

Soil Conservation Service



Drought-induced hysteresis in iron and sulfur cycling within Lake Cathie - Innes ICOLL

Team: Thor Aaso (SCS) Professor Scott Johnston (SCU)
Professor Damien Maher (SCU) Mat Birch (ASM)

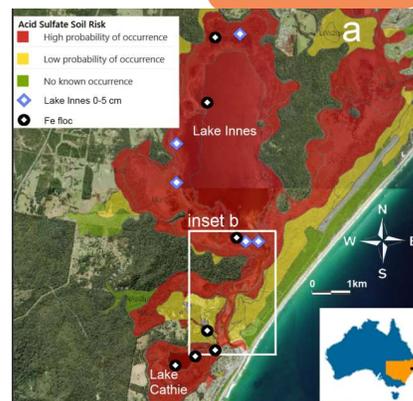
Custodians: Birpai People

29th Coastal Conference 2022

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Overview

- 1. Source of iron & acid**— 2018-2019 drought and oxidation event
- 2. Force to move iron & acid** — entrance opening events, translocation of iron to surface
- 3. Response** — altered Iron and Sulfur cycling
- 4. Consequences** — heightened drought sensitivity, ongoing dynamic iron cycling, trace metals/nutrients

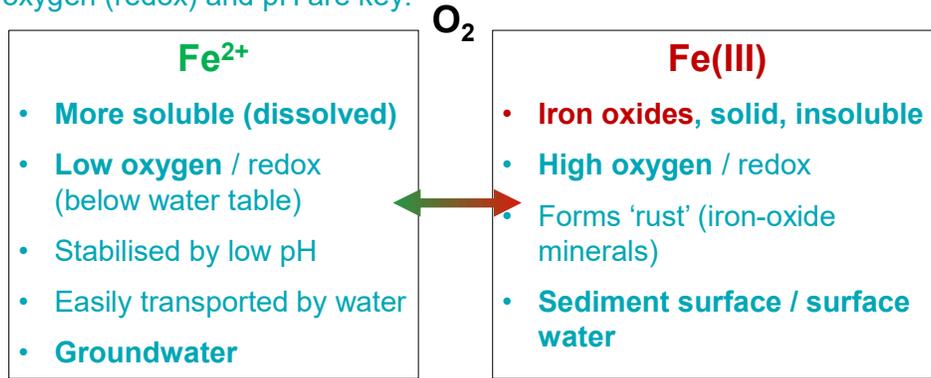


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Iron in the environment

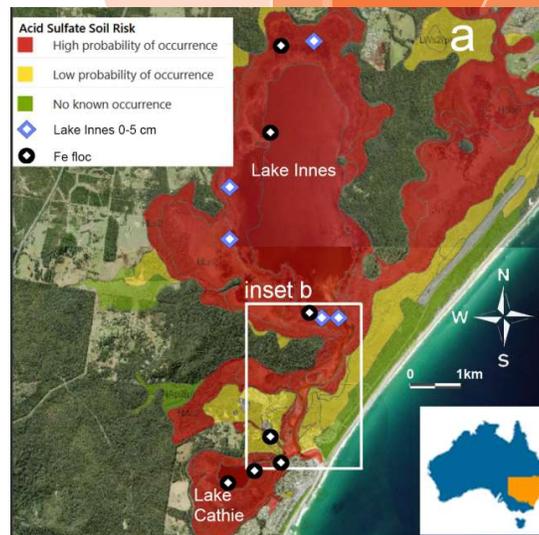
Two main forms, switch between them – oxygen (redox) and pH are key:



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The site

- ICOLL – two lakes
- Lake Innes - originally freshwater lake
- Connected to Lake Cathie 1933
- Introduction of sea-water over ~90 years >> introduced sulfate
- New pyrite formed in tidal organic-rich lake sediments



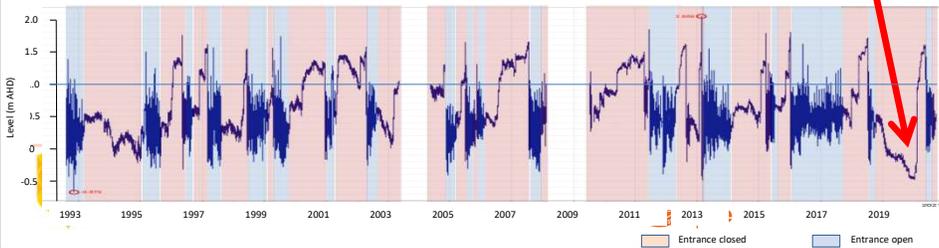
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A source of iron

