ARC CENTRE FOR
MINE SITE RESTORATION

ANNUAL WORKSHOP 2019

PROGRAM

5TH AND 6TH NOVEMBER 2019
CURTIN ST.GEORGE'S TERRACE, PERTH

ARC Centre for
Mine Site Restoration
An Industrial Transformation Training Centre

ARC Centre for Mine Site Restoration
An Industrial Transformation Training Centre

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ARC Centre for Mine Site Restoration
An Industrial Transformation Training Centre

Curtin University

THE UNIVERSITY OF WESTERN AUSTRALIA

KINGS PARK & Botanic Garden
BOTANIC GARDENS & PARKS AUTHORITY

'Images in this publication are courtesy of Sophie Cross Photography, Holly Bradley, Curtin University and CMSR.'

'Document design by Tom Cleave Creative.'

Venue:

The venue of the ARC CMSR Annual Workshop 2018 is Curtin St George's Terrace, Perth.
Constructed in 1854 as the Old Perth Boys' School, the building is heritage listed and 6 star green rated.

Public parking is available in the vicinity at:

His Majesty's, 377 Murray Street

Citipark, 427 Murray Street

Perth Convention Centre, 21 Mounts Bay Road

Central Park, 152-158 St Georges Terrace

There is also a taxi rank immediately outside the venue.

Address: Curtin St Georges Terrace, 139 St Georges Terrace Perth WA 6000

WELCOME MESSAGE

The Australian Research Council's Industrial Transformation and Training Centre for Mine Site Restoration (CMSR) commenced in June 2016, and is increasingly regarded as one of Australia's most significant restoration research hubs. The CMSR is a multi-organisation group comprising two universities, one government department, one non-government organisation and five mining companies. Since its initiation the team has grown to almost 40 restoration ecologists, including four post-doctoral researchers, 19 postgraduate students, six senior research scientists, eight supporting supervisors and three Centre management staff.

The CMSR aims to deliver proven, cost-effective and scalable industry-relevant restoration solutions across the key disciplines of restoration genetics, seed technology and enablement, rare species management, restoration ecophysiology, and mining industry policy extension. 2019 represented the half-way milestone for the Centre, and the last year has seen great progress towards its objectives of integrated and cross-disciplinary projects delivering a holistic approach to mine site restoration.

Our students and post-doctoral fellows are embedded in industry across the state, and many have spent significant periods of time either on mine sites or in specialist research laboratories both in Australia and overseas. Research focus has ranged from fauna to soil health and beyond, and many studies are now in advanced stages and demonstrating promising, impactful outcomes for the mining industry. Examples include the demonstration of DNA metabarcoding as an effective tool for predicting restoration trajectories, the importance of soil-microbial-interactions in examining the functional integrity of soils and post-mining substrates, development of an effective standardised protocol for seed coating, demonstration of the capacity for drones to identify, track and monitor the performance of plants as small as individual seedlings, and evidence for accelerated rates of pedogenesis (soil formation) in some of the most highly modified substrates produced from mined material processing.

The public profile of the CMSR has increased markedly over the past three and half years. The Centre was formally launched at Curtin's Old Boys School (Perth) and then at Parliament House (Canberra) in May 2017 by the Minister for Education and Training, Simon Birmingham. The CMSR returned to Parliament House later in 2017 with industry partner SERA, for acting Prime Minister Senator Anne Ruston to launch the second edition of the National Standards for the Practice of Ecological Restoration. The CMSR was prominent in the international launch of the 2nd edition of the International Principle and Standards for the Practice of Ecological Restoration at the 7th World Conference on Ecological Restoration in Cape Town (South Africa), a document that was simultaneously endorsed by a key commission of the UN, the UN Commission on Combating Desertification. The CMSR had a lead role in the development of the WABSI Completion Criteria Framework, with the comprehensive report being the first of its kind in Australia, providing a valuable reference for industry, government and research.

The research network of the CMSR has expanded from its original core group to form alliances and projects with domestic and international institutions including the Western Australian Biodiversity Institute, Greening Australia, Mullewa Employment & Economic Development Aboriginal Corporation, Chinese Academy of Sciences Kunming Institute of Botany, and many more (see infographic of partners). The CMSR has proven itself, and is seen as a key resource for policy advice, strategic guidance and technical know-how for both industry and government as evidenced by contributions to the Resources 2030 Taskforce, lead roles in development of the National and International Standards for the Practice of Ecological Restoration, and representation on several national advisory committees and international professional organisations. Ongoing engagement and outreach activities within academic, industry, government and community groups communicate the wider impact and significance of CMSR research activities.

A high point in the activities of the Centre includes the development of effective linkages to traditional owner groups. These, with the support of the Industry Advisory Council of the CMSR, have enabled the Centre to guide and develop potential new 'on country' business opportunities in the restoration economy for the mining industry. This has translated to the CMSR taking a major role in the CRC bid Transition in Mining Economies (TIME), which has been successful in moving to the second round of the bidding process. If successful, CRC TIME will be a $133M initiative that will greatly expand development capacity in restoration technologies and traditional owner engagement in the restoration and rehabilitation of post-mining landscapes.

The CMSR would like to extend thanks to the mining industry partners who continue to provide significant support to our staff and students, facilitating research programs by providing many hours of logistical assistance and support for site-based field work. The translation of research from the laboratory to the field is core to successfully achieving successful outcomes for the CMSR, and we could not achieve these without this strong support. We also thank our major research partner Curtin University for their $1.3M cash investment in the Centre, and research partners the University of Western Australia, the Department of Biodiversity, Conservation and Attractions, and the Society for Ecological Restoration Australasia. All partners and contributors have invested significantly in terms of additional funding, resources and time to establish and support the research activities of the Centre.

We hope you enjoy and find value from today's events and we look forward to seeing you at the next workshop in 2020.

CMSR Centre Management Team

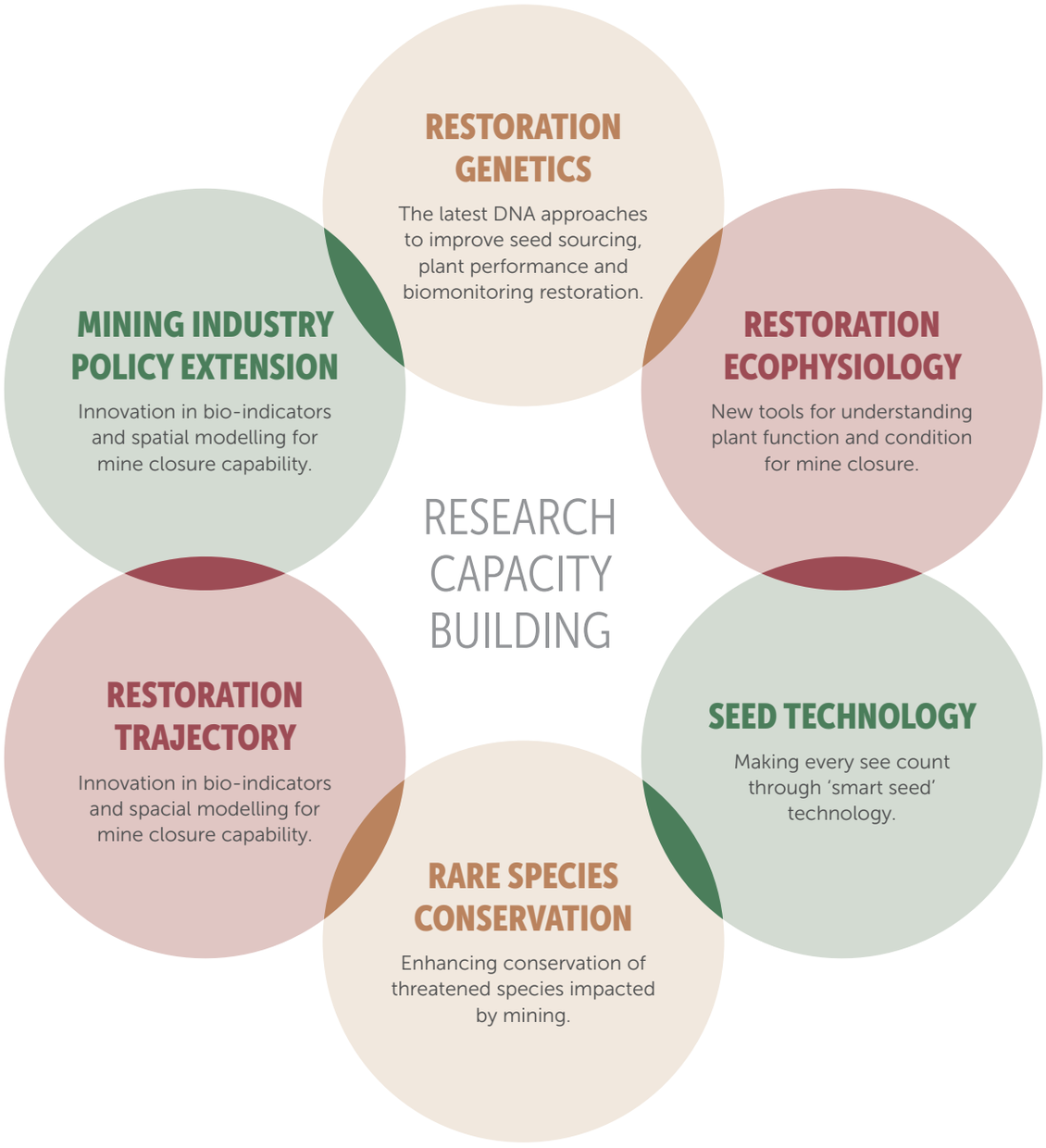
CMSR RESEARCH AT A GLANCE

BUILD

Our Australian Research Council Industrial Transformation and Training Centre for Mine Site Restoration (CMSR) is committed to training and developing a new generation of researchers while building collaborative networks to enhance restoration outcomes for industry.

