Arctic Freshwater Systems: Hydrology and Ecology Highlights and Preliminary Results

Fred Wrona and Peter di Cenzo

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Arctic Freshwater Systems: Hydrology and Ecology

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Arctic Freshwater Systems: Hydrology and Ecology

Through integrated, multidisciplinary hydrological, climatological, and ecological field studies and laboratory analyses this research project will:

- **improve our process-level understanding of freshwater and nutrients flow to the Arctic Ocean**
- **develop improved predictive models for freshwater and nutrient flux**
- **develop a unique legacy database of freshwater biodiversity and related environmental information on Arctic freshwater ecosystems**
- **develop and provide tools and capacity in northern communities for improved community-based monitoring and assessment of the status and trends of the health and integrity of Arctic freshwater ecosystems**

Thematic Components – Arctic Freshwater Systems

Theme 1: Freshwater Flux and Prediction

Theme 2: Nutrient Flux and Prediction

Theme 3: Aquatic Ecosystem Hydro-ecology and Ecological Integrity

Theme 4: Community-based Capacity Building and Outreach

Theme 1: Freshwater Flux and Prediction
(Theme Leaders: Pomeroy and Pietroniro)

- Quantification of key hydrological/cold regions processes/parameters affecting freshwater flux to the Arctic Ocean.
- Validation and improved coupling of hydrological/land surface models to predict freshwater flow/flux to the Arctic Ocean.
- Improved assessment of the hydro-climatology of the Canadian Arctic (including trends and teleconnections).





Theme 2: Nutrient Flux and Prediction

(Theme Leaders: Lesack and Marsh)

- Develop an improved hydraulic model of river-flow and water levels in the Mackenzie Delta considering break-up and ice-jam flooding.
- Assessment of the role of lakes in storing water, and in affecting nutrient dynamics.
- Quantify and predict nutrient fluxes into the Delta and seasonal dynamics of nutrient fluxes to the Beaufort Shelf.

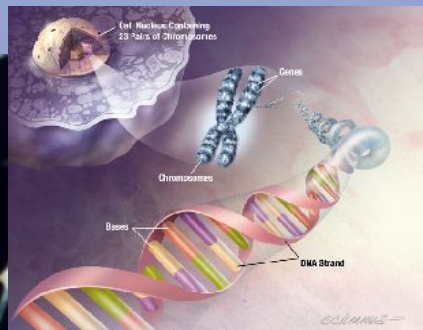
Theme 3: Aquatic Ecosystem Hydro-ecology and Ecological Integrity

(Theme Leaders: Wrona and Culp)

- Synoptic assessment of freshwater biodiversity and ecological integrity in relation to latitudinal gradients, and development of a unique legacy database of freshwater biodiversity (including geo-referenced and genetically bar-coded specimens) and related environmental information on Arctic freshwater ecosystems.
- Hydro-ecological sensitivities/responses of *lentic* ecosystems to climate variability and landscape perturbations.
- Hydro-ecological sensitivities/responses of *lotic* ecosystems to climate variability and landscape perturbations.







Theme 4: Community-based Capacity Building and Outreach

(Theme Leaders: Kent and Spence)

- Community-based aquatic biomonitoring programs – training and implementation.
- Acquisition and incorporation of TK into aquatic ecosystem monitoring programs.
- Community outreach.





Ties with other IPY Projects

Arctic Freshwater Systems: Hydrology and Ecology ties in with other Environment Canada IPY projects: (a) the Zadra TAWEPI IPY (to make use of its high resolution (15 km) gridded meteorological data over the Arctic); and (b) the Walker State and Fate of the Cryosphere IPY (to take advantage of improved knowledge of cryospheric processes for hydrological and ecological modelling purposes).

In terms of linkages to other Canadian IPY projects, this project links in with the Reist et al. (DFO) Arctic Char project to assess ecological biodiversity and integrity of Arctic freshwater ecosystems and food webs.

In terms of other International IPY projects, the proposal links to Arctic-HYDRA (Iceland), the Circumpolar Biodiversity Network (CBMP), Northern Lakes (Denmark), and the Biological Diversity Network (Norway).

Arctic Freshwater Systems: Relevance to IPY Priority Themes

1. To determine the present environmental status of the polar regions by quantifying their spatial and temporal variability.
2. To quantify, and understand, past and present environmental and human change in the polar regions in order to improve predictions.
3. To advance our understanding of polar - global interactions by studying teleconnections on all scales.
4. To investigate the unknowns at the frontiers of science in the polar regions.
5. To use the unique vantage point of the polar regions to develop and enhance observatories studying the Earth's inner core, the Earth's magnetic field, geospace, the Sun and beyond.
6. To investigate the cultural, historical, and social processes that shape the resilience and sustainability of circumpolar human societies, and to identify their unique contributions to global cultural diversity and citizenship.

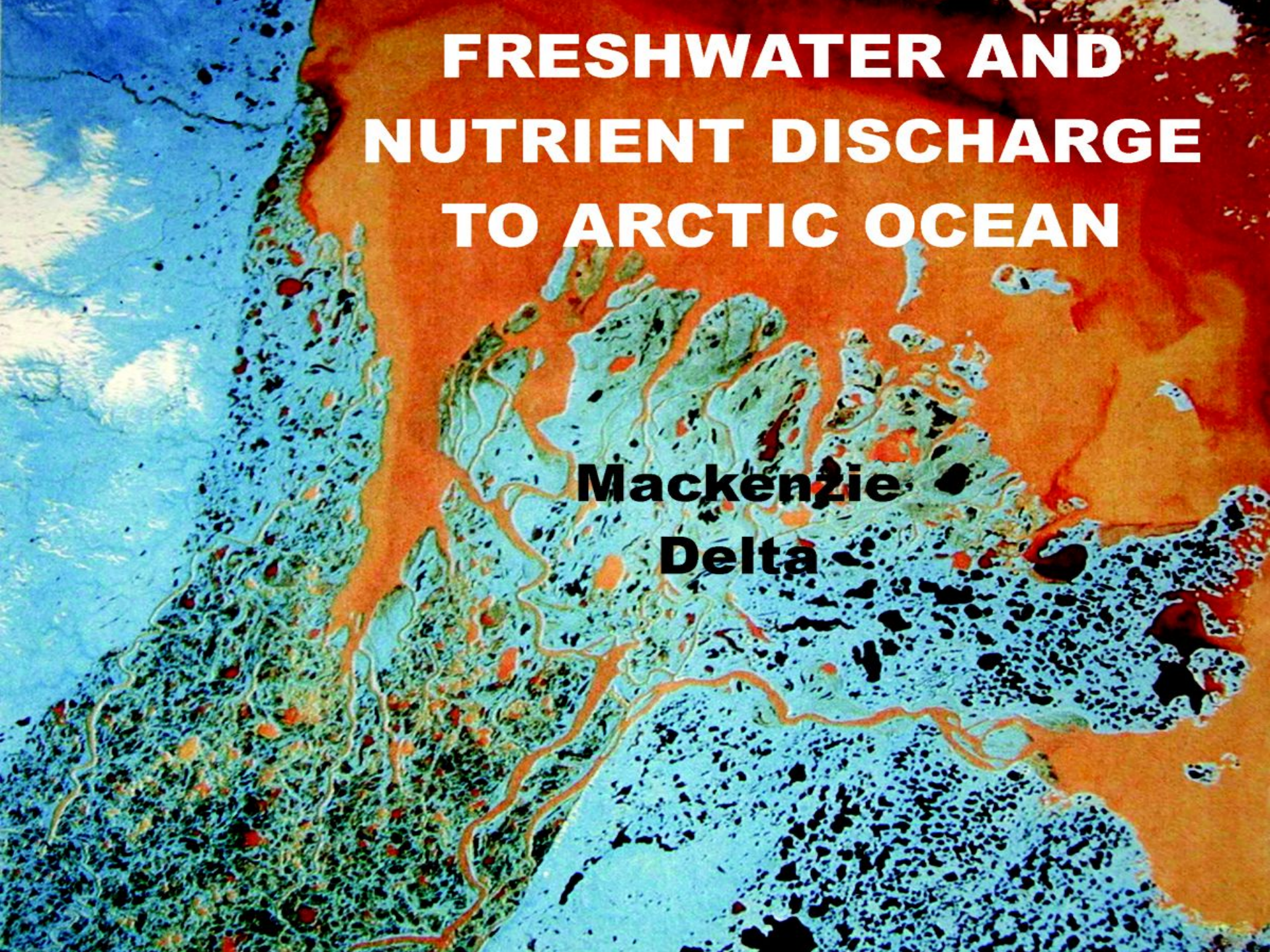
ADDRESSES CANADIAN IPY PRIORITIES:

- Science for climate change impacts and adaptation
- Health and well-being of northern communities

Highlights and Preliminary Results

Over the past couple of days, we have heard in detail the great progress made on many fronts that contribute to our Theme 1.

