Challenges of defining what ‘success’ looks like for closure of pit lakes as aquatic ecosystems.

Mark Lund and Rachele Bernasconi

ACARP

MiWER Centre

AUSTRALIA ECU EDITH COWAN UNIVERSITY

Closing pit lakes

- Regulators across Australia are starting to recognise that closing pit lakes as aquatic ecosystems is a good option for the environment, local communities and industry.
- We provide arguments for why closure as aquatic ecosystems is a good option for closure in: Lund MA, Blanchette ML (2023) Closing pit lakes as aquatic ecosystems: Risk, reality, and future uses. WIREs Water 10(4):e1648. https://doi.org/https://doi.org/10.1002/wat2.1648

Pit lakes as aquatic ecosystems

- Aquatic ecosystems typically have riparian and fringing vegetation
  - This can be challenging to create in pit lakes due to the time taken to fill and unstable edges.
  - In most of the abandoned pit lakes we have studied, even after 50 years there is little colonisation by either riparian or fringing vegetation.
- Pit lakes are new lakes without any sediment at formation
- Pit lakes can have restricted littoral areas
- Carbon and P are generally limited, sometimes N can be as well (but it is much less common)
- Pit lakes can occur in regions with relatively few natural waterbodies
- Water quality can be problematic or subject to evapoconcentration.

Expectations at Closure

- Safe, Stable and Sustainable
- E.g. Office of the Queensland Mine Rehabilitation Commissioner – Technical Paper on aquatic ecosystems as a post-mining land use (https://www.qmrc.qld.gov.au) identified the following as relevant indicators
  - Physical and chemical
  - Biota
  - Ecosystem Processes (e.g. primary production)
  - Toxicants
  - Physical Form (mainly suited to flowing systems)
  - Habitat (e.g. riparian)
  - Hydrological indicators (e.g. groundwater interaction, seasonality)

Aim


This study aims to explore and begin to define characteristics that indicate successful rehabilitation of pit lakes as aquatic ecosystems

Study Sites

State	NSW	Queensland	Western Australia
Location	Hunter Valley	Bowen Basin	Collie
No. Pit Lakes studied	2	6	15
Fully rehabilitated	1 (HL2)		1 (Kepwari)
Partially rehabilitated			10
Not rehabilitated	1	6	4
pH	5.6-8.7	5.5-9.5	2-8.14
Specific Conductance ($\mu S\ cm^{-1}$)	2600-6900	3200-14500	1000-2700

Study Sites

Unrehabilitated

No contouring, no revegetation

Study Sites

Partially Rehabilitated

Contouring of catchment, revegetation of catchment, some contouring below water line, no riparian planting or water quality remediation

Study Sites

Rehabilitated

Contouring above and below water level (to at least 5 m deep), revegetation of upland and riparian/fringing, no water quality remediation

