Extreme northern aquatic ecosystems as sentinels of global environmental change

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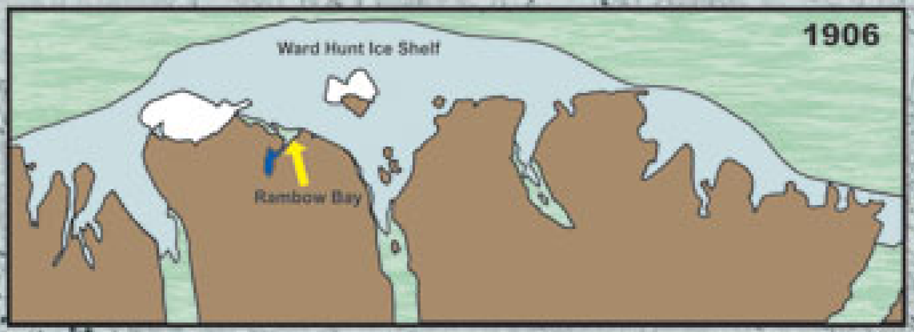
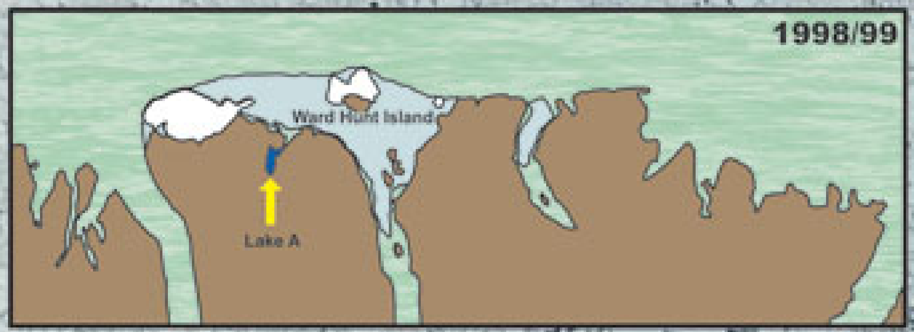
Introduction

Polar regions have been shown to be especially sensitive to global climate warming. Although many high arctic ecosystems have undergone dramatic change in the past 150 years, no records exist to give long-term climatological context to these recent changes. Due to the sensitivity of arctic environments to global change, aquatic ecosystems at extreme latitudes are particularly well suited as sentinels of past and future environmental change. We are studying fiords and meromictic lakes located along the northern coast of Ellesmere Island (82-83°N, 71-84°W) to understand their responses to recent climate change, and to reconstruct long-term environmental change in the High Arctic.

Northern Ellesmere Island Ice Shelves



In the early 20th century, an ice shelf fringed much of the northern coast of Ellesmere Island. However, since that time, over 90% of the Ellesmere Ice Shelf (EIS) has disappeared due to climate warming. Little is known of the EIS prior to 1906, although the Ward Hunt Ice Shelf is thought to have been fully formed by about 3000 years BP. Very little is known of the dynamics of these ice shelves since that time.

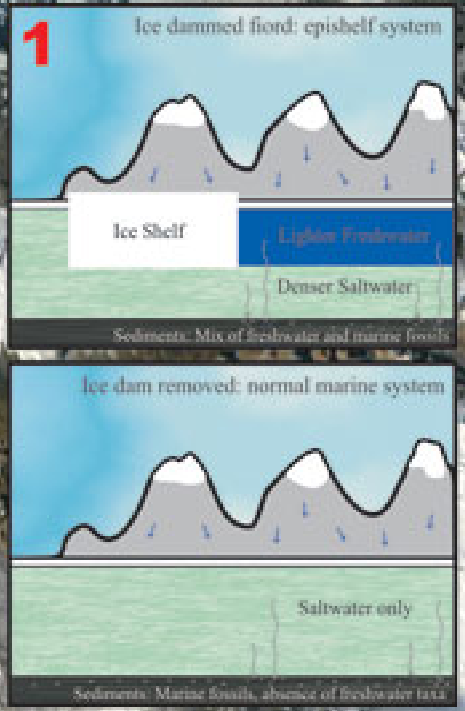


These northern ice shelves are also unique cryo-ecosystems that contain complex microbial communities. Despite the harsh environmental conditions, these communities are highly productive and diverse. They are dominated by cyanobacteria, but also contain green algae, diatoms, flagellates, bacteria, and viruses.

