Spatio-temporal assessment (quarter century) of pulp mill metal(loid) contaminated sediment to inform remediation decisions

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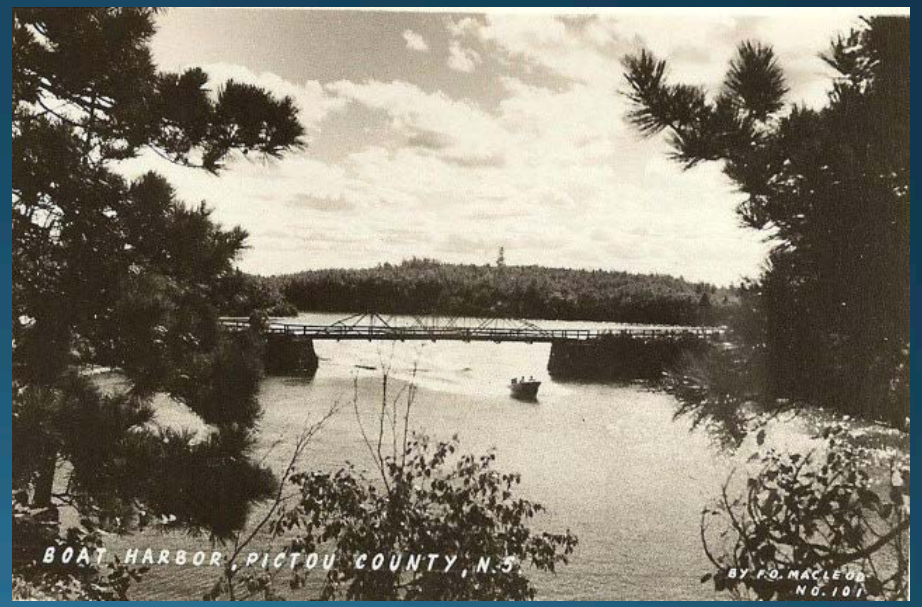
Dalhousie University

Agenda

- Background
- Boat Harbour Remediation Project
- Sediment Chemistry Assessment
- Results and Discussion
- Recommendations
- Closing Remarks