What follows are highlights and preliminary results of some activities (not all inclusive) under our Themes 2 - 4.


FRESHWATER AND
NUTRIENT DISCHARGE
TO ARCTIC OCEAN
Mackenzie
Delta


The Mackenzie Delta

1. Implementing, refining, and testing an enhanced 1-D hydraulic model of river flow

2. Field investigations of real-time ice jams

3. Identification of river ice cover and breakup patterns via satellite image analyses

4. Linking the hydraulic model to a model of storm surging effects from the Beaufort coast

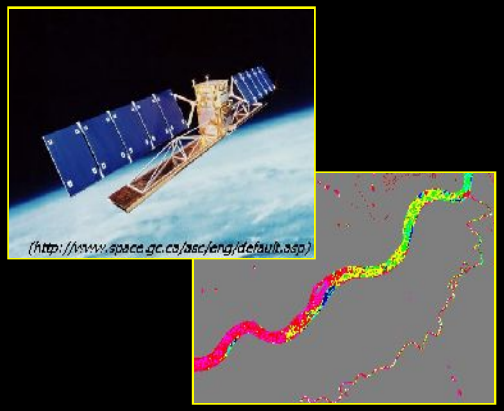
5. Estimation of off-channel water storage

12. Improved nutrient characterization of the Mackenzie River water

Intensive Field Investigations

Meteorological data

Ice characteristics



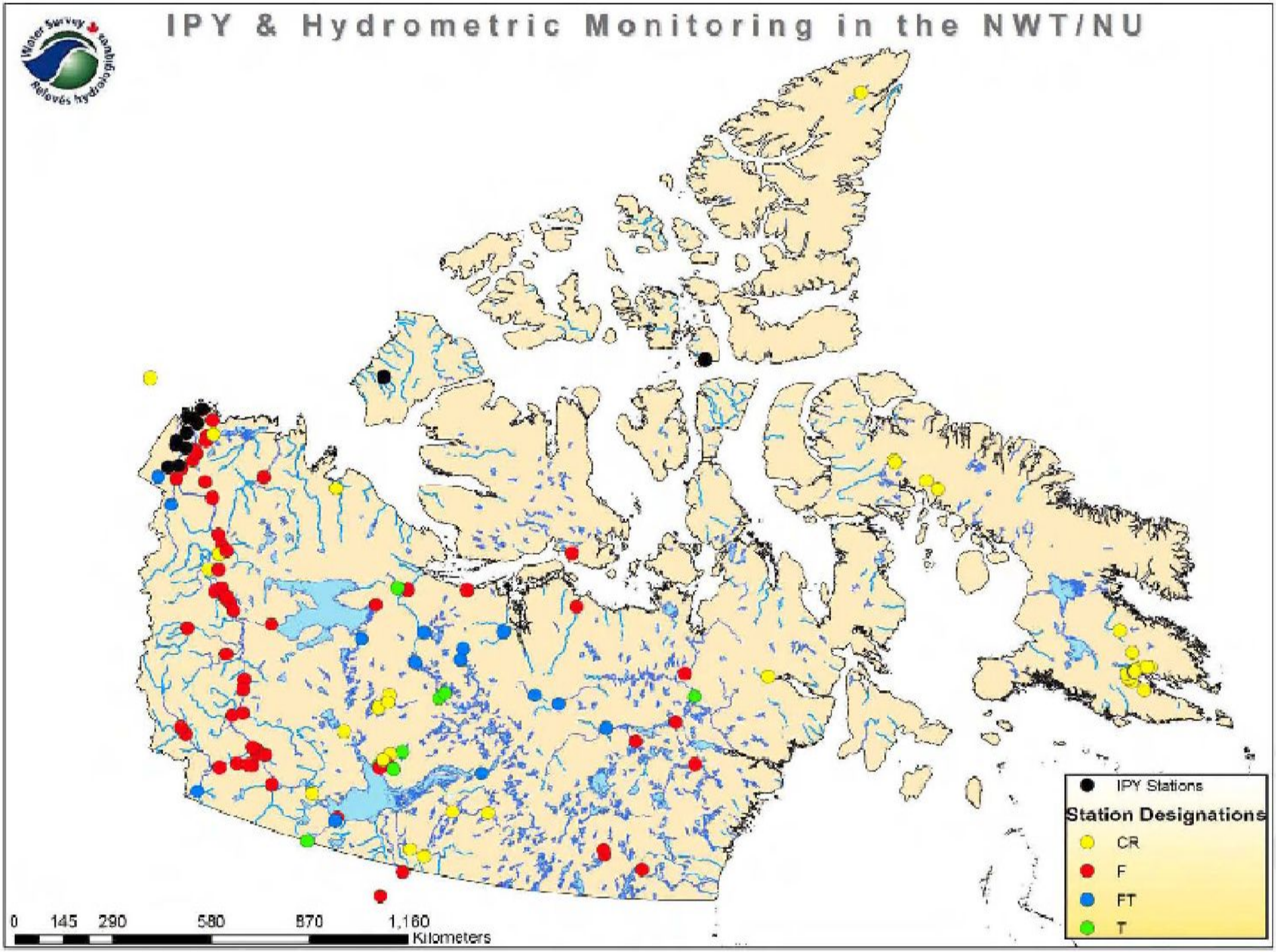
Remote Sensing

Breakup monitoring

Discharge measurements

GPS surveys

IPY & Hydrometric Monitoring in the NWT/NU



Over the past 30+ years, summer low-water levels in the lower Mackenzie Delta may have increased by an amount (0.3 m) equivalent to three times local sea level rise (0.1 m) over the same period. Such amplification of recent sea level rise has been unexpected and may be a result of enhanced storm surges in response to receding arctic sea ice or coastal backwater effects on the river flow.

Also, investigations suggest a recent decline in river-ice breakup effects in the delta that historically have been an important control on annual peak water levels, resulting in lower water levels in the lakes located at higher elevations further away from the Beaufort Sea.

If these two changes in the system (*via* two differing global change mechanisms) are real, fish habitat in the delta will change, overall biodiversity of the system may decline, and relative subsidence of the land-surface associated with future oil and gas extraction in the region could be substantially higher than expected.

MUTATING MAZE / *A warming climate has turned the massive Mackenzie delta into a bewildering puzzle that imperils the future of wildlife and aboriginal hunters*

DELTA FACTS

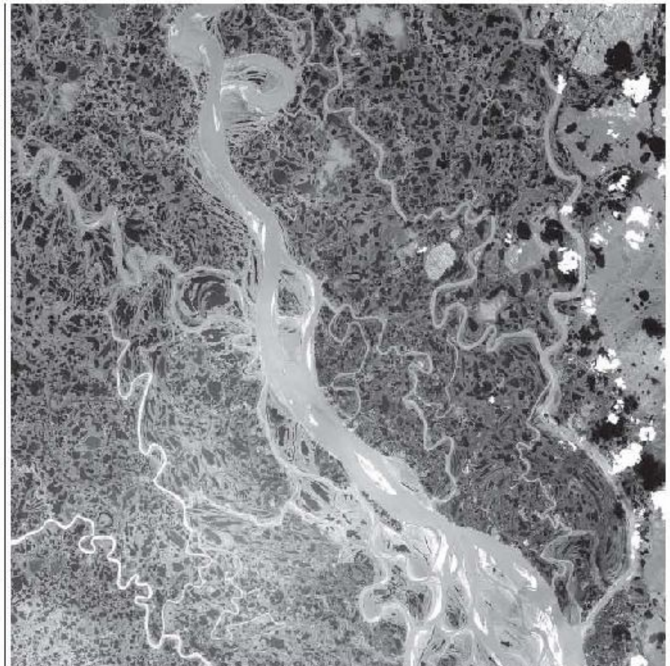
Drying times for a delta

THE NEW CLIMATE | INTERNATIONAL POLAR YEAR

River delta's rise puts Arctic's future in flux

Climate change in Arctic seas is driving summer water levels at the Mackenzie's mouth to three times normal, B.C. researchers find

MARK HUME



SEA CHANGE

Water levels rising in Mackenzie Delta lakes, scientist warns

Last Updated: Friday, April 4, 2008 | 9:50 AM CT
CBC News

Climate change and a warming Arctic Ocean are having a dramatic effect on the vast network of lakes in the Northwest Territories' Mackenzie Delta, according to a geographer who has discovered rising water levels over the last few decades.

