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Book of Abstracts

Abstracts

Transferring theory into practice - how hard can it be?

Linda Bell[1]

[1]**Manager, Threatened species conservation at Office of Environment and Heritage, New South Wales**

What started, in 2009, with a realisation that we could be more strategic about threatened species recovery in New South Wales turned into the NSW government's Saving our Species program with a $100 million plus budget. The theory about better prioritisation including cost effectiveness, sounded straightforward so putting it into practice should be straightforward too - well maybe not.

Transferring theory into practice has been challenging and building this comprehensive program is still underway. It is in equal measures inspiring, fascinating and frustrating. We pursued a long-term goal that is simple and ambitious - focusing attention on increasing the number of species in targeted projects, including restoration programs and the number of partners.

Strategies for each species, ecological community and key threatening process need to be clear about what, how and where if possible. Developing monitoring plans for each species and community is important so that objectives are clear and monitoring is realistic, but it is also difficult. Transparent monitoring each year helps us to track progress or decline and gives us the opportunity to mitigate species decline immediately if possible and tell a story of what we have achieved with public money.

Bringing about change in how we do threatened species conservation has taken strong leadership and good science. Change management is an important theme in our work both within our organisation and externally. It also takes good science and good scientists helping us to invest in new approaches such as artificial intelligence and understanding where to work in the landscape and why. Good operational policy and procedures has provided context and consistency about issues such as translocation or climate change. There is more to be done. Finally the most important ingredient has been the incredible expertise and positivity in the field with a strong on ground commitment. With the program in place we are taking small steps to increase involvement by volunteers and citizen scientists to complement the specific on ground work.

The story is not complete but we have survived our own success and delivered a substantially expanded program, we have learnt a lot and importantly we have invested in over 300 threatened species and threatened ecological communities – many for the first time.

Biography

Linda Bell is the Manager of Threatened species conservation at the Office of Environment and Heritage in NSW. As manager of the Saving our Species (SoS) program Linda oversees the allocation and management of $100 million over 5 years. Saving our Species is an innovative conservation program in NSW. It aims to halt the growing numbers of Australian animals and plants facing extinction. This program aims to secure as many threatened species that can be secured in the wild as possible, for the next 100 years. The program extends to threatened ecological communities and how to strategically focus threat abatement.

One of the NSW Government's most innovative programs, Saving our Species sets a clear management framework to prioritise between species. Sustainability projects such as this are collaborative efforts, so the program invites participation from the NSW community and businesses, including research organisations, schools, landholders, government agencies, local conservation groups and more.

How genetics can influence long term restoration outcomes

Linda Broadhurst[1]

[1]Director, Centre for Australian National Biodiversity Research (CANBR); Director, Australian National Herbarium (ANH) at CSIRO National Research Collection Australia

Restoring degraded Australian landscapes has been occurring for more than 30 years with involvement and investment across a range of sectors including governments, communities, NGOs, researchers and land holders. The importance of using a broad genetic base in seed-based restoration has been advocated for much of this time to avoid any negative inbreeding effects, especially in seed from populations that are small and isolated. However, it is unclear whether this has been broadly applied in on-ground practices and if not, what the long term consequences of this might be. As we move into a time of rapid environmental change, the genetic background of seed being used for restoration may be even more important as we try to rebuild ecosystems that have the flexibility required to cope with current and emerging challenges.

This presentation will highlight why genetics is important for seed-based restoration, review our track record in restoring genetic diversity and discuss the role and importance of genetics in improving restoration practices.

Biography

Dr Linda Broadhurst has been working at CSIRO since 2000 after completing her PhD at Curtin University of Technology in Perth followed by a short Post-doctoral position with the then Department of Conservation and Land Management (CALM). Her research is primarily focussed on conserving and restoring the long term prospects of Australia's unique floral biodiversity. Her most recent research is assisting NRMs and NGOs establish good seed sourcing and production practices to help restored populations respond to changing environments. Dr Broadhurst continues to publish in national and international peer-reviewed journals, with more than 40 peer-reviewed papers and book chapters as well as numerous reports and plain language information sheets. She has also been an Associated Editor with Australian Journal of Botany since 2009.

Balancing the science and politics of an urban ecological restoration project

Bruce D. Clarkson[1]

[1]Environmental Research Institute, University of Waikato, Hamilton, New Zealand

Waiwhakareke Natural Heritage Park, a 60-ha ecological restoration in Hamilton (Kirikiriroa), North Island, New Zealand, resulted from a millennium project proposal. Following a short campaign, public land, originally land banked for open space development, received approval for community-led reconstruction of five indigenous ecosystems characteristic of the district. The project as conceived was markedly different to the previous traditional parks and gardens developed within the city since its establishment in 1864.

The Park has been a focus for ecological research and local politics since its inception (2004) and the interaction of these two elements is the subject of this address. This is analysed from the point of view of an ecologist trying to understand the dynamics and functioning of urban ecosystems but needing to ensure the project retains adequate funding in the long-term for intergenerational restoration success. Key principles of restoration ecology are useful not only for undertaking the actual restoration but also for retaining political support in the face of a changing political landscape. Successfully navigating the boundary between science and advocacy and finding the balance and style of communication most suited to the target audience – local politicians is the major ongoing challenge. Understanding the political ecosystem is at least as important as understanding the restoration ecology.

Biography

Professor Bruce Clarkson is a restoration ecologist interested in habitat restoration to bring indigenous nature back into cities, based at the University of Waikato in Hamilton New Zealand. He leads a Ministry of Business, Innovation and Employment funded research programme: People, Cities and Nature: restoring indigenous nature in urban environments.
(https://www.peoplecitiesnature.co.nz/).

In 2016 he received the Royal Society of New Zealand Charles Fleming medal for environmental achievement for his efforts to advance and communicate understanding of native plant ecology and vegetation pattern and process, inform conservation efforts in terrestrial, freshwater and urban environments, and support effective on-the-ground restoration practice. He is a board member of the Australasian chapter of the International Society for Ecological Restoration, on the Governance Group for the Building Better Homes, Towns and Cities National Science Challenge and is ambassador for the New Zealand's Biological Heritage National Science Challenge.

Restoring the coral reefs of the future

Sarah Frias-Torres[1]

[1]Nature Seychelles, Republic of Seychelles; Smithsonian Marine Station, Fort Pierce, Florida, USA; Vulcan Inc, Seattle, Washington, USA

We are living through an unprecedented trajectory of coral reef decline towards ecological extinction due to local stressors (pollution, overfishing, disease, habitat destruction) and global climate change. We cannot return to the pristine coral reefs of the past when humanity's impact was non-existent. Coral reef conservation and restoration should aim to maintain ecological function with the highest possible biodiversity in a human-dominated world. While we aim to reduce drastically the causes of global climate change, our strategy must focus on restoring species that provide key ecological functions. Here I present the challenges and opportunities I encountered when restoring coral reefs using three case studies: reef fish spawning aggregations, giant clams and corals. I combine behavioral ecology with adaptation to climate change as the main drivers of how to restore the coral reefs of the future.

Biography

Dr Sarah Frias-Torres is the Coral Reef Conservation and Restoration Specialist at Vulcan Inc, Seattle, WA, and a Research Collaborator for the Smithsonian Marine Station, Fort Pierce, FL, USA. She does research in how coral reefs and marine megafauna can recover from overfishing and survive global climate change. Dr Frias-Torres has led large-scale coral reef restoration projects in Seychelles, Indian Ocean, and coral reef, mangrove and megafish conservation projects in Florida and the Caribbean Sea. She is a Fulbright Fellow, and a former Schmidt Ocean Institute Research Fellow, and U.S. National Academy of Sciences Postdoc Fellow. She has worked at the U.S. National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA)-Kennedy Space Center, and has been a consultant for the United Nations Development Program (UNDP)

Dr Frias-Torres is committed to science communication and outreach using art, social media, documentary filmmaking and broadcast media (TV, radio).

Native seed production 'farming for restoration supply': Lessons from local and US sectors

Paul Gibson-Roy[1]

[1]Greening Australia; Honorary Fellow, University of Melbourne, Victoria

The feasibility of restoring or reinstating complex grassy communities has been much debated in this country over the past decade. Despite good evidence having emerged during that time that this is technically feasible there has been relatively little uptake of such approaches by the restoration sector at scale. The reasons for this are varied, but limitations on seed resources from the wild and a lack of market drivers to support the use of seed production (to grow native seed for large-scale restoration) are among the most obvious among them. At the same time there have been ongoing reports of much greater successes restoring native plant communities in the United Sates. There seed production or 'seed farming' has been established as a critical and established sector that supplies the resource required for nation-wide restoration projects. This disparity in experience led Paul to apply for a Winston Churchill Memorial Trust Fellowship. The generous support of the Churchill Trust enabled him to tour the United States and observe firsthand that sector. His presentation will contrast the local and US seed and restoration sectors shedding light on their relative scales and structures. He will describe the production systems used in the US to procure, grow and process native seed and give insights into the different restoration models and outcomes made possible through this mature seed supply chain. He will also discuss the various market drivers, which together created the opportunities for that seed production and restoration sector to develop and mature. Finally, he will reflect on insights from the US experience and those gathered from a 2016 Australian national seed sector survey to reflect on pathways that might move our sector in more positive and constructive directions.

Biography

Dr Paul Gibson-Roy is a restoration ecologist specializing in the conservation and maintenance of species-rich grasslands and grassy woodlands.

As an ecologist and researcher Dr Gibson-Roy has focused on the restoration of complex, biodiverse grasslands and grassy woodlands since 1998. In 2004 he joined Greening Australia, instigating the Grassy Groundcover Research Project as a partnership between Greening Australia and Melbourne University. Paul headed the Victorian Grassy Groundcover Research Project team until heading to NSW in 2011, during which time the project developed industry-first methods for reconstructing species-rich native grasslands and grassy woodlands.

Paul now leads the Sydney Grassy Groundcover Research Project team which is focussed on restoring the EPBC listed Cumberland Plain Grassy Woodland to Sydney's West where in the past four years they have seeded 47 ha. They are also developing what is currently Greening Australia's largest seed production facility, growing native wildflowers and grasses on a 5 ha footprint at the Western Sydney University Richmond campus. In 2016 he toured the US to investigate firsthand the native seed production and prairie restoration sectors.

Understanding potential synergies and trade-offs between biodiversity and ecosystem services to inform forest restoration strategies

Fangyuan Hua[1] Paula Meli[2], Phillip A. Martin[1], David P. Edwards[3], Andrew Balmford[1]

[1]**Newton International Fellow, Conservation Science Group, Department of Zoology, University of Cambridge, UK**

[2]**Departamento de Ciências Florestais, Universidade de São Paulo, Brazil**

[3]**Department of Animal and Plant Sciences, University of Sheffield, UK**

Forest restoration (FR) carries much promise for mitigating the environmental impacts of forest loss, and is gaining global policy momentum. Worldwide, tree plantations represent a prominent FR outcome, largely because many restoration programs aim to generate certain ecosystem services (ES), and consider tree plantations effective in delivering the target ES. However, tree plantations generally support much lower levels of biodiversity than native forests, therefore fail to meet one of the goals of FR that also fundamentally underpins ES. Compared with restoring native forests, plantation-dominated FR thus effectively displaces biodiversity and worse yet, may even result in poor outcomes for the intended ES.

The key to making more decision space for biodiversity under FR, and more generally, designing FR strategies that can better deliver a range of environmental benefits, lies in understanding the synergies and trade-offs between biodiversity and ES for forest types that represent different FR strategies. For this purpose, we compiled a global database on biodiversity and three ESs that dominate the global FR agenda – i.e. carbon storage, soil erosion control, and water regulation - for a range of forest types representing major FR outcomes. We found that while trade-offs exist between biodiversity and the focal ESs in some situations, compared with restored native forests, tree plantations tend to be associated with lower levels of service supply for all three focal ESs, in addition to lower levels of biodiversity. The remarkable synergy between biodiversity and the focal ESs for different forest types established under FR suggests that in most situations, FR can better achieve overall environmental benefits and importantly, make more decision space for biodiversity, through the restoration of native forests rather than tree plantations.

Biography

Dr Fangyuan Hua is a field ecologist and conservation scientist. Dr Hua's research directions are unified under the theme of global change ecology in relation to biodiversity conservation where she aims to understand how ecological populations, communities, and interactions respond to anthropogenic impacts, and what policy and socioeconomic opportunities exist to mitigate such impacts.

Between 2013 and 2016, Dr Hua was a postdoctoral research associate with Professor David Wilcove at Princeton University and is currently a Newton International Fellow funded by the British Royal Society, working with Professor Andrew Balmford and the Conservation Science Group at the University of Cambridge, and Professor Jianchu Xu at the Kunming Institute of Botany, Chinese Academy of Sciences.

Dr Hua's research on opportunities for biodiversity gains under China's Grain-for-Green Program - the largest reforestation programme in the world - constitutes a powerful example of the challenges and opportunities faced by biodiversity during large-scale ecological restoration efforts, particularly when such efforts are driven by the pursuit of a small number of ecosystem services. Her research findings provide significant insights into the biodiversity implications of this massive reforestation program and the socioeconomic feasibilities of better biodiversity outcomes. Combining policy analysis, Dr Hua's research in turn provides concrete policy recommendations for China's efforts of forest landscape restoration to achieve more positive biodiversity impacts.

Are historical reference conditions an ecological fairy tale, or are they more relevant than ever?

Daniel C. Laughlin[1]

[1]**University of Wyoming, Department of Botany, Laramie, Wyoming, USA**

Restoration ecologists have an innate desire to restore what has been lost. Our first instinct is to use historical reference conditions as empirical benchmarks for restoration success. However, historical reference conditions in many regions are undefinable and are increasingly viewed as irrelevant under climate change. The important question to ask is why were species dominant historically? The answer, presumably, is because they exhibited traits that conferred high fitness in those environments. As the environment changes, optimal traits may shift, making historical trait distributions less fit and ill-suited for the task. If this is the case, then we may need a new framework for setting targets to meet desired functional outcomes in ecological restoration in a rapidly changing world. In this talk I will compare and contrast the use of historical reference conditions with those based on functional traits in a variety of contexts, but will emphasize a fire-adapted mixed conifer forest on the North Rim of Grand Canyon National Park. This forest has increased in tree density since the age of fire suppression, which makes it more susceptible to stand-replacing crown fire. I will show how management actions designed to restore historical conditions work remarkably well to enhance forest resilience, but will also discuss alternative options that might lead to success in a hotter, drier climate. Additionally, I will review recent applications of traits in ecological restoration being conducted around the world

Biography

Daniel is an Associate Professor of Plant Ecology at the University of Wyoming. Before recently moving back to the USA, he spent 6 years as a professor at the University in Waikato, where he continues to collaborate on restoration projects such as the New Zealand government funded project "People, Cities and Nature: restoring indigenous nature in urban environments" **(https://www.peoplecitiesnature.co.nz/).** Daniel's research group (www.plant-traits.net) integrates ecophysiology and community ecology to predict population dynamics and restore wild landscapes. He develops predictive models of community assembly that integrate trait-based environmental filtering and species interactions, and is currently interested in identifying functional traits that predict plant population dynamics and fitness. He has been actively involved in studying the restoration of prairies, wetlands, shrublands, montane forests, and temperate rainforests around the world, and is currently developing quantitative frameworks for generating trait-based assemblages to meet functional objectives in restoration. Daniel has served as an Associate Editor for the journal Ecology and Ecological Monographs since 2012. He currently lives in Laramie, Wyoming, on the front range of the Rocky Mountains where he spends all his free time wandering through prairies, forests, and alpine meadows identifying a bewildering variety of forbs and grasses and collecting their seeds for propagation.

Key lessons from long-term research for restoration and integrating conservation and agricultural production

David B. Lindenmayer[1, 2] Mason Crane[1], Damian Michael[1], Daniel Florance[1, 2]

[1]**Sustainable Farms, Fenner School of Environment and Society, The Australian National University, Canberra, Australian Capital Territory**

[2]**Threatened Species Research Hub, National Environmental Research Program, Fenner School of Environment and Society, The Australian National University, Canberra, Australian Capital Territory**

Over the past 20 years, researchers at the ANU have worked with many hundreds of farmers in Victoria, New South Wales and Queensland to quantify the ecological effectiveness and the cost-effectiveness of restoration strategies on grazing and cropping farms. This presentation briefly outlines some of the key lessons and emerging new insights arising from this long-term work. In particular, research and monitoring have conclusively shown that restored and remnant vegetation are markedly different habitats which support different biotic assemblages but that together are critical environments for management in agricultural landscapes. These different habitats have key roles for species in wet versus drought conditions, with restored areas acting as particularly important refuges for key groups such as woodland birds during periods of climate stress. The body of research to date clearly underscores the fact replanted woodlands are a key natural asset in farmland environments and should be well managed including being exempt from high-intensity set stocking grazing.

Biography

Professor Lindenmayer is an Australian scientist and academic. He is an expert in landscape ecology, conservation and biodiversity. His areas of expertise also include environmental management, forestry management and environment, terrestrial ecology, wildlife and habitat management, environmental monitoring, forestry fire management, natural resource management, zoology and forestry sciences. He currently runs 6 large-scale, long-term research programs in south-eastern Australia, primarily associated with developing ways to conserve biodiversity in reserves, national parks, wood production forests, plantations, and on farm land.

A Professor of Ecology and Conservation Biology at The Australian National University's Fenner School of Environment and Society, he has published more than 1100 scientific articles including over 700 peer-reviewed scientific papers and 45 books on a wide range of topics associated with forestry, woodlands, wildlife and biodiversity conservation and ecologically sustainable natural resource management. His areas of expertise also include environmental management, forestry management and environment, terrestrial ecology, wildlife and habitat management, environmental monitoring, forestry fire management, natural resource management, zoology and forestry sciences, with a particular focus on the endangered Leadbeater's possum. His work on wildlife conservation and biodiversity has, for many years, led world research in this area. Lindenmayer's conservation and biodiversity research has been recognised through numerous awards, including the Eureka Science Prize (twice), Whitley Award (seven times), the Serventy Medal for Ornithology, and the Australian Natural History Medallion.

He is an Australian Research Council Laureate, a member of the Australian Academy of Science and was appointed an Officer of the Order of Australia "for distinguished service to conservation and the environment in the field of landscape ecology, to tertiary education, and to professional organisations".

How the National Restoration Standards' affirmation of native ecosystems as references can strengthen SERA's function as a broad church

Tein McDonald[1]

[1]Board member, Society for Ecological Restoration Australasia; Principal, Tein McDonald & Associates, New South Wales

The National Restoration Standards emphasise relationships between ecological restoration and other activities that reduce damage or improve the functionality of ecosystems, even though these may not directly improve a site's 'native' condition. While some distinction between restoration and these activities is necessary to avoid lowering standards for ecological restoration, we must nonetheless strengthen, not weaken, the links between the fields through all the work of the Society. This is because (i) all restorative activities are essential if native ecosystems are to remain viable in the future and (ii) the restoration framework is needed as a compass for all allied activities.

This keynote will consider the range of ways that SERA can strengthen its function as a broad tent, through promoting the restoration of native ecosystems as the 'glue' in the restorative continuum; and through continuing to emphasise participation in environmental repair and reduction of society's environmental footprint.

Biography

Tein's professional involvement in ecological restoration over the past 35 years has been as a bush regenerator, technical officer, TAFE teacher, mentor and planner. For the last couple of decades Tein has worked as Editor in Chief of the journal Ecological Management & Restoration, the management -oriented journal of the Ecological Society of Australia. More recently Tein has led the SERA project to develop the National Standards for the Practice of Ecological Restoration in Australia. For this project SERA brought together 12 other Australian NGOs working to make a difference in on-ground restoration of indigenous ecosystems. The result is an online document that draws on both restoration theory and practice to encourage best practice in ecological restoration and provide a framework for all efforts to improve the condition of ecosystems. Tein is currently President of the Australian Association of Bush Regenerators and has served on the board of SERA since its inception.

Challenges in innovation in ecological restoration: data from the U.S.

