Arctic LTER Project

Overview of Streams Research

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26 February 2019

The Arctic LTER Streams Team

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- Tamara Harms, University of Alaska-Fairbanks
- Alex Huryn, University of Alabama
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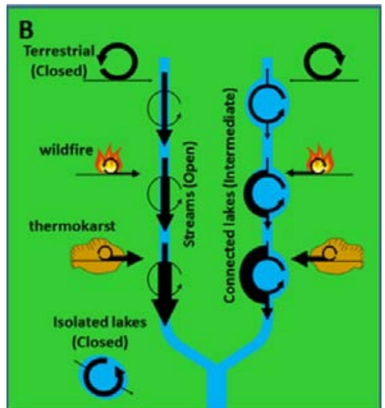
- Mark Urban, University of Connecticut
- Adam Wlostowski, University of Vermont
- Jay Zarnetske, Michigan State University
- …and numerous REU, graduate, and collaborator alumni

Central Framework and Core Questions for the Current Arctic LTER

- How does *biogeochemical* openness influence responses to climate and disturbance?
- How does *community* openness influence responses to climate and disturbance?
- How does system *connectivity* modify responses to climate and disturbance in a changing Arctic landscape?

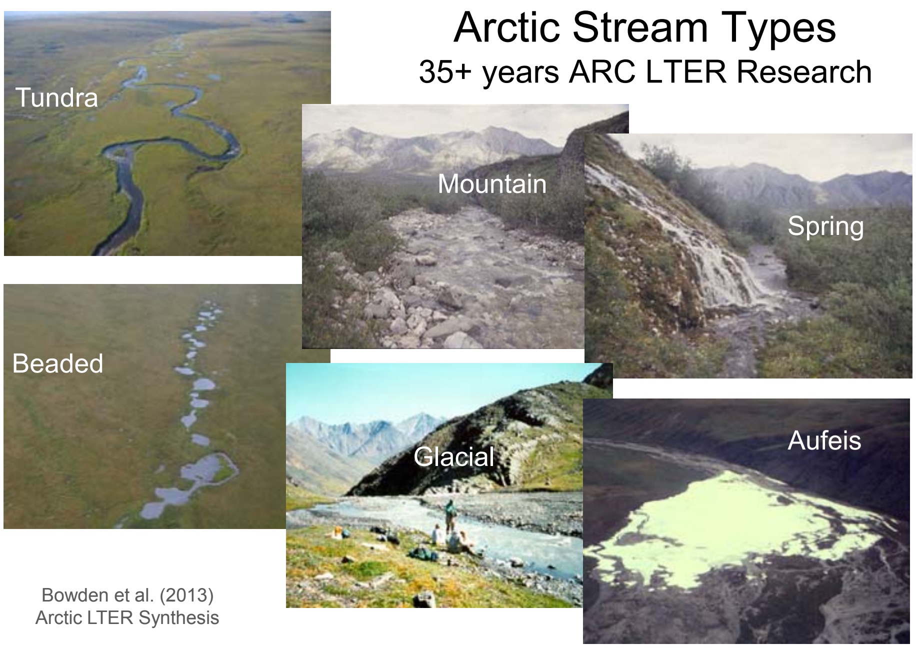
Streams
- *High openness*
- *High connectivity*



Landscape of interconnected ecosystems with various degrees of openness to C, nutrients, organisms, and species.

Arctic Stream Types

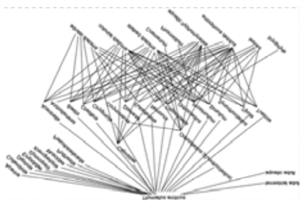
35+ years ARC LTER Research



Bowden et al. (2013)
Arctic LTER Synthesis

Characteristics of Arctic Streams
(All based on previous ARC LTER research)

- Each stream type has characteristic hydrological and biogeochemical regimes
- All have high inter- and intra-annual variability in discharge
- In general, oligotrophic but moderately productive
- Fewer food web components than other biomes, but…
- Reasonably complicated food web interactions



Kuparuk River, Parker (2008)

Thymallus arcticus , M. Kendricks

Environmental Drivers for Arctic Streams
(All based on previous ARC LTER research)

- Primary Producers: nutrient (primarily phosphorus) delivery, discharge
- Benthic Macroinvertebrates: substrate disturbance from variable discharge events, freezing conditions
- Fish: discharge, temperature, over-wintering habitat

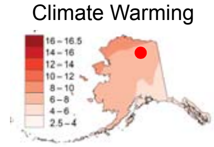
These drivers are characteristics of open systems that are well connected.

