Predicting ecological impacts

Jon Harding
Olivier Champeau
Dev Niyogi

Mine drainage framework
Roadmap

- What is the ecology of a natural stream?
- How do we measure ecological impacts?
- Mechanisms of mine impacts
- Acid & metal toxicity
- Predicted ecology of systems in PAF & NAF
- What effects might alluvial gold mining have?
- Effects of hard rock gold mining
- Summary
What is the ecology of a natural stream?

Dissolved organic matter (DOM)

Algae (periphyton)

Stream invertebrates

Bacteria & fungi

Fish & crayfish

Moss & Larger plants

Invertebrate consumers & predators

Top predators

Food
How do we measure ecological impacts?

1. Field surveys
2. Ecotoxicological trials
3. Literature reviews
Benthic macroinvertebrates

Mayflies

Stoneflies

Snails

Caddisflies

True flies
Confounding factors in measuring stream health on West Coast

Flood disturbance +
Naturally acidic streams
Confounding factors in measuring stream health in Southland
Mine outputs which effect stream communities

- pH
- Metals e.g. Fe, Al, Ni, Zn, As
- Precipitates

Turbidity?
Potential acid-forming coal (PAF)

Predicted stream water chemistry

- Very low pH (pH < 4)
- Low pH (pH 4 – 6)
- Circum-neutral pH (pH > 6)

Impact of pH: first major driver
Impact of water acidification – on plants

- Photosynthesis
- Productivity
- Abundance of filamentous algae
- Species diversity
- Bioaccumulation of metals
Impact of pH

$H^+$ inhibits respiratory function. Levels of $H^+$ disrupt ionic equilibrium.
Impact of water acidification on animals

**Physiology**
- Disruption of ionic regulation $\text{Na}^+$, $\text{Ca}^{2+}$
- Hatching delays
- Arrested development of embryos
- Deformities
- Increased bioaccumulation and toxicity of aluminium and other trace metals
- Growth reduction

**Behaviour**
- Drift, avoidance, migration
- Modified prey/predator relationship

Impact of water acidification on animals
Impact of metals e.g. aluminium + pH

Al concentration

pH toxicity affected by competition between Al and H+ ligand

Impaired ion regulation

Toxicity of pH

Al adsorption onto gills and asphyxiation
Impact of precipitates

**Physiology**
- General abrasiveness
- Breathing disruption (gills surface clogging)

**Behaviour**
- Disruption of movement
- Disruption in feeding
- Reductions in vision
Potential Acid Forming (PAF)

Predicted stream chemistry

- **Very low pH** (pH < 4)
  - High metals (>2 mg/l any metal)
    - Severe impact
  - Low metals (<2 mg/l each metal)
    - High impact

- **Low pH** (pH 4 – 6)
  - Metals present (>1 mg/l)
    - Moderate impact
  - Minimal metals (<1 mg/l)
    - Minor or no impact

- **Circum-neutral pH** (pH > 6)
  - Metals present (>0.2 mg/l)
    - Variable impact
  - Very low metals (<0.2 mg/l)
    - No detectable impact

Outcome 1
Outcome 2
Outcome 3
Outcome 4
Outcome 5
Outcome 6
Outcome 1 & 2

Dissolved organic matter (DOM)

Algae (periphyton)

Bacteria & fungi

Stream invertebrates

Fish & crayfish

Moss & Larger plants

pH

Dissolved metal
Potential Acid Forming (PAF)

Predicted stream chemistry

- **Very low pH** (pH <4)
  - High metals (>2 mg/l of any metal)
    - Severe impact
  - Low metals (<2 mg/l of each metal)
    - High impact

- **Low pH** (pH 4 – 6)
  - Metals present (>1 mg/l)
    - Moderate impact
  - Minimal metals (<1 mg/l)
    - Minor or no impact

- **Circum-neutral pH** (pH >6)
  - Metals present (>0.2 mg/l)
    - Variable impact
  - Very low metals (<0.2 mg/l)
    - No detectable impact

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Outcome 1  Outcome 2  Outcome 3  Outcome 4  Outcome 5  Outcome 6
Non Acid Forming (NAF)