CMSR is a multi-organisation group comprising two universities, one government department, one non-government organisation and five mining companies. Our students and post-doctoral fellows are embedded in industry across Western Australia and many have spent significant periods of time either on mine sites or in specialist research laboratories both in Australia and overseas.

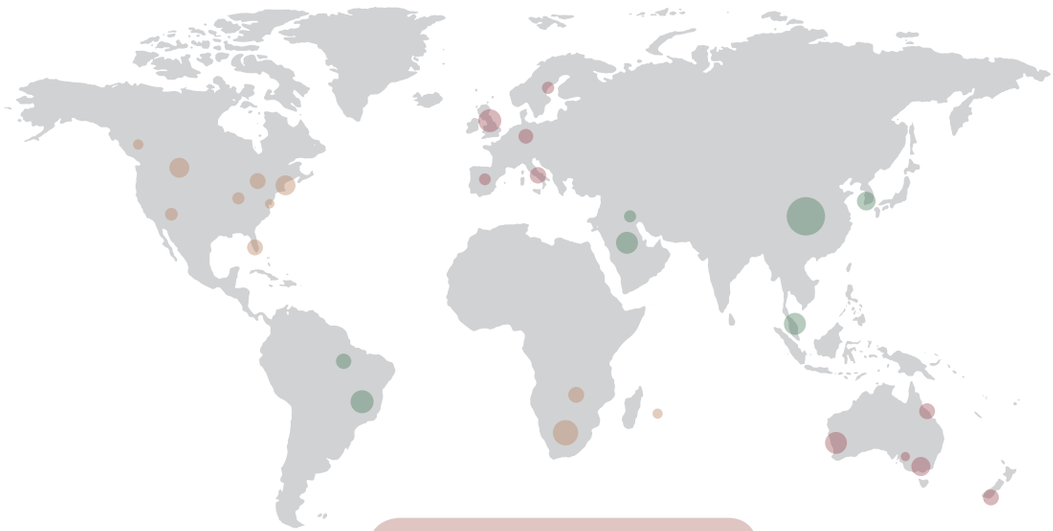
CMSR is structured as six thematic research areas: restoration genetics, seed technology and enablement, rare species management, restoration ecophysiology, restoration trajectory, and mining industry policy extension.



CMSR RESEARCH AT A GLANCE

UNDERSTAND

CMSR actively collaborates with colleagues and organisations around the world, contributing to the development of knowledge and expertise in restoration.



Africa

- Institute of Water,South Africa
- University of Mauritius, Mauritius
- University of Zambia

Asia

- Kunming Institute of Botany, China
- University of Malaysia
- Sabah Parks & Monash University, Malaysia
- University of Mining and Technology, China
- Seoul National University,South Korea,
- Chinese Academy of Science, Beijing, China.
- Green Development and Sustainability Center NGO, Mongolia
- Kuwait Kuwait Institute of Scientific Research
- Saudi Arabia King Abdullah University of Science and Technology

Australia and New Zealand

- University of Western Australia
- Kings Park and Botanic Garden
- CSIRO Tropical Ecosystems Research Centre
- Murdoch University
- University of Adelaide
- University of Queensland
- University of Otago, New Zealand

North America

- University of British Columbia
- University of Northern Arizona
- Meadowview Biological Research Centre
- Missouri Botanical Garden
- United Nations Convention on Combatting Desertification, New York
- Chicago Botanic Garden
- Florida Institute for Regional Conservation
- University of Montana
- United States Department of Agriculture

South America

- Universidade Federal de Minas Gerais, Brazil
- Xingu Seed Network, Brazil

Europe

- University of Loughborough, UK
- Czech Academy of Sciences
- University of Bayreuth, Germany
- University of Munich, Germany
- University of Cadiz, Spain
- Universities of Rome and Pavia, Italy
- Royal Botanic Gardens Kew, UK
- Royal Botanic Gardens Edinburgh, UK
- Germany National Seed Network
- Swedish University of Agricultural Sciences
- University of New Caledonia

We collaborate with five leading industry partners in mine site restoration

BHP Hanson KARARA MINING LTD MINERAL RESOURCES SINOSTEEL SMC

CMSR RESEARCH AT A GLANCE

INVOLVE

We work with relevant groups and individuals globally to provide expertise to inform work and decision making,including:

Contribution to the 2018 Senate Hearing and Senate Report 'Environment and Communications References Committee. Rehabilitation of mining and resources projects as it relates to Commonwealth responsibilities'.

Contribution to the Galgenyam Trust report for Argyle Mine Closure as a model of successful engagement with Traditional Owners.

Advisory role in the closure of Ranger Uranium mine.

Ongoing engagement with Traditional Owner groups and contribution to the development of Australia's first Native Seed enterprise owned and operated by Traditional Owners.

CMSR researchers are actively involved in external decision-making groups at a state, national and international level to improve restoration outcomes.

This includes Chair, Board, Committee and Advisory group membership in:

WESTERN AUSTRALIA

- **Project Numbat Inc.**
- **Cambridge Coastcare Inc.**
- **Closure Planning Practitioners Association**

INTERNATIONAL

- **Society for Ecological Restoration (Australasian Branch)**
- **Landscape Scale Restoration Group**, **SER**
- **Society for Ecological Restoration**
- **International Network for Seed-based Restoration**
- **International Union for the Conservation of Nature (IUCN) Species Survival Commission (SSC) Carnivorous Plant Specialist Group**
- **IUCN SSC Freshwater Plant Specialist Group**

- Plus Editorial positions in Journals such as **Plant and Soil** (Springer), **Restoration Ecology** (Wiley), **Drones** (MDPI) and **Journal of the Royal Society of Western Australia** (RSWA).

CMSR RESEARCH AT A GLANCE

TRANSLATE

Our researchers are working to discover and trial new methods and technologies to improve mine site restoration.

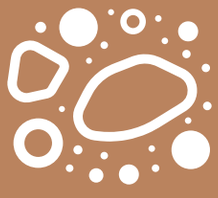
CMSR is actively involved in applied research which translates into real-life outcomes for industry and the wider community, such as:

DNA metabarcoding as an effective tool for predicting restoration trajectories.

Development of an effective standardised protocol for seed coating.

Demonstration of the capacity for drones to identify, track and monitor the performance of plants as small as individual seedlings.

Soil-microbial-interactions in examining the functional integrity of soils and post-mining substrates.



Evidence for accelerated rates of pedogenesis (soil formation) in some of the most highly modified substrates produced from mined material processing.

Increasing focus on fauna monitoring and behavioural studies as a way of understanding the long-term success of mine site restoration.

Our research has real-world impacts, contributing to guidelines, policy and practice, including:

2nd edition of the National Standards for the Practice of Ecological Restoration

2nd edition of the International Principle and Standards for the Practice of Ecological Restoration, launched at the 7th World Conference on Ecological Restoration in Cape Town (South Africa)

Australian Government Resources 2030 Taskforce and Report

WABSI Completion Criteria Framework and Report

Development of the first International Seed Standards

Development of the first International Mining Standards

OUR AWARD WINNING RESEARCHERS

CMSR researchers have been recognised for their research excellence by multiple awards and achievements in 2019, including the WA Premier's Science Awards and 2019 Australian Native Plant Award.

Dr. Adam Cross

Premier's Science Awards 'Woodside Early Career Scientist of the Year'

CMSR Research Fellow Dr Adam Cross was awarded the 'Woodside Early Career Scientist of the Year' at the Premier's Science Awards. The award is recognition of Dr Cross' research to transform sterile mining landscapes into healthy ecosystems. Dr Cross' techniques are currently assisting the Australian mining industry in meeting regulatory requirements on landforms for which no previous rehabilitation strategies existed, and for which no successful revegetation has been demonstrated globally. The results are practical, scalable and economical, ensuring fundamental restoration science has been translated into end-user outcomes for industry partners.

Dr. Adam Cross WA Premier's Science Awards 'Woodside Early Career Scientist of the Year'

Dr. Adam Cross discovery of a new population of the critically endangered aquatic carnivorous plant, *Aldrovandavesiculosa*,in Kimberly, Western Australia

Dr Cross is also an internationally renowned expert on carnivorous plants, considered the world authority on two iconic genera (*Aldrovandavesiculosa* and *Cephalotusfollicularis*) and made an exciting discovery of a new population of the critically endangered aquatic carnivorous plant, *Aldrovandavesiculosa*, growing in a billabong in a remote part of the Kimberley of Western Australia in July 2019. Recognition of Dr Cross's research excellence was highlighted by the publication of two articles in The Conversation in 2019, 'The waterwheel plant is a carnivorous underwater snap trap' and 'The Albany pitcher plant will straight up eat you (if you're an ant)', amongst media traction from over 150 outlets globally.

OUR AWARD WINNING RESEARCHERS

John Curtin Distinguished Professor Kingsley Dixon

2019 Australian Native Plant Awards - Professional Award

Professor Kingsley Dixon, the Director of the ARC Centre for Mine Site Restoration (CMSR) was awarded the 2019 Australian Native Plant Professional Award in recognition of his outstanding contribution to the knowledge of Australian plants.

Throughout his career, Professor Dixon has made a significant contribution to restoration ecology, conservation biology and plant science.

"My passion for saving threatened and extinct native species and restoring the Australian landscape that has suffered land degradation drives my work every day and it is a true honour to be recognised in this way."