- Extreme, extended drought 2019
- Rainfall = 514 mm vs 1550 mm average
- Lake water levels low, long time (<-0.5 m AHD)
- Pyritic sediments on lake bed and fringes exposed to air
- Some pyrite oxidises >> **releases iron** – Fe(II) / Fe(III)



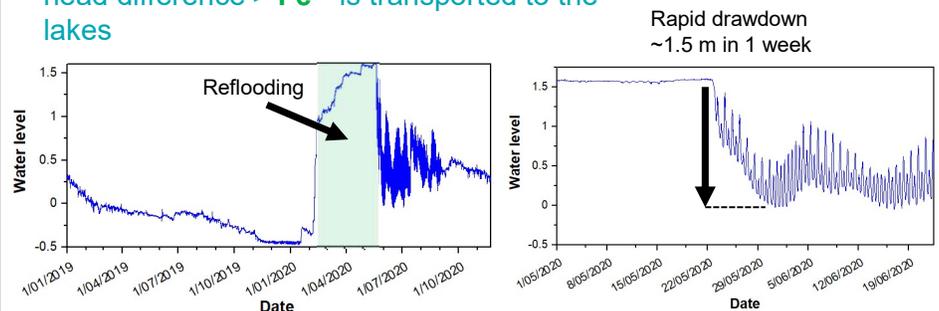
2019 - extreme drought
low water level



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A force to move iron

- Drought ends > re-flooding, for 4 months
- Dissolved Fe^{2+} accumulates in shallow groundwater in Lake bed / fringing sediments
- Entrance opened, late May 2020 > rapid fall in lake levels
- **Lake low + adjacent groundwater high = head difference > Fe^{2+} is transported to the lakes**



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Response

- Abundant Fe(III) oxide floc near surface



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Response

Abundant Fe(III) floc at surface

- Fe is limiting ingredient for new pyrite / $AVS >$ near surface $>$ elevated risk of oxidation during future drought?



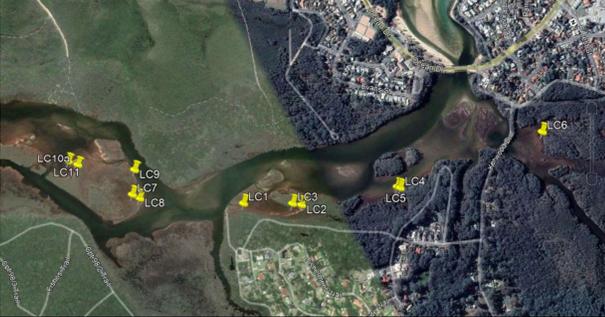
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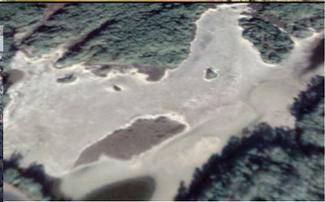
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Response

Abundant Fe(III) floc at surface

2. Fe oxides are important host for trace metals / phosphate (small size + surface charge + redox sensitive / transient) > >> **implications for metal / nutrient cycling?**

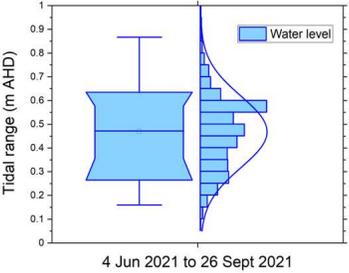
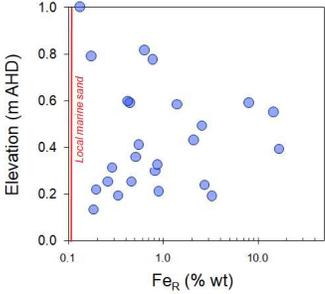