Study Sites

Unrehabilitated

Rehabilitated

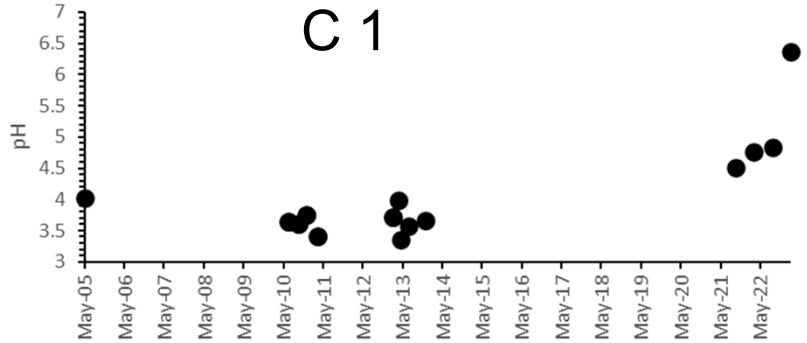
Partially Rehabilitated

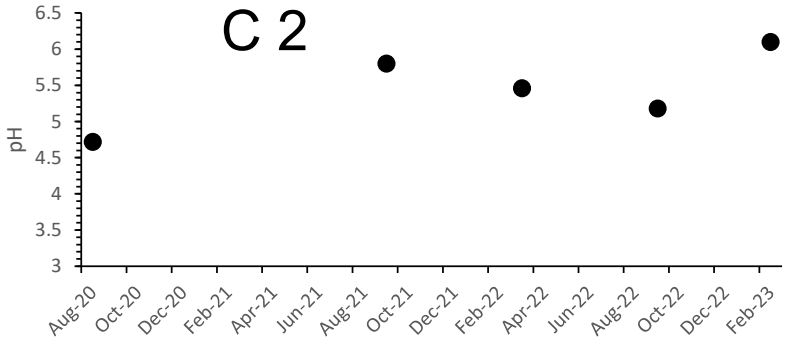
Sampling

- Water column physico-chemical profiles using a Multiprobe Sonde
  - temperature, pH, dissolved oxygen (mg L^{-1} and % saturation), conductivity standardized at 25 ˚C and oxidation-reduction potential (ORP, platinum electrode)
- Top and bottom of water column sampled
  - Metals/metalloids and nutrients
- Phytoplankton and zooplankton sampled at surface WQ sites
- At the lake edges, macroinvertebrates and diatoms sampled.

Physical, chemical and toxicants

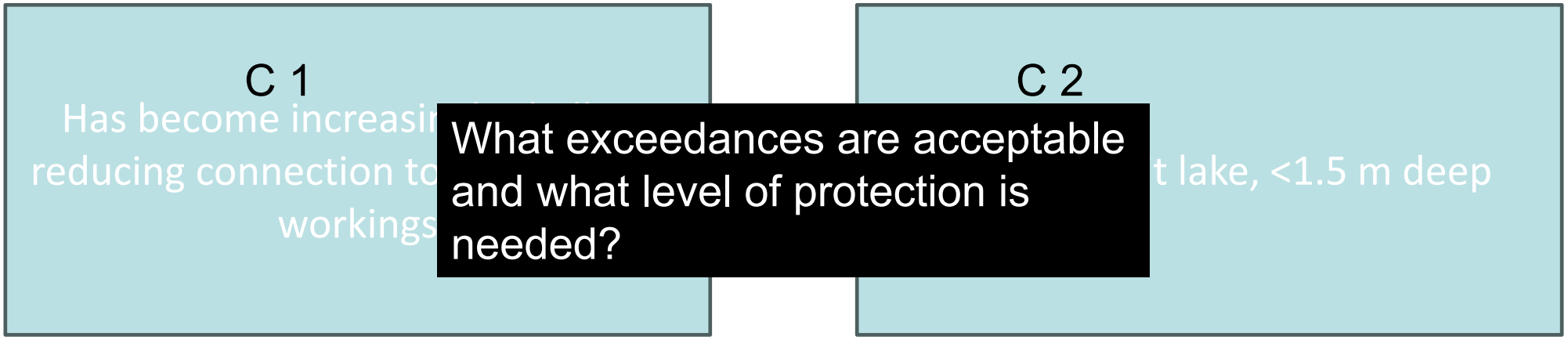
- National guidelines can inform closure regarding levels of select parameters for the protection of aquatic ecosystems
- Use of relatively high protection levels (e.g. 95% moderately disturbed) can inform on parameters that might limit certain taxa.
- Low pH (<5) tended to be associated with problematic metal levels
- Only two acidic lakes have become less acidic over time





Physical, chemical and toxicants

- National guidelines can inform closure regarding levels of select parameters for the protection of aquatic ecosystems
- Use of relatively high protection levels (e.g. 95% moderately disturbed) can inform on parameters that might limit certain taxa.
- Low pH (<5) tended to be associated with problematic metal levels
- Only two acidic lakes have become less acidic over time, one became more acidic.



Evapoconcentration

- Most of the pit lakes in the Bowen Basin have no outflows and are predicted to increase in salinity over time
  - Only two lakes studied had no water pumped in or out
    - Specific conductance over three years varied by ≈3000 µS cm^{-1}, over a very dry and very wet year. Overall, no strong evidence was found supporting increasing salinity levels.
    - All sites were below a TDS of 10,000 mg /L (≈ 15,600 µS cm^{-1}) which is generally considered to a threshold where biodiversity starts to decline, and other ecosystem processes are impacted.

Are our models predicting salinity reliable?