Jakki J. Mohr[1]

[1]**Fellow, Institute on Ecosystems, College of Business, University of Montana, Montana, USA**

The aim of this research was to understand how businesses engaged in ecological restoration experience and navigate tensions between ecological objectives and business objectives. In addition, this research sought to discover barriers and facilitators of the use of innovation in ecological restoration. Data on perceived uncertainty, personal risk tolerance, willingness to engage with research scientists and other variables were collected from a national sample of U.S.-based restoration businesses. After using standard scale purification techniques to assess reliability and validity of the measures, the analysis reveals various groupings of restoration businesses based on their propensity to innovate and perceptions of uncertainty. Implications for both the science of restoration ecology and the practice of ecological restoration are derived from a finer-grained understanding of the tensions and motives businesses face in conducting restoration work on the ground.

Biography

Dr. Jakki Mohr is the Regents Professor of Marketing, the Poe Family Distinguished Faculty Fellow, and Fellow, Institute on Ecosystems, at the University of Montana. She received her Ph.D. in Marketing from the University of Wisconsin-Madison. Prior to joining the University of Montana in 1997, Mohr was an assistant professor at the University of Colorado, Boulder.

Jakki studies challenges companies face in developing and commercializing break-through innovations, including a broad range of technologies ranging from scientific innovations to innovations in restoration and ecology. She served on the National Academies of Sciences Committee to overcome barriers to electric vehicle deployment in the United States (2012-2015).

An innovator in the field of marketing high-technology products and services, Mohr has achieved international acclaim for Marketing of High-Technology Products and Innovations (2010, 3rd edition, with Sanjit Sengupta and Stanley Slater), used by colleges and universities worldwide (translated into three languages) as well as by managers for executive training sessions. In addition, her book has resulted in invitations to guest-teach universities around the world, including ORT University (as a Fulbright Specialist) in Montevideo, Uruguay, Chile, Switzerland, Finland, Sweden, India, France, and Italy and to conduct executive education at companies both large and small.

Her recent research is situated at the intersection of the natural world and business. For example, she studies the business of restoration, how companies use biomimicry (innovations inspired by nature, based on underlying biological mechanisms) to solve technical and engineering challenges, and business impacts on nature. Her early research focused on organizational communication between partners in strategic alliances/ partnerships in distribution channels.

Mohr's research has received national awards, and has appeared in Restoration Ecology, the Journal of Marketing, the Strategic Management Journal, the Journal of the Academy of Marketing Science, the Journal of Product and Innovation Management, the Journal of Public Policy and Marketing, among others. She has also received numerous teaching awards.

Slow Food: The Arc of Taste.

Bruce Pascoe[1]

[1]Prime Minister's Literature Award for Young Adult fiction, Australian Literature Award, FAW Short Story Award

European invaders insisted that Australian Indigenous people were recent migrants and too inept to make use of the soil in anything but hapless hunter gatherer fashion. This was a necessary furphy for the soul of Christian imperialists intent on preparing the propaganda to justify the usurpation of the land blinded ourselves to Aboriginal agricultural achievement. The 'Australian explorers' witnessed massive agricultural systems right across the country but bigotry and ignorance disallowed us from examining the nature of that agriculture. We imported sheep and cattle, wheat and oats and released a host of feral plants and animals, refusing to accept any hint of Aboriginal sovereignty and achievement. It has blighted Australian intelligence ever since and our conservation of the land.

Aboriginal people had many domesticated plants, over 120 grains and probably as many different tubers apart from the fruits and nuts which we now label derisively as bush tucker, the food of primitives.

We are now re-examining this heritage because soil loss and plunging fertility as well as a drying continent are forcing to reconsider the use of European food plants and animals in such a sensitive southern ecosystem. Now that we have begun growing Panicum decompositum (native millet), Themeda (kangaroo grass), Microseris lanceolata (murrnongor yam daisy), and bulrush (cumbungi) just to name a few we realise the benefits of using agricultural domesticates of Australia. They only require the moisture and fertility this country can provide and as they are all perennial they cut down the use of farm machinery and the compaction which results as well as sequestering carbon.

Black Duck Foods and Gurandgi Munjie have been experimenting with these plants for the last five years and we have had to re-learn all the old knowledge that our old people developed over a minimum of 80,000 years.

Australians have been assisting us by funding our planting trials and now we hope they will join with us as we begin to sell our produce.

It is probably impossible for us to prevent mainstream Australia from making use of these plants, many of which still grow on relict pasture, but with the help of Slow Food we hope to convince Australia with the justice of ensuring that Aboriginal people are assisted in their participation in this burgeoning industry.

The first thing we lost after the European invasion of our continent was our land and now we hope that a more generous mood in the country and a greater appreciation of the nutrition to be gained and the environmental benefits to be accrued from using Aboriginal domesticates might see a more helpful approach to our claims for land justice.

Australia's more recent embrace of Australian Aboriginal art, dance, sport and agriculture means that in this more benign mood we will be able to conduct a conversation of mutual respect which has been beyond us since 1788.

We are excited by the prospect of bringing our food onto the Australian and world market as well as the chance to redress our environmental abuse of the land.

Biography

Published and Edited Australian Short Stories magazine1982-1999, winner Prime Minister's Literature Award for Young Adult fiction (Fog, a dox) 2013 Australian Literature Award 1999, Radio National Short Story 1998, FAW Short Story 2010. Books include: Night Animals, Shark, Ocean, Bloke, Cape Otway, Convincing Ground, Little Red Yellow and Black Book. Bunurong/Tasmanian heritage. Board member of Aboriginal Corporation for Languages. Lives in East Gippsland. His latest novels are, Bloke, published by Penguin in 2009, Chainsaw File, Oxford 2010, Fog, Magabala 2012 and Mrs Whitlam, Magabala 2016. Dark Emu, a history of Aboriginal agriculture was published by Magabala in 2014 and has been shortlisted in the Queensland, Victorian and New South Wales Premiers' Awards. His film, Black Chook was filmed in 2015 and starred Brendan Cowell, Jack Davis and Lynette Curran.

Thinking differently about restoration: economists' perspective?

Maksym Polyakov[1]

[1]Centre for Environmental Economics and Policy, UWA School of Agriculture and Environment, The University of Western Australia, Crawley, Western Australia

European invaders insisted that Australian Indigenous There has been a steady flow of concepts and tools from economics into the work of ecologists concerned with ecological restoration. The importance of considering costs when ranking project options and the value of information from Bayesian decision theory are two prominent examples. Some other concepts have not been so well embraced, or in some cases, not so well understood: discounting and non-market valuation for two.

There is great potential for benefits from additional cross-fertilisation. The thinking about restoration is largely ecological, but this is a human endeavour, driven and constrained by both social and economic considerations.

In this presentation, I discuss how various economic principles, tools and instruments can assist to deliver more effective and more valuable restoration outcomes. I will provide a range of examples where economics has been used to assess social and economic benefits of restoration, to estimate a comprehensive set of costs, and to prioritise restoration investments spatially. I will show how the accounting for the participation of the public, stakeholders and government agencies can be important in restoration planning and decision making. Existing spatial prioritisation approaches focus on spatial heterogeneity of the biological and physical contexts, but neglect heterogeneity of opportunity costs, which can be at least as important.

Overall, my aim is to highlight concepts and principles from economics that have not yet been widely applied in ecological restoration but have significant potential to be productively applied.

Biography

Maksym Polyakov is an applied economist whose interests focus on the integration of ecology and economics to better understand the choices humans make regarding natural resources and consequences of these choices for the environment. He is trained as a forester in Ukraine and received a PhD in applied economics from Auburn University, USA. Maksym is currently a Senior Research Fellow at the Centre for Environmental Economics and Policy, the University of Western Australia. His research focuses on the economics of conservation, bioeconomic modelling, urban forestry, and land use change. He is involved with the ARC Centre of Excellence for Environmental Decisions where he has been leading a program of research on economically optimal strategies for restoration of degraded native vegetation. Maksym is a member of editorial board of Restoration Ecology, responsible for social science submissions.

Working with Indigenous Biocultural Knowledge in natural resource management

Gerry Turpin[1]

[1]**Ethnobotanist and manager of the Tropical Indigenous Ethnobotany Centre**

For thousands of years Australian Indigenous peoples have lived on and managed this country, shaping the landscapes and environments, and adapting to changing climates. The knowledge that has been accumulated through intimate and sustained connections to the land had been passed down orally through generations, existing in stories, paintings, song and dance. While a lot of knowledge has been lost due to colonisation and in some places resulted in disconnection to country, many Indigenous groups continue to practice culture.

A more recent term recognising this knowledge is Indigenous Biocultural Knowledge (IBK). IBK is 'knowledge that encompasses people, language and culture, and their relationship to the environment' (Ens et al, 2014). Globally, IBK is well recognised, accepted and respected in contemporary biodiversity conservation and management. However, in Australia, where Indigenous people manage nearly half of the continent, there is a lack of understanding and reluctance to recognise IBK and explore ways that it can be respectfully employed with Western Science to benefit communities and society. This strong and diverse presence on country presents a great opportunity to work with Indigenous knowledge systems and strengthen awareness of biocultural knowledge. This presentation will highlight the view that IBK has an important role in rapid and uncertain times of environmental changes; demonstrate some of the potential opportunities; and also some important considerations in cross-cultural research.

Biography

Gerry is a Mbabaram man from north Qld and been employed by the Queensland State Government for about 30 years. Gerry has previously been involved in the Queensland Herbarium's Vegetation Surveys and Regional Ecosystem Mapping Project in Queensland. He currently manages the Tropical Indigenous Ethnobotany Centre at the Australian Tropical Herbarium, in partnership with James Cook University, Dept. of Science and CSIRO, and has worked with many Traditional Owner groups on Cape York and other parts of Queensland. As an Indigenous ethnobotanist Gerry has a strong cultural commitment to facilitating effective partnerships that support Indigenous communities to protect, manage and maintain their cultural knowledge on the use of plants. Gerry is a member of the Ecological Society of Australia Board of Directors with the role of Indigenous Engagement, and a member of the NESP Threatened Species Recovery Hub Indigenous Reference Group. In 2013, Gerry took out the first ever science award at the 2013 National Indigenous Deadly Awards for best scientist or science Project of the Year category.

Better decision making in ecological restoration

Kerrie Wilson[1]

[1]ARC Future Fellow at The University of Queensland; Director, Australian Research Council Centre of Excellence for Environmental Decisions; Affiliated Professor in Conservation Science, The University of Copenhagen

Ecological restoration is a complex endeavour and prioritization of where, when and how habitat is restored is critical for managing risks, ensuring works represent value for money, are feasible, and will be supported by stakeholders. The underlying social and environmental motivations for restoration are diverse. As such, restoration projects can benefit from formal processes of objective setting, particularly when there are multiple stakeholder groups with varying values. Ecosystem restoration also requires choosing between potential interventions that differ in cost and the time required to achieve outcomes of varying quality. Furthermore, land managers have different preferences for timeframes, certainty, and quality of outcomes, which can influence the implementation of restoration projects. Nonetheless, the expected outcomes from restoration can be quantified, allowing for operational constraints and alternative time preferences, and this can inform scheduling of restoration works. In this talk I will describe examples of best practice restoration planning and prioritisation approaches. This body of research has facilitated transparent and inclusive establishment of restoration objectives and plans, and is applicable across terrestrial, marine, freshwater and coastal realms in both Australia and overseas.

Biography

Professor Kerrie Wilson is an ARC Future Fellow at The University of Queensland (UQ), Director of the Australian Research Council Centre of Excellence for Environmental Decisions, and an Affiliated Professor in Conservation Science at The University of Copenhagen. Kerrie holds a degree in Environmental Science (First Class Honours) from UQ and a Doctor of Philosophy from The University of Melbourne in 2004 undertaken in collaboration with the United Nations Environment Programme – World Conservation Monitoring Centre located in Cambridge. Kerrie has a particular interest in applied conservation resource allocation problems, such as where to invest limited

resources to protect or restore biodiversity and the role of ecosystem services in achieving conservation goals. Her research has been published in high impact journals such as Nature and Science.

Professor Wilson has had leading roles in several large collaborative projects within Australia and internationally. As examples, she has collaborated with The Nature Conservancy to develop a research program for optimising the allocation of expenditure and efforts to Reduce Emissions through Avoided Deforestation and Degradation (REDD) and a US-based private firm (the Irvine Ranch Conservancy) has sought her expertise to develop a US$14 million restoration prioritisation plan for a private national park in the Los Angeles Basin. Professor Wilson has also led ARC Linkage projects on the topic of restoration involving three of Australia's largest non-government conservation organisations and local councils as Linkage Partners. Since 2010 Professor Wilson has been the UQ lead scientist of the Borneo Futures Research Initiative, a collaboration of ~250 researchers from 70 institutions from around the world working in genuine partnership with scientists, global institutions and organisations, governments, non-governmental organisations, and industry. Her disciplinary leadership is evidenced by roles on the (international) IUCN Save our Species Science Committee, the Ecosystem Services Partnership Steering Committee, the Independent Expert Panel of the Reef 2050 plan and the Natural Sciences representative for the Australian National Commission of UNESCO.

SYMPOSIUM: Emerging Eco-engineering Solutions and Seed Enhancement Technologies to Combat Land Degradation

Organiser and moderator: **Todd Erickson**[1]

[1]**The University of Western Australia, Western Australia; Kings Park Science (Department of Biodiversity, Conservation and Attractions), Western Australia**

Session Description: Reduced plant establishment in rehabilitation is often attributable to poor seed handling practices. Knowledge of seed ecology, development of seed enhancement technologies, and adoption of agricultural-engineering practices for precision sowing all contribute to greater seed regeneration. This session will showcase examples from Kings Park Science's collaborations focused on innovative ecologically-guided seed enhancement technologies and engineering approaches for large-scale rehabilitation.

Introduction: The science underpinning Western Australian restoration programs... And beyond

Jason Stevens[1]

[1]**Kings Park Science - Program Leader (Department of Biodiversity, Conservation and Attractions), Western Australia**

Kings Park Science undertakes integrated and innovative research in native plant biology, underpinning the conservation and ecological restoration of Western Australia's unique biodiversity, and biodiversity generally. Successful conservation and restoration outcomes are achieved through world-class research and strategic collaboration with industry, land managers, the community and other research organisations. Research is focused in the key areas of restoration ecology, seed science, conservation genetics, conservation biotechnology, ecosystem ecology, fire ecology and systematics, with a focus on ex-situ conservation, and through strategic partnerships, in situ conservation and ecological restoration outcomes. Research is prioritised to enhance practical outcomes in conservation and management and sustainable development of the State's unique natural resources.

Using one of Kings Park Science's longest running collaborations spanning over 20 years, and to set the scene for some of our more recent emerging technologies, this presentation will highlight some examples of how we (1) tackle restoration in biodiverse ecosystems using a science-meets-practice framework, (2) work collaboratively with industry as a multi-disciplinary team, and (3) implement this research across various ecosystems, locally and internationally, at the scales required.

Recent advancements in restoration-engineering and seed enhancement technologies for use in land rehabilitation

Todd Erickson[1]

[1]The University of Western Australia, Western Australia; Kings Park Science (Department of Biodiversity, Conservation and Attractions), Western Australia

Restoration engineering is a swiftly developing field that partners biological research with innovative ecologically-guided engineering solutions. From a plant recruitment perspective, best-practice use of seeds can be coupled with the invention and modification of seeding equipment needed to deliver native seeds at scale. Improving seed use efficiency through seed enhancement technologies is one approach that has gained recent attention in dryland restoration. Techniques including precision flash flaming, hydro- and osmo-priming, polymer-based seed coating, and extruded seed pelleting, all aim to improve the germination and establishment potential of seeds under sub-optimal conditions. When combined with modifications to existing mechanical seeders or with new-builds, these technologies are one potential solution to overcome major inefficiencies in dryland seeding efforts (i.e. >90% of seeds failing to establish). For instance, 'flash flaming' is a technique that removes unwanted hairs and appendages of bulky and fluffy seed batches (e.g. Winterfat/ Krascheninnikovia lanata [Chenopodiaceae] in the USA, Triodia wiseana [Poaceae], and Ptilotus exaltatus [Amaranthaceae] in Australia). After removal, seed batch volume is vastly reduced, while the flow properties of seeds through cleaning equipment and mechanised seeders are vastly improved. This recent Australian invention allows many species that are historically hard-to-handle, and/or deliberately avoided, to be used in large scale restoration programs.

In this presentation we will highlight some key findings for a selection of our restoration engineering approaches that include the benefits of flash flaming in Australian and US species, polymer-based seed coating combined with priming of seeds, and discuss the modes of treatment applications across large-scale, high-impact mine restoration scenarios. Outcomes of these programs are applicable to degraded lands requiring restoration across the United States, Australia, and other semi-arid global regions.

Restoration Engineering solutions to direct seeding problems guided by practitioner perceptions and seed requirements

Monte Masarei[1]

[1]University of Western Australia, Western Australia

The ability to restore degraded ecosystems at scale in a reliable and efficient manner is a major challenge. Scaleable solutions that can reliably establish plants on a degraded site therefore need to be developed. Although direct seeding

has the potential to be effective at scale and operate at much lower cost when compared to the alternative of cultivating and planting nursery grown seedlings, many of the currently adopted direct seeding methods are unreliable and lack the versatility needed to plant a range of species in a range of sowing environments. Responses from a global survey of 183 restoration practitioners have confirmed that improvements to the ability of direct seeders to: (1) operate over complex topographical structures, (2) sow seeds with complex morphologies; and, (3) control weeds would enhance their usability and versatility. Coupling this with improving the use of diverse assemblages of native seed adds further complexity when operating in unpredictable environments. In this presentation we discuss both the perceptions of practitioners and fundamental seed biology to show where engineering design could improve the efficiency, performance and versatility of direct seeders at scale.

Innovative nature-based strategies for dryland restoration: the potential of indigenous cyanobacteria

Miriam Munoz-Rojas[1]

[1]University of New South Wales, New South Wales

Despite the widely-accepted importance of drylands - which store 45% of the global carbon and comprise a third of global biodiversity hotspots - and the large amounts of money invested in restoration, success rates are generally low. Given the large scale of restoration required, and severe deficits of locally-sourced soil materials that contain beneficial nutrients, microbes and a residual soil seedbank, direct seeding is often needed for reinstating biodiverse vegetation communities. However, seed-based restoration is extremely inefficient, and rates of seed mortality are frequently above 90%. Cyanobacteria from soil biocrusts have the capacity to act as bio-fertilizers by promoting growth of certain plant species, and contribute to multiple key ecosystem services and functions in desert ecosystems including soil structure, stability, improved surface hydrology, C sequestration, and N fixation. These organisms can survive extreme conditions such as low precipitation, high solar radiation and extreme temperatures. However, despite their global importance and their many environmental applications, the potential of cyanobacteria for ecosystem restoration in drylands, is yet to be harnessed. Here, we investigated i) the effects of bio-priming seeds of native plants used in restoration with a consortium of cyanobacteria species, on seed germination, seedling recruitment and growth; and, ii) the potential of inoculating cyanobacteria on soil substrates used in dryland restoration, including topsoil and mine waste, to restore soil functions such as soil carbon sequestration. Our results showed that cyanobacteria does not impede and can promote germination and early seedling growth - phases known to be problematic for restoration success in dryland ecosystems - of native arid species, e.g. Senna, Acacia, Triodia and Grevillea spp. We also found that cyanobacteria inoculation can rapidly modify properties of reconstructed soil substrates such as increased soil carbon, underpinning the potential key role of these organisms as bio-tools to initiate recovery of soil functions in infertile, reconstructed soil substrates.

Innovative seed technologies for restoration in a biodiversity hotspot

Alison Ritchie[1]

[1]University of Western Australia, Western Australia; Kings Park Science, (Department of Biodiversity, Conservation and Attractions), Western Australia

Despite technological advances in the agricultural industry to successfully create and reliably exploit seed germination, establishment and plant production niches for many species, there is currently limited capacity to deliver this technology to restore biodiverse natural ecosystems at scale. This can only be established through identifying translational technologies, developing novel approaches and integrating this with ecological theory of native systems under highly altered environmental conditions. Ecological filters such as water repellency (a strong abiotic barrier), interactions between plants and other organisms (e.g. weed species, a biotic barrier) and lack of topsoil (operational barrier) can prevent establishment of native species and have important consequences for community reassembly in restoration. To overcome these barriers, this project builds on the agricultural seed enhancement technologies that have advanced native ecological restoration within the US.

