Three lectures ...

- Polar limnology
- Polar paleolimnology
- Environmental change
IBP International Biological Program

- Canada + Europe, and US joined in 1968

- Large-scale ecological and environmental studies
- Allowed for comparative studies of ecosystems across 5 biomes, productivity
- Lakes: control of production, food web structure
Lakes are diverse ... ... and there are more!

Modified from Pienitz et al. 2008
Lake Hazen

\[ Z_{\text{max}} \quad 289 \text{ m} \]

Length \quad 70 \text{ km}

Width_{\text{max}} \quad 11\text{km}
Lakes and ponds are a dominant feature of Arctic landscapes

Important for migratory birds, mammals...
→
Northern peoples (hunting and fishing)
...and Antarctic ...ice free regions and englacial regions
Thick ice still allows for dim light to penetrate algal mats: benthic life in Dry Valleys, Antarctica's weird algal mats. No diatoms in the plankton.

Spaulding et al., 2000
Don Juan Pond, Dry Valleys, Antarctica.

So saline, it never freezes!
Sub-glacial lakes
Lakes and ponds are a dominant feature of Arctic landscapes

Vary according to:

- Size
- Depth
- Chemistry
  - pH
  - conductivity
  - nutrients
- Ice cover
- Biology
  - fish
  - fishless
- Geology, climate, ...
- vegetation
Ice thickness varies

Implications for what kinds of organisms are present:
planktonic (open water) vs benthic (bottom &/or attached to substrate)
Overriding effect of ice on microhabitat availability

Smol 1988
- Thermal stratification strengthened
- Increased nutrients
- Increased sedimentation
- Increased methane production (?)
pH, Cond, DOC, Total P across Canadian Arctic Archipelago

Michelutti et al, 2007
Thermister data from Camp Pond

Growing seasons (ice free season in lakes) is longer

(M. Douglas, unpublished data)
The colors indicate the change in the number of days in the growing season from the present to 2070-2090 under the Hadley 3 climate scenario. An average of three climate model’s results suggests about a 20-30 day increase in the growing season for areas north of 60° latitude. The growing season is defined as the number of consecutive days in which the minimum temperature is above 0°C.
Evidence is bi-polar!

- Air temperature increased 1°C over 40 years
- Water temperature increased 0.9°C over 15 years
- Mean ice-free days increases 31 days over 15 years
- Productivity increased 4 fold in 15 years

Quayle et al. 2002. *Science*
Cold environment:
Snow and ice
Pronounced seasonality

Connected continent
⇒ climate, colonization, and biodiversity

Lakes and ponds:
terrestrial vegetation and
sources of allochthonous C
Aquatic mosses
Higher plants
Benthic microbial mats
Diatoms - algae

- Algal class
- Taxa have distinct environmental optima and tolerances
- Useful in assessing ecosystem health and paleoenvironmental conditions

10 µ
Factors affecting diatom distributions in polar regions:

<table>
<thead>
<tr>
<th>Environmental Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical</td>
</tr>
<tr>
<td>pH</td>
</tr>
<tr>
<td>salinity</td>
</tr>
<tr>
<td>conductivity</td>
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<tr>
<td>DOC</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Physical</td>
</tr>
<tr>
<td>Ice Cover</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Microhabitat</td>
</tr>
<tr>
<td>Rock, moss, sediment</td>
</tr>
<tr>
<td>Lotic (streams, rivers)</td>
</tr>
<tr>
<td>Temperature</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Thermal Stability</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Lake Level/Hydrology</td>
</tr>
</tbody>
</table>
Responses to climate scenarios

<table>
<thead>
<tr>
<th>Environmental Variable</th>
<th>Colder</th>
<th>Warmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing season</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Ice cover</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Thermal stratification</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Water levels</td>
<td>↑ or ↓</td>
<td>↑ or ↓</td>
</tr>
<tr>
<td>Plankton</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Mosses</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Diversity</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Nutrients</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Production</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>pH</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Conductivity</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>DOC</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>River Discharge</td>
<td>↑ or ↓</td>
<td>↑ or ↓</td>
</tr>
</tbody>
</table>
Community diversity model:

**Cooler:** few taxa, simple

**Shorter growing season**

**Warmer:** diverse, intricate

**Longer growing season**
Nutrient additions...
Meretta Lake, Resolute Bay (★), Cornwallis Island, NU.
IBP study site
The Meretta Lake "sewage stream" is now a regular High Arctic Stream, as is also Meretta Lake = a typical High Arctic lake.

(Douglas and Smol)
Nuisance freshwater algae (diatom)
e.g., *Didymosphenia geminata*
(aka “Didymo”)

- **Occurrence:** usually oligotrophic streams and rivers throughout western NA, although spreading to east. Non-toxic

- **Threat:** harms aquatic ecosystems through microhabitat alteration in form of massive benthic mats.

- **Impacts:** reduced biodiversity
  - nuisance blooms
  - fish spawning, food web

- **Concerns:** spreading rapidly

- **Scope of project:** survey and monitoring of sites in Canadian Arctic (and elsewhere); ➔ economic impact
Global Significance of Polar Lakes

• Polar amplification ➔ Experiencing rapid climate (and environmental change) change ➔ Sentinels of climate change (next lecture)

• Carbon cycle complex and some additional lakes will become sources of greenhouse gases

• Important refugia for biological communities
Thank you!
Impacts of (invasive) algae on aquatic ecosystems

• Livestock health (eg toxic blue-green algae)
• Fisheries (eg affects spawning habitats)
• Populations dependent upon harvests (esp. First Nations and Inuit)
• Increased pesticide usage
• Altered food webs
• Ecosystem services affected
Lakes and ponds are a dominant feature of Arctic landscapes. They vary according to:
- Size
- Depth
- Chemistry (pH, conductivity, nutrients)
- Ice cover
- Biology (fish, fishless)

Important for migratory birds.
Ice thickness varies

Implications for what kinds of organisms are present:
planktonic (open water) vs benthic (bottom &/or attached to substrate)
Research Gaps

• Invasibility
• Water quality – climate change interactions
• Land-use changes

Management Concerns

• Need to include climate change in management plans and goals.
• What are new conditions?
• Species expansions?
• Ecosystem services
Invasion pathways and barriers

Hellman et al 2008
Diatoms: two different assemblages