Recent data shows water levels have risen in 60 per cent of the Delta's 45,000 freshwater lakes over the past 30 years, with some low lying lakes going up by nearly 30 centimetres.

The results are about three times more severe than predicted, said Lance Lesack, a

Aquatic Biodiversity Assessments

- **Yukon Synoptic Survey**
- **Mackenzie Upland Lakes Study**
- **Eastern Arctic Synoptic Survey**
- **Parks Canada Study**



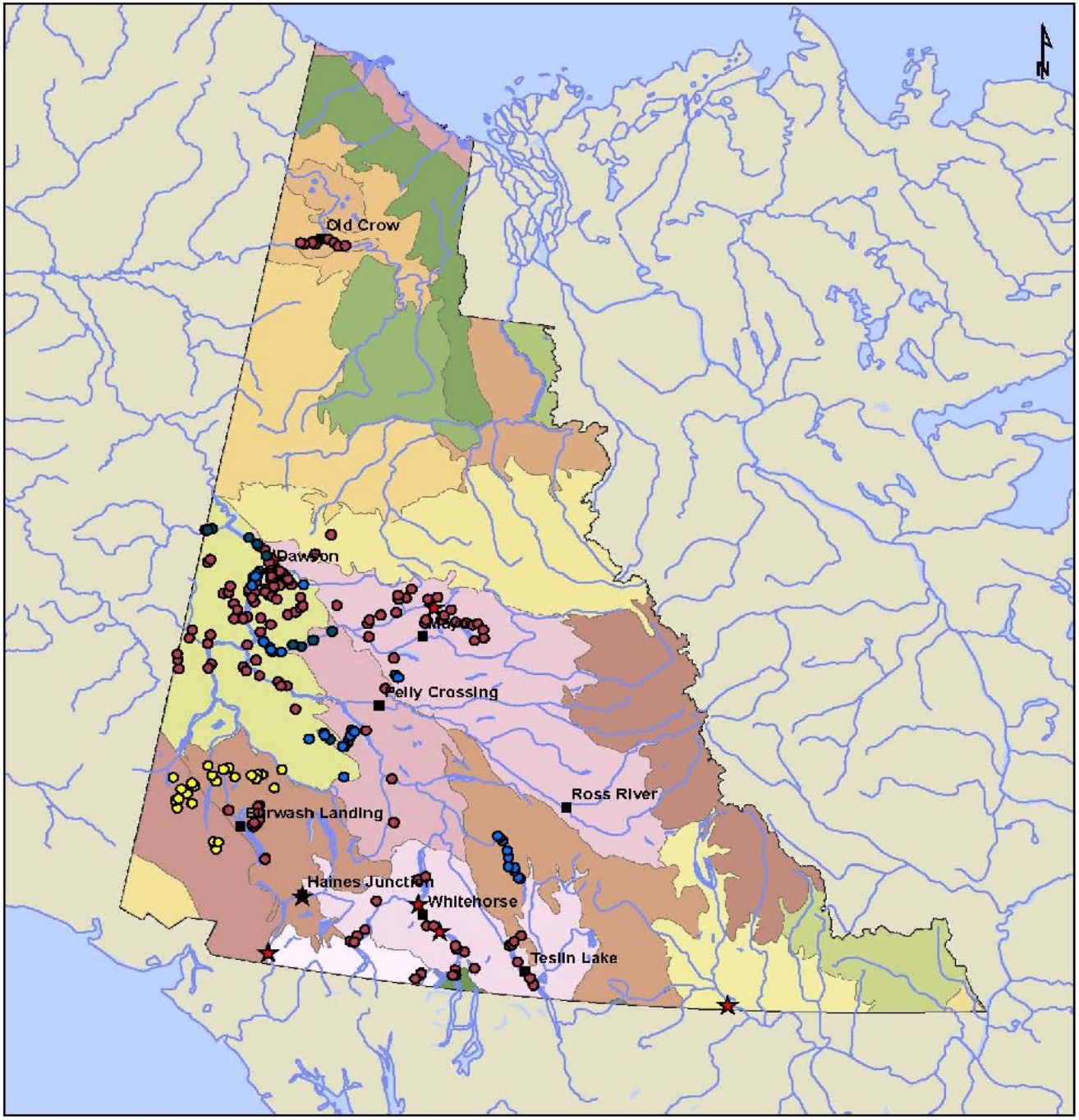









Yukon Synoptic Survey



Biomonitoring Stations in Yukon Territory

- Cities/Towns
- EC Water Quality Stations
- Yukon border

Biomonitoring Site Locations

- DFO & YTG '07
- EC '07
- YTG '07
- Pre 2007

Yukon Ecoregions

Ecoregion Name

- Boreal Mountains and Plateaus
- British-Richardson Mountains
- Eagle Plains
- Fort MacPherson Plain
- Hyland Highland
- Klondike Plateau
- Liard Basin
- Mackenzie Mountains
- Mount Logan
- Muskwa Plateau
- North Ogilvie Mountains
- Northern Alberta Uplands
- Old Crow Basin
- Old Crow Flats
- Pelly River Plateau
- Pelly Mountains
- Ruby Ranges
- Selwyn Mountains
- St Elias Mountains
- Yukon Coastal Plain
- Yukon Plateau-Central
- Yukon Plateau-North
- Yukon Southern Lakes
- Yukon-Stikine Highlands

100 50 0 100 200 km

Scale 1:6,400,000

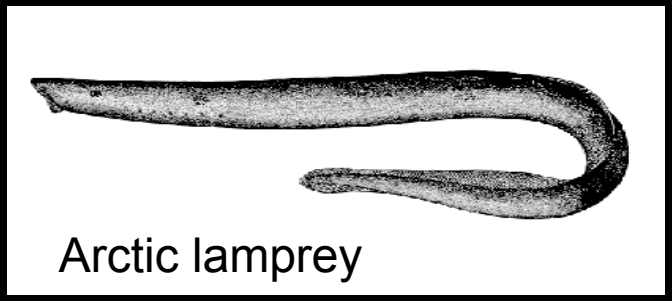
Produced by:

Pacific & Yukon Water Quality Monitoring Office
Environment Canada

Data provided by UWO and Environment Canada

Date Created: 24 October 2007

Fish species observed 2004-2007



Benthic Macroinvertebrates observed 2004-2007

- 9 Classes
  - Insecta, Clitella, Arachnida, Gastropoda, Pelecypoda, Malacostroma, Nematoda, Crustacea, Entognatha
- 21 Orders
- 65 Families
- 130 Genera