Fiords and epishelf lakes as paleoclimate indicators

Epishelf lakes are bodies of freshwater that sit over colder, denser salt water, and are typically confined behind ice shelves. While they are remarkable ecosystems that support a unique mixture of freshwater and marine species, the biota of epishelf lakes are poorly understood. Because the existence and properties of epishelf lakes depend on ice shelves, their sedimentary records have the potential to yield insights into past ice shelf dynamics.

Rambow Bay (83° 03'N, 75° 15'W) was the western end member of the Disraeli Fiord epishelf system. Diatom assemblages in sediment cores from Rambow Bay have preserved the onset of community change that reflects the recent transition from epishelf to marine conditions (see Figure 4). We will reconstruct the paleorecord of the Disraeli Fiord epishelf lake system through further analyses of Rambow Bay cores, with diatoms and fossil pigments. In addition, we anticipate coring several other fiords along Ellesmere Island's northern coast in an effort to understand the dynamics of the Ellesmere Ice Shelf during the Quaternary.

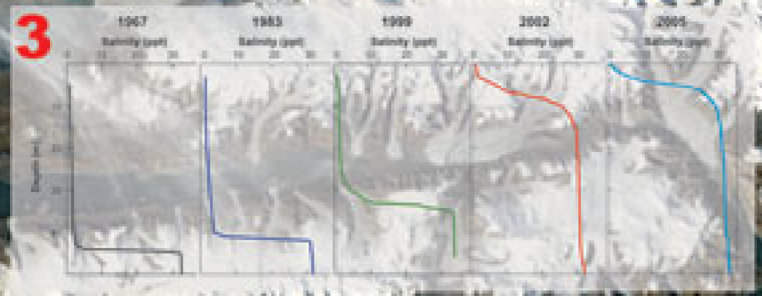


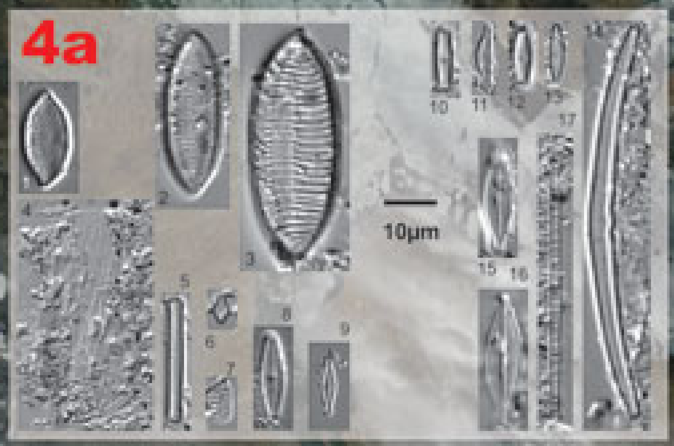
1: Sedimentation in fiords can change from marine to freshwater due to the presence/absence of ice shelves. As such, the sedimentary record of fiords can be used to reconstruct ice shelf dynamics.

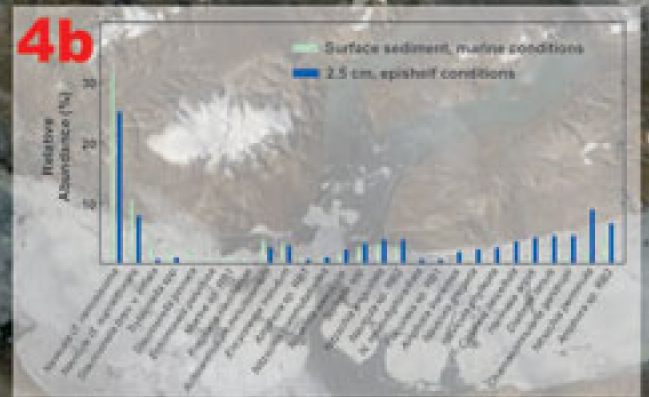
2: RADARSAT images showing the Ward Hunt Ice Shelf before (A) and after (B) fragmentation that allowed Disraeli Fiord's freshwater to drain.

