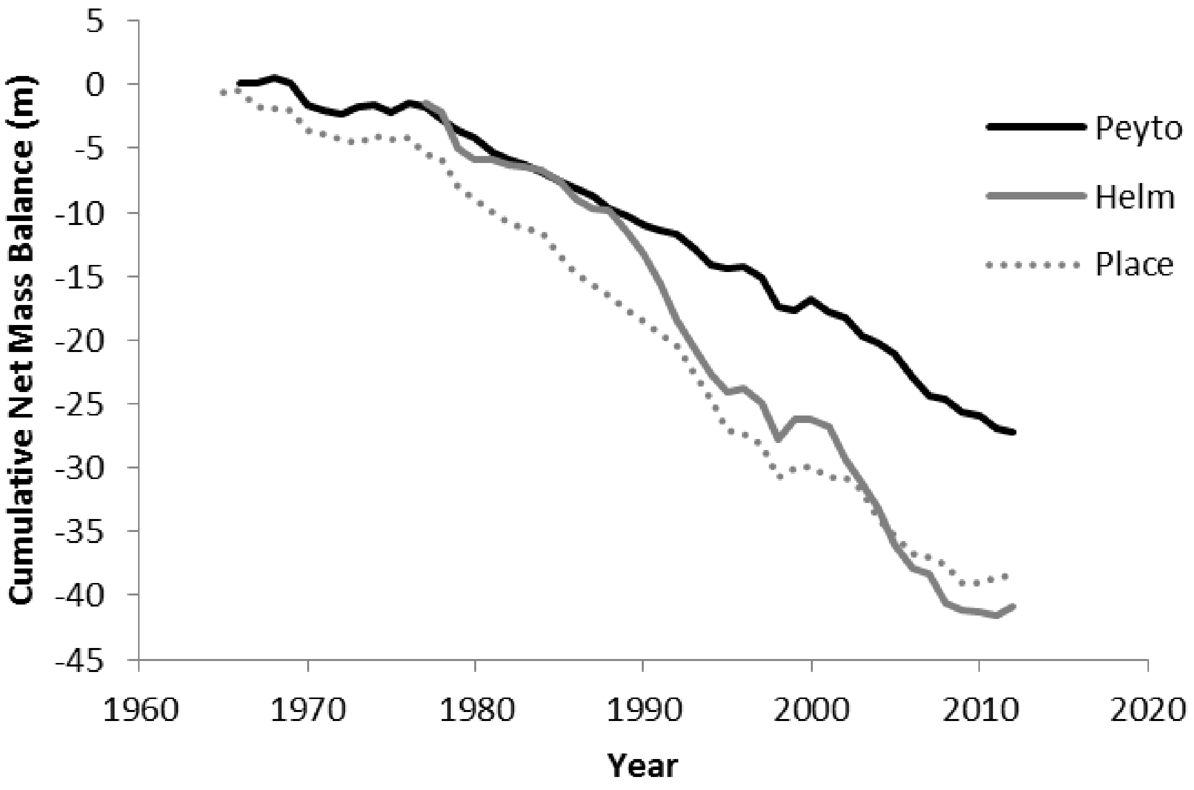



Selkirk Geospatial Research Center

Brahney et al. 2017

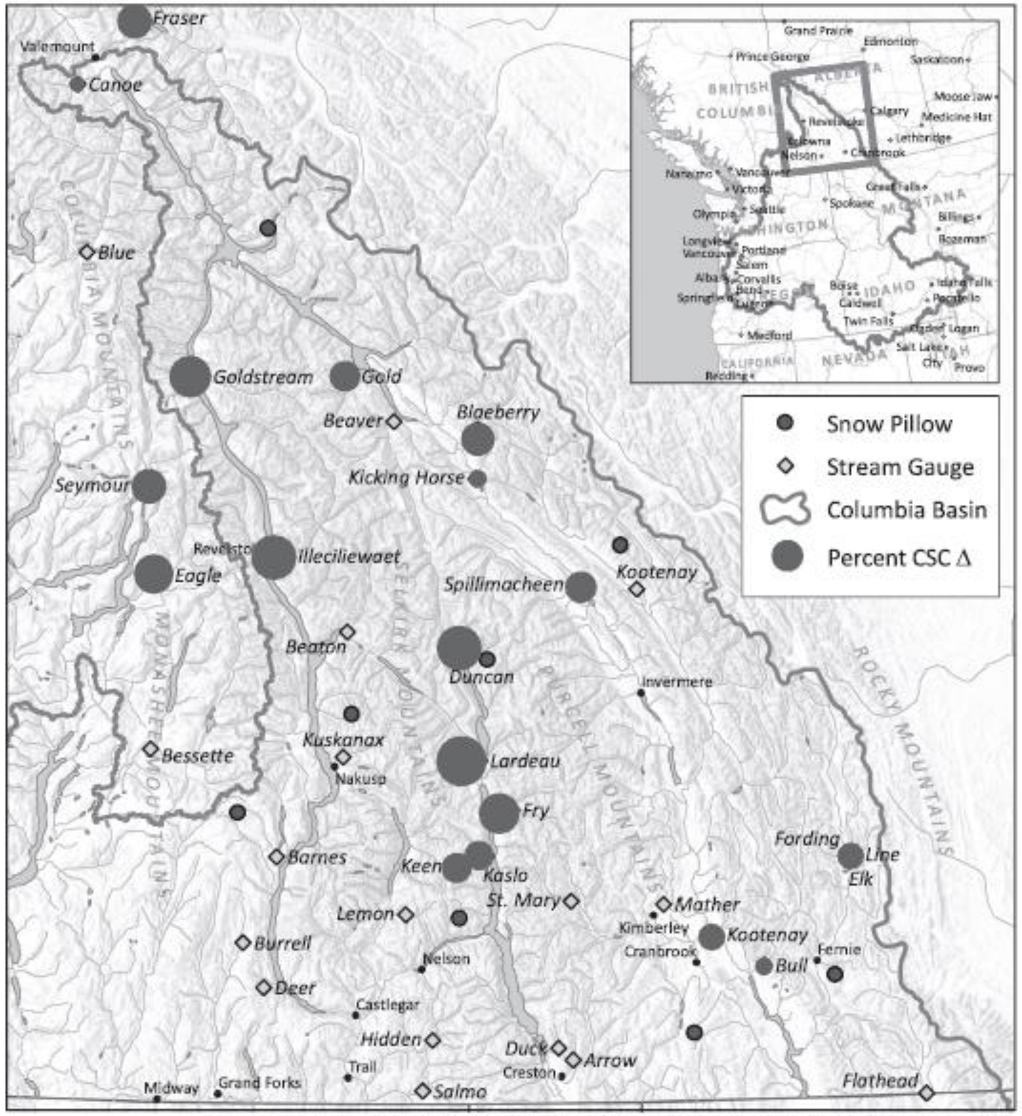
# Rapid retreat of glaciers

- Cumulative loss of 25-40 m.w.e
- Many already gone or will be gone by end of century




Demuth, 2013

# Glacier contribution




Sources: Esri, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

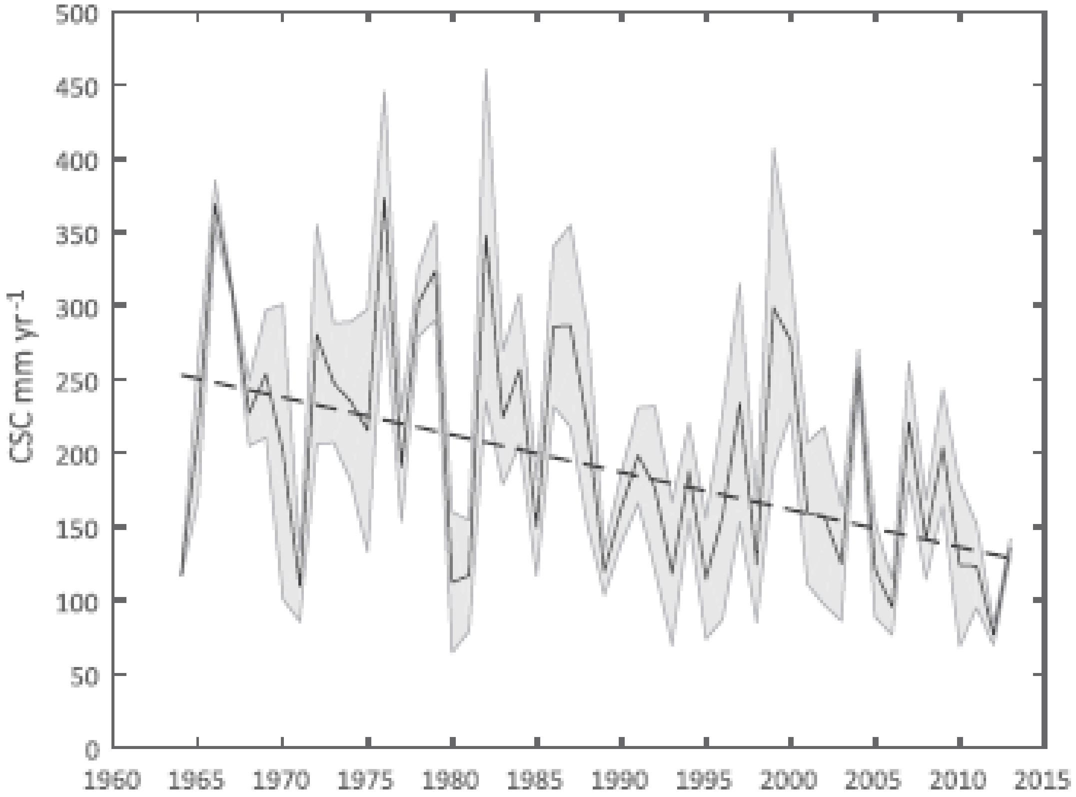



**FIGURE 8** Mean (black) and two standard deviation (shade) estimate for annual CSC to streamflow for the Illecillewaet River

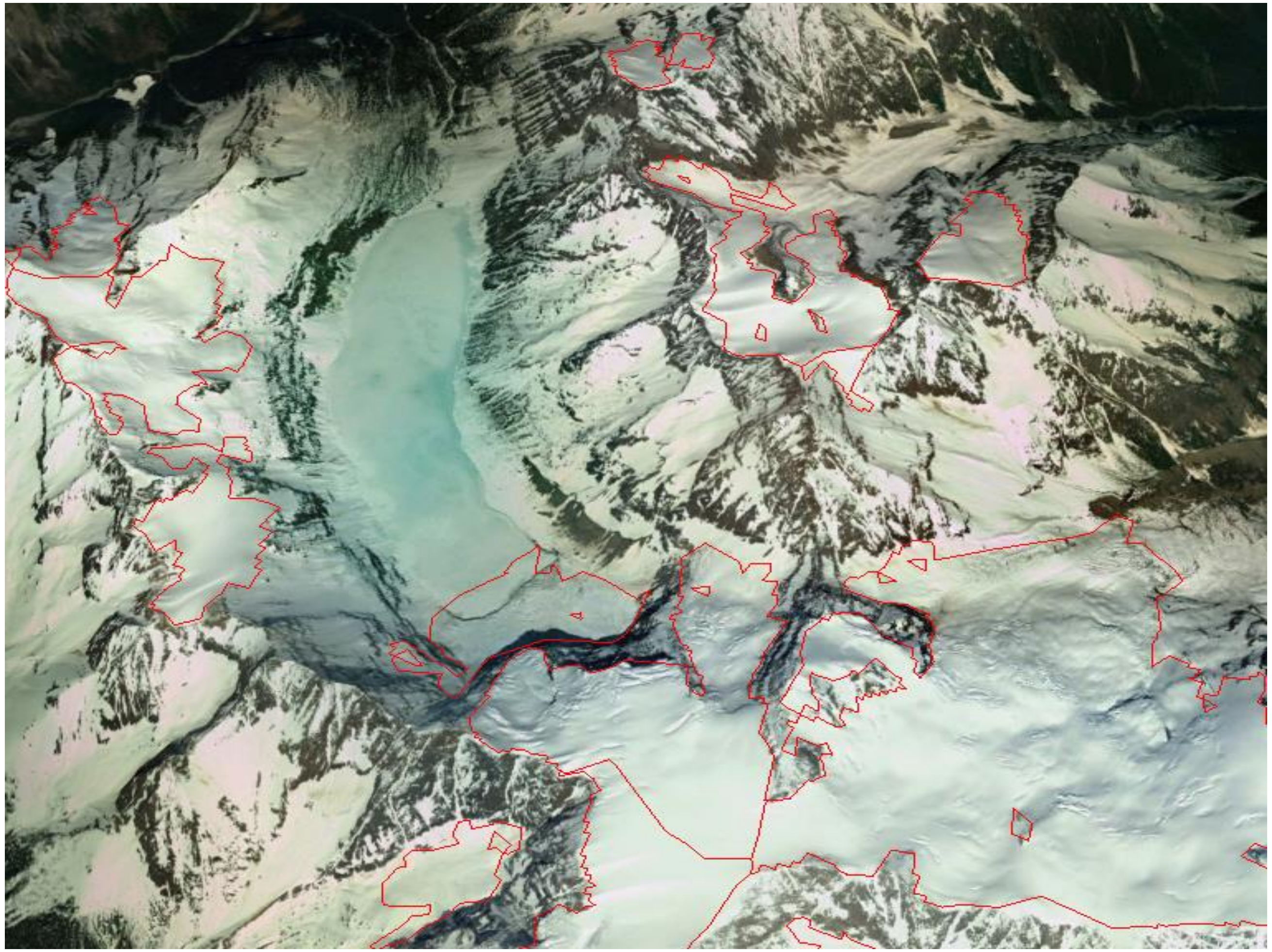
## Decreasing glacier contributions to flow

Brahney et al. 2017, Hyd. Proc.