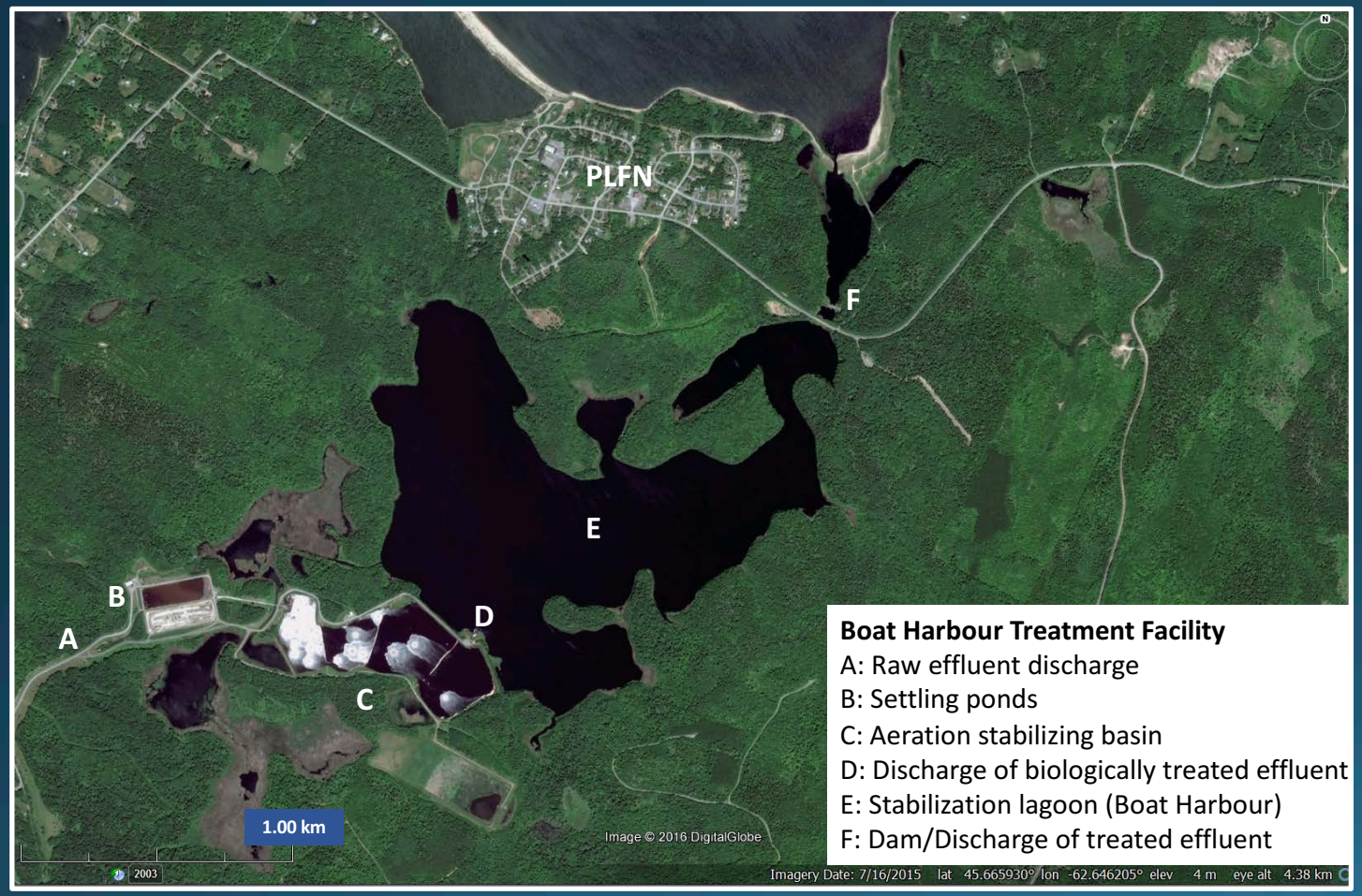


Background

- A bleached kraft pulp mill ('the mill') has been operating in Pictou County, Nova Scotia since 1967
- Effluent is discharged to the Boat Harbour Treatment Facility, within a former tidal lagoon near and within the Mi'kmaq Pictou Landing First Nation (PLFN) community

Fig. 1. Location of Boat Harbour in Pictou County, Nova Scotia relative to communities (e.g., Pictou, and Pictou Landing First Nation [PLFN]).

Boat Harbour Treatment Facility (BHTF)



- Effluent (>87,000 m^3/d)
- >170,000 m^3 of unconsolidated sediment
- Inorganic and organic contaminants (metal[loid]s, polycyclic aromatic hydrocarbons [PAHs], dioxins and furans)

Fig. 2. Components of the Boat Harbor Treatment Facility (BHTF), relative to the neighboring Pictou Landing First Nation (PLFN) community (©Google Earth).

Boat Harbour Remediation Project

- Remediation commencing in 2020 by the province of Nova Scotia; Boat Harbour will be returned to a pre-1967 tidal state

- Boat Harbour Environment Advisory Committee (BHEAC)

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- To spatio-temporally characterize impacted sediments to help inform decisions for a $89 million (CAD) remediation program

Holistic Review

- Over 200 documents were reviewed for relevant sediment metal(loid) chemistry data. Only 12 relevant to this study
  - 8 reports related to BH and reference locations (i.e., Fergusons Pond); 4 reports from downgradient receiving waters

- Metal(loid) chemistry data from BH sediment samples (up to 37 parameters) were collected between 1992 and 2015

Sediment Sample Sites (1992-2015)

