The Mining Water Symposium: a personal reflection & attempt at a synthesis by an ecologist

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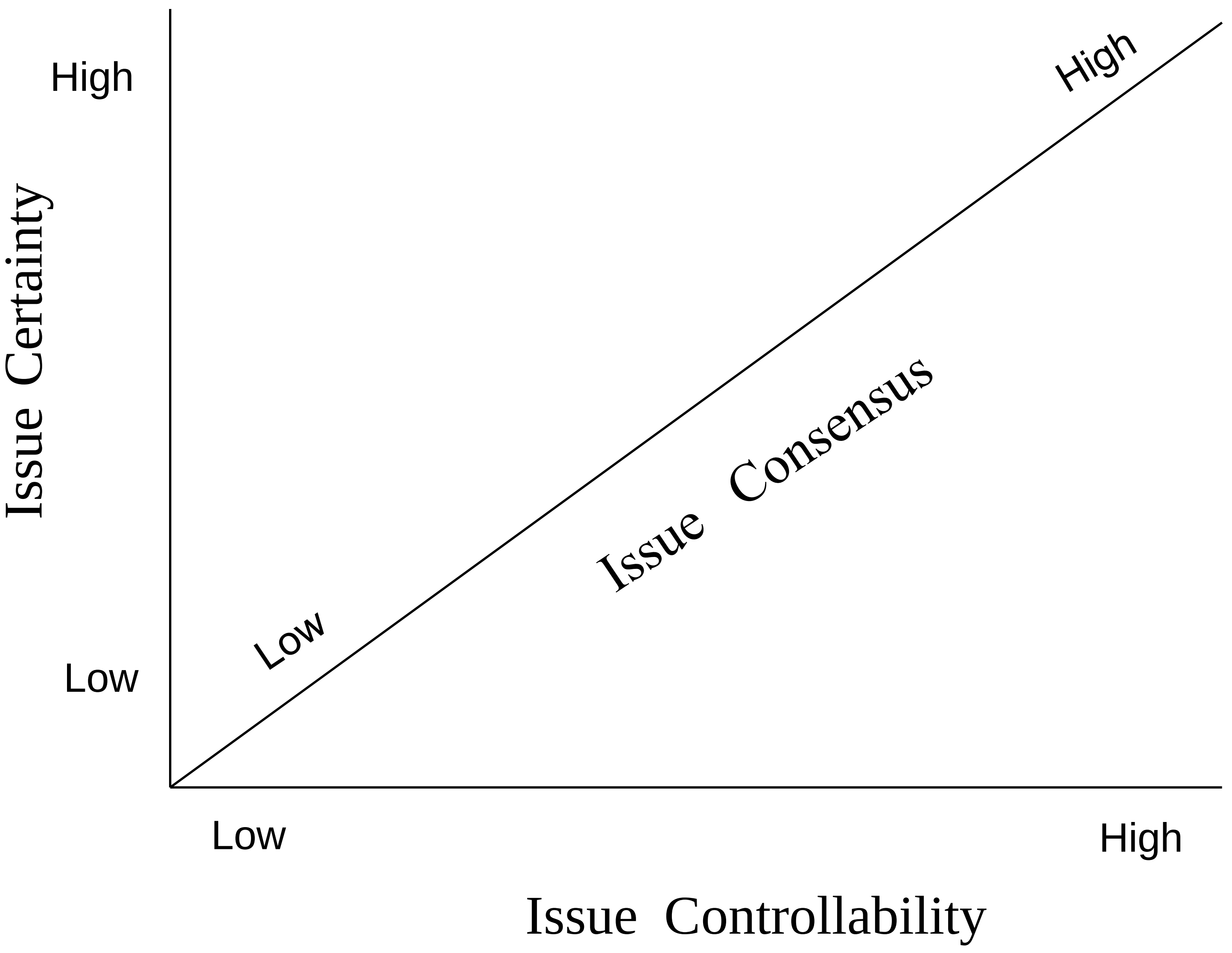
Yan's Relevant Background

34 years of work in the greater Sudbury area, with an MSc on acid rain effects on algae, and a PhD on Cd accumulation in plankton, but little new work on metals until very recently