## Space-for-time

## Actively glacierized: >5%

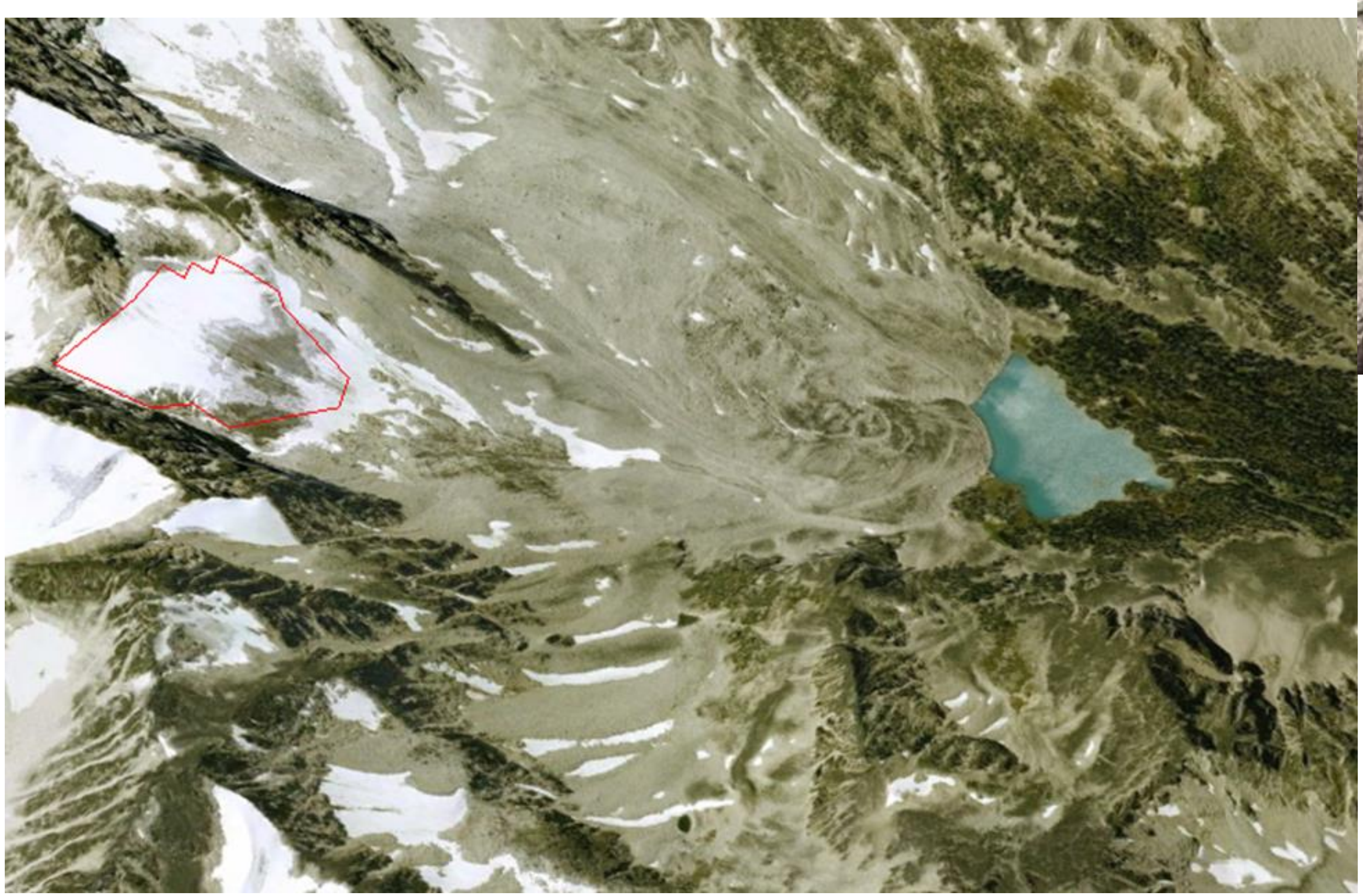
Down valley rivers



Headwater Lakes

Red polygons = 1985 glacier cover

## Space-for-time Transitional: < 5% (remnant ice)

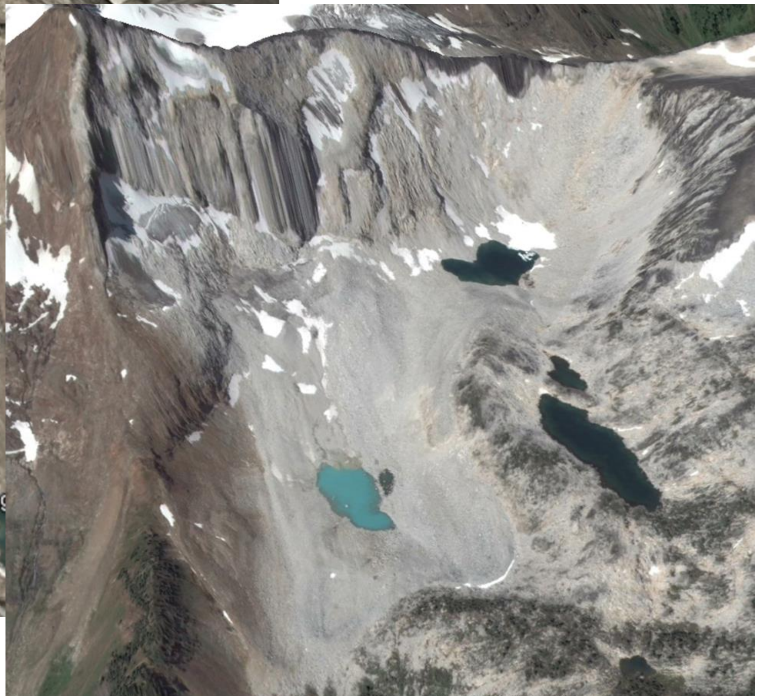


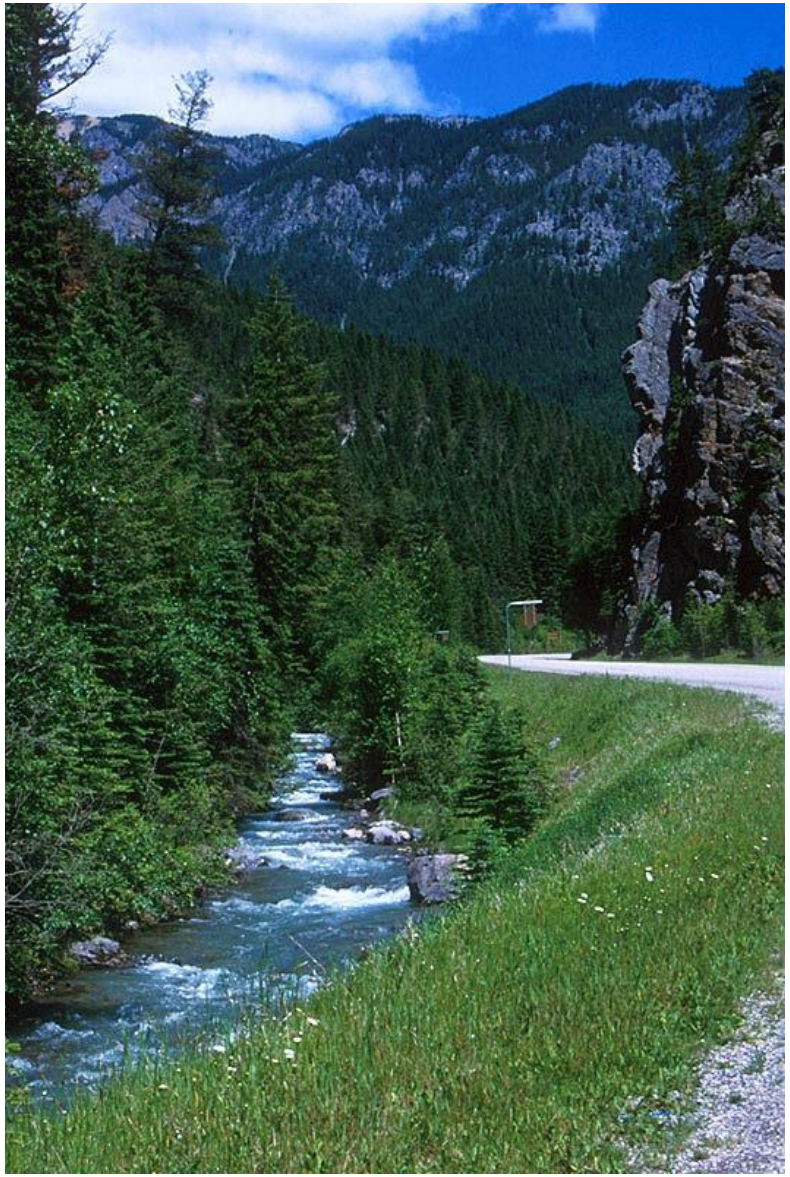
Down valley rivers

Headwater Lakes

## Space-for-time

## Transitional: Recently-lost glaciers

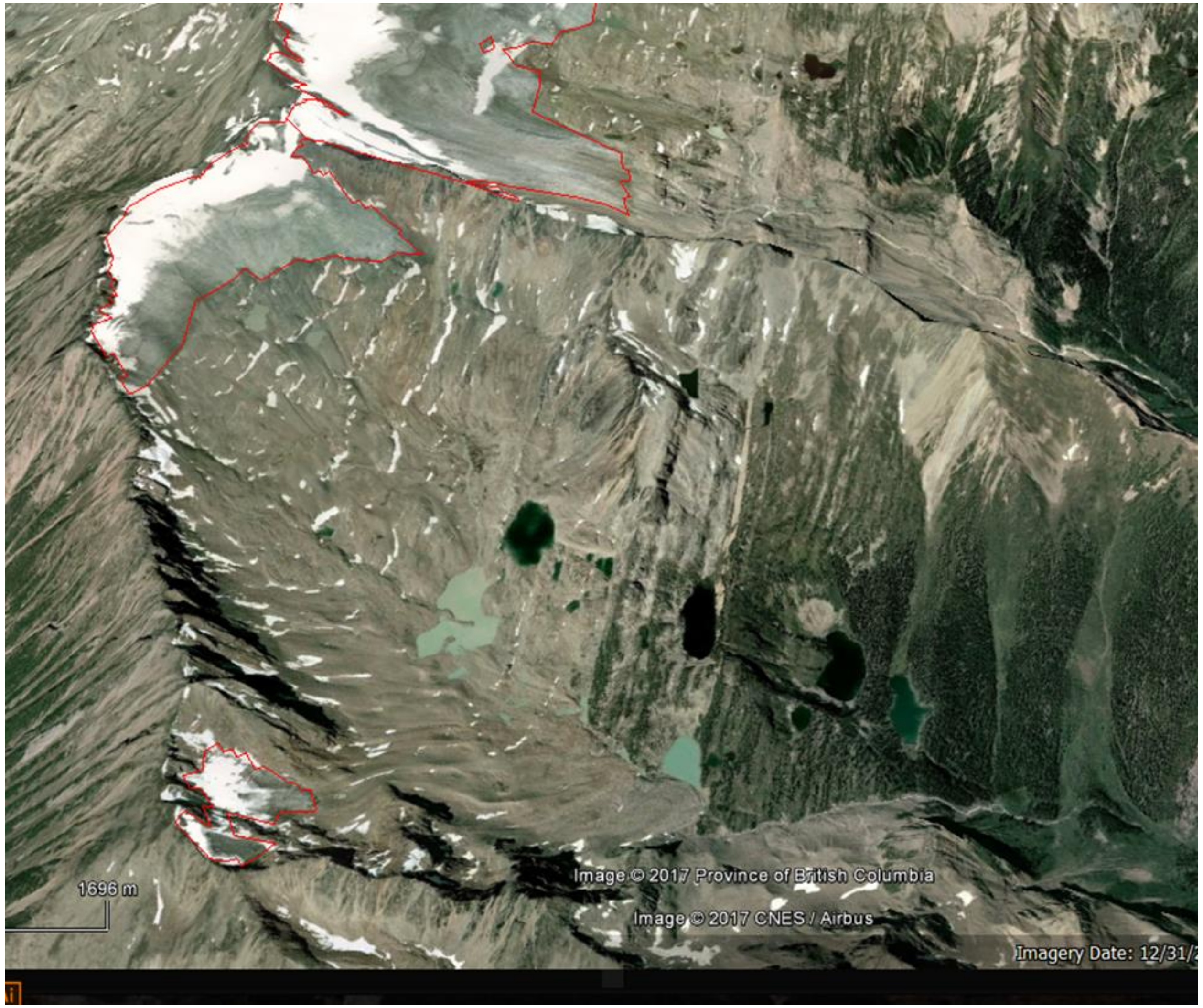





Down valley rivers

# Space-for-time

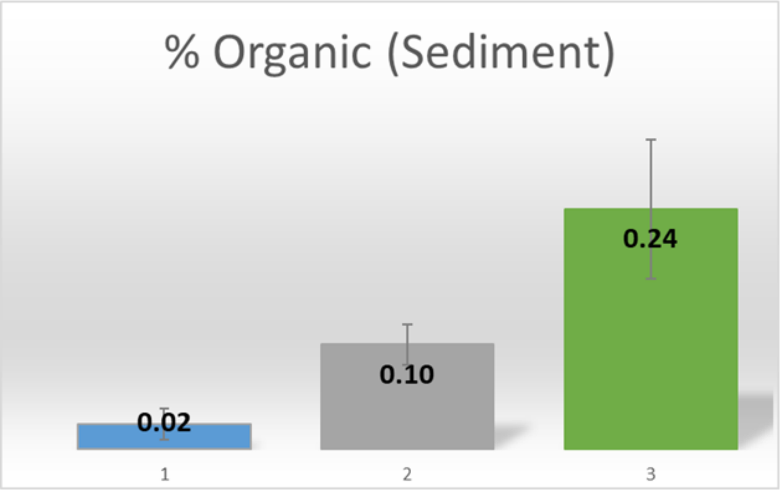
## Snowfed

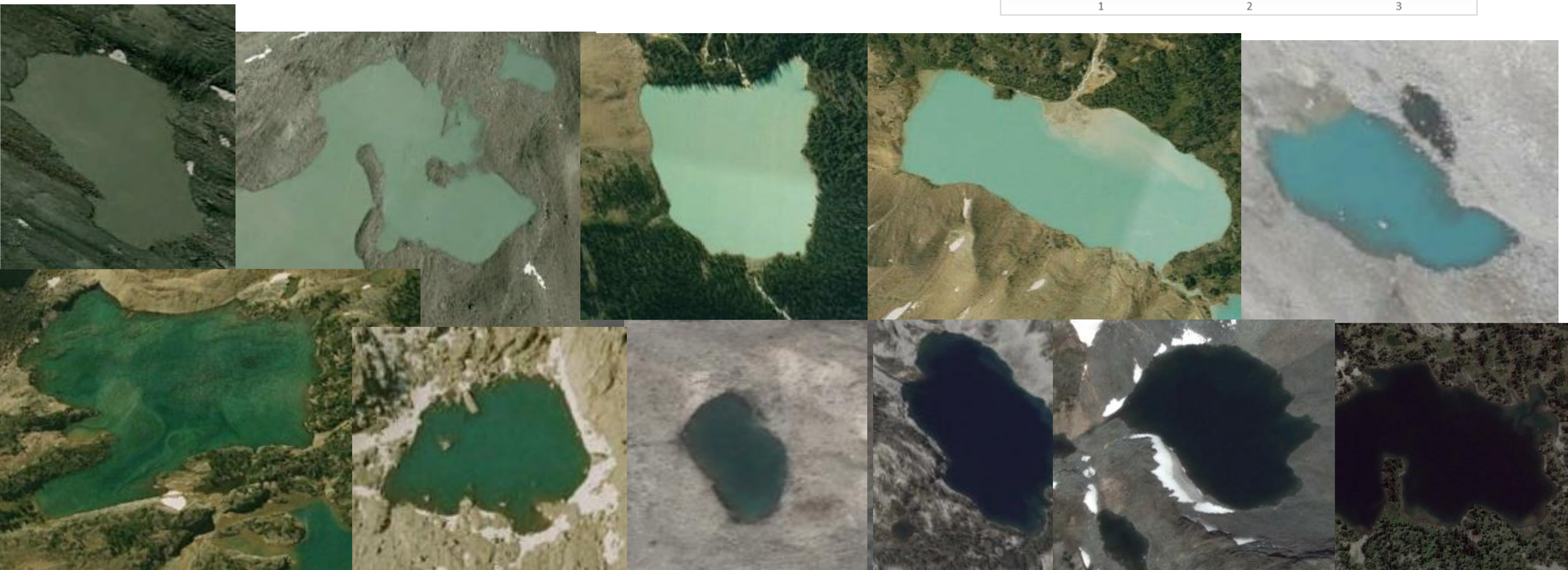


# Changing habitats

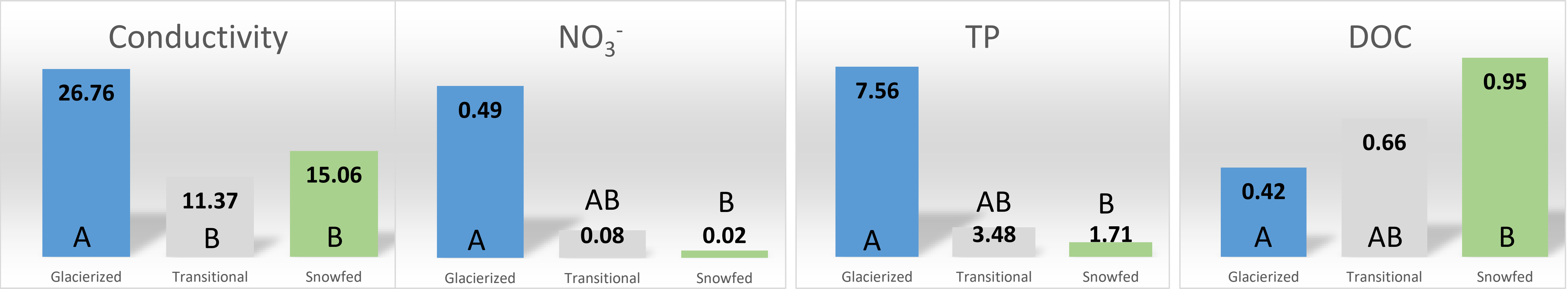
- Changes in the character of many lakes
- Longer growing season -> Greater production
- New Lakes (156) + expansion (5.2km$^2$)

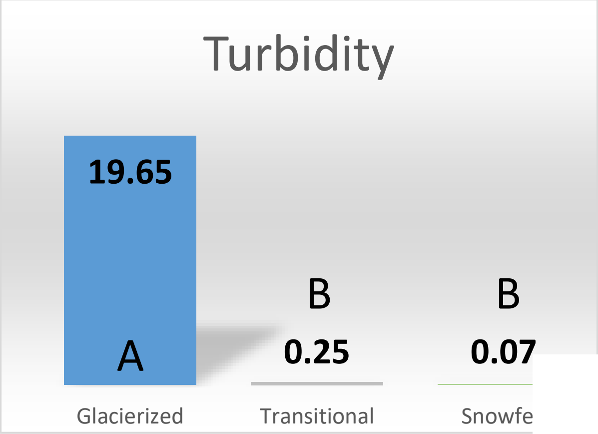
Brahney et al. unpublished

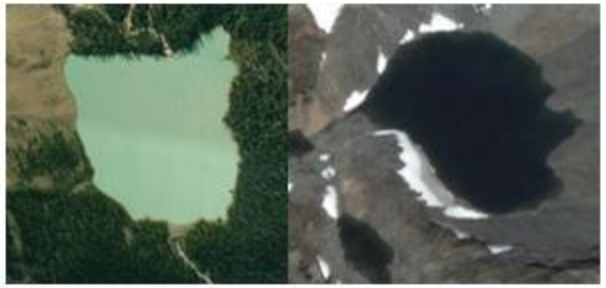


