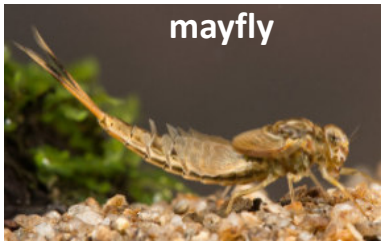
Biodiversity of Benthic Macroinvertebrates Across the Circumpolar Region: Latitudinal Declines in Richness of Lakes and Rivers

Jennifer Lento[1], Joseph Culp, Willem Goedkoop (+20 contributors)

[1]Canadian Rivers Institute, University of New Brunswick, Canada

Arctic Benthic Macroinvertebrates (BMIs)

- BMI: Important component of Arctic freshwater food webs and ecosystems that reflects conditions of the freshwater environment
- Regional latitudinal shift in taxa:



INCREASING LATITUDE

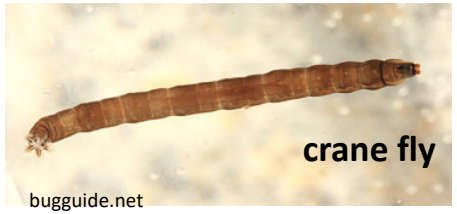


Photo credits: www.lifeinfreshwater.net

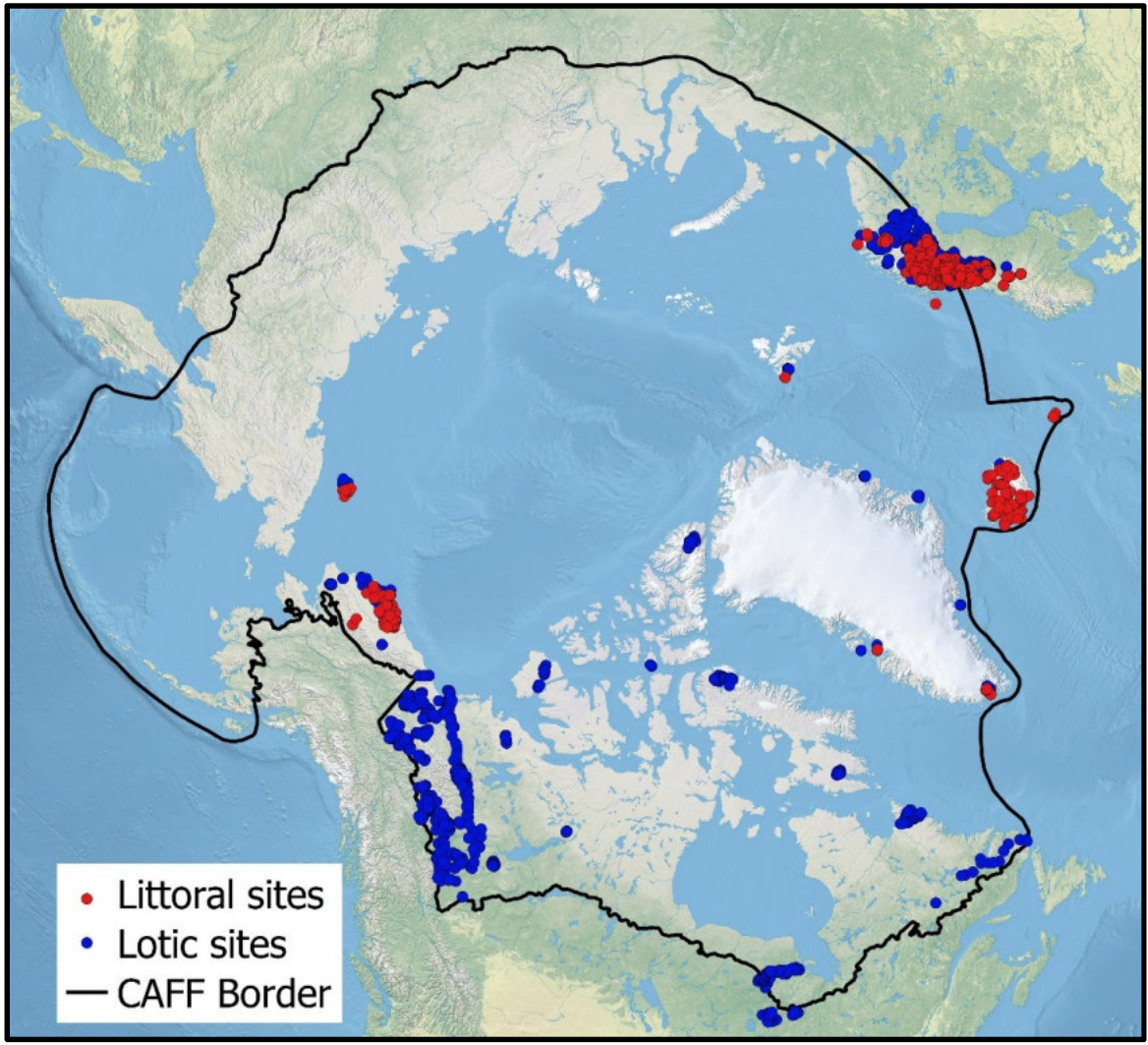
Objectives:

- Evaluate alpha diversity (taxon richness) across ecoregions and latitudes
- Assess environmental drivers of diversity
- Produce baseline for future assessments and identify monitoring gaps

Oswood 1997, Castella et al. 2001, Scott et al. 2011; CAFF 2013;Culp et al. 2018

BMI Data

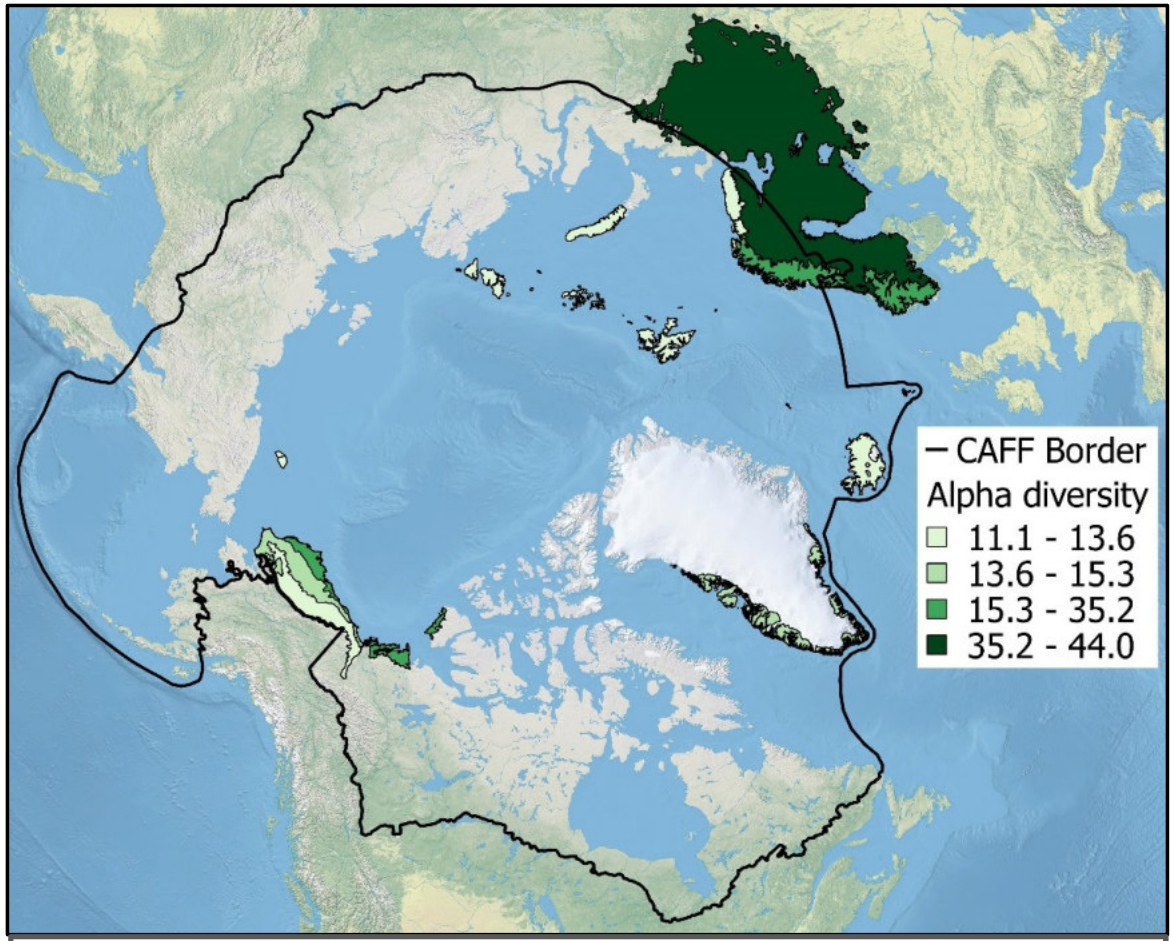
- Database includes over 1250 river BMI stations and over 350 littoral lake stations
- Nomenclature harmonized across circumpolar region
- Data selected by methods and habitats
- Presence/absence for analysis where necessary (e.g., different mesh sizes)



