# Paleolimnology of Lesser Slave Lake

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## Presentation Outline

- INTRODUCTION
- PALEOECOLOGICAL APPROACH
- RESULTS
- DISCUSSION AND GENERAL CONCLUSIONS

## Introduction

•Lesser Slave Lake is very productive (eutrophic)
•High productivity can lead to blooms of 'nuisance' algae
•Need to place present trophic status in historic context

## Introduction

Does the present level of productivity reflect natural conditions?

•Many boreal lakes are naturally productive
•Monitoring record for Lesser Slave Lake extends to ca. 1940; a more continuous record is required for proper trend analysis, and to constrain variance. Such records are rare.
•Present trajectory of human influence in the area began 1750-1800

## Introduction

Does the present level of productivity reflect natural conditions?

•Noton (1998) concluded that nutrient export from ‘developed’ catchments not significantly different than from ‘undeveloped’ catchments

**Table 5-1. Lesser Slave Lake phosphorus budget, 1991-93**

| | TOTAL PHOSPHORUS | | | |
|---|---|---|---|---|
| | Load kg/yr | FW Mean mg/L | Drainage Area $km^2$ | Export kg/ha/yr |
| EXTERNAL INPUTS -1991-1992: | | | | |
| - South Heart | 36655 | 0.108 | 6834 | 0.054 |
| - Driftpile | 8876 | 0.079 | 840 | 0.11 |
| - Other, West Basin | 10403 | 0.1 * | 1623 | |
| - Swan | 32809 | 0.104 | 1923 | 0.17 |
| - Assineau | 1210 | 0.103 | 144 | 0.08 |
| - Marten | 3490 | 0.092 | 201 | 0.17 |
| - Other, East Basin | 5378 | 0.095 * | 885 | |
| Total Tributaries: | 98822 | 0.102 ** | | 0.084 ** |
| Precipitation (est.) | 23109 | | | |
| TOTAL EXTERNAL LOAD: | 121931 | | | |
| Est. Areal Ext. Load - $g/m^2/yr$ | 0.11 | | | |
| OUTFLOW - Lesser Slave R. | 26829 | 0.034 | | |
| % Retention in lake | 78 | | | |
| INTERNAL LOAD: Summers, 1992 and 1993 | Load kg/yr | Net Release Rate $mg/m^2/d$ | | |
| - West Basin | 122239 | 2.45 | | |
| - East Basin | 106653 | 2.14 | | |
| TOTAL INTERNAL LOAD: | 228892 | | | |
| MEAN ANNUAL TP LOAD: | 350823 | | | |

## Introduction

Does the present level of productivity reflect natural conditions?

•Paleoecological data suggest that productivity (in the east basin) prior to 1750 was consistently low. Lesser Slave Lake was probably oligotrophic.

•Productivity began to increase ca. 1750

•Productivity has increased geometrically since ca. 1950

## Paleoecological Approach

Using this approach, we will:

- Identify if and when ecological change has occurred
- Identify the nature of ecological change, using appropriate paleoecological indicators
- Quantify past ecological conditions using inference models (e.g. TP)
- Aid in establishing ecologically defensible management targets

## Paleoecological Approach

We take a two-phased approach to the paleolimno-logical study:

- Phase 1: qualitative phase. Using sediment geochemistry and fossil pigments, we examine:
  - whether ecological change has occurred
  - when such change has occurred
  - how phytoplankton communities have been affected (e.g. increase in cyanobacteria?)
  - potential drivers of ecological change (by correlation with environmental changes or by geochemical signature)
- Phase 1 is complete, pending completion of the technical report.

## Paleoecological Approach

We take a two-phased approach to the paleolimno-logical study:

•Phase 2: quantitative phase. Using sediment assemblages of algal microfossils (diatoms and chrysophytes), we will:

- •reconstruct lake TP concentrations, permitting establishment of management targets
- •corroborate phase 1 findings, especially with respect to fossil pigments
- •conduct a qualitative assessment of environmental change, based on ecological preferences of diatom and chrysophyte species (e.g. potential changes in mixing regime?)

•Phase 2 is underway – microfossil identification and enumeration 1/3 complete. Complete by January 2008?