Recent developments that include 'extruded' seed pellets (seeds embedded in a soil matrix) with soil surfactants (wetting agents) have shown promise in restoring proteaceous species in the Southwest of Western Australia. Lambertia inermis seedling emergence was 20% greater from pellets in comparison to the control seeds. The same pellet formation was a favourable medium for seedling emergence, establishment and growth of Banksia menziesii significantly improving survival post-drought on average by 2.6 days. Pellets containing low quantities of activated carbon ("herbicide protection pods") successfully provided protection to grass seeds from selective weed herbicide spraying. Pellets with low quantities of activated carbon had on average 22% mortality in comparison to 77% mortality in pellets with no activated carbon. Investigations into extruded pelleting technologies for the deployment of seeds and as a possible method of creating favourable microsite conditions for growth on landforms lacking growth media (topsoil) in the Pilbara are also underway. These proof-of-concept studies provide important steps in improving the success of restoration seeding programs across Australia.

Seed ecology supports and enhances restoration practices

Shane Turner[1]

[1]University of Western Australia, Western Australia; Kings Park Science, (Department of Biodiversity, Conservation and Attractions), Western Australia

Restoration is challenging, especially in arid environments such as the Pilbara region of Western Australia where mining has been a driving feature of the local economy for many decades. With a current mine disturbance footprint of >200,000 ha across the region, over 800 tonnes of seed (at an average cost of ~$750 per kilogram) is required for direct seeding purposes; well above the amount that

can be sustainably supplied at present. Large-scale restoration in the region utilises wild-collected seeds from over 100 native species but current practices typically result in less than 10 % seedling emergence from directly sown seeds, an outcome which is clearly inadequate. This poor return is due to a number of factors such as low seed quality, substandard seed collection, processing, handling and storage, ineffective direct seeding approaches and a limited understanding of native seed biology. While all of these factors contribute to poor outcomes in some way, one of the keys to the development of better restoration is an improved understanding of the seed ecology of locally adapted native species.

The term seed ecology refers to the study of seeds and how they interact with their natural environment and through targeted investigations of seed attributes such as seed dormancy, seed germination rate, responses to incubation temperatures, seed mass, dispersal strategy, depth of emergence capacity, and sensitivity to water stress a thorough picture can be developed of the environmental filters regulating the recruitment of native species under natural conditions. These insights can greatly assist in solving complex restoration problems with this information aiding to "engineer" effective solutions to restoration constraints. This presentation outlines how investigating the seed biology and ecology of native species informs the development of improved restoration approaches for returning biodiverse plant communities to degraded landscapes.

SYMPOSIUM: Community-based Ecological Restoration in the Tropics

Organiser and moderator: **Robert Fisher**[1]

[1]School of Geosciences, The University of Sydney, New South Wales; Tropical Forests and People Research Centre, University of the Sunshine Coast, Queensland

Session Description: The largest areas of forest loss have occurred in tropical countries where populations are growing quickly and where there is fragile governance and huge social inequality. Consequently, ecological restoration has emerged as a method for promoting poverty alleviation along with achieving ecological goals. However, local communities have been frequently neglected in planning and implementing restoration programs. In this session, we will explore different aspects of how community participation impacts on restoration success in tropical regions. The presenters will explore a range of issues involved in community-based restoration based on field experiences in a variety of countries.

Community-based native seed production for restoration in Brazil

Danilo I. de Urzedo[1], Isabel B. Schmidt[2], Fatima C.M. Piña-Rodrigues[3], Daniel L. M. Vieira[4], Gustavo M. de Rezende[4], Alexandre B. Sampaio[5], Rodrigo G. P. Junqueira[6]

[1]**The University of Sydney, New South Wales, Australia**

[2]**Universidade de Brasília, Brazil**

[3]**Federal University of São Carlos, Brazil**

[4]**EMBRAPA, Brazil**

[5]**ICMBio, Brazil**

[6]**Instiuto Socioambiental, Brazil**

Large-scale restoration programmes in the tropics require large volumes of high quality, genetically diverse and locally adapted seeds from a large number of species. However, scarcity of native seeds is a critical limitation affecting achievement of restoration targets. We analyse community-based networks that supply native seeds and seedlings for Brazilian Amazon and Cerrado restoration projects. For this we explore three case studies, encompassing native seed production and restoration in Upper Xingu; grassland and savanna restoration at Chapada dos Veadeiros region; and restoring areas around a large hydroelectric dam in the western Amazon. Local restoration networks can emerge from and significantly contribute to the establishment of effective restoration actions. Establishing inclusive, fair-trade seed and seedling markets, as well as decreasing bureaucracy associated with these markets may foster restoration associated with income generation for local communities. We argue that effective community-based restoration arrangements should follow some principles: (i) seed production must be based on real market demand; (ii) non-governmental and governmental organisations have a key role in supporting local organisations, legal requirements and selling processes; (iii) local ecological knowledge and labour should be valued; (iv) applied research can help develop appropriate techniques and solve technical issues.

Designing effective community-based ecological restoration: the case of ACIAR forest restoration project in the Philippines

Nestor Gregorio[1], John Herbohn[1, 2]

[1]**Tropical Forests and People Research Centre, University of the Sunshine Coast, Queensland**

[2]**School of Agriculture and Food Sciences, The University of Queensland**

Restoring forest landscapes is recognized as an important measure to improve

and mitigate impacts of major global environmental problems. A community-based approach to forest and landscape restoration has been adopted in many developing countries in the tropics including the Philippines. However, devolving the sustainable development of Philippine forestlands to communities is fraught with many problems. A case study to pilot test an improved community-based forest restoration project has been implemented in Biliran Province, Philippines under the auspices of ACIAR. The project was developed using the systems approach and informed with lessons from past reforestation projects. It also integrates smallholder-based silvicultural techniques developed from ACIAR-funded forestry research projects in the Philippines. Initial results of the study revealed that the success of community-based ecological restoration program is achieved when the project recognizes the various land-uses within the landscape and considers the multiple interests of stakeholders. The presence of sustainable livelihoods that provide food and income to smallholders is essential. Security of land and tree tenure, adequate institutional arrangements, and supportive policy environment are also necessary. The factors contributing to mixed results of community-based forest restoration are complicated and designing and implementing interventions is equally difficult. A systems approach to understanding the complex interactions of the factors affecting community-based ecological restoration and developing intervention measures proved to be essential in improving community-based ecological restoration outcomes. The application of participatory process at all levels of the project and use of best-practice derived from research results and lessons in forest restoration programs are factors that are also crucial in promoting the success of community-based ecological restoration.

Social landscape and community capacity are important considerations in the design of community-based ecological restoration

John Herbohn[1], Jack Baynes[1], Liz Ota[1], Nestor Gregorio[1], Robert Fisher[1], Grahame Applegate[1], Robin Chazdon[1,2], Brian Sharp[1], Kanchana Wiset[1] and Christine Jacobsen[1]

[1]**Tropical Forests and People Research Centre, University of the Sunshine Coast, Queensland**

[2]**University of Connecticut, United States of America**

In developing tropical countries, smallholders and communities are often engaged to undertake restoration projects. However, the funders of reforestation and the government agencies and NGOs who are responsible for implementing restoration programs often treat both smallholders and communities, along with the landscapes within they live, as homogeneous. The capacity of smallholders and communities to implement restoration is however highly heterogenous; and also impacts substantially on their ability and willingness to become involved in restoration /reforestation projects, such as those implemented as part of Forest and Landscape Restoration. This paper outlines our recent thinking about the relationship between community capacity and restoration. We develop a conceptual model which we then use to illustrate that communities with different levels of community capacity will require different levels and types of assistance if FLR projects are to have a high chance of success. We outline how this conceptual model can be used to design restoration projects to be implemented by community and smallholders and to better inform policy decisions.

Ecological restoration and negotiated landscapes: Case studies from Asia

William Jackson[1, 2], Robert Fisher[1, 3]

[1]Tropical Forests and People Research Centre, University of the Sunshine Coast, Queensland

[2]Intellagama Pty Ltd, New South Wales

[3]School of Geosciences, The University of Sydney, New South Wales

Ecological restoration, including Forest Landscape Restoration, is increasingly advocated for its conservation benefits to populations within landscapes. This paper argues that much of the discussion and practice ignores some of the basic concepts behind landscape thinking, such as the need to focus on ecosystem functionality rather than focusing on trees or simplistic definitions of forest and the importance of trade-offs between functions in different parts of the landscape and at different scales. In addition, while discussions of ecological restoration and forest landscape restoration repeatedly stress stakeholder participation, the implication of this is not fully recognised. We argue that meaningful participation must lead to restored landscapes that meet stakeholder needs and wishes and that this implies that landscape needs to be understood as being about negotiated landscapes rather than planned landscapes. The paper looks at examples of the application of FLR in two cases in Asia, one from Myanmar and one from Northern Thailand.

Leading and lagging impact indicators for evaluation and adaptive management of forest restoration

Liz Ota[1], Jennifer Firn[2], John Herbohn[1], Nestor Gregorio[1]

[1]Tropical Forests and People Research Centre, University of the Sunshine Coast, Queensland

[2]Queensland University of Technology, Queensland

Current forest restoration approaches are not only concerned with re-establishing forest cover and promoting biodiversity conservation, but also with elevating the status and well-being of people and communities involved. These emerging forest restoration efforts are often based on a landscape-scale approach, which is characterised by multi-governance structure and management, and is embedded in a larger socioeconomic-political context. In such a complex setting, in which stakeholders have their own objectives at different levels of governance, one single measure of success is not sufficient. In this study, we argue for multidimensional impact indicators. We adopt the terms leading and lagging indicators, using the components of the Sustainable Livelihoods Framework as the criteria, and consider the changing nature of forest restoration objectives to develop a prospectus of impact indicators of forest restoration to be used across time and scale. This prospectus is based on previous literature and existing forest restoration assessment frameworks, focus group discussions and key-informant interviews. We then develop structural

equation models with data from community-based forest initiatives in the Philippines as a proof of concept of the ways in which multidimensional leading and lagging indicators can be used to assess forest restoration and provide information for adaptive management. We hope that this study will give researchers, practitioners and policy makers insights on the goals of forest restoration, the ways to assess the impacts of a given activity and the ways that information from monitoring and evaluation can be used in adaptive management.

SYMPOSIUM: Mine Waste Rehabilitation for Ecological Sustainability –Industry Perspectives

Organiser and moderator: **Longbin Huang**[1]

[1]**The University of Queensland, Queensland**

Session Description: Rehabilitation of mine waste domains (e.g., tailings/residues, waste rocks, wastewater pits/dams) are by far the greatest challenges in mined land rehabilitation and mine closure. This session aims to bring together industry and government representatives to update the current state of industry concerns and expectation. The speakers will mainly consist of industry representatives who are closely involved in management and rehabilitation of mine waste domains. As a result, the present session will be a special industry forum, providing opportunities to generate academic and industry interactions within the broad framework of the conference.

Introduction: Current frontiers of the closure and rehabilitation of mine wastes – industrial needs shape R&D direction

Longbin Huang[1]

[1]**The University of Queensland, Queensland**

Rehabilitation of mine waste domains at metal mines is a complex process, requiring the integration of knowledge and practical experience at multiple scales from substrate to landscape systems. Many studies in the literature have focused on the understanding of fundamental factors and processes in mine wastes at substrate level under defined physicochemical and environmental conditions. However, the success of transferring the knowledge into practical solutions at mine sites has been poor because of the lack of consideration of site-specific conditions, practical constraints in resource availability and associated costs, and associated secondary risks in the process. Much of current research in the field of mine waste rehabilitation have remained at substrate level, without evaluating the requirements of system integration and associated secondary risks on site under local climatic conditions. The lack of comprehensive consideration from substrate to system scales has hindered the transfer of knowledge into practice and site-adoption of recommended methods and techniques recommended in academically oriented research. The barrier

between knowledge discovery and technological solutions has also resulted in a widening gap in communications between researchers and industry partners in mining and mineral processing sectors. This unfortunately leads to industry's reluctance to commit large sums of funding for long-term research programs, both of which are so critical to breaking through the limitations of current conventional technology and methodology used in mine waste rehabilitation (such as rehabilitation of red mud and sulfidic Pb-Zn tailings). Based on my own industry-engaged research over the past decade, the present talk will illustrate the importance of understanding site conditions and integration of knowledge across the scales of substrate to landscape systems, by using the examples of acidic waste rocks, sulfidic tailings and bauxite residues. Transformational technologies and methodologies are much needed to rehabilitate mine waste domains, with the expected outcomes of safe, stable, nonpolluting (on-/offsite), and sustainable landscape systems.

Results from nine years of continuous monitoring of the ecosystem restoration of a waste rock landform at Ranger uranium mine, Northern Territory

Ping Lu[1], Longbin Huang[2], Lindsay Hutley[3], Sean Bellairs[3], Jill Segura[3]

[1]**Energy Resources of Australia Ltd, Australia**

[2]**University of Queensland, Queensland**

[3]**Charles Darwin University, Northern Territory**

Energy Resources of Australia Ltd (ERA) owns and operates the Ranger uranium mine, which is located in the wet-dry tropics of northern Australia. Ranger is surrounded by, but separate from, the world heritage listed Kakadu National Park. Ranger mine has been in operation for over 35 years, and ERA is currently actively planning for its closure.

Currently there is about 1000 ha of disturbed land to be rehabilitated. To test and demonstrate ERA's ability to successfully build and rehabilitate mine landform, with the ultimate goal of establishing self-sustaining ecosystems, ERA constructed and revegetated, with about 40 local native species, an 8 ha trial wasterock covered landform. The experimental design of the trial landform was based on the outcomes of extensive past research, including characterisation of analogue habitats and revegetation trials on wasterock stockpiles at Ranger.

Since its construction in 2009, the evolution of the trial landform has been monitored and studied for plant growth and regeneration, resilience to weed and fire, plant available water, nutrient cycling and fauna colonisation. To date, the monitoring data demonstrates that the vegetation and ecosystem are tracking positively towards that of the reference sites. These results are critical in the development of revegetation strategy, closure criteria, and design specifications and construction methodologies for the final landform.

This paper discusses the importance of collaborative research and large-scale field trials in the development of cost-effective rehabilitation planning.

Challenges of mine waste rehabilitation: From environmental quality to ecological sustainability

David Parry[1]

[1]Rio Tinto Aluminium, Australia

Mining companies from juniors to global companies are required to develop closure plans that describe the full scope of activities prior to, during and after closure necessary to ensure that closure outcomes meet all regulatory requirements and any other agreed performance criteria. Wherever practicable, sites should be left in a condition which is compatible with a beneficial land use – whether this be an economic activity, environmental or community use. However, it is recognised that in some cases the landscape is permanently altered, and may not be amenable to beneficial re-use. In these cases, the goal is to ensure the sites remain safe, stable and non-polluting.

As many mine sites are entering into the end of life of mine and the closure phase, new and practical technologies and methodologies are needed, to address the challenges of mined land rehabilitation, particularly the mine waste domains, such as acidic waste rocks, tailings and bauxite residues. Any new technologies for mine waste rehabilitation need to be in a framework of ecological sustainability for post-mining land use. The technological pathways to be used for closure can also be greatly influenced by stakeholders, including cultural values of indigenous land owners. These complex challenges require researchers to develop collaborative and site-specific options, rather than knowledge-oriented research without relevance to site-conditions and constraints. Expected outcomes of rehabilitation and closure have to meet the expectations of local communities and environmental/ecological standards set by regulatory bodies of governments.

Waste rock rehabilitation of magnetite-Fe ore mine under dry land conditions - plant establishment consideration

Jason Stevens[1]

[1]Botanic Gardens and Parks Authority, Western Australia

A 7 year research partnership between Kings Park Science and Western Australian Midwest Mining companies was established to tackle the complex environmental and biodiversity issues associated with post-mining restoration of a Threatened Ecological Community in banded iron formation (BIF) landforms. In the absence of any prior knowledge, the research partnership embarked on a framework to test ecological restoration theory based on integrated restoration science (linking core restoration disciplines – restoration ecology, seed ecology, ecohydrology, and ecophysiology) within the traditional confines of resource management through mine planning.

The research delivered a comprehensive restoration plan for SMC iron-ore mining operations east of Morawa in the Koolanooka Hills including practical outcomes including (1) established methods for defining restoration targets based on complex plant community definitions (2) achieved 70% flora species richness for both post-mining and post-exploration activities (3) developed soil surface reconstruction to support plant development and surface stability (4) used waste rock to offset topsoil deficits without compromising restoration outcomes (5) developed novel means to measure restoration success (6) adapted the research findings directly into company restoration activities (adaptive management). Additionally these findings were compiled to deliver the first WA industry manual for BIF mine site restoration to inform the broader mining community of the approach underpinning this leading standard and to broaden the knowledge base of research and management outcomes.

Bauxite residues rehabilitation – environmental challenges and ecological expectation under subtropical conditions

Anja Urban[1]

[1]**Queensland Alumina Ltd, Queensland**

Bauxite residue (red mud) is produced during the Bayer Process to refine alumina from bauxite. Red mud is a highly alkaline (pH 13), clay like substance containing mainly iron and aluminium oxides. Queensland Alumina Ltd (QAL) neutralises the red mud with seawater, as one of the only two refineries worldwide, before storage at its residue disposal area. The seawater neutralization (SN) lowers its risks to the environment, due to reduction in pH to below 10 and the feasible discharge of neutralized wastewater. However, this significantly elevates its salinity and chloride content to the magnitude far exceeding physiological tolerance of plants. As a result, rehabilitation of SN red mud is challenging.

So far, there has been no successful method established to rehabilitate the SN red mud world-wide. Technologies capable of delivering successful rehabilitation outcomes have to pass critical evaluations of cost-effectiveness, ecological sustainability, and secondary risks to the environment. Additional rehabilitation challenges arise from local environmental constraints such as subtropical climate with extended dry periods and resource availability, such as a shortage of available cover materials and soil.

As an industry-academic partnership, a long-term rehabilitation field research project has commenced in 2018, to investigate how these challenges can be overcome to establish a self-sustaining vegetation cover. The project will firstly focus on eco-engineering a soil-like material from the SN red mud to offset or lower the volumes of soil materials required to construct functional root zones for supporting plant growth, via addition of various locally available organic materials and minerals, as well as accelerated leaching using treated greywater supply. As an example case, this project has closely engaged industry and integrated site-concerns and limitations, for developing site-feasible, cost-effective and sustainable options of technology and methodology. These considerations would ensure technology transfer and site-adoption in the future. Pure academic research without being calibrated and aligned with industrial challenges would be a costly lesson for industry partners facing such complex environmental challenges.

SYMPOSIUM: The Multidisciplinary Aspects of Successful Mine Site Rehabilitation

Organiser and moderator: Marit Kragt[1]

[1]University of Western Australia, Western Australia

Session Description: Mine site rehabilitation is a multi-faceted issue that requires consideration of ecological, environmental, social, regulatory, and economic values. In this session, a multidisciplinary team of researchers and practitioners will discuss the challenges associated with mine closure planning from different perspectives. We will demonstrate how interdisciplinary approaches can complement the guidelines for ecological restoration, and what challenges remain.

Introduction: Mine site rehabilitation – an interdisciplinary approach

Marit Kragt[1]

[1]UWA School of Agriculture and Environment, The University of Western Australia, Western Australia

Introduction to the session.

The new standards for improving mine site restoration

Kingsley Dixon[1]

[1]ARC Centre for Mine Site Restoration, Curtin University, Western Australia

Mining has been an integral part of the Australian economy for almost 150 years. Yet, rehabilitation, let alone restoration has rarely been achieved across the spectrum of mining operations. With cumulative impacts of mining increasing the National Standards for the Practice of Ecological Restoration published by SERA address directly the need for a more integrated and comprehensive approach to mining restoration. As stated in the Standards there is a clear social obligation on extractive industries that degrade natural ecosystems for profit that every effort is made to reinstate the original or best fit natural ecology. Whereas many mining operations will claim that alteration of substrates means that the original ecosystem cannot be reinstated, the Standards provide for opportunities whereby sound science and use of an appropriately matched native reference ecosystem should be attempted. Importantly within the regulatory framework, the Standards provide a clear pathway whereby the mining industry can be held accountable for ensuring the highest and best outcomes in post-mining restoration.