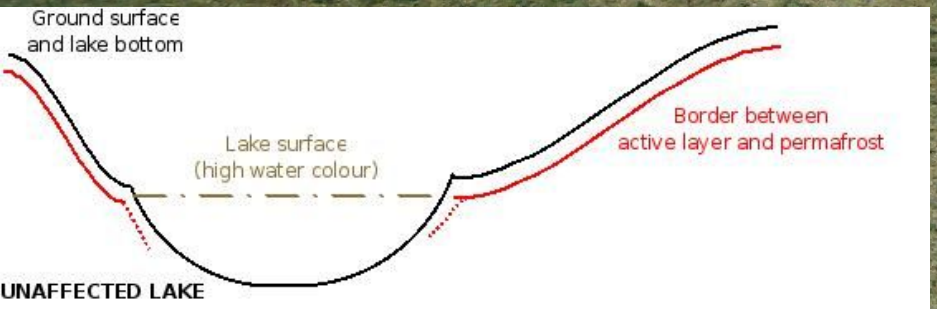

Mackenzie Upland Lakes

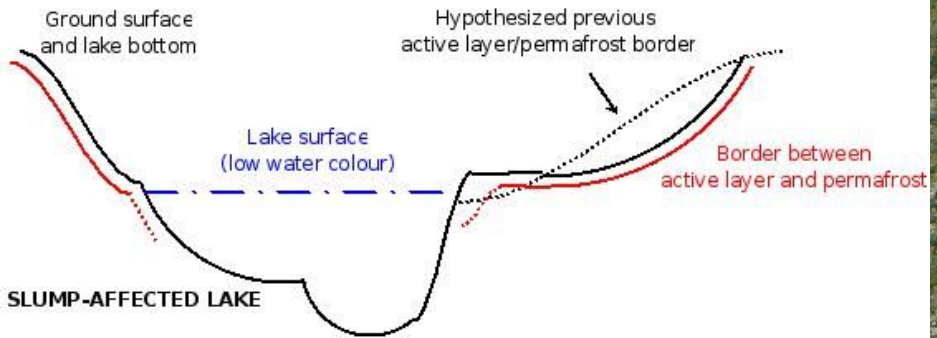
Mackenzie Upland Lakes

Sampling Program – Each Lake

Sample	Significance
water quality	nutrient availability, water chemistry, physical aspects of water column
water column chlorophyll *a* content	phytoplankton, macrophyte biomass estimate
phytoplankton dissolved oxygen uptake (incubated bottle experiment)	phytoplankton, bacterioplankton production (carbon uptake)
Phytoplankton/zooplankton net haul	Phytoplankton/zooplankton assemblages
periphyton chlorophyll *a* content (sediment core)	periphyton biomass estimate
zooplankton net haul	zooplankton assemblage
sediment core	invertebrate biomass/diversity Sediment chemistry

Mackenzie Upland Lakes - “counter-intuitive” clearing of lake water





Hypothesis 1:

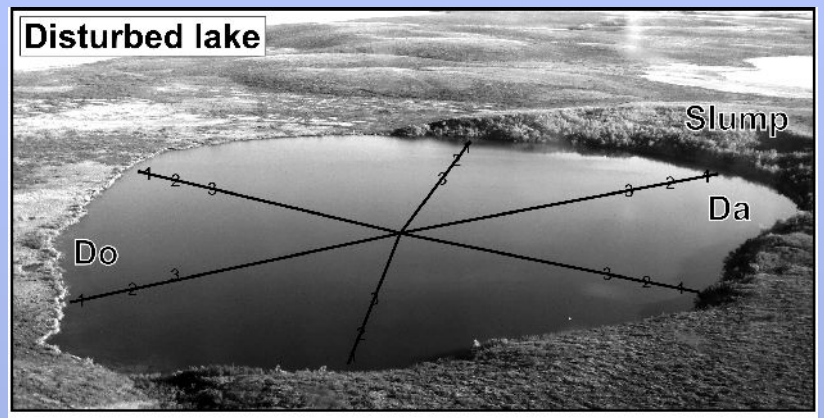
Increased water column turbidity/colour/nutrient geochemistry and related productivity/food web relationships are determined by geophysical watershed characteristics (e.g. Drainage Ratio - drainage area/lake area, Watershed Slope, and Water Residency Time).

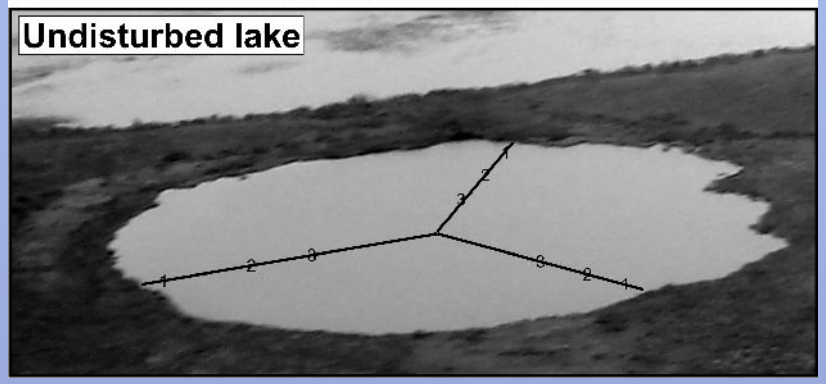
Hypothesis 2:

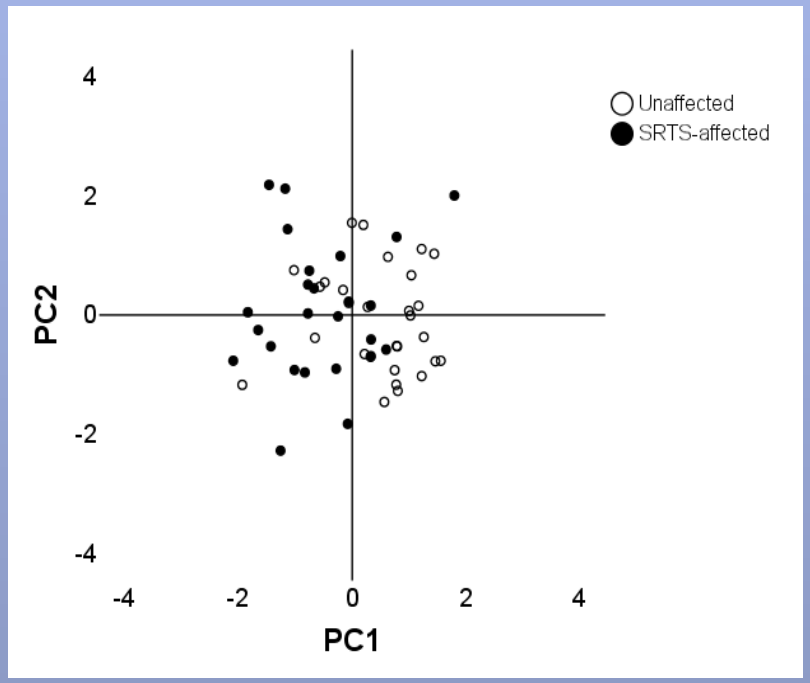
Permafrost-related geochemical-sediment interactions in "thermokarst slumped" lakes reduce DOC and nutrient concentrations in lake water .

Hypothesis 3:

A combination of hypotheses 1 and 2.