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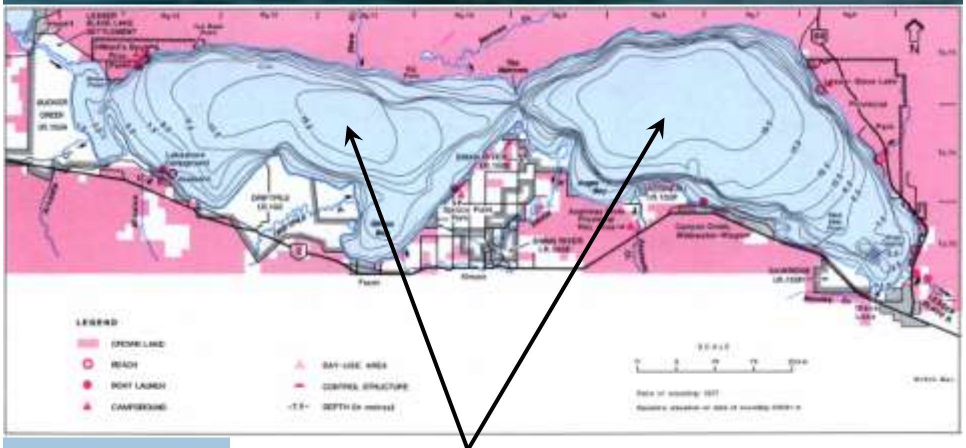
## Paleoecological Approach



Sediment sampling locations
•West basin: October 2005
•East basin: January 2006

## Paleoecological Approach

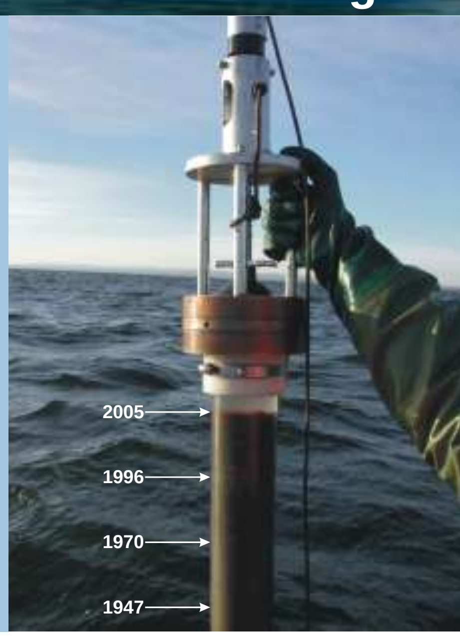
Sediment coring methodology:

## Paleoecological Approach

West basin core

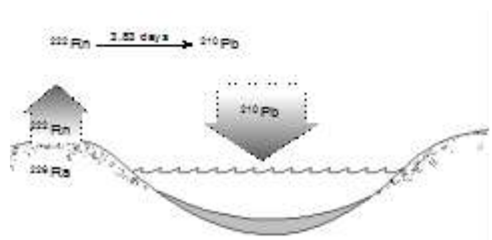
## Paleoecological Approach

Sediment chronology: stratigraphic series = time series
•Dateable using radioisotopes



## Paleoecological Approach

$^{210}$Pb chronology



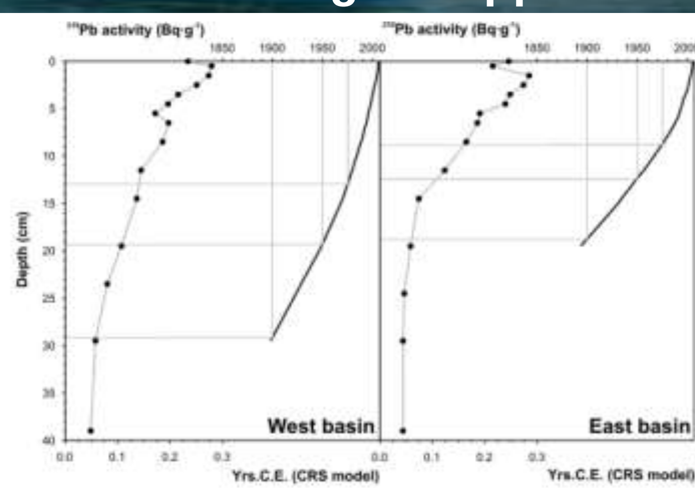

•$^{222}$Rn decays to $^{210}$Pb in the atmosphere, is deposited in the water, adsorbs onto suspended particles, and precipitates

•Half-life of $^{210}$Pb is 22.8 yrs.