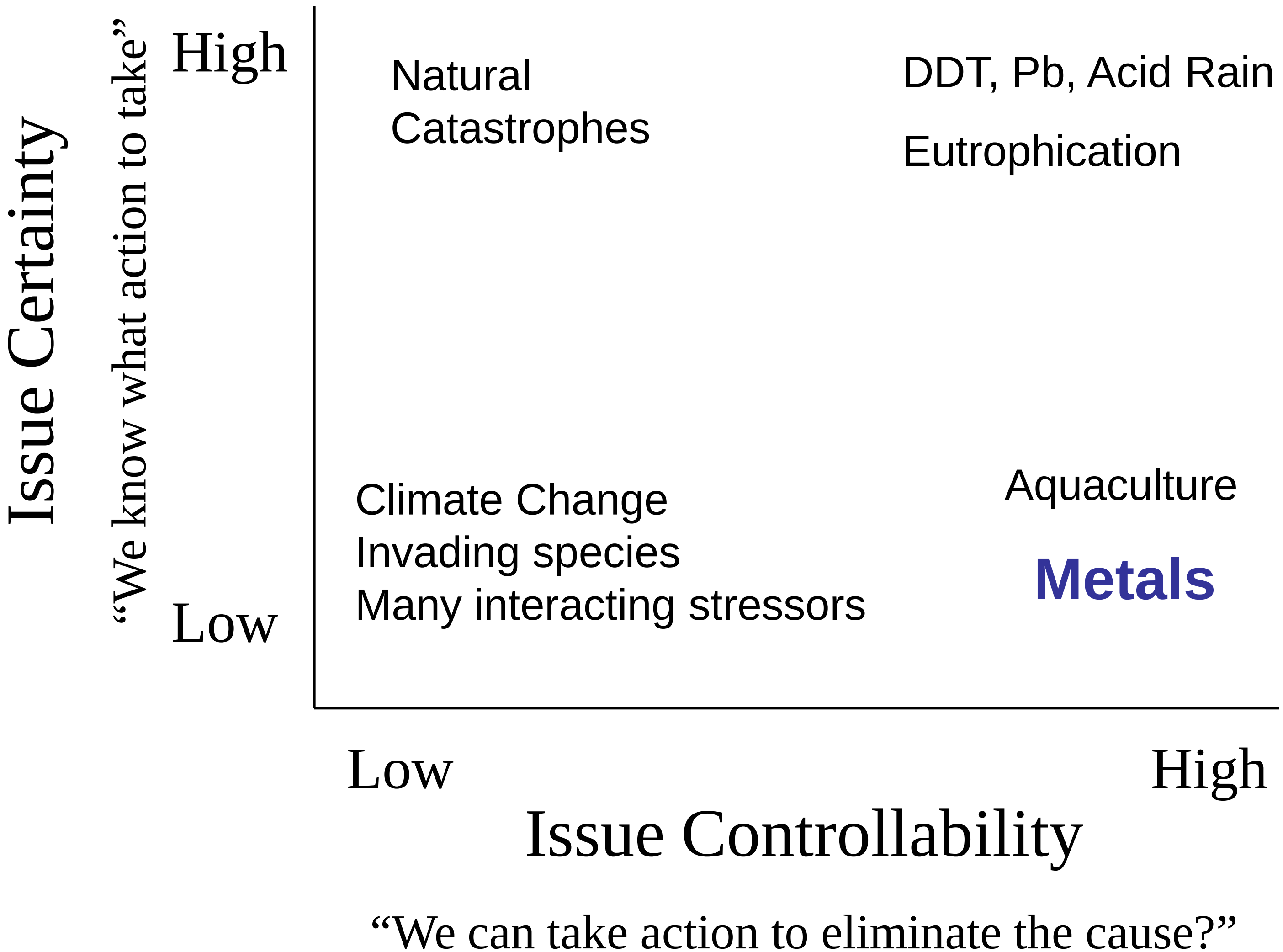
My Approach

Ask what seemed to me to be the relevant questions about what research and monitoring "should be done" on mining, metals and water, then compare this with what has being done and has been learned