The global knowledge base on the social aspects of mine closure

Sarah Holcombe[1], Nick Bainton[2]

[1]Centre for Social Responsibility in Mining (CSRM), Sustainable Minerals Institute, University of Queensland, Queensland

It has been observed that 'the excitement and fanfare that surrounds the opening of a new mine is never present when it finally closes'. For our purposes, this pragmatic statement, by Laurence, frames the challenge for industry, governments and locally affected peoples to shift this dominant 'front-end' approach, to actively account for the collateral social, political, and economic impacts that almost inevitably occur when a mine closes. The need to reimagine the practice of mining in order to positively re-frame the legacies that are left, because 'it's not over when it's over', is a pressing one. The impacts and negative legacies of mining are increasingly under scrutiny by a growing civil society and an active local citizenry who are not always 'excited' when a mine opens and where effective closure may be more important to them than effective operations. It is increasingly the case that stakeholders expect mining operators to proactively manage the multi-dimensional impacts of closure – just as they would manage impacts at other stages of mine life.

In this paper, we review current practices and the status of the global knowledge base on the management of the social aspects of mine closure. Drawing on the results of a recent literature review on the social aspects of closure, we identify the common planning and management approaches, and the key themes and gaps in this knowledgebase. This provides the basis for mapping out an agenda for priority research areas that will help to fill the knowledge gaps we identify, and support the critical task of building capacity across the industry to better understand the socio-economic possibilities and limitations of mine closure.

Economics to the rescue: non-market valuation of mine site rehabilitation

Marit Kragt[1]

[1]UWA School of Agriculture and Environment, The University of Western Australia, Western Australia

It is an inevitable part of the mining process that a loss in environmental quality will occur. Implicitly, accepting a mine development project indicates that—from a societal perspective—the value of expected benefits generated by the project exceed the expected costs, including the external cost to ecosystems and landscapes.

However, over the past decades, society and decision makers are increasingly recognizing that we are trading off tangible economic benefits from mineral exploitation on the one hand, against potential environmental and social damages on the other. For decision makers, financial benefits like job provision and company profits are typically easy to measure and quantify. A major challenge arises when comparing such direct financial benefits to less tangible impacts on socio-environmental systems. How does one compare apples and oranges?

Fortunately, economists have a number of tools available to estimate the values that people attach to environmental assets and social constructs that are difficult to measure. Ecologists sometimes refer to these tools as 'willingness to pay' methods. This presentation will give an overview of economic valuation methods, and how they can or have been used to quantify the 'non-market' value impacts of mine development and closure. I welcome a discussion on the assets that warrant valuation when considering different mine site rehabilitation practices.

Why is designing effective and efficient policies for mine rehabilitation proving to be so hard?

Ben White[1]

[1]UWA School of Agriculture and Environment, The University of Western Australia, Western Australia

Mining generates about 9.1 per cent of GDP (2018), employs around 2 per cent of Australia's workforce and contributes royalties and taxes of $23 billion (2014). The downsides of mining from an environmental and economic perspective are its significant external costs (costs to other parties not directly accounted for in the firm's decision making process), such as greenhouse gas emissions, water pollution and land damage. The focus of this presentation is on policy for land damage.

Roughly three stages in the evolution of environmental policy for mines can be identified in Western Australia. Similar stages can probably be identified in other states. Stage 1, dig it up and move on, maximized the firm's profit and ignored external costs. Stage 2, guaranteeing minimum environmental standards, commenced with the 1978 Mining act which required larger firms to secure bonds (surety) that 'guaranteed' mine sites were rehabilitated to a minimum standard in the event that a firm abandoned the mine or was non-compliant. In practice, such surety provides only a weak incentive to engage in timely rehabilitation. Stage 3, incentives -based, started when the Mining Rehabilitation Fund Act 2012 introduced a Mining Rehabilitation Levy payable as a proportion of the rehabilitation liability. For the first time in Australia, this introduced an incentive for progressive rehabilitation as the firm could reduce its levy payments by getting mine rehabilitation signed-off.

What is the next stage in the evolution? Progress has been made, but current policies are far from optimal and the role of economic valuation is still peripheral. Over the long lifetime of a mine, market conditions and community preferences change. The range of policy instruments will also change (e.g. offsets and off-site rehabilitation). The challenge to economists and policy makers is to design policies that provide incentives to guide mining firms towards a socially optimal set of rehabilitation actions.

A risk-based framework for completion criteria development for mine closure planning in Western Australia

Renee Young[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

The development of acceptable and achievable completion criteria is a necessary part of mine closure planning. Completion criteria can be defined as agreed standards or levels of performance, which demonstrate successful closure of a site. Once achieved, they demonstrate to the mining company, regulators, and other stakeholders, that financial assurances and liabilities can be removed. Setting and meeting socially desirable completion criteria can increase mining industry's social licence to operate and are required to guide monitoring programs.

Western Australia has a long history of mining activity. There are a diversity of challenges and opportunities for achieving mine closure. There has been considerable progress with mine closure and rehabilitation planning in Western Australia (WA). Yet there remains a need to build capacity and understanding of measuring rehabilitation success and to set practical outcomes and measurable completion criteria, particularly with respect to ecological parameters.

As one of the WA Biodiversity Science Institute's founding projects, a research group with representatives from UWA, Murdoch, Curtin and Kings Park Science bring together the expertise to deliver independent, scientific information about the state of completion criteria in WA.

Here we present an analysis of state, national, and international rehabilitation research that has been informed by industry consultation and leading experts. We discuss the draft framework and recommendations for developing site-specific completion criteria, incorporating risk-based assessments and associated monitoring for Western Australian post-mining rehabilitation. Common challenges related to developing completion criteria are presented, ranging from the consideration of end land use, disconnection between approval and completion stages, and residual lack of resources. The framework presented includes a risk-based approach to the development of closure criteria, with the identification of attributes, indicators, and parameters to measure, and the setting of benchmarks.

SYMPOSIUM: Ecological Restoration Practice in the Big Scrub in North-east NSW

Organiser and moderator: Mike Delaney[1], Tein McDonald[2]

[1]National Envite Operations Manager, EnviTE Environment, New South Wales

[2]Tein McDonald & Associates, New South Wales

Session Description: Rainforest restoration has evolved on the NSW north coast over the past decades with significant developments in practice and techniques. This collection of case studies from the Big Scrub landscape shows how recovery of an Endangered ecological community and Threatened species is progressing in a social-ecological context. Ecological restoration is implemented in partnership with private and public landholders, local communities, Indigenous groups, schools and others. These partnerships are key to ensuring investment in ecological restoration is successful in the long term.

Camphor conversion to rainforest: Restoration of mixed rainforest and camphor laurel patches to lowland rainforest case study

Dan Cox[1]

[1]Restoration Ecologist, EnviTE Environment, New South Wales

The cleared landscape, fertile basaltic soils and high annual rainfall have provided the perfect conditions for camphor laurel and other woody weeds to colonise areas previously occupied by the Big Scrub. A native of China and Japan, camphor laurel (Cinnamomum camphora) was originally introduced to Australia in the 1800s and promoted as a useful tree for windbreaks, shade tree in agriculture and school yards. The trees can reach maturity within 10 years of age and are long lived with individuals in China believed to be in excess of 500 years of age. A large mature tree can produce over 100,000 fruit a year. Seed of the Camphor laurel is mainly distributed by frugivorous birds, gravity and water. Camphor laurel has rapidly colonised disturbed areas and neglected agricultural lands. While the reclamation of lands by this exotic is seen as a loss to agricultural productivity there are benefits to biological function that include but are not limited to the facilitation of the natural regeneration of sub-tropical rainforest. The control of Camphor laurel is not as simple as killing it because it is a weed; there are many reasons and ways to either retain or remove them. There have been several studies in recent years quantifying the benefits of different bush regeneration techniques and strategies in undertaking camphor conversion. Some aspects of these studies will be discussed in relation to recent successful camphor conversion work undertaken by EnviTE Environment using patch and staged removal of camphor laurel within the Big Scrub region.

Saving the Big Scrub

Mike Delaney[1], Maree Thompson[2]

[1]National Envite Operations Manager, EnviTE Environment, New South Wales

[2]Environment Manager, EnviTE Environment, New South Wales

The Big Scrub was the largest expanse of lowland subtropical rainforest in Australia covering an area of approximately 75,000 hectares between Byron Bay, Ballina and Lismore in Northern NSW. Tragically it was cleared for agriculture and by 1900 only one percent remained in the form of 100 small remnants scattered across a largely cleared landscape. Over the following decades an array of environmental weeds caused increasing damage to the remaining remnants. Efforts to bring back the Big Scrub started as early as the 1930s however it was not until the 1970s that some momentum began which eventually led to the formation of the Big Scrub Landcare (BSL) in 1992. The following year Envite Environment was also formed and together they have engaged with landholders, government and the community to lead a successful restoration program to arrest the degradation of remnants, and to restore them to good condition and provide ongoing care.

The small scattered remnants of the Big Scrub are mostly less than five hectares in area and cover less than 1000 hectares in total. The critically endangered lowland subtropical rainforest remnants contain significant habitats for the in-situ conservation of biological diversity, including 32 threatened species of flora and 12 threatened species of fauna listed under Australia's Environmental Protection and Biodiversity Conservation Act.

Caring for the remnants is the most important aspect of restoring the Big Scrub Rainforest. Another important aspect of rainforest restoration is re-establishing rainforest on land from which it has been cleared. This often involves plantings to: create a new patch of rainforest; expand a remnant or connect two remnants; enrich a patch of regrowth rainforest or convert camphor laurel forest to rainforest. Another important component of the overall BSL project is the engagement with the community which includes a bi annual BS day, regular field days and the production of publications that assist landowners in the fundamentals of rainforest restoration work.

Recovery processes underpinning rainforest restoration in the Big Scrub

Tein McDonald[1], John Nagle[2], Tim Roberts[3], Sophy Millard[4]

[1]RPrincipal, Tein McDonald & Associates, New South Wales

[2]Senior Land Services Officer - North East, Local Land Services, New South Wales

[3]Principal, Macaranga Bush Regeneration Services, New South Wales

[4]Sophy Anne Millard, Consultant, New South Wales

Victoria Park Nature Reserve is one of a small number of remnants of the once-continuous subtropical rainforest of the Big Scrub landscape in northern NSW.

This paper reports on increases in rainforest species regenerating over 3-4 decades in pioneer plantations established in completely cleared ex-pasture sites surrounding the remnant, as well as under tall isolated native trees and poisoned camphor laurels. Species richness and density of seedlings and saplings were sampled in 36 (50m2) quadrats under three pioneer plantations, a grassy opening, tall isolated remnant trees and poisoned camphor laurels in 1995. At that time (approximately 10 years after planting) a total of 61 tree and shrub species were recorded in the 36 quadrats, representing 64% of the 94 tree and shrub species occurring in the remnant. Substantial recruitment of rainforest trees and shrubs have subsequently occurred across the site, with monitoring in 1995, 2002 and 2018 providing evidence later secondary and mature phase species are colonising and moving up in height class, demonstrating that successional processes towards primary forest are progressing.

The processes of recovery at Victoria Park are a microcosm of the similar processes occurring throughout the once-cleared landscape of the Big Scrub where scores of projects are harnessing natural processes to create new secondary forests, particularly triggered by the spread of camphor laurel (Cinnamomum camphora) which can act as a 'starter' for rainforest regeneration. There is no doubt that the landscape has increasing amounts of potential 'receiving areas' for reweaving some of the fabric of the lost Big Scrub, but there are very few remnants to act as seed sources. This begs the question of whether we have sufficiently diverse seed source plantations located near these receiving sites to ensure species characteristic of the ecosystem can move into them, ultimately allowing them to progress to maturity?

Big Scrub - making a vision of genetically appropriate seed production areas a reality

Tony Parkes[1], Maurizio Rossetto[2]

[1]**Chair, Big Scrub Landcare, New South Wales**

[2]**Senior Principal Research Scientist, The Royal Botanic Garden, New South Wales**

Recent research has confirmed long-term concerns based on seed collection practices that there is inadequate genetic diversity in planting stock of key species used in the many restoration plantings of critically endangered lowland subtropical rainforest in the Big Scrub region. Genetic diversity is the key indicator of population fitness that includes a species' capacity to survive and reproduce in the short term, and is fundamental to species ability to adapt to changing conditions such as climate change and pathogens in the long term.

Big Scrub Landcare's vision is to work in partnership with the Royal Botanic Gardens Sydney and other experts to apply cutting-edge genetic research to guide the development of a plantation to produce seed with optimal genetic diversity to grow planting stock for use in ecological restoration planting projects. This will provide an opportunity to ameliorate the adverse genetic impacts of fragmentation and the poor distribution of many key species across the 99% cleared Big Scrub landscape.

In this internationally-innovative project, cutting-edge genomic analysis technologies (similar to the approaches used in the 'Human Genome Project') will capture detailed genetic, climatic and ecological information from 30-50 remnant populations of 20 widely planted 'main-frame' structural rainforest tree species. This information will identify 20 individual trees of each species that collectively have the optimal

genetic diversity to be used as the source of planting stock in future restoration projects.

Cuttings will be collected from of each of the selected trees to produce the planting stock for an innovative, specially developed rainforest seed plantation. The seeds of each species ultimately produced from the plantation will be mixed and provided to nurseries, thereby ensuring that trees grown from this seed have the optimum genetic diversity required to enhance the long-term sustainability of rainforest plantings to restore the critically endangered rainforests of the Big Scrub.

Wanganui Gorge ecological restoration – a ten year case study in rainforest restoration in a biodiversity hotspot

Iain Stych[1]

[1]Bush Regeneration Team Leader, Envite Environment, New South Wales

A ten year case study in rainforest restoration in a biodiversity hotspot. Includes cost effective, large scale lantana (Lantana camara) control in a resilient ecosystem. The site provides habitat for over 27 threatened plant and animal species and is being systematically restored with work now in the tenth year. Wompoo Gorge is located between Nightcap and Goonengerry National Parks with Coopers Creek Creek running along the eastern boundary. Since 2009 systematic ecological restoration works have been implemented over 30 hectares. Each stage of work has been undertaken in a timely manner to ensure that weed re-establishment was minimal. The range of weed control techniques used were adapted to suit the range of site conditions, from mechanical control with a tractor, manual weed control around threatened species, to cutting tracks through and splattering large areas of lantana and cut, scrape and paint of woody weeds, regenerating over more than 30 hectares. Fruit from native plants on site has been collected and spread throughout regeneration areas, adding to seed in the soil bank and naturally distributed. A monitoring program was established on site prior to commencement of works. This included eight monitoring transects. Structural and floristic information was collated and photos taken prior to the commencement of works, at the end of the first year and twice in year two. Monitoring has continued as various stages of works have been undertaken. Most of the southern area of the site now requires minimal work to maintain restoration. The project continues to produce significant and sustainable outcomes, including improved habitat for fauna, demonstrating what can be achieved on a cost effective basis. The site has been conserved for the long term with incorporation into National Parks estate.

SYMPOSIUM: Novel Techniques and Applications for Restoration Monitoring

Organiser and moderator: **Paul Nevill**[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

Session Description: Monitoring is a critical component of ecological restoration. It is required to track trajectories, enable adaptive management, and provide evidence to stakeholders and regulators that goals are being achieved. However, it is often not undertaken, or not undertaken effectively, and one of the main reasons is that traditional monitoring approaches are time-consuming and expensive. The goal of this symposium is to communicate the diversity of monitoring applications and approaches available, with the restoration community.

Automated monitoring of seedling emergence and early mortality from drone imagery

Todd Buters[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

One of the main barriers to restoration is mortality during the seedling emergence and early establishment phases. While this could be alleviated with monitoring from teams of botanists, the price involved and the scale at which restoration efforts take place make this an unrealistic proposition. However, recent years have seen an explosion in the affordability and usefulness of even small commercially available drones. These drones have been used for all sorts of monitoring, from monitoring remote tropical forests to more unusual tasks such as collecting whale mucus. The increasing availability of drones presents an opportunity to conduct low cost monitoring with high accuracy and very low turnaround times. This project has focussed on the use of commercially available drones to produce geo-rectified orthomosaics to monitor seedling emergence and early establishment, and automated identification of seedlings by use of object based image analysis. Initial results suggest that this method will produce a high level of accuracy in identification of both newly sown seeds and emerging seedlings, and has very low ongoing costs. The addition of a multispectral camera to the drone has additionally allowed for the monitoring of seedling health, and early detection of mortality due to water stress. Simply generating high resolution orthomosaics allows for the identification of seedlings by qualified professionals, however the addition of an appropriate image analysis program and multispectral sensor removes the ongoing need for professional monitoring and allows for restoration to continue undisturbed unless intervention is needed.

Using UAV-based LiDAR to assess forest structural attributes for monitoring of restoration plantings

N. Camarretta[1], A. Lucieer[2], P.A Harrison[1], B. Potts[1], N. Davidson[3], M. Hunt[1]

[1]**School of Natural Sciences & ARC Training Centre for Forest Value, University of Tasmania, Tasmania**

[2]**School of Technology, Environments and Design, University of Tasmania, Tasmania**

[3]**Greening Australia, Tasmania**

The long-term monitoring of forest restoration plantings will be fundamental to guide restoration decisions, and provide feedback into the adaptive management of such restoration activities. To quantify the on-going effectiveness of these plantings, we propose monitoring the development of structural complexity through the measurement of forest structural attributes (i.e. three-dimensional arrangement of biomass). Attributes describing structural complexity are well-recognised indicators of forest ecosystem health, but can be time consuming and expensive to quantify on a large-scale in field inventories. Therefore, we here test and validate the use of a Light Detection and Ranging (LiDAR) sensor mounted on-board an Unmanned Aerial Vehicle (UAV) for the assessment of key structural attributes measured in an 8-year old mixed species restoration planting. These plantings, comprised of dry sclerophyll eucalypt species and other sub-dominant tree species, arranged across four adjacent plots (5 ha in total), were remotely monitored for tree-level attributes calculated from a dense (> 1000 points/m2) point cloud. These traits were also assessed in the field for validation during the same growing season. We here report (i) the success of quantifying forest structural attributes using UAV LiDAR-derived metrics at the tree-level, and (ii) the development of a baseline assessment of structural complexity.

DNA metabarcoding – a new approach to fauna monitoring in mine site restoration

Kristen Fernandes[1,2], Mieke van der Heyde[1,2], Michael Bunce[2], Kingsley Dixon[1], Richard J. Harris[3], Grant Wardell-Johnson[1], **Paul Nevill**[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

[2]**Trace and Environmental DNA (TrEnD) Laboratory, Curtin University, Western Australia**

[3]**School of Molecular and Life Sciences, Curtin University, Western Australia**

Ecological restoration of landscapes is an integral part of the mining process. However, restoration is often constrained by a lack of consistent monitoring approaches. For example, the need for specialist techniques and trapping approaches often limits monitoring of fauna recovery. Application of molecular tools has made important

contributions to understanding factors influencing restoration success. Here we outline advances in next-generation sequencing (NGS) methods, especially metabarcoding of environmental DNA (eDNA). These have potential to revolutionize the practical contribution of genetics to the monitoring of fauna in a restoration context. DNA metabarcoding involves the simultaneous characterization of biota using DNA barcodes. It is a powerful method to assess the biodiversity contained within environmental samples (e.g. scats, bulk arthropods, soil, water and sediment). This review outlines the challenges associated with current approaches to monitoring faunal biodiversity throughout ecological restoration. We also demonstrate how the emergence of DNA metabarcoding could recast monitoring capacity for improved ecological restoration outcomes, while discussing current limitations of a DNA based approach to biodiversity assessment.

Assessing the use of metabarcoding to monitor mine site restoration

Mieke van der Heyde[1]

[1]ARC Centre for Mine Site Restoration, Curtin University, Western Australia

Biological surveys are challenging, expensive, and time consuming, yet crucial for both biodiversity conservation and ecological restoration. Metabarcoding is a disruptive technology that can enable biological auditing from DNA in the environment, and may provide cost-effective monitoring, which can detect flora, fauna and microbial communities. Metabarcoding involves the use of next generation sequencing to sequence barcode regions of the genome to determine the community composition of a sample. These samples can be soil, scat, arthropods, and plant material. This study aims to test multiple substrates (soil, ant middens, scat, plant material, arthropods in pitfall and vane traps) to determine what organisms can be detected from each and where they overlap, as well as how many samples of each may be necessary. Samples were collected in the Pilbara and Swan Coastal Plain regions of Western Australia and transported to facilities in Perth where the DNA was extracted, amplified and sequenced using multiple primers and targeting multiple gene regions. Preliminary results indicate that soil samples, despite showing promise for biological auditing in some regions, yield little plant or animal DNA. While soil samples are necessary to determine soil microbial communities, they may be less able to represent flora and fauna communities. Likely, this is a result of the high temperatures and UV radiation of these Western Australian regions, both of which degrade DNA. Bulk samples, such as arthropods from pitfall traps and vane traps, show far greater promise as DNA is extracted directly from homogenized arthropod samples. The goal of this study is to provide a guide for terrestrial metabarcoding sample collection to be used for biological surveys, particularly in subtropical and Mediterranean regions.