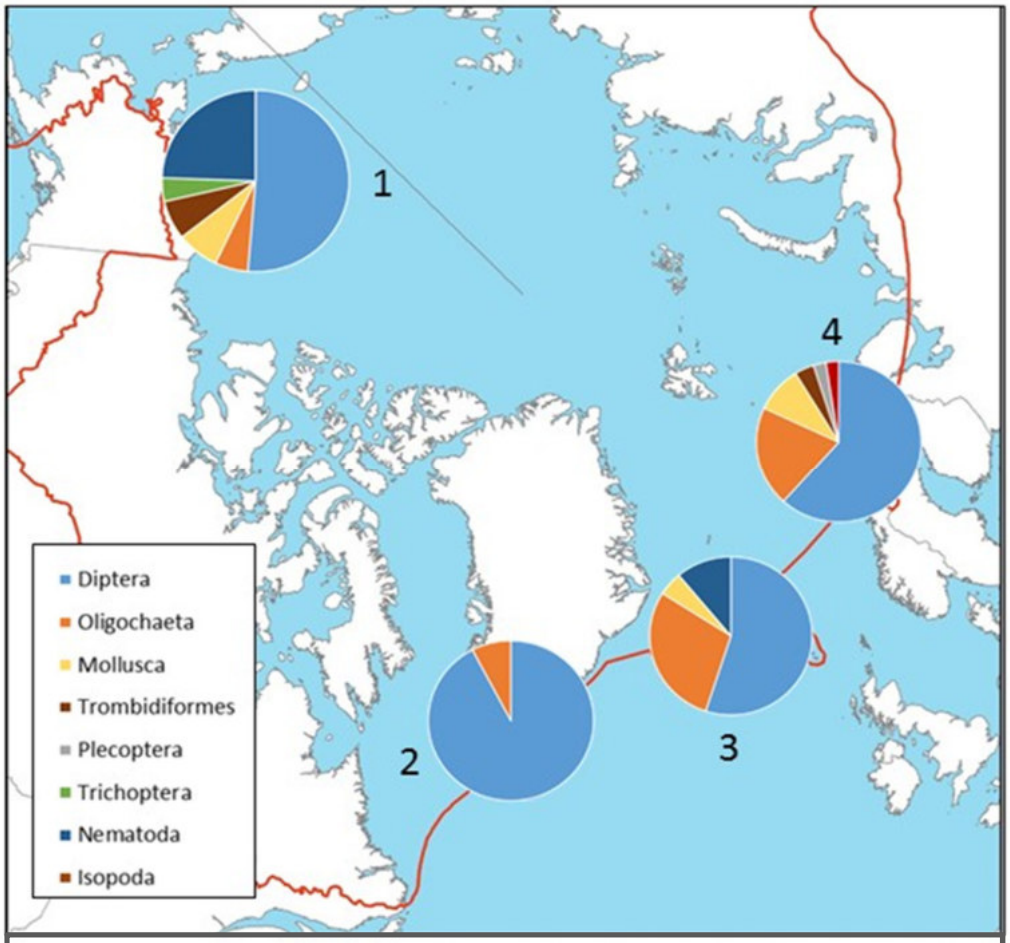
Facilitating Circumpolar Assessment

- Stations grouped within hydrobasins (USGS/WWF) to standardize watersheds
- Analysis by ecoregion (Terrestrial Ecoregions of the World; WWF) to group climatically-similar stations
  - Alpha diversity (number of taxa) estimated for each ecoregion, compared across circumpolar region
- Geospatial variables derived for each Hydrobasin to standardize drivers

BMI Diversity in Arctic Lakes

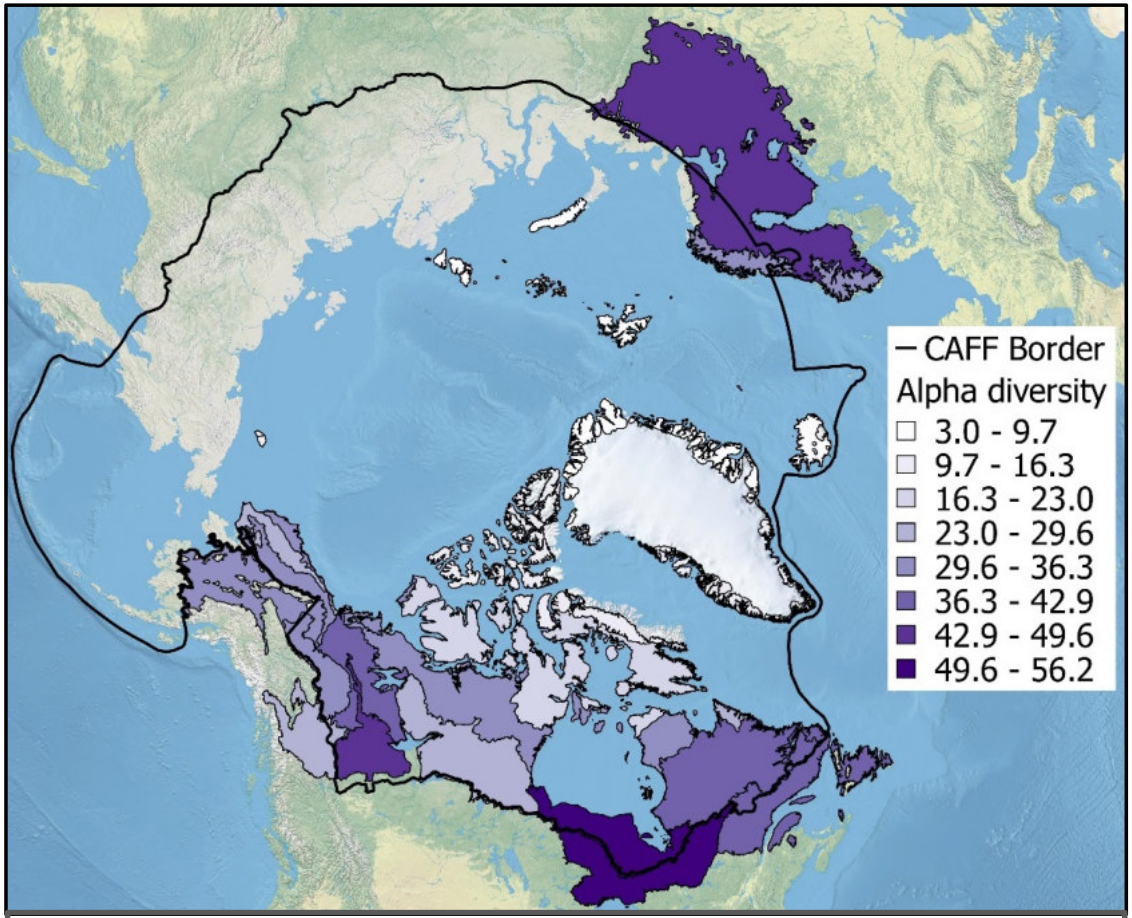


Estimated alpha diversity (number of BMI families) in 10 stations within each sampled ecoregion