Curtin University Vice-Chancellor Professor Deborah Terry congratulated Professor Dixon on being acknowledged for his valuable work. *"A passionate community scientist, Professor Dixon's research has resulted in WA being recognised as an international hub in mining environmental science, making him a most deserving recipient of this award."*

Sophie Cross

Fresh Science WA, Fresh Scientist 2019

CMSR PhD student Sophie Cross is a finalist in this year's Fresh Science, WA contingent. Fresh Science is a national competition helping early-career researchers find and share their stories of discovery.The program takes up-and-coming researchers with no media experience and turns them into spokespeople and science communicators, with media training and exposure to public events.

In 2019, Sophie participated in the eminent 'Industry Mentoring Network in STEM (IMNIS)' mentoring program and was invited to present at a 'Leaders in STEM' event, speaking on a panel of leading industry mentors and mentees.

Sophie's' research featured in this year's Australian Research Council (ARC) publication 2018-2019 'Making a difference—Outcomes of ARC supported research', highlighting bias in ecological restoration assessments and illustrating a need for increased fauna monitoring and behavioural studies to understand the long term success of mine site restoration.

"My PhD has not only furthered my love of science and research, but also my interests in science communication".

Holly Bradley

Postgrad Australia 2019 Scholarship winner

CMSR PhD student Holly Bradley won the 2019 Postgrad Australia Scholarship, awarded to a student for showing passion and social media engagement in a research field. Holly's research on the Western Spiny-tailed Skink has seen her conduct a significant amount of fieldwork in the mid-west of WA. In 2019, Holly was also successful in securing a grant from Gunduwa Regional Conservation Associationto further support the LiDAR and genetic analysis components of her research.

"I hope to continue this path to develop my skills in the design of meaningful research, to inform threatened species management and preserve biodiversity for the future."

HIGHLIGHTS FROM 2019

January

Professor David Read, eminent mycorrhizal specialist from Sheffield University and former secretary to the Royal Society of London visits CMSR and presents seminar at Curtin University.

Establishment of the first Indigenous owned and operated Native Seed Farm in Morowa, WA; a collaborative project between ARC CMSR, MEEDAC (Midwest Employment and Economic Development Aboriginal Corporation), Greening Australia, Green Values Australia and Karara Mining. The seed farm's initial planning will supply critically important species used in post-mining restoration, with an ongoing plan to employ local Indigenous people in operational activities including planting, management, harvesting and processing of seeds.

February

Perth Festival event 'Boorna Waanginy'presented a spectacular light projection display celebrating the unique biodiversity of South West WA, Noongar culture, science and art to an audience of over 110,000 people. Prof. Kingsley Dixon contributed to the stories projected on to the living canvas of Kings Park's iconic canopy of trees.

Prof. Kingsley Dixon advises the mine closure plan for the Ranger Uranium Mine in Kakadu, Northern Territory, one of the first Uranium mines to gain a closure certificate.

March

Noted US Restoration Ecologist Prof. James Aronson met with CMSR staff and students to discuss soil microbial health in mining.

Prof. Dixon presented a key note presentation at the Society for Ecological Restoration (SER) conference in Fort Collins, Colorado.

The Senate Report on 'Environment and Communications References Committee Rehabilitation of mining and resources projects and power station ash dams as it relates to Commonwealth responsibilities.' has been released.

Professor Kingsley Dixon contributed to this report and Senate hearing in March 2018.

April

CMSR Students Mieke van der Heyde, Holly Bradley and Sophie Cross presented at the recent L'Oréal UNESCO Girls in Science Forum discussed their pathway to their PhD and inspiring students to pursue a career in STEM.

May

Prof. Kingsley Dixon and Dr. Adam Cross work with Galganyem Trust on the development of a program to link indigenous communities in the region to mine restoration. In particular, looking at rehabilitation-relevant aspects of Argyle Diamond Mine closure plan and working successfully with Traditional Owners.

CMSR research media release on the ability of native flora to re-establish on post-mining landforms identified a small portion of species that are able to thrive in challenging growing conditions; the first time that research has demonstrated that a local native plant community can grow in alkaline mine tailing, giving hope for more effective mine site rehabilitation in the future.

June

Prof.Kingsley Dixon presented a key note presentation on International Seed Testing Association Congress in Hyderabad, India on 27 June.

A University of Zambia delegation visit the CMSR labs and participate in a workshop to foster international linkages, share and build capacity in teaching and research of sustainable mining practices.

Acting Centre Manager Vanessa MacDonald attended the ARC Major Investments Forum in Canberra, along with 140 ARC Centre Directors and Managers to discuss broad issues of establishing and managing a research centre, including outcomes from the Major Investments Working Group to better support Major Investments.

July

CMSR Student Sophie Cross invited panel speaker at IMNIS Mentoring Program event 'Leaders in STEM'

August

Prof. Kingsley Dixon presented at the ARC Science Week seminar series in Canberra. The seminar series showcases current research projects supported by ARC funding and creates links between ARC personnel and researchers in the field.

Prof. Kingsley Dixon participated in the annual Indigenous Australian Engineering School (IAES) program at Curtin University, where 24 Aboriginal and Torres Strait Islander students undertook a week of activities and site visits at Curtin and Industry partner sites. The aim of this program is to promote Indigenous perspectives to be represented in WA's engineering and science professions.

The WABSI Completion Criteria Framework and Full Report was formally released. ARC CMSR Centre Manager Renee Young lead the delivery of this project, along with Guy Boggs (WABSI), Marit Kragt (UWA), Ana Manero (UWA, Rachel Standish (Murdoch) and Ben Miller (KP) completing significant engagement and collaboration with wider stakeholders.This comprehensive report is the first of its kind in Australia and will provide a valuable reference for industry, government and research.

Dr Adam Cross awarded the 'Woodside Early Career Scientist of the Year' at the 2019 Premier's Science Awards.

September

The second edition of the 'International principles and standards for the practice of ecological restoration' is published in Restoration Ecology Journal. CMSR contributed to this set of Standards which is the first of its kind, linking researchers, practitioners, land managers, community leaders and decision-makers globally.

CMSR staff and students attended the SER2019 8th World Conference on Ecological Restoration in Cape Town, South Africa presenting, oral and abstract presentations and workshops including the in the Mining Restoration symposium.

October

CMSR Director and Curtin Distinguished Prof. Kingsley Dixon has been recognised with the 2019 Australian Native Plant Awards - Professional Award.

November

CMSR Annual 2 Day Workshop including student and industry presentations, invited speaker sessions and professional development workshops.

OUTREACH

CMSR researchers engage in outreach activities all year round, including media interviews, public presentations, National Science week activities and events promoting STEM careers to school students. Here are a few outreach highlights from 2019!

Prof. Kingsley Dixon contributed to the stories projected on to the living canvas of Kings Park's iconic canopy of treesduring the Perth Festival event 'Boorna Waanginy'. This spectacular light projection display celebrating the unique biodiversity of South West WA, Noongar culture, science and art to an audience of over 110,000 people in Western Australia.

Prof. Kingsley Dixon participated in annual Indigenous Australian Engineering School (IAES) program at Curtin University, where 24 Aboriginal and Torres Strait Islander students undertook a week of activities and site visits at Curtin and Industry partner sites. The aim of this program is to promote Indigenous perspectives to be represented in WA's engineering and science professions

CMSR Students Mieke van der Heyde, Holly Bradley and Sophie Cross presented at the recent L'Oréal UNESCO Girls in Science Forum discussed their pathway to their PhD and inspiring high school students to pursue a career in STEM.

Dr. Adam Cross engaged in interviews on radio and media articles distributed by over 170 media outlets in 2019, discussing CMSR research activities and promoting importance of ecological restoration, as Woodside Early Career Scientist of the Year.

CMSR Student Sophie Cross attended Fresh Science events, achieving the difficult 3 minute thesis challenge!