Disturbed lake
Slump
Da
Do


Undisturbed lake


Unaffected
SRTS-affected
PC2
PC1
4
2
0
-2
-4
-4
-2
0
2
4

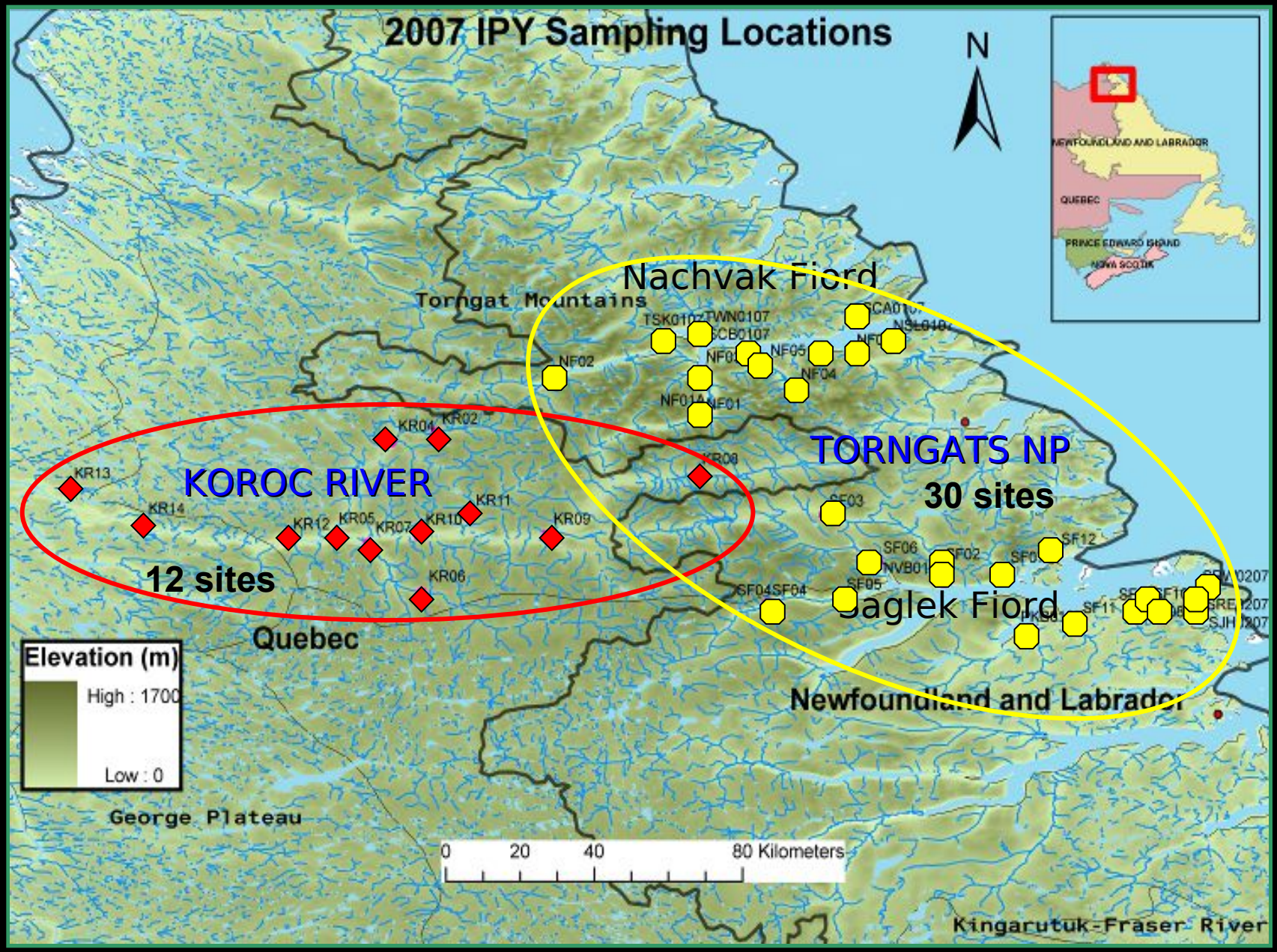
Eastern Arctic Synoptic Survey

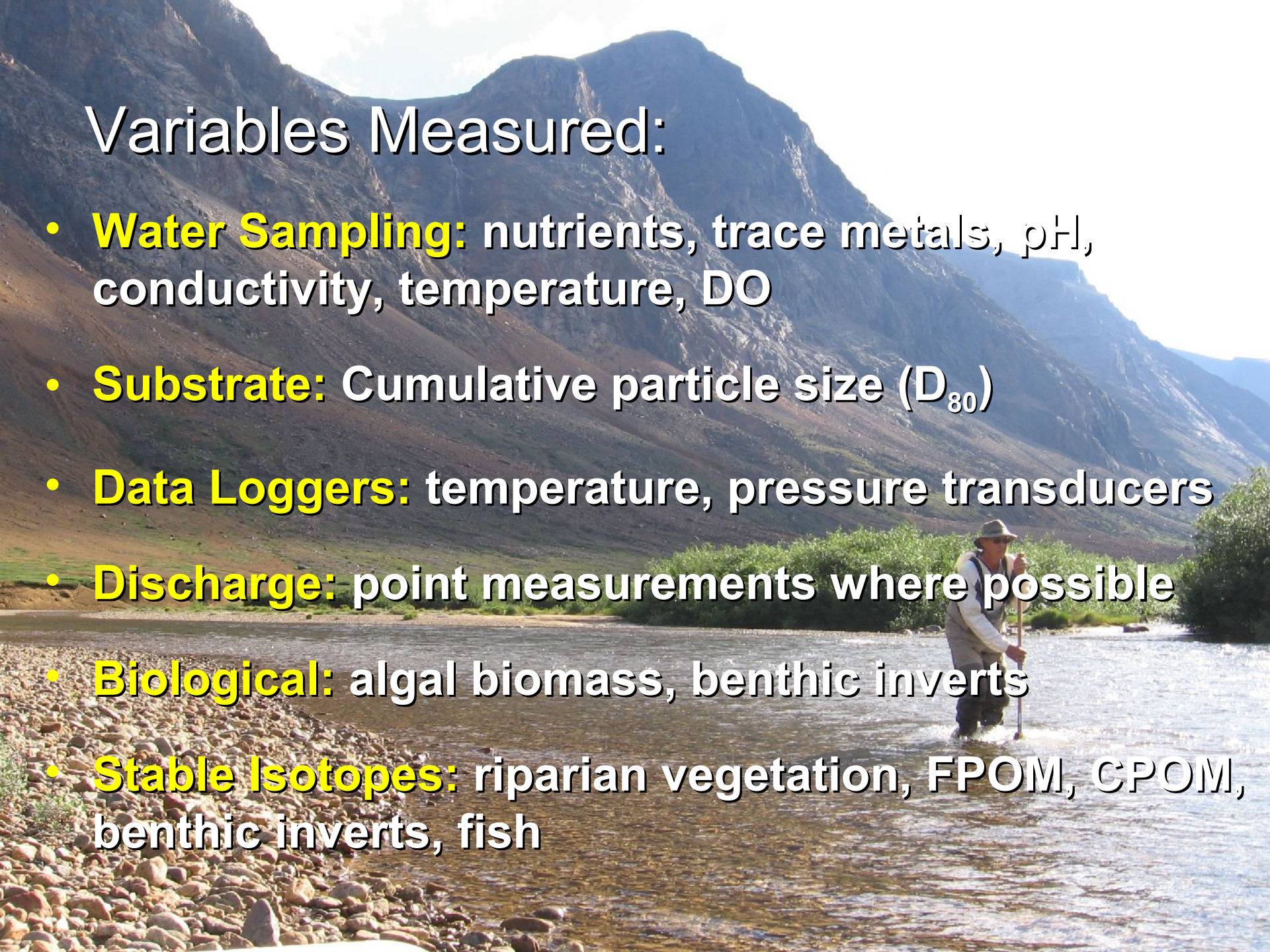
Eastern Arctic River Biodiversity and Function

Primary Objectives:

- Establish baseline physico-chemical and benthic biological data with emphasis on eastern Arctic rivers
- Determine focal sites for long-term biomonitoring
- Undertake intensive research of benthic food web structure and function at selected focal sites
- Support community-based biomonitoring programs to extend baseline coverage across the Arctic
- DNA barcoding of field collections

Initial Focus: Northern QC and Labrador





Variables Measured:

- **Water Sampling:** nutrients, trace metals, pH, conductivity, temperature, DO
- **Substrate:** Cumulative particle size (D_{80})
- **Data Loggers:** temperature, pressure transducers
- **Discharge:** point measurements where possible
- **Biological:** algal biomass, benthic inverts
- **Stable Isotopes:** riparian vegetation, FPOM, CPOM, benthic inverts, fish