Using invertebrate DNA (iDNA) metabarcoding to track restoration trajectories of arthropods across two mine site chronosequences

Kristen Fernandes[1, 2], Mieke van der Heyde[1, 2], Megan Coughlan[2], Grant Wardell-Johnson[1], Michael Bunce[2], Richard Harris[3], Paul Nevill[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

[2]**Trace and Environmental DNA (TrEnD) Laboratory, Curtin University, Western Australia**

[3]**School of Molecular and Life Sciences, Curtin University, Western Australia**

Ecological restoration is a global endeavour implemented to address biodiversity declines and extensive land degradation. Biomonitoring is a crucial component of restoration; facilitating baseline understanding of ecological condition, and determining restoration trajectories. However, most projects are poorly monitored. Traditional approaches to invertebrate monitoring have been used in a restoration context, but are underutilised due to the levels of expertise, time, and cost required. Invertebrate DNA (iDNA) metabarcoding has been used to characterise arthropod biodiversity but its application in restoration remains untested. We investigated the invertebrate composition from pitfall traps at two mine site restoration chronosequences in south-western Australia. Invertebrates were profiled using two arthropod COI and a plant trnL assay to investigate insect biodiversity and plants they vector. The assemblages of taxa at the age groups were examined to determine both differences between the sites and the various restoration ages from within each site. The important arthropod taxa that characterise restoration age were also identified. The data revealed significant differences between arthropod communities within both chronosequences. Several significant characteristic taxa were identified for each age within the chronosequence. Including; ants (Family: Formicidae), springtails (Order: Collembola) and millipedes (Order: Julida). A diverse range of plants were identified from their DNA within the insect samples but did not show any clear patterns between sites or age plots. This study represents the first step in development of an iDNA molecular 'toolkit' for monitoring of ecological restoration projects. Our results demonstrate that an iDNA metabarcoding approach, even at early stage of development, can complement current monitoring practices. Collectively, these data suggest an iDNA approach will become integral to best-practice restoration monitoring.

SYMPOSIUM: Native Seed for Restoration, Challenges and Opportunities

Organiser and moderator: **Simone Pedrini**[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

Session Description: Seeds are an adaptation to survive unfavorable conditions and to disperse in space and in time, thus playing a key part in the assembly and regeneration of existing and future plant communities. Seed-based restoration harnesses the practicality and diversity of these attributes to revegetate, enrich, or conserve plant communities. This is especially true and important as restoration sites worldwide are increasingly altered and degraded by extreme wildfires, invasive species, fragmentation, mining and climate change. For these situations, seed-addition is essential along with management to achieve restoration goals. The native seed sector has advanced in recent decades, however, there are many challenges and opportunities associated with the use of native plant seeds in restoration. This symposium covers best-practices and current research relevant to obtaining seeds for restoration including seed needs assessment, seed sourcing, seed procurement models, seed collection, seed technology, seed innovations, and seeding and deployment.

Introduction: The international network for seed based restoration

Kingsley Dixon[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

As the speakers in this symposium will highlight, there is a growing gap between restoration need and the ability through provision of plant materials to achieve the scale of restoration hoped for and indeed, promised. Whether it is the Bonn Challenge or more modest 'backyard' restoration, seed sits at the heart of providing the foundational restorative materials. Three major issues sit at the heart of the seed-based capability to deliver effective restoration - sourcing seed at the tonnages required; ensuring seed is stored and managed to ensure effective germinative capacity and, deployment to site ensures seed wastage is minimised. These three core areas are the backbone of moving forward with seed-based restoration. The International Network for Seed-based Restoration (INSR), the only seed-dedicated restoration organisation and a Section of the Society for Ecological Restoration (SER) International is committed to linking seed producers and seed users for more effective global outcomes. Ecological restoration is now a partner in delivering conservation and enhancement of biodiversity with effective seed use being critical to ensuring on-going growth and success in delivering a greener more biodiverse world.

A Protocol Development Tool for native seed coating

Khiraj Bhalsing[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

Here we present an open access, reproducible, and customisable Protocol Development Tool (PDT) for the native seed industry to test and develop seed coating procedures tailored to species- and site-specific needs. Seed coating, either encrusting or pelleting, requires at least two types of materials, fillers (inert powder material) and binders. The seed coating process is divided into six phases, described in attached table along with equipment's required. Seed technologies are widely used to improve horticultural and agricultural crop production but are rarely deployed in native seed restoration. Most agricultural and horticultural seeds currently available are coated, with global markets for coating and pelleting seed products worth over $1B annually. Despite the significance of seed coating technologies in the seed industry, most methodology and protocols remain commercial in-confidence of a handful of transnational seed companies. Thus it is difficult to evaluate and adopt the technologies from the commercial agricultural sector to the native seed industry which supports an $18 billion /year restoration sector. For small seed producers, particularly the emerging native seed sector, seed enhancement technologies are either unavailable or rarely adopted due to their inaccessibility. Here we present the first fully disclosed Protocol Development Tool (PDT) for seed pelleting and encrusting. The PDT is customisable, applicable to a wide range of commercial crop and native seeds and represents a variety of coating materials. The PDT will allow researchers and seed suppliers to test and develop project-specific pelleting and encrusting methods within a standardised and replicable framework that will enable incorporation of germination and plant growth enhancers, stress limiting compounds, anti-predation compounds while providing a means for standardising seed shape and size for the highly variable native seed batches. Such approaches are critical if seed use efficiencies and precision seeding technologies are to deliver large scale restoration outcomes.

Table 1. *Description of the six phases of the PDT and list of the main equipment required at each phase. *Units are either pelleted or encrusted seeds.*

Phase	Stage	Process description	Required equipment
General Information		Record information on date, operator name, species of seeds to be coated and material to be used	None
Before coating		Record initial weight of seed, powder, and binder, and time when the process start	Scale
Coating process	One	Deliver small quantities of binder and powder alternatively until the desired amount of binder is delivered. Then weight the units and powder left.	Rotary coater Air brush Paint brush Scale
	Two	Deliver binder and powder alternatively until the desired amount of binder is delivered. Then sieve and weight the units. This ends the encrusting process	Rotary coater Atomizer Measuring spoon Scale Sieves
	Three	Deliver binder and powder alternatively in larger quantities than stage two, until the desired unit's size is achieved. Unit size is tested by sieving. This ends the pelleting process.	Rotary coater Atomizer Measuring spoon Scale Sieves
Wet		Weight the fractions of desired, small and large units and discard the last two. Record the weight of leftover powder and binder and the time when the process ended. Place seed in the drying oven.	Sieves Scale Drying oven
Dry		Record weight of dried units, oven temperature and duration of the drying phase.	Scale
Quality control		Perform crush test and mechanical integrity test and report the results in the pro-forma	Force gauge Dissecting kit

Status of the Australian native seed sector: results of a nationwide survey

Paul Gibson Roy[1]

[1]**Greening Australia, New South Wales**

For many years, there have been concerns raised within the native seed sector of the need for change from one that is essentially a disparate, poorly supported or capitalised cottage-industry to a forward-focussed, structurally sound and cohesive restoration-supporting industry – a transition that is required if it is to meet the many challenges facing ecological restoration in Australia. But there have been many more unknowns than there are knowns about the native seed sector and providing solutions to its many challenges has always been hampered by a lack of quantifiable data. For this reason, a survey on the status of the Australian native seed sector was instigated by the Australian Network for Plant Conservation. It was conducted between October 2016 and April 2017 with parties from all states and territories contributing (including seed collectors, growers/sellers/suppliers, purchasers/distributors, researchers). The survey aimed to provide base data on a range of seed-related subjects including seed collection and handling practices, seed end-use and seed business structure and models. The survey also tested common perceptions on a range of sector-related topics to gauge opinions and gather feedback from those working in the sector. The survey provided an important snapshot of the status of the Australian native seed sector and furthers knowledge on its structure and its capacity to meet current and future seed demand for ecological restoration. This presentation will give an overview of survey findings and discuss implications for the broader restoration sector.

Resolving dormancy in difficult-to-germinate Australian Ericaceae

Michael Just[1]

[1]**Edith Cowan University, Western Australia; ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

The Ericaceae in Southwest Australia contains species with difficult to germinate seeds, including many species with deep intractable dormancy. An improved understanding of seed biology and species-specific dormancy and germination mechanisms is required to overcome these difficulties. Land clearing, salinity and disease has resulted in over 125 species within 15 genera being listed as rare, highly restricted, threatened and endangered (Western Australian Herbarium 1998–). The present study examined the seed biology of eight species of Ericaceae native to Western Australia, exploring fruit and seed morphology, dormancy and germination. Cold and warm stratification were used in combination with gibberellic acid to classify dormancy. Between the two distinct fruit types that occur within the Ericaceae separate patterns of dormancy were identified.

Seeds held within a dehiscent capsule were found to possess non-deep and intermediate physiological dormancy whilst those within an indehiscent drupe possessed morphophysiological dormancy. Oxygen enriched atmospheres and the removal of seeds from endocarps provide potential avenues for the propagation of study species.

Optimisation of seed coating technology to native grasses

Simone Pedrini[1]

[1]ARC Centre for Mine Site Restoration, Curtin University, Western Australia

Grasslands across the globe are undergoing constant degradation due to climate change and human impacts. If restoration of degraded native grassland is to be achieved at the scale now required, cost effective means for seed-based establishment of grass species is crucial. However, grass seeds present numerous challenges associated with handling and germination performance that must be overcome to improve the efficiency of seeding. Seed coating technology, allowing for increase of seed size and weight, and providing active ingredients for seed protection and enhancement, could improve grassland restoration efficacy. However the presence of floret on grass seed could render the seed coating process unfeasible. Here we present an optimised procedure for complete floret removal on four Australian grass species (Austrostipa scabra, Chloris truncata, Microlaena stipoides var. Griffin and Rytidosperma genicula var. Oxley), followed by evaluation of seed coating on cleaned caryopses on three of those grass species. The results show that floret removal on its own improves germination performance. Seed coating, although not providing increase in germination and emergence, when loaded with the stress-resistant inducing compound Salicylic acid, improve plant survival and growth.

SYMPOSIUM: Adaptive Coastal Restoration - Responding to Change and Implementing Management

Organiser and moderator: Jemma Purandare[1]

[1]Australian Coastal Restoration Network; TropWATER, James Cook University, Queensland

Session Description: This session will present an update of active and proposed coastal restoration projects, including the Great Barrier Reef coral restoration projects, ongoing coral restoration projects in the Philippines, and recent developments in estuarine mangrove restoration projects in the southern Great Barrier Reef catchment in response to mitigate flood damaged shorelines caused by TC Debbie. Following the presentations, a talk will be given that discusses the conversion of scientific research in coastal restoration to management practice, with specific reference to the Great Barrier Reef.

Introduction: Coastal restoration in Australia and the Coastal Restoration Network

Jemma Purandare[1], Ian McLeod[1], Damien Burrows[1], Chris Gillies[1]

[1]**TropWATER, James Cook University, Queensland**

[2]**The Nature Conservancy, Victoria**

Restoration of coastal and marine environments is a relatively new concept in Australia. Historically, restoration has been conducted at a small scale by research institutes and/or local governments responding to community requirements or localised environmental damage. Large scale restoration, as seen in other parts of the world, such as the Caribbean, North America, and the Indian Ocean, have not been tested or implemented in Australia, and as such, many specialists, managers and practitioners have often worked in isolation of other restoration projects around Australia.

In August 2017, the first Australian Coastal Restoration Symposium was held in Townsville to bring together restoration scientists working on marine and coastal restoration projects across Australia, with the intention of connecting, learning, and sharing with each other. The Symposium brought together 60 specialists, managers, academics, practitioners and engineers working in restoration across a broad spectrum of marine and coastal ecosystems, including kelp and macro algae, coral and shellfish reef, mangroves, salt marsh, seagrass, and dunal systems. The Symposium concluded with a round table forum to discuss whether a Coastal Restoration Network was needed in Australia. The Network would recognise and support the need for the (mostly existing) specific restoration and ecosystem-based networks, such as the Shellfish Reef Restoration Network and the Seagrass Restoration Network, providing a conduit for broader restoration information, and a platform for networking that particularly enable access to multidisciplinary and cross-disciplinary specialities, such as economists and social scientists, to connect with specific projects. The Network would also recognise the larger national and international organisations, such as the Australian Marine Sciences Association, the Society for Ecological Restoration, and the Australian Coastal Society, and work with them to provide opportunities for restoration specialists to present at conferences, provide and attend workshops, and enable a more direct link to organisations where policy changes and reports are required to be reviewed by experts in the field, or for advocacy activities as appropriate.

The round table concluded that the Network was needed, and as such, it was created at the end of 2017 and is currently growing.

Sexual restoration on coral reefs

Peter L. Harrison[1]

[1]Marine Ecology Research Centre, Southern Cross University, New South Wales

Scleractinian reef-building corals are foundation species on coral reefs, creating the complex three-dimensional reef structure and providing essential habitats for many species within these spectacularly biodiverse reef ecosystems. The loss of breeding corals on many reef systems around the world is seriously impairing reef function and reducing resilience.

Traditional coral restoration approaches using fragmentation and coral gardening are mostly small scale and create clonal populations with limited genetic diversity. In contrast, restoration techniques using sexual reproduction enable restoration at potentially larger scales with enhanced genetic diversity. This presentation highlights the successful outcomes from repeated coral restoration trials on degraded reefs in the Philippines and the Great Barrier Reef using millions of genetically diverse coral larvae. Larvae are reared on the reef or in mariculture facilities after coral spawning events, then temporarily contained in fine mesh enclosures on the reef to enhance larval settlement rates. Long-term monitoring of growth and survival of the settled corals have demonstrated that juvenile survivorship stabilises after six to nine months, and rapid colony growth can produce sexually reproductive adults within three years, thereby rapidly re-establishing breeding coral populations and initiating restoration of degraded reef areas. The results show that coral larval restoration is feasible and can enhance reef recovery.

The challenge now is to scale up coral and reef restoration over larger reef areas to sustain genetic diversity and enhance evolutionary potential in the Anthropocene era plagued by increasing climate change impacts and other chronic human disturbances.

Can bivalve habitat restoration improve degraded estuaries?

Ian McLeod[1], Philine S.E. zu Ermgassen[2], Chris Gillies[3], Boze Hancock[4], Austin Humphries[5, 6]

[1]TropWATER, Centre for Tropical Water and Aquatic Ecosystem Research, James Cook University, Queensland

[2]School of GeoSciences, University of Edinburgh, United Kingdom

[3]The Nature Conservancy, Victoria

[4]The Nature Conservancy, Graduate School of Oceanography, University of Rhode Island, United States of America

[4]Department of Fisheries, Animal and Veterinary Science, University of Rhode Island United States of America

[6]Graduate School of Oceanography, University of Rhode Island, United States of America

Bivalve habitats were once a dominant ecosystem in temperate and subtropical estuaries worldwide. While bivalve habitats are greatly reduced from their former abundance, remnant and restored populations have been shown to provide a suite of important ecosystems services including improving water quality, and providing coastal protection and fisheries nursey habitat, in addition to providing a direct food value. Although it is unlikely that bivalve habitats can be brought back to their former abundance in most locations, bivalve restoration has been shown to be possible at large-scale if the drivers of decline have been addressed. Restoring bivalve habitats can improve the health of estuaries, but restoration activities need to be supplemented with improved management practices, including in the surrounding catchments. Taking an estuary-wide approach to restoration, with bivalve habitat restoration complementing the restoration of other habitat types such as seagrasses, saltmarshes and mangroves is likely to yield both greater ecosystem benefits, and may result in positive feedbacks resulting in greater restoration success of complimentary habitats. Motivation for bivalve and other coastal habitat restoration has moved beyond simply restoring an imperilled ecosystem and its biodiversity, to restoring food security, local employment, green engineering, shoreline protection and nutrient trading. In the future it is likely that innovative engineering solutions will improve the success and value of bivalve habitat restoration. In addition to restoring natural bivalve habitats and the benefits that they bring to estuaries and the people who depend on them, novel solutions to improving estuary health and food security should be considered. There are likely to be benefits from using bivalve aquaculture as a tool for ecosystem modification (for example harnessing the filtering power of bivalves at high densities to improve local water quality) and creating green engineering solutions that include living elements such as bivalves to protect shorelines.

Reinventing the wheel: The use of the standards and recovery wheel for marine and coastal restoration projects

Adam Smith[1], Paul Marshall[1], Nathan Cook[1], Ian McLeod[2]

[1]**Reef Ecologic, Townsville, Queensland**

[2]**TropWATER, James Cook University, Queensland**

The National Standards for the Practice of Ecological Restoration in Australia (the 'Standards') aim to provide a blueprint for voluntary and regulatory organisations to encourage, measure and audit ecologically appropriate environmental repair in all land and water ecosystems of Australia.

There appears to be reasonable use of the Standards in terrestrial restoration. However, the uptake for marine restoration, and notably in the burgeoning sector of coral reef restoration, has been slower. This may be due to the more recent history of these sectors but is also likely to reflect differences in needs across these environments. We examined the utility of the SERA 'Recovery Wheel' for use in coral reef restoration projects, with a specific focus on its suitability for generating project-specific KPIs and including important socio-ecological indicators.

We suggest that the SERA Recovery Wheel provides an excellent structure for generating and applying standard approaches, but that some adaptation is required to optimize its utility and value to marine restoration projects. A key area for development relates to the benefits to human wellbeing that are often a core objective of coral reef restoration. We propose that to be useful as a framework for coral reef restoration, standards would need to include consideration of key social benefits such as aesthetics, satisfaction, stewardship and capacity building.

Additionally, there are a range of enabling conditions that must be considered and strategically addressed if the huge momentum building for coral reef restoration is to be channelled to effective and sustainable outcomes. These include legal and regulatory environment and issues such as social licence. We are at a critical juncture where the rapid expansion in reef restoration can learn from, and benefit from, the experiences in terrestrial restoration. However, we need to rapidly increase our effort to exchange knowledge, compare systems, adapt frameworks, test tools and implement case studies in an adaptive learning construct.

Coastal wetland fish nursery function in an agricultural dominated river catchment – 20 years of management investment

Nathan J. Waltham[1], C. Buelow[1], D. Burrows[1]

[1]**TropWATER (Centre for Tropical Water and Aquatic Ecosystem Research), Division of Tropical Environment and Societies, James Cook University, Queensland**

We are losing in the order of 95 km2 of global floodplain wetlands each year and this is not likely to slow with continuing urban and industrial expansion in many coastal locations. Because coastal wetlands provide essential habitat for so many aquatic species, managers are moving towards implementing large scale programs to repair and restore them.

A fish survey in ten lagoons along Sheep Station Creek, Burdekin floodplain was completed to examine whether 20yrs of water and aquatic weed management has contributed to habitat and biodiversity return for this investment.

Fish and water quality measurements were recorded in September 2017 and May 2018 from ten lagoons situated along Sheep Station Creek, nowadays a floodplain distributary channel delivering water to sugar cane growers on the lower Burdekin River floodplain. These lagoons are subject to ongoing weed management by the local shire Council, necessary in order to reduce flood mitigation, but also to ensure delivery of water through the channel to farmers. The lagoon fish community represents a subset of the wider assemblage across the floodplain. There was a seasonal difference in fish community, with fewer species and total numbers in the post wet season survey, possibly owing to upstream movement restrictions among lagoons following seasonal flow. Water temperature and dissolved oxygen concentrations were important determinants contributing to seasonal and among lagoon differences in species richness.