Environmental Context for Arctic Streams

Current Permafrost Extent

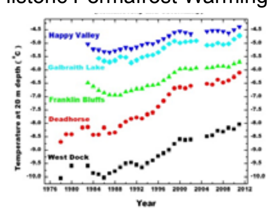
Jorgenson et al. (2008) NICOP

Current and Continued Climate Warming



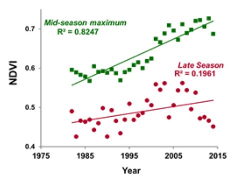
Fourth National Climate Assessment – Alaska (2018)

Historic Permafrost Warming



Romanovsky et al. (2011)

Greening (and Browning)



Guay et al. (2015)

More Frequent Wildfires

Anaktuvuk Burn (2007)

Primary Stream Research Activities from Current ARC LTER Proposal

Ongoing activities

1. Long-term sentinel river monitoring.
2. Estimate whole-stream metabolism.
3. Synthesize results of the long-term experimental fertilization of the Kuparuk River.

New Activities

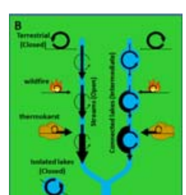
1. Does the mass flux of nutrients (notably nitrogen) increase during the early autumn season?
2. Do Arctic grayling provide an important nutrient or energy subsidy to piscivorous fish in larger arctic lakes?
3. How do geospatial characteristics interact with river network connectivity to influence biogeochemical and community dynamics in arctic rivers?
4. Does the genetic composition of fish communities change over time in response to changes in connectivity among aquatic ecosystems?

Ongoing activities

- Long-term sentinel river monitoring
  - Core monitoring continuing: Kuparuk, Oksrukuyik, Trevor
  - Interacting with NEON on Oksrukuyik Creek monitoring
- Estimate whole-stream metabolism
  - Paper in review: Bowden et al.
  - Added to core monitoring effort, continuing
- Synthesize results of the long-term experimental fertilization of the Kuparuk River
  - Reference data synthesized in Kendrick et al. (2018)
  - Fertilized data manuscript in draft form

Rationale of the Current Streams Research

How do <u>openness</u> and <u>connectivity</u> govern the response of Arctic stream ecosystems to disturbances like climate change, thermokarst activity, and wildfire?

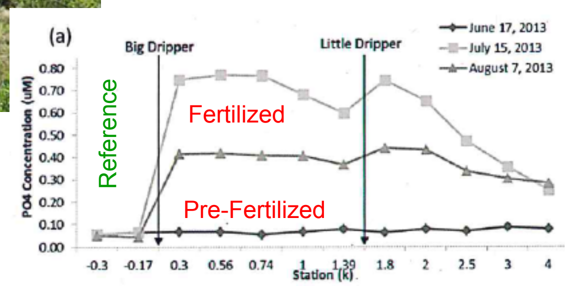


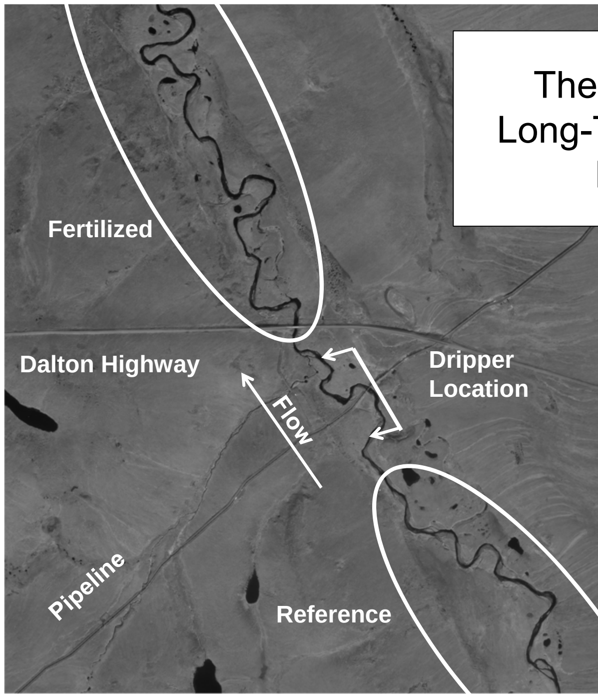
Landscape of interconnected ecosystems with various degrees of openness to C, nutrients, organisms, and species.

