

## More Than Water Quality: Ecological Limitations to a Pit Lake Fishery

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## Pit Lake Resources

- Legacy of many mine pit lakes worldwide
- Acid Mine Drainage (AMD)
  - Greatest environmental problem facing water management in the international mining industry today
- AMD affected pit lakes typically have reduced environmental values
  - Low pH
  - Low nutrients
  - High metals
- Large waterbodies represent valuable resources to environment and communities

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## Australia Mine Pit Lake Importance

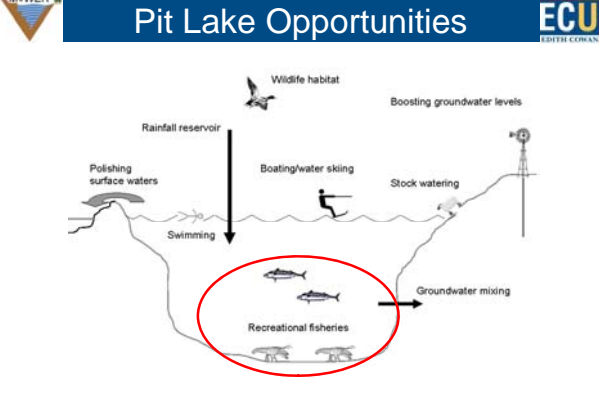
- Mining widespread Australian major industry
- Many mine pit lakes across country
- Australia one of the driest continents in the world
  - Demand for water resources increasing
  - Climate change predictions
- Water from pit lakes can be of potential use




*After: Kumar, N. R.; McCullough, C. D. & Lund, M. A. (2009). Water resources in Australian mine pit lakes. Australasian Institute of Metal and Metallurgy (AusIMM) Water in Mining conference, Perth, Australia. 15 September – 17 September 2009.*

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## Pit Lake Opportunities





*From: McCullough, C. D. & Lund, M. A. (2006). Opportunities for sustainable mining pit lakes in Australia. Mine Water and the Environment 25: 220-226.*

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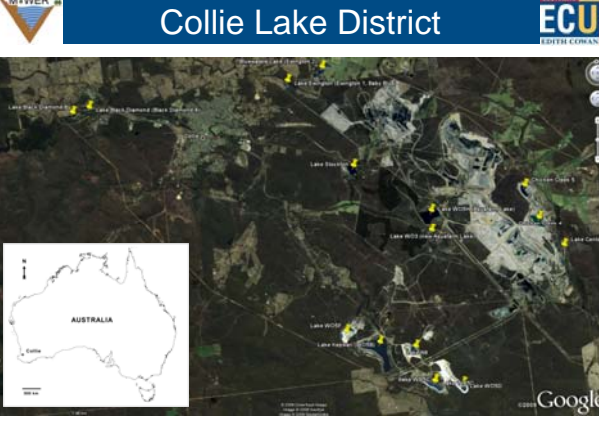
## Collie Lake District

- Collie Coal Basin, 160 km south of Perth, Western Australia
- More than 15 pit lakes ranging from:
  - <1–100 ha surface area
  - <10–70 m depth
  - 1–50 years age
  - pH 2.4–5.5
  - No rehabilitation (groundwater filled), extensive (fast fill, revegetation)

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## Collie Lake District



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## Collie Pit Lakes

- All affected by AMD
- Low metal and nutrient concentrations
  - Particularly carbon and phosphorus
  - Many metals still at toxic levels e.g.,  $Al(OH)_4^-$
- Nutrient limitation restricts productivity and hence lake foodwebs





Depth (m)	5-70
Area (km <sup>2</sup> )	0.06-1.03
pH	3.8-5.9
Total P	<0.006-0.008
Total N	<0.05-1.5
DOC	3.1-7.3
E.C. (µS cm <sup>-1</sup> )	0.42-1.4
<b>Sulfate</b>	<b>11-107</b>
Aluminium	0.001-0.006
Calcium	2.3-6.0
Chromium	<0.007
Copper	<0.002-0.05
Iron	0.0003-0.005
Magnesium	0.077-16.3
Uranium	0.0005-8.9
Zinc	0.0005-8.9
Chlorophyll a (µg L <sup>-1</sup> )	0.1-64

After: Kumar, N. R.; McCullough, C. D. & Lund, M. A. (in press). Pit lakes in Australia. In, *Acidic Pit Lakes - Legacies of surface mining on coal and metal ores*. Geller, W. & Schultze, M. (eds.) Springer, Berlin.  
<http://www.chs.ecu.edu.au/MW/ER/>

## Marron

- Large, endemic freshwater crayfish (Parastacidae: *Cherax cainii*)
- Prized recreational fishery in south-western Australia
- Marron and other crayfish introduced to Collie pit lakes



➤ **What environmental factors limit the marron fishery in these lakes?**

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## Pit Lakes Studied

- 5 historic (ca. 50 y.o.) pit lakes studied representative of other Collie lakes
- No remediation prior to natural filling with rainfall and groundwater
  - Limited catchment size; nutrient input low
  - High settled sediment loading
  - Limited littoral edge
  - Riparian vegetation depauperate

Blue Waters  
Black Diamond  
<http://www.chs.ecu.edu.au/MW/ER/>


## Collie Lake District



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## Methods - Water Quality



- Water column profile:
  - Dissolved oxygen, pH, ORP, specific conductance, chlorophyll a, turbidity and temperature
- Surface water:
  - Metal suite by ICP-AES
  - Nutrients total N, P and their fractions



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## Methods - Environmental

- Detritus (fine and coarse organic matter)
- Benthic algae biomass sampled by divers
- Benthic macroinvertebrates
  - Collected with kick-nets
  - Mass approximated
- Phytoplankton biomass
- Habitat traps as refugia

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### Methods – Marron Health



- Marron (n = 28) and any other co-habiting crayfish (n = 9) trapped
- Health indices calculated for each individual:
  - Body mass
  - Wet hepatopancreatic index
  - Dry hepatopancreatic index
  - Hepatopancreas moisture
  - Tail muscle moisture index

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### Water Quality

Collie pit lake physico-chemical and metal concentrations (mg L<sup>-1</sup> unless indicated). Shading indicates value exceeds Australasian water quality guidelines (ANZECC/ARMCANZ, 2000).