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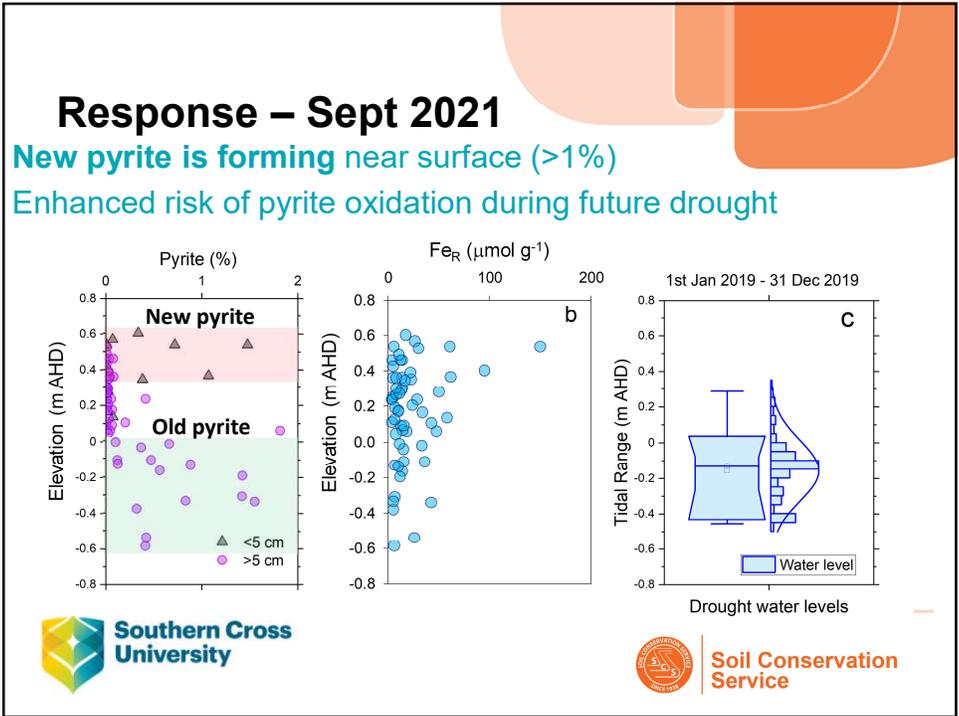
Response – Sept 2021

- **Fe(III) floc accumulation** at surface (0-1 cm)
- Abundant Fe(III) (~20%), elevated well above local marine sand
- Within intertidal zone (reflects porewater seepage)

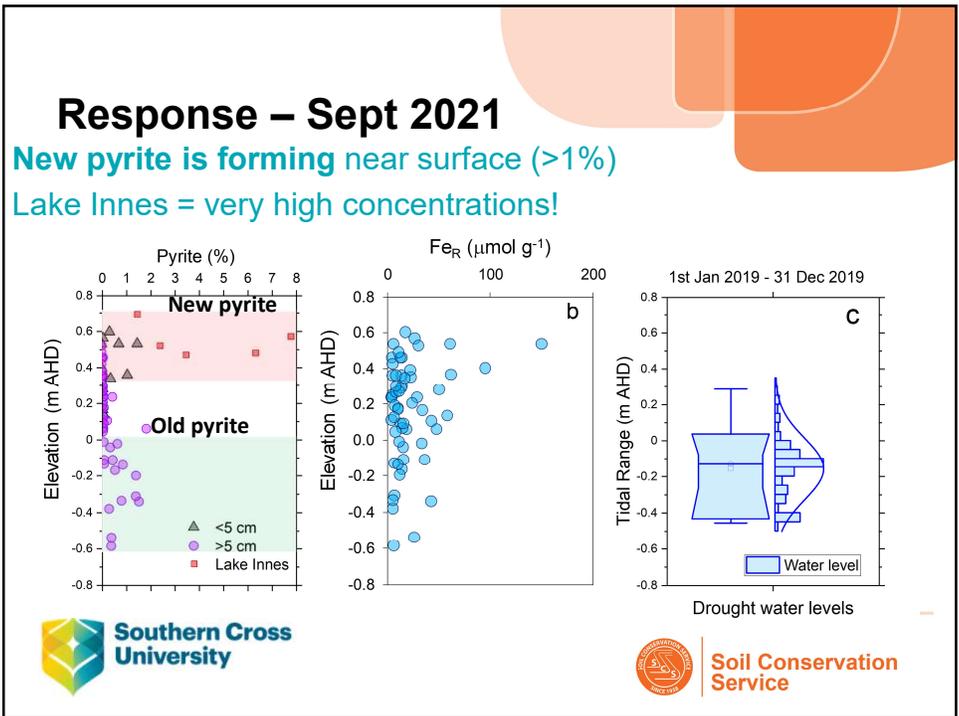






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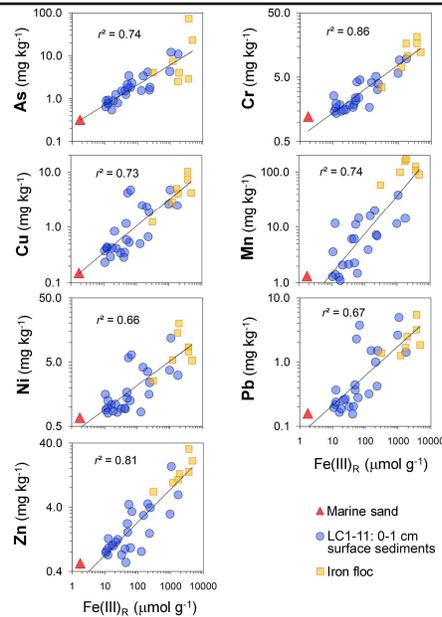
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Response – Sept 2021