What we know about *biogeochemical* openness in Arctic stream ecosystems

Adding the limiting nutrient (P) to these oligotrophic systems may change them significantly

Simple Phosphorus "Dripper" Experiment





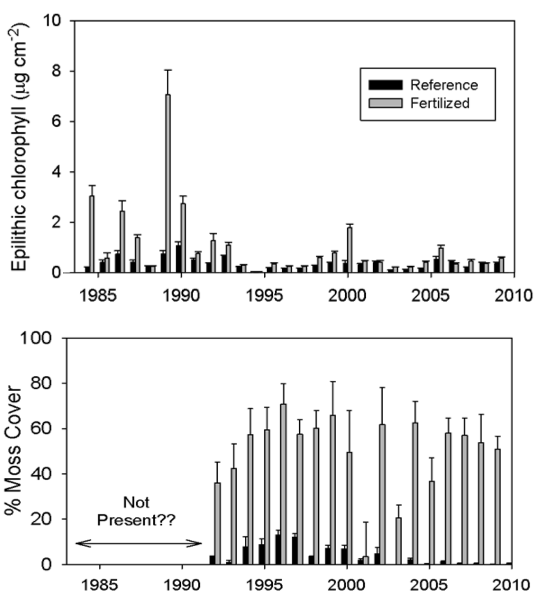
The Kuparuk River Long-Term Fertilization Experiment

Core ARC LTER Stream Experiment

Fertilized from 1983 to 2016

Monitoring recovery 2017 - present

Kuparuk River



We observed the expected response, at first…

Then…

…an intersection between *biogeochemical* and *community* openness – bryophyte colonization

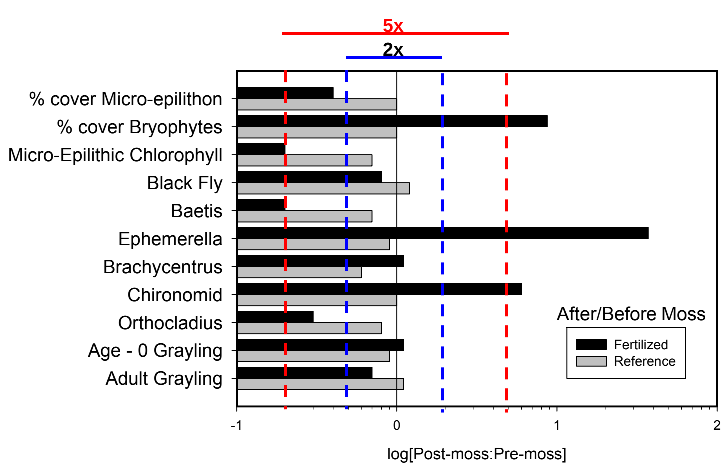
ARC LTER Core data

Long-term low-level fertilization with P significantly altered the Kuparuk ecosystem

Reference reach substrate

Fertilized reach substrate

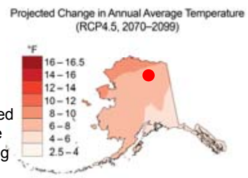
Increasing nutrient flux through an open system substantially altered the community [Field Trip]



Slavik et al. 2004

What might increase nutrient loading in this permafrost-dominated landscape?

Continued Climate Warming



Fourth National Climate Assessment – Alaska (2018)

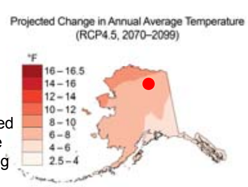
Current Permafrost Extents

Jorgenson et al. (2008) NICOP

- Localized thaw near streams (hyporheic thawing)
- General thawing across the landscape
- Catastrophic thawing (thermokarst)
- Extended Season

What might increase nutrient loading in this permafrost-dominated landscape?