•The decay of the short-lived radioisotope $^{210}$Pb marks the age of recent sediments (<150yrs)

## Paleoecological Approach

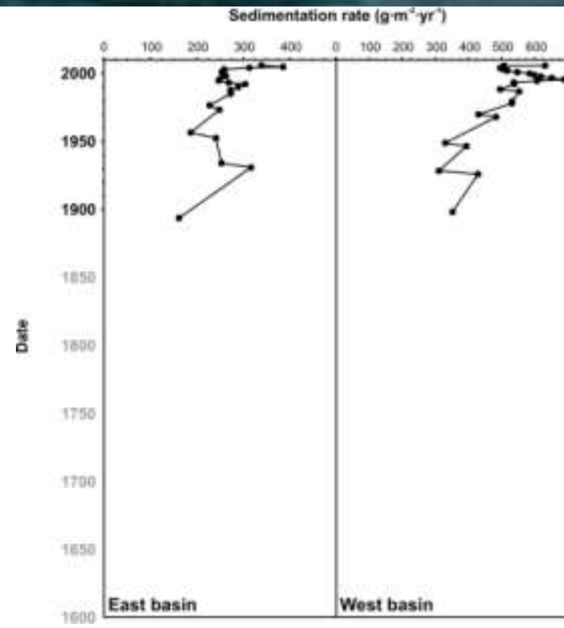
Unsupported $^{210}$Pb activity in sediments, and sediment chronology based on CRS model




•Coherent $^{210}$Pb stratigraphy = no mixing
•Assuming constant rate of $^{210}$Pb deposition, we can estimate the sediment deposition rate

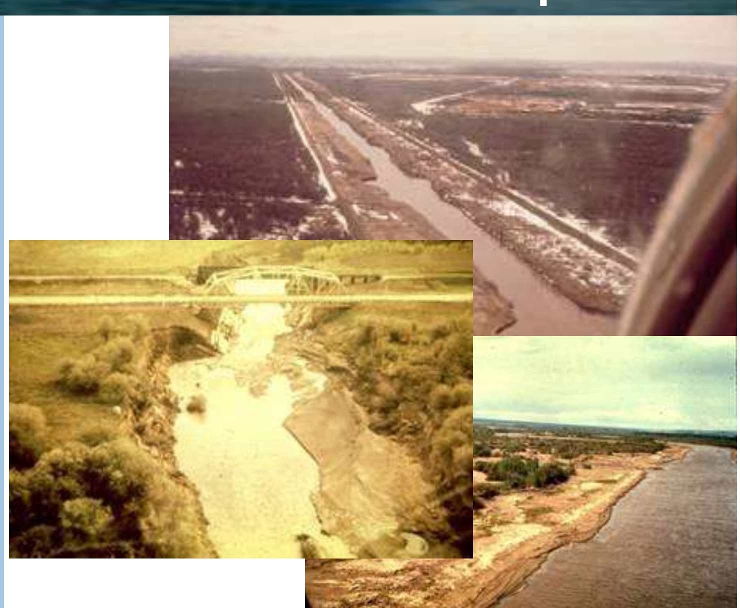
## RESULTS: Sediment deposition

- Seasonal variability at surface
- Slight increase in dep. rate in east basin, doubling of dep. rate in west basin
- Decline in west basin ca. 1996, possibly due to scouring or bed armouring



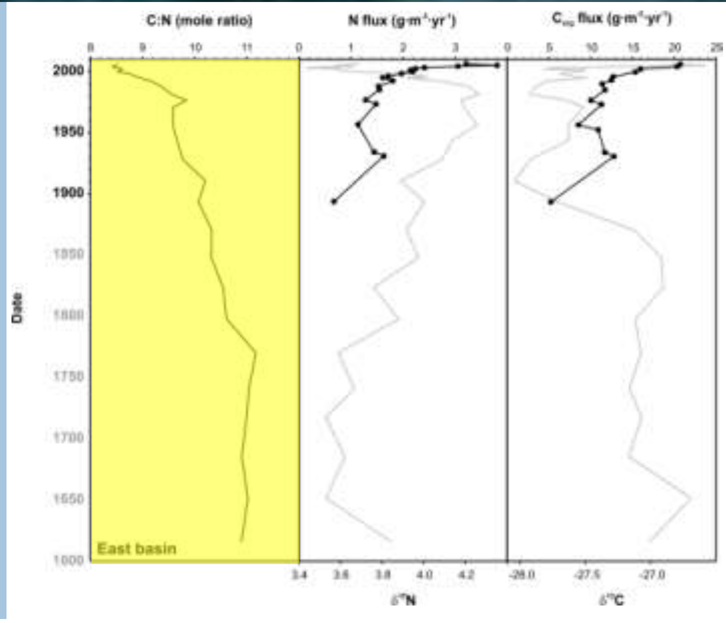

## RESULTS: Sediment deposition

- Foreshorten-ing and canalisation of East and West Prairie Rivers likely major contributor to sedimentation
- Exacerbates nutrient loading



