MIT(H)E-RN: Research Highlights 1998→2004

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MITE Research Network

- History (workshop 1996; network 1999-2004)
- Industrial partners (MAC; OPG; ICA; ILZRO; ...)
- Government partners (NRCan, DFO, EC)
- NSERC research partnerships program
- 3 research domains; focus on Environmental Risk Assessment
  - **sources; processes; impacts**
- 15 universities, 6 government labs; >30 senior researchers, plus PDFs and graduate students (~50)
- Core metals: Cd, Cu, Ni, Pb, Zn, Hg

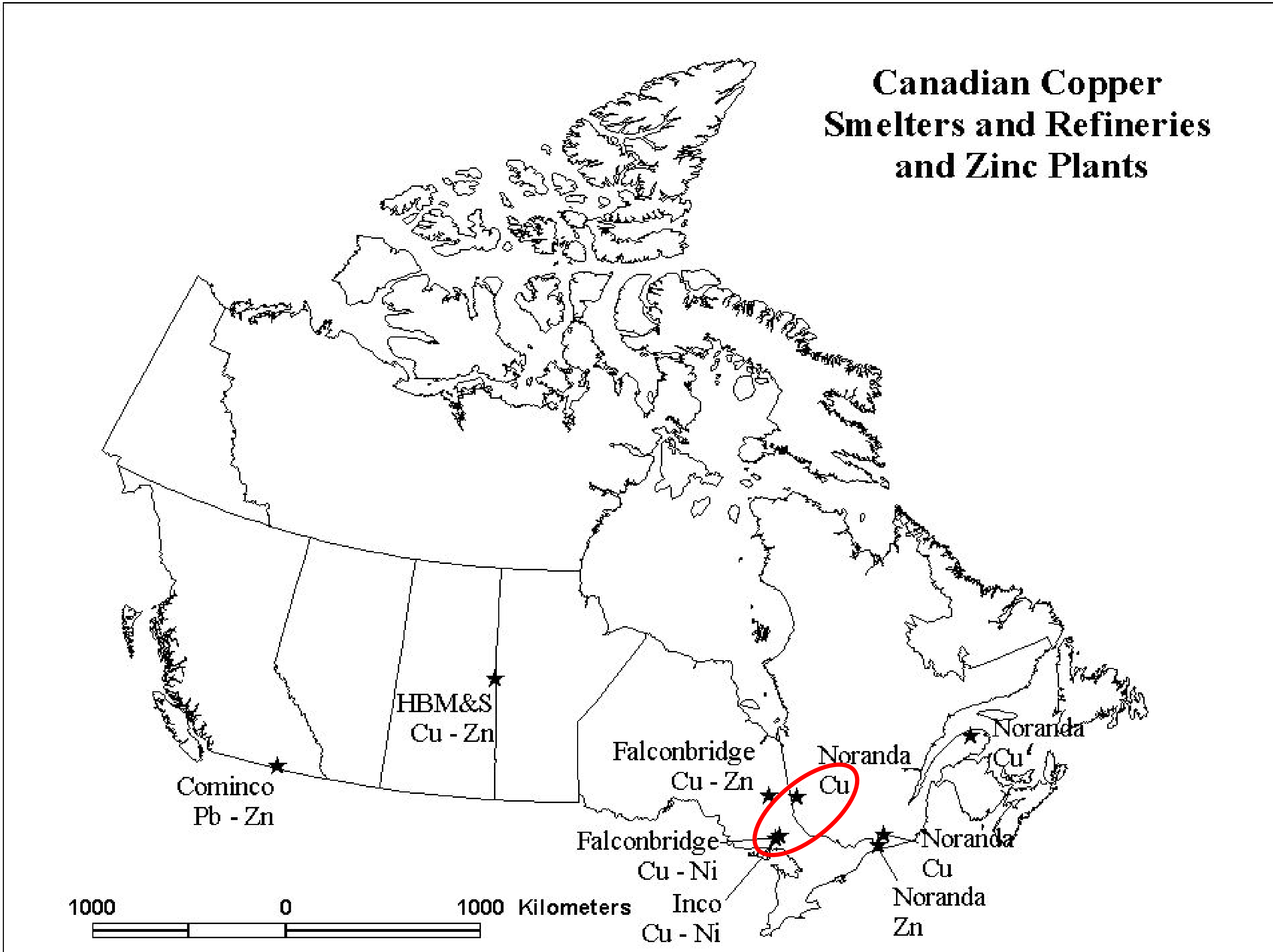
<SOURCES>

Key Words

- atmosphere
- particles / aerosols
- speciation / particle size
- natural / anthropogenic sources
- background metal levels

Projects

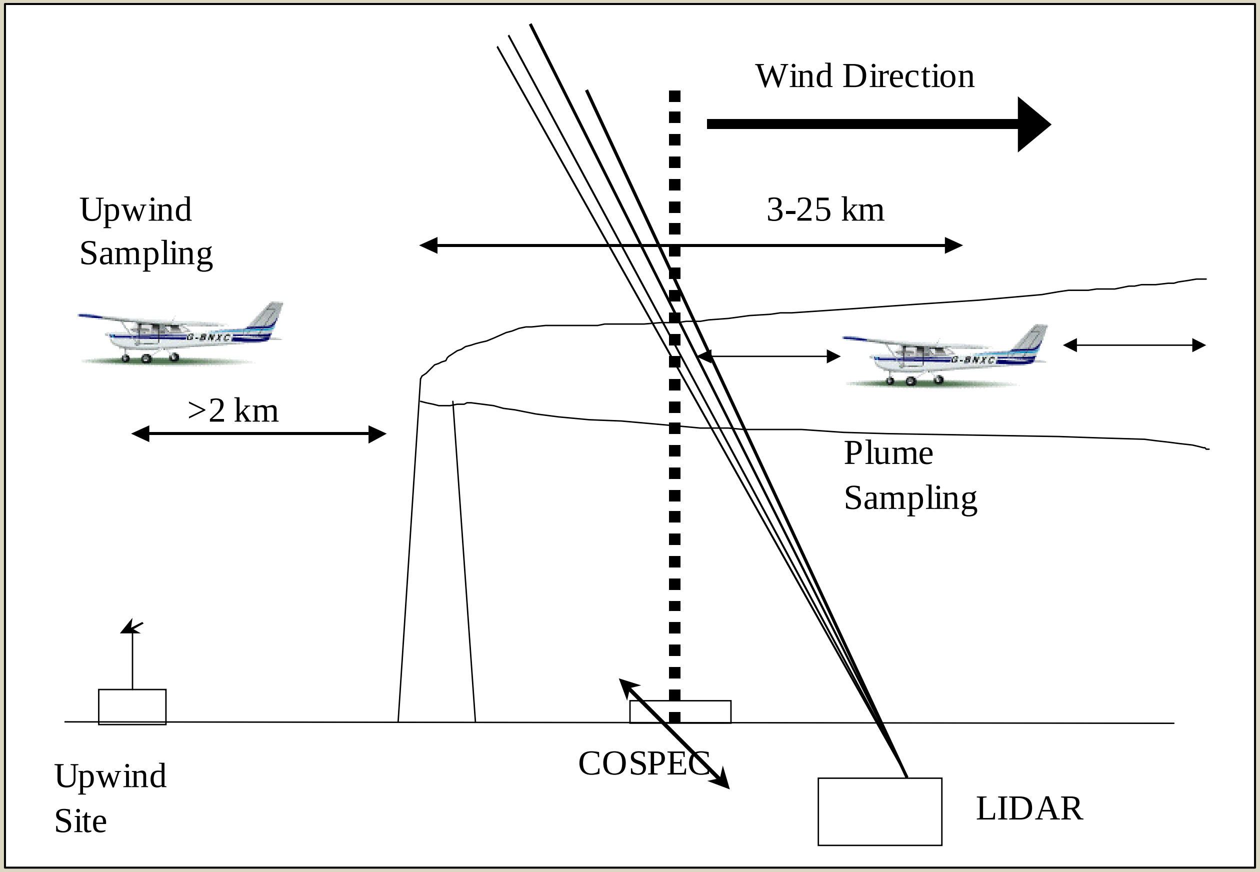
- plume studies (C. Banic et al.)
- sediments as historical archives (R. Carignan & A. Tessier)


Canadian Copper
Smelters and Refineries
and Zinc Plants
HBM&S
Cu - Zn
Cominco
Pb - Zn
Falconbridge
Cu - Zn
Noranda
Cu
Noranda
Cu
Falconbridge
Cu - Ni
Inco
Cu - Ni
Noranda
Cu
Noranda
Zn
1000
0
1000 Kilometers

HORNE SMELTER - ROUYN-NORANDA

Physical and chemical evolution of aerosols in smelter and power plant plumes

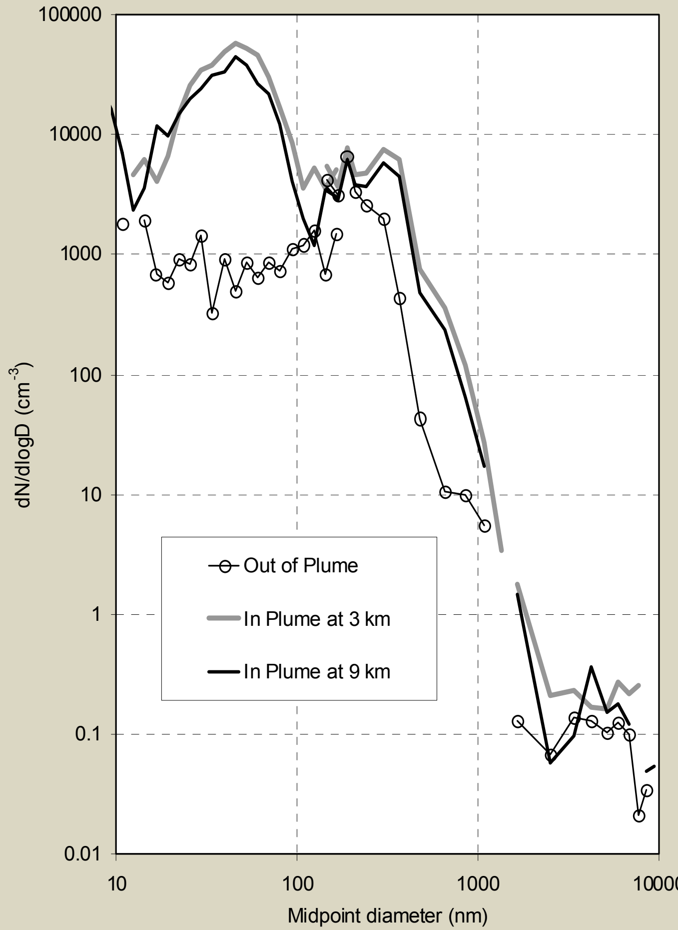
MITE-RN: C. Banic et al. (EC)