Continued Climate Warming



Fourth National Climate Assessment – Alaska (2018)

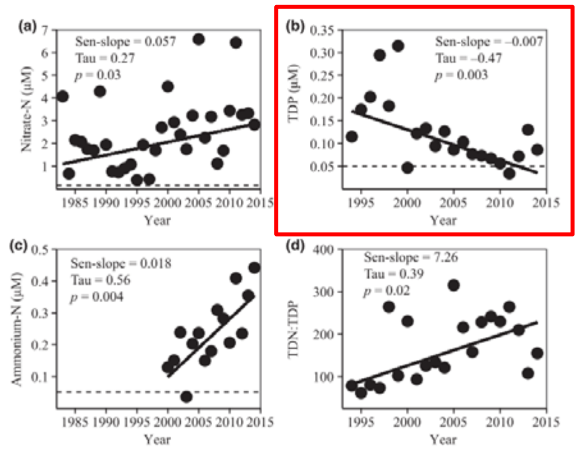
Current Permafrost Extents

Jorgenson et al. (2008) NICOP

- Localized thaw near streams (hyporheic thawing)
  - Not Likely
- General thawing across the landscape
  - Possibly? *Current work*
- Catastrophic thawing (thermokarst)
  - Yes, but short term
- Extended Season
  - Possibly? *Current work*

Synthesis: Does generalized thawing increase nutrient loading?

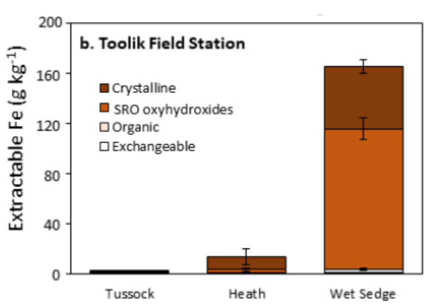
While N concentrations have tended to increase, TDP has decreased!



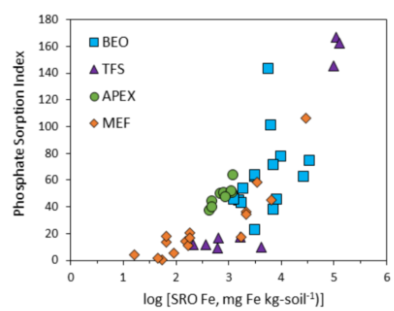
Kendrick et al. (2018) Global Change Biology

Iron-Phosphorus Interactions

A potential unifying explanation



Lots of iron in soils at Toolik...

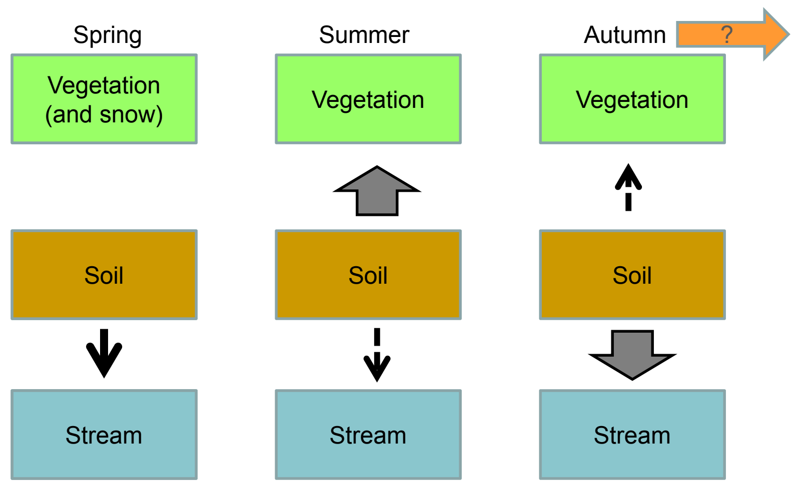


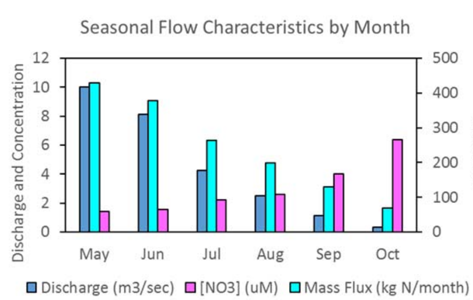
…high capacity to retain phosphorus.