3: Changing water column profiles in Disraeli Fiord track the disappearance of an epishelf lake due to the disintegration of the Ward Hunt Ice Shelf.

4: Typical diatom taxa (a) and changes in species abundances (b) under epishelf and marine conditions in Rambow Bay.







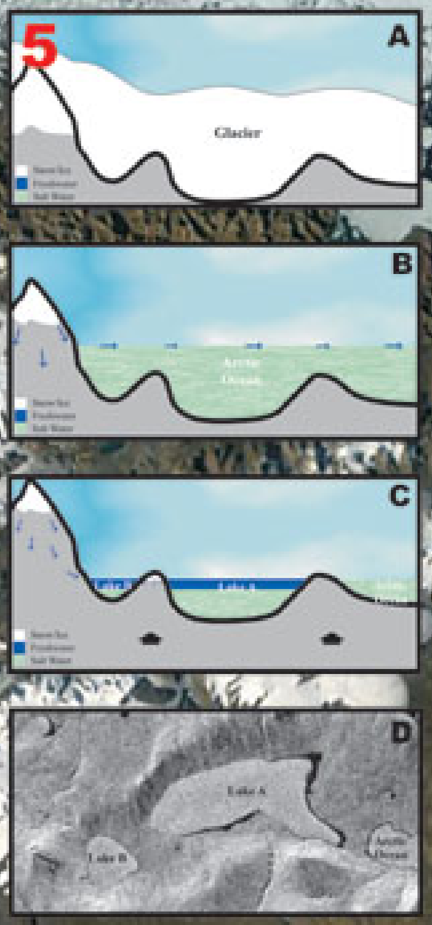
Left: Diatoms more common in surface sediments, under marine conditions. 1-3: *Tryblionella* spp.; 8: *Navicula* cf. *ramosissima*; 5: *Navicula* cf. *supralittoralis*; 6: *Staurosirella brevistriata* var. *inflata*; 7: *Staurosirella pinnata*; 8: *Fragilariopsis cylindrus*; 9: *Entomoneis paludosa*.

Right: Diatoms more common at 2.5 cm interval, during epishelf conditions. 10: *Chamaepinnularia gandrupii*; 11: *Amphora* sp. RB2; 12: *Caloneis lancetulla*; 13: *Nitzschia perminuta*; 14: *Hannaea arcus*; 15: *Navicula gregaria*; 16: *Navicula phyllepta*; 17: *Diatoma tenuis*.

Meromictic lakes: high resolution records of change

Meromictic lakes are permanently stratified due to density differences in their water column, and their bottom waters are anoxic. In the High Arctic, such lakes are typically fiords that have been disconnected from the sea due to isostatic rebound. Meromictic Lake A (83° 02'N, 75° 30'W) is perennially ice covered, chemically stratified, and has saline water below 10m.

Because of their anoxic bottoms, meromictic lakes such as Lake A preserve high quality, annually resolvable records of environmental change in their sediments. External, fluvial inputs are a source of a significant proportion of the diatoms in Lake A's sediments, and *Hannaea arcus*, a species characteristic of streams, is the most common taxon in the sedimentary record. Because of the links between precipitation and streamflow in the High Arctic, this may permit high-resolution reconstructions of regional paleohydrology from Lake A sediment cores. Preliminary analyses (see Figure 8) show changes in species abundances, diversity, and diatom: chrysophyte ratios in recent sediments that are indicative of reduced ice cover and greater precipitation. In addition, preliminary analysis has shown that well-preserved fossil pigments are abundant in Lake A sediment, and will allow for the reconstruction of algal dynamics through the lake's history.