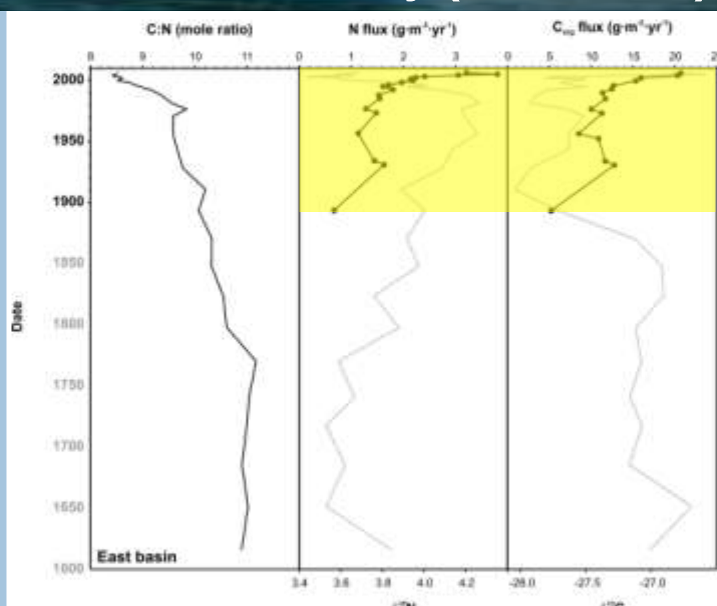
## RESULTS: Geochemistry (east basin)

- C:N ratio declining
- Indicator of relative contribution of organic matter
- Stable prior to 1750
- In-lake contribution has increased since ca. 1750-1800, esp. since ca. 1970



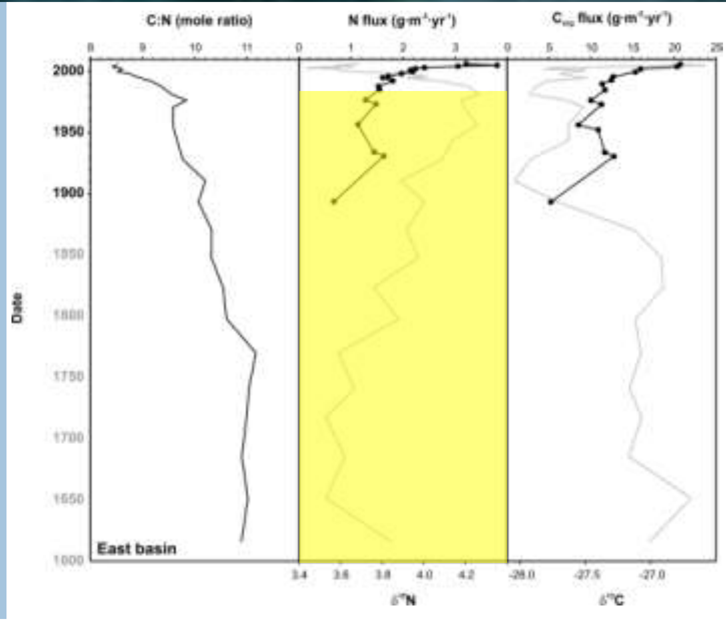

## RESULTS: Geochemistry (east basin)

- C & N flux increasing
- In part, indicator of microbial processes
- Consistent with other indicators, therefore ‘real’
- Shows geometric increase in productivity since ca. 1950



## RESULTS: Geochemistry (east basin)

- Nitrogen stable isotope ratio increasing between ca. 1750 and 1980
- Possibly source indicator (unlikely), probably ‘Rayleigh fractionation’
- Increasing productivity

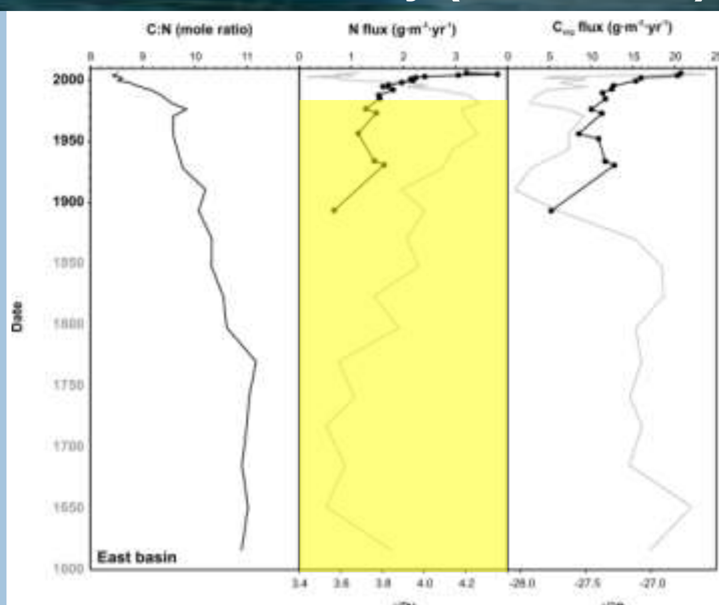



## RESULTS: Geochemistry (east basin)

- Algae ‘prefer’ $^{14}N$, but are forced to use $^{15}N$ when $^{14}N$ becomes ‘scarce’