Water Quality

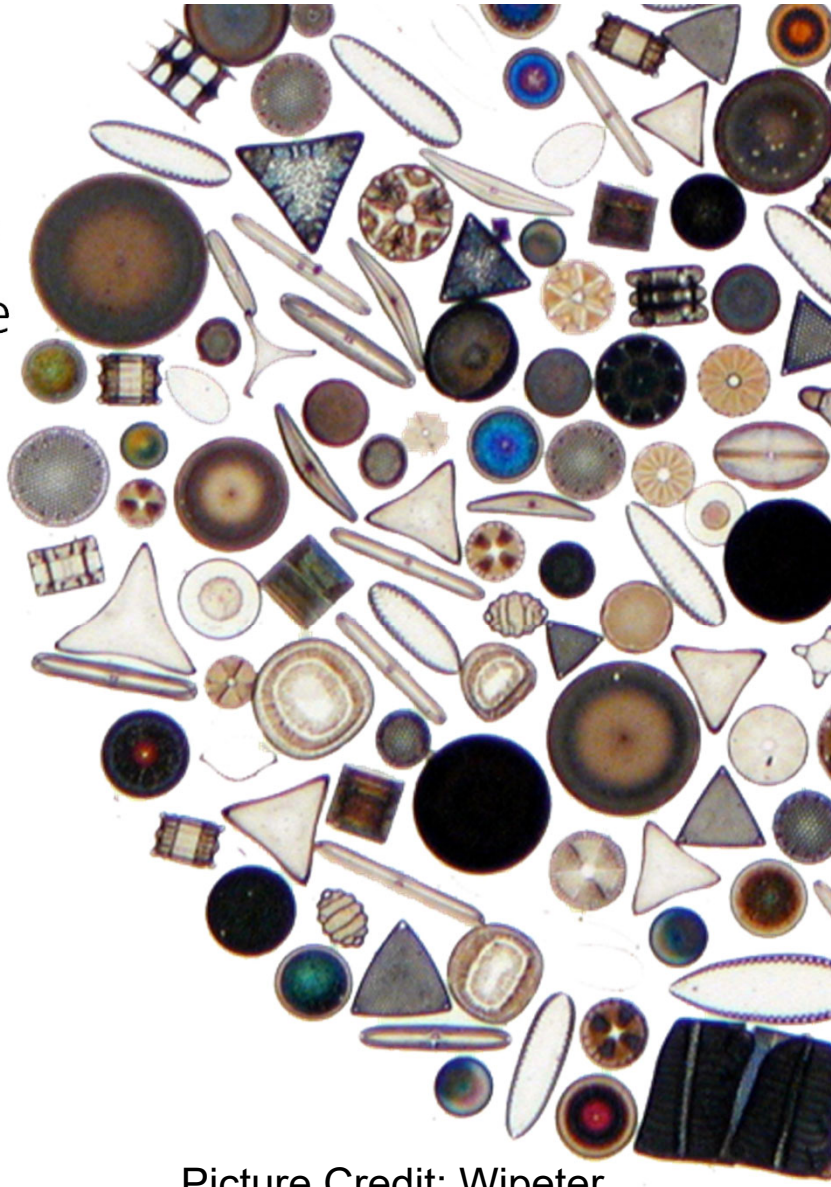
- Flow through is very effective for remediation of problematic waters although the main benefit is initially caused by dilution and washing out rather than reductions in sources of contamination.
- Key feature of rehabilitation success is the ability to control erosion which if high typically leads to poorer water quality.
  - Contouring and plants combine to control erosion.
  - Correct prediction of final water heights is also essential
- Groundwater, if a source of contamination will need specific remediation strategies

Biota - Phytoplankton

- In Lake Kepwari, post flow through compared to pre-flow there was a slight change in both richness (and taxa collected) and abundance likely due to the improvement in water quality.
- At the other rehabilitated lake mean and total richness was lower than other unrehabilitated lakes but this could also be related to climatic differences (NSW to Qld)
- Frequency of sampling was probably too low to get a good understanding of populations.
- Presence of cyanobacteria potentially a problem and being spread by interlake transfers