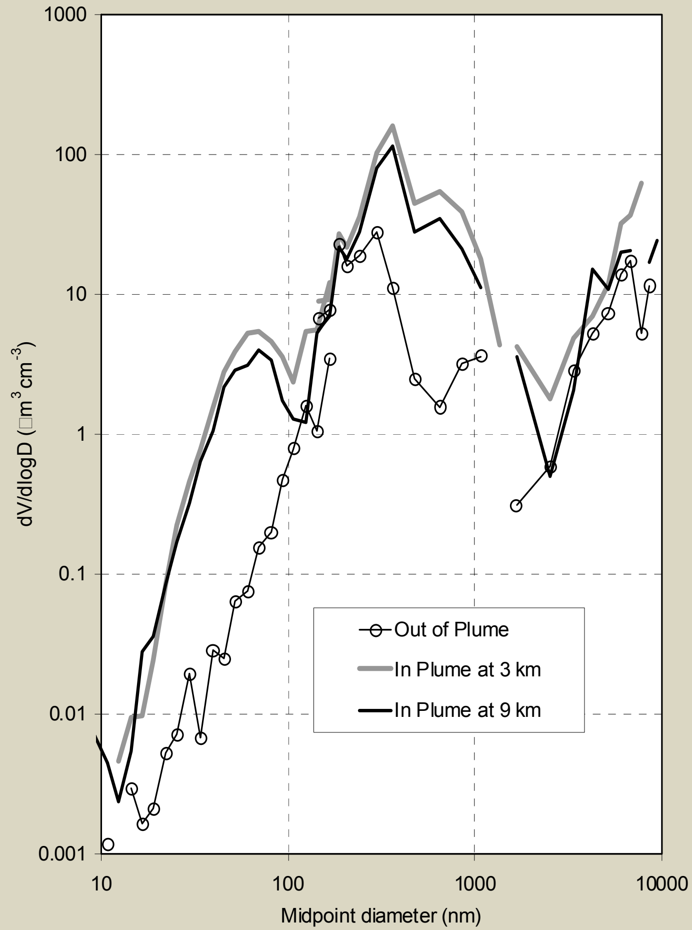
NRCC Twin Otter

MITE-RN: C. Banic et al. (EC)

Distribution of particle number and volume by particle size



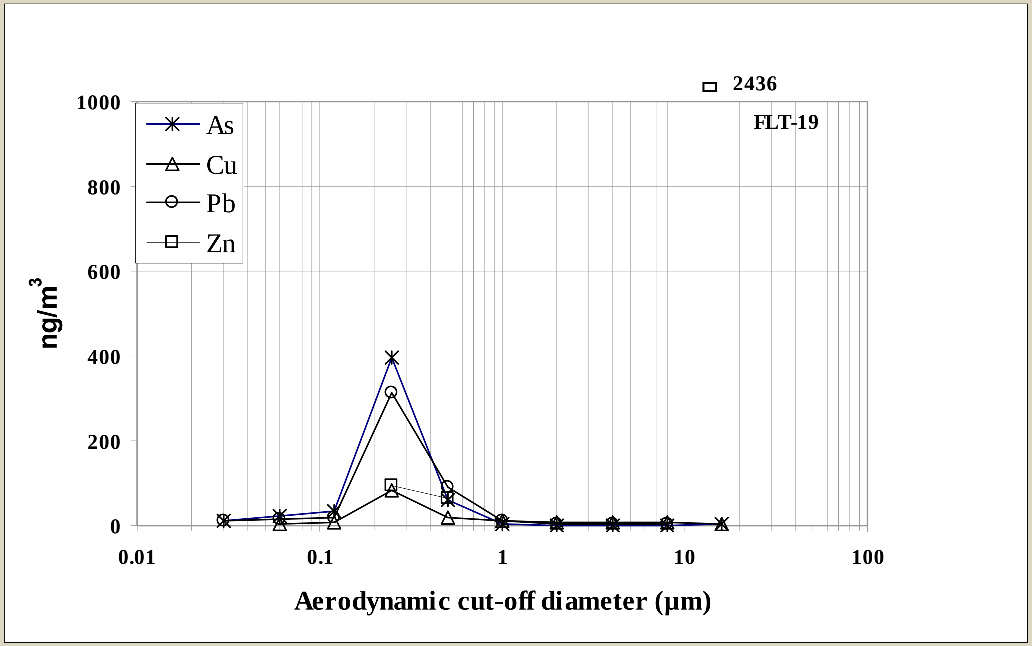
Number distribution



Volume distribution

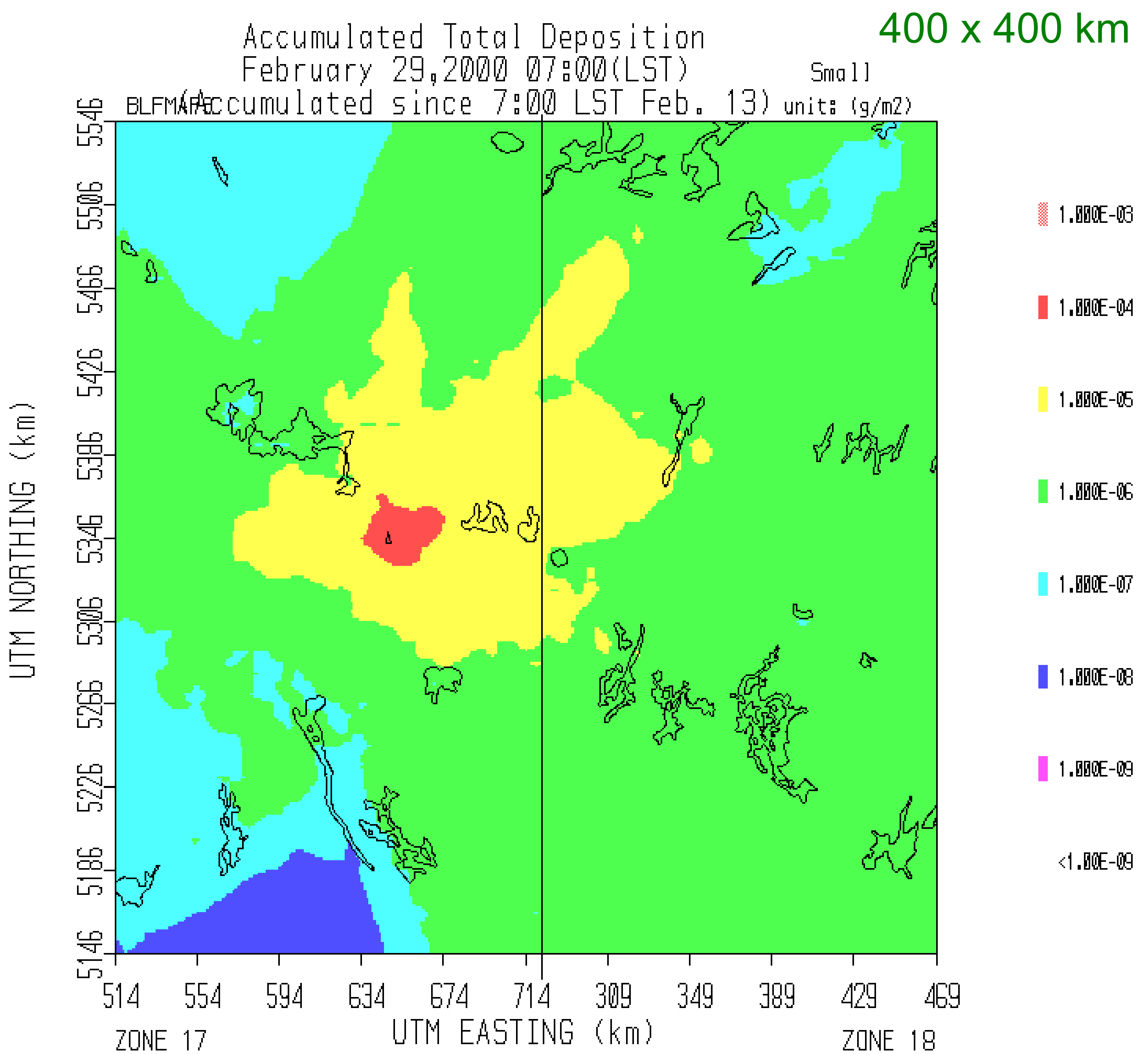
MITE-RN: C. Banic et al. (EC)