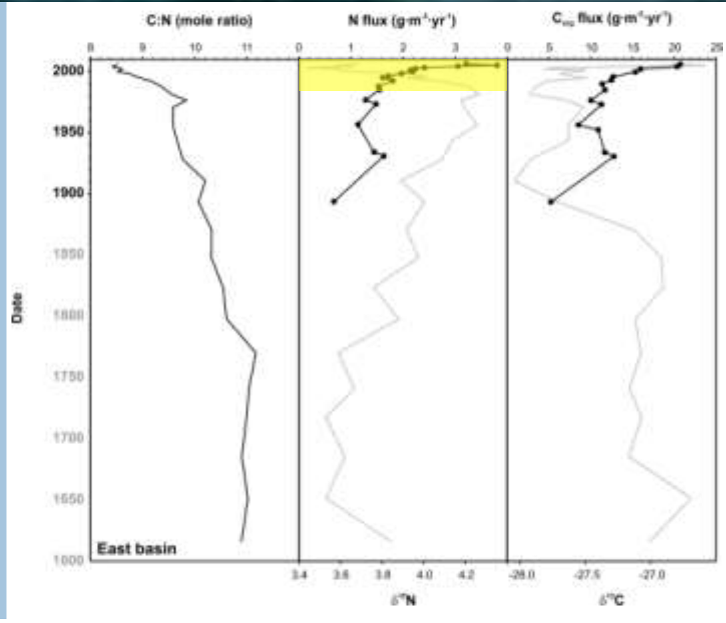
  <u>or</u>

- Denitrification (fixed N to $N_2$) in water column preferentially removes $^{14}N$



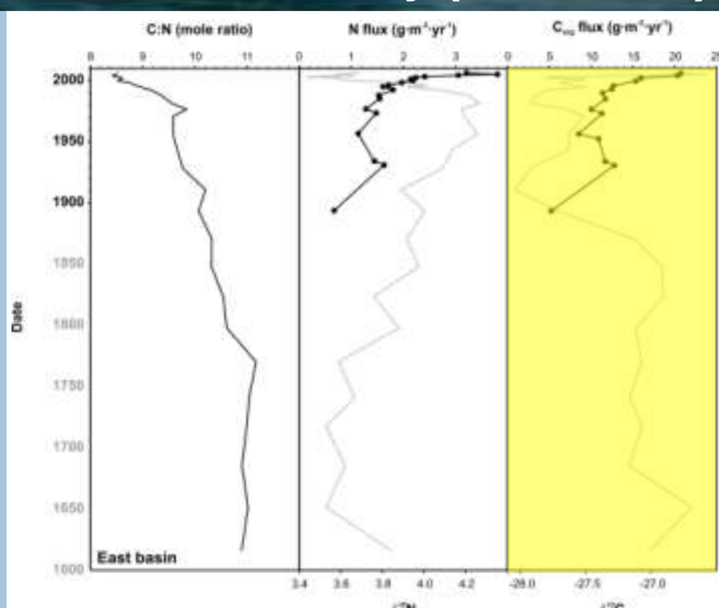
## RESULTS: Geochemistry (east basin)

- Nitrogen stable isotope ratio declining in surface sediments
- N fixation by cyanobacteria (blue-green algae)
- N normally not limiting, but may be under bloom conditions
- More ‘algal’ blooms