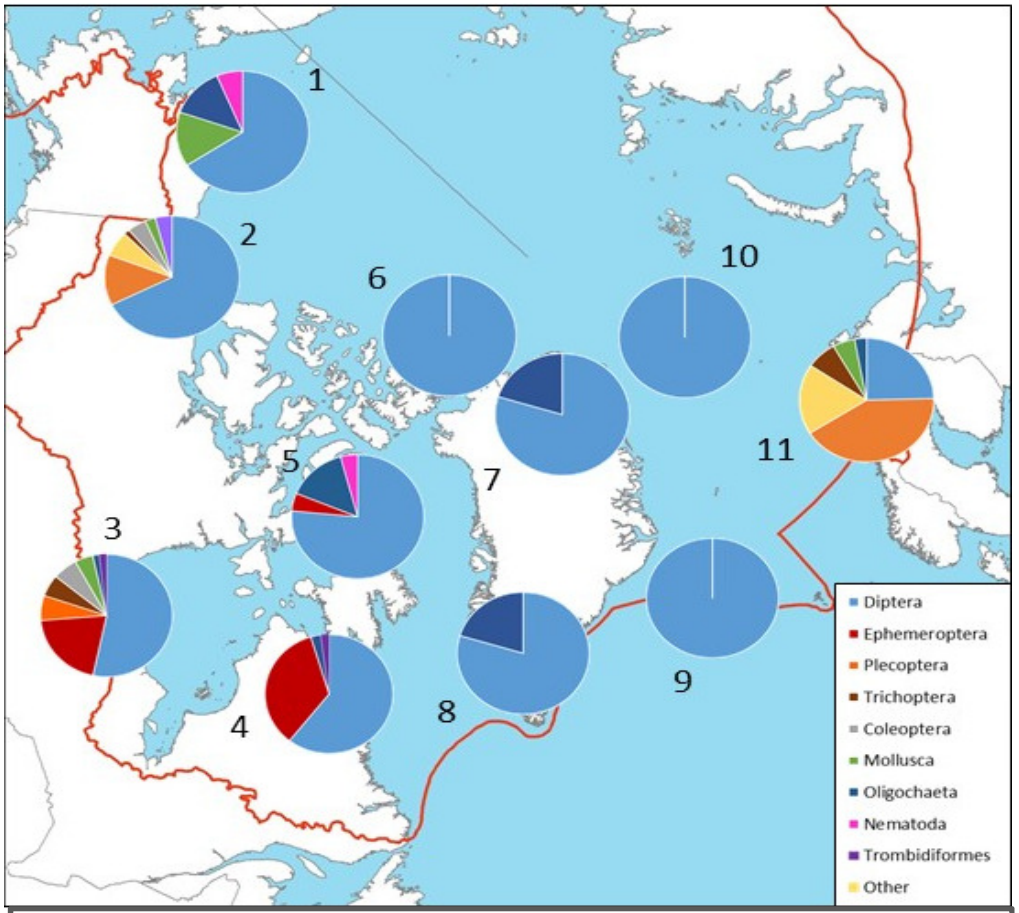


Composition of the 8 most abundant BMI groups in: 1-Alaska, 2-Greenland, 3-Iceland, 4-Fennoscandia

BMI Diversity in Arctic Rivers

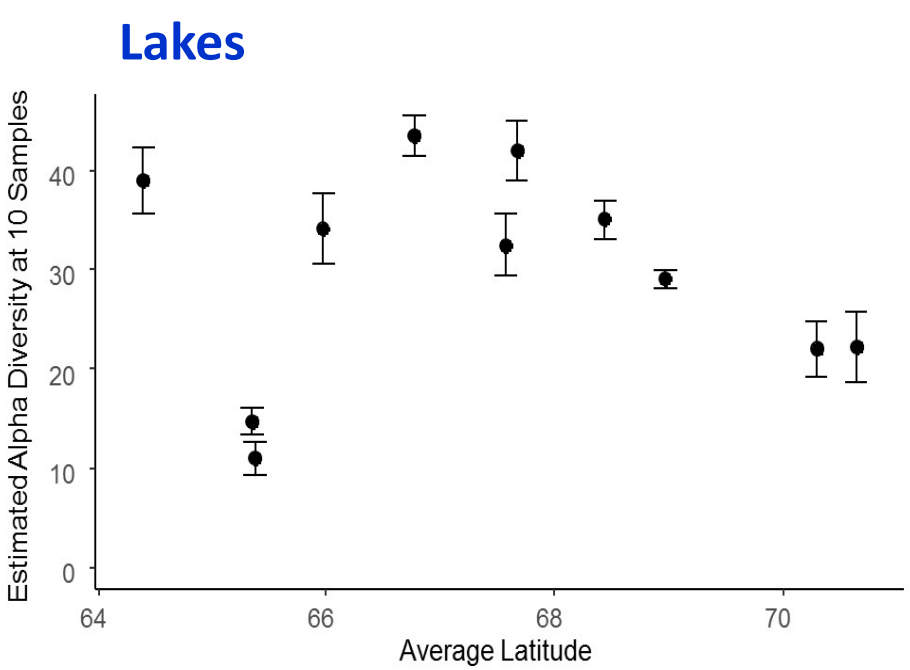


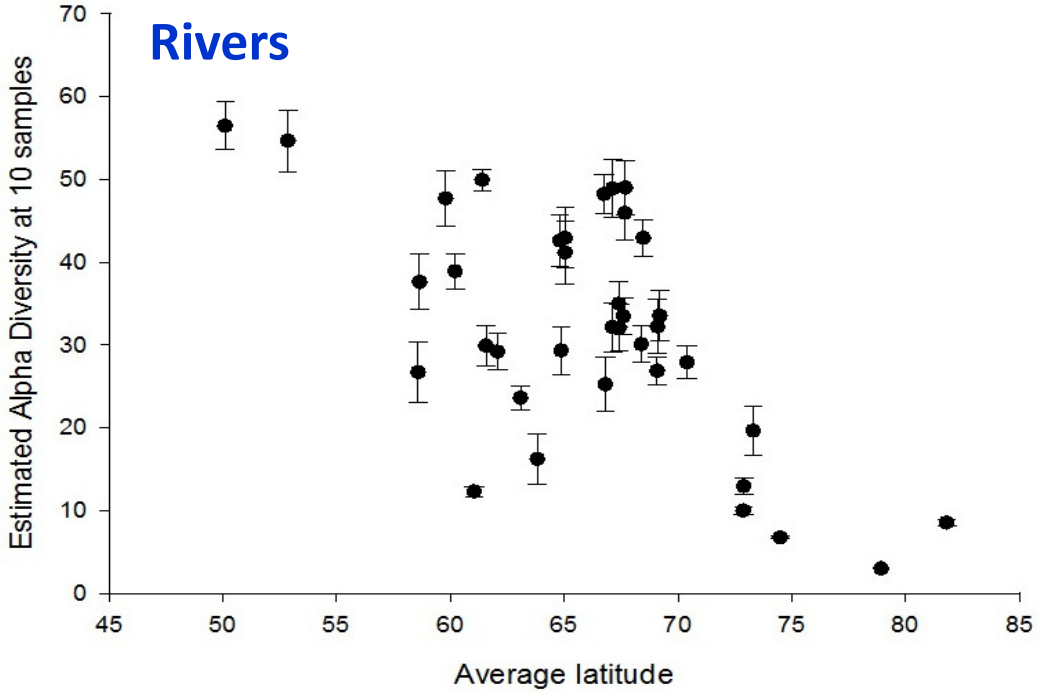
Estimated alpha diversity (number of BMI families) in 10 stations within each sampled ecoregion