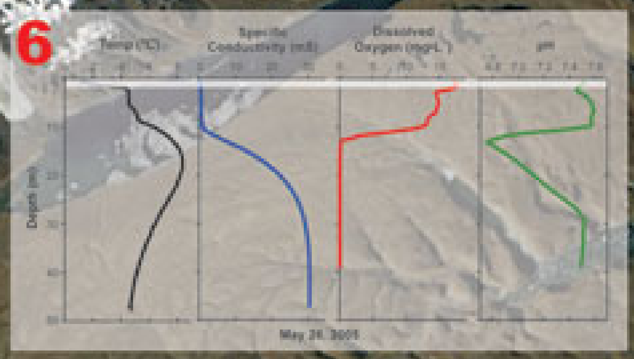
5: Stages in the evolution of typical high arctic, coastal meromictic lakes: Lakes A and B (not to scale).
A. Fiord carved by glacier. B. Fiord in deglaciated terrain.
C. Isostatic rebound separates fiord from ocean, less dense freshwater inputs do not mix with dense, trapped saline waters. D. RADARSAT image of meromictic lakes A and B.

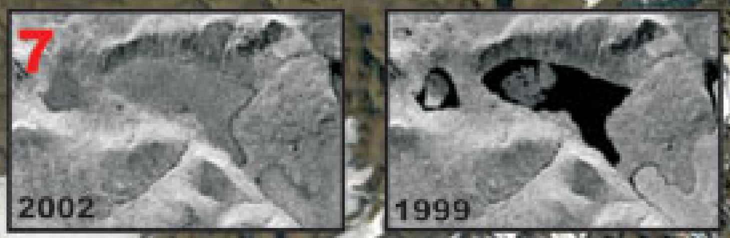
6: Limnological profiles of Lake A, showing chemical stratification of water column, May 26, 2005. Shaded top 1.5m represents perennial ice cover.

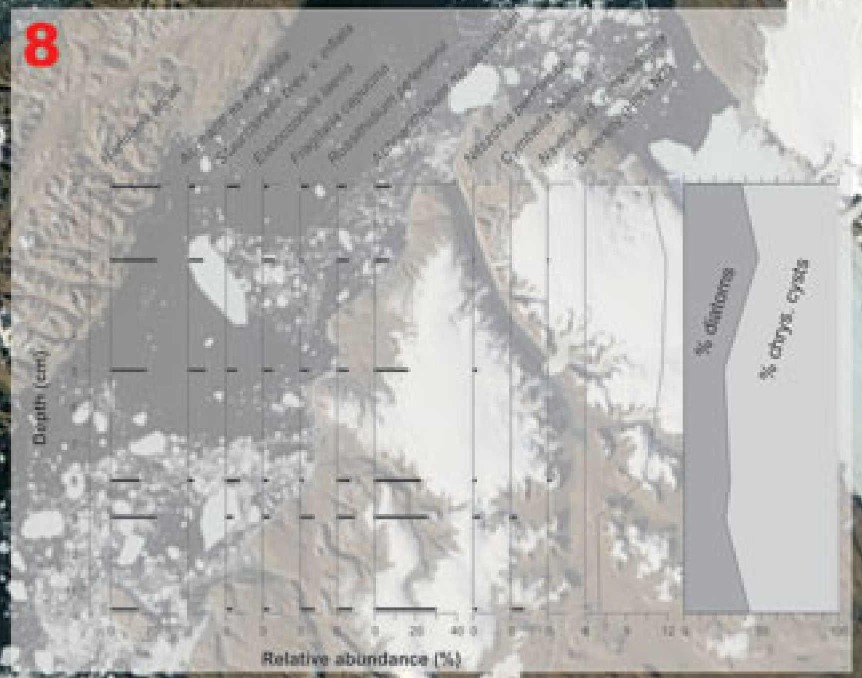
7: Lake A's ice cover responds to variations in climate. Left: no thaw, summer 2002. Right: ice-free, summer 1999.

8: Preliminary results of diatom analysis from the Lake A sedimentary record (Selected taxa shown).

Lake A







Conclusions

- Several rare ecosystem types characterize the northern coast of Ellesmere Island, including ice shelves, epishelf lakes, and meromictic lakes
- This region is also highly susceptible to ongoing changes in the global environment, which threaten the existence of many of these ecosystems and their biota
- Fiords and meromictic lakes have the potential to provide proxy records of long-term climate change in the region that are crucial to understanding both regional climate change and the future viability of these rare ecosystems
- Due to the sensitivity of these extreme northern ecosystems and the amplification of climate change in polar regions, these systems may be viewed as sentinels of global environmental change

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Satellite images courtesy of RADARSAT Inc. and NASA.