# Retreat of glaciers = changing water chemistry in lakes

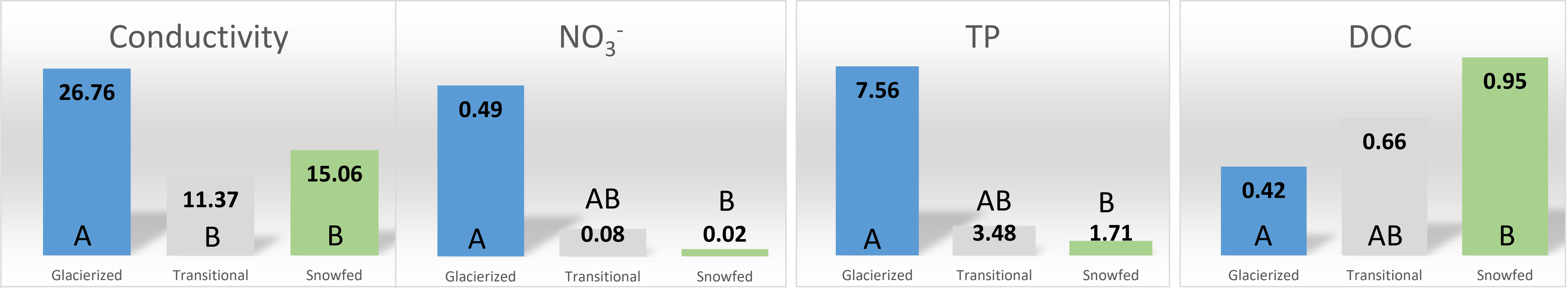


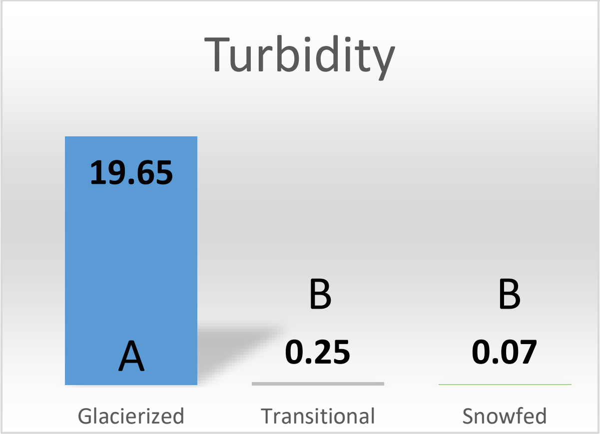



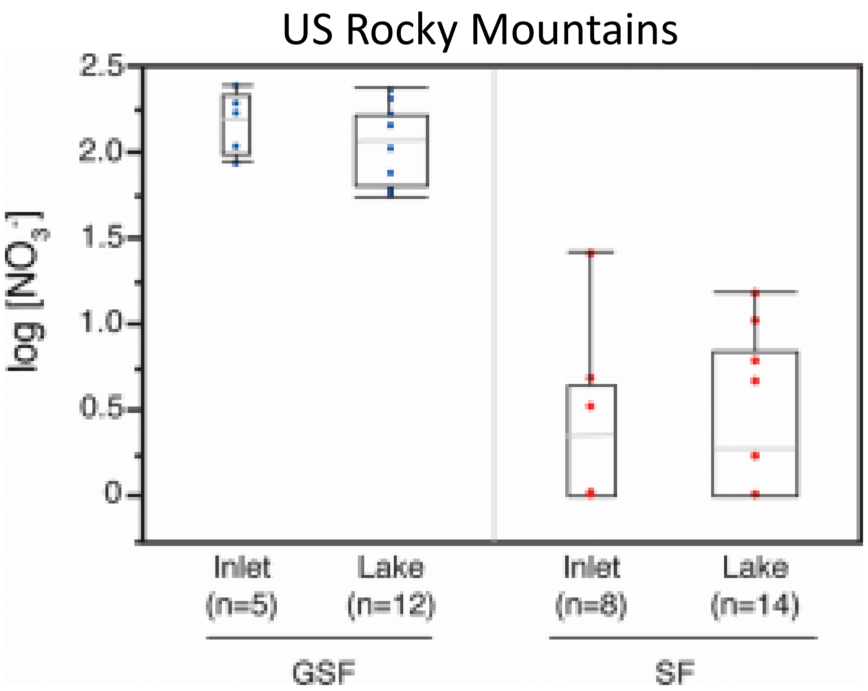




Brahney et al. unpublished

# Retreat of glaciers = changing water chemistry in lakes



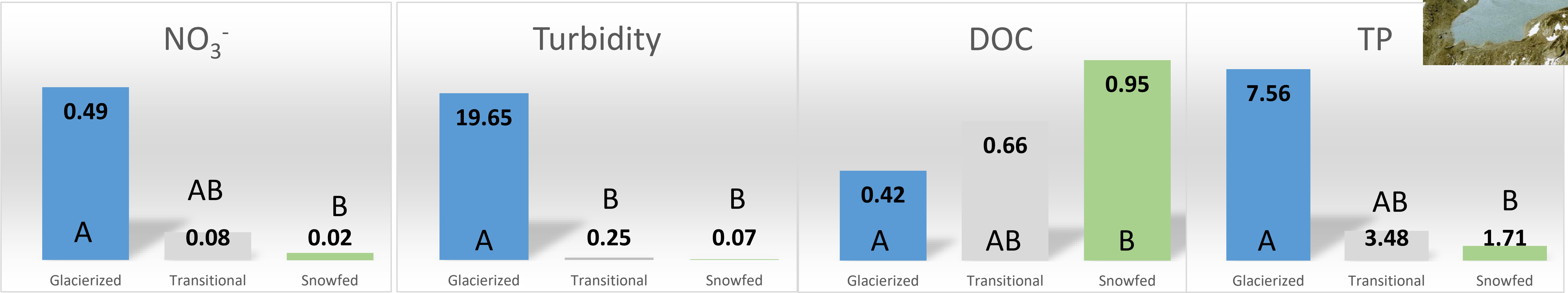



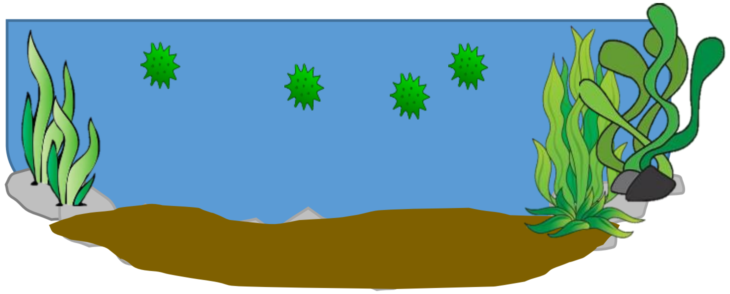

**Melting Alpine Glaciers Enrich High-Elevation Lakes with Reactive Nitrogen**

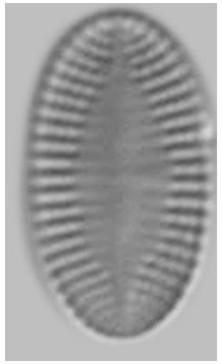
JASMINE E. SAROS,*,† KEVIN C. ROSE,‡ DAVID W. CLOW,§ VERLIN C. STEPHENS,§ ANDREA B. NURSE,† HEATHER A. ARNETT,† JEFFERY R. STONE,‖ CRAIG E. WILLIAMSON,‡ AND ALEXANDER P. WOLFE⊥

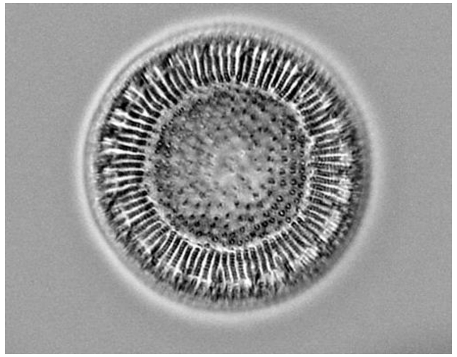
Brahney et al. unpublished

# Retreat of glaciers = changing water chemistry in lakes





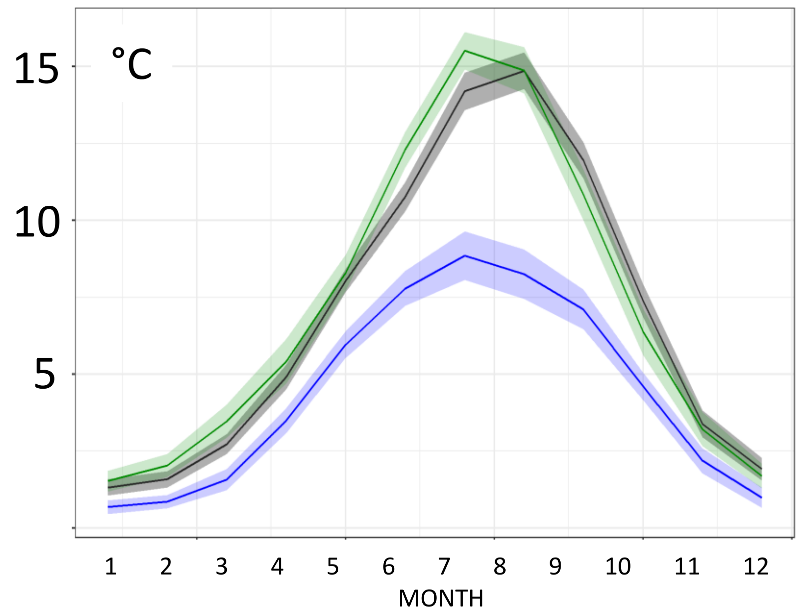


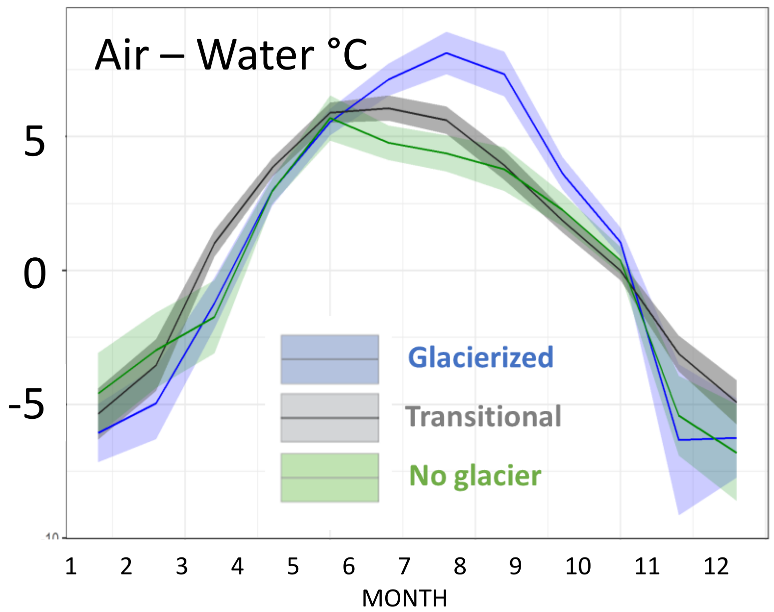
**Glacierized** -> **Transitional** -> **Snowfed** -> **Forested**