New collaborative research on iron biogeochemistry

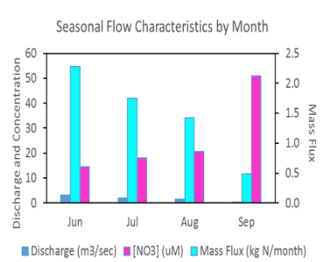
Herndon et al. 2019 (JGR)

NEW ACTIVITY: Does the mass flux of nutrients increase during the early autumn season?





Tundra (Kuparuk River, 2013)



Mountain (Trevor Creek, 2016)

Nitrate concentration, yes.

Instantaneous mass flux, no.

Cumulative mass flux, maybe, if season is extended, but….

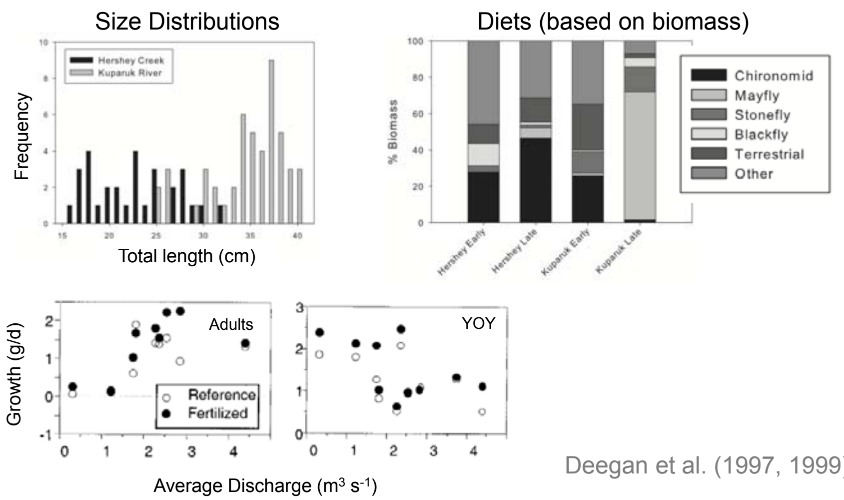
No evidence of extended seasonality at Toolik, yet.

And no evidence of extended P loss

ARC LTER Core Data

What we know about *community* openness and connectivity in Arctic stream ecosystems

We know a lot about the fish populations in local rivers



Deegan et al. (1997, 1999)

Droughts at crucial times can reduce the openness of the system

Photo credit:
W. Bowden

Photo credit: A. Huryn

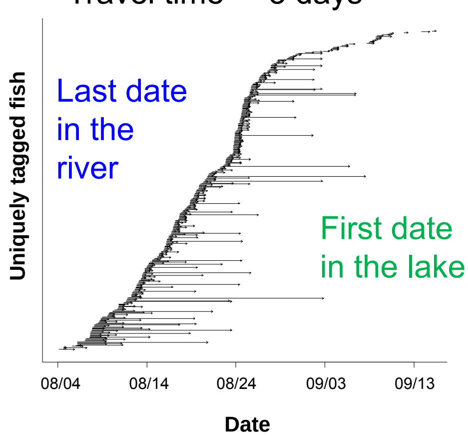
Photo credit: C. Mackenzie

Kuparuk River – Pool of grayling trapped in main-stem below dry channel (≈1000 adults)