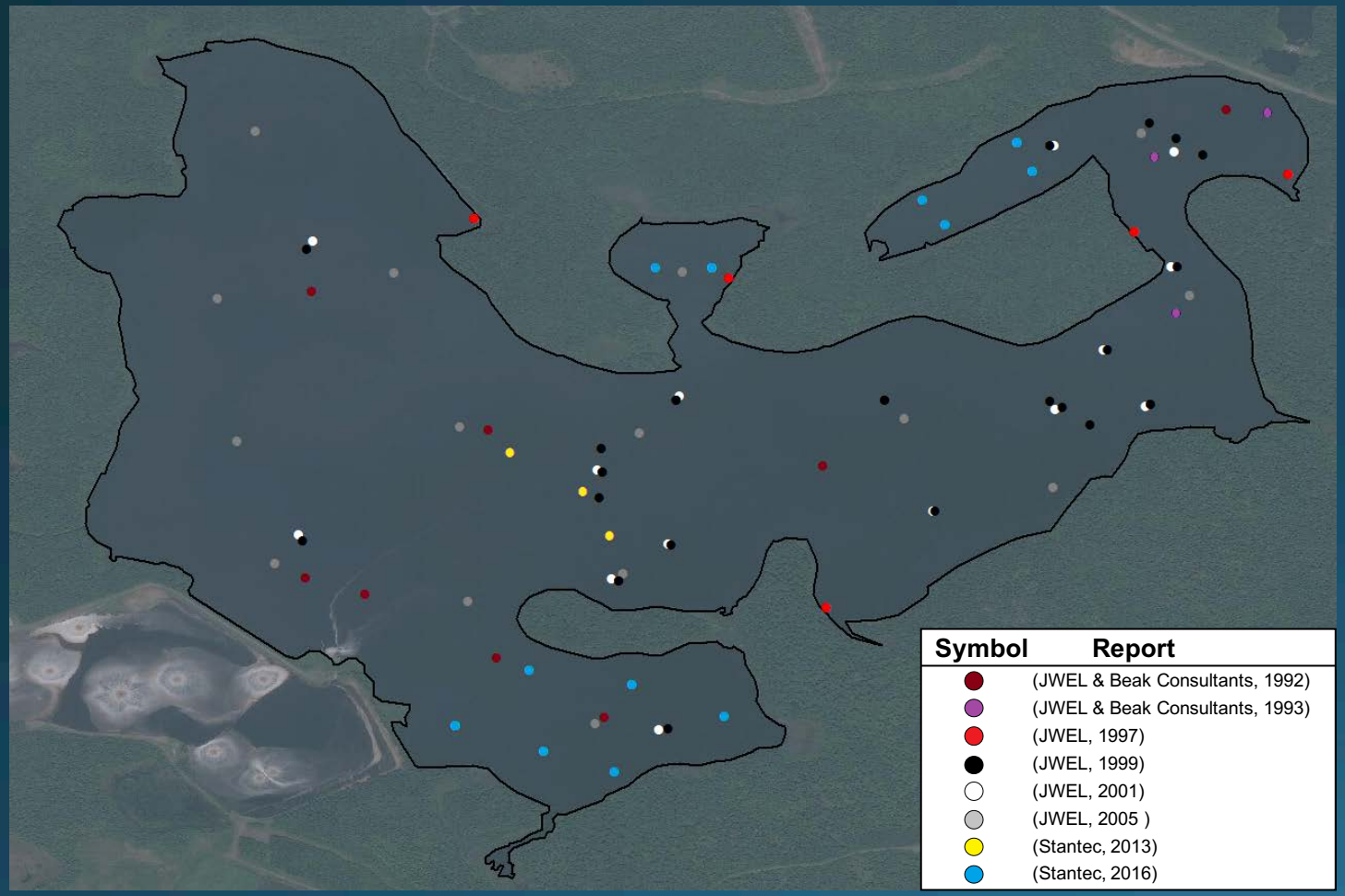


Fig. 3. Spatio-temporal coverage (1992-2015) of sediment sampling in Boat Harbour are indicated by coloured circles.