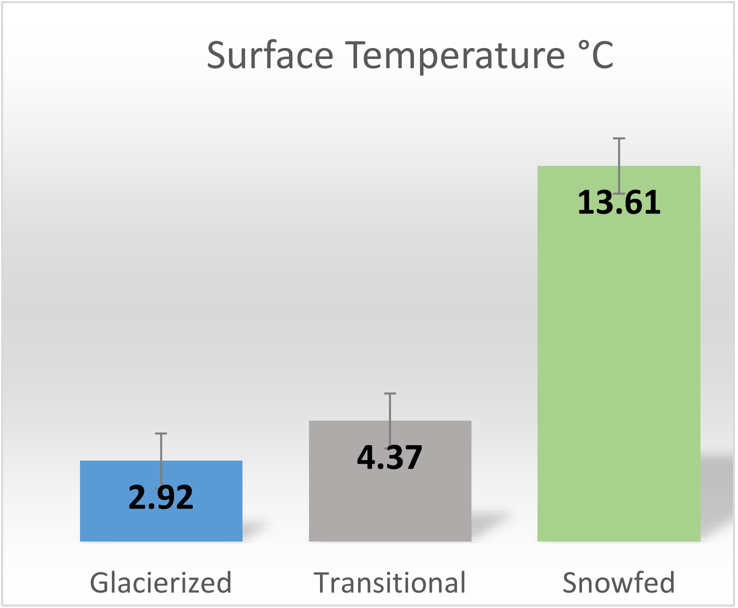
**Epilithic** -> **Episammic** -> **Planktonic** -> **Epiphytic**