While water quality conditions in some lagoons were below acute effects thresholds, overall the return on management investment, including fish stocking, probably ensures these lagoons provide at least some level of aquatic habitat value for fish occurring more broadly across the floodplain. Stocked barramundi in this system probably contribute to regional recruitment success; however, limited connection probably prevents fish returning upstream, in addition to recruiting juveniles, to this network post flood period.

Freshwater wetland on the Burdekin floodplain, Northern Queensland

Panel Discussion: Crossing the divide between theoretical and applied: the value of science informing management

Moderated by Jemma Purandare, including all speakers, Susie Chapman and Mark Read

This presentation will consist of a panel discussion involving Susie Chapman from Healthy Land and Water, Mark Read, Nathan Waltham, Ian McLeod, Adam Smith, and Peter Harrison, moderated by Jemma Purandare. The panel will discuss the need to bridge the gap between research and management, and how theoretical science can be applied and scaled in the real world. The session will cover off the local context (south east Queensland) and the Great Barrier Reef as examples of where research has successfully been applied, such as the Sheep Station Creek Burdekin Management Project, and where applied research has included community and social context, such as the Pumicestone Passage Shellfish Habitat Restoration Project.

SYMPOSIUM: Expanding the Restoration Toolkit

Organiser and moderator: Luke Shoo[1], Valerie Hagger[1]

[1]The University of Queensland, Queensland

Session Description: A major challenge in restoration is how to design programs and projects to achieve as much as possible with limited resources. Challenges arise because stakeholders can have different preferences for outcomes and there is potentially an enormous array of possible management strategies, each with their own costs and risks. This session will bring forward new and emerging tools in restoration practice from planning to establishment to ongoing care and learning. New tools integrate conservation biology, functional ecology and restoration ecology and draw on principles and practices in finance, weather forecasting, conservation genetics, forestry and mathematics.

Introduction: Expanding the restoration toolkit

Luke Shoo[1]

[1]The University of Queensland, Queensland

Knowledge and practices in restoration are constantly evolving. Our main aim is to showcase new and emerging tools in restoration and share ideas. We have endeavoured to assemble a diverse mix of talks under a united theme which we believe will be of wide interest and spark discussion about what might be possible in the future of restoration.

Using traits to learn lessons from sub-optimal restoration outcomes

John Dwyer[1, 2], Ronald Gardiner, Luke Shoo[1]

[1]The University of Queensland, Queensland
[2]Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Restoration projects frequently achieve less than satisfactory outcomes due to poor performance of plants during the establishment period. Critical evaluation of factors that lead to sub-optimal outcomes is vital to improve practice but is often constrained by a lack of monitoring and reporting. We interrogated data describing environmental conditions and species characteristics that potentially contributed to poor survival and growth of > 7000 seedlings during the establishment of a rainforest restoration planting in southeast Queensland, Australia. We found that height of seedlings at the time of planting strongly influenced plant survival and growth. Intermediate heights generally performed best but the optimal height for individual species was mediated by functional traits. Environmental variables had weaker, though significant effects on growth and survival. High planting day temperatures reduced plant survival rates, especially when seedlings

were planted in high bulk density soils. Early growth of surviving seedlings was limited for those planted on hot days in high elevation areas. These results suggest remediating compacted soils prior to subtropical rainforest restoration, avoiding very hot planting periods and planting seedlings taller than 25 cm for most species.

Use of seasonal forecasting to manage weather risk in ecological restoration

Valerie Hagger[1], John Dwyer[1, 2], Luke Shoo[1], Kerrie Wilson[1]

[1]**The University of Queensland, Queensland**
[2]**Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia**

Ecological restoration has widely variable outcomes from successes to partial or complete failures and there are diverse perspectives on the factors that influence the likelihood of success. However, not much is known about how these factors are perceived, and whether people's perceptions match realities. We surveyed 307 people involved in the restoration of native vegetation across Australia to identify their perceptions on the factors influencing the success of restoration projects. We found that weather (particularly drought and flooding) has realised impacts on the success of restoration projects, but is not perceived to be an important risk when planning new projects. This highlights the need for better recognition and management of weather risk in restoration and a potential role of seasonal forecasting. We used restoration case studies across Australia to assess the ability of seasonal forecasts provided by the Predictive Ocean Atmosphere Model for Australia, version M24 (POAMA-2) to detect unfavourable weather with sufficient skill and lead time to be useful for restoration projects. We found that rainfall and temperature variables in POAMA-2 predicted 88% of the weather issues encountered in restoration case studies apart from strong winds and cyclones. Of those restoration case studies with predictable weather issues, POAMA-2 had the forecast skill to predict the dominant or first-encountered issue in 67% of cases. We explored the challenges associated with uptake of forecast products through consultation with restoration practitioners and developed a prototype forecast product using a local case study. Integrating seasonal forecasting into decision making through (a) identifying risk management strategies during restoration planning, (b) accessing the forecast a month prior to revegetation activities and (c) adapting decisions if extreme weather is forecasted, is expected to improve the establishment success of restoration.

Restore & Renew: Large scale evolutionary, environmental and ecological information in support of restoration practices

Maurizio Rossetto[1]

[1]**National Herbarium of New South Wales, New South Wales**

Restore & Renew is an initiative aimed at creating a comprehensive and easy

to use web-based tool supporting sustainable land restoration, and readily accessible to restoration stakeholders. Utilising genomic analyses and environmental modelling techniques, the project is uncovering an unparalleled level of information to understand how genetic diversity is partitioned across the landscape, and if genetic provenances are associated with climatic and environmental variables. The project is collecting, analysing and sharing genetic, adaptive, environmental, and ecological data for over 200 plant species commonly used in restoration projects across Australia's Eastern seaboard and representing the region's floristic, ecological and phylogenetic diversity. This community resource aims to improve the success and long-term viability of land restoration projects, as well as improve predictive capacity to respond to climate change. The genetic data is used to identify local neighbourhood boundaries, to reduce relatedness, and to maximise diversity within specific climate-based scenarios. Interpretations are backed by an increasing number of collaborative experimental trials testing, for example, relative genetic fitness and climate adaptation profiles. Beside supporting restoration practices, the project will also provide significant information from species to landscape levels, discover regions of high genetic diversity, identify commonalities among taxonomic and functional groups that will improve our ability to generalise beyond the 200 species, and enable us to explore how species and assemblages are likely to respond through time.

Smart allocation of restoration funds

Luke Shoo[1], Carla Catterall[2], Hawthorne Beyer[1], Paul Cockbain[3], Michael Duncan[3], Tim Robson[3], Darren Roche[3], Howard Taylor[3], Zoe White[3], Kerrie Wilson[1]

[1]**The University of Queensland, Queensland**

[2]**Griffith University, Queensland**

[3]**City of Gold Coast, Queensland**

The Smart Allocation of Restoration Funds project has developed a decision support tool to deliver a cost-effective 'roadmap' for investment in land restoration. In this project, restoration ecologists and decision scientists have partnered with natural area managers to make public expenditure on restoration more effective, efficient and transparent across approximately 800 conservation areas, covering over 12,000 hectares. We have reduced complex forest recovery to a series of time discrete and tractable steps. We also account for changing cost of restoration projects over time and time delays between starting projects and realising on-ground outcomes. This enables land managers to: (1) forecast outcomes of management strategies over long timeframes; (2) address the question of how long it will take and how much it will cost to achieve specific outcomes; and (3) reveal potential trade-offs in outcomes among alternative management strategies. The work is to guide future management decisions about where to undertake restoration work in an environment where there are competing priorities and it is not possible to do everything at once. Importantly, these methods can also be scaled up and are transferable to other regions.

Conservation orientated restoration – rescuing threatened plant species by restoring their environments and restoring environments using threatened plant species.

Sergei Volis[1]

[1]Kunming Institute of Botany, Chinese Academy of Sciences, Beijing, China

There is a need in conceptual integration of plant conservation biology and restoration ecology to cope with the rapid disappearance of species and ecosystems. On the one hand, habitat restoration is vital for the majority of threatened species. Because ecological restoration encompasses ecological processes involving abiotic factors and multispecies assemblages and emphasizes community structure, function, and resilience, this discipline can help to identify and restore the conditions under which the threatened species can maintain viable populations. On the other hand, although it may seem paradoxical, threatened plant species can be useful for restoration of partly degraded natural habitats. Introduction of multiple threatened species into a partially degraded site can serve two important goals: habitat/landscape restoration and increased chances of global survival for the threatened species. Therefore ecological restoration with conservation goals should incorporate threatened plant species into their designs and management plans, with the latter being introduced not only into locations where they currently grow or grew in the recent past, but also into suitable locations within their potential distribution range. This strategy can be especially applicable in the regions having many threatened species within particular environments, with both threatened species and the whole ecosystem requiring immediate actions. The usefulness of wide-scale usage of threatened species for solving conservation concerns, and the limits of applicability of this approach will be clear after testing this approach in comparison with the traditional species- and population-based in situ conservation approaches.

SYMPOSIUM: Seagrass Restoration Network: A New Community of Research and Practice

Organiser and moderator: Elizabeth Sinclair[1]

[1]The University of Western Australia, Western Australia

Session Description: The Seagrass Restoration Network (SRN) launched across Australia and New Zealand in July 2017 – to link scientists, industry practitioners, community groups and government policy makers for an up-to-date look at the development and implementation of conservation, recovery and restoration of seagrass meadows. This symposium will contain a series of talks on the latest restoration projects. It will showcase success stories and introduce new methods to tackle some of the global problems around restoration in a marine environment.

Introduction: Seagrass Restoration Network: a new SER community building confidence in seagrass restoration

John Statton[1]

[1]**The University of Western Australia, Western Australia**

The Seagrass Restoration Network (SRN) is a new SER community (with some old faces) with a mission to enable the sharing of knowledge and tools for seagrass conservation, recovery and restoration and foster an integrated long-term approach to developing restoration solutions. We aim to implement this through awareness of socio-ecological values of seagrass, marine conservation, and practical restoration methods. SRN's members strive to deliver an integrated scientific approach to research which includes: taxonomy, genetic connectivity, transplant and seed-based restoration solutions, community engagement, hydrodynamic modelling, metapopulation dynamics, seeds and seedbank viability, long term monitoring, catchment monitoring, carbon storage, and integrated recovery with other marine ecosystems. The SRN members deliver a range of restoration activities throughout Australia and New Zealand, and the presentations in this symposium will provide examples of integrated approaches with successful restoration outcomes. The overarching goal of SRN is connecting scientists, industry practitioners, community groups and government policy makers and is achieved by sharing up-to-date information on restoration progress, showcasing our innovative solutions to seagrass conservation and restoration, and building confidence that this is achievable at the appropriate scale and costs society demands.

Understanding the tropical seagrass seed story for improved seagrass restoration

Emma L. Jackson[1], Kristie Dillon[1], Amanda Dodds[1], Andrew D. Irving[1]

[1]**Department of Agriculture, Science and the Environment, School of Health, Medical and Applied Sciences, Central Queensland University, Queensland**

With general agreement that successful seagrass restoration is linked to scaling up of restoration areas, the use of seagrass seed offers a method to overcome impacts on donor meadows and logistical difficulties in the transplant of adult plants. However, successful germination of tropical seagrasses is recognized as a knowledge gap limiting Australian seagrass restoration. There are several factors which may impede germination process, such as storage technique after collection, sterilisation technique, viability of seeds after being stored for a long period of time, and the physiological ability of seeds to adapt to various environmental conditions. Focusing on the species Zostera muelleri in sub-tropical Queensland we report on the results of multiple experiments to investigate the influence of seed age and colour, sterilisation techniques and environmental factors influencing germination and early seedling survival. The results are discussed in the context of restoring of seagrass meadows in Central Queensland, and the practical pathways for enhancing, restoring and engineering seagrass meadows.

Spreading the seeds of change: Optimising community engagement efforts to improve seagrass restoration

L. Kajlich[1], A. Dowd[3], A.G.B. Poore[1, 2], S. Graham[4], J.W. Turnbull[2], E. Marzinelli[1, 2, 5], P.D. Steinberg[1, 2, 5], A. Vergés[1, 2]

[1]**Sydney Institute of Marine Science, Mosman, New South Wales**

[2]**Centre for Marine Bio-Innovation, School of Biological Earth and Environmental Sciences, The University of New South Wales, New South Wales**

[3]**Commonwealth Scientific and Research Industrial Organisation (CSIRO), Queensland**

[4]**School of Social Sciences, The University of New South Wales, New South Wales**

[5]**Singapore Centre for Environmental Life Sciences Engineering, Nanyang Technological University, Singapore**

The restoration of Posidonia australis meadows, an endangered seagrass community, is currently being planned for waterways in Port Stephens, NSW. To avoid exacerbating damage to existing Posidonia meadows, this project relies on active participation by the community, with locals being asked to collect seagrass shoots washed up after storm events for scientists to transplant. In addition, restoration also relies on the awareness and willingness of mooring owners to adopt Environmentally Friendly Moorings (EFMs), an innovative alternative solution to the scouring of seagrass beds from traditional block and chain moorings. "Operation Posidonia" is a science communication campaign that aims to increase knowledge and shift environmental attitudes to encourage proactive and collaborative behaviours related to seagrass conservation and EFM practices. Key to successfully delivering on this outcome is understanding the campaign's target audience. Given the campaign's limited resources, effective and efficient interactions are crucial. Our research will use a multi-dimensional social network approach to investigate how individual factors (e.g. environmental attitudes or readiness to embrace innovations), and social drivers (e.g. levels of social connectivity) influence the uptake of new knowledge and/ or shift environmental attitudes. To uncover potential drivers of change and to determine where in the network the shift originates, diffuses and is challenged, two key questions are posed: (1) How are individual factors and social drivers related to how individuals source and share information and attitudes? (2) To what extent does the degree of social connections constrain or promote the adoption of new information and innovations? Findings from previous studies applying the 'strength of weak ties' concept have found transformational change most often arises from members on the periphery of the network, those deemed the least connected, which challenges traditional engagement 'best practice' principles. The findings from this research will identify strategies to optimise effective community engagement in restoration efforts.

Tackling a global problem – developing seagrass restoration methods for boat mooring scars

E.A. Sinclair[1], T.M. Glasby[2], J. Statton[1], S. Powell[3, 4], L. Kajlich[3, 4], G. Ferretto[3, 4], G. Housefield[2], G.A. Kendrick[1], A.G.B. Poore[3, 4], A. Vergés[3, 4]

[1]**School of Biological Sciences and Oceans Institute, University of Western Australia, Western Australia**

[2]**Port Stephens Fisheries Institute, New South Wales Department of Primary Industries, New South Wales**

[3]**Sydney Institute of Marine Science, New South Wales**

[4]**Centre for Marine Bio-Innovation and Evolution & Ecology Research Centre, School of Biological, Earth and Environmental Sciences, University of New South Wales, New South Wales**

Seagrass meadows support diverse ecological communities and provide a range of essential ecosystem services to inshore coastal environments. They are, however, under threat worldwide due to a range of anthropogenic impacts including boating infrastructure. Traditional block-and-chain moorings are a major threat to Posidonia australis meadows in Australia as they directly remove seagrass shoots and rhizomes, causing the formation of unvegetated patches that fragment meadows and de-stabilise the sediment. In eastern Australia, P. australis meadows in the Manning-Hawkesbury ecoregion have been listed as endangered under the Federal EPBC Act (1999). Meadows are continuing to decline in some estuaries, despite this protection. Alternative mooring designs (Environmentally Friendly Moorings or EFMs) that do not damage sensitive seagrass meadows now exist and are slowly replacing block-and-chain moorings in some estuaries. The natural recolonization of these mooring scars by P. australis, however, is often slow, especially when mooring scars have expanded and local hydrodynamics and sediment porosity have been altered. Here, we provide a first look at recent innovations to restore P. australis to old mooring scars in Shoal Bay, Port Stephens. Initial trials were conducted in bare sand patches and patches where Zostera/Halophila seagrass had started to recolonise. Rhizome fragments with living shoots, which regularly wash-up along beaches following large storms were collected to avoid exacerbating damage to existing meadows. These rhizome fragments were grown in sediment in large outdoor tanks for up to five months prior to transplanting into mooring scars. Jute mats were used to help stabilise sediment and secure fragments on bare sand, while rhizomes were planted and anchored directly into recolonising patches. This solutions-focused approach aims to engage with local communities to develop effective restoration methods while raising awareness about the importance of seagrass meadows and the benefits of using EFMs.

Developing the steps required for the effective use of seed in seagrass restoration

John Statton[1], R.J. Orth[2], K.W. Dixon[3, 4], G.A. Kendrick[1]

[1]**University of Western Australia, Western Australia**

[2]**Virginia Institute of Marine Science, United States of America**

[3]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

[4]**Botanic Gardens and Parks Authority, Western Australia**

Restoration performance in degraded seagrass habitat has been under increasing scrutiny. Recent reviews suggest that the scale of seagrass cover, density, and diversity, globally, are not being re-instated to levels that approximate pre-disturbance conditions. To address these concerns in Western Australia, a global biodiversity hotspot for seagrasses, researchers at the University of Western Australia have been collaborating with leading national and international seed ecologists and local coastal industries and authorities for over 10 years to develop and mobilize seed-use practices. The core aspect of this research is focussed on developing the steps required for the effective use of seeds for restoration and identifying, on a species by species basis, bottlenecks during the restoration process. It is well known that more than 95% of seeds fail to establish, though bottlenecks typically occur during earlier life stages. For the majority of seagrass species found in Western Australia, there is limited understanding of seed biology or the nuances of the local abiotic and biotic environment in which to guide restoration approaches and improve restoration performance. In this presentation, key findings will be discussed using examples from two widespread species with contrasting life-histories; Posidonia australis and Halophila ovalis. Outcomes suggest that individual seed and seedling traits, as well as interactions with the local environment, influence restoration performance and the intervention approaches for each species. We conclude this talk with how we are working with local authorities, industry partners and communities to translate this seed management information into tangible on-ground changes in restoration practice.

Recruitment facilitation to rehabilitate lost Amphibolis antarctica in South Australia

Jason Tanner[1]

[1]**South Australian Research and Development Institute, South Australia**

Since 1949, ~6200 ha of seagrass has been lost off the Adelaide metropolitan coast in South Australia. Much of this loss has occurred in shallow waters, with the seagrass line receding seaward, and has been attributed to increased nutrient levels from waste water treatment plants, industrial development and urban runoff. With a concerted effort to reduce nutrient inputs, a seagrass rehabilitation program was commenced in 2002, initially trialling techniques used elsewhere, such as transplanting and planting seedlings. However, the relatively high wave energy along the Adelaide coastline

resulted in poor success. This high wave energy, as well as high levels of bioturbation, also limit natural recolonization.

The use of hessian sandbags has proven to be more promising, as well as relatively low cost, as it works with the life history of the local Amphibolis antarctica, which viviparously produces seedlings that have evolved to entangle in things such as exposed Posidonia root matte. The hessian sand bags provide a substitute for this root matte, which seedlings naturally attach to, and persists long enough for them to become established. Seedlings can attach to these bags in high numbers, sometimes exceeding 1000 m-2. However, medium-term results appeared disappointing, with stem densities rapidly declining to well below those in natural meadows. It was only after 5-7 years that stem densities again increased in many plots. As well as recovery of the seagrasses themselves, studies of the fauna have indicated that these have also returned to what is present in nearby natural meadows. While more labour intensive as seedlings need to be manually planted, the bags can also be used for Posidonia restoration. Initially, seedlings were planted in situ by divers, but recent trials indicate that 1 year survival is similar for seedlings planted into the bags and glued in place before deployment.

SYMPOSIUM: From Small- to Large-scale Marine Coastal Restoration

Organiser and moderator: **Phoebe Stewart-Sinclair**[1]

[1]**The University of Queensland, Queensland**

Session Description: More than 85% of Australians live coastally, resulting in many coasts and estuaries being modified. While initiatives for restoring coastal environments are plentiful, these programs rarely focus on ecosystem services provision at broader scales. Scaling-up marine restoration will have important ecological and socio-economical outcomes. We explore: Over which scales is marine restoration currently occurring? How can we scale-up? And, what is the role of marine restoration in a changing climate?