Metal content of particles determined as a function of particle size

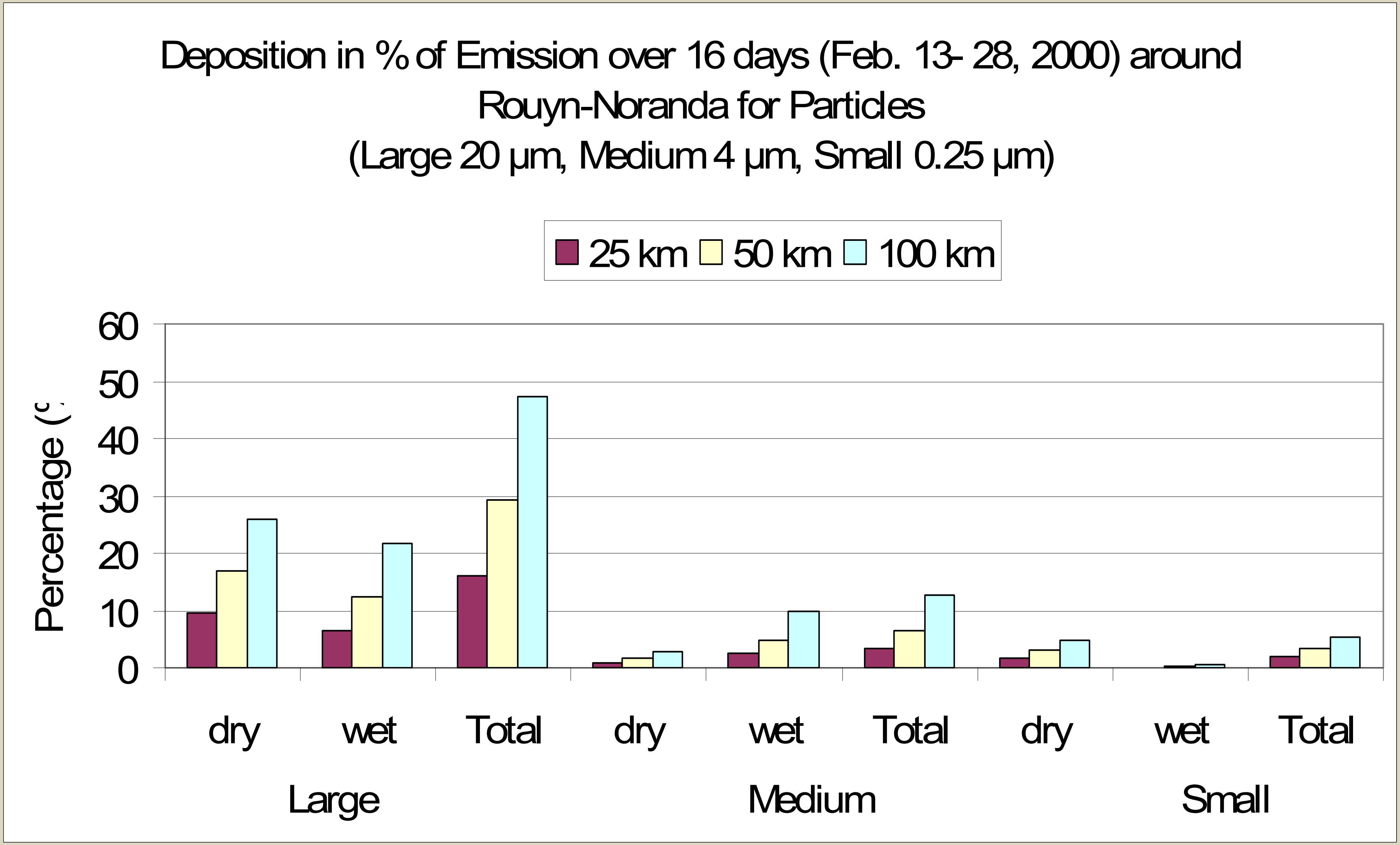


Relative importance of the emissions into the small, medium and large (<2 μm diameter, 2-8 μm and >8 μm diameter) bins selected for the modeling studies.

MITE-RN: C. Banic et al. (EC)



400 x 400 km
Accumulated Total Deposition
February 29,2000 07:00(LST)
Small
BLFMAPAccumulated since 7:00 LST Feb. 13) unit: (g/m2)
UTM NORTHING (km)
5546
5506
5466
5426
5386
5346
5306
5266
5226
5186
5146
514
554
594
634
674
714
309
349
389
429
469
ZONE 17
UTM EASTING (km)
ZONE 18
1.000E-03
1.000E-04
1.000E-05
1.000E-06
1.000E-07
1.000E-08
1.000E-09
<1.00E-09



MITE-RN: C. Banic et al. (EC)

Plume Study Results

- Atmospheric modeling, using meteorology and measured properties of particles, reproduces the "bull's-eye" of increased metal concentrations around the smelter, but also suggests that "the most of the As, Cu and Pb is transported beyond 100 km".

High loading

Rouyn-Noranda

Medium loading

Haute-Mauricie

Low loading

Havre-St-Pierre

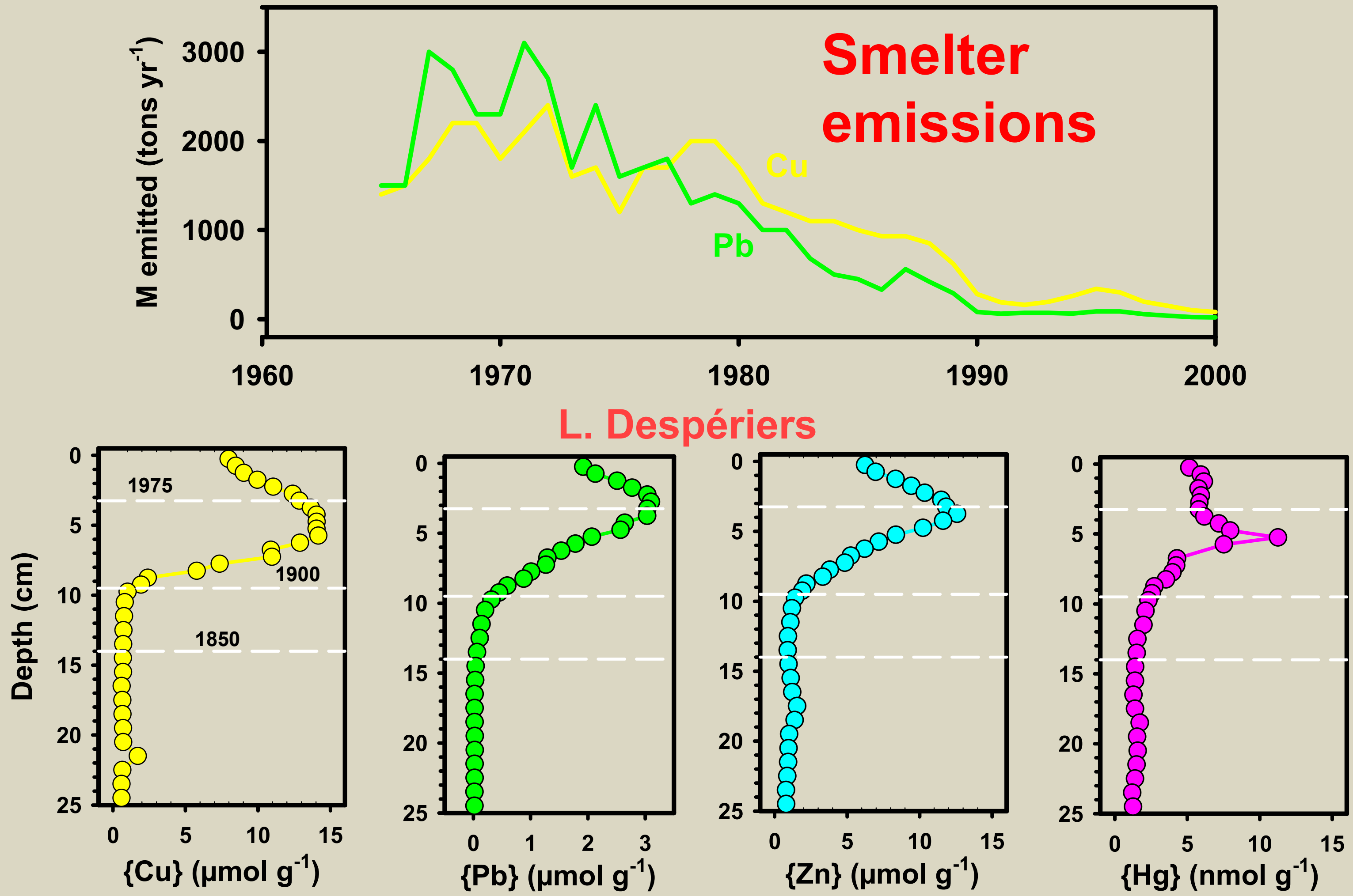
Manicouagan

Lake/Watershed characteristics

- Headwater lakes
- Low ratio watershed/ lake surface area
- Undisturbed/uninhabited
- Hypolimnion seasonally anoxic <u>*or*</u> Low benthic community

- Similar pH, DOC

Progressive and substantial decrease in M deposition (last 20-30 yrs)



<SOURCES>
Ideas to retain

- Smelters still contributing to airborne metals, but clear evidence for reduced atmospheric deposition of metals since ~1980.
- In lake sediments, post-depositional mobility varies among metals:
  - in most cases (but not all), metal vertical profiles in sediment cores can be interpreted as records of historical metal deposition (e.g., Cd, Pb; not As, Pd)
  - i.e., use of metal profiles for *a posteriori* monitoring

<PROCESSES>

Key words

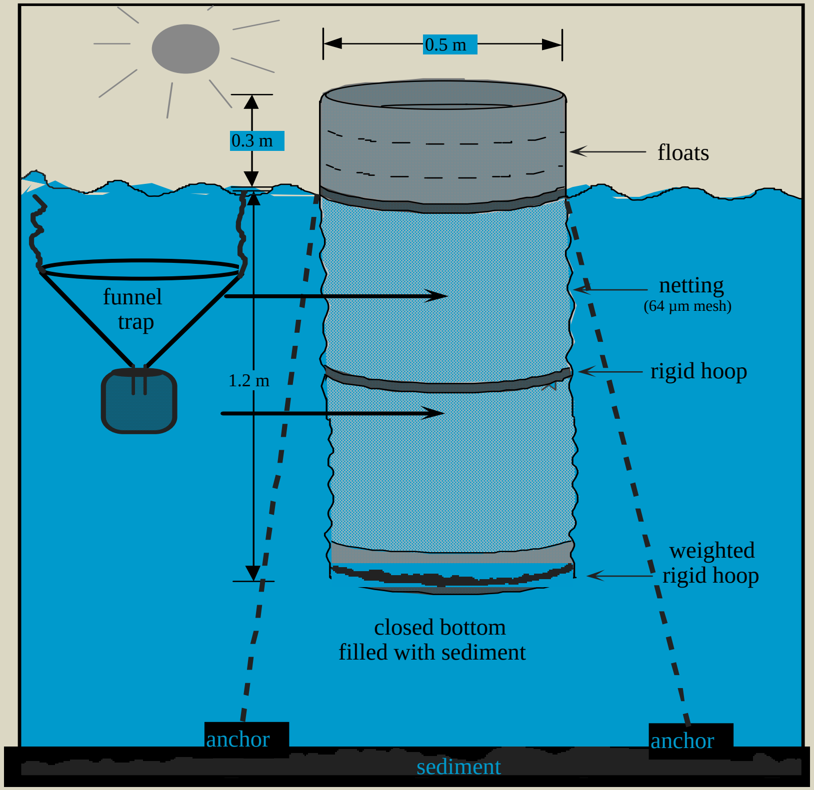
- bioavailability
- metal speciation
- metal mobility
- biotic <-> abiotic partitioning
- exposure