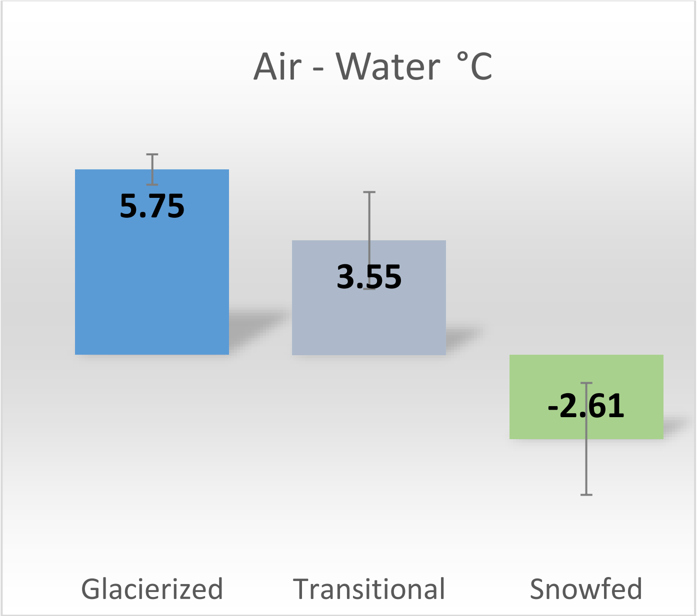
Brahney et al. unpublished

# Retreat of glaciers = warmer waters



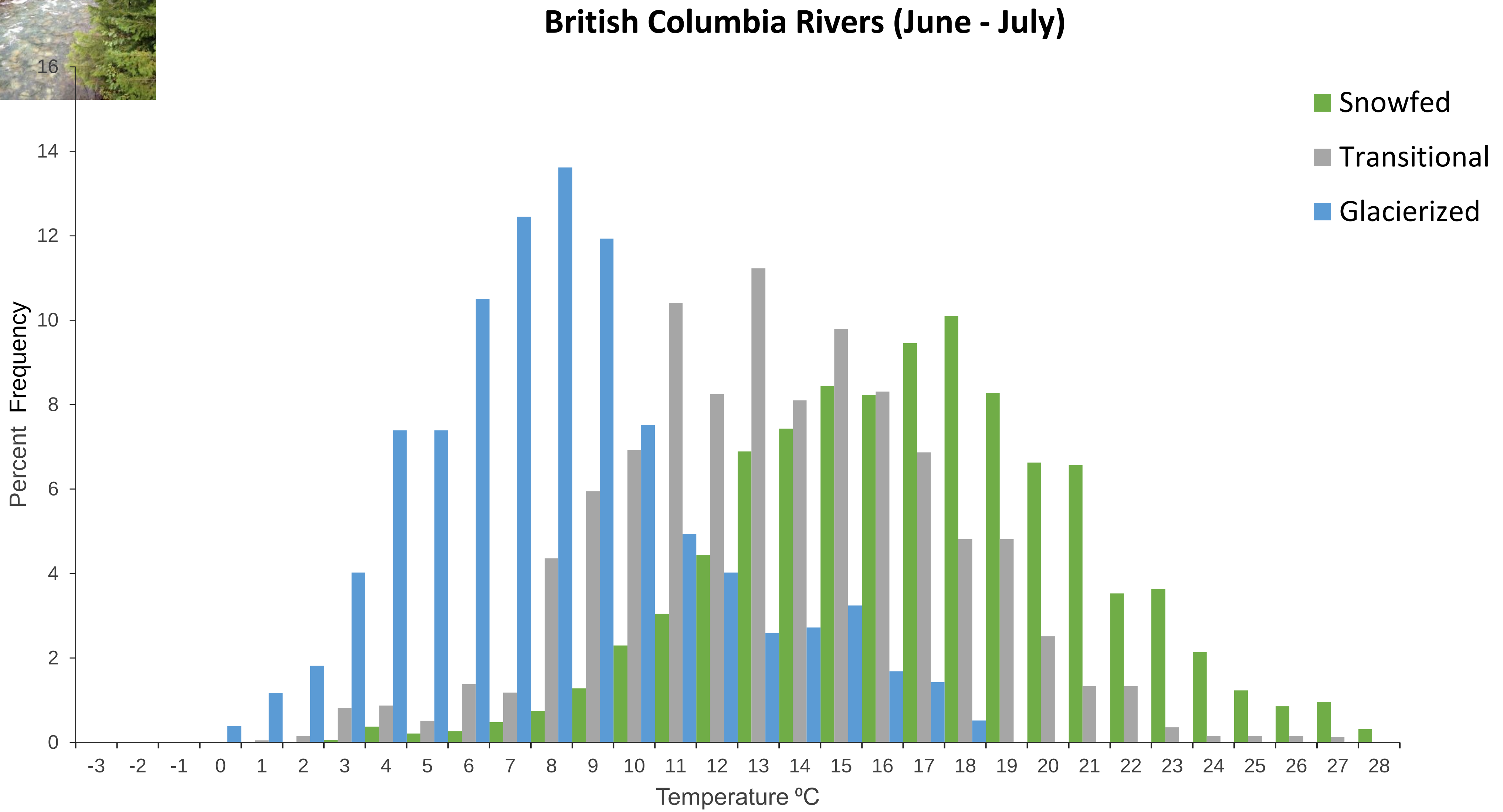




## Glacier suppression of temp:

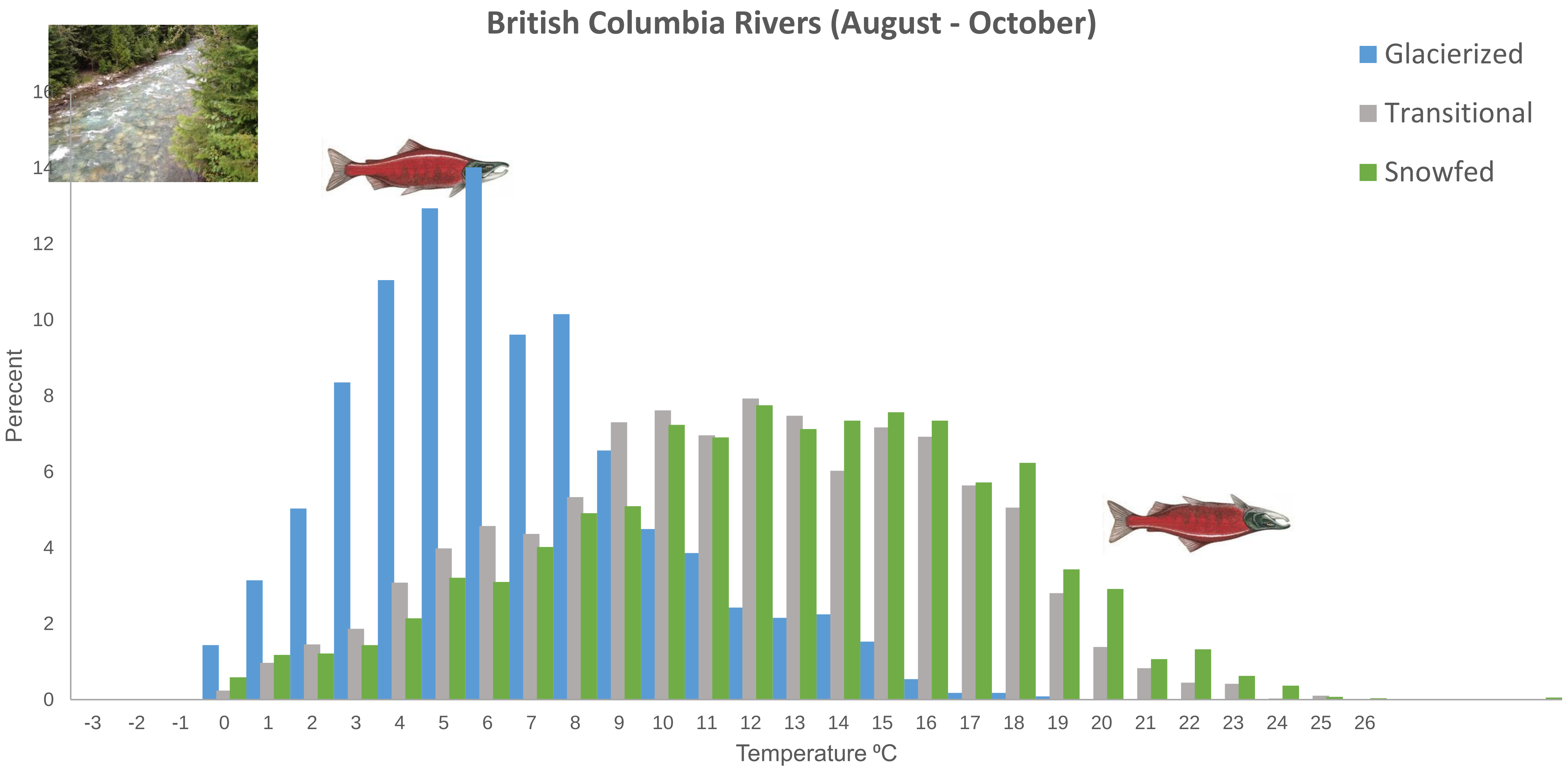
Brahney et al. 2021 STOTEN

# Retreat of glaciers = warmer waters



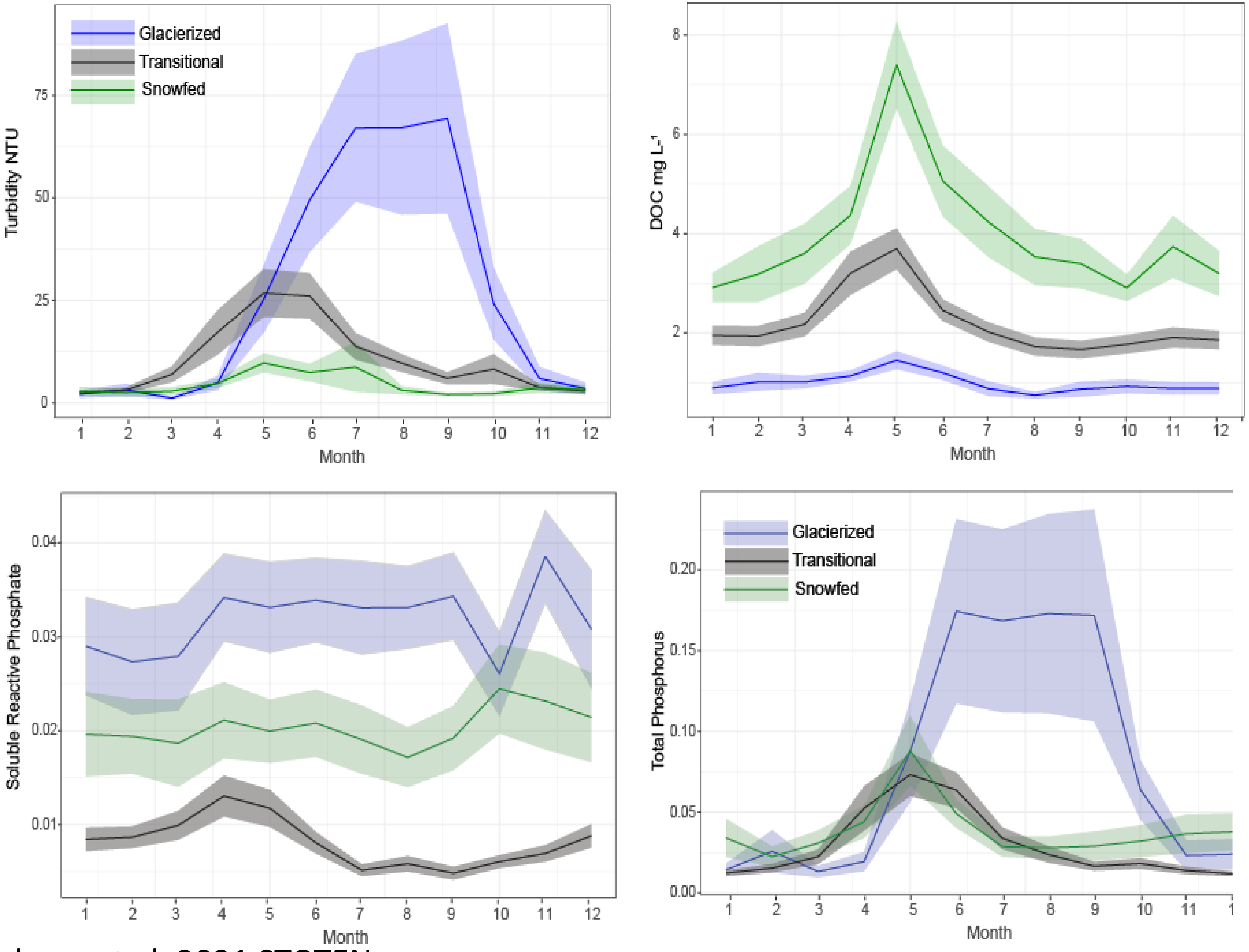

Brahney et al. 2021 STOTEN

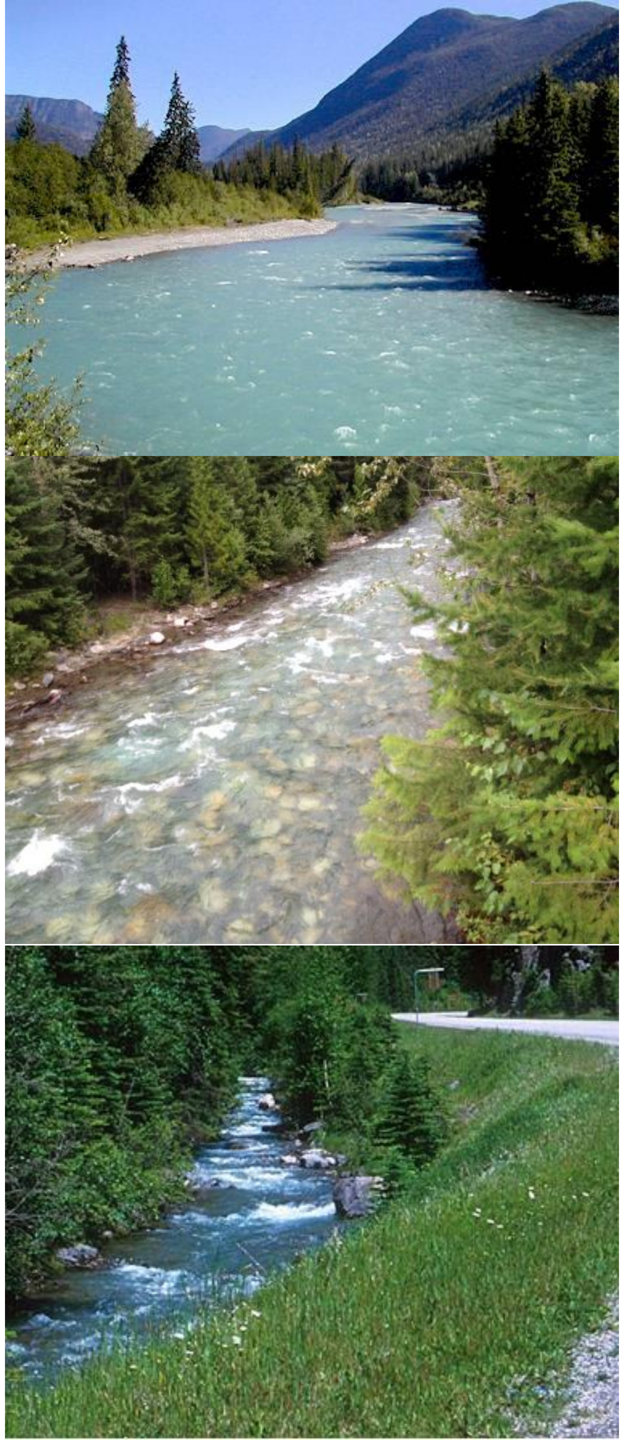
# Retreat of glaciers = warmer waters




Brahney et al. 2021 STOTEN

# Retreat of glaciers = changing water chemistry in rivers

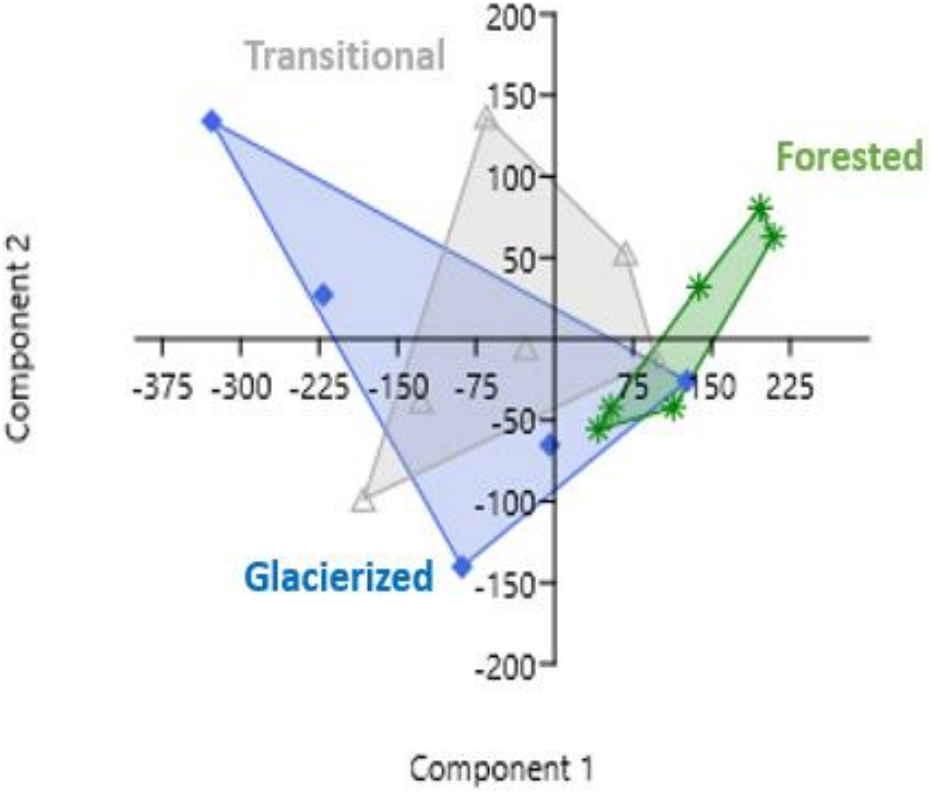


Brahney et al. 2021 STOTEN

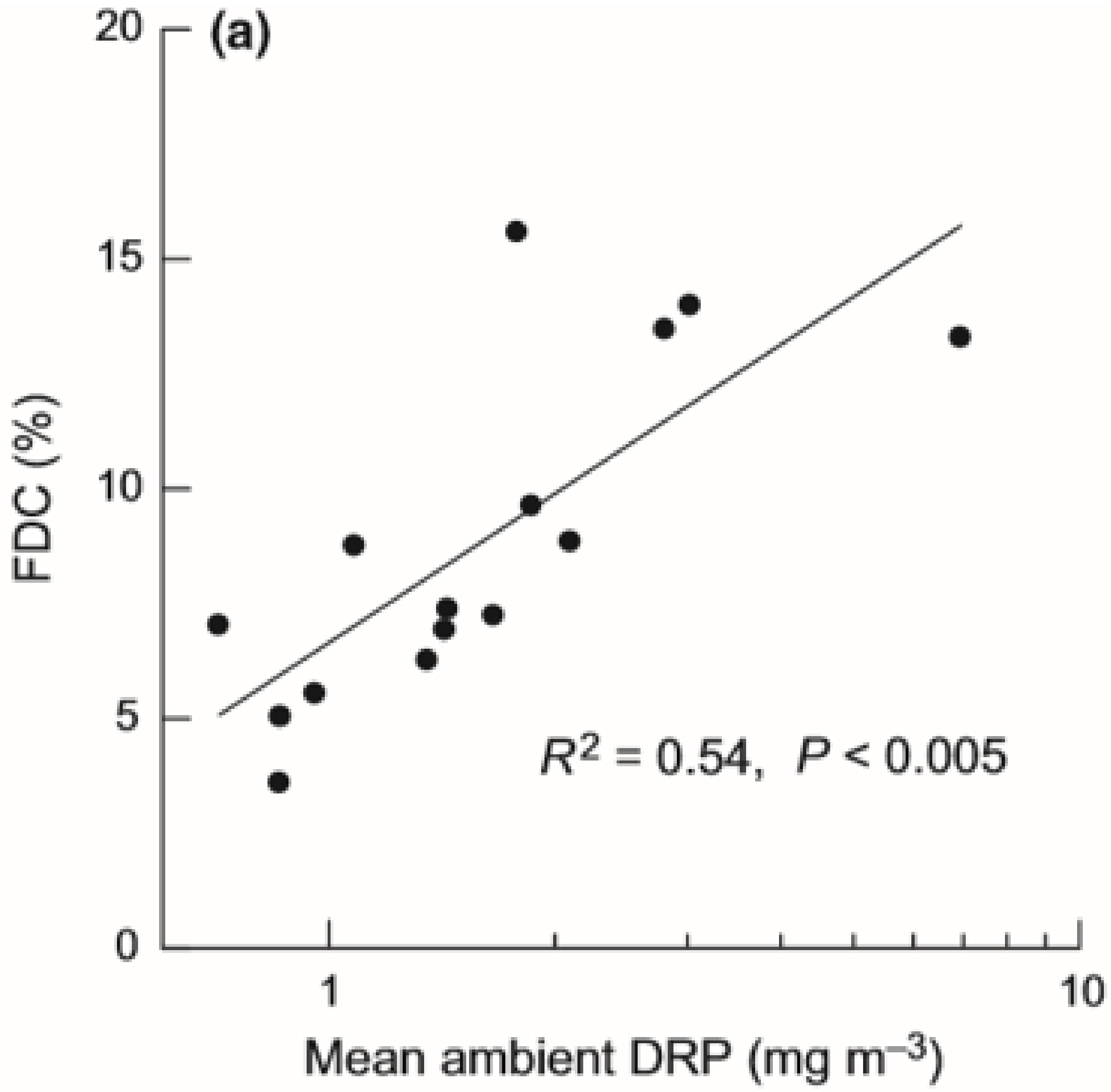
# Retreat of glaciers = changing community composition