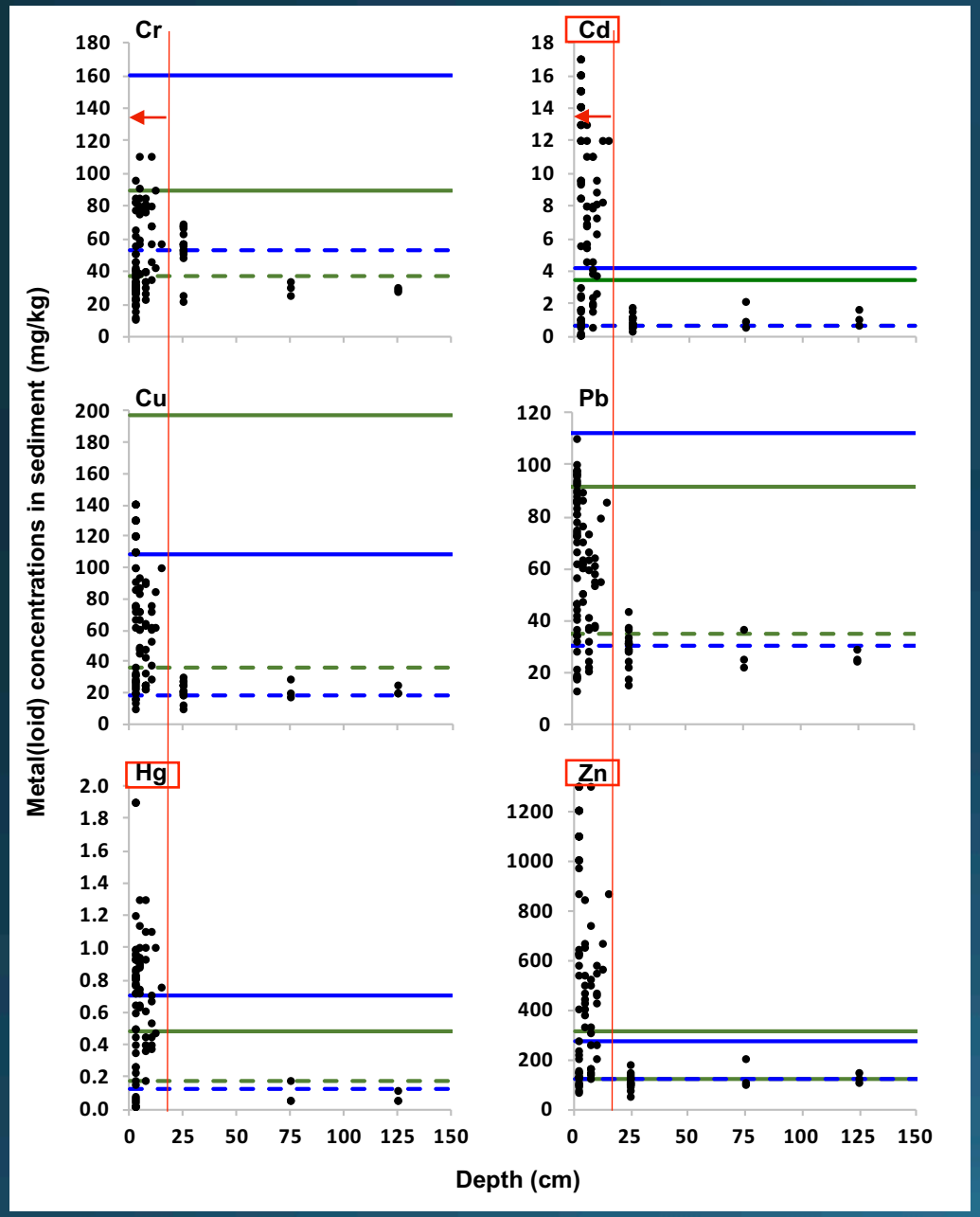
- → Only 8 reports w/ metal(loid) chemistry
- → 103 samples from 81 sites
- → Various sampling methods (e.g., core or grab; discrete or composite sample; sample depth)
- → Overall, inadequate spatial coverage

Analysis

- Compared metal(loid) concentrations to current Canadian Council of Ministers of the Environment (CCME) sediment quality guidelines (SQGs)
  - Freshwater and marine SQGs
  - Interim Sediment Quality Guidelines (ISQGs) (lower limit)
  - Probable Effect Levels (PELs) (upper limit) → biota are highly likely to be negatively affected by contaminants

- Spatio-temporal analysis applied to six priority metal(loid)s (Cd, Cr, Cu, Pb, Hg, Zn), due to frequent SQG exceedances