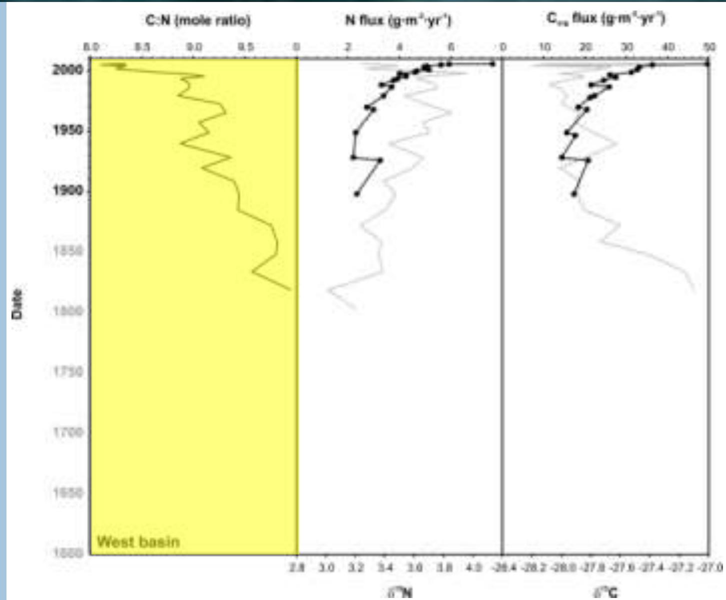

## RESULTS: Geochemistry (east basin)

- Carbon stable isotope ratio declines ca. 1900, remains low
- Not consistent with other indicators
- Reflects increased C recycling
- May be related to extirpation of lake whitefish



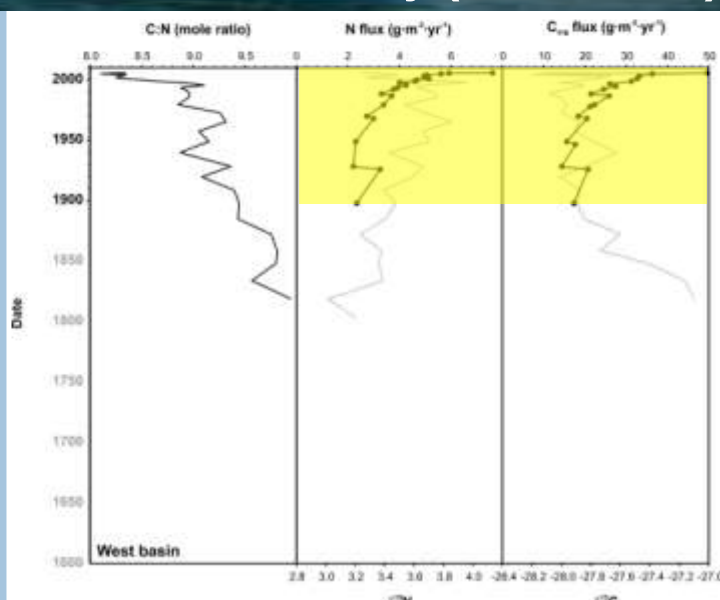
# RESULTS: Geochemistry (west basin)

- As in east basin, C:N ratio increasing since at least 1820
- Sharp change at surface
- Indicator of relative contribution of organic matter
- Increasing in-lake contribution