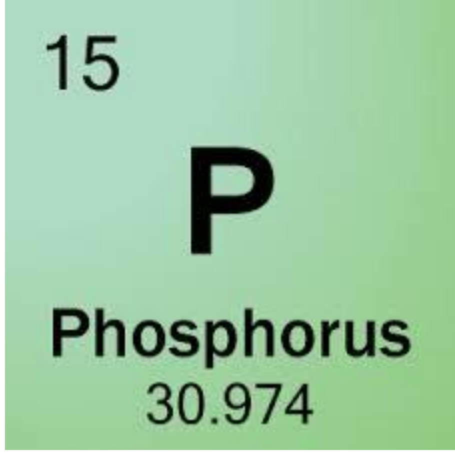
**Epilithic diatom populations**




Brahney et al. 2021 STOTEN

# Earlier glacial and snow melt effects on community composition

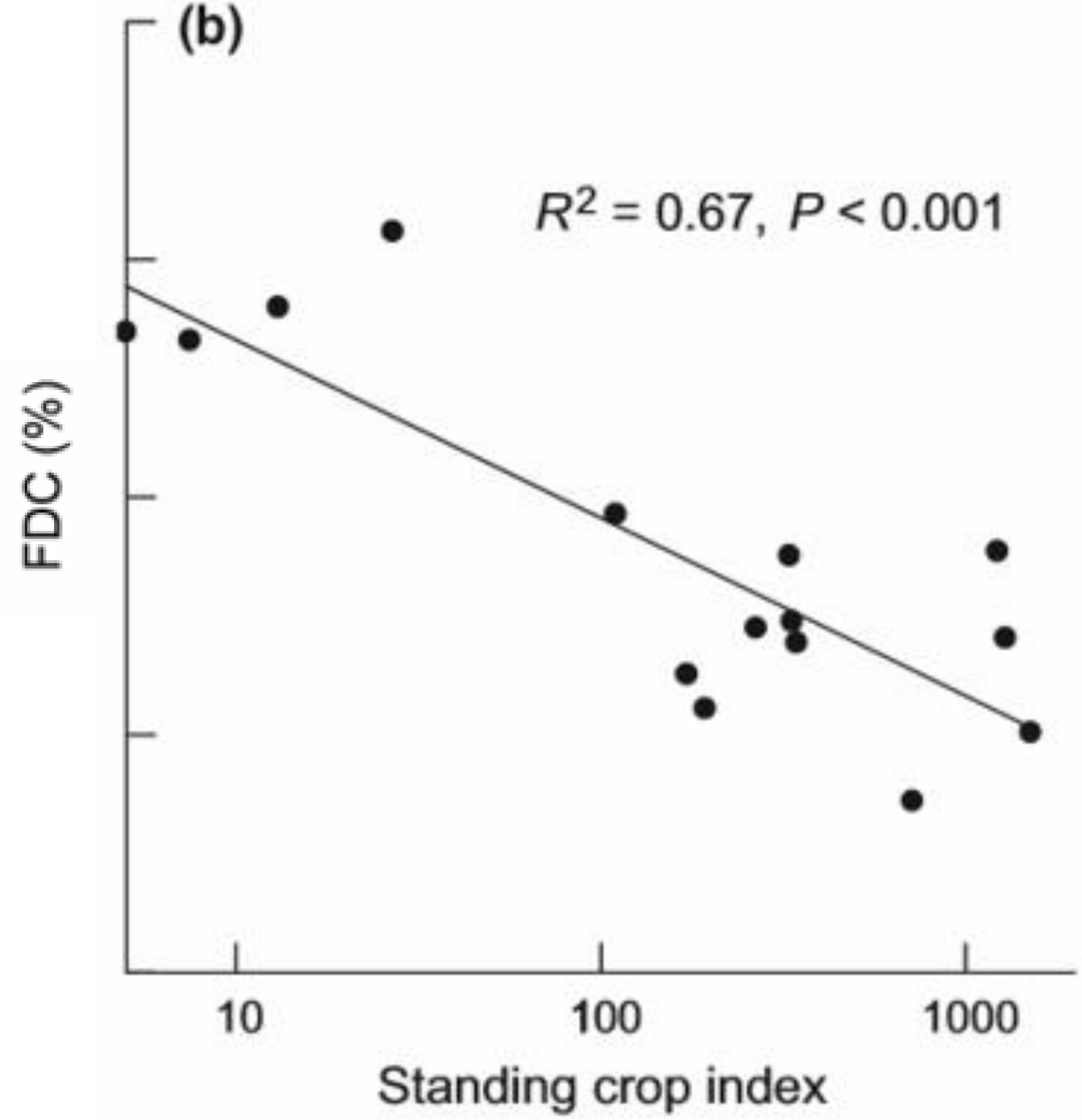



Kilroy & Bothwell 2012

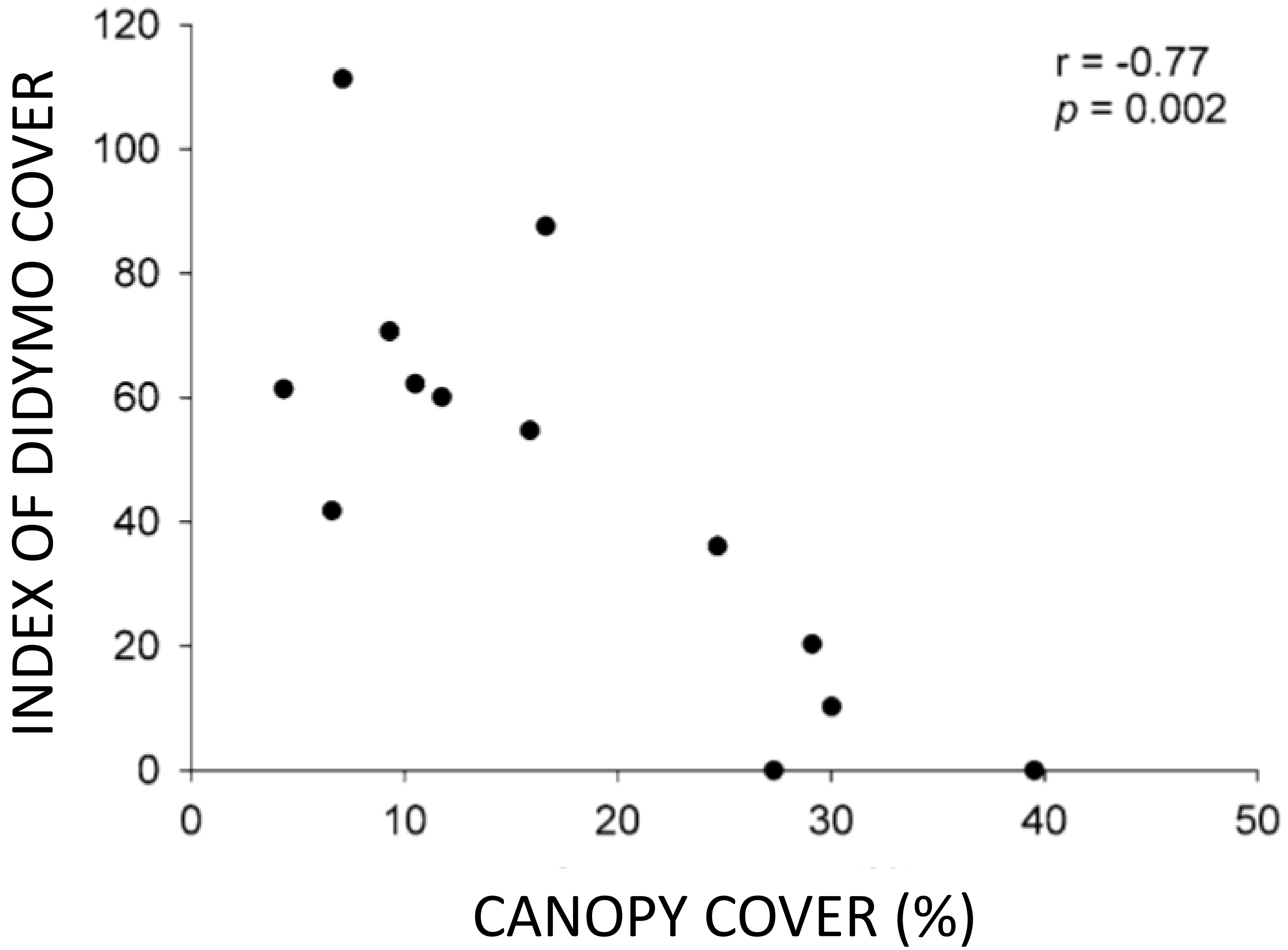
# Earlier glacial and snow melt effects on community composition

15
**P**
**Phosphorus**
30.974



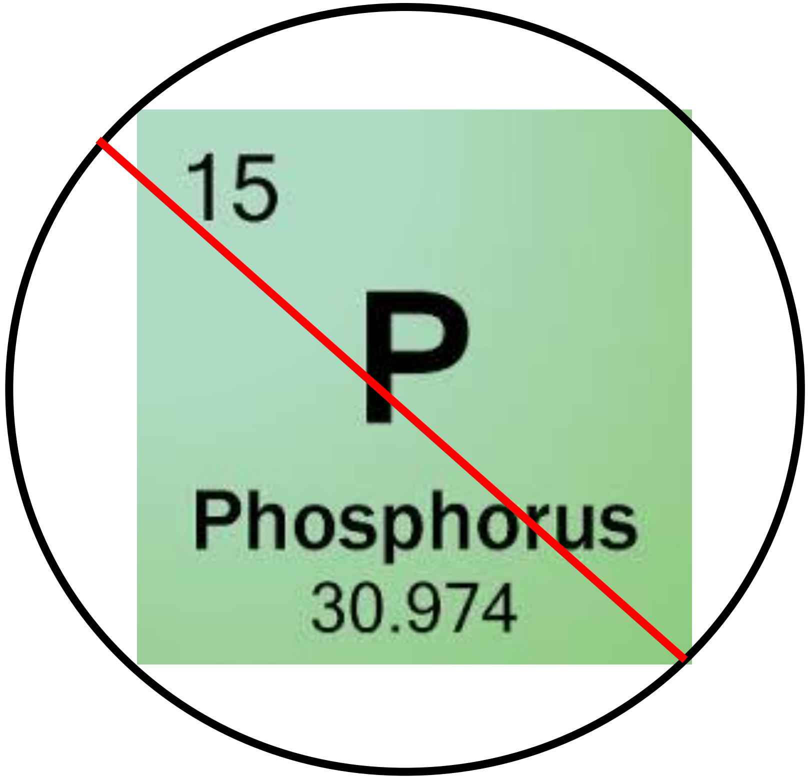

Kilroy & Bothwell 2012

# Earlier glacial and snow melt effects on community composition

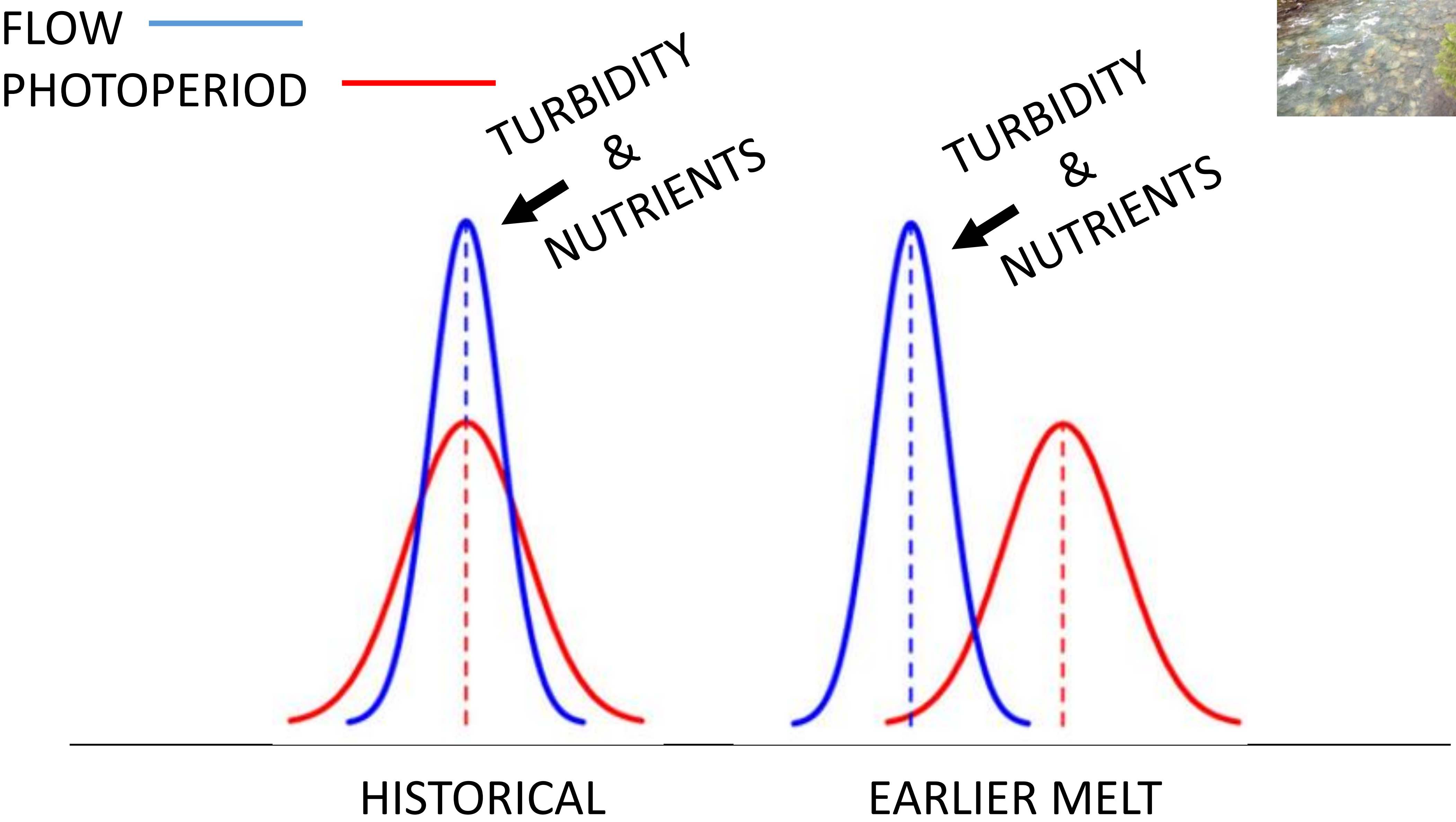



James et al. 2014

# Photosynthetic overflow



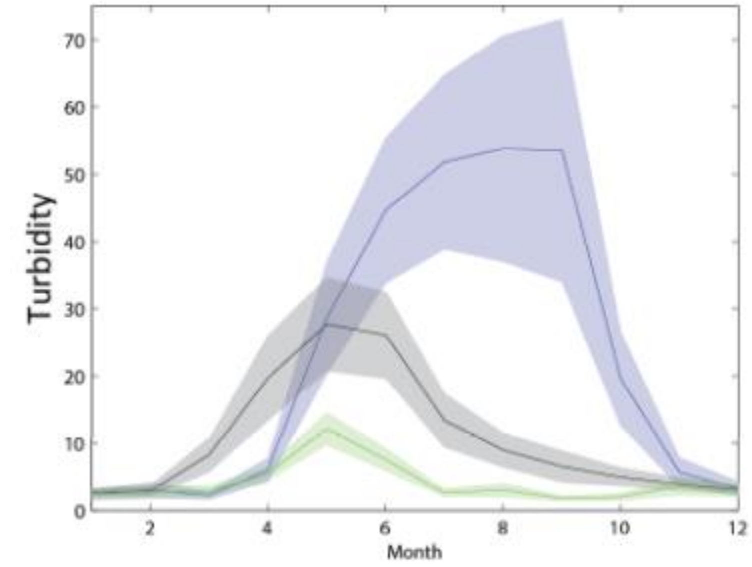

# Earlier glacial and snow melt effects on community composition

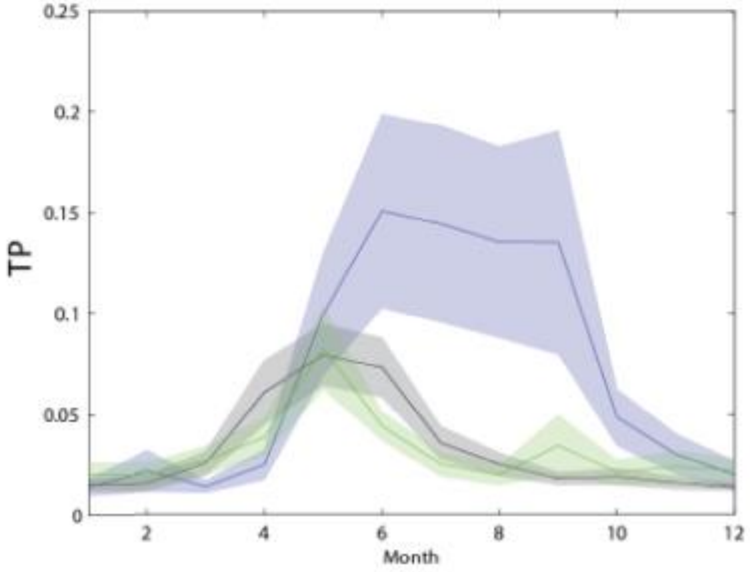


# Earlier glacial and snow melt effects on community composition

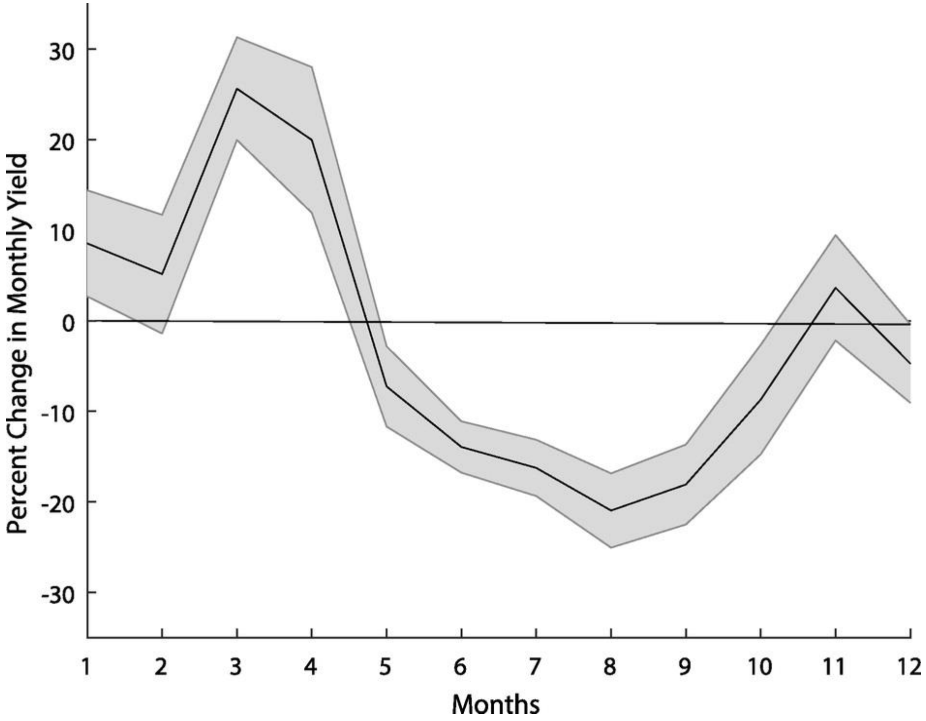
- Lower late summer flow
- Increased transparency
- Decreased TP/SRP
- Warmer temperatures