ANNUAL WORKSHOP 2019 PROGRAM

Tuesday 5th November - Industry and Student Presentation Day	
08:15 - 08:30	Registration
08:30 - 08:40	Welcome - Prof. Kingsley Dixon, ARC CMSR
08:40 - 09:20	**Dr. Paul Nevill - ARC CMSR Research Theme Session: Restoration Genetics** **Sheree Walters** 'Genetic patterns in sympatric parasitic and non-parasitic species and implications for restoration' **Bahram Mirfakhraei** 'Genecological assessment of seed sourcing for plant community restoration under changing environmental conditions' **Mieke Van der Heyde** 'Using DNA to monitor mine site restoration'
09:20 - 09:25	Q&A
09:25 - 09:40	
09:40 - 10:20	**Dr. Sean Tomlinson - ARC CMSR Research Theme Session: Keystone and Rare Species** **Holly Bradley** 'Improving translocation management for restricted range reptiles' **Harrison Palmer** ' Longevity and seed metabolism' **Subhashi Rajapakshe** 'Hydrological and thermal responses of seeds from four co-occurring tree species from southwest Western Australia'.
10:20 - 10:25	Q&A
10:25 - 10:45	Morning Tea Break
10:45 - 11:00	Industry Speaker - Tim Berryman, MRL
11:00 - 12:00	Guest Speakers - 'Working with Traditional Owners'; Kia Dowell and Amanda Wheeler, Gelganyem Trust.
12:00 - 12:45	Lunch Break
12:45 - 13:00	Guest Speaker - 'An international perspective on developing effective seed programs with traditional cultures'. Danilo Ignacio Urzedo, University of Sydney.
13:00 - 13:15	Industry Speaker - Zoe Keller, Hanson
13:15 - 13:45	**Dr. Adam Cross - ARC CMSR Research Theme Session: Seed Technology and Enablement** **Michael Just** 'Understanding the seed biology of Rutaceae for improving restoration outcomes' **Khiraj Bhalsing** 'Making Small Seeds Matter in Restoration'
13:45 - 14:20	**Dr. Adam Cross - ARC CMSR Research Theme Session: Monitoring Trajectory** **Sophie Cross** 'Behavioural responses of varanids to mine site restoration' Impacts for Industry Session: Completed students Todd Buters and Simone Pedrini
14:20 - 14:25	Q&A
14:25 - 15:00	Afternoon Tea Break
15:00 - 15:40	**Dr. Justin Valliere - ARC CMSR Research Theme Session: Restoration Ecophysiology** **Wei San Wong** 'Soil-microbial-plant signals and effects on plant eco-physiological performance for mine site restoration' **Christine Lison** 'Maximisation of topsoil via addition of waste rock in restoration of semiarid lands' **Jaume Ruscalleda** 'Near-surface remote sensing of plant condition in mine site restoration environments'
15:40 - 15:50	**Chris Tiemann - ARC CMSR Mining Policy.** 'Mine relinquishment policy in Australia: Barriers and enablers'
15:50 - 15:55	Q&A
15:55 - 16:10	Industry Speaker - Damien (Sam) Juniper, Karara
16:10 - 16:20	Closing of Day 1, Prof. Kingsley Dixon, ARC CMSR
16:30 - 18:00	Sundowner event
Wednesday 6th November - Student Workshop day	
08:30 - 08:50	Registration
08:50 - 09:00	Introduction - Prof. Kingsley Dixon, ARC CMSR
09:00 - 10:00	Workshop: Career Perspectives Panel. Blair Parsons (Greening Australia), David Hancock (Natural Area Management) Dr. Fiamma Riviera (Mattiske Consulting)
10:00 - 10:30	Workshop: Career Perspectives, Panel Q&A
10:30 - 10:50	Morning Tea Break and networking
10:50 - 11:10	WABSI Completion Criteria update
11:10 - 11:20	**Dr. Fiamma Riviera** - Research Update, Focus on long-term vegetation recovery
11:20 - 11:30	**Dr. Haylee D'Agui** - Research Update, Focus on soil health
11:30 - 11:45	**Danilo Ignacio de Urzedo** - PhD research findings
11:45 - 12:15	Lunch Break
12:15 - 12:30	Depart Old Boy's School and walk to Supreme Court Gardens, to start at 12:30pm.
12:30 - 15:30	**'Amazing Race'** activity around the city, start time 12:30pm, finish time 3:30pm.

INVITED SPEAKERS

Kia Dowell, Chair of Gelganyem Trust and Amanda Wheeler, CEO of Gelganyem Trust.

Gelganyem is a connected, culturally strong and sustainable organisation that creates meaningful change and choice for a healthier community and business success for all generations of Traditional Owners of the Argyle Participation Agreement. Gelganyem Trust manages the funds and assets under the Argyle Participation Agreement on behalf of the Traditional Owners.

The CMSR is privileged to welcome two exceptional speakers to this year's Annual Workshop Presentation day.

Kia Dowell

Chair of Gelganyem Trust

Kia Dowell is a Gija woman from Warmun Community (Turkey Creek) in the East Kimberley of Western Australia. Her traditional Aboriginal name is Wadjbarreyal and her skin name is Nangala.

Kia has over 15 years of national and international business and leadership experience and continues to work to strategically build models of cultural connection that lead to long-term transformation.

Before becoming Head of Strategy and Innovation at Indigenous Business Australia (IBA) Kia co-founded Codeswitch, an Indigenous strategic advisory and consulting firm she continues on in the capacity of Non-Executive Director. Prior to this, Kia spent 5 years working with a global mining company implementing Native Title Agreements in the East Kimberley and Pilbara regions of Western Australia. This experience saw her co-design innovative large-scale Cultural Education Training Programs with Traditional Owners, develop business opportunities with Aboriginal people, design culturally appropriate strategies and policies and establish a professional development exchange program that could utilize professionals in local Aboriginal communities.

Kia has spent time with school, community and corporate audiences in the US, Vanuatu, Turkey, Mexico and across Australia sharing her experiences of cultural identity, resilience and the power of female leadership. Kia is a past participant of the Global Ambassadors Program, a partnership between Vital Voices and Bank of America Merrill Lynch, a finalist in the 2016 AIMWA and The West Australian's WestBusiness Pinnacle Awards for Emerging Business Excellence, a 2015 Business News 40under40 Award Winner and holds her MBA in International Business from the University of Texas at El Paso (UTEP).

Amanda Wheeler

CEO of Gelganyem Trust.

Amanda Wheeler joined the Gelganyem Ltd as the Chief Executive Officer, with over 20 years in high level strategic leadership, advisory and operational management roles. Gelganyem Ltd supports the Traditional Owners who are party to the Argyle Participation Agreement. With operations soon to cease at Argyle Diamond Mine, Gelganyem Ltd is now heavily involved in preparing Traditional Owners for participating in the restoration of the site and for a life without royalty payments. Amanda has previously held CEO positions at the Forum for Directors of Indigenous Organisations (FDIO) and the Kuruma Marthudunera Aboriginal Corporation (KMAC) and is well versed in the challenges and opportunities confronting Indigenous organisations as they strive to balance cultural and corporate governance obligations. Amanda has extensive experience in maintaining key high level relationships with external stakeholders including government and non-government organisations, resource companies, funding bodies and other Aboriginal representative groups, including the people who have land access and participation agreements with Rio Tinto in the Pilbara region of Western Australia. As Director within management consulting groups Deloitte and Anson Management Consulting, and CEO at Outcare and Lifeline WA, Amanda provided governance and strategic advice to Boards and executive teams with a focus on the not-for-profit sector.

In 2019, the Galganyem Trust are working with the CMSR on the development of a program to link indigenous communities in the region to mine restoration. In particular, looking at rehabilitation-relevant aspects of Argyle Diamond Mine closure plan and working successfully with Traditional Owners.

A highlight of 2019 for the CMSR is the development of effective linkages to traditional owner groups. These, with the support of the Industry Advisory Council of the CMSR, have enabled the Centre to guide and develop potential new 'on country' business opportunities in the restoration economy for the mining industry and development capacity in restoration technologies and traditional owner engagement in the restoration and rehabilitation of post-mining landscapes.

We welcome Amanda and Kia to the CMSR 2019 Annual Workshop.

ABSTRACTS

Adam Cross

CMSR Theme Leader – Seed Technology and Enablement

Title Optimising seed use planning for ecological restoration

Contact email adam.cross@curtin.edu.au

Abstract Native seeds underpin the majority of post-mining rehabilitation and ecological restoration projects globally, yet their inefficient use often results in poor ecological recovery outcomes. It is becoming increasingly recognised that early and comprehensive planning for project-specific seed use requirements can significantly enhance restoration outcomes. However, numerous knowledge gaps continue to act as roadblocks to seed use planning. Research undertaken in the CMSR Seed Technology and Enablement and Restoration Trajectory themes is working to close some of these gaps, with key studies examining stages such as a) how to select species appropriate to local edaphic conditions, b) how to optimise seed sourcing for project requirements, c) how seed preparation and delivery to site can be improved, and d) how seed broadcasting, emergence and establishment can be monitored at very fine scales to examine and predict restoration trajectory.

Bahram Mirfakhraei

CMSR PhD student

Title Genecological assessment of seed sourcing for plant community restoration under changing environmental conditions

Supervisors Siegy Krauss, Erik Veneklaas, Jason Stevens

Contact email bahram.mirfakhraei@research.uwa.edu.au

Abstract: Environmental changes such as climate change can have major impacts on plant growth and survival. Thus, in ecological restoration projects, it is important to use seed sources that are genetically appropriate and are able to tolerate predicted environmental changes. Although many strategies for seed sourcing have been proposed to address environmental change, there are few empirical tests to support the benefits of different strategies. In this project, multiple genetic provenances of *Banksia* species were tested in post-mining rehabilitation field sites, glasshouse experiments and controlled environments. In addition, chemical and biological properties of soils from these multiple source sites are being assessed and compared to performance of seeds and seedlings.This research aims to provide a comprehensive test of influence of climatic and edaphic variation on the performance of genotypes from multiple provenances, to identify best-practice seed sourcing. The findings of this project will improve seed sourcing decisions and guidelines for plant restoration purposes. Outcomes of this project will also improve the efficiency of ecological restoration projects.

ABSTRACTS

Chris Tiemann

CMSR PhD student

Title Mine relinquishment policy in Australia: Barriers and enablers

Supervisors Kingsley Dixon, Tein McDonald, Garry Middle, David Kendal

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Abstract The profile of mine rehabilitation and closure continues to gain momentum in Australia, with an increasing focus by governments, industry and the broader community on a range of mine closure related topics. Despite decades of mine closure research and rehabilitation activities, there are limited examples within Australia of mining operations closing successfully and allowing relinquishment of mine tenure. A review of policy across Australia demonstrates that no clear pathway to relinquishment exists within mine closure legislation. While policy gaps contribute to the limited examples of successful relinquishment, defined in this paper as the transfer of liability, there are a number of additional roadblocks. A major one being the reality of residual risk and liability existing after a mine has been successfully closed. Closing a mine is an investment decision, with mining executives and boards requiring certainty of process and outcome to invest in closure. Moving forward government, industry and the community need to understand and accept that residual risk and liability will exist in successfully closed post mined land. To ensure that mining is a temporary land use, mechanisms for improving relinquishment outcomes, explored in this paper, and innovative thinking around post mining land uses must also be employed. This paper presents approaches to relinquishment, including risk and liability determination and post closure funding arrangements throughout the mining lifecycle. When coupled with a defined regulatory process for relinquishment, these can drive better mine closure outcomes.