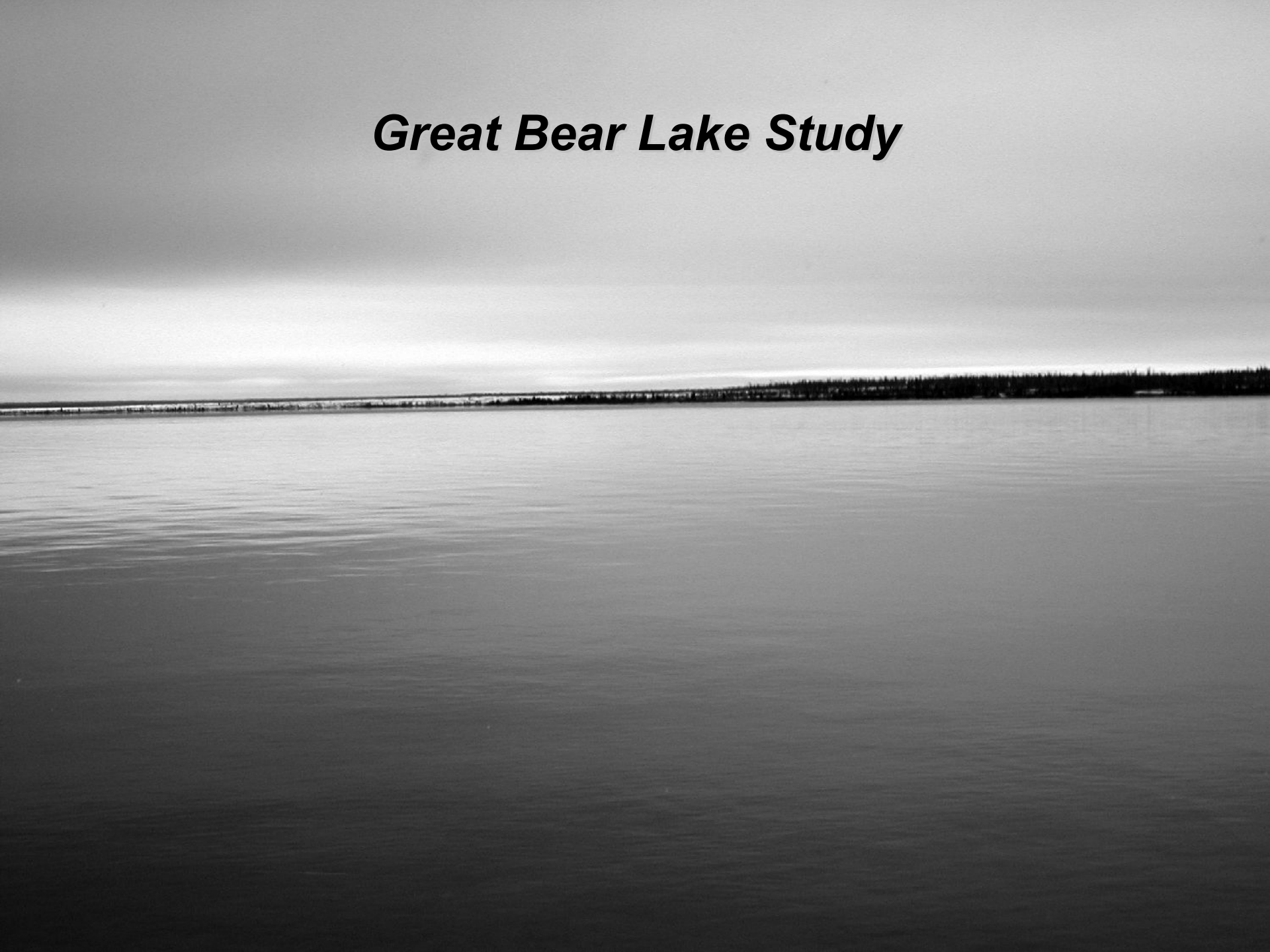
Research Program for 2008-2009

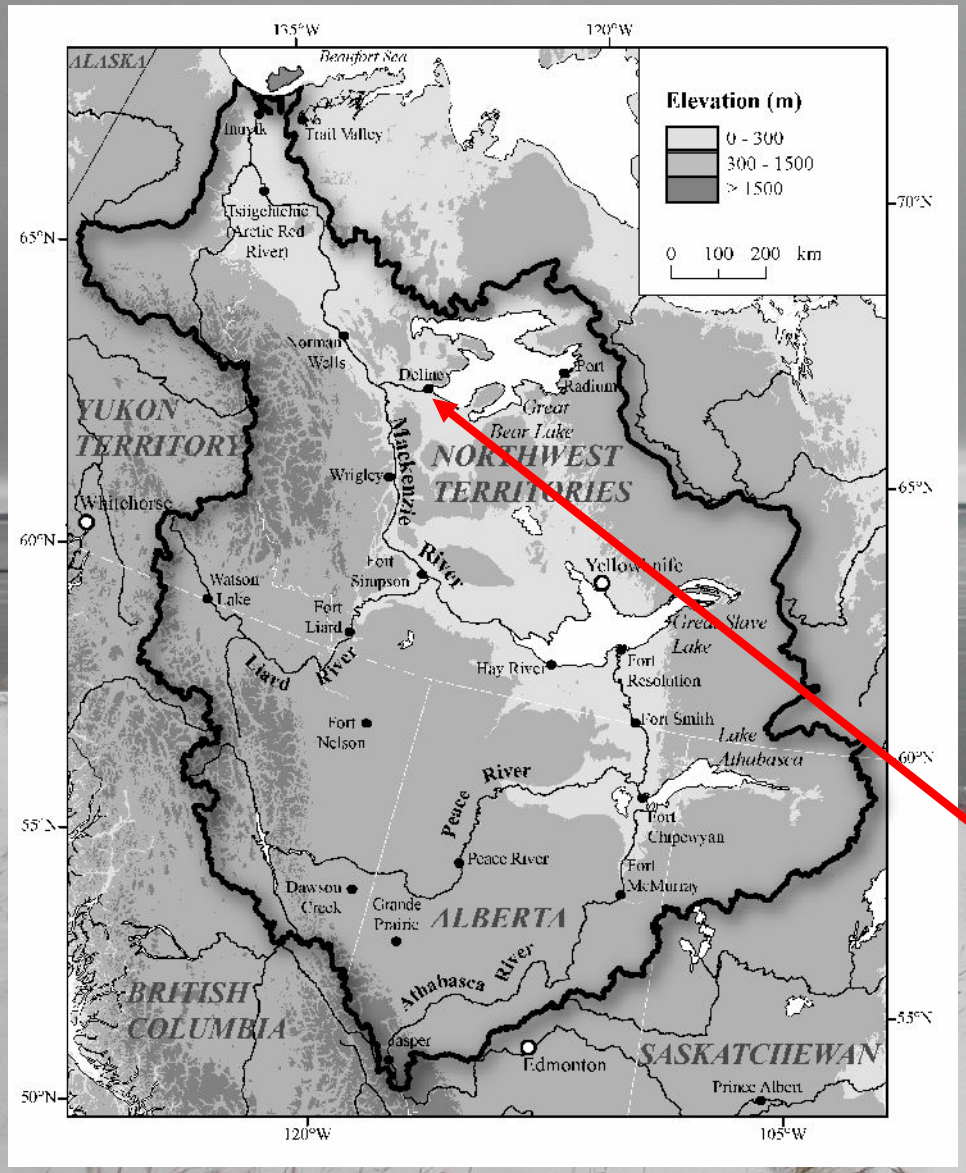
- Koroc River: links to QC park & George River community
  - repeat sampling (BMI, WQ, data loggers) of focal sites
  - fish community surveys of focal sites
  - fish community surveys in lower lakes (stakeholder linkage)
  - citizen monitoring outreach for CABIN sampling

2. Torngats National Park:
   - river ecosystem productivity (lake vs non-lake; fish vs fishless)
   - collaborative monitoring with Parks Canada

3. Eastern Arctic Latitudinal Gradient:
   - ecosystem function in Torngats, Baffin & Ellesmere Islands
   - DNA bar coding

- CABIN North: extend functional and structural assessments to western Parks through collaboration with CABIN program + DNA