Concentration vs. Depth

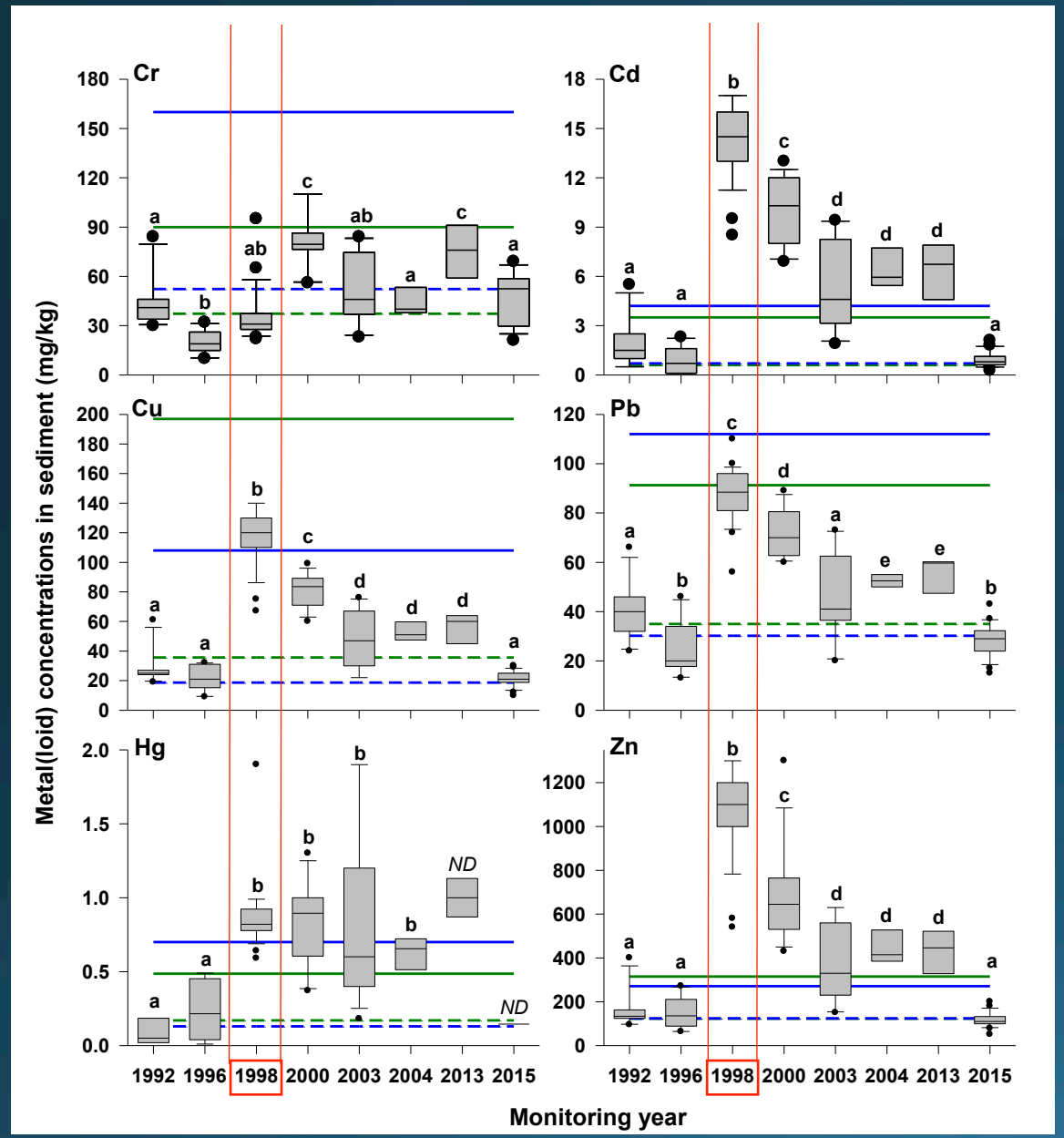


→ Most samples (75%) exceeded ISQGs
- Cd, Hg and Zn were frequently higher (52%) than PELs

→ Majority of samples were from shallow horizons

Fig. 4. Relationship between metal(loid) concentrations and depth (1992-2015). CCME freshwater (green) and marine (blue) SQGs are indicated using *solid horizontal lines* for PEL and *dashed lines* for ISQG values.