Projects

- relative importance food and water as metal exposure vectors
- recovery following reduction in smelter emissions

(L. Hare & A. Tessier)

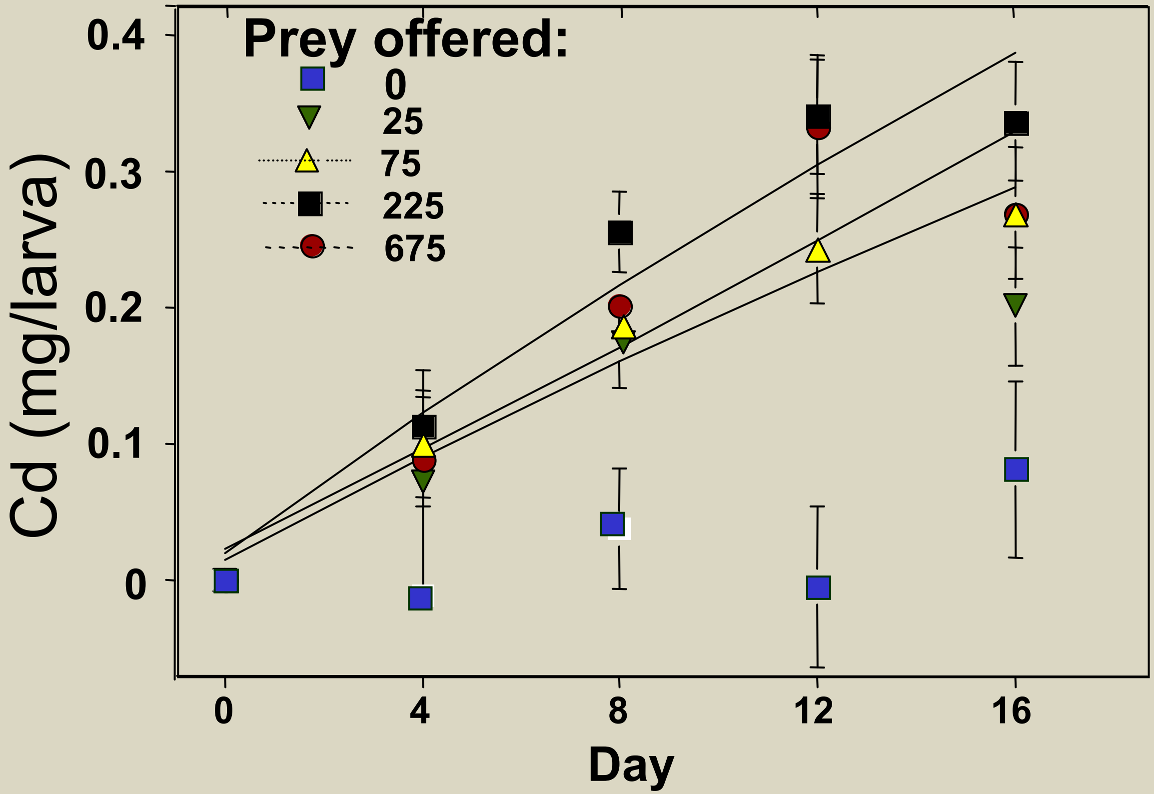
Relative importance water *vs.* food



Transfer of *Chaoborus* from a control lake to a lake with high ambient [Cd]

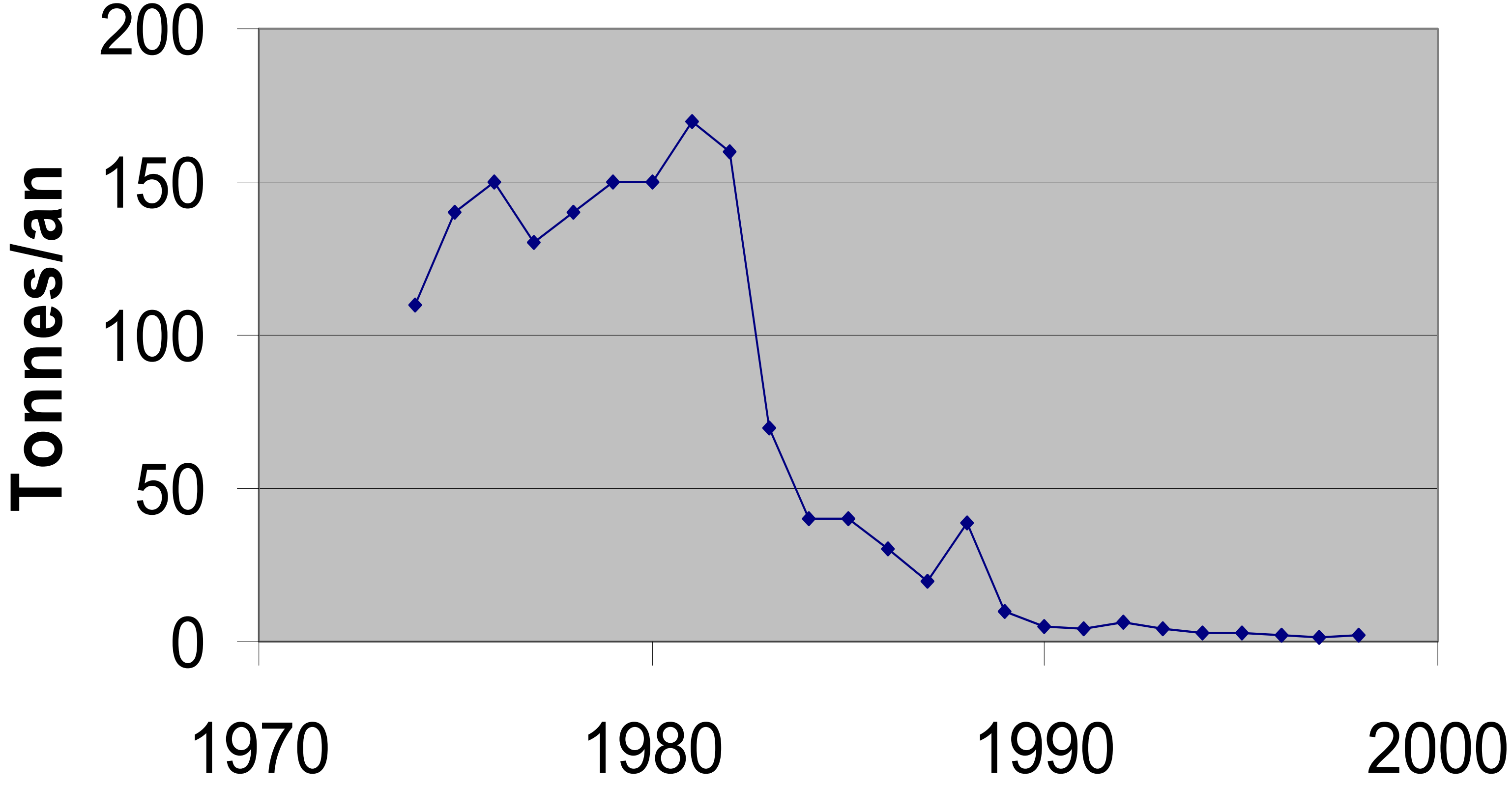
MITE-RN: L. Hare et al.