Introduction

Phoebe Stewart-Sinclair[1]

[1]**The University of Queensland, Queensland**

More than 85% of Australians live coastally resulting in many coasts and estuaries being modified. While initiatives for restoring coastal environments are plentiful, these programs rarely focus on ecosystem services provision at broader scales. Scaling up marine restoration will have important ecological and socio-economical outcomes. This session explores: Over which spatial scales is marine coastal restoration currently occurring? Which environments have had the greatest success at scale, and what can we learn from them? Are larger restoration projects more or less successful than smaller efforts? Is the scale of coastal restoration different depending on the economic status of the country? Are there economies of scale? Does restoration become cheaper per unit area restored as we scale up? If not, why? And, what is the role of marine restoration in a changing climate? Can climate change mitigation offer a new motivation for proactive coastal restoration?

Marine coastal restoration of the last 45 years – objectives, successes, costs and scales

Elisa Bayraktarov[1], Shantala Brisbane[1], Phoebe Stewart-Sinclair[1], Valerie Hagger[1], Chris Gillies[2], Hugh Possingham[1,2], Kerrie Wilson[1]

[1]**The University of Queensland, Queensland**

[2]**The Nature Conservancy, Australia**

Land-use change in the coastal zone has led to worldwide degradation of marine coastal ecosystems. Restoration may assist the recovery of an ecosystem that has been degraded, damaged, or destroyed. Uncertainties about restoration cost and feasibility can impede decisions on whether, what, how, where, and how much to restore. Here, I present a synthesis of 276 studies with 1098 observations from restoration projects of coral reefs, seagrass, mangroves, saltmarshes and oyster reefs worldwide, and evaluate cost, survival of restored organisms, project duration, area, and techniques applied. Beyond cost and feasibility, I also outline the proportion of published marine restoration studies that had clearly defined objectives for restoration, measurable metrics of success and whether these were aligned with the restoration outcome. Findings from published literature until 2018 showed that the median reported cost for restoration of one hectare of marine coastal habitat were around 53,000 US$ (2010). Coral reefs and seagrass were the most expensive to restore while mangrove projects were the largest and the least expensive. Survival was highest for saltmarshes (64%) and coral reefs (60%) and lowest for oyster reefs (27%). However, success rates reported could be biased towards publishing successes rather than failures. The majority of restoration projects were short-lived (1-2 years) and seldom reported monitoring costs. Except for mangroves, marine coastal restoration has been reported for small experimental scales of < 1 ha. The main objectives for restoration documented in the literature were to answer ecological questions or to improve restoration techniques. Survivorship, growth and productivity were the main characteristics used to monitor restoration success. Success depended primarily on the ecosystem, site selection, and techniques applied rather than on money spent. I conclude by identifying the needs to transition from small-scale to ecologically, socially and economically meaningful large-scale restoration.

How to restore a coral reef: When bigger is better

Sarah Frias-Torres[1]

[1]**Nature Seychelles, Republic of Seychelles**

[2]**Smithsonian Marine Station, Fort Pierce, Florida, United States of America**

[3]**Vulcan Inc, Seattle, Washington, United States of America**

Coral reef restoration is still criticized for not producing tangible results. But the restoration signal is often obscured by confounding factors such as a restoration effort too small to generate a response, local stressors in the restored area, or a

monitoring period too short to quantify recovery of ecosystem function. Here I present a large-scale coral reef restoration project I led at the Cousin Island Special Reserve in Seychelles, Indian Ocean, to recover coral loss due to the 1998 El Nino-Indian Ocean Dipole and 2004 Indian Ocean tsunami. Using "coral gardening", first, we harvested thumb-sized fragments from donor colonies (survivors of previous bleaching and corals of opportunity) and reared them in mid-water ocean nurseries for 1 year. Second, we outplanted the nursery corals (10-20 cm wide) to a degraded reef site. We scaled-up experimental-sized restoration techniques. We developed time-saving "cleaning stations", so fish conditioned corals prior to outplanting. Animal-assisted cleaning at nurseries reduced diving person-hours 2.75 times. A total of 24,431 corals of 10 branching and tabular species were outplanted to 0.52 ha of degraded reef from December 2012 to April 2014. Coral cover increased 300% by the end of the project. Fish species richness increased five-fold, fish density increased three-fold, and coral settlement and recruitment increased two-fold at the restored site when compared with the control sites (degraded and healthy). During the 2014-2016 El Nino, the restored reef had lower coral bleaching mortality than the control sites. The use of survivors of previous bleaching events as donor colonies, cementing nursery corals on natural substrate, size at outplanting, high outplanting density (4-8 corals/m2) and a species composition similar to the control healthy site were critical for success. These results support the application of large-scale, science-based coral reef restoration projects with long time scales to assist the recovery of damaged reefs.

From small to large to largest: The Nature Conservancy's approach to scaling marine restoration

Chris Gillies[1]

[1]**The Nature Conservancy Australia**

Here we reveal the magic formula for delivering large-scale marine habitat restoration...or would do, if there was one. Instead, we focus on distilling a few lessons learnt from undertaking 20 years of marine habitat restoration across different geographies and communities. We highlight three principles that typically differ from terrestrial ecosystems and which typically underpin The Nature Conservancy's approach to marine restoration:

1) Be entrepreneurial: Far fewer people will ever touch or see the focus ecosystem, understand the intricate web of decline or positive impact of restoration. Marine projects therefore need to state the case for restoration in an entrepreneurial manner, where the ecosystem is more thoroughly described and visualised and the tangible benefits of restoration (in the absence of charismatic megafauna and easy access) can be clearly articulated to governments, funders and the community.

2) Make friends (and lots of them): Partnerships are critical for working in the marine environment where the 'land' is no one's but everyone's. Single organisation initiatives rarely succeed at reaching scale but multi-partner projects can be difficult and time consuming to manage.

3) Patience is a virtue: Marine restoration is a relatively new initiative in the psyche of many groups despite its growing prominence. Understanding how best to work with stakeholders to more efficiently undertake project planning, regulation and reporting can reduce (but not eliminate!) the level of 'red tape' associated with

undertaking habitat restoration in the marine environment.

How these philosophies manifest in real life to help establish successful marine restoration projects will be discussed with examples during this presentation and the associated session: From small- to large-scale marine coastal restoration.

Social and ecological challenges and new directions in seagrass restoration

Gary Kendricks[1], **John Statton**[2]

[1]**Oceans Institute, University of Western Australia, Western Australia**

[2]**School of Biological Sciences and Oceans Institute, University of Western Australia, Western Australia**

Seagrass ecosystems provide numerous valued services to society but are also threatened by population growth and industrial developments in coastal waters, globally. These ecosystems are experiencing rapid ecological degradation with losses being reported at 5-7% of global seagrass distribution, annually. There is a need for broad spatial scale, cost-effective restoration approaches capable of promoting the recovery of coastal ecosystems and to revive valuable ecosystem services. Presently seagrass restoration is predominantly funded through environmental offsets and charges associated with industrial and coastal developments and resource extraction, with the spatial extent being limited to the footprint of the expected loss associated with the activity. This presentation will explore the present status and trends both in seagrass loss and restoration efforts globally and within Australia. It will then address an alternative social-ecological and community-based strategy for future efforts in seagrass restoration. The next steps steps include building a sustainable green economy around coastal and marine restoration, potentially focussing on fisheries enhancement, green eco-engineering coastlines and blue carbon markets. This would require a translation step from science experiments into scaling restoration to restore 10s km2 - 1000km2 in situ, including the development of flexible and integrative restoration tools and techniques. Importantly, the ecological and social management objectives need also to be integrated across policy, management and community awareness and involvement. This would also require fostering a change in attitude from restoration being a cost to coastal development to community acceptance and passion for seagrass restoration, underpinned by an acceptance it is a scientifically-credible management approach.

Restoration of coastal ecosystems and blue carbon

Cath Lovelock[1]

[1]**The University of Queensland, Queensland**

"Blue Carbon" describes the greenhouse gas (GHG) mitigation potential of coastal wetlands which underpins emerging strategies for their conservation and restoration. Although restoration of coastal wetlands provides a wide range of ecosystem

services, Blue carbon can provide additional incentives which can be important to the uptake, financing and success of coastal wetland restoration projects. Using case studies from a range of countries I illustrate the range of existing projects which have been mostly small scale mangrove projects, as well as potential larger scale Blue Carbon coastal wetland restoration projects. I focus on 1) best practice in how Blue Carbon restoration projects have been developed, 2) the available methods which can be used to estimate and measure the GHG benefits of coastal wetland restoration projects; and 3) some of the limitations to scaling up Blue Carbon projects. Blue Carbon offers optimistic new pathways for incentivising coastal wetland restoration in order to mitigate and adapt to climate change, but continuing work across science, economics and policy are needed to bring large projects to scale.

SYMPOSIUM: Trait-based Ecological Engineering – Are Plant Traits a Useful Indicator of Restoration Targets?

Organiser and moderator: **Jarrah Wills**[1] **and Jennifer Firn**[2]

[1]**Department of Environment and Science, The University of Queensland, Queensland**

[2]**Queensland University of Technology, Queensland**

Session Description: The greatest challenge of restoration ecology is to restore healthy and functioning ecosystems. To track a restoration effort over time and evaluate its effectiveness, it is vital to know which mechanisms govern compositional and functional changes during the process. Ecosystem dynamics are thought to be reflected in functional trait composition; thus, the application of trait-based ecological theories and models may be useful in supporting practical restoration. It is crucial to test the explanatory power of plant traits during restoration interventions, and it is also necessary for the development of predictive and general plant trait models. Despite considerable research on plant functional traits and their usefulness for understanding community and ecosystem dynamics, it remains a challenge to restore functional ecosystems promoting biodiversity and the ecosystem services they provide. This session will evaluate existing evidence of the utility of trait-based ecology for restoration efforts and whether plant functional traits should be considered the 'holy-grail'.

Introduction: Theoretical understanding of global patterns plant traits

Angela Moles[1]

[1]**The University of New South Wales, New South Wales**

Plant traits give ecologists quantifiable indicators of a range of vital biological processes that affect ecosystem dynamics and function. They can therefore give insights in to the effectiveness of restoration efforts, and can help inform species' selection for planting efforts. However, the global trait literature is immense and accumulating rapidly, so it is a nightmare to keep up with. I will therefore begin by reviewing

important changes in our understanding of trait biology in recent decades. For example, I will explain why the seed-size /number trade-off idea has to be abandoned, show evidence that large-seeded species have greater seed dispersal distances than do small-seeded species, explain why small plants are more important than you thought, and argue that SLA is not strongly or consistently related to plant traits outside the leaf economics spectrum, or to broad gradients in environmental conditions. I will discuss how our theoretical understanding of plant traits can be applied to invasion biology and restoration, including commenting on why Baker's traits of the "ideal weed" have been so elusive, and how I think we can better use trait biology to predict the types of species that will succeed under changed conditions. I hope that my seminar will include results that surprise you, and perhaps even make you look at plant traits in a new light.

Seed size: crucial in the dynamics and practice of tropical forest restoration?

Carla Catterall[1]

[1]Griffith University, Queensland

Restoration of diverse native vegetation to land previously used for pasture or crop production depends on processes that govern plant regeneration. Irrespective of the restoration pathway (from spontaneous regeneration to resource-intensive planting), increased community similarity to indigenous vegetation will only develop over time if native plants and animals disperse into the site, and successfully establish. For plants, seed size is easily quantified, increasingly available from web sources, and its interspecific variability is associated with ecological characteristics that determine regeneration capacity. For example, plants with larger seeds can be advantaged as seedlings (e.g., higher germination, survival and shade tolerance, and more able to compete with pasture grasses). However larger-seeded species are often poorer colonisers of new sites because they produce smaller or less frequent crops, whose seeds are poorly dispersed. Using a combination of published information and selected case studies I here consider the importance of seed size to processes of rainforest restoration and regeneration on land retired from agricultural use.

The seeds of rainforest tree and shrub species vary greatly – for example, within Australian rainforests, their diameters range from under one millimetre to several centimetres. Additionally, some 80-90% are enclosed by fleshy fruits and depend on frugivorous birds and mammals for dispersal. Worldwide, an association between seed size and woody species' roles following rainforest disturbance has been noted (although less often quantified). Many pioneer species produce large crops of small seeds that are widely dispersed by generalist frugivores, producing fast-growing but shade-intolerant seedlings. Later-successional species (which dominate mature forests) often have large seeds with seedlings that tolerate shade (but grow slowly), dispersed mainly by larger-bodied, forest specialist, frugivores. Larger-seeded species are slow to colonise regenerating vegetation, and they are under-represented in replanted sites. The resulting constraints and opportunities for restoration practice will be discussed.

Leaf nutrients, not specific leaf area, are consistent functional indicators of short-term environmental change in grasslands

Jennifer Firn[1]

[1]**Queensland University of Technology, Queensland**

Theory predicts that leaf traits such as specific leaf area (SLA, a composite measure of leaf area per unit mass) and leaf nutrient contents provide a 'common currency' for understanding how anthropogenic pressures such as eutrophication and reduced herbivory impact overall functioning in ecosystems such as grasslands. Here, we show for the first time in a global experimental network comprised of 27 grassland sites across four countries that one of the most commonly measured leaf traits, SLA, does not increase significantly in response to fertilizer and herbivore exclusion treatments as theory predicts. Leaf nitrogen, phosphorus and potassium contents did increase in response to soil nutrient addition, but contrary to expectations, we found few significant increases when vertebrate consumers were excluded. We also found significant context dependency in how leaf traits changed depending on species turnover over time in response to treatments and climatic and soil nutrient conditions. We revealed generalizable local response syndromes (explained by combinations of intraspecific and interspecific trait variation) where plants change physiologically without necessarily investing differently in leaf area and leaf tissue content, suggesting that leaf traits such as SLA may not be appropriate indicators of adaptation to short-term perturbations.

Plant ecological strategies and restoration: how functional traits shape community assembly, structure and diversity

Robert Kooyman[1]

[1]**Macquarie University, New South Wales**

Trait expression in rainforest tree assemblages reflects species lifestyles and competence in the rainforest habitat, while biogeographic history delimits the species pool. Some of the traits and factors that influence rainforest assembly include seed size and dispersal, maximum height at maturity and position in the canopy, leaf longevity - leaf economics and shade tolerance, and wood density reflecting growth and persistence.

As part of the explanation for the maintenance of high diversity in rainforest, competition and competitive effects have been suggested as operating more strongly among phylogenetically related species with more similar traits. However, recent work suggests that stronger competitors are also more tolerant of competition. Something that could promote coexistence and result in a higher abundance of more closely related taxa with similar traits, but still allow for trait-mediated niche partitioning during vegetation development.

Australian tropical and sub-tropical rainforest assemblages are drawn from species with origins in Sunda (Indo-Malesia) and Sahul (Austral-Gondwana). Paleo-ecological research suggests many Gondwanan rainforest lineages have strong fidelity to environmental conditions (e.g., cool, moist refugia) and are slow to adapt (i.e., functional conservatism). In contrast, the movement of some Sunda taxa into Australia aligned with the expansion-contraction dynamics of rainforest habitats, reflected seed size (small) and dispersal capacity, and was limited (in places) by the persistence of Sahul lineages in moist refugia.

In Austral-Asia, different evolutionary origins and bio-geographic histories (Sunda v Sahul) interact with current day (functional) trait variation to influence rainforest assembly processes, and shape genetic structure and diversity across landscapes.

Understanding species ecological strategies and traits can provide critical insights into community assembly processes, including how 1) after disturbance, vegetation development follows height-structured competition for light, 2) diversity is structured relative to trait-mediated niche-partitioning and abundance, and 3) biogeographic history can shape genetic diversity and the pool of available species.

Trait-based species assemblages for ecological restoration in a changing world

Daniel Laughlin[1]

[1]University of Wyoming, Wyoming, United States of America

Restoration ecologists innately desire to restore what has been lost, so our first instinct is to use historical reference conditions as empirical benchmarks for restoration success. However, historical reference conditions in many regions are undefinable, and are increasingly viewed as irrelevant under climate change. Why were species dominant historically? Because they exhibited traits that conferred high fitness in those environments. As the environment changes, optimal traits will shift. We need a new framework for setting targets to meet desired functional outcomes in ecological restoration in a rapidly changing world.

We have developed a modelling tool that can be used to generate species assemblages based on any desired trait profile in the community. While current trait-based models have been limited to algorithms that select species assemblages that only converge on specified average trait values, these cannot accommodate the common desire among restoration ecologists to generate functionally diverse assemblages. We have solved this problem by applying a nonlinear optimization algorithm to solve for the species relative abundances that maximize Rao's quadratic entropy (Q) subject to other linear constraints. Rao's Q is a closed-form algebraic expression of functional diversity that is maximized when the most abundant species are functionally dissimilar.

The selectSpecies R function can derive assemblages for any size species pool that maximizes the diversity of any set of traits, while simultaneously converging on average values of any other set of traits. The quantitative selection of species based on their functional traits for ecological restoration and experimentation must be both rigorous and accessible to practitioners. The selectSpecies function provides

ecologists with an easy-to-use open-source solution to objectively derive species assemblages based on their functional traits. Historical conditions work in some cases, but global problems require a global solution. Trait-based models offer an alternative solution for setting theory-based restoration objectives.

Do leaf traits reflect ecosystem processes useful for tropical reforestation?

Jarrah Wills[1]

[1]**Department of Environment and Science, The University of Queensland; Queensland**

Plant functional leaf traits (such as leaf nutrient content and specific leaf area) are used to elucidate insights into ecological processes that are suggested to be able to guide on-ground reforestation in forests as complex as tropical forests. However, the relationships between leaf traits and ecological processes such as growth rates or competition are complex and are often co-correlated with other variables specific to the environment in which the plant is growing. In this talk I will discuss how leaf traits reflect growth rates within tropical forest of Northern Queensland (NQ) and how leaf traits reflect community assembly processes in communities growing beneath different reforestation types within the Philippines. I will also discuss how species mean leaf trait values may not be meaningful in tropical forests due to the variation in individuals and within -individuals that comprised the mean species value.

We find that leaf traits reveal little about growth rates in canopy trees, and that this relationship becomes stronger and adheres more to theoretical predictions for trees occurring within the shaded sub-canopy. This indicates that species mean leaf trait values obtained from individuals occurring across different forest strata may not be useful in guiding reforestation projects. In the recruitment pools beneath different reforestation methods within the Philippines, mean leaf trait values could not be differentiated from random assembly processes. In this study we found that within species variation in specific leaf area was more ecologically meaningful. Species that had both high and low intra-specific variation were found to be co-occurring within the more diverse forests, providing more ecological insights.

Given these two case studies the size-dependency of leaf traits, the light environment in which the plant is growing and the variation in both within species and within individuals need to be more carefully considered if leaf traits are going to have on-ground reforestation applications within tropical forests.

Using the National Standard's Recovery Wheel at your site: a participatory workshop

Tein McDonald[1], Paul Gibson-Roy[2], Jen Ford[3] and Damien Cook[4]

[1]**Board member, Society for Ecological Restoration Australasia, New South Wales**

[2]**Chief Restoration Ecologist, Greening Australia, New South Wales**

[3]**Principal Restoration Ecologist, Ecosure, Queensland**

[4]**Senior Ecologist - Rakali Ecological Consulting, Victoria**

The 'recovery wheel' from Australia's National Restoration Standards can readily convey to stakeholders how a restoration site is progressing. This interactive/open session will commence with a brief introduction to using the recovery wheel, illustrated by case studies. Participants keen to share their own examples are encouraged to send a short summary of the project's 'before and after' condition to **tein.mcdonald@seraustralasia.com** by August 31st but delegates will also have a chance to fill in a wheel for their own site during the workshop. Worksheets will be provided but please also consider bringing your smartphone with the recovery wheel loaded on it
http://www.seraustralasia.com/standards/appendix5.html

Issues in monitoring restoration workshop: Novel techniques and applications for restoration monitoring

Paul Nevill[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

This workshop follows the symposia and open sessions on restoration monitoring.

In this workshop we aim to identify knowledge gaps and practical barriers that need action by researchers, policymakers, and practitioners to improve monitoring of restoration.