Publication details: Tiemann, CD, McDonald, MC, Middle, G & Dixon KW. (2019). 'Mine relinquishment policy in Australia', in AB Fourie & M Tibbett (eds), *Proceedings of the 13th International Conference on Mine Closure, Australian Centre for Geomechanics, Perth,* pp. 1451-1460.

Christine Lison

CMSR Masters student

Title Maximisation of topsoil via addition of waste rock in restoration of semi-arid lands

Supervisors Erik Veneklaas, Adam Cross, Jason Stevens, and Kingsley Dixon

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Abstract A standard procedure to address topsoil deficits during restoration of arid and semi-arid environments is the inclusion of waste rock within the topsoil cover mix. Provided waste rock materials have been shown to have no net negative impact on the environment (non-acid forming), mine waste material can provide an effective substrate for restoration. Previous research has shown that the addition of up to 25% waste rock to topsoil cover mixes has no negative effect on seedling emergence or hydrological properties. The performance of topsoil cover mixes incorporating greater than 25% waste rock remains to be tested.

We tested the physio-chemical and hydrological properties and the physiological responses of plants and seeds grown on topsoil covers incorporating greater than 25% waste rock. We hypothesised that the addition of waste rock would improve water retention in topsoil mixes.

We found that the addition of waste rock maximised soil available water improving plant survival over drought periods although plant growth was reduced compared to plants grown on topsoil only. We also found that the addition of waste rock increased salinity of topsoil mixes where topsoil was already moderately saline. The effect of increasing salinity was a reduction in seed germination percentage. Further testing of seed germination in laboratory conditions confirmed that seed germination is limited at greater than 0.1M NaCl.

ABSTRACTS

Justin M. Valliere

CMSR Theme Leader – Restoration Ecophysiology

Title Using plant ecophysiology to guide mine site restoration

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Abstract Plant ecophysiology – the study of the complex interactions between plants and the environment – can provide a useful framework for guiding mine site restoration. By understanding the physiological mechanisms that allow plants to establish and persist in these highly disturbed environments, practitioners may be able to improve restoration outcomes. Specifically, methods in plant ecophysiology can (1) inform site preparation and the selection of plant material for restoration projects, (2) aid in monitoring restoration success by providing additional insight into plant performance, and (3) ultimately improve our ability to predict restoration trajectories. I will review the potential applications of an ecophysiological perspective to mine site restoration in Western Australia, including successes and challenges associated with such an approach. I will also discuss new research directions to be pursued over the next two years in the ecophysiology node. This work will aim to identify physiological indicators of restoration success that can be incorporated into current monitoring efforts, explore the impacts of environmental stressors on restored communities, and investigate new methods to improve plant performance in a restoration context.

Jaume Ruscalleda

CMSR PhD student

Title Near-surface remote sensing of plant condition in mine site restoration environments

Supervisors Erik Veneklaas and Jason Stevens

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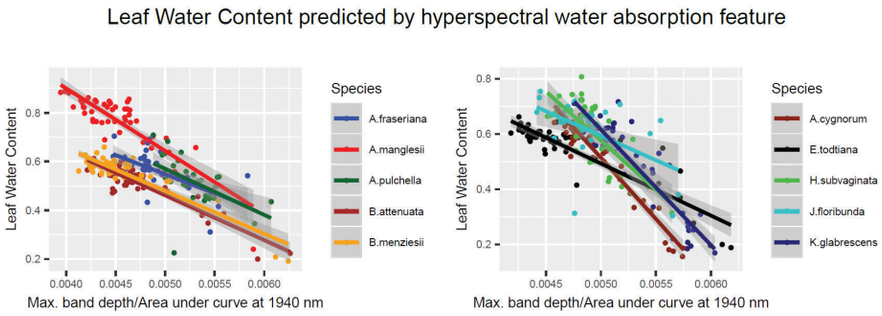
Abstract This research project aims to determine if near-surface remote sensing measurements can reliably quantify plant drought stress condition in a biodiverse and heterogeneous plant community. This project also aims propose quantitative criteria to evaluate restoration success, by defining a fast, accurate and easy to perform methodology, potentially establishing the foundations for scaling up to more remote imaging platforms that allow monitoring of larger areas in shorter periods of time. Results from a glasshouse experiment indicate that hyperspectral data can predict drought stress related physiological variables in all 10 native Banksia woodland plant species studied with relatively high precision at the leaf level both with an artificial light source and with mid-day sunlight, and to a lesser extent at plant canopy level with mid-day sunlight. Short wave infrared radiation-based data, such as absorption features and spectral indices, provide most useful information in order to predict plant water status in the studied species. Ongoing field work is being undertaken to validate these findings by monitoring the physiology of young plants (in parallel with near-surface remote sensing measures) growing in a restored mine site in WA.



ABSTRACTS

Holly Bradley

CMSR PhD student

Title Improving translocation management for restricted range reptiles

The Western Spiny-tailed Skink (*Egernia stokesii badia*)

Supervisors Bill Bateman, Sean Tomlinson, Adam Cross, Michael Craig, Mike Bamford

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Abstract Translocation is an accepted tool in biodiversity conservation, and is increasingly applied to a range of threatening processes. Mitigation translocations respond to an immediate crisis and focus on the removal of individuals from a threat rather than long-term conservation goals. The relative success of conservation translocations, which are generally projects with longer timelines and specific targets, has been used to justify the use of mitigation translocations as a management tool. However, as there is limited global conservation funding and the number of mitigation translocations have increased to outnumber conservation translocations, it is important to understand the effectiveness of mitigation translocation for wildlife management. A selective, systematic, quantitative review was used to investigate the trajectory of mitigation translocation science, and the best strategy forward to improve mitigation translocation management. The findings provide a strategic approach that can be applied to improve the success of future case studies, including the translocation management of the endangered Western Spiny-tailed Skink (*Egernia stokesii badia*), a subspecies with no published successful translocation attempts, anecdotal reports of failed attempts, and an indication of complex requirements for establishment and persistence.

Khiraj Bhalsing

CMSR PhD student

Title Making small seeds matter in restoration

Supervisors Adam Cross and Kingsley Dixon

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Abstract In ecosystems where the severity of disturbance precludes autogenic recovery, targeted seeding with a diverse mix of native species can be the only means of restoring ecosystems. However, the success rate of broadcast seeding can be constrained by biotic & abiotic factors that impair seedling emergence and development. These effects are felt most strongly for small seeded species. Pelleting small seeds has emerged as a promising strategy to address issues such as poor seedling emergence, physical soil crusting, seed predation and low rates of seedling establishment. However, there have not yet been any comparative studies undertaken to understand whether, single seed or multi-seed pellets represent the most effective strategy for delivery of native seeds in seed-based restoration activities. In this study, the efficacy of single versus multi-seed pelleting was assessed for three different small seeded species from the Midwest region of Western Australia, *Eucalyptus loxophleba* subsp. *supralaevis, E.leptopoda* subsp. *elevata* and *Melaleuca hamata* (Myrtaceae). Seeds were coated using a Pan Coating machine due to their small size and mass representing the first such attempt in the seed coating literature for native seeds. The study focused upon the comparative performance of un-pelleted seeds, single seed pellets and multi-seed pellets based on pellet physical quality and germination performance in lab based experiments.

ABSTRACTS

Mieke van der Heyde

CMSR PhD student

Title Using DNA to monitor mine site restoration

Supervisors Paul Nevill, Nicole White, Grant Wardell-Johnson, Michael Bunce

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Abstract Metabarcoding is an emerging technology that is currently being applied to biodiversity assessments in a broad array of systems, and may prove useful in monitoring mine site restoration. It involves the use of High-Throughput Sequencing to sequence barcode regions of the genome to determine the community composition of a sample. This study aims to test multiple substrates (soil, scat, plant material, arthropods in pitfall and vane traps) to determine what organisms can be detected from each and where they overlap. Samples were collected in two regions of Western Australia; the DNA was extracted, amplified and sequenced using multiple primers and targeting multiple gene regions. Results indicate that soil samples yield little plant or animal DNA, likely because the high temperatures and UV radiation of Western Australia degraded the DNA in the surface soil. This substrate will require further troubleshooting to be useful in biodiversity assessment. Bulk samples, such as arthropods from pitfall traps and vane traps, as well as scat samples detected greater diversity. Scat and arthropod samples were then collected from chronosequences of mining restoration to investigate the use of metabarcoding in restoration monitoring. The goal of this project is to provide a guide for terrestrial metabarcoding sample collection to be used for biological surveys, and an example of how this method may be applied to restoration monitoring.

Publication details Submitted:
van der Heyde, M., Bunce, M., Wardell-Johnson, G., Fernandes, K., White, N., Nevill, P. Testing multiple substrates for terrestrial biodiversity monitoring using environmental DNA (eDNA) metabarcoding.

Published:
Fernandes, K., van der Heyde, M., Coghlan, M., Wardell-Johnson, G., Bunce, M., Harris, R., & Nevill, P. (2019). Invertebrate DNA metabarcoding reveals changes in communities across mine site restoration chronosequences. Restoration Ecology. doi: 10.1111/rec.12976

Fernandes, K., van der Heyde, M., Bunce, M., Dixon, K., Harris, R. J., Wardell-Johnson, G., & Nevill, P. G. (2018). DNA metabarcoding—a new approach to fauna monitoring in mine site restoration. Restoration Ecology, Vol. 26, pp. 1098–1107. doi: 10.1111/rec.12868

van der Heyde, M., Liu, H., Ohsowski, B., & Hart, M. (2018). Arbuscularmycorrhizal community recovers rapidly along a tallgrass restoration chronosequence. Ecological Restoration, 36(2). doi: 10.3368/er.36.2.108

Harrison Palmer

CMSR PhD student

Title Longevity and seed metabolism

Supervisors David Merritt, Sean Tomlinson, Emma Dalziel, Christine Cooper

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Abstract Experiments into predicting seed longevity involving novel application of closed system respirometry to measure the metabolic rate of germinating seeds of various WA natives.