Uptake from water: negligible in the field



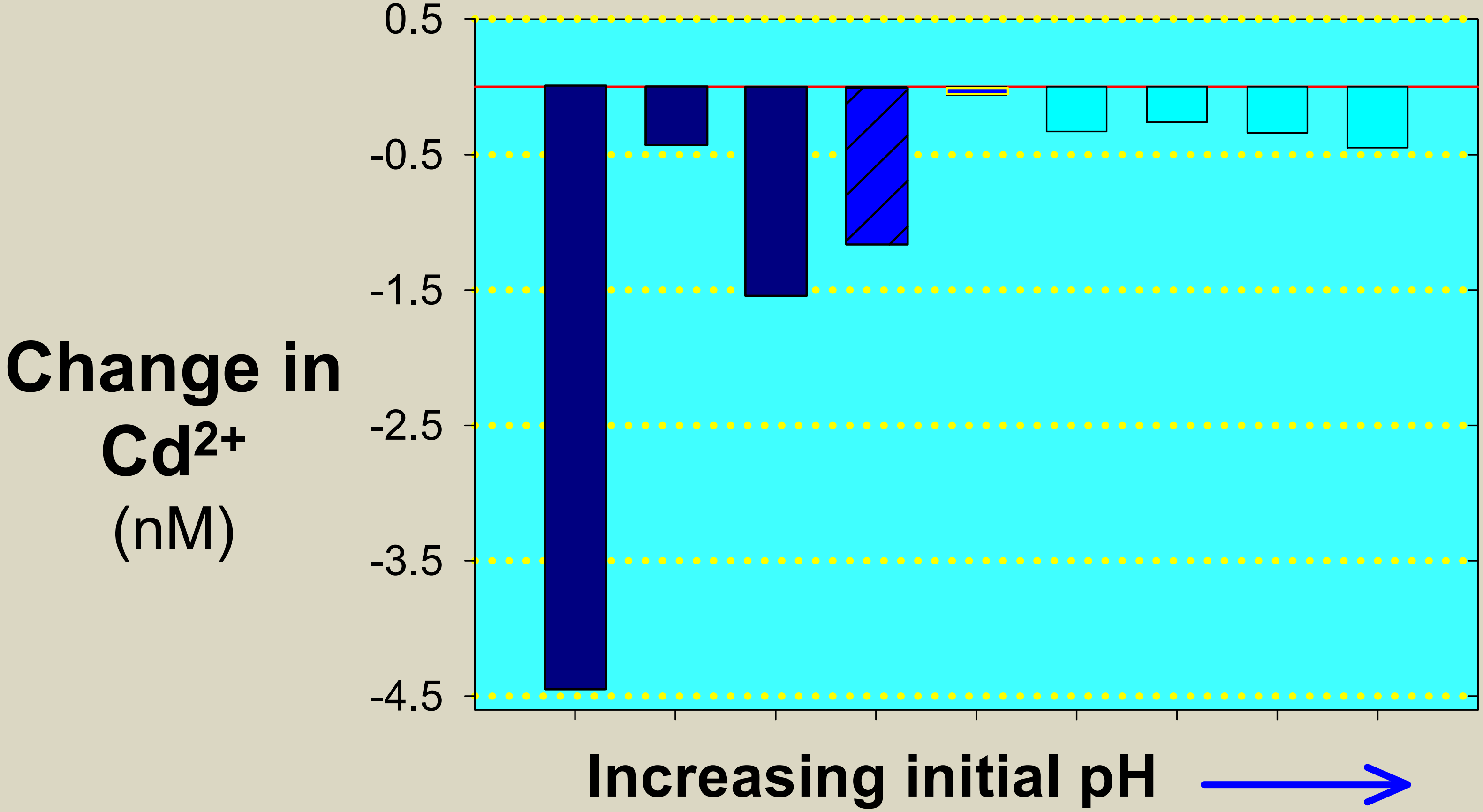
MITE-RN: L. Hare et al.

Rouyn-Noranda smelter - Cd emissions



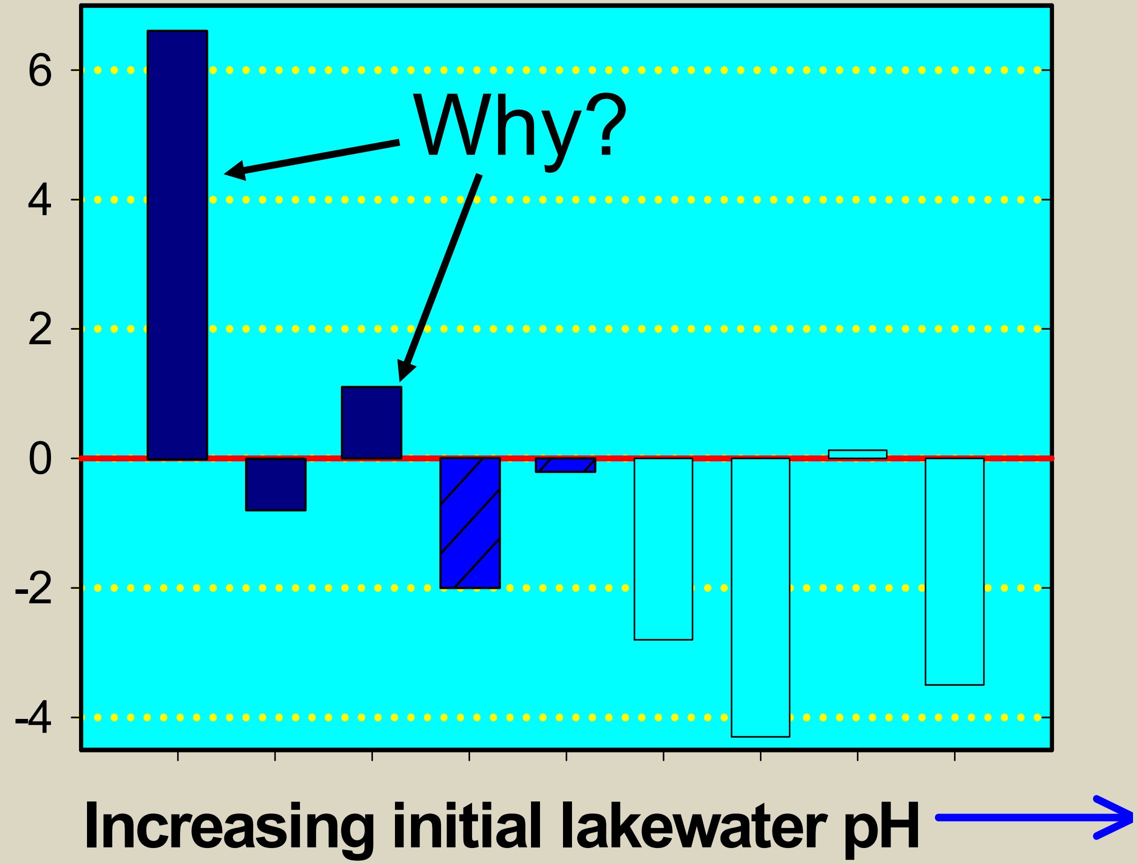
Data from Noranda Inc.

Changes in [Cd^{2+}] in Rouyn-Noranda lakes from 1987-2001



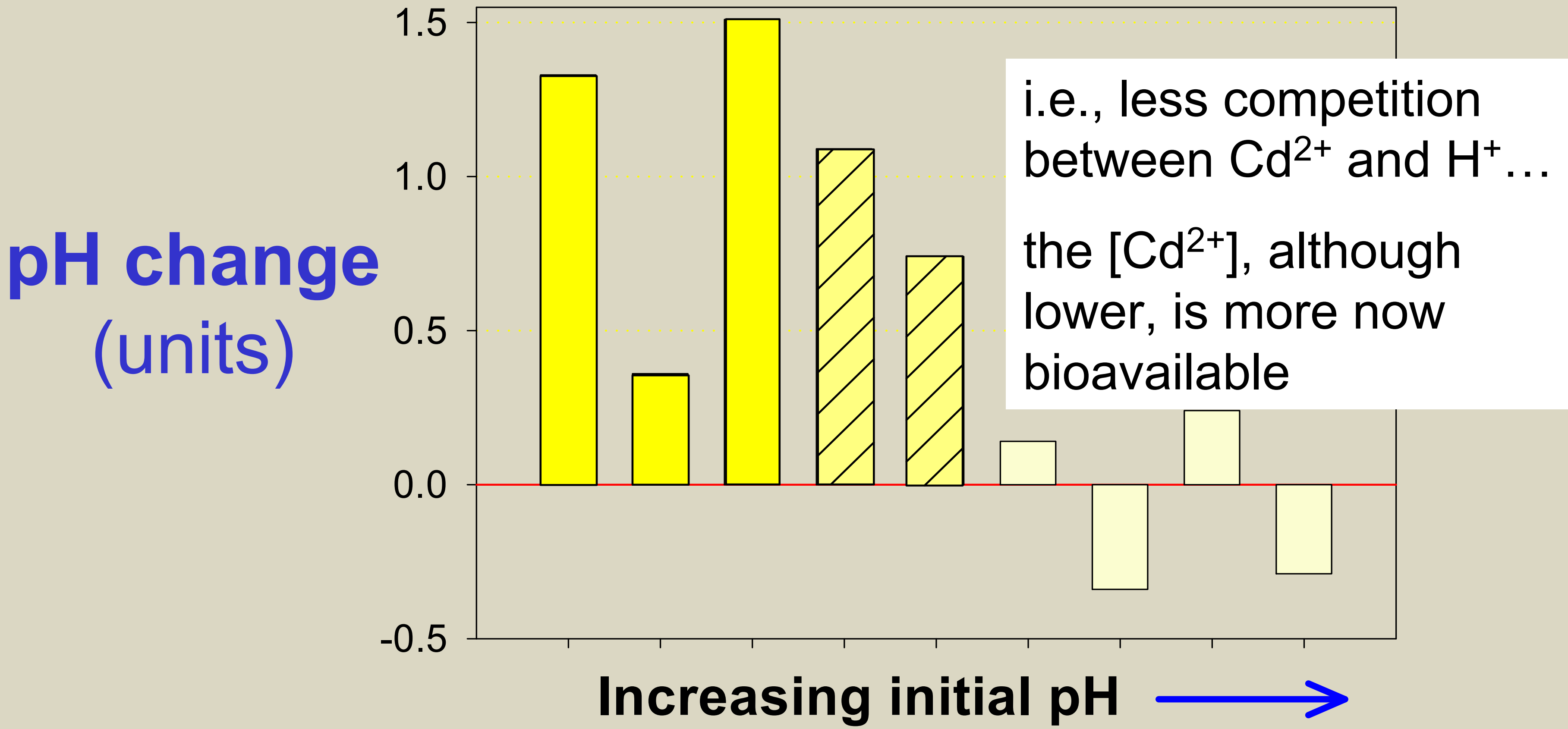
MITE-RN: L. Hare et al.

Changes in *Chaoborus* Cd in these lakes from 1987-2001



MITE-RN: L. Hare et al.

Because in addition to $[Cd^{2+}]$ ↓, also $[H^+]$ ↓



MITE-RN: L. Hare et al.

<PROCESSES>
Ideas to retain

- Diet-borne metals may be more important that previously thought (potential implications for setting Water Quality Guidelines for metals).
- Interplay between $[H^+]$ and $[M^{z+}]$.
- Importance of historical water quality data for interpreting the response the (aquatic) ecosystem to emission controls.