Temporal Variation



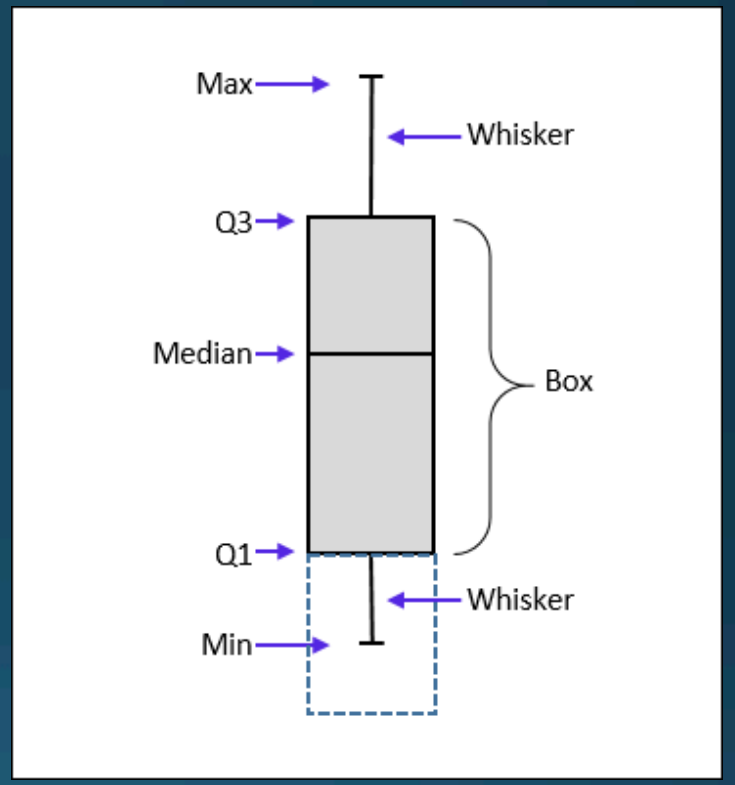
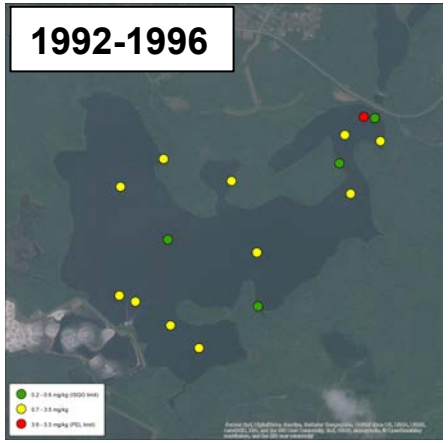
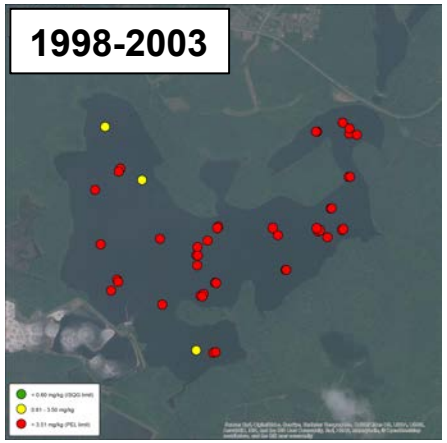


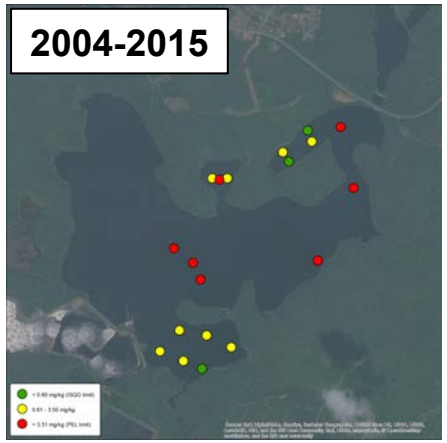
Fig. 5. Temporal variation (1992-2015) of metal(loid) concentrations in Boat Harbour sediment.Years attributed with same letters were not significant and those with different letters were significantly different ($p < 0.05$).