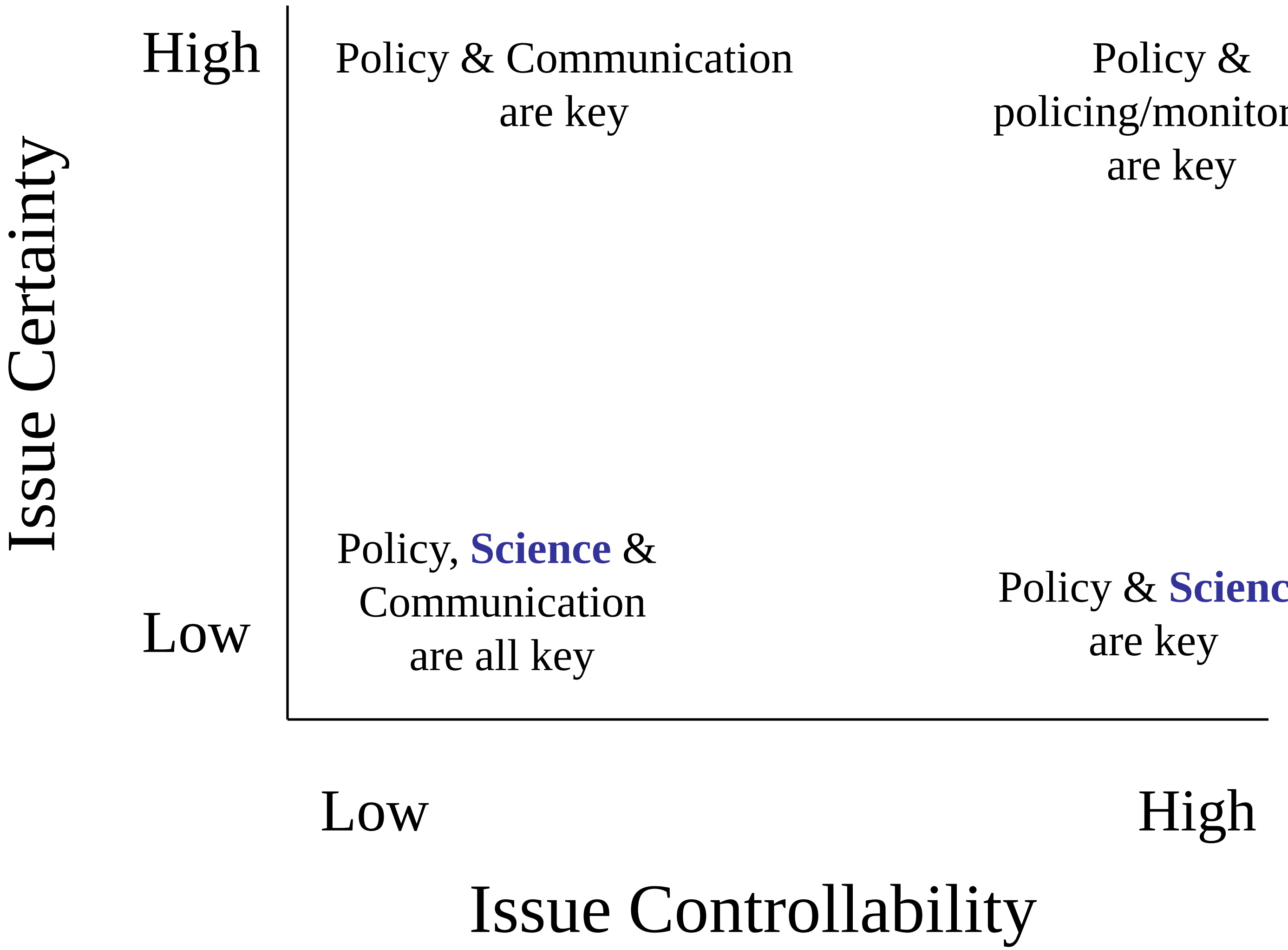
When is environmental management "easy"?



Assuming we agree on the issue, what work needed to be done?



When are Policy/Action + **Science** + Communication most needed?



What are the environmental metal science dilemmas?

- We agree metal discharges pose an environmental issue
- We agree the issue can be controlled, and this control must include reductions in metal discharges, but
- We aren't certain of the metal thresholds at which damage or recovery occurs in nature
- Nor do we even know how exactly to recognize damage.
- Hence, we can't yet construct and verify models, eg. critical load models for metals, as a basis for managing the issue.
- We don't understand what the regulators of and capacity for recovery are, especially at a landscape scale.
- Acidity and metals are commonly confounded, and
- There is a potential for confounding with other stressors such as climate change, Ca decline, DOC rise, and invaders, and
- A possibility that food web and behavioural linkages will alter the effects

So what should scientists do?