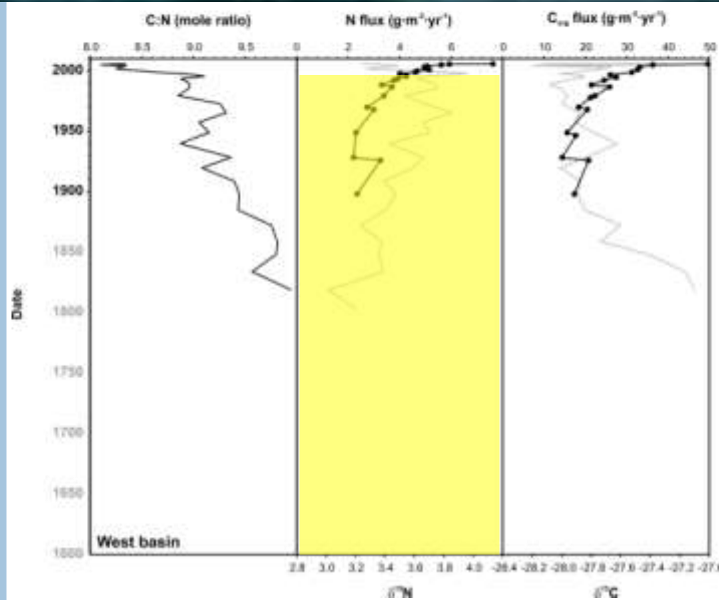

# RESULTS: Geochemistry (west basin)

- C and N flux increasing geometrically since ca. 1950
- Increasing productivity



# RESULTS: Geochemistry (west basin)

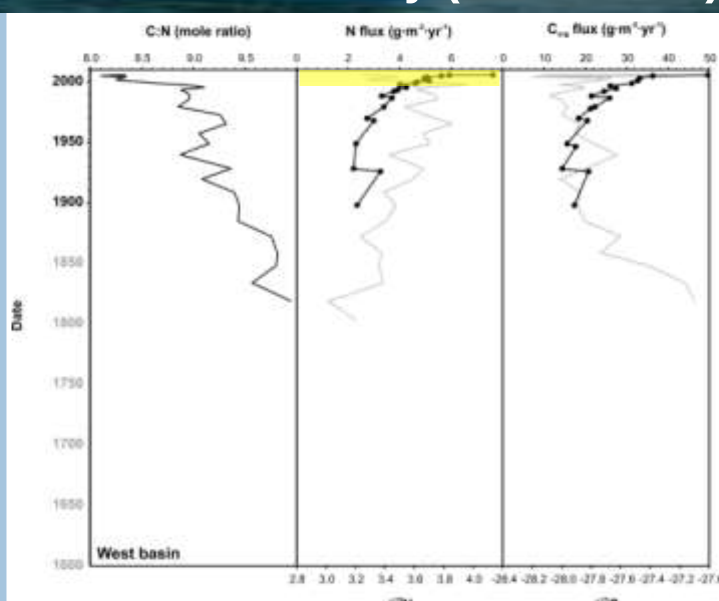
- Nitrogen stable isotope ratio increasing ca. 1800 to 1998
- As in east basin, probably stable isotope fractionation associated with increasing productivity





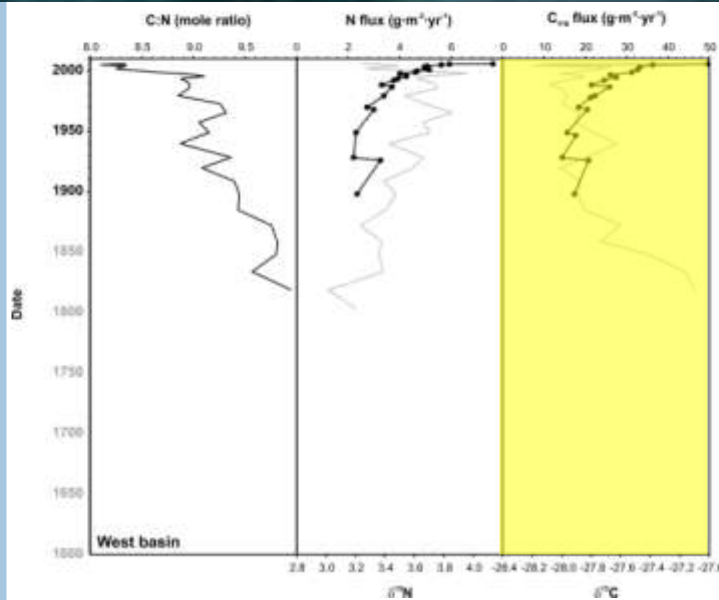
# RESULTS: Geochemistry (west basin)


- Nitrogen stable isotope ratio declining in surface sediments
- N fixation by cyanobacteria (blue-green algae) – no isotope fractionation, more like atmospheric $N_2$
- More ‘algal’ blooms



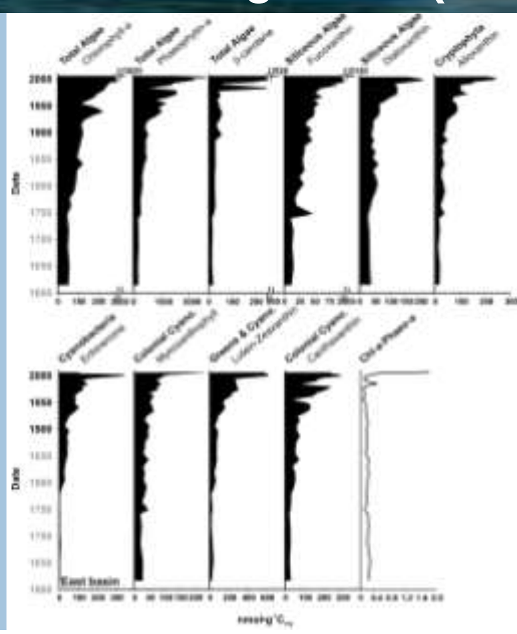
# RESULTS: Geochemistry (west basin)

- •Carbon stable isotope ratio declines ca. 1850, remains low
- •Not consistent with other indicators
- •Reflects increased C recycling



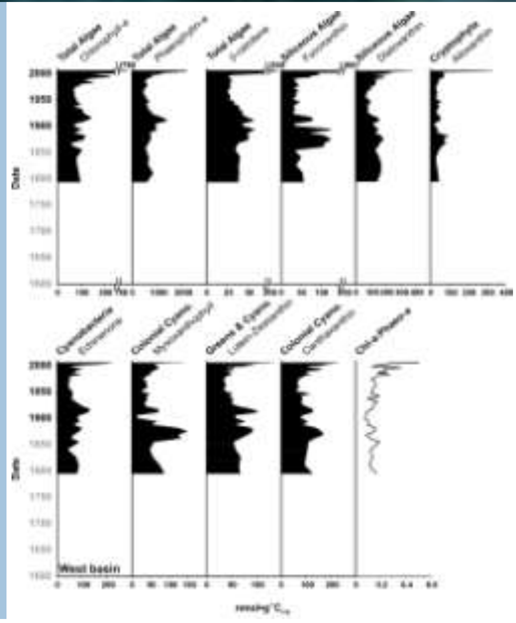

# RESULTS: Pigments (east basin)

- •Minimal pigment degradation
- •Gradual increase in productivity beginning ca. 1750
- •Geometric increase in productivity during 20$^{th}$ C.
- •Spike in productivity since late 1990s