Composition of the 8 most abundant BMI groups in: 1-Alaska, 2-W Canada, 3-S Hudson Bay, 4-N Labrador, 5-Baffin Island, 6-Ellesmere Island, 7-Greenland H Arctic, 8-Greenland L Arctic, 9-Iceland, 10-Svalbard, 11-Fennoscandia

Diversity Declines with Increasing Latitude

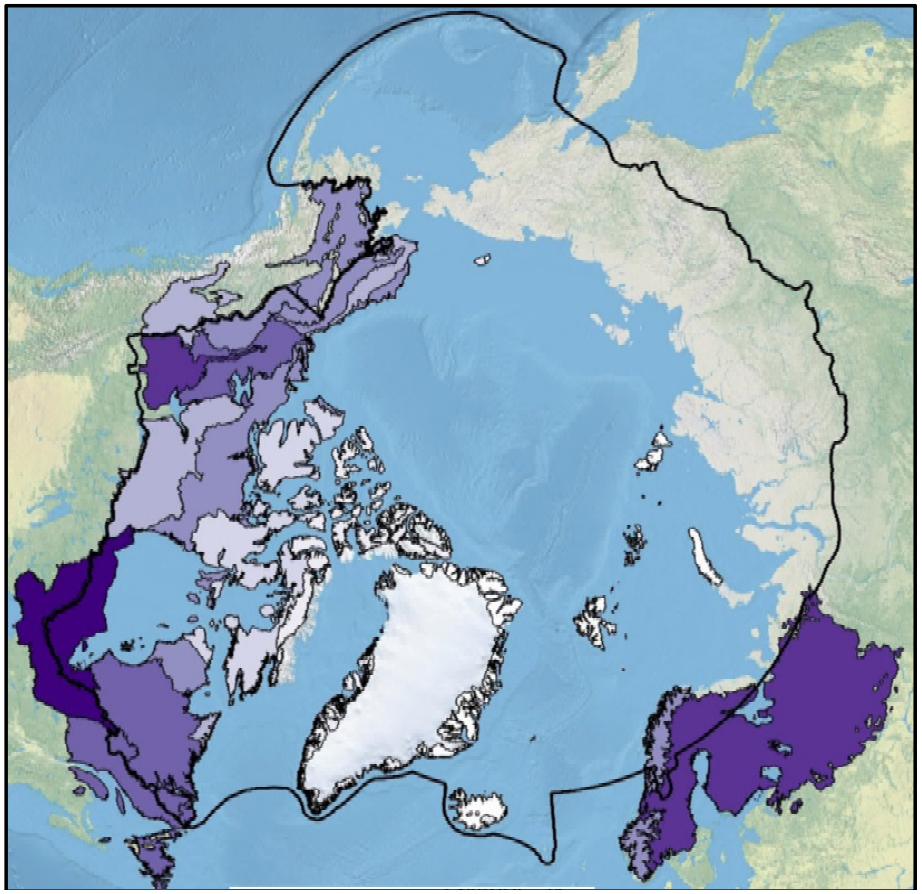


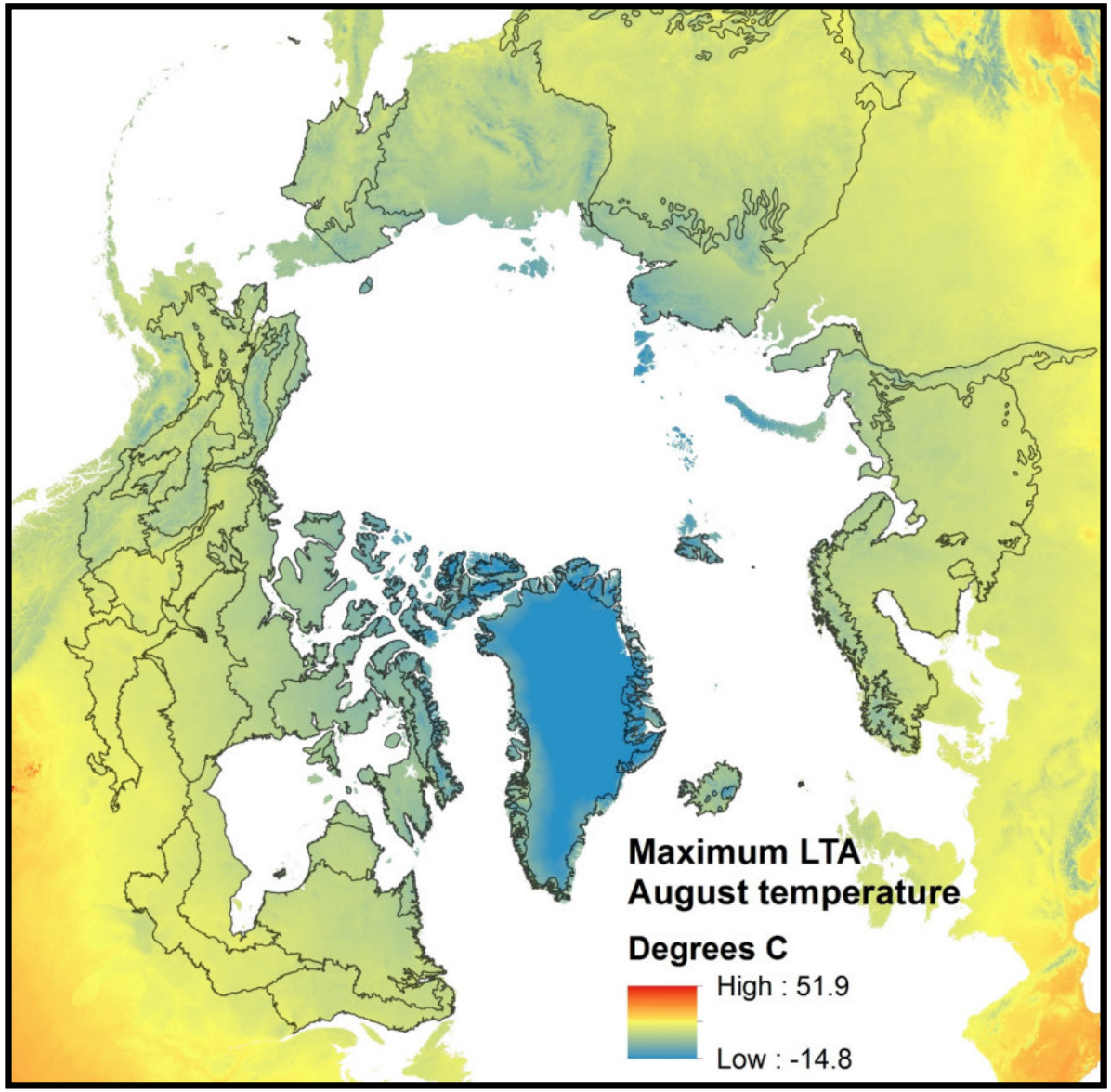


- Sharp decline in diversity above ~68°N for both lakes and rivers
- Variability around ~65°N in lakes due to lower diversity in Iceland
- Variability around ~65°N in rivers due to east-west gradients in North America