Predicted stream chemistry

- Very low pH (pH <4)
  - High metals (>2 mg/l of any metal)
  - Severe impact
  - Outcome 1

- Low pH (pH 4 – 6)
  - Low metals (<2 mg/l)
  - High impact
  - Outcome 2

  - Metals present (>1 mg/l)
  - Moderate impact
  - Outcome 3

  - Minimal metals (<1 mg/l)
  - Minor or no impact
  - Outcome 4

- Circum-neutral pH (pH >6)
  - Metals present (>0.2 mg/l)
  - Variable impact
  - Outcome 5

  - Very low metals (<0.2 mg/l)
  - No detectable impact
  - Outcome 6
Outcome 5 & 6 (NAF)

- Dissolved organic matter (DOM)
  - Algae (periphyton)
  - Bacteria & fungi
  - Stream invertebrates
  - Moss & Larger plants
  - Fish & crayfish

- Predicted stream chemistry:
  - Very low pH (pH < 4)
  - Low pH (pH 4 – 6)
  - Circum.neutral pH (pH > 6)
  - High metals (>2 mg/l of any metal)
  - Low metals (<2 mg/l of each metal)
  - Metals present (>1 mg/l)
  - Minimal metals (<1 mg/l)
  - Metals present (>0.2 mg/l)
  - Very low metals (<0.2 mg/l)

- Outcome:
  - Outcome 1
  - Outcome 2
  - Outcome 3
  - Outcome 4
  - Outcome 5
  - Outcome 6
Gold hard rock

Predicted stream chemistry

No oxidation processing at mine site

- Very low metals
  - Minor dissolution
  - As, Sb = 0.01 to 0.1 mg/L
  - Minor impact

- Minimal Metals
  - Moderate dissolution
  - As, Sb = 0.1 to 1 mg/L
  - Moderate impact

- Metals present
  - Rapid dissolution
  - As, Sb > 1 mg/L
  - High impact

Oxidation processing at site

- As is pH-dependant
  - 20 mg/L at pH 7
  - 0.2 mg/L at pH 5
  - Sb up to 50 mg/L
  - High to severe impact
Impact of metals - Arsenic

- Photosynthesis
- Productivity
- Survival of juveniles
- Reproduction
- Hatching
- Blood haemoglobin
What effects might alluvial gold mining have?
Turbidity

Before mining

During mining
Predicted stream chemistry

- **Circum-neutral pH** (pH > 6)
  - Metals present (>0.2 mg/l) → No detectable impact
  - Metals present (>1 mg/l) → Variable impact
  - High metals (>2 mg/l of any metal) → High impact
  - Low metals (<2 mg/l of each metal) → Moderate impact

- **Low pH** (pH 4 – 6)
  - Metals present (>1 mg/l) → Minor or no impact
  - Minimal metals (<1 mg/l) → Moderate impact
  - Low metals (<2 mg/l of each metal) → High impact
  - High metals (>2 mg/l of any metal) → Severe impact

- **Very low pH** (pH < 4)
  - Very low metals (<0.2 mg/l) → No detectable impact
  - Low metals (<2 mg/l of each metal) → Moderate impact
  - High metals (>2 mg/l of any metal) → Severe impact

Outcome

- Outcome 1
- Outcome 2
- Outcome 3
- Outcome 4
- Outcome 5
- Outcome 6
Impact of turbidity

Algae (periphyton)

Stream invertebrates

Moss & Larger plants

Fish & crayfish

Bacteria & fungi
Impact of turbidity

Algae (periphyton) Bacteria & fungi

Stream invertebrates

Fish & crayfish

Moss & Larger plants
Impact of turbidity

- Photosynthesis
- Productivity
- Schooling ability
- Predator/prey relationship
- Feeding efficiency
- Growth
- Gills irritation
- Stress
- Smothering of non-mobile organisms and eggs
- Prolonged hatching time
Summary

- Healthy streams include communities of algae, invertebrates and fish

- PAF mining has the potential to severely degrade stream communities; limiting algae and invertebrates and killing fish

- pH < 4 and metals (depends on metal) > 2 mg/l

- NAF mining likely to have much less effects depending on presence of any metals and sediment

- Gold mining is likely to cause turbidity, possible problems with a limited number of metals