Dry reaches obstruct fish movement

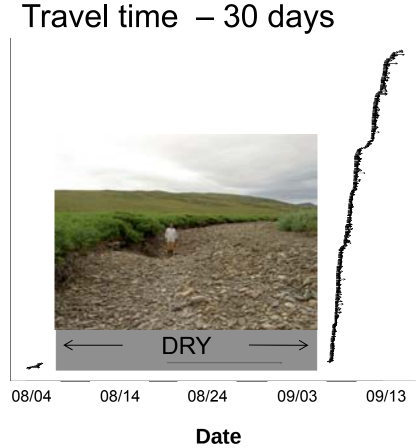
2010

Typical river flow
Travel time – 3 days



2011

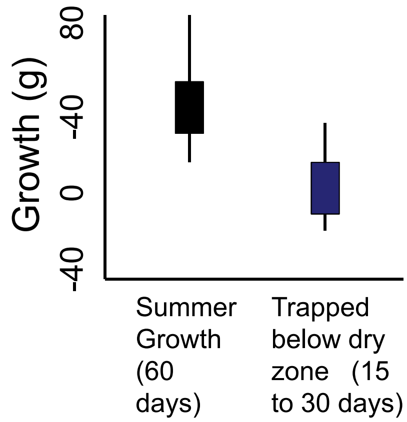
Trapped in River
Travel time – 30 days



Trapped fish lost 75% of their summer growth

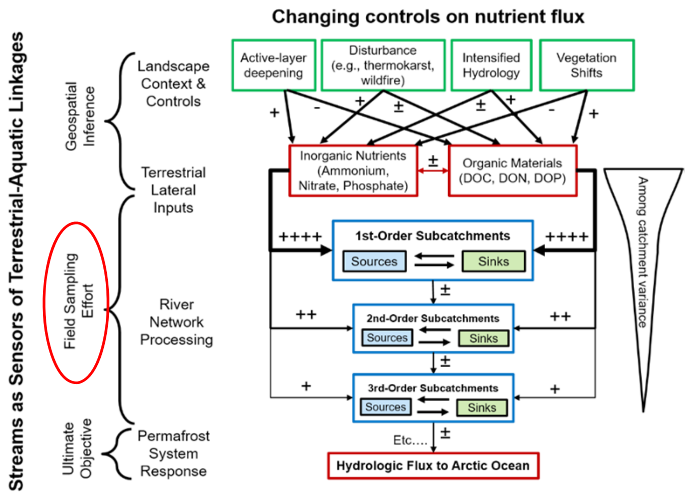
- Competition
- Little insect production
- Predation

Kuparuk River – Grayling trapped for 30 days below dry channel bed.



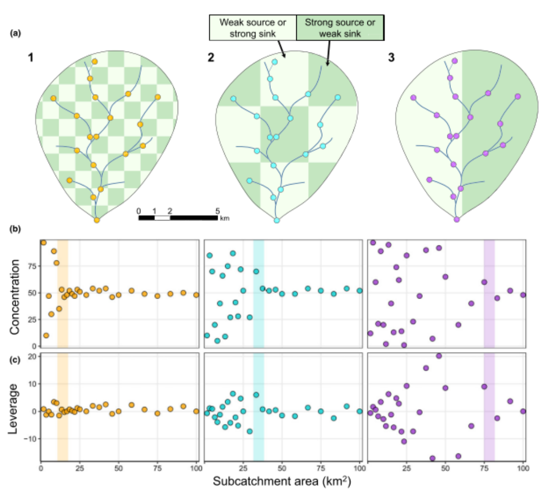
Current research on connectivity in Arctic streams

NEW ACTIVITY: How do geospatial characteristics interact with river network connectivity to influence biogeochemical and community dynamics in arctic rivers?



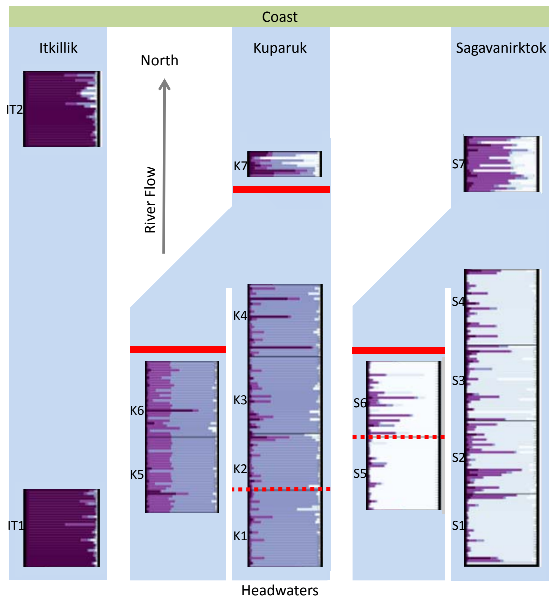
Abbott, Zarnetske, Bowden, and Shogren, unpublished