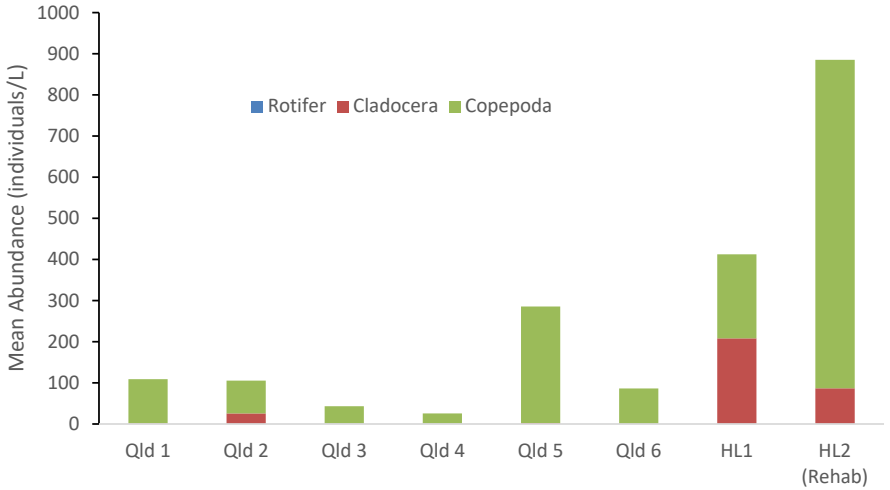
Diatoms

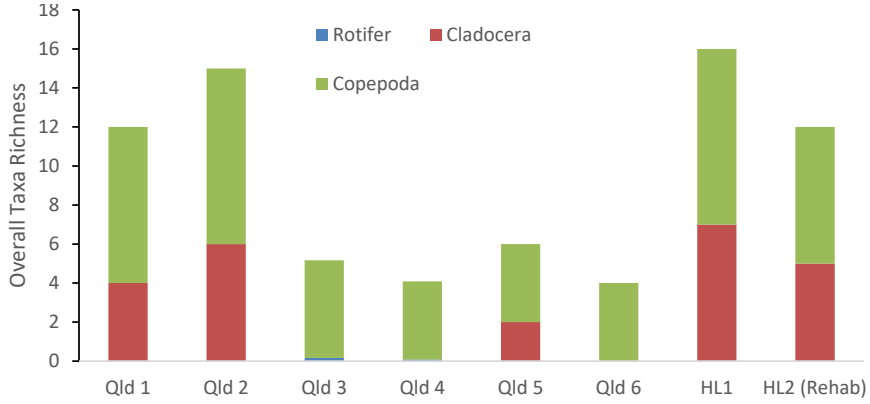
- Lake Kepwari contained more species than any other lake, probably due to inclusion of riverine species
- HL2 (rehabilitated) had the same richness as the other NSW lake with poorer water quality
- Richness in Qld lakes was lower and appeared unrelated to water quality



Picture Credit: Wipeter

Zooplankton





Macroinvertebrates

HL2 (rehabilitated) had the highest mean taxa (Family or higher) richness (10) and mean abundance (1064 individuals per sampling time)

- Followed by HL1 (5), Qld 1(6) and Qld 2 (6)
- HL 1 had lowest mean abundance (269 individuals per sampling time).