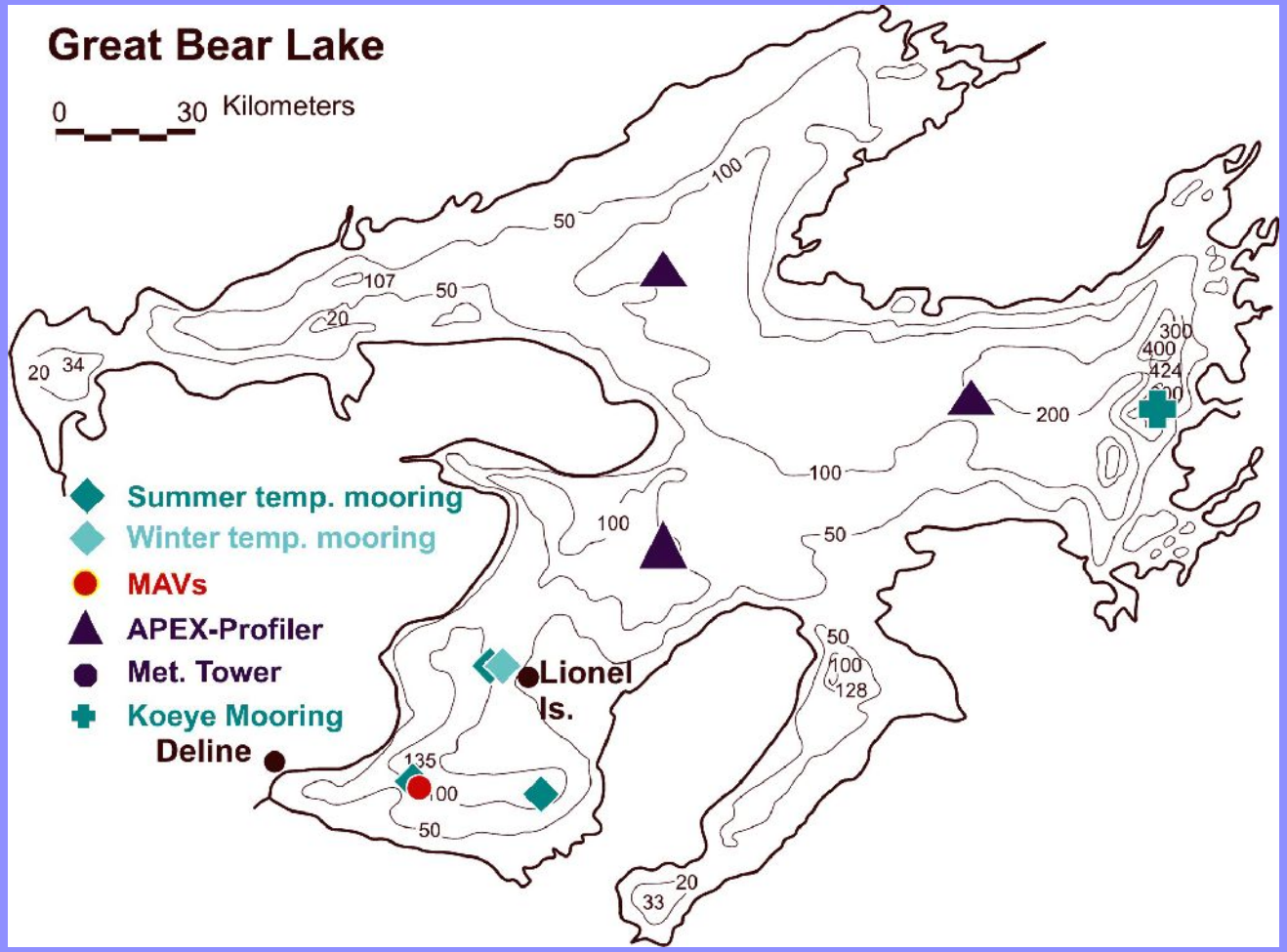

Great Bear Lake Study



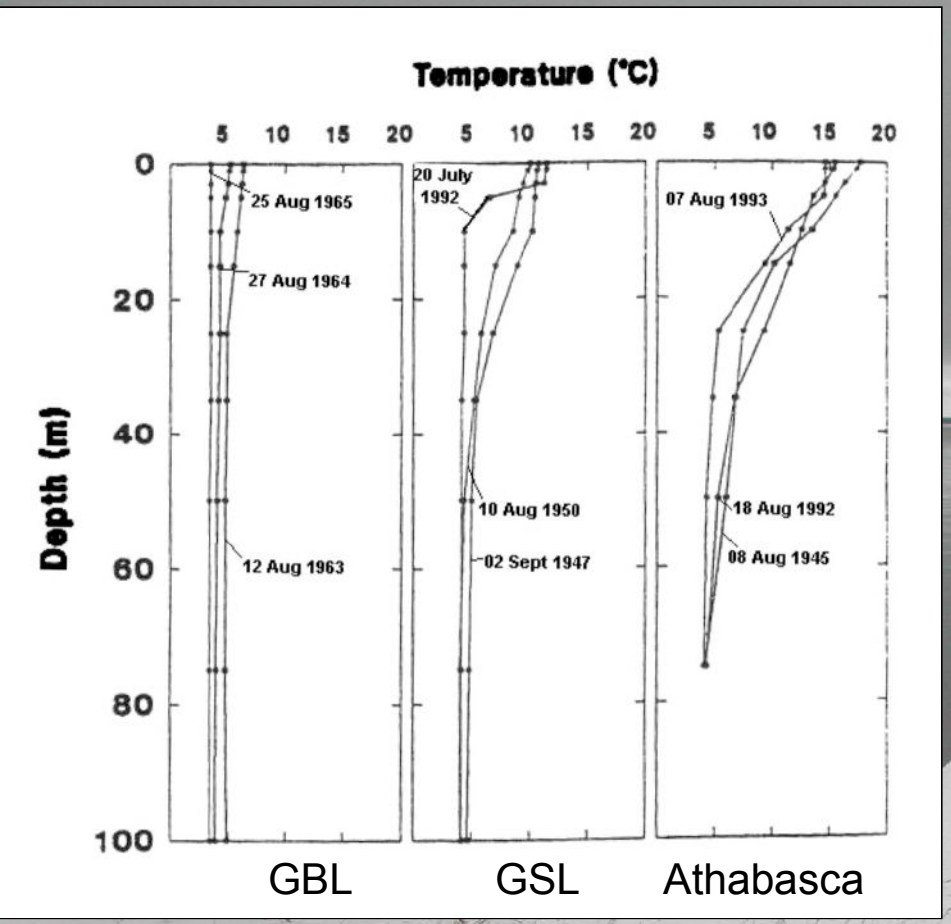
Great Bear Lake

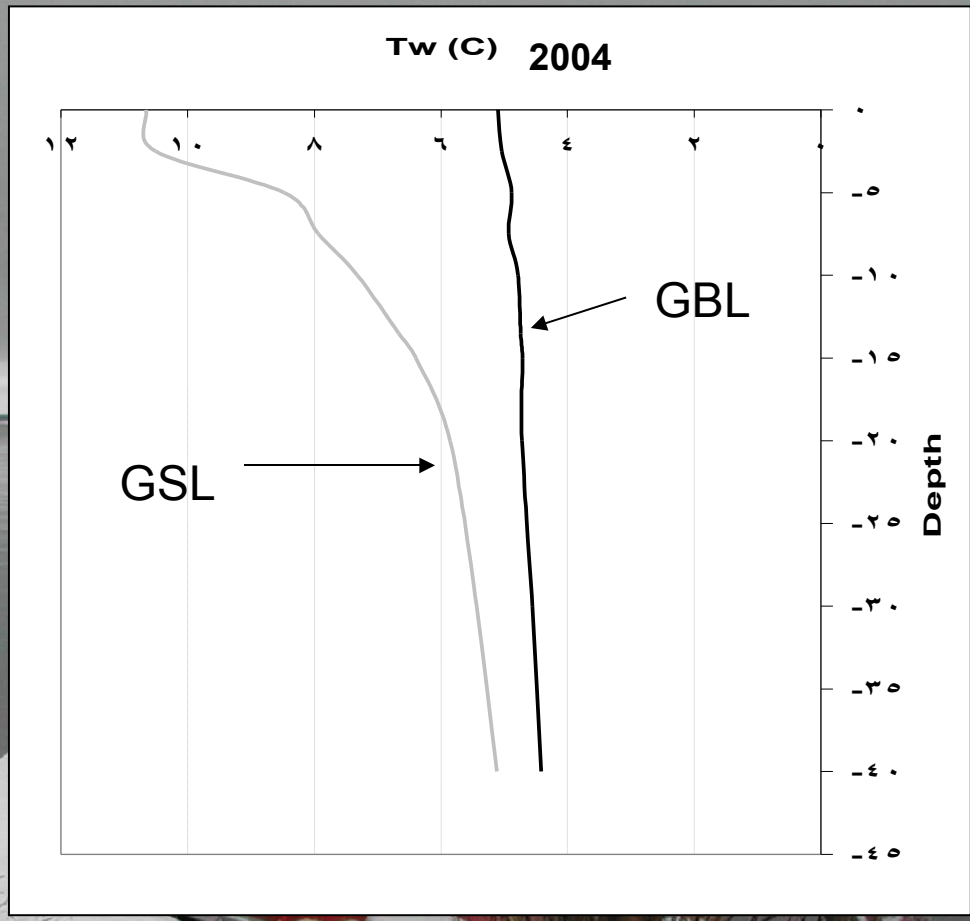
Latitude	65.8	°N
Longitude	120.8	°W
Altitude	156	m, ASL
Drainage Area	158	km^2x10^3
Surface Area	31	km^2x10^3
Mean Ice Free Period	139	days
Mean Ts Ice-free	4.3	°C
Volume	2,240	km^3
Max. Depth	413	m
Mean Depth	72	m
Downstream Discharge	515	$m\ s^{-1}$
Residence Time	124	years