Protocol for measuring native seed MR has been developed by authors as the technology is relatively novel and has not been applied en masse to wild species. I present the optimised method of measuring native seed MR and data regarding how seed age affects metabolism, which will be used to develop predictive equations for seed longevity.

ABSTRACTS

Michael Just

CMSR PhD student

Title Understanding the seed biology of Rutaceae for improving restoration outcomes

Supervisors Adam Cross, Shane Turner, David Merritt, Kingsley Dixon

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Abstract Seed-based ecological restoration is the most effective practice for ecological recovery of degraded sites. In Western Australia, 30% of plant species occur within families possessing complex seed dormancy mechanisms that pose a significant barrier to their successful integration into seed-based restoration. One diverse family is the Rutaceae, representatives of which comprise significant components of diverse understory vegetation communities throughout southwestern Australia. Species of Rutaceae possess intractable seed dormancy, and while globally the family is a highly-utilised group in both horticulture and medicine, little information is available about the cues they require for alleviation of seed dormancy as well as germination stimulation. Observation of post-fire recruitment within Rutaceae suggests fire plays a significant role in their germination ecology. Methods for dormancy alleviation and germination stimulation centred on the role of fire are common however; they are yet to be successfully applied to the Rutaceae. Thus, to increase the ability of land managers to utilise Rutaceae within restoration projects in southwestern Australia, a better understanding of the mechanisms regulating seed dormancy, and the ecological stimuli driving and supporting germination is required.

Paul Nevill

CMSR Theme Leader – Restoration Genetics

Title Expanding the molecular 'toolbox' for better restoration outcomes

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Abstract The key objectives of the CMSR genetic node include: 1) the application of molecular, genecological, remote sensing and mapping approaches for understanding the drivers of adaptively significant genetic variation and its spatial structure, to inform decisions regarding seed sourcing and seed farming, 2) development of a 'DNA toolbox' for restoration monitoring, and 3) study of soil microbial communities, particularly in novel substrate mixes and stored topsoil. Over the last 12 months we have made strong progress in all our core themes. Our projects are deliberately cross disciplinary and we have built several new and exciting collaborations with spatial sciences and environmental DNA labs at Curtin University. Our research programs are located across all industry partner sites and in 2019 our team members have spent significant periods in the field. Exciting results from the research program include the demonstration of DNA metabarcoding as a tool for predicting restoration trajectories and the completion of several high impact studies on key issues in restoration planning. These include projects focused on understanding the recovery of soil microbial communities following restoration and the importance of habitat suitability in maintaining genetic connectivity between populations.

ABSTRACTS

Sean Tomlinson

CMSR Theme Leader – Rare Species

Title What are they doing there? Spatial analyses in ecological restoration

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Abstract

There is a growing recognition that ecological restoration is one of a set of representatives of a category called "wicked" problems. These are problems that are difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize, and whose social complexity means that they have no determinable stopping point. I contend that wicked problems require fiendish solutions, and that spatial ecology, particularly the construction of spatially-informed models, is one such, but there are challenges to implementing these solutions. The first is that, even where the modelling processes have been well developed, practical outcomes require spatial data at an appropriately high resolution. The second is that the spatial data must be informative of conditions that are meaningful to the ecological processes being reinstated. Here I present some spatial modelling using high resolution geomorphological and edaphic data to indicate how practical outcomes can be guided by model expectations. I then further indicate how appropriate spatial data can facilitate the incorporation of biological mechanisms into the resulting models. These mechanisms generally offer more nuanced insights and guidance to practical programs than the simple correlations that are more commonly deployed.

Sheree Walters

CMSR PhD student

Title Genetic patterns in sympatric parasitic and non-parasitic species and implications for restoration

Supervisors Paul Nevill, Margaret Byrne, Grant Wardell-Johnson, Todd Robin

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Abstract

Seed collection strategies should be designed to maximise genetic health of restored vegetation, avoid poor plant establishment, and ensure that the restored area has the genetic diversity to adapt to changing conditions in the future. While parasitic species have important ecological, cultural and biological values, few studies have examined the importance of parasitic life history traits in determining spatial patterns of genetic variation and adaptation to climatic conditions. In this study, we collected samples from across the range of two plant species – the hemiparasite *Nuytsia floribunda* and the sympatric non-parasitic *Melaleuca rhaphiophylla* – with the aim to examine the effect of different life history traits on the geographic distribution of genetic variation. The nuclear genome was sequenced using DArTseq technology and quality control filtering applied to obtain 4,433 high-quality SNPs for *M.rhaphiophylla* and 4,759 SNPs for *N. floribunda*. Global genetic differentiation values of 0.121 and 0.197 were obtained for *M. rhaphiophylla* and *N. floribunda* respectively. Analysis of population structuring identified four genetic clusters for *M. rhaphiophylla* and three genetic clusters for *N. floribunda*. Furthermore, fewer loci with signals of selection were observed in the parasitic species with a total of 309 SNPs identified across four methods for *N. floribunda* while 782 SNPs were identified using the same methods for *M. rhaphiophylla*. These signals of selection are currently being assessed against climatic variables to identify the possible environmental drivers of adaptation. The final step of this study will be to combine data on contemporary population structure, local adaptation and chloroplast DNA diversity to create provenance maps that will guide seed sourcing.

ABSTRACTS

Sophie Cross

CMSR PhD student

Title Behavioural responses of varanids to mine site restoration

Supervisors Bill Bateman, Sean Tomlinson, Michael Craig, Kingsley Dixon

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Abstract Understanding the behavioural responses of animals to habitat change is vital to their conservation in landscapes undergoing restoration. Studies of animal responses to habitat restoration typically assess species presence/absence; however, such studies may be restricted in their ability to show whether restoration is facilitating the return of self-sustaining and functional fauna populations. In arid Australia, varanids (monitor lizards) fill high order predator roles in the broad absence of apex mammalian species. Being the high order predators in these ecosystems, varanids exert top-down control of prey with some acting as keystone species. Australian varanids are highly diverse, both ecologically and in size, occupying a range of arboreal and terrestrial niches and encompassing almost the entire of the size range of the genus. The diverse range of body sizes, and therefore home ranges, make the varanids an ideal group to monitor landscape change over a range of spatial scales. We assessed the behavioural responses of varanids to restoration at a Mid West Western Australian mine site, using a combination of direct and indirect monitoring methods, including camera trapping, VHF/GPS tracking, and mapping of habitat usage signs. Although facilitating return, restoration areas appear to be used with increased selectivity by varanids, supporting fewer signs of foraging and shorter foraging trips. Understanding the behavioural responses of animals to changing habitats, particularly those which may have increased susceptibility to fluctuating temperatures, is key to facilitating their conservation in altered landscapes undergoing restoration.

Publication details

Cross S.L., Tomlinson S., Craig M.D., Dixon K.W., and Bateman P.W. 2019. Overlooked and undervalued: the neglected role of fauna and a global bias in ecological restoration assessments. Pacific Conservation Biology. doi: 10.1071/PC18079

Cross S.L., Bateman P.W., and Cross A.T. (2019). Restoration goals: why are fauna still overlooked in the process of recovering functioning ecosystems and what can be done about it? Ecological Management and Restoration. In Press.

Under review:

Cross S.L., Tomlinson S., Craig M.D., and Bateman P.W. (2019). The Time Local Convex Hull (T-LoCoH) method as a tool for assessing responses of fauna to habitat restoration: a case study using the perentie (Varanusgiganteus: Reptilia: Varanidae). Australian Journal of Zoology. Under Review.

Cross S.L., Craig M.D., Tomlinson S., Bateman P.W. (2019). I don't like crickets, I love them. Invertebrates are an important prey source for varanid lizards. Journal of Zoology. In Press.

ABSTRACTS

Subhashi Rajapakshe

CMSR PhD student

Title Hydrological and thermal responses of seeds from four co-occurring tree species from southwest Western Australia

Supervisors Sean Tomlinson, Shane Turner, Adam Cross, Katherine Trinajstic

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Abstract Seed germination is a critical stage in the life cycle of plants defined by specific tolerance thresholds beyond which success of germination rapidly declines. Previous studies have demonstrated that widespread plant species commonly germinate over a broad range of environmental conditions, whereas range-restricted species often exhibit a narrower germination window in terms of temperature and moisture. We investigated the relationship between maximum germination (Gmax), and time to 50% germination (t50) in response to temperature and water stress in four co-occurring Western Australian native Eucalyptus species. *Eucalyptus caesia* subsp. *caesia* and *E. ornata* exhibit a highly localised distribution and a narrow geographical range. These species were compared with the widespread sympatric species *E. salmonophloia* and *E. salubris*. There was a distinctive hump-shaped response of t50 to temperature and an exponential response to water stress characteristic of rate- and threshold-limited processes, but no consistent pattern in the response of Gmax. The two range-restricted taxa had narrower thermal tolerance ranges than their widespread, eurythermic congenerics. The two short range-endemics exhibited higher lability to temperature and drought stress compared to the two widespread species in terms of final germination percentage. The insights gained in this study could be beneficial for identifying thresholds for temperature and water stress tolerance in seeds of other flora of conservation concern.

Publication details Rajapakshe, R.P.V.G.S.W, Turner, S.R., Cross, A.T. and Tomlinson, S.T. 2019. Hydrological and thermal responses of seeds from four co-occurring tree species from southwest Western Australia. Functional Ecology. Under Review.