- Dominated by common generalist species

Biota

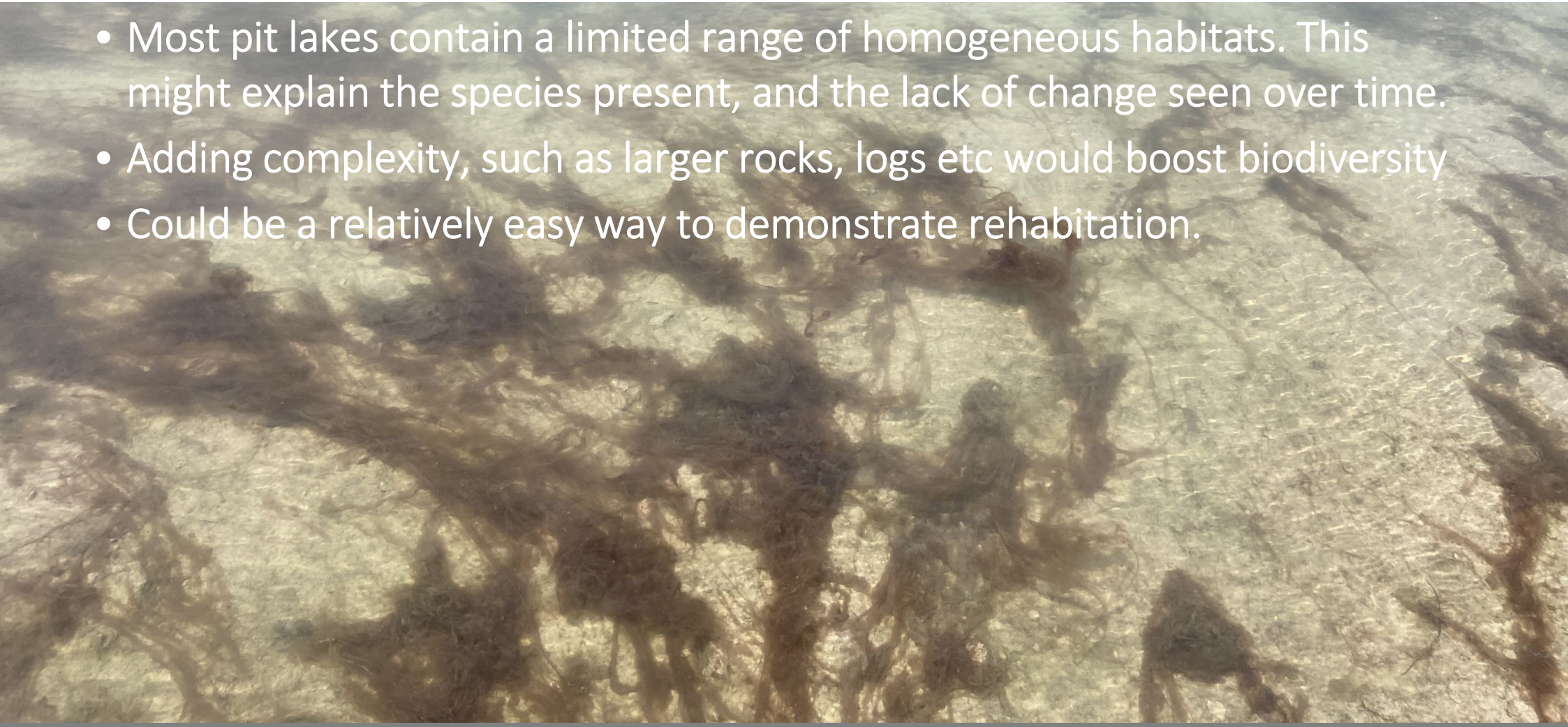
- Species richness in pit lakes, will be a subset of the regional biodiversity
  - Large lakes should have more species than smaller ones, over time
  - Pit lakes closer to natural waterbodies will contain more species than those further away over time.

Presence of certain taxa? Keystone species
Certain species richness? E.g. Is 15 species enough? Or should it be 16
Quality (sensitivity) of species should be a consideration
Do we mandate species introductions?
Over what time frame is colonisation likely?

Ecosystem Processes

- Assessments of primary production rates, sediment development etc offer a chance to show the lake is functioning or on the way to functioning as natural lake in the region would.
- These types of measurements would avoid many of the problems inherent in biodiversity measures, but little work has been done in this area in pit lakes (exception Canadian Oil Sands) and regionally.

Habitat



- Most pit lakes contain a limited range of homogeneous habitats. This might explain the species present, and the lack of change seen over time.
- Adding complexity, such as larger rocks, logs etc would boost biodiversity
- Could be a relatively easy way to demonstrate rehabitation.

Conclusions

- Pit lakes don’t occur in isolation and so must be considered in a landscape context.
- Littoral, fringing and riparian areal extents initially should aim to reflect regional norms, however habitat variability is perhaps more important than area.
- Species richness as a measure of ‘success’ is problematic, as it is dependent on the rate of colonisation.
- It is likely that ecosystem processes or habitat assessments might be useful for establishing completion criteria, but much work is required.
- Considerable challenges remain to demonstrate that a pit lake has developed a successful aquatic ecosystem to allow for closure.

Acknowledgements

- Thanks to the Australian Coal Association Research Program (ACARP) for funding the projects that contributed to this paper.
- Several mining companies provided financial and logistic support for the project.
- Thanks to Edith Cowan University and the School of Science Analytical Facility for assisting the project.