Temperature as a Driver

- BMI patterns closely resemble long-term temperature patterns

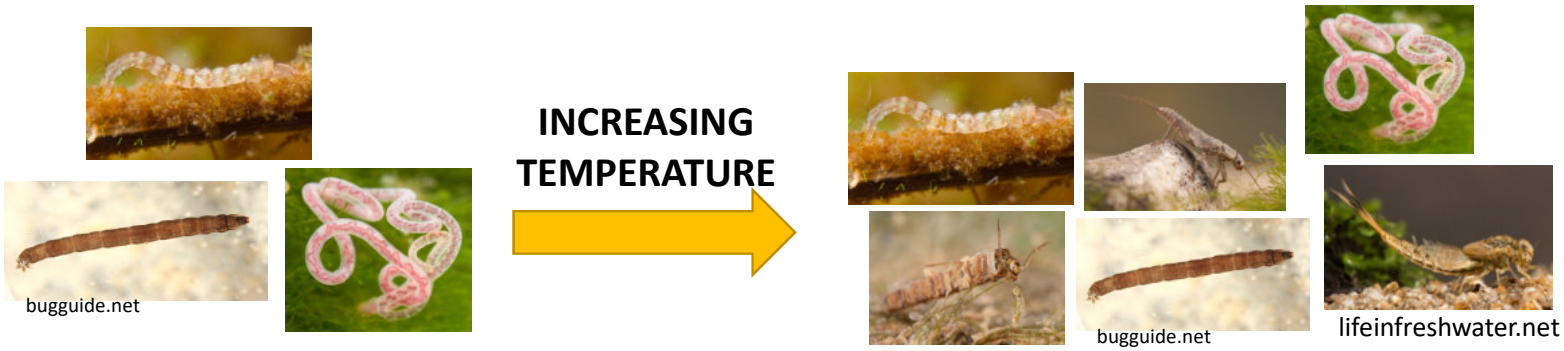




Summary

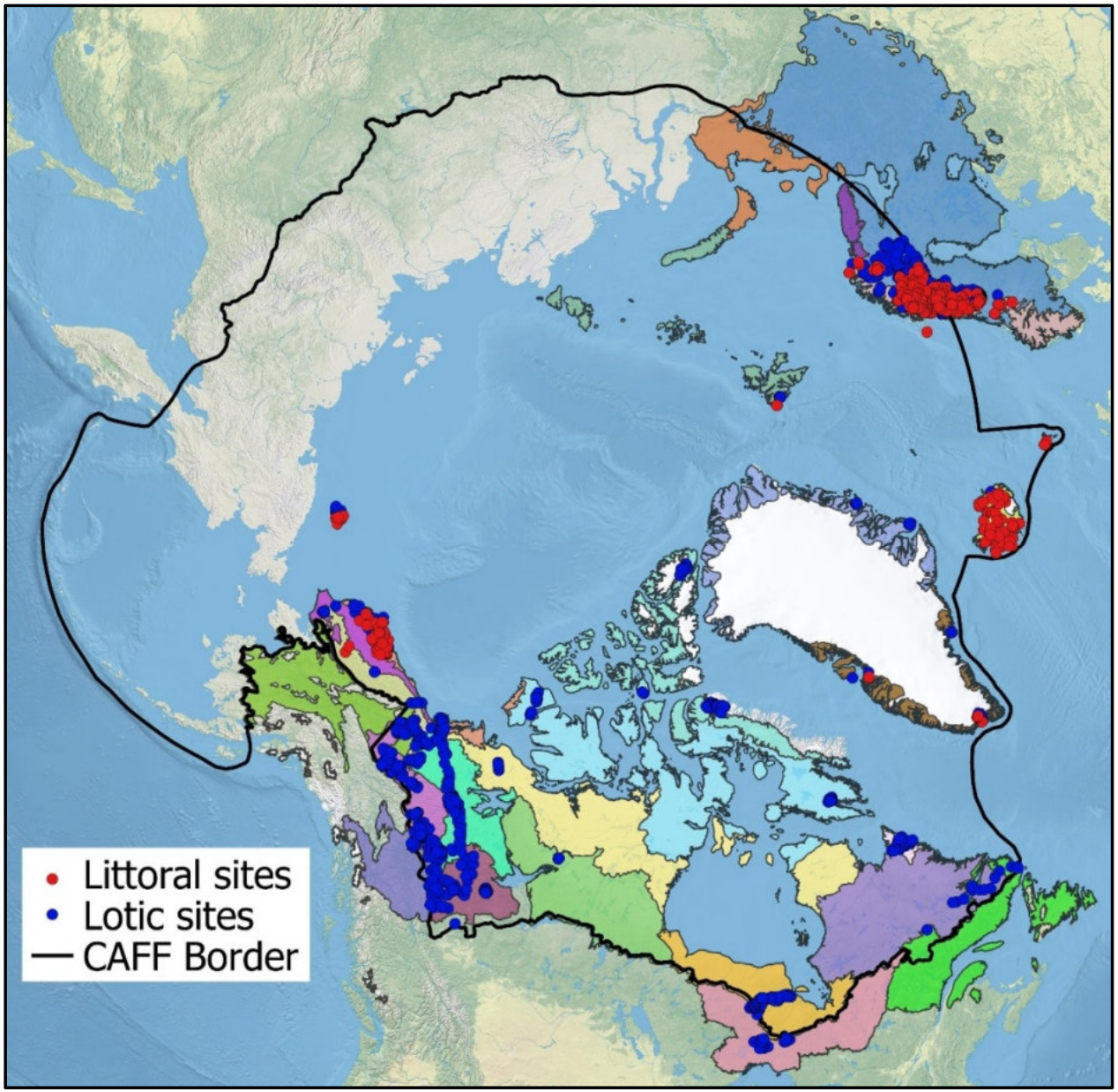
- Taxa richness of BMI decreases with increasing latitude
- BMI communities generally had lower alpha diversity in mountainous, colder and drier ecoregions and on remote islands
- Diversity of BMI appears to be strongly related to temperature patterns

Implication: Warming may lead to drastic shifts in composition



Monitoring Needs

- Identified areas of high and low diversity
- Need for standardization of sampling methods
  - Lake habitats
  - Sampling equipment
  - Collect similar supporting data (chemistry, habitat)
- Spatial gaps need to be filled
- Repeat sampling needed for temporal trends



Please visit caff.is/freshwater for more information!

Contributors:

- Jukka Aroviita
- Maria Baturina
- Daniel Bogan
- John Brittain
- Krista Chin
- Catherine Docherty
- Arni Einarsson
- Nikolai Friberg
- Jani Heino
- Thora Katrin Hrafnosdottir
- Dean Jacobsen
- Danny Chun Pong Lau
- Brianna Levenstein
- Olga Loskutove
- Alexander Milner
- Heikki Mykrä
- Anna Novichkova
- Jón S. Ólafsson
- Ann Kristin Schartau
- Rebecca Shaftel

Acknowledgements:
Data sources and funding providers, including:
Parks Canada Western Arctic Field Unit
MOE Cooperative Freshwater Ecology Unit