Spatio-temporal Variation: [Cd]

CCME Freshwater SQGs

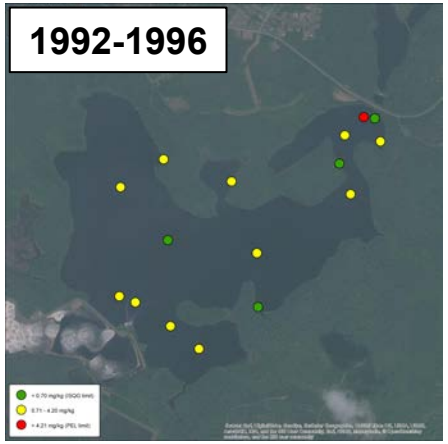


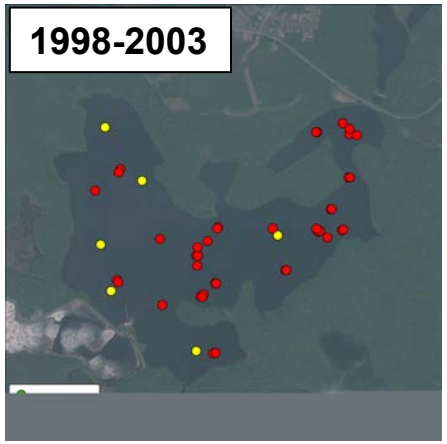


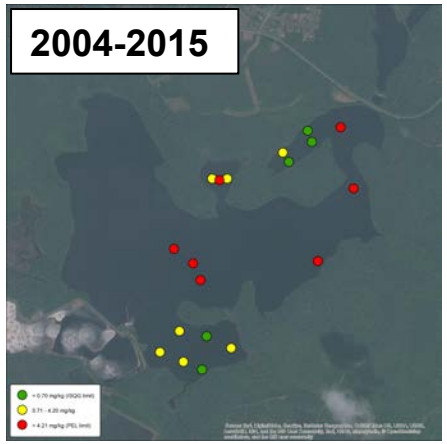


- < 0.6 mg/kg (ISQG limit)
- 0.61 – 3.50 mg/kg
- > 3.51 mg/kg (PEL limit)

CCME Marine SQGs





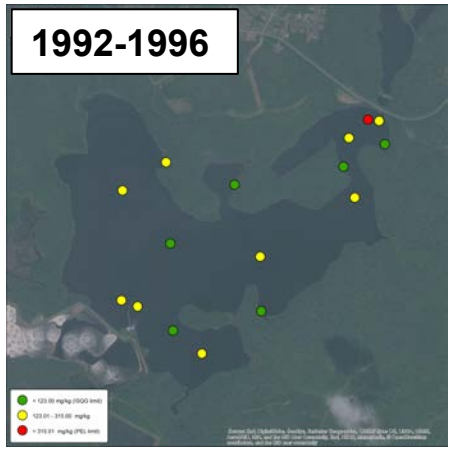


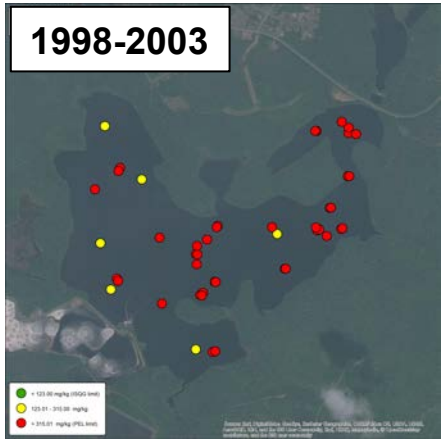
- < 0.70 mg/kg (ISQG limit)
- 0.71 – 4.20 mg/kg
- > 4.21 mg/kg (PEL limit)