Wei San Wong

CMSR PhD student

Title Soil-microbial-plant signals and effects on plant eco-physiological performance for mine site restoration

Supervisors Erik Veneklaas, Jason Stevens, John Yong, Robert Trengove

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Abstract Mining activities alter the soil biological properties which are important for conferring various benefits to the soils and plants. Learning from the agricultural sectors, inoculation of beneficial microorganisms could be a plausible way to rejuvenate soil biological properties and in turn enhance restoration success. However, little is known if the reported benefits, such as growth stimulation, increased nutrient uptake, enhanced plant tolerance against abiotic stress observed in crop plants, will be conferred onto the targeted plant species for restoration.

Glasshouse experiments were conducted to investigate the effects microbial inoculations have on various plant species native to Banksia Woodlands and Mid-West of Western Australia. Plant growth performance and various physiological parameters (such as xylem sap phytohormone profile, foliar nutrient content etc.) were utilised to determine the efficacy of the microbial inoculations. Experimental results indicated variable responses in the tested plant species which could be attributed to the growth stage at which the inoculations were applied and plant-microbe compatibility.

Simone Pedrini

CMSR PhD Student

Project: 'Seed enhancement research for improving ecological restoration'

The goal of this PhD is to test seed coating technologies on native plant species to improve the efficiency of seed use in ecological restoration.

Literature review – What is seed coating? Seed coating is used to modify seed physical properties for improved handling, and deliver beneficial compounds to protect seeds from pathogens/predators, enhance germination, and promote seedling growth. Seed coating technology has been developed for the seeds of crop and horticultural species, but most of the know-how is owned by private companies and kept trade secret, making its application to native seeds particularly challenging.

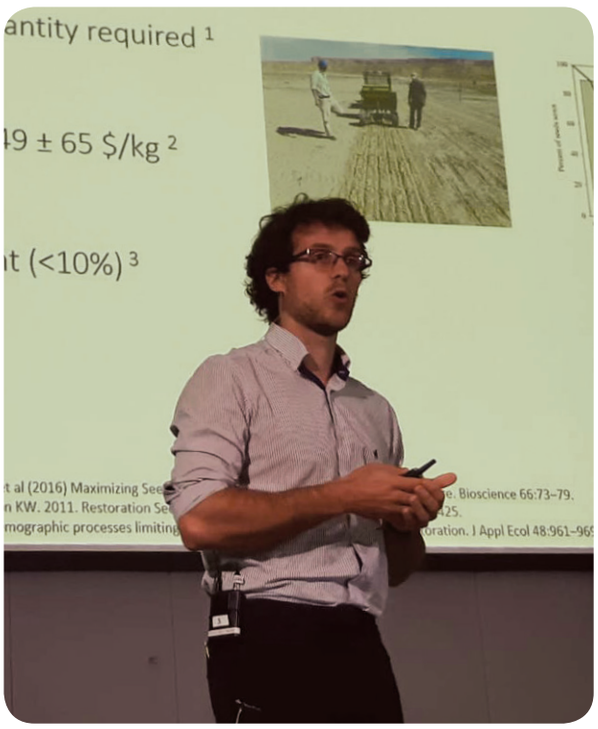
Methodological Chapter – How is seed coating done? The lack of publicly available information on seed coating required for the re-development of seed coating methodologies. This resulted in the publication of the first openly-accessible protocol development tool (PDT) for coating seeds, a step-by-step guide for customising coating recipes and processes. The PDT, initially aimed at native seed users for testing seed coating formulations to native species, could also be employed by farmers and small seed producers that don't have access to proprietary commercial seed coating treatment.

Experimental Chapter 1 – How does seed coating work? The method described in the PDT was used to evaluate the effect of coating materials on seed germination on a test species (tomato). In the literature, seed coating was commonly reported to reduce seed germination, but the causes were not clear. Seed germination experiments, performed in controlled laboratory environment, revealed a correlation between increased mechanical integrity of the coating and reduction in germination speed. The optimal combination of materials that would maximise coat integrity with the least delay on germination was then determined.

Experimental Chapter 2 – How to make native grass seed coat-able? Seed coating was tested on native grass species commonly used for pasture and ecological restoration in temperate *Australia: Austrostipascabra, Chloris truncata, Microlaena stipoides* and *Rytidospermageniculum*. Direct application of the coating was unfeasible due to the complex morphological features of the grass florets. Seed processing techniques for the reduction of the floret (mechanical cleaning, flash flaming and sulphuric acid digestion) were therefore tested and optimised. Sulphuric acid processing proved to be the most cost-effective method and provided the best germination outcomes.

Experimental Chapter 3 – How to improve native grass seed performance with coating? The processing of *A. scabra, M. stipoides* and *R. geniculatum* seeds allowed for the successful application of seed coating. Salicylic acid (SA), a compound known to induce stress resistance in plants, was delivered to the seed by imbibition and coating, and its effects were tested in laboratory conditions and field trials. SA treatments were not detrimental to germination and emergence. In fact, SA treatment improved plant survival and growth in the field after the dry, summer months.

Seeds are instrumental for the reintroduction of plant species in terrestrial restoration. However, the successful use of native seed in restoration is usually limited by ecological and logistical barriers to seed germination and establishment. The results presented in this thesis highlighted the benefit of employing seed processing and coating technologies to native grass seeds. The methodologies here developed can be applied to a broader range of species and tested with a wide array of promoters to overcome the constraints that limit native seed use efficiency in ecological restoration.



PROJECT COMPLETION AND INDUSTRY IMPACT SUMMARIES

Impacts for industry

Seed pelleting and encrusting protocol development tool (PDT) allows for:

- Development of species specific protocols.
- Quality control of pellets batch and improvement of pelleting/encrusting recipes
- Testing of material effect on pellets mechanical resistance and batch quality
- Customisation of the pro-forma and table to different seed coating apparatus
- Scalability of seed pelleting/encrusting processes

Seed pelleting: trade-off between germination and mechanical integrity allows for:

- The fine tuning of seed pelleting material for optimal germination outcomes and pellets' mechanical proprieties.
- The replicable and scalable evaluation of new pelleting material

Optimizing seed processing techniques to improve germination and sowability of native grasses for ecological restoration allows for:

- Improved efficacy of seed processing techniques
- Improved flowability of treated seed resulting in more efficient sowing
- Improved germination of processed seed of grass species

Seed encrusting with salicylic acid: a novel approach to improve survival of native grasses allows for:

- Efficient seed encrusting on grass seeds
- Improved plant survival in the field

Publications:

Pedrini S, Bhalsing K, Cross AT, Dixon KW. 2018. Protocol Development Tool (PDT) for seed encrusting and pelleting. Seed Science and Technology http://www.ingentaconnect.com/content/ista/sst/pre-prints/content-21_sst46-2-393-405

De Vitis M, Abbandonato H, Dixon KW, Laverack G, Bonomi C, Pedrini S. 2017. The European Native Seed Industry: Characterization and Perspectives in Grassland Restoration. Sustainability 9, 1682. https://www.mdpi.com/2071-1050/9/10/1682

Abbandonato H, Pedrini S, Pritchard HW, De Vitis M, Bonomi C. 2017. Native seed trade of herbaceous species for restoration: a European policy perspective with global implications. Restoration Ecology, 1–7. https://onlinelibrary.wiley.com/doi/full/10.1111/rec.12641

Pedrini, S., Lewandrowski, W., Stevens, J. C., & Dixon, K. W. 2018. Optimizing seed processing techniques to improve germination and sowability of native grasses for ecological restoration. Plant Biologyhttps://onlinelibrary.wiley.com/doi/abs/10.1111/plb.12885

Todd Buters

CMSR Masters Student

Project: 'Drone-based remote sensing as a novel tool to assess restoration trajectory at fine-scale by identifying and monitoring seedling emergence and performance'

Background: The overarching goal of this project was to investigate the use of unmanned aerial vehicles (UAVs) in mine site restoration through a literature review, and investigate any knowledge gaps that were presented over the course of the two experimental chapters.

Literature review: As the first stage of this project, I undertook a literature review that investigated the use of UAVs in the monitoring of ecological restoration monitoring. This review highlighted several key deficiencies in the use of UAVs in restoration monitoring. First and foremost was a simple lack of studies in the field. While there have been numerous studies focussing on UAV monitoring, 2133 all told, only 56 focussed on the monitoring of ecological restoration, and only 48 of those presented experimental results. However, the review showed that interest in the field is increasing, with >65% of those studies occurring in the last three years. Secondly, studies generally restricted themselves to only a single sensor, most commonly Red-Green-Blue (RGB) digital cameras, and thirdly, studies that attempted to automate the image classification process were limited, with more than two thirds of the assessed papers using only manual classification techniques. The two data chapters were planned based on the findings from the literature review, which has since been published in the journal *Remote Sensing*.

Experimental chapter 1: While not a key finding of the literature review, it was found that most studies focussing on UAV-based restoration monitoring did not take full advantage of the high spatial resolution offered by UAVs, commonly being employed solely as a cheaper alternative to manned aircraft. This, coupled with the restoration bottleneck of seedling mortality during seed germination, seedling emergence, and early seedling establishment prompted me to focus on the automatic classification of smaller objects than any previous study has ever focussed on – seeds and seedlings. This study centred around a trial area made up of four different substrate areas (control, waste rock, topsoil, and tailings), each of which was ripped over half of its area, and seeded in three different densities. The Object-Based Image Analysis (OBIA) program eCognition was used to classify orthomosaics created from images of the trial site taken from a UAV. Overall classification accuracies for target seeds exceeded 90%, and for seedlings of our target species exceeded 80% - despite the presence of background grasses. The results of this experiment have been written up in the paper "Unmanned Aerial Vehicles and automated image classification are effective tools for detecting target seed and seedlings in the monitoring of ecological recovery", which has been published in the journal *Drones*.