<IMPACTS>

Key Words

- essential *vs.* non essential metals
- interplay between lab <=> field
- metal speciation; modeling
- emphasis on aquatic organisms
- uptake, bioaccumulation, toxicity, detoxification
- tissue / body metals

Projects

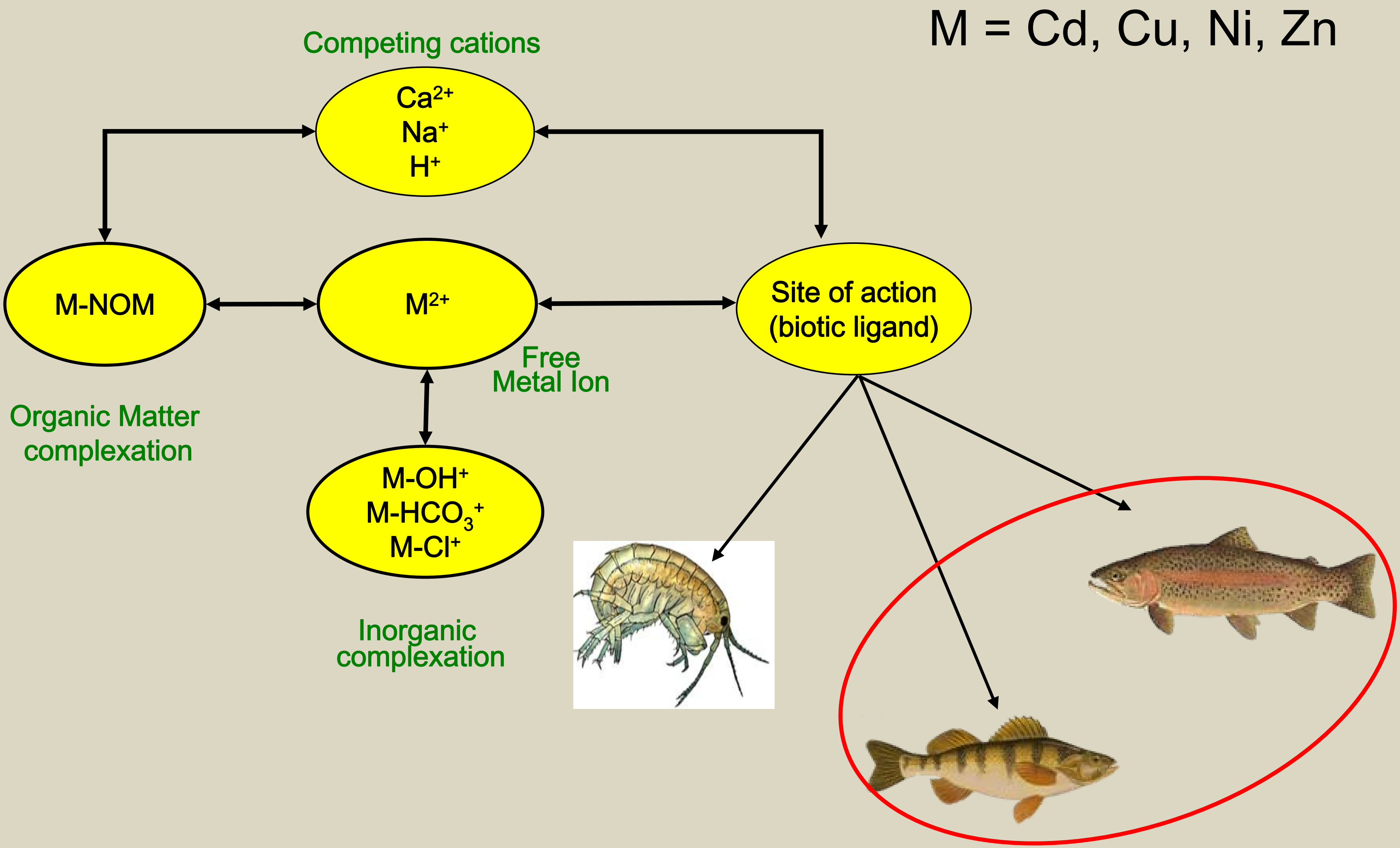
Lab

- Biotic Ligand Model development (C. Wood)

Field

- Failure of “spillover” model of metal toxicity (A. Hontela & P. Campbell)
- Indirect (food-web mediated) effects of metals (J. Rasmussen)

Biotic Ligand Approach

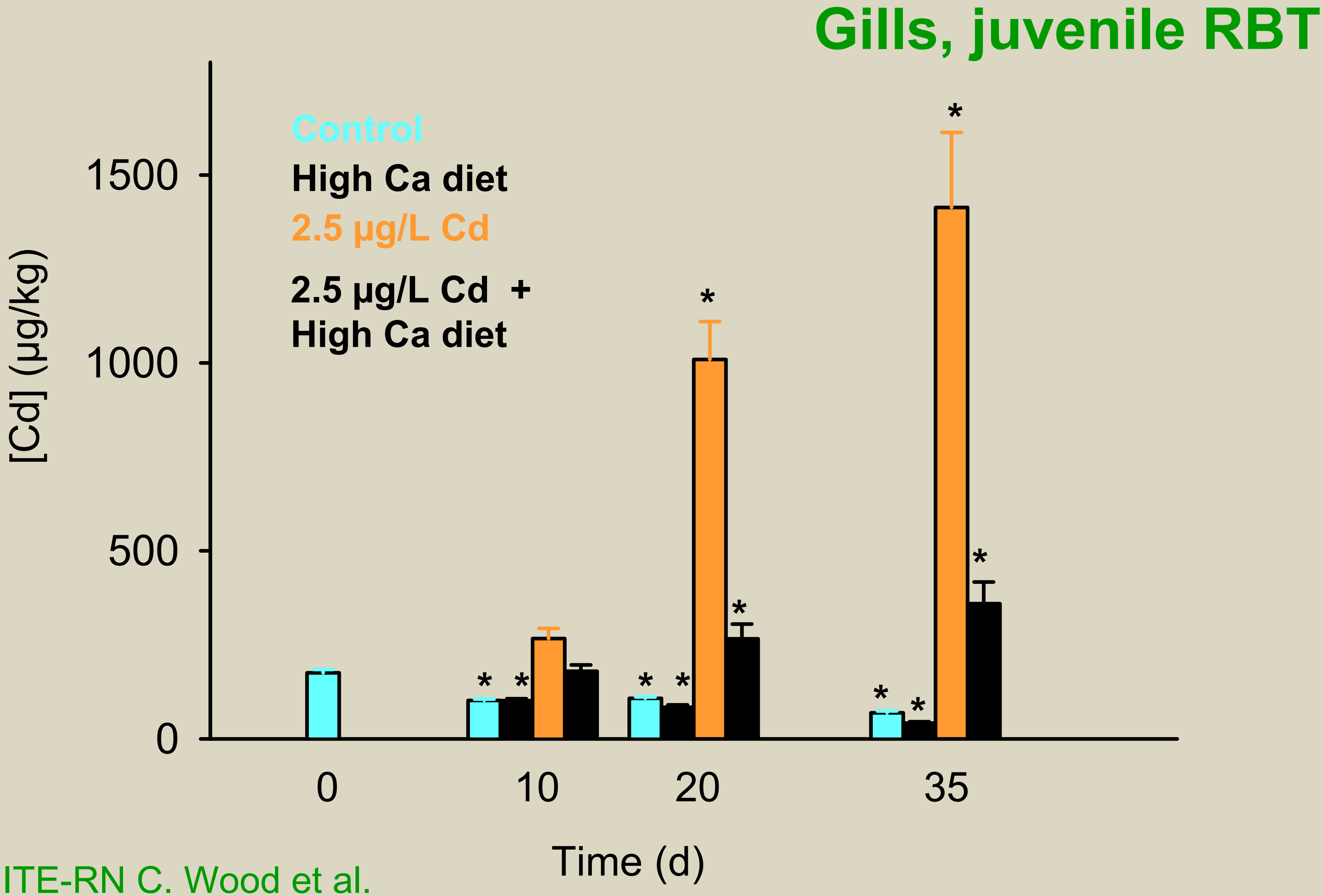


Towards a chronic Biotic Ligand Model

- Study influence of diet on metal uptake and toxicity (ration; major ions; diet-borne metals).
- Compare lab test species (rainbow trout) with species found in lakes (yellow perch) but lab-raised.
- Compare lab-raised and wild yellow perch.

MITE-RN C. Wood et al.

Influence of diet (Ca) on Cd accumulation



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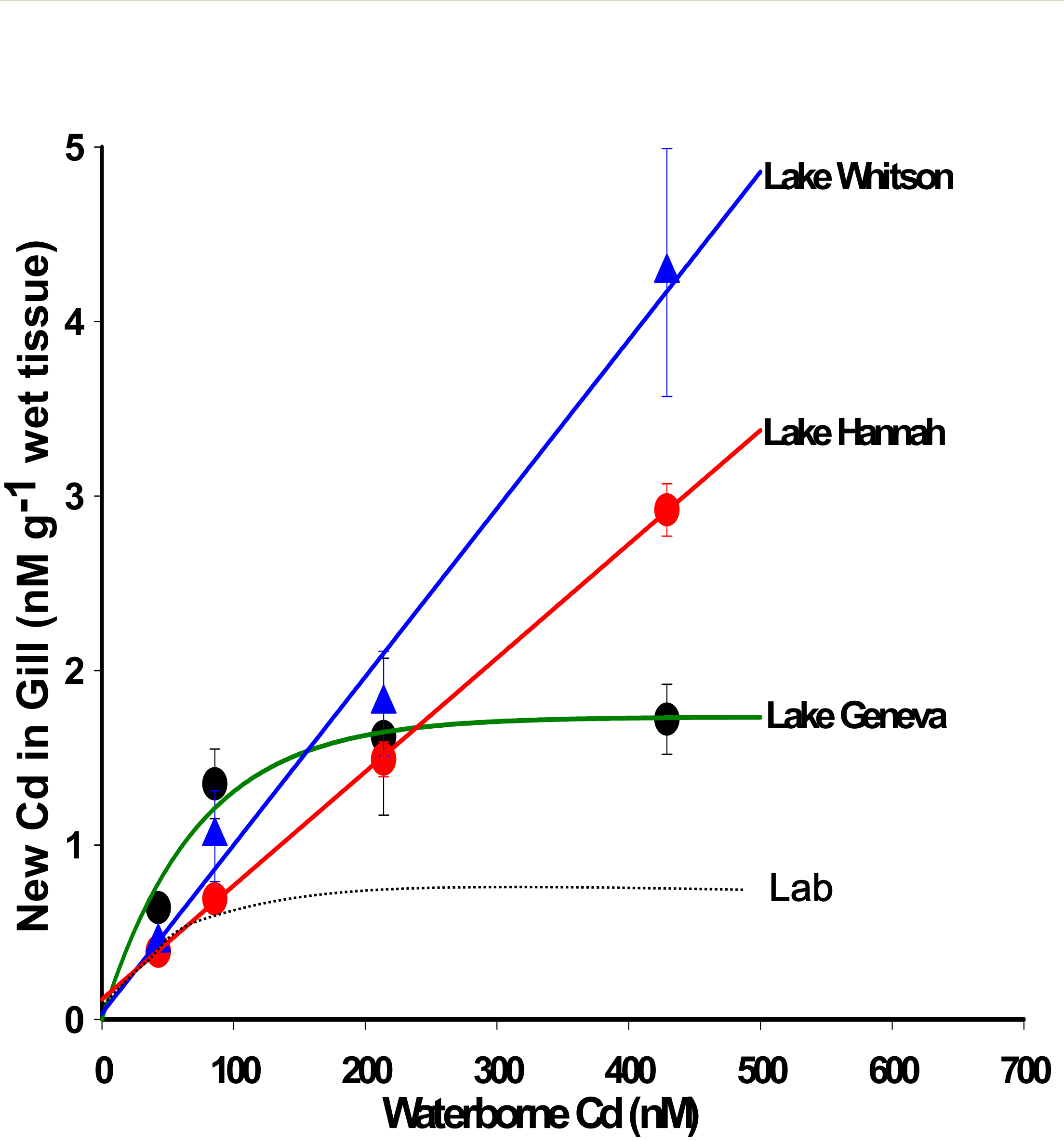
Comparison rainbow trout & yellow perch
(both lab-raised)