**Increase in *Didymosphenia* overgrowth?**




Brahney et al. 2021 STOTEN




Brahney et al. 2017, CWRJ

# Earlier glacial and snow melt effects on community composition

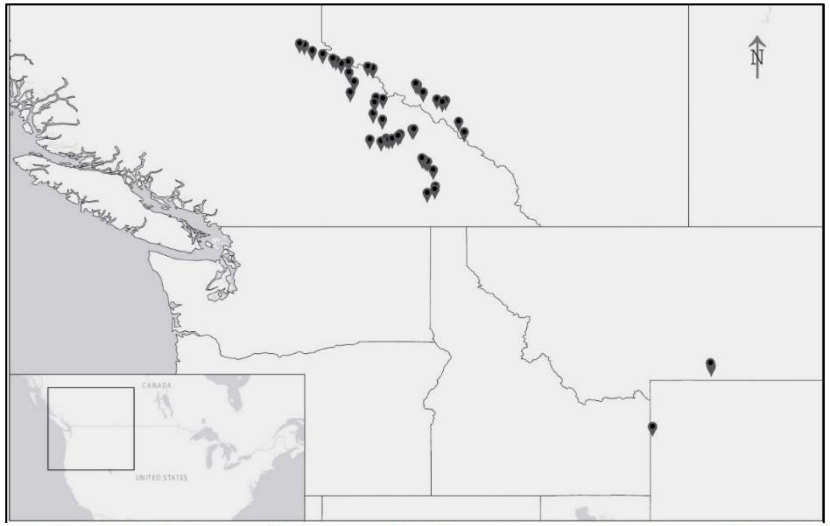
| | Non-Glacierized | Transitional | Glacierized |
|---|---|---|---|
| Didymo blooms | 4 | 1 | 0 |
| Didymo present | 1 | 5 | 1 |
| No Didymo | 1 | 3 | 4 |

$X^2 : p < 0.05$

Brahney et al. in review

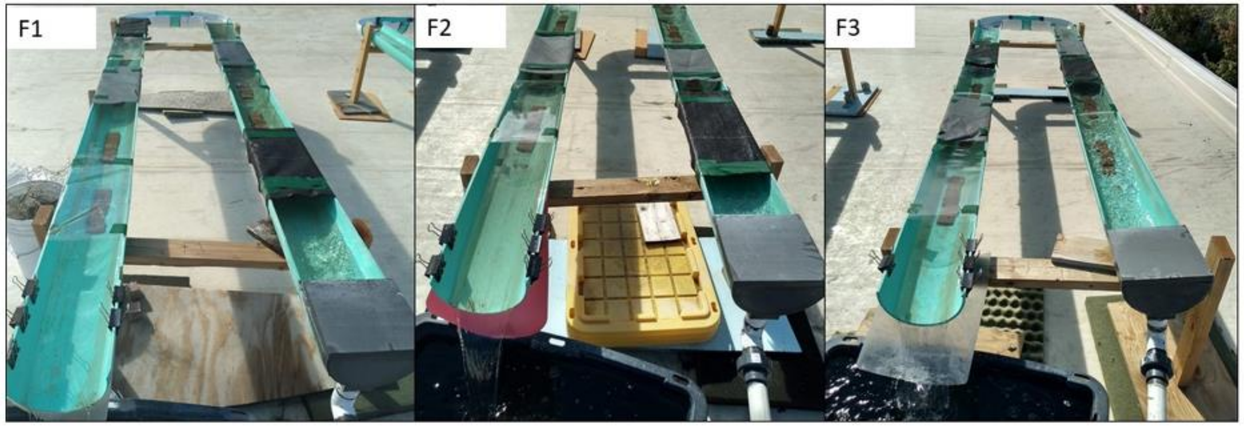
Brahney et al. 2021 STOTEN

# Earlier glacial and snow melt effects on community composition



MS Student (1)

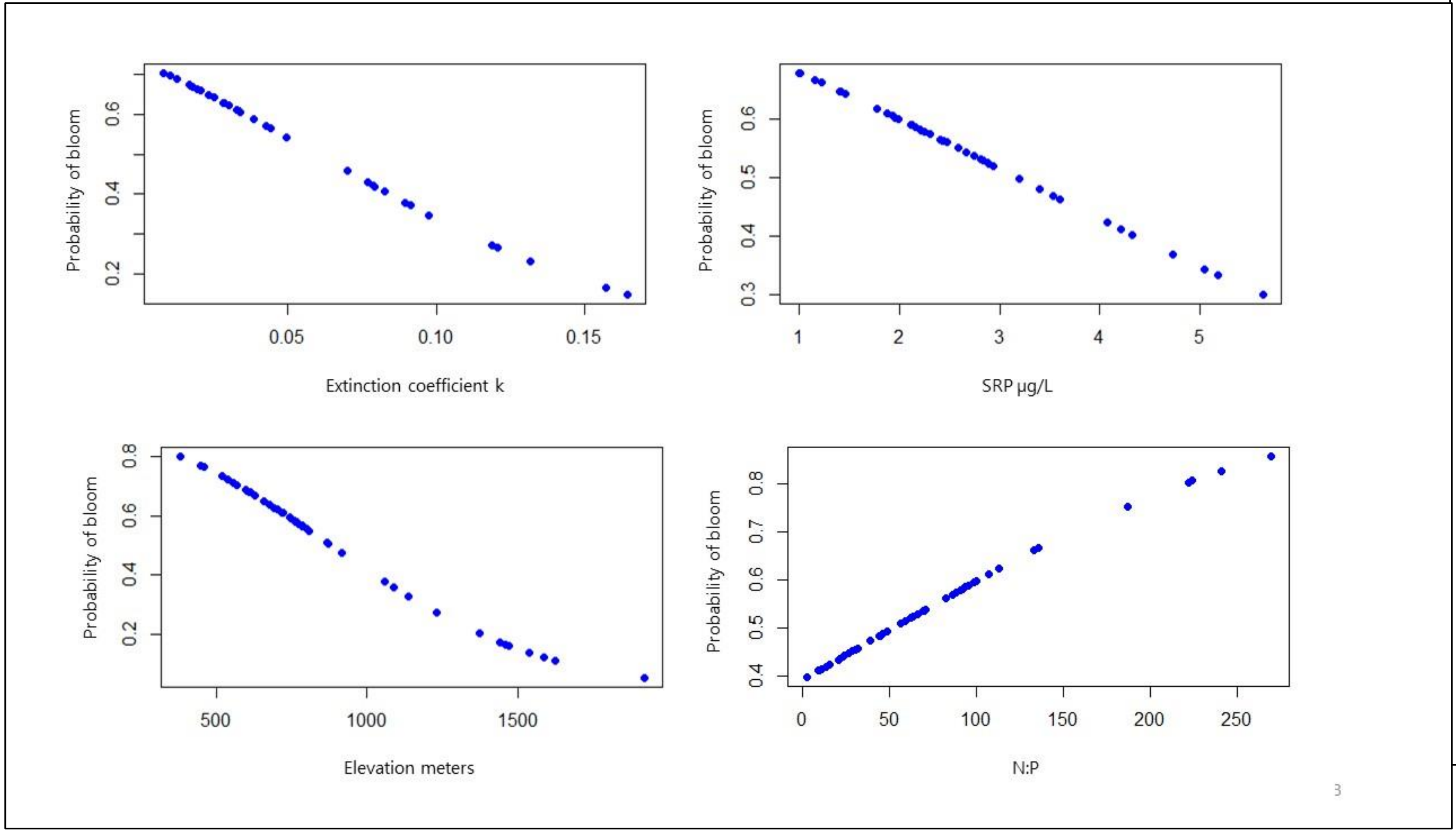
- Increase the space for time study (53 sites)
- Experimental flumes
- High frequency study

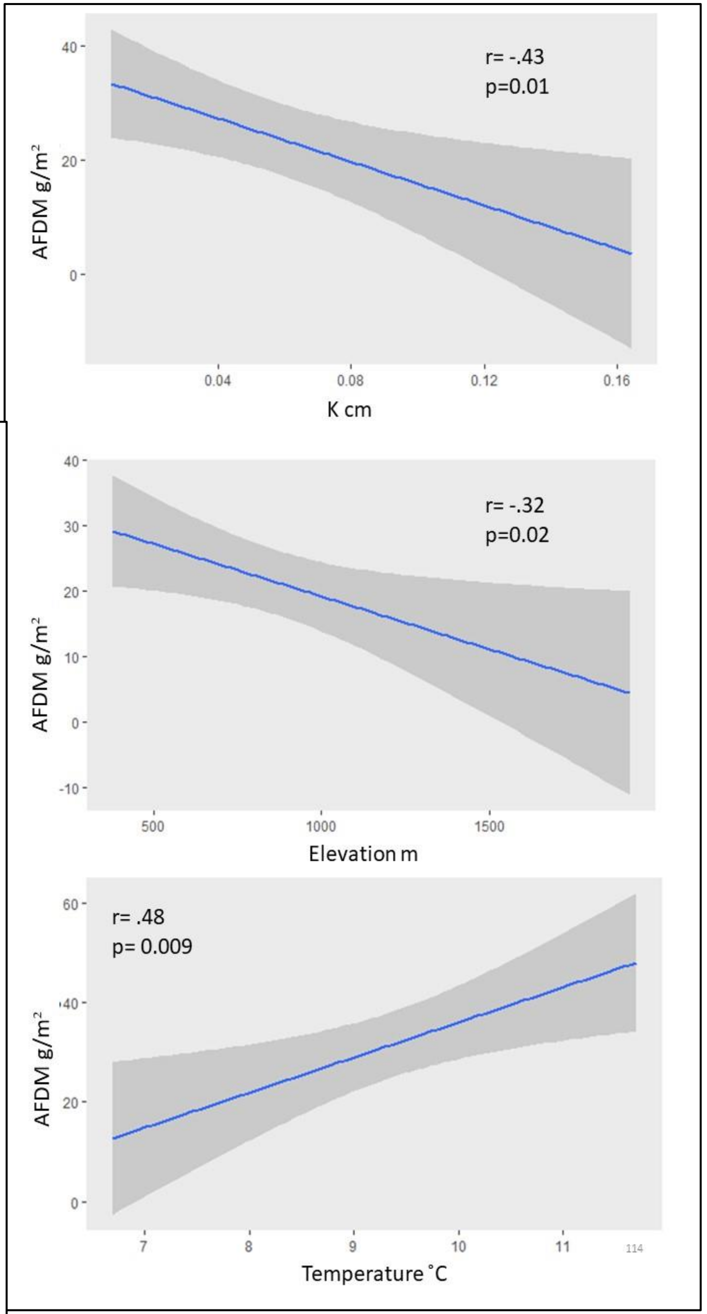


# Earlier glacial and snow melt effects on community composition

## MS Student (1)

- Glaciated rivers had reduced didymo blooms



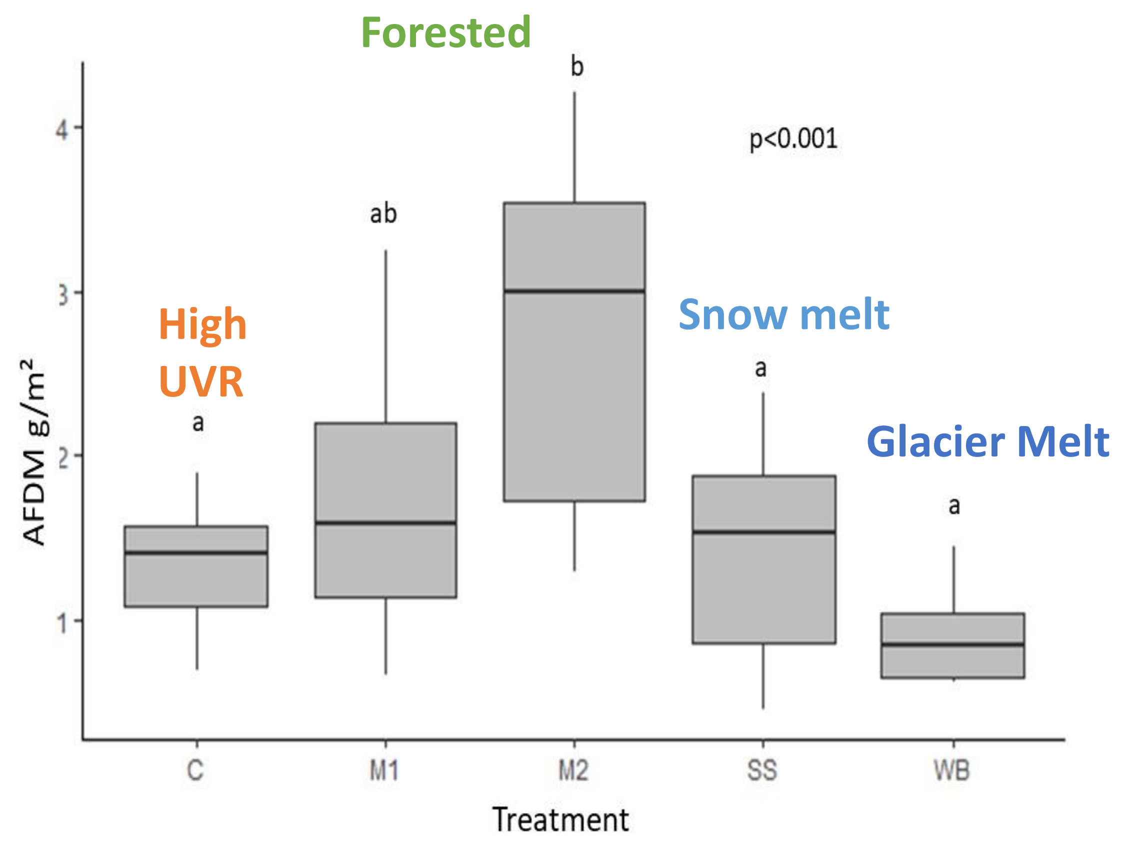




Capito et al. in prep.