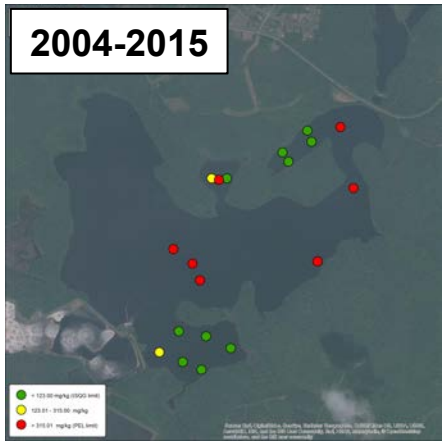
Background level: 0.3 mg/kg

Spatio-temporal Variation: [Zn]

CCME Freshwater SQGs

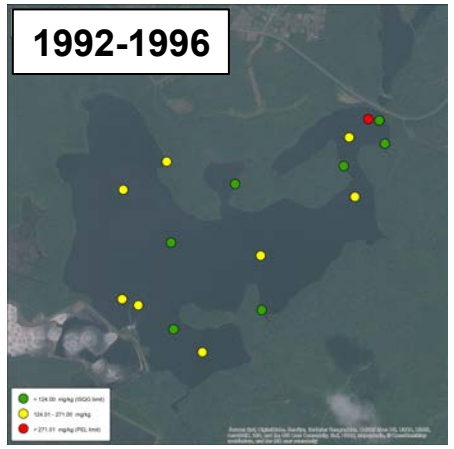


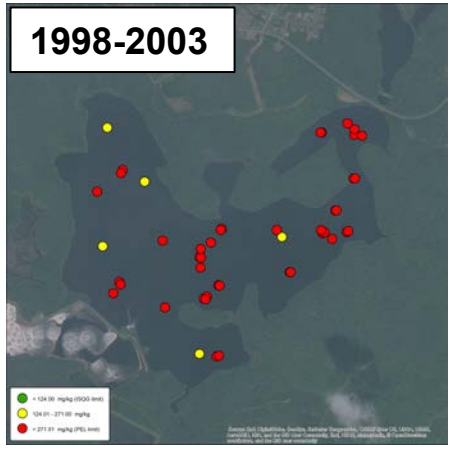


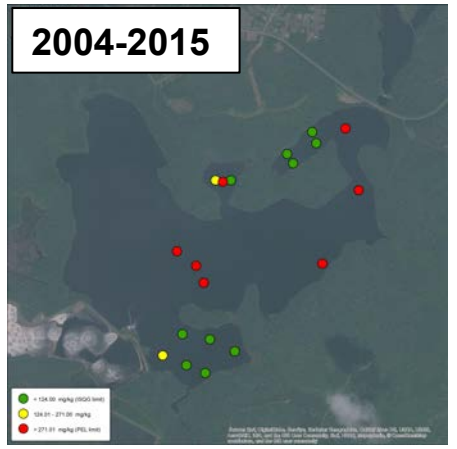


- < 123.00 mg/kg (ISQG limit)
- 123.01 – 315.00 mg/kg
- > 315.01 mg/kg (PEL limit)

CCME Marine SQGs







- < 124.00 mg/kg (ISQG limit)
- 124.01 – 271.00 mg/kg
- > 271.01 mg/kg (PEL limit)

Background level: 150 mg/kg

Sources of Metal(loid)s

- Results implicate the mill's effluent as the primary source of metal(loid) loadings in BH

- Other *potential* metal(loid) sources:
  - Atmospheric deposition from local point source emitters (e.g., the mills smokestacks, thermal generating station)
  - Effluent discharged from a chlor-alkali facility between 1971-1992
  - Natural sources (e.g., geological weathering)

Recommendations

- More detailed sediment sampling (e.g., piston coring, discrete sampling across vertical horizons, dating and greater spatial coverage), should be conducted in BH prior to remediation
- Replicate sampling post-remediation (i.e., before and after study) to monitor changes in BH
- Baseline monitoring at a reference or control site (e.g., Fergusons Pond) is critical to establish a benchmark for comparing contaminated sites before and after remediation

Closing Remarks

- Decades of pulp mill effluent releases has resulted in a large quantity of unconsolidated sediment being deposited in BH
- Gaps and limitations in the historical dataset (e.g., various sampling techniques); however, useful for remediation planning
- Six priority metal(loid)s, due to frequent SQG exceedances
- More detailed sediment sampling should be conducted in BH prior to remediation

Thank you!

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