Experimental chapter 2: The second experimental chapter focussed on a major failing in previous studies identified by the literature review – the overabundance of single-sensor setups, and the limiting nature of the data gathered in this manner. The second experiment built on the first, utilising the same setup. However, while the seedlings were watered daily during the first experiment, the reticulation was turned off for the second experiment, and the seedlings were allowed to gradually dry out and die over the course of the experiment. As this was occurring, flights were being conducted with the same UAV used for experiment one, however it was now equipped with a multispectral sensor, in addition to the standard RGB camera. The same technique used for identifying seedlings and background grasses created in experiment 1 was utilised to identify the seedlings, and a variety of RGB and multispectral indices were used to track the decline in the seedlings' condition. Very few previous studies have attempted to monitor plant health on an individual basis, and this study is the first to attempt to do so on recently established seedlings.

PROJECT COMPLETION AND INDUSTRY IMPACT SUMMARIES

Impacts for industry:

Classification of seeds:

- Can classify and count seeds
- Repeated flights allow for assessment of how many seeds are being lost to granivores
- Can determine spread of seeds across restoration project

Classification of seedlings:

- Can classify and count seedlings
- Can identify areas of mortality by decreasing seedling numbers
- Can estimate restoration success by increasing seedling numbers/increasing seedling area
- In conjunction with micro topographic data and seed classification, future projects could identify germination niches. Currently can identify areas which have germination levels above or below expected amounts.

Monitoring of seedling health with vegetation indices:

- Can see signs of failing health
- Future studies could conduct more frequent flights, and potentially identify failing health before any visible signs appear
- Can identify exactly where plants are struggling
- Future studies with hyperspectral sensors could also identify the cause of ill health

Identification and tracking through time of individual seedlings:

- Can identify seedlings (distinct from classification – classification is saying this is a seedling, identification is saying exactly which seedling
- Can monitor the same seedlings through time – first ever instance of UAV based remote sensing being used to monitor plant health on the individual level.
- Could lead to the advent of "precision restoration" – rather than addressing failures across broad areas, be as precise as single seedling level

Publications:

Buters TM, Bateman PW, Robinson T, Belton D, Dixon KW, Cross AT. 2019. Methodological ambiguity and inconsistency constrain unmanned aerial vehicles as a silver bullet for monitoring ecological restoration. Remote Sensing https://www.mdpi.com/2072-4292/11/10/1180

Buters TM, Belton, D. Cross, A. 2019. Seed and Seedling Detection Using Unmanned Aerial Vehicles and Automated Image Classification in the Monitoring of Ecological Recovery. Drones. https://www.mdpi.com/2504-446X/3/3/53

GUEST SPEAKER ABSTRACT

Danilo Ignacio de Urzedo

PhD Candidate, University of Sydney

Title Is it possible to supply tonnes of native seeds for large-scale restoration? Experiences of community-based networks in Brazil

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Abstract Landscape restoration has emerged as a key strategy for human wellbeing and livelihoods opportunities along with achieving ecological goals. However, scarcity of native seed is a critical restriction to achieve restoration programs and local communities have been frequently neglected in planning and implementing these actions. In Brazil, several community-based systems have been established to create opportunities for indigenous communities and smallholders to supply native seeds from terrestrial ecosystems. This strategy involves linking communities who have harvested, processed and stored seed with restoration market. Brazilian seed networks have promoted the development of seed knowledge, markets, technical support and participatory approaches, affecting policies and decision-making in the restoration sector. Overall, these initiatives have produced 386 tonnes of seeds and engaged 1,046 collectors (45.5 kg of seed yearly/collector) over the last 10 years. The Xingu Seed Network has the largest commercial production system (over 25 tonnes annually) which has generated about US$ 1.2 million for 600 collectors in the Amazon since 2007. These community networks have established inclusive, fair-trade seed markets, as well as decreasing bureaucracy with income generation for local households. Experiences such as these have spread to different Brazilian Biomes, creating new opportunities based through restoration economy. I argue that effective community-based arrangements should consider: (i) seed production must be based on real market demand; (ii) long-term partnership between stakeholders with clear institutional roles; (iii) support for capacity building to promote local organisation and trading processes; (iv) local knowledge and labour should be valued; (v) applied research for developing appropriate techniques and solving technical issues.

Haylee D'Agui

Research Scientist, Leveraged Project, Soil Health

Title Bio-auditing of topsoil health in mine site restoration

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Abstract Topsoil is a scarce and highly valuable resource in post-mining rehabilitation. However, the mining industry often has insufficient understanding,or inadequate tools to assess the impact of topsoil storage methods on vitality of topsoil as a restoration resource.A key component of topsoil health is ensuring a competent microbial community, but soil functionality in restored soils has been found to be non-comparable to that of undisturbed native soils. Research is necessary to understand and manage the constraints imposed by inefficient topsoil storagein order to improve existing restoration practices.

This study aims to determine how the diversity, abundance, and activity of the soil microbiome(fungi and bacteria) contained within stockpiled topsoil is influenced by factors such as storage time, for different regions and commodity types in mining provincesofWestern Australia. Topsoil was collected from stockpiles and reference sites from seven mine sites (from the Pilbara to the South West) encompassing major commodity types(iron ore, nickel, bauxite, coal, and mineral sands). The chemical properties of each sample were determined, microbial respiration measured (Solvita one-day CO2 test), and microbial composition elucidated through next generation amplicon sequencing (16S and ITS), while an investigation into plant growth in each of the soils is currently underway.This study will contribute to the development of a science-based topsoil management toolto inform resource companies and restoration practitioners in design and management of effective topsoil storage strategies that maintain topsoil function for improved restoration outcomes.

LEVERAGED PROJECT

FOCUS ON LONG-TERM VEGETATION RECOVERY

Dr. Fiamma Riviera

Long-term monitoring data can inform long-term patterns of recovery after mining as well as the long-term impacts of restoration practices and environmental variables. However, few such datasets exist and they are seldom made available for research and publication. When they are, results indicate that patterns and drivers of recovery are often site or at least region specific. Therefore, more long-term datasets need to be analysed and published to better understand variation in recovery globally as well as inform local restoration efforts and expectations.

We took vegetation restoration monitoring data from the Hanson Heidelberg Cement Group sand quarry on the northern periphery of Perth. The company is undertaking restoration of the pre-mining banksia woodland vegetation, which ischaracterised by extremely nutrient poor soils and seasonal drought. Initial analyses of patterns of recovery indicate that restoration outcomes are highly variable and that while some measures of recovery are approaching native reference, others are not.

We are currently compiling an extensive dataset on restoration practices (e.g. seeding, ripping) and environmental variables (e.g. climate variables, soil horizon) to identify the drivers of patterns described. We are also investigating the use of a plant functional trait approach to further clarify patterns and their drivers as well as provide insight into the trajectories of species of interest.

LEVERAGED PROJECT

NEW FOCUS ON TOPSOIL HEALTH

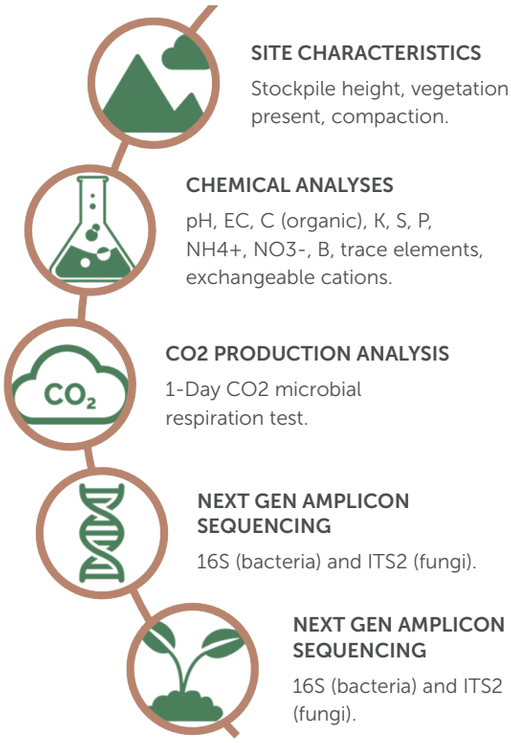
This leveraged project, led by Dr Haylee D'Agui, involves mine sites across Western Australia (from the Pilbara to the South West), encompassing different commodities (iron ore, nickel, bauxite, coal, and mineral sands), and aims to determine the changes that occur in microbial communities (fungi and bacteria) as topsoil is stockpiled.

Topsoil is a valuable resource in mine site restoration. However, the mining industry often has insufficient understanding, or inadequate tools to assess the impact of storage on the vitality of topsoil as a restoration resource. A key component of topsoil health is ensuring a competent microbial community, but soil functionality in restored soils has been found to be non-comparable to that of native, undisturbed soils.

We sampled topsoil from stockpiles and native sites at 7 mine sites across Western Australia (including iron ore, nickel, bauxite, mineral sands) with the aim of determining how the diversity, abundance, and activity of the soil microbiome of stockpiled topsoil is influenced by factors such as storage time, for different regions and commodity types in the major mining provinces of Western Australia.

Dr Haylee D'Agui

Topsoil Health Is Being Assessed Through Analysis Of:



SIGNIFICANCE

This study will contribute to the development of a science-based topsoil management tool to inform resource companies and restoration practitioners in design and management of effective topsoil storage strategies that maintain topsoil function for improved restoration outcomes.

Funding to support this project was received from: the Centre for Mine Site Restoration, the Research Office at Curtin, Independence Group (IGO), Fortescue Metals Group (FMG), and an anonymous mine in South West Australia. In-kind support was provided by: BHP, Alcoa, and Tronox.

NOTES

ARC Centre for Mine Site Restoration

An Industrial Transformation Training Centre

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