	Yellow Perch	Rainbow Trout
96-h LC50 (in μg/L)	8140*	19
Gill Cd-binding Affinity (log K_{Cd})	7.2	7.34
Gill Cd-binding site density (B_{max}) (nmol/g wet wt.)	0.67	0.85
Lethal gill Cd accumulation at 3-h (3-h LA50) (nmol/g wet wt.)	17.9*	0.34

Comparison cultured and wild yellow perch



	Geneva	Lab
log K_{Cd}	7.2	7.2
B_{max} (nmol/g wet wt.)	1.8	0.67

MITE-RN C. Wood et al.

BLM Ideas to retain

Diet

Elevated dietary Ca protects against waterborne Cd uptake and gill Cd binding ; elevated dietary Na protects against waterborne Cu uptake and gill Cu binding

Lab-raised YP *vs.* Wild YP

Gill Cd-binding characteristics <u>change</u> with acclimation to different water hardness levels as well as chronic waterborne Cd exposure.

i.e., metal-binding properties of the gill are dynamic and not fixed, a phenomenon that has to be taken into account for the future development of chronic BLMs.

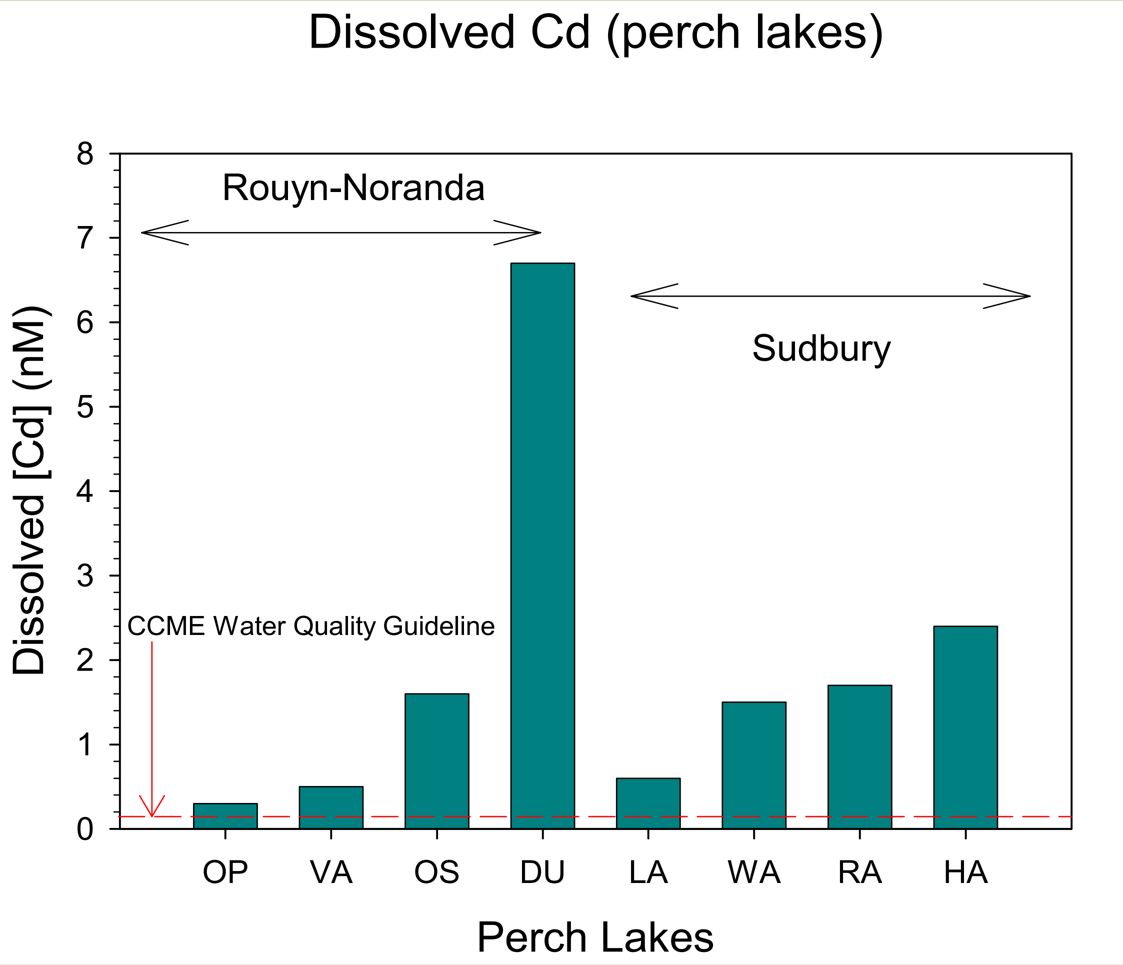
Metal-induced effects… in the field

- **Studies in lakes located along metal concentration gradients**
- **Indigenous organisms (Yellow perch)**
- **Organ-specific metal accumulation; metal subcellular partitioning; biomarkers**
- **Effects at the cellular, organism and population levels**

MITE-RN Campbell, Hontela, Rasmussen

Metal exposure - perch

Lake (code)	[Cd]	[Ni]	[Cu]
Rouyn-Noranda			
Opasatica (OP)	0.3	12	33
Vaudray (VA)	0.5	12	42
Osisko (OS)	1.6	17	141
Dufault (DU)	6.7	8	184
Sudbury			
Laurentian (LA)	0.6	839	139
Wavy (WA)	1.5	895	114
Raft (RA)	1.7	1830	125
Hannah (HA)	2.4	2500	373
max/min	**22**	**313**	**11**



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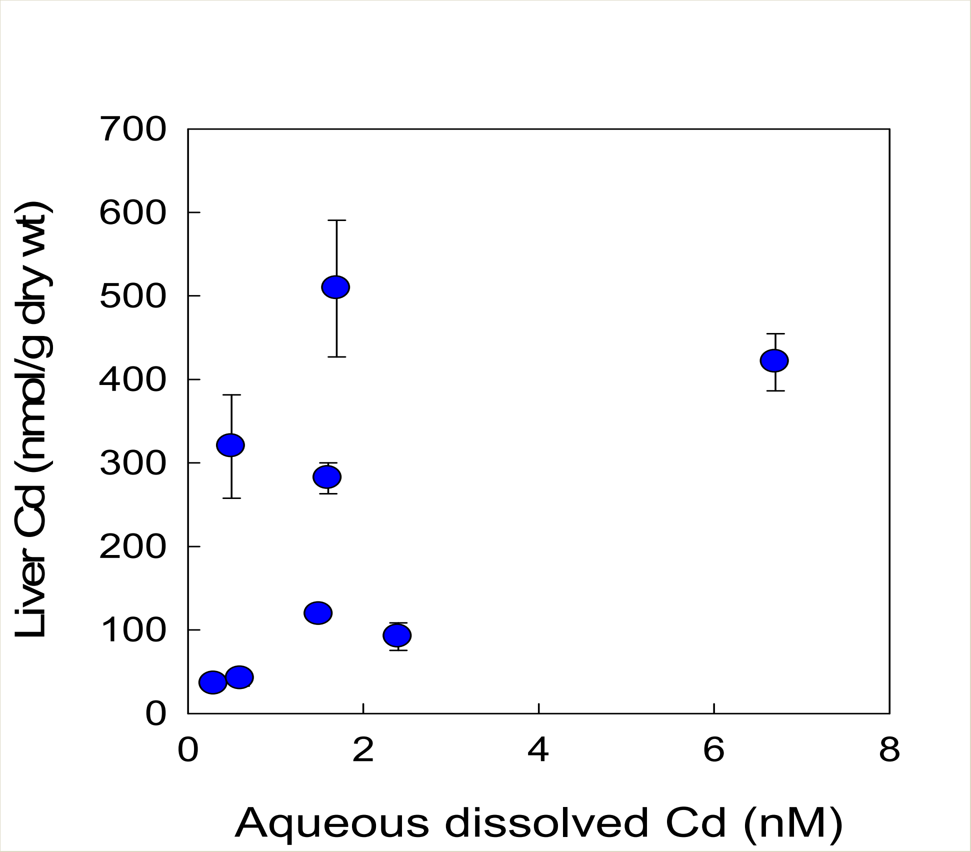
Cd bioaccumulation