CIRCUMPOLAR BIODIVERSITY MONITORING PROGRAM

CAFF
Conservation of Arctic Flora and Fauna

ARCTIC COUNCIL

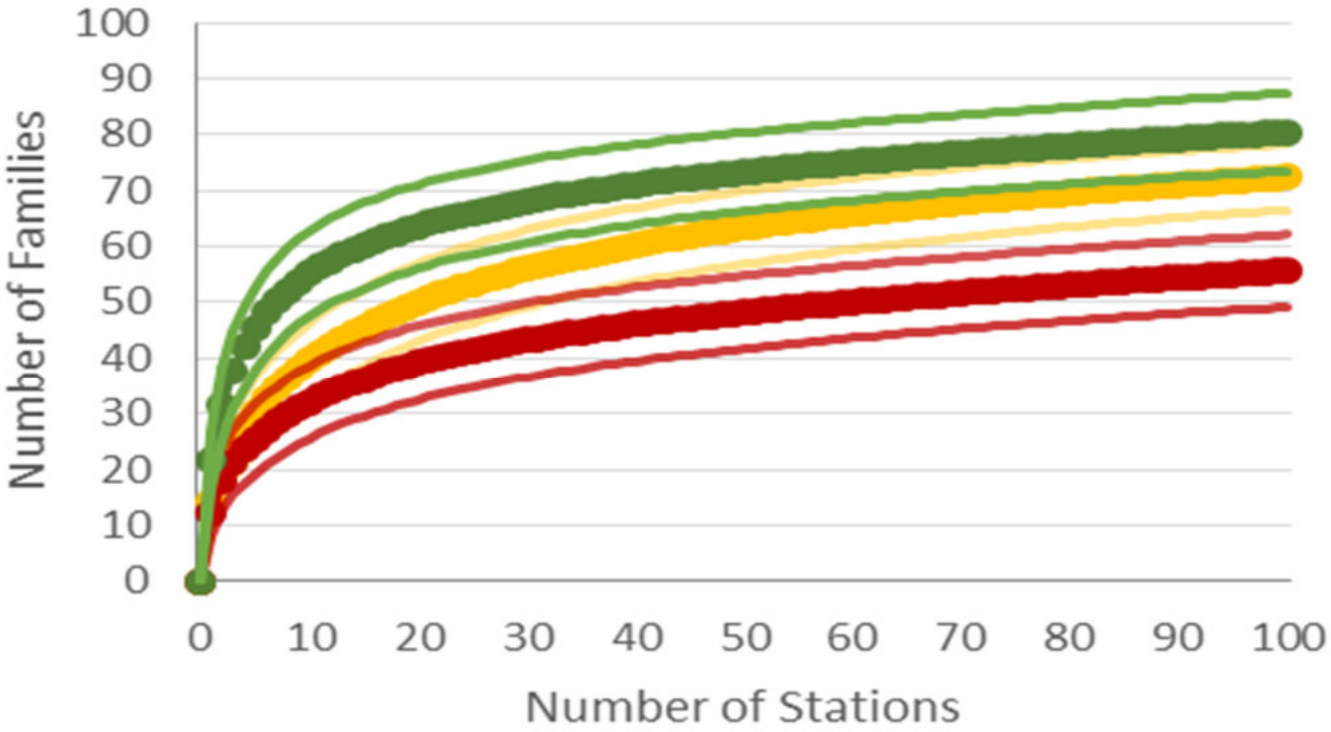
UNB
EST. 1785
UNIVERSITY OF NEW BRUNSWICK

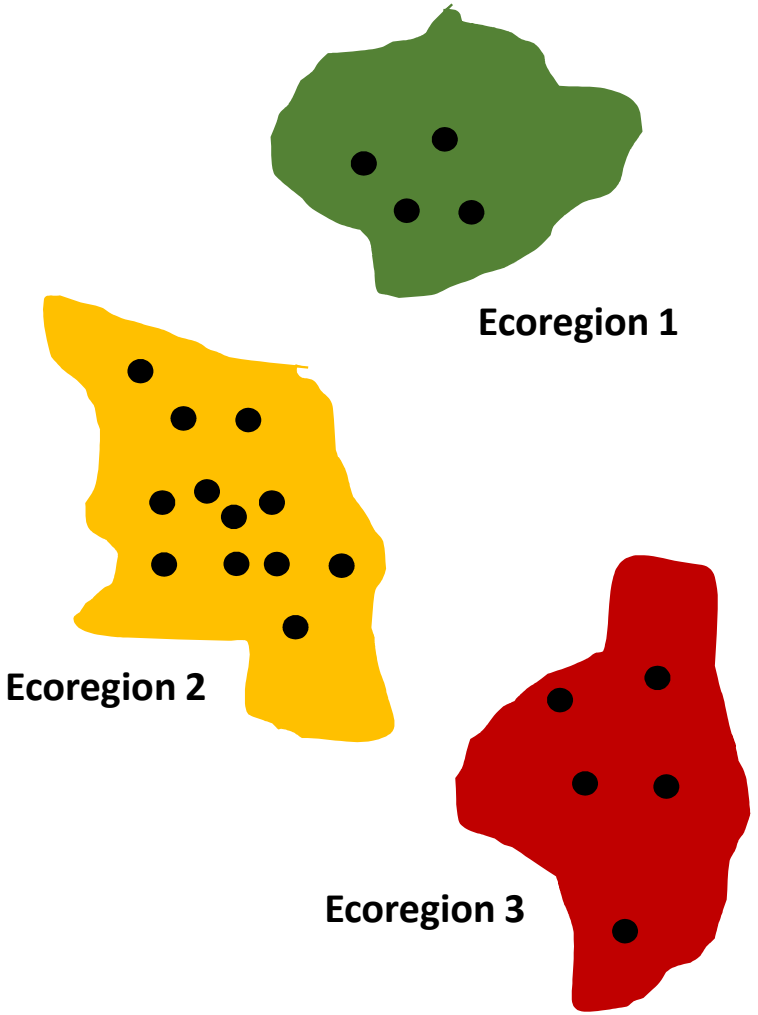
Canadian Rivers Institute

Environment and Climate Change Canada
Environnement et Changement climatique Canada