The theory and practice of distribution modelling for conservation and ecological restoration

Sean Tomlinson[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

Increasingly spatial modelling is becoming a part of how long-term conservation activity is planned and undertaken. This has partly been encouraged by the emergence of simple, freely available software packages that are capable of executing these analyses, and partly by the emergence of large, freely-available data sets that inform these analyses. Species distribution projections are now used to suggest all kinds of complicated conservation actions, from reintroduction and assisted colonisation programs, through ecological restoration programs. The fact that these analyses are increasingly simple, and produce very convincing outcomes is worrying, because often there is very little consideration devoted to the meaning of the associations between the model projections and what mechanisms might be limiting the distributions of the species in question. It is only by understanding what these interactions between the organism and the environment might entail that we can tailor really useful conservation actions on the basis of distribution projections. Misunderstanding these relationships, or misrepresentation of them in poor quality models can lead to conservation and restoration failure, or worse, to a perennial management encumbrance causing more harm than benefit. This workshop is designed to cover the basics on different approaches to spatial modelling, with simple interactive exercises demonstrating some of the more common mistakes encountered. It also finishes up with a review of some of my recent developments in species distribution modelling of short range endemic flora, with suggestions for a standardised technique for the guidance of translocation and restoration of such species in Australia.

Thirty years of ecological restoration of mining-degraded areas in New Caledonia: synthesis and production of success indicator

Hamid Amir[1], Bruno Fogliani[2], Gilles Durrieu[1], Simon Gensous[1], Danielle Saintpierre[4], Alexandre Lagrange[4]

[1]**ISEA, Université de la Nouvelle-Calédonie, New Caledonia-**

[2]**ARBOREAL, Institut Agronomique néo-Calédonien,New Caledonia**

[3]**SIRAS Pacifique Company, New Caledonia**

[4]**Bota Environnement Company, New Caledonia**

Within the framework of the "CNRT RECOSYNTH" project, the analysis and synthesis of 30 years of ecological restoration of mining-degraded areas in New Caledonia have been achieved. Among 381 restored zones, 35 have been selected as representative of the diversity in terms of geographical and climatic features, substrates and technical practices.

The 35 areas involved a total of 67 modalities corresponding to distinct treatments. Characteristics of these modalities and details of the plant species, the technics and treatments used have been obtained from mining companies; then a current statement of the areas and their vegetation has been assessed, taking into account the biomass productivity, the plant species diversity and the dynamic of the created ecosystems. All these data were stored in a data base. Here we develop the synthesis part of the project.

A Hierarchical Clustering of the restored areas led to 3 distinct clusters having distinctive features. The Factor Analysis of Mixed Data followed by a modelling approach provided the following conclusions:

- The study of the 3 clusters, using the 12 most determinant variables, indicated that the sum of the projections of these variables on the PCA first component correspond to the best expression of the restoration success.
- About 20% of the restored areas showed a good evolution towards a maquis similar to the ecosystem present before mine exploitation, but need at least 20 years to reach it. About 45% to 50% will need more time to reach this state; the other areas will probably need a new enrichment to evolve correctly.
- A ranking of the restored areas in terms of success was obtained in each of the three clusters.
- A global indicator of the restoration success with a simple way of use for practitioners was then proposed.

Model for Integrated Peatland Restoration in Indonesia: a study from Utar Serapat

Grahame Applegate[1], Timothy Jessup[2], Blair Freeman[3], Alue Dohong[4], Marcel Silvius[3], Zukifli Lubis[5], Julia Fideles[3]

[1]**University of the Sunshine Coast, Queensland**

[2]**Global Green Growth Institute, Indonesia**

[3]**Indufor - Australia**

[4]**Indonesia Peatland Restoration Agency, Indonesia**

[5]**University of North Sumatra, Indonesia**

Indonesia contains over 45% of the world's tropical peatland. These areas are "domes" of woody peat, formed between major rivers, which support peat swamp forests found mainly in the lowlands on the islands of Borneo, Sumatra and Papua. Large areas of peatland have been subjected to deforestation and drainage, contributing directly to peatland and peat fires, which in 2015 caused USD 16 bn damage and burnt 2.6 m ha.

The Indonesian government has now prioritised the protection, restoration and sustainable utilization of peatlands to reduce the noxious smoke and haze. Based on previous experience in Central Kalimantan and Sumatra, the Government of Indonesia through the Peatland Restoration Agency (BRG) and other partners are supporting an integrated landscape model for peatland restoration and enterprise development; recognizing that approaches based on full protection or full cultivation on peat have generally failed to address environmental requirements and local communities' needs. An integrated peatland management approach aims to reduce environmental impacts on the peat and includes economic models intended to strengthen the existing local livelihood and sociocultural aspects of smallholders. The model secures the conservation of the middle of the peat dome which is where the peat is deepest. The next outer part of the dome is a buffer zone which is shallow peat, suitable for limited economic activities and private investment; outside this, the surrounding mineral soils can be used to support protection and restoration of the dome.

Utar Serapat is a peat hydrological unit covering an area of 100,000 ha, extending across the border between Central and South Kalimantan. Based on the data currently available, restoring this peatland could reduce greenhouse gas (GHG) emissions by over 600,000 tCO2e per year. This paper provides details of the integrated landscape restoration model designed to improve livelihoods and business opportunities.

Rehabilitating Roe 8: A standard approach to a not so standard restoration project

Tom Atkinson[1], Rachel Omodei[1], Joseph Sollis[2]

[1]**Emerge Associates, Australia**

[2]**Creating Communities, Australia**

Addressing the social aspects of restoration projects can demand at least as much attention as getting the ecological aspects right, especially in cases that have attracted significant public interest. In high profile situations it makes sense to adhere to agreed standards of practice that may best meet community and stakeholder expectations. This paper reports on the experience of an environmental and community engagement consultant team who assisted in the preparation of a restoration plan associated with the controversial 'Roe 8' highway extension in Western Australia. Some 18 hectares of bushland were cleared along the proposed alignment of Roe 8 before construction on the project was suspended in April 2017. This clearing was (and still is) a source of significant concern for many Western Australians and interested community and stakeholders have since urged management authorities to ensure that the cleared areas are fully restored. In addition to addressing 'ecological' impacts, the restoration plan for Roe 8 was required to attend to the 'social' impacts of clearing, such that both the bushland and the community may be 'rehabilitated'. Close attention was paid during the plan's preparation to the National Standards for the Practice of Ecological Restoration in Australia, as a source of agreed, principles and approaches. The Standards provided a systematic yet flexible framework through which clear goals and objectives were defined over a ten-year implementation period, in a process involving extensive community and stakeholder consultation. The resulting restoration plan combines social orientated activities ('communications, engagement and involvement') with activities that are more typically linked to ecological restoration ('management' and 'monitoring, evaluation and reporting'). 'Rehabilitating Roe 8' is therefore not a standard restoration project and provides a unique, recent example of the benefits of applying the Standards to restoration planning and management in a complex social and ecological context.

Some results of research on the quality of native plant seeds collected from an arid zone of Mongolia

Altantsetseg Balt[1], Erdenetsetseg Batdelger[2], Boldgiv Bazartseren[2], Undrakhbold Sainbileg[2]

[1]**Oyu Tolgoi LLC, Mongolia**

[2]**National University of Mongolia, Mongolia**

The southern part with the desert biome of Mongolia is home to animal and plant communities with unique characteristics that have evolved over millennia to the Gobi's specific natural and climatic conditions. With rapid development of

mining activities in the Gobi region during the last two decades, the use of native plant seeds for rehabilitation purposes in the region is considered to be a foundation for effective, sustained ecosystem restoration. In this research, we tested for the quality of seeds from five species, which were collected between 2010 and 2015 by growing in vitro. They were Anabasis brevifolia, Reamuria soongorica, Salsola passerina, Zygophyllum xanthoxylon and Eurota ceratiodes, which dominantly grow in the desert region. Temperature, lighting and the year of seed collection had statistically significant effects on seed germination rates. The duration of lighting had a tendency to influence negatively seed germination rate; especially for A. brevifolia, which showed a statistically significant negative correlation with the duration of lighting. R. soongorica exhibited a positive correlation with temperature. Correlation between seed germination rate and the storage period showed a negative correlation for all species studies, except A. brevifolia, which showed no relationship. The results of this study provide guidance for planning rehabilitation or restoration projects in the desert and desert-steppe habitat. Most critical is the importance of using seeds of native plants within a short period of time following seed collection. If the seeds need to be stored for a prolonged period, appropriate storage facilities are required to control temperature and light exposure to maximize germination rate. It also suggests that large scale rehabilitation projects, such as those that are commonly undertaken by mining projects, will require operations to breed fresh seeds for successful rehabilitation.

RegenTV - a new way to share stories about restoration

Virginia Bear[1], Louise Brodie[2], Suzanne Pritchard[3]

[1]**Little Gecko Media, Australia**

[2]**Australian Association of Bush Regenerators, Australia**

[3]**Springboard Science, Australia**

If there is no video, did it ever happen? For many years AABR (Australian Association of Bush Regenerators) has been sharing knowledge about ecological restoration through seminars, field days, newsletters, and other events. But no matter how popular or well-organised our offerings, their value was always limited because only a limited number of the potential audience could attend these events. Video is increasingly people's first port of call for learning and connecting, but ecological restoration videos are scarce. Our breakthrough to help fill this gap came in 2016 when we obtained three-year NSW Environmental Trust Education grant to establish a video platform on an open-access website. RegenTV was born, with the aim of providing videos of restoration case studies and virtual field trips to increase the understanding of and capacity for best practice ecological restoration. We have produced and uploaded 39 videos so far, as well as educational support materials (including work sheets and fact sheets) that link RegenTV case studies with the National Restoration Standards. We aim to provide resources for ongoing professional development and introductory training, as well as to generally spread inspiration about some of the many amazing restoration projects that deserve to be more widely known. This presentation will provide an overview of RegenTV, how it was developed, the production process and results of our user monitoring. As our three-year establishment phase draws to a close we will reflect on what we have learned, and share our plans for next stage.

Connecting restoration science, policy and industry: Lessons from the WA Biodiversity Science Institute

Guy Boggs[1]

[1]**WA Biodiversity Science Institute, Western Australia**

The Western Australian Biodiversity Science Institute (WABSI) has been established to shape strategic priorities in biodiversity knowledge, to deliver excellence in biodiversity research and ensure that biodiversity information is accessible to stakeholders. WABSI brings together Western Australia's leading capability in biodiversity science through a joint venture partnership that includes CSIRO, UWA, Curtin University, ECU, Murdoch, Dept of Biodiversity Conservation and Attractions and the WA Museum together with the Department of Water and Environmental Regulation, Department of Mines, Industry Regulation and Safety and Department of Primary Industries and Regional Development.

The ability to restore ecosystems is fundamental to Western Australia's ability to support biodiversity while enabling sustainable development. Over the past two years, WABSI has been working closely with researchers and end users from government, industry and the NGO community to identify research priorities and enable improved connectivity between research and end users decision making to support continual improvement in ecological restoration and achieve at-scale activity.

Here, I will present an overview of key initiatives that WABSI has been involved in and the emerging lessons and priorities from this work. The presentation will draw on work undertaken in the urban, agricultural and mining sectors, highlighting critical knowledge gaps that have been identified, the research initiatives being developed to address these and the emerging understanding of key drivers and barriers to achieving the goals of ecological restoration across these domains in Western Australia.

A diagnosis of institutional readiness to implement mangrove forest landscape restoration in Indonesia

Benjamin Brown[1]

[1]**Charles Darwin University, Northern Territory**

Two critically degraded mangrove landscapes in Indonesia were assessed for mangrove forest landscape restoration opportunity in collaboration with national and sub-national stakeholders. Subsequent to the development of restoration opportunity maps and a cost-benefit analysis, a diagnostic of institutional readiness was performed. Stakeholders from both landscapes felt that motivating, enabling and implementation factors to undertake mangrove forest landscape restoration were largely in place, yet noted several key biophysical, economic and social bottlenecks. Amongst the most glaring barriers were lack of experience with large-scale hydrological restoration, lack of stakeholder and political will to resolve land-use conflicts, and lack of feasible

livelihood alternatives to offset opportunity costs of restoration to fish farmers in both regions. Policy analysis was performed using a management-in-transition framework in order to further explore bottlenecks and opportunities specific to four mangrove restoration management regimes. This paper concludes with a decision-making framework to assist practitioners, managers and policy makers in reforming national mangrove restoration strategic plans, policies and practices.

Restoring coastal wetland water quality: ecosystem service provisioning by a native freshwater bivalve

Christina Buelow[1], Nathan Waltham[1]

[1]**Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University, Queensland**

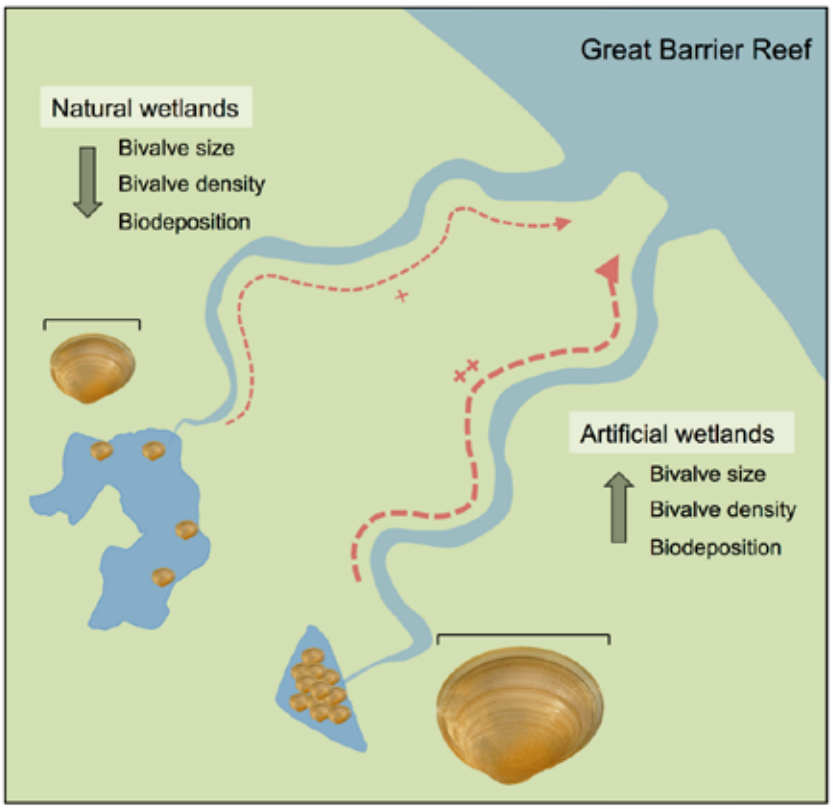
Restoring coastal wetlands for the objective of water quality improvement may help alleviate broader degradation of the Great Barrier Reef (GBR) ecosystem. Native freshwater bivalves (Corbicula australis) are abundant in coastal wetlands of GBR catchments and are likely to play an important role in nutrient cycling through water filtration and nutrient biodeposition. We investigated the ability of freshwater bivalves to provide an ecosystem service benefit of improved water quality to the GBR through nutrient cycling processes.

The filtration and biodeposition rates of C. australis were measured in natural and artificial wetlands across 1) the population's size range and 2) the temperature range of the wetlands they inhabit. High frequency water temperature loggers were deployed in wetlands throughout the year, allowing the effect of temperature seasonality on bivalve filtration and biodeposition to be inferred. Bivalve population densities were measured to estimate ecosystem service provisioning for the entire study area.

Bivalve biofiltration did not increase with bivalve size or differ between natural and artificial wetlands, but did increase under cooler water temperatures that primarily occurred during winter months.

Phosphorus and nitrogen biodepsoition rates were higher in artificial wetlands relative to natural wetlands. Phosphorus biodeposition rates increased as bivalves became larger in size and as water reached maximum summer temperatures. Conversely, nitrogen biodeposition rates did not change with bivalve size or water temperature.

Given their filtering capacity and nutrient sediment storage potential (i.e. biodeposition), C. australis may help restore water quality in GBR catchments. Artificial wetlands could be targeted for restoration, as larger and denser bivalve populations mean that biodeposition rates are elevated and may lead to greater processing of nutrient rich water delivered to the GBR (Figure 1).



(Figure 1).

Pest Free Auckland - enabling community-led conservation

Brett Butland[1], Jane O'Hagan[1]

[1]**Auckland Council, New Zealand**

Auckland's natural environment is central to the health and wellbeing of the region's people, cultural and spiritual identity and economic success. However, continuing biodiversity loss is an on-going challenge for the Auckland region.

Less than 30% of Auckland's original native vegetation cover remains and our remnant terrestrial, marine and freshwater ecosystems are all at threat from habitat loss, invasive pest species and contaminants.

The Pest Free Auckland initiative, launched at the inaugural Auckland Pestival in June 2017, is a community-centric approach to concurrently eradicate eco-system transforming pest species and restore native ecosystems and species. It also incorporates Auckland Council's biosecurity and biodiversity programmes in parks and on private land.

There is unprecedented and growing social license and expectation for pest control and restoration. Leveraging this upsurge of support, from schools to CEOs and everyone in-between, Pest Free Auckland has articulated a shared vision that will deliver huge benefits across the Auckland region - for the social and cultural links with our environment, for our economy through primary industries and tourism, and for our threatened native species.

Partnerships and relationships with community groups, mana whenua, landowners, schools, Auckland Council, Department of Conservation, and private and philanthropic sectors are the key to the success of this initiative.

The presentation will discuss the unprecedented growth in community-led conservation action, the difference that has been made, lessons learnt and future plans.

Developing objectives and completion criteria for post-mine landforms following silica sand mining

Andrew Butler[1], Susan Walker[1], Tim Andrerson[1]

[1]**NRA Environmental Consultants, Australia**

The presentation describes work conducted at Cape Flattery Silica Mine in north Queensland. It lies within a coastal dunefield containing an unusually diverse range of constructional and erosional landforms. The mosaic of landforms types (19) and vegetation mapping units (27) is an intrinsic dunefield characteristic.

The rehabilitation strategy developed in the 1980s and 1990s recognised the natural heritage significance of the dunefield through the commitments made in the statutory Environmental Management Overview Strategy (EMOS). This was prepared through a consultative process involving the mining company, Traditional Owners, government agencies and conservation groups. The consultative approach was, and remains, a rarity because it involved a wide range of stakeholders in the negotiation of rehabilitation performance targets.

A change to the administering authority and governing legislation in the 2000s saw a transition to an Environmental Authority (EA) with statutory conditions. The EA did not specify rehabilitated landform criteria, and it included poorly defined or unachievable ecological rehabilitation performance targets. The uncertainty created has prevented the validation of rehabilitation progress to date. To resolve this, the EA holder commissioned a review of rehabilitation objectives and completion criteria.

The post-mine replication of pre-existing landforms through rehabilitation is not proposed. Nevertheless, important rehabilitation objectives include the re-creation of assemblages of landform elements (unique combinations of slope, elevation and aspect) that are characteristic of the unmined landscape and the generation of landform element richness at different spatial scales.

Mapping the occurrence of different landform elements showed that the complex dunefield landscape contained a common set of characteristic landform elements. The richness and distribution of landform elements provided a valuable tool for comparing rehabilitated and unmined landforms, and this allowed the development of meaningful rehabilitation objectives and completion criteria consistent with EMOS commitments to retain the essential character of the dunefield post-mining.

Integrated solutions for ecological restoration and management of tropical freshwater swamp forest

Yixiong Cai[1], Geoffrey Davison[1], Shie-Yui Liong[2]

[1]**National Parks Board, Singapore**

[2]**National University of Singapore, Singapore**

Freshwater swamp forest is a threatened and overlooked ecosystem in Southeast Asia. Characterised by predominantly mineral soils supporting a subset of flora and fauna of lowland forest, including important habitat specialists, freshwater swamp forest is constrained by an array of hydrological processes. Nee Soon freshwater swamp forest, surrounded by three reservoirs and with rapidly urbanized areas, is critical to the retention of a large number of Red List plant and animal species in Singapore. Physical changes along stream banks have taken place to various degrees. Observation showed raised water levels on some areas, drying on other areas, and shifts in the boundary between swampy and dry land forest. There are some concerns over alien invasive species, loss of big emergent trees, small population sizes and vulnerability of various endangered species, and the uncertain outcomes of changes in water quality and quantity. A research programme, including an eco-hydrological modelling was designed to understand the roles of the various ecological and hydrological components in freshwater swamp forest, and to determine the effectiveness of different intervention and restoration scenarios. Restoration solutions to maintain the hydrological and ecological integrity of the swamp forest will be addressed, e.g. nature friendly retention ponds for over-flooding; infiltrated "