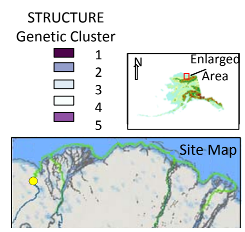
The spatial arrangement of source “patches” defines spatial patterns of concentration and subcatchment leverage (influence) in river networks



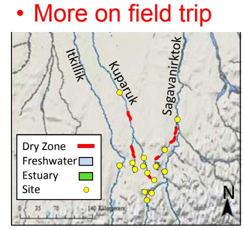
Abbott et al. (2018) Ecology Letters

COLLBORATIVE ACTIVITY: Riverscape Genetics

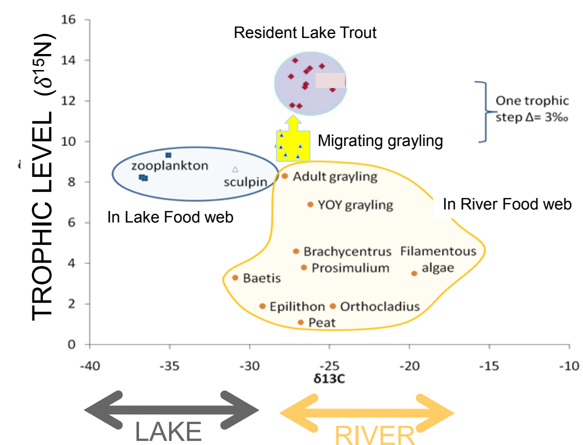




- Watershed effect
- Drying effect
- Downstream effect
- More on field trip

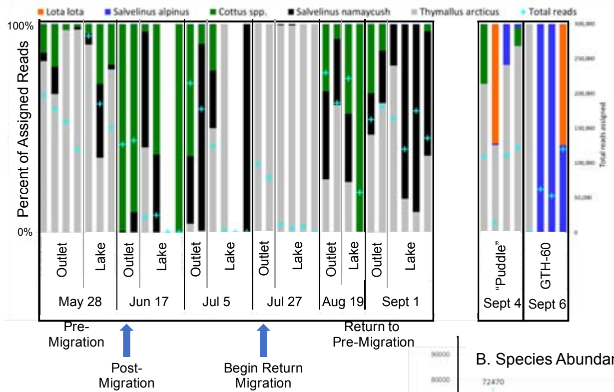


NEW ACTIVITY: Do Arctic grayling provide an important nutrient/energy subsidy to piscivorous fish in arctic lakes?



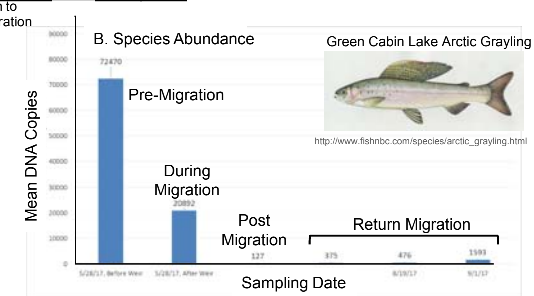
Deegan, Golden, Peterson and Urban, in review

NEW ACTIVITY: Environmental DNA (eDNA) Pilot Studies



Potential Benefits

1. Species Presence
2. Community Structure
3. Species Abundance



ArcLTER Streams Research
Take-home messages

ArcLTER Objectives

1. How does *biogeochemical* openness influence responses to climate and disturbance?
2. How does *community* openness influence responses to climate and disturbance?
3. How does system *connectivity* modify responses to climate and disturbance in a changing Arctic landscape?

Key messages

- Arctic rivers are strongly P limited. Additional P subsidies support increased production of local species but also facilitate colonization and production of distal species
- There are strong indications of warming and degrading permafrost leading to increases in some solutes
- Somewhat surprisingly, P is *not* increasing. Iron may play a crucial role.
- Synoptic biogeochemical patterns may provide clues to key land-water connections
- Changing seasonality may threaten the survival of important fish species in these streams.
- Changing river network connectivity may affect fish genetic diversity.

Thanks for your attention!