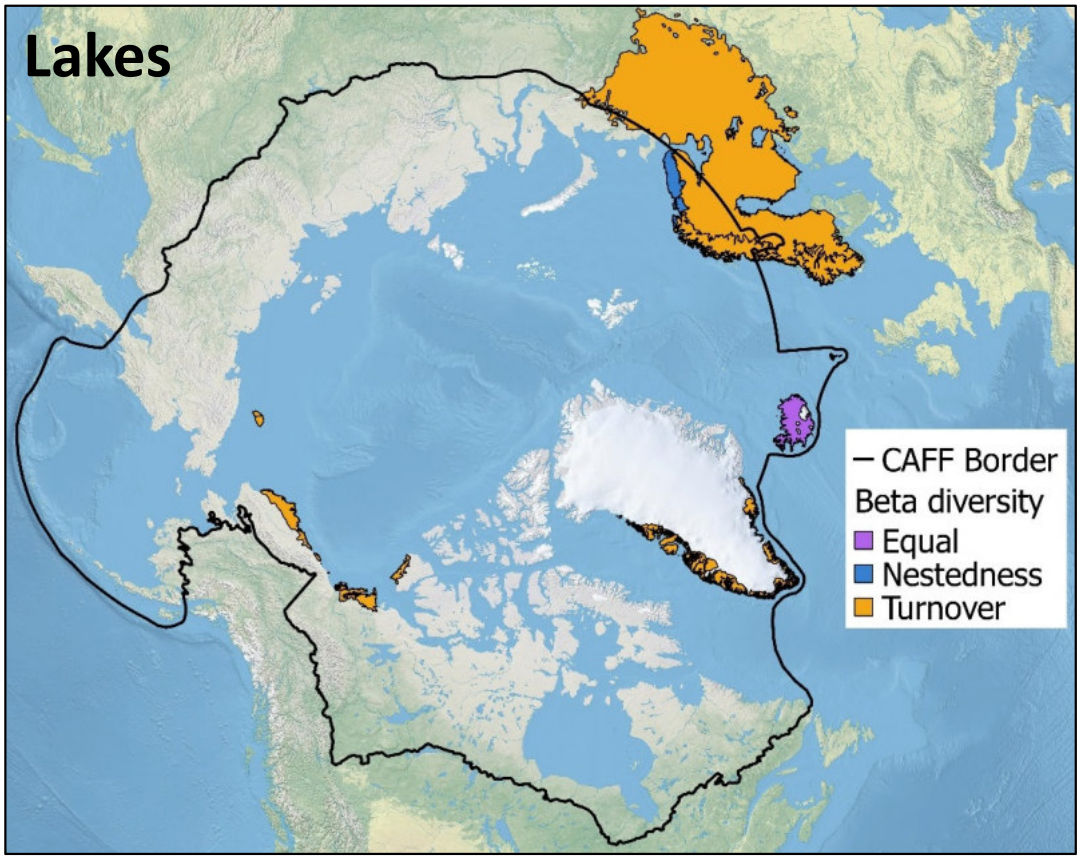
Alpha diversity

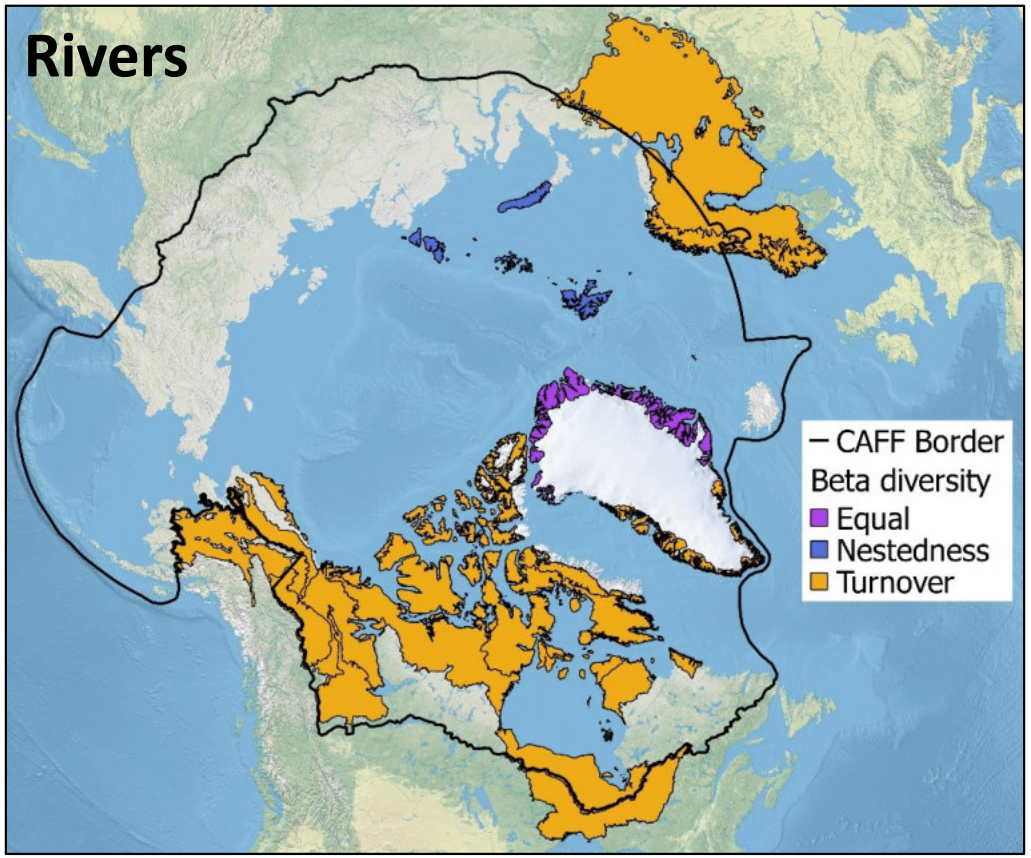
- Number of taxa (e.g., BMI families); taxon richness
- Species accumulation curves used to estimate taxa diversity for ecoregions at a set number of stations (control for unequal sampling effort)





Beta Diversity Components

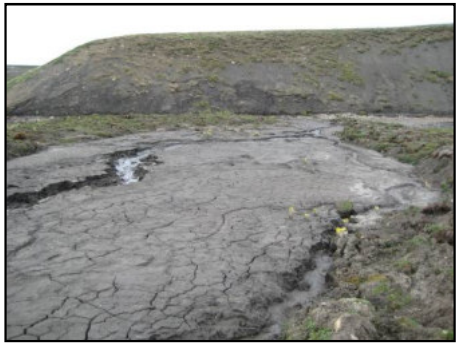


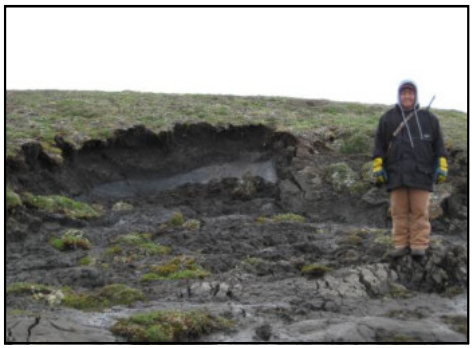


- Dominance of turnover indicates different taxa found in different stations in each hydrobasin – widespread sampling required to capture diversity

Hypothesized Shifts With Climate Change

Ecosystem Components:	Present	⟶	Future
• Physical disturbance (ice / floods)	ice breakup	⟷	variable
• Nutrients (TN, TP)	very low	⟷	higher
• Terrestrial input (e.g. leaves)	very low	⟷	higher
• Aquatic insects:			
Taxa richness	low	⟷	higher
Growth rate	low	⟷	higher
Body size	small	⟷	larger
Feeding traits	omnivory	⟷	specialists

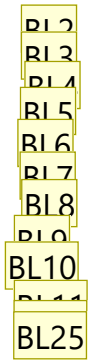


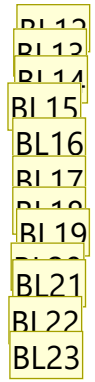


Ecoregions

- 27 ecoregions explored in this study (24 ecoregions for rivers; 11 ecoregions for lakes) from Olson et al. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. BioScience **51**:933-938.

- Boreal forests/Taiga
  - Northern latitudes with precipitation ranging from 40 – 100 cm per year
  - Favors conifers, but deciduous trees still prevalent
  - Low alpha and beta diversity (compared to world-wide ecoregions)
    - Southern Hudson Bay taiga – High precip (40-75), warmer, lowlands
    - Northwest Territories taiga – low precip (20-40), cooler, lowlands and plateaus
    - Northern Canadian Shield taiga – colder,, lower precip (20-40), bedrock outcrops, hilly
    - Northern Cordillera forests – warmer, higher precip (35-60), mountains and plateaus
    - Muskwa-Slave Lake forests – higher precip (25-50), warmer, plains and lowlands, some mountains
    - Interior Alaska-Yukon lowland taiga – higher precip (25-55), colder, rolling hills and lowlands
    - Eastern Canadian Shield taiga – warmer, higher precip (30-40 up to 100), rolling morainal plans with some higher areas
    - Eastern Canadian forests – warmer, high precip (80-100), rocky landscape with rolling and undulating slopes
    - Central Canadian Shield forests - warmer, high precip (55-90), bedrock outrops and wetlands with some higher peaks
    - Iceland boreal birch forests and alpine tundra – mild, higher precip (40-100), volcanic landscape with high winds
    - Scandinavian and Russian taiga
    - Scandinavian Montane Birch forest and grasslands - mountainous
- Tundra
  - Treeless polar desert with long, dry winters and very cold temperatures
  - Vegetation consists of sedges, heaths and dwarf shrubs
    - Torngat Mountain tundra – colder, higher precip (40-70), mountainous
    - Ogilvie-Mackenzie alpine tundra – cooler, higher precip (30-60), mountainous and steep
    - Middle Arctic tundra – very cold, dry (10-20), lowland plains and plateaus
    - Low Arctic tundra – colder, low precip (20-50), rolling uplands and lowlands
    - Kalaallit Nunaat low arctic tundra – colder, mountainous with fjords
    - Kalaallit Nunaat high arctic tundra – very cold, very dry (2.5-20), ice sheet
    - Interior Yukon-Alaska alpine tundra – cooler, high precip (30-60), mountain ranges separated by lowlands
    - High Arctic tundra – very cold, dry (10-20), mountains and plains
    - Brooks-British Range tundra – cold, low precip (35), mountainous
    - Arctic foothills tundra – cool, dry (14), rounded hills and plateaus
    - Arctic Coastal tundra – colder, low precip (10-30), lowlands with many thaw lakes
    - Kola Peninsula tundra – cold and windy, higher precip, rolling hills with bedrock outcrops, history of contamination





BL2 Mean annual temps range from -5 C to -2 C (~-17 C for winter; ~11 C for summer). Mean annual precip ranges from 40 to 75 cm. Short cool summer, cold winter. Lowlands with extensive wetland complexes.
Brianna Levenstein; 15.5.2018

BL3 Short cool summer, long cold winter. Mean temps range from -10 C in North to -1 C in south (mean summer ~11 C). Low precip ranging from 20 - 40 cm. Low subarctic and high subarctic ecoclimates. Lowlands and plateaus with major rivers. Seasonal flooding and fire important disturbances.
Brianna Levenstein; 15.5.2018