- Trace metals and phosphate closely associated with Fe(III) floc (more Fe(III) = more trace metals)
- Elevated above local sand background >10x
- An unstable storehouse....
- Prone to release when redox / pH conditions change

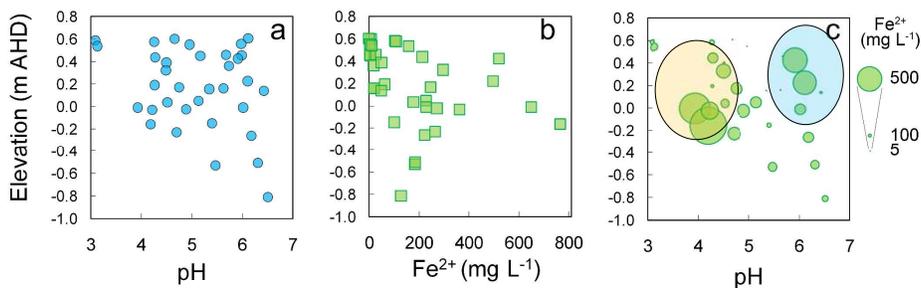


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Response – porewater still primed

- Substantial Fe²⁺ remains in porewaters (up to 800 mg/L) – within intertidal zone elevation range (not yet recovered).
- Wide pH range (3-7) > two modes mobilisation (acidic; reductive)



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Consequences

ICOLL main channel at elevated risk of degraded water quality / amenity:

- **Now:** Entrance breach > residual Fe^{2+} seepage > Fe(III) floc event(s) > fringing embayments



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Consequences

- **Future:** droughts > oxidation of new shallow pyrite > new acidity (localised?)
- **Future:** changes in pH or upward redox boundary migration >> destabilise iron oxides >> encourage **release of phosphate / trace metals?**



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Consequences

- ICOLL in new biogeochemical state - **hysteresis**
- Persistent, dynamic cycling of iron in ICOLL intertidal-zone sediments and porewaters
- **Enhanced sensitivity** to climate oscillations
- Gradual decline in intensity of surface Fe(III) oxides
- Next drought?

Extreme drought 2019

- Pyrite (FeS₂) oxidises
- Release of Fe²⁺ and acid production

ICOLL fills

Rainfall fills ICOLL

- Iron (Fe²⁺) dissolves in groundwater on ICOLL fringe

Altered geochemistry

- Enhanced Fe(III) oxides at surface
- Trace metals associate with Fe(III) oxides
- New pyrite forms** near surface
- Enhanced sensitivity to drought

ICOLL entrance opened

- Lake level falls rapidly
- Fringing groundwater Fe²⁺ drains into lake
- Fe²⁺ oxidises, Fe(III) floc forms and accumulates near surface

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What if?.....

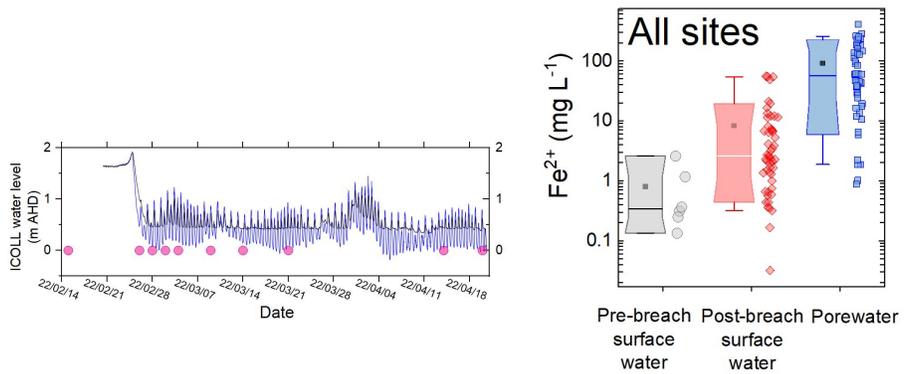
Royal HaskoningDHV
Enhancing Society Together

Comparison of measured and modelled daily water level for the 2019-2020 drought management period

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Response

Feb. 2022 – 3rd breach event monitoring



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