# Earlier glacial and snow melt effects on community composition

MS Student (1)

- Glac flour/DOC suppress didymo
- Blooms initiated at peak photo when P & Turb decrease

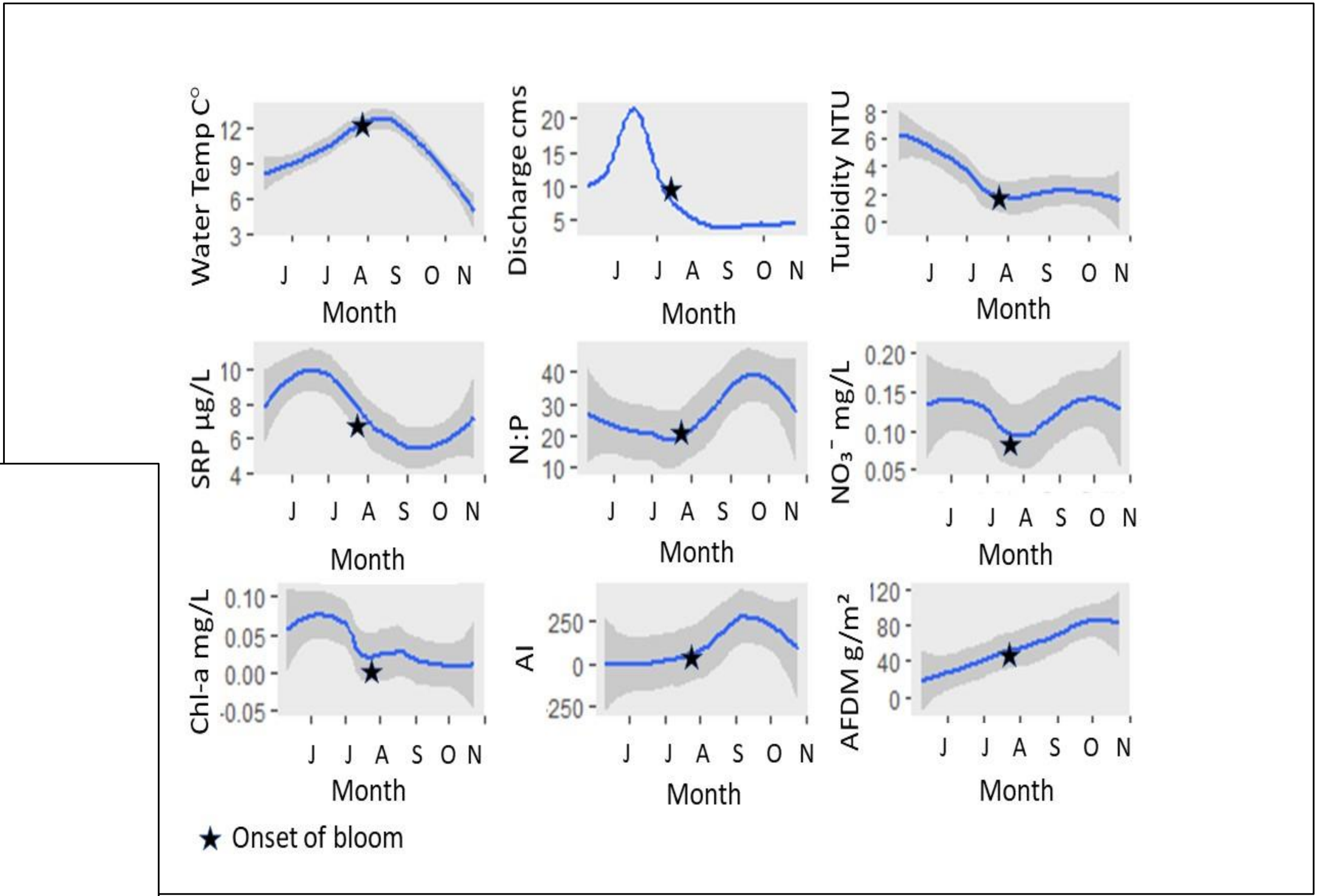


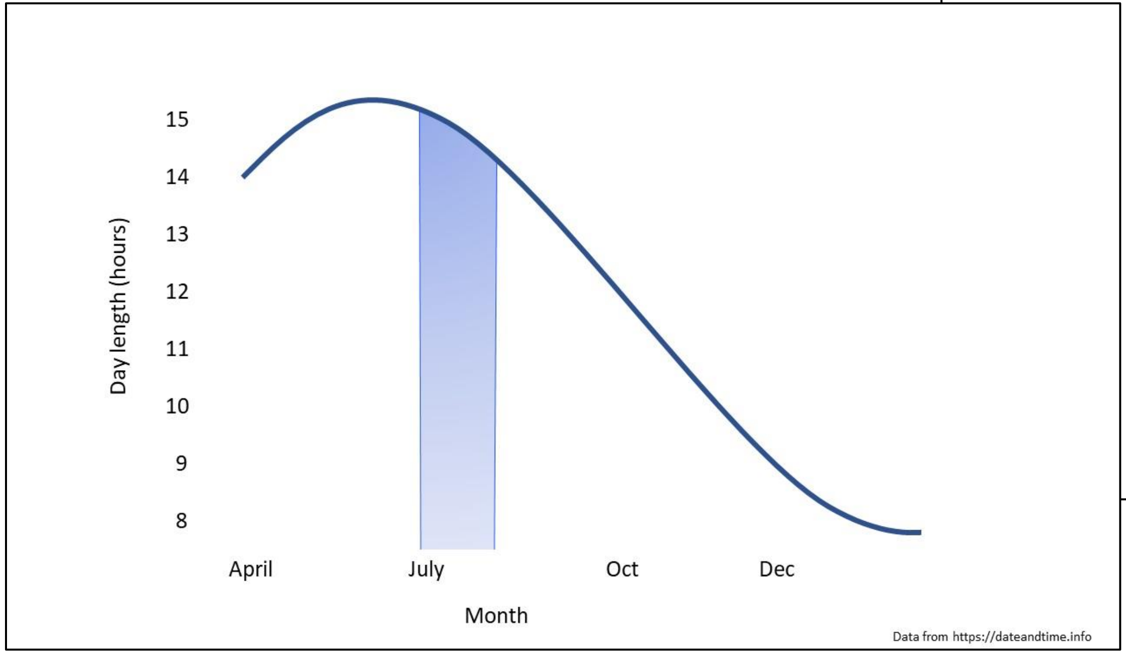

Capito et al. in prep.

# Earlier glacial and snow melt effects on community composition

MS Student (1)

- Blooms initiated at peak photo when P & Turb decrease




Capito et al. in prep.

## Earlier glacial and snow melt effects on community composition

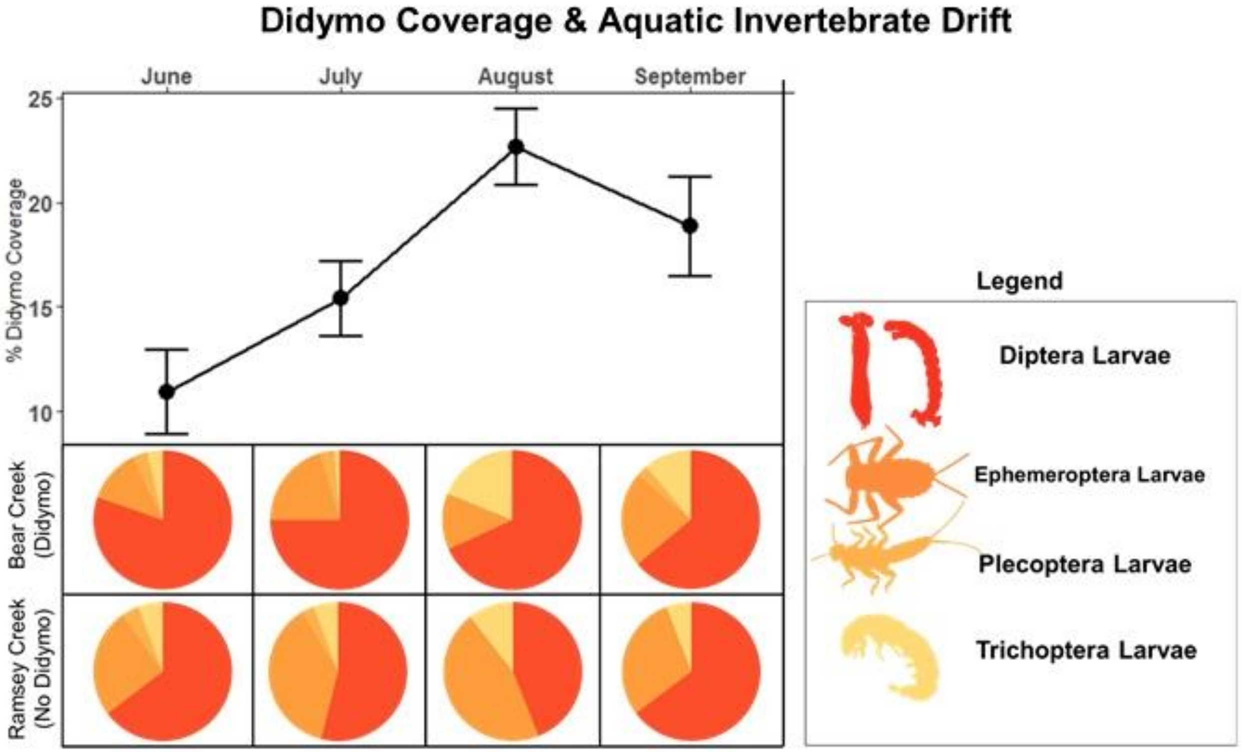
MS Student (2) (with Phaedra Budy)

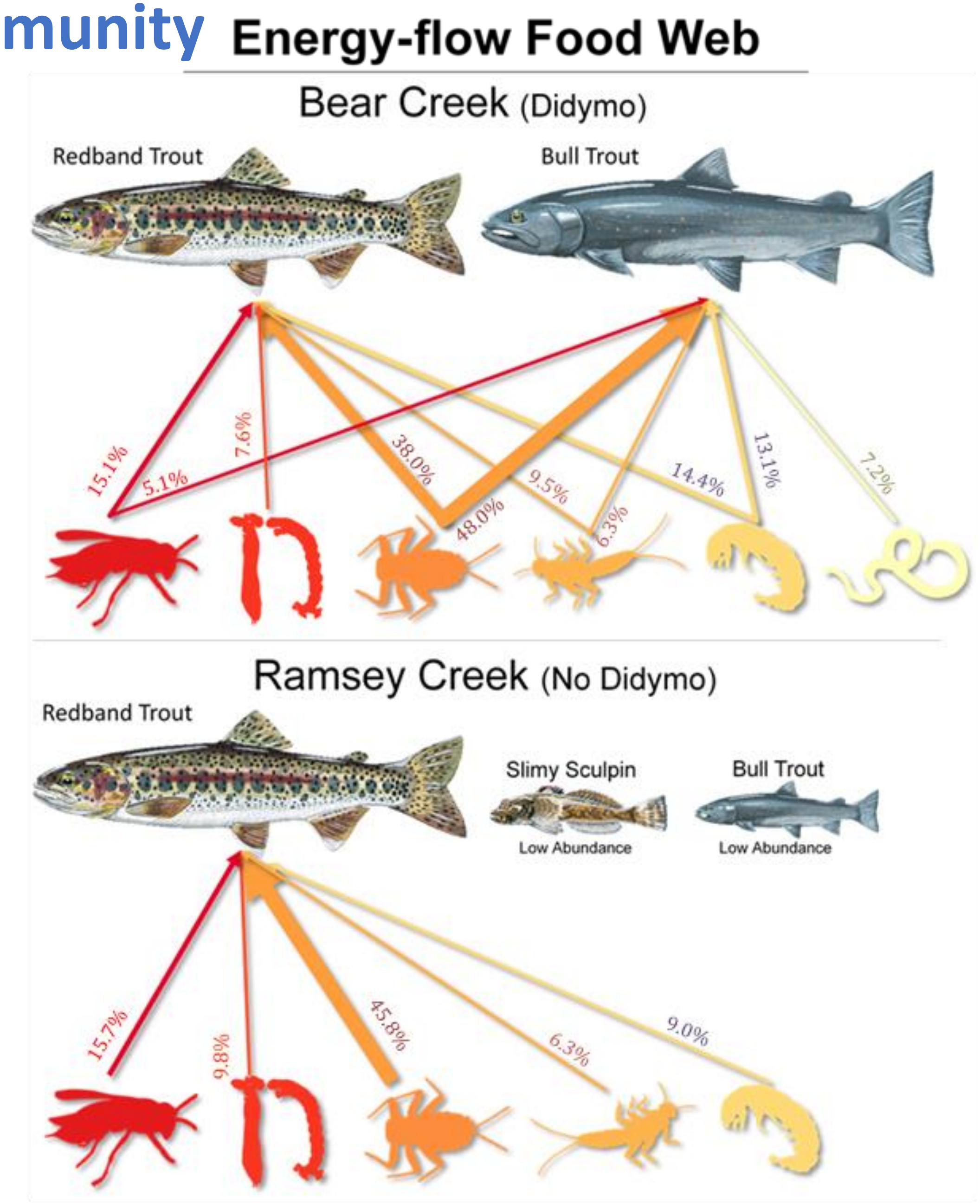
- Change in macroinvertebrates?
- Impacts to Trout, Char, Sculpin?

# Earlier glacial and snow melt effects on community composition

MS Student (2) (with Phaedra Budy)

- Similar to other studies, different macroinverts
- No impact on diet of fish condition




Clancy et al. 2021, CJFAS

# Thank you

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