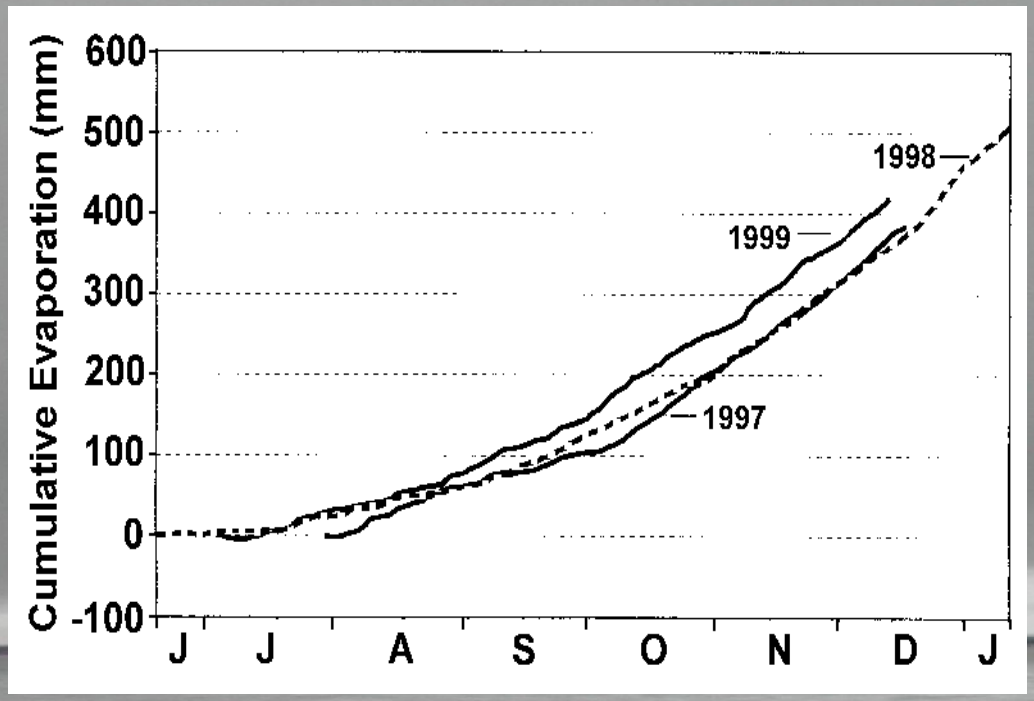
Investigations on Great Bear Lake are the most spatially intensive and extensive research ever conducted on this very large northern lake which includes meteorological observations at Deline and Lionel Island, and limnological observations of temperatures, currents, and light transmission in the water column.

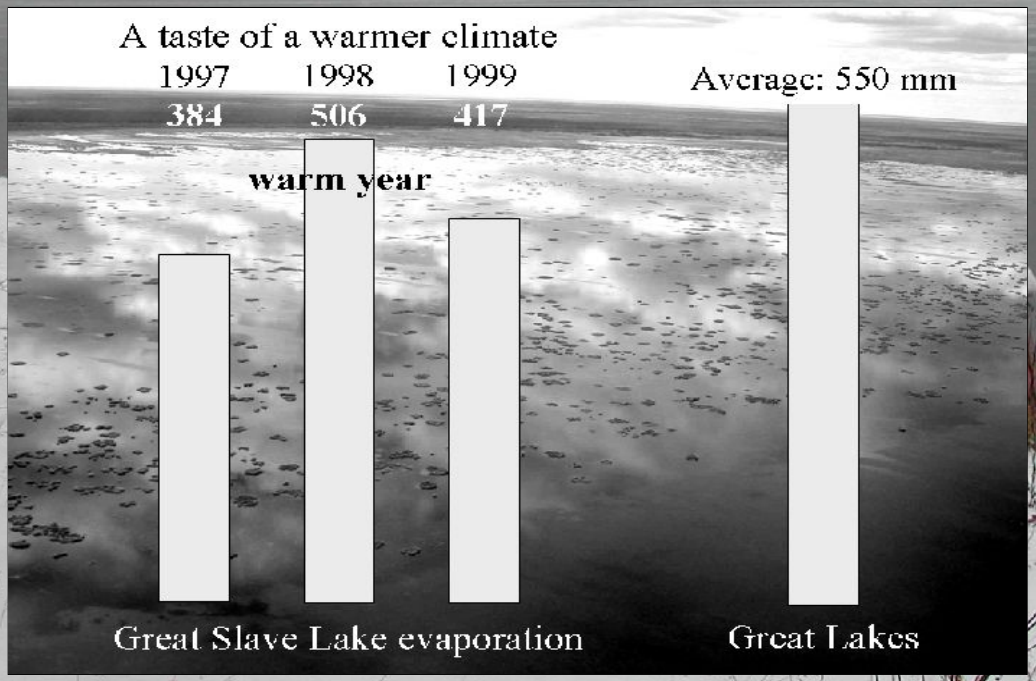


An APEX buoy which rises to the surface every three days to transmit temperature, depth and conductivity via satellite.


Temperature (°C)
5 10 15 20
0
20
40
60
80
100
Depth (m)
25 Aug 1965
27 Aug 1964
12 Aug 1963
20 July 1992
10 Aug 1950
02 Sept 1947
07 Aug 1993
18 Aug 1992
08 Aug 1945
GBL
GSL
Athabasca


Tw (C) 2004
GBL
GSL
Depth


Cumulative Evaporation (mm)
600
500
400
300
200
100
0
-100
J
J
A
S
O
N
D
J
1998
1999
1997


A taste of a warmer climate
1997
1998
1999
384
506
417
warm year
Average: 550 mm
Great Slave Lake evaporation
Great Lakes

Parks Canada Study

Parks Canada's involvement in the IPY "Arctic Freshwater Systems" is providing critical baseline information to establish a cost effective long-term program for assessing ecological change in freshwater ecosystems in arctic and subarctic National Parks.

Four inter-related sub-projects have been developed:

1. **Development and evaluation of a hierarchical ecological classification system for freshwater ecosystems in northern national parks**

2. **Development and evaluation of freshwater monitoring measures for use in northern ecosystems**

3. **Development and application of protocols to monitor the ecological integrity of northern streams: testing protocols at a landscape scale in the South Nahanni Watershed**

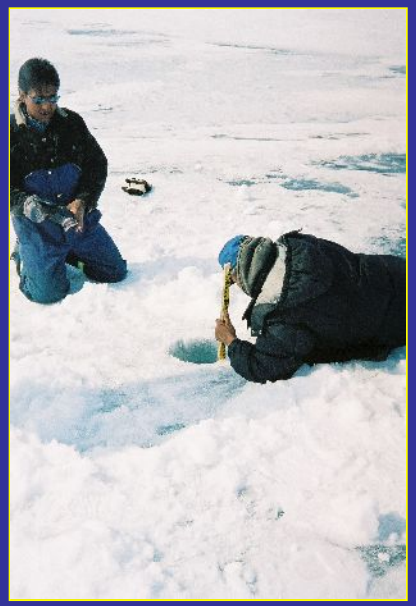
4. **Development of a modular and incremental multi-scale watershed-based monitoring design to assess multiple ecosystems and their linkages**

Community-based Capacity Building and Outreach

A community-based aquatic biodiversity monitoring consortium/network involving long-term monitoring sites in the Canadian Arctic is being established through CABIN, which is a collaborative programme developed and maintained by Environment Canada to establish a network of reference sites with the data collected easily and freely available through the Internet to all users interested in assessing the biological health of fresh water in Canada.

Information collected and archived through community-based monitoring will provide excellent baseline information of the current state of aquatic ecosystems in the North.

Other capacity building and outreach activities include training and hiring of northern students and community members, community consultations and meetings, presentations, websites, posters, etc.



Capacity building and community involvement.

To Sum Up

Through integrated, multidisciplinary hydrological, climatological, and ecological field studies and laboratory analyses, this research project will: (i) improve our process-level understanding of freshwater and nutrients flow to the Arctic Ocean, (ii) develop improved predictive models for freshwater and nutrient flux, (iii) develop a unique legacy database of freshwater biodiversity (structure and function) and related environmental information on Arctic freshwater ecosystems and (iv) develop and provide tools and capacity in northern communities for improved community-based monitoring and assessment of the status and trends of the health and integrity of Arctic freshwater ecosystems.

Even though Arctic Freshwater Systems is only in the second year of its research program, much information has been collected thus far, and this project is making great advances with regard to its research priorities.


http://www.ec.gc.ca/api-ipy
Thank You