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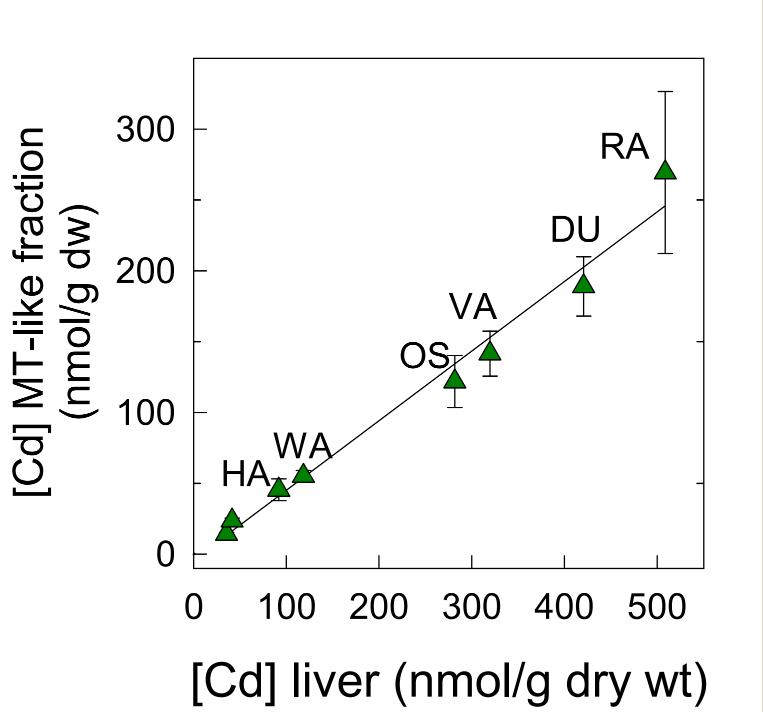
Cd detoxification - metallothionein

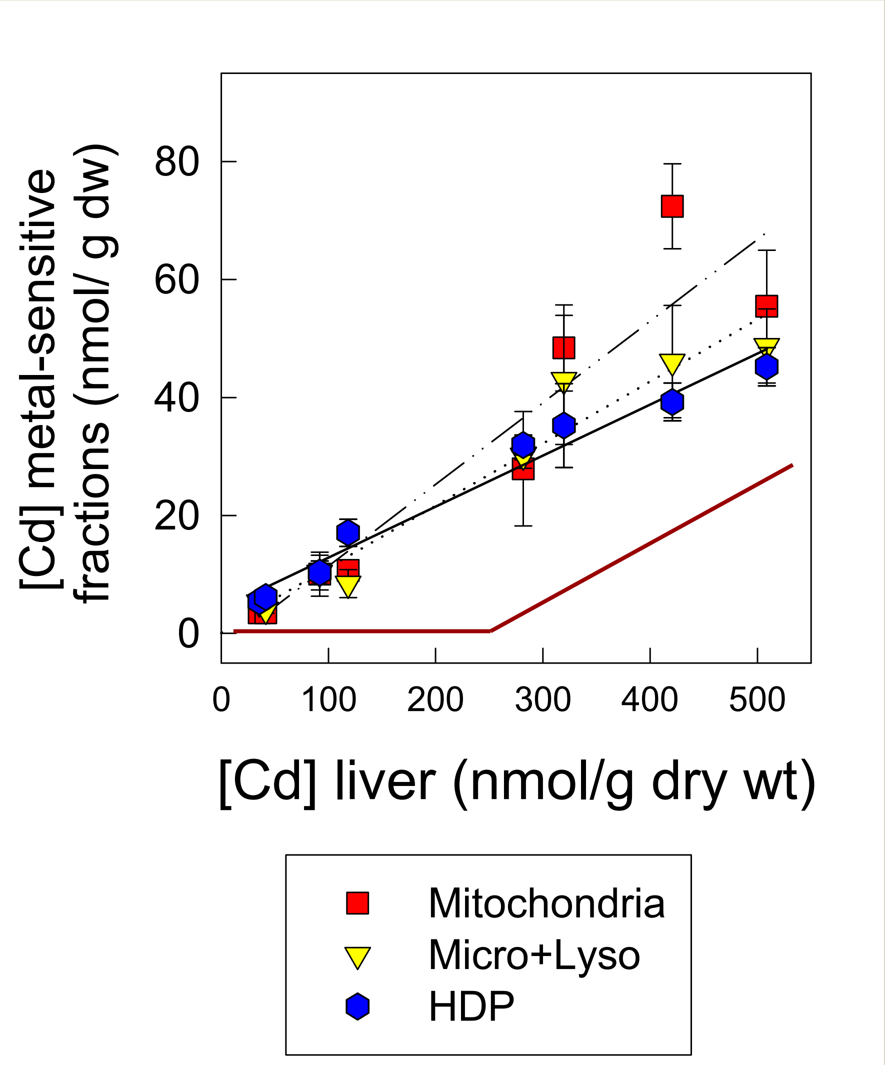


MITE-RN Campbell et al.

 liver

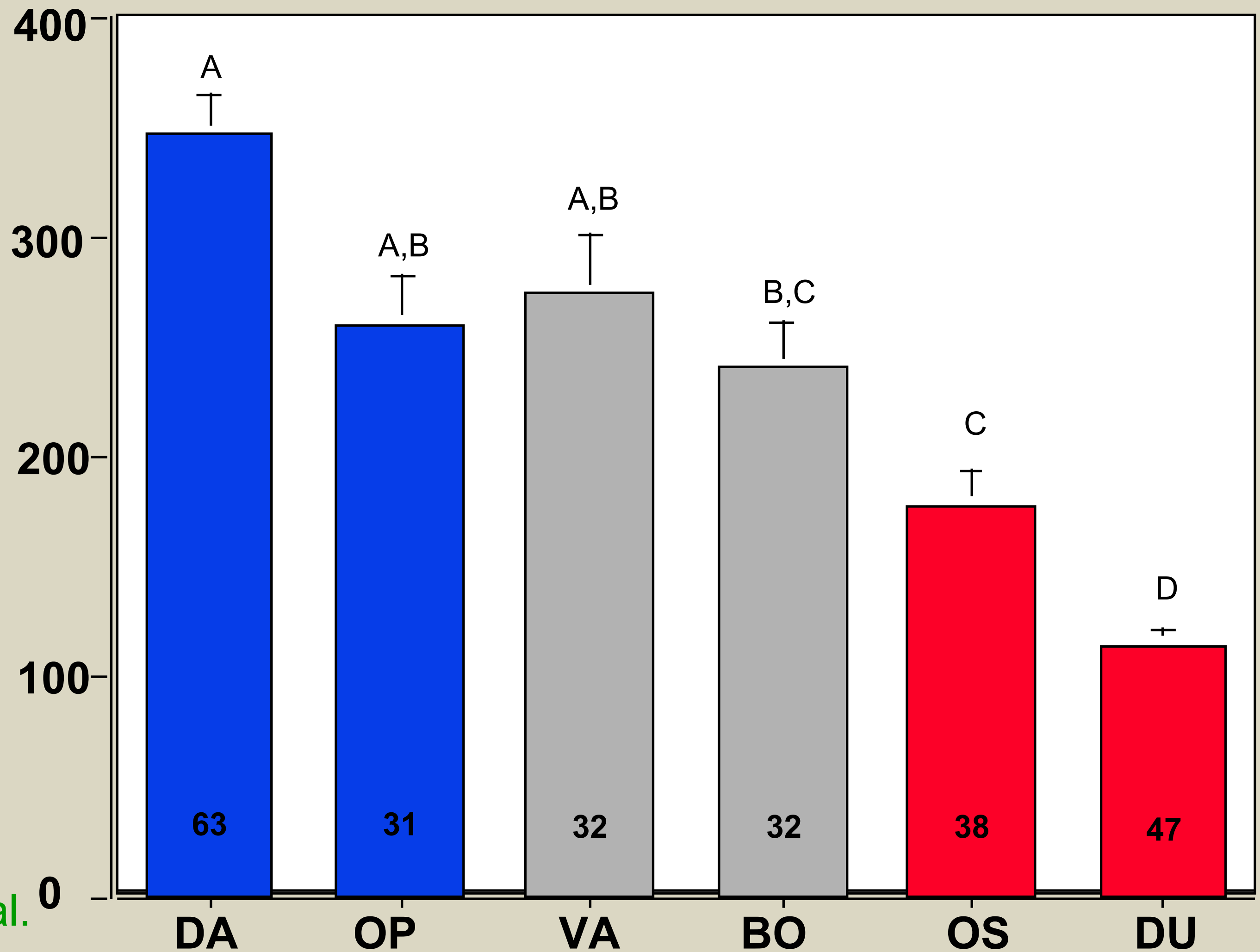
Cd sub-cellular partitioning:

- note increase in all fractions, <u>including</u> HDP
- no threshold below which Cd is not found in HDP or organelles



MITE-RN Campbell et al.

Impaired cortisol response to a stress test



MITE-RN Hontela et al.

Field Ideas to retain

- Cd and Ni increase in all sub-cellular fractions along the inter-lake concentration gradient
- No “hockey stick”; no exposure threshold below which Cd or Ni doesn’t accumulate in putative metal-sensitive fractions
- Metal detoxification is incomplete, even at low metal exposures
- Evidence for physiological / metabolic effects… (Alice Hontela)

MITE Research Network Benefits

- Improved estimates of relative importance of anthropogenic sources of metals to the environment
- Improved understanding of fates of metal emissions
- Better metal exposure characterization for terrestrial and aquatic biota in ecological risk assessment

MITE Research Network Benefits
(continued)

- Improved links between metal exposure in the field and the incidence of metal-induced effects
- Progress towards better water and sediment quality guidelines for metals
- Enhanced ability to choose more relevant and more cost-effective risk management strategies

Metals In The Human Environment

Research Network

Canadian Network of Toxicology Centres

Cathy Banic, EC

Richard Carignan, U de M

Landis Hare, INRS

Alice Hontela, Lethbridge

André Tessier, INRS

Chris Wood, McMaster

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