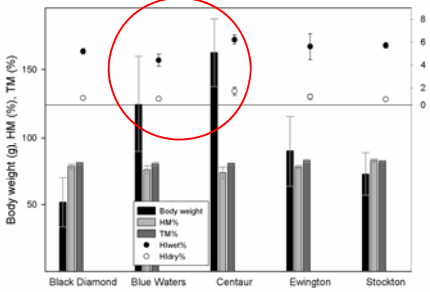
Lake	pH	DO	EC (mS cm <sup>-1</sup> )	ORP (mV)	Al	Ca	Cl	Cu	Fe	Mn	Ni	Pb	Zn
Black Diamond	4.7	12	0.61	233	0.11	6.5	131	0.002	0.032	0.130	<0.004	<0.01	0.015
Blue Waters	3.5	12	2.25	370	2.80	11	452	0.002	0.380	0.081	0.039	<0.01	0.150
Centaur	6.3	11	2.11	153	0.09	20	603	0.003	0.280	0.011	<0.004	<0.01	0.015
Ewington	3.7	13	1.46	300	1.40	3.1	339	0.004	0.260	0.023	0.005	0.030	0.037
Stockton	4.1	12	0.57	378	0.49	2.9	137	0.003	0.150	0.087	0.020	<0.01	0.120

- pH highest in Lake Centaur, lowest in Blue Water/Ewington
- Dissolved oxygen near saturation in all lakes
- Al, Cu and Zn >Australasian water quality guidelines in all pit lakes
- Concentrations of Fe, Ni and Pb elevated in some lower pH lakes

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### Marron Health

- Hepatopancreatic indices similar across all pit lakes
- Marron body weight similar in Black Diamond, Ewington and Stockton
- Body weight greatest in Centaur and Blue Waters

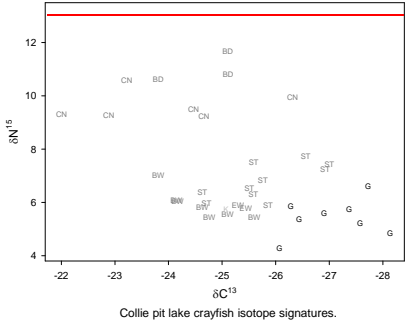


Collie pit lake mean marron health indices (± standard error). HM% and TM% = hepatopancreas and tail moisture % content, Hwet% and Hdry% = hepatopancreatic wet and dry indices.

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### Food Quality

- Centaur/Black Diamond most enriched N
- Food quality
- Natural marron δN<sup>15</sup> = 13

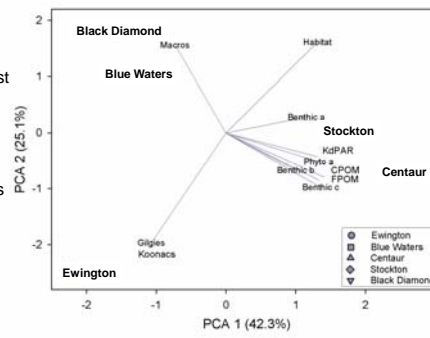


Ewington

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### Ecological Quality

- Habitat lowest in Ewington
- Competition highest in Ewington
- Algae/detritus highest in Stockton/Centaur
- Macroinvertebrates highest in Black Diamond/Blue Waters

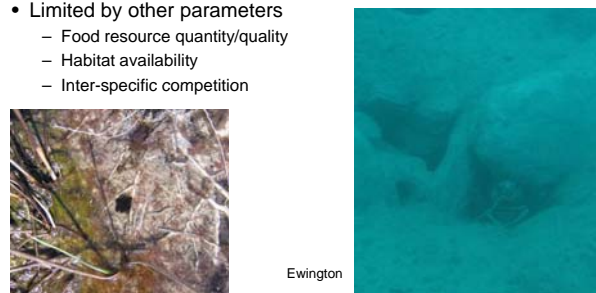


PCA ordination of indicators of primary and secondary productivity, habitat and competition of Collie pit lakes.

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### Conclusions – Pit Lake Marron

- May be limited by water quality
  - Low pH water
  - Metal toxicity (esp. Al(OH)<sub>3</sub>)
- Limited by other parameters
  - Food resource quantity/quality
  - Habitat availability
  - Inter-specific competition




Ewington

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## Conclusions – Pit Lakes

- Pit lakes most frequently most severe environmental impacts
- In dry(ing) climates such as Australia, newly developing vast open cut pit lakes could represent boon for environment and communities left behind
- Environmental values a common relinquishment goal

Goldfields pit lake




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## Conclusions – Pit lake Ecology

- Pit lake biota ecological requirements
  - Rarely studied
  - Poorly understood
- Assumption of water quality
  - Water quality guidelines as a 'gold standard'
- Ecology more than just water quality
  - Higher levels have demanding environmental requirements
  - Need for functioning ecosystems to realise high food web levels



Black Diamond Lake



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## Acknowledgements

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