## RESULTS: Pigments (west basin)

•Minimal pigment degradation below sediment surface (note scale)
•Changes in rate of pre-deposition degradation obscure trends
•Increasing productivity since ca. 1950



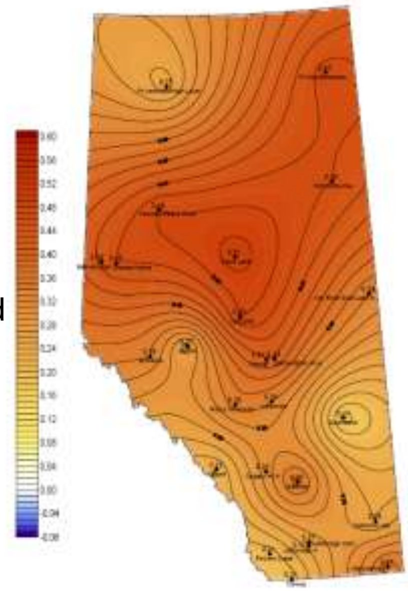

## RESULTS: Summary

•Increasing sediment sepositon rate since ca. 1950, consistent with flood mitigation in East and West Prairie Rivers
•Prior to ca. 1750, Lesser Slave Lake was probably oligotrophic
•Gradually increasing productivity in both basins dating to as early as 1750-1800, supported by multiple proxies
•Geometric increase in productivity since ca. 1950
•Increasing frequency or severity of cyanobacterial blooms during past two decades

## Discussion: long-term trends

Mean temperature trends in Alberta 1960-1995 (Chaikowski 2000)

•Consistent with emergence from ‘little ice age’, and with onset of anthropogenic climate change
•Earlier ice-out means longer growing season, and longer period during which water column is isothermal, permitting greater upwelling of nutrients



## Discussion: long-term trends

Trapping?

•At the beginning of the 1800s, traders were exporting three tonnes of beaver pelts from the area each year
•Trapping so decimated the beaver population that by 1924 the industry was no longer considered viable
•Trapping may have reduced the number of beaver dams in the area, permitting more direct export of organic matter and nutrients from the catchment

## Discussion: recent trends

**Nutrient loading**

- Noton (1998) concluded that nutrient export from developed catchments was not significantly different than from undeveloped catchments
- Spike in productivity in lake 1990s suggests enhanced nutrient export associated with flooding

Table 5-1. Lesser Slave Lake phosphorus budget, 1991-93

| | TOTAL PHOSPHORUS | | | |
|---|---|---|---|---|
| | Load kg/yr | FW Mean mg/L | Drainage Area km$^2$ | Export kg/ha/yr |
| EXTERNAL INPUTS - 1991-1992: | | | | |
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| Total Tributaries: | 98822 | 0.102 ** | | 0.084 ** |
| Precipitation (est.) | 23109 | | | |
| TOTAL EXTERNAL LOAD: | 121931 | | | |
| Est. Areal Ext. Load - g/m$^2$/yr | 0.11 | | | |
| OUTFLOW - Lesser Slave R. | 26829 | 0.034 | | |
| % Retention in lake | 78 | | | |
| INTERNAL LOAD: | Load | Net Release Rate | | |
| Summers, 1992 and 1993 | kg/yr | mg/m$^2$/d | | |
| - West Basin | 122239 | 2.45 | | |
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| TOTAL INTERNAL LOAD: | 228892 | | | |
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## Discussion: recent trends

**Nutrient (Phosphorus) loading**

- Correlation of productivity spike with 1996 floods strongly suggests that the recent (since 1950) increase in productivity is associated with nutrient loading
- Extensive agricultural development in East and West Prairie River and South Heart River catchments (~45,000 cattle in RM Big Lakes)
- Limited riparian areas
- Channel modification = direct conveyance of nutrients to lake
- Finish feeders (confined feeding operations) produce large volumes of manure; also lagoons for both human and animal waste
- Erosion from activities of forestry and petroleum sector may contribute to nutrient loading