1. Assessment research
   - Indicators, targets, SOE reports
2. Diagnosis
   - Determine the problem's cause – is it metals? What are the mechanisms of effect?
3. Prognosis
   - Develop techniques to inform decision making, perhaps eventually culminating in critical load models for metals?
4. Evaluate success of and develop a science of recovery (develop and test conceptual models)
   - Do indicators for all biota return to target value? What are the regulators of recovery?

What science and engineering was done?

1. Research on assessment techniques - 3
2. Research on metal impacts (diagnosis):
   - at molecular and genetic level - 2
   - on sensory physiology - 1
   - with lab toxicology - 2
   - speciation - 2
3. Integrative modelling (prognosis) – 2
4. Research on recovery (effects of management)
   - Case studies of recovery - 6
   - Regulators/modifiers of recovery - 3
   - Specific remediation techniques - 3
   - Ecosystem studies and recovery - 2

What is being done - 1?

- Detecting effects and effect thresholds in the field
  - Evaluate potential (traditional and new) bio-indicators, develop reference site selection methods, and test/reference site comparison methods for lakes, sediments & streams
    - Keller, Somers, Colbourne, Fletcher, Severo
  - Once proven, apply the methods across metal gradients
    - Sarrazin-Delay
- Evaluation of causes of changes in the field
  - Appropriate lab and field experiments to identify the causes of observed changes
    - Shaw, Celis-Salgado, Valois, Pyle

What is being done - 2?

- Begin to develop and test components needed for critical load models for metals?
  - Kharouba, Bhavsar and Gandhi: metal speciation, fate, partitioning, single-species toxicity
  - Shaw, Celis-Salgado, Pyle, and Antunes: lethal, sublethal, sensory physiologic, and long-term effects
  - Severo: Bioaccumulation and distribution
- Evaluate remedial options
  - Connors, Gunn

What is being done - 3?

- Evaluate success of remediation. Do indicators return to target values?
  – Arnott, Winter, Tropea, Greenaway, Jackson
- Determine regulators of recovery
  – Morgan, Arnott

What have we learned - 1?

- We have the field methods needed to detect effects and recovery of species assemblages.
- It is much rarer that we have proof of the causes of ecological change, and it appears that complex, sub-lethal effects cannot be ignored, yet
- We are developing sophisticated biogeochemical models to predict ecotoxicological effects (eg. BLM), yet they currently have overly simplistic assumptions, eg. no food web interactions or behavioural effects, limited watershed interactions, no confounding effects of climate change.
- The daphnia genome project is extraordinary, and appears to hold enormous promise. We are identifying the genes that are up-regulated to allow metal acclimation, and linking ecotoxicological with biochemical responsiveness of acclimated animals to metal exposure, with to me some real surprises

What have we learned - 2?

- Recovery from historical damage does occur!!
  - Rates very tremendously among sites, eg. Wawa vs. Killarney
  - It appears that chemistry alone is enough to predict recovery of phytoplankton, but
  - Recovery of 1^{o} & 2^{o} consumers depends on chemistry, food web interactions, and animal behaviour
  - Recovery rates may interact with climate change, invaders and Ca decline in as yet unknown ways
  - Watershed/lake effects should not be ignored.
  - We need to move from case studies to mechanistic studies to explain differences in recovery between species and sites

What is left to do assuming no resource limitations – my biases

1. Quantify the interactive effects of multiple metals in soft-water with native biota over a range of temperatures
2. Acknowledge the struggle to construct recovery models above the population level
3. Bring new genomics tools to this mechanistic struggle
4. Formally consider the influence of food-web interactions and behaviour on projections of recovery for the common categories of recovering lakes, i.e. move to the community level of analysis
5. Consider watershed effects on recovery, i.e. move to the ecosystem scale
6. Examine the possibility of constructing critical load models for metals, that include both biogeochemical and biogeographic processes, i.e. move to the landscape scale
7. Repeat 5 for the world

What new work should be done given the limitations?

- Keep monitoring, but link recovery case studies within landscapes to see if meta-community dynamics matters for recovery
- Explore building common biogeochemical models linking the AMD and atmospheric acid deposition fields.
- Determine if species commonly used in mandated toxicological work organisms are good surrogates for local species, if this hasn’t already been done
- Consider the potential effects of climate change and Ca decline on regulation of recovery by metals
- Continue the development of integrative models of the biogeochemical dynamics and effects of metals but include or consult animal behaviourists, ecologists and molecular ecologists to ensure relevance of models to real systems.