BL4 Short cool summer very cold winter. Mean annual temp range from -8 C to -5 C (~9.5 C in summer and -22.5 C in winter). Mean annual precip 20-40 cm). Low to high subarctic ecoclimate. Bedrock outcrops common, permafrost discontinuous to continuous. Max elevation ~490 m. Tree limit at northern reach of ecoregion.
Brianna Levenstein; 15.5.2018

BL5 Alpine, sub-alpine and boreal mid-Cordilleran habitats. Mean annual temp is -2 C (10 C in summer and -15 C in winter). Mean annual precip 35-60 cm but increases at higher elevations. Hyland Highland in southeast YT, Liard Basin, mountains, plateaus. Discontinuous permafrost.
Brianna Levenstein; 15.5.2018

BL6 Subhumid mid- to high boreal ecoclimate. Cool summers, very cold winters. Mean annual temp -2 C to -6.5 C (winter ~-21 C, summer ~12.5 C). Annual precip between 25-50 cm. Plains and lowlands, Horn Plateau, some mountains.
Brianna Levenstein; 15.5.2018

BL7 Spruce and hardwood forests, continental climate, lack of Pleistocene glaciation. Rolling hills and lowlands, flat bottomlands along rivers. Sea level to 600 m in elevation. Short warm summer, long cold winter. Annual precip 25-55 cm. Av min winter temp from -35 to -18 C and av summer max temps from 17 to 22 C. Eastern portion mean annual temp from -10 C to -6.5 C increasing to south. High subarctic ecoclimate. Discontinuous permafrost.
Brianna Levenstein; 15.5.2018

BL8 Mean annual temp from -6 C to 1 C (summer 5.5 to 10, winter -18 to -1). Mean precip 30-40 cm south of Ungava Bay to 100 cm in southeast. Low, mid and high subarctic ecoclimates. Cool summers and very cold winter except coastal barrens with short cool moist summer and long winter. Rolling morainal plain with many small shallow lakes. Isolated permafrost. Higher elevations and plateaus also present.
Brianna Levenstein; 15.5.2018

BL9 More maritime influence than central shield forests. High to mid-boreal and perhumid mid-boreal to Oceanic, Atlantic and maritime mid-boreal. Summer av temp from 8.5-14.5, mean winter temp -8 to 13 C. Precip ranges from 80-100 cm inland to 100-120 on coast. Isolated permafrost. Large rivers. Rocky landscape, rolling and undulating slopes.
Brianna Levenstein; 15.5.2018

BL10 Mean annual temp from -2 C to 1.5 C (summer 12.5-14, winter -17 to -12 C) Mean precip from 55 cm to 90 cm. Moist humid to

high boreal ecoclimate. Bedrock outcrops. Wetlands. Isolated permafrost. Some high mountains.
Brianna Levenstein; 15.5.2018

BL11 Volcanic. Cold and wet weather, blanket bogs common. Bare rock, snow and glaciers. Mild coastal climate. Average temp of 6 C in summer and 0 C in winter. Precip ranges from 40 to 100 cm. High winds. Interior largely arctic desert with mountains glaciers and waterfalls.
Brianna Levenstein; 15.5.2018

BL12 Mountainous. Moist low arctic ecoclimate. Humid, cold. Short cool moist summer (mean 4 C) and long cold winter (mean -16.5C). Mean annual temp of -6.5C. Mean annual precip is 40-70 cm. Permafrost continuous to discontinuous.
Brianna Levenstein; 16.5.2018

BL13 Steep and mountainous. ALpine to sub-alpine northern subarctic Cordilleran. Summers warm/cool with mean 9C. Winters long and cold with mean temps -20C. Annual precip from 30-60 cm. Glaciers common.
Brianna Levenstein; 16.5.2018

BL14 Mid-Arctic ecoclimate. Coldest and driest landscapes in Canada. Summer mean from 0.5 C to 4.5 C. Winter mean from -30C to -20C. Mean annual precip is 10-20 cm. Polar desert with snow on ground for 10 months/yr. Lowland plains and plateaus. Permafrost is continuous.
Brianna Levenstein; 16.5.2018

BL15 Low arctic ecoclimate. Short cool summers (4-6 C). Wintgers long and cold (-28 to -17.5). Mean annual precip 20-50 cm. Rolling uplands and lowlands with bedrock exposures and eskers. Numerous lakes ponds and wetlands. Continuous permafrost.
Brianna Levenstein; 16.5.2018

BL16 Ice-free coastal region with stunted vegetation. Mountainous with many fjords. Mainly rocky. Arctic climate except subarctic in south.
Brianna Levenstein; 16.5.2018

BL17 Ice sheet can extend to coast. Arctic climate. Continuous permafrost. Arctic desert near ice cap. Summer high no more than 5 C. Sparse vegetation. Annual precip from 2.5-20 cm in northernmost Greenland.
Brianna Levenstein; 16.5.2018

BL18 Combination of alpine, sub-alpine and boreal northern Cordileeran climate. Short cool summers (10-10.5 C) and long cold winters (-20 to -23 C). Precip ranges from 30-60 cm. Mountain ranges separated by wide valleys and lowlands. Permafrost common to sporadic.
Brianna Levenstein; 16.5.2018

BL19 High arctic ecoclimate. Very dry and cold. Mean summer temp as low as -1.5, mean winter temp from -32C to -23 C. Mean precip from 10-20 cm. Mountains and plains, plateaus and ri=ocky hills. Permafrost continuous.
Brianna Levenstein; 16.5.2018

Slide 15 (Continued)

BL20 Mountainous. Arctic climate. Mean annual temp -10 C, summer temp 6.5C and winter temp -25 C. Mean annual precip 35 cm. Alpine to subalpine northern subarctic Cordilleran ecoclimate. Permafrost continuous.
Brianna Levenstein; 16.5.2018

BL21 Mountainous to plains. Rounded hills and plateaus. Mean precip 14 cm. Somewhat warmer than surrounding areas. Continuous permafrost.
Brianna Levenstein; 16.5.2018

BL22 Plains with many thaw lakes. Arctic climate conditions with continuous permafrost. Precip ranges from 10-30 cmk. Mean summer temp 4.5 to 1 C. Mean daily min temp in winter is -30 C and max daily temp is 8 C. Region is low and wet.
Brianna Levenstein; 16.5.2018

BL23 Cold and windy, continuous permafrost. History of human activity with contamination from nuclear waste and nickel smelting. Steep and high coastline. Warmer and wetter than other Arctic regions.
Brianna Levenstein; 16.5.2018

BL24 Situated between tundra in north and temperate mixed forests in south. Conifer dominated.
Brianna Levenstein; 16.5.2018

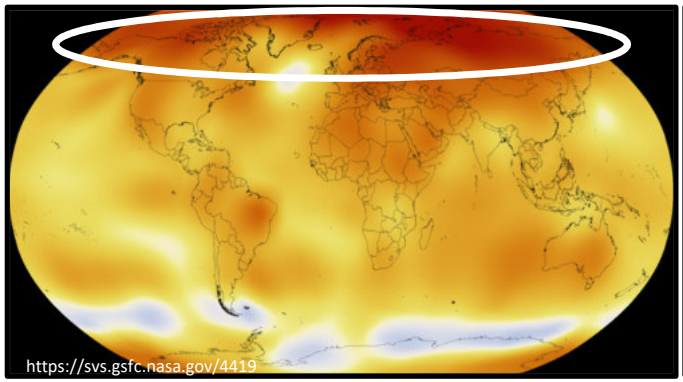
BL25 Large glaciers. high mountains and plateaus. High alpine tundra to low alpine tundra and montane birch zone. Lowland conifer to mixed forests at low elevations.
Brianna Levenstein; 16.5.2018

Introduction

- Freshwater ecosystems can cover >80% of the Arctic landscape and some of the largest deltas, rivers and wetland complexes are located in the Arctic

- The Arctic is warming faster than other parts of the planet and is also facing increasing pressure from development

- Looking at baseline data from the CBMP database allows us to see changes in Arctic freshwater biota as the climate shifts and human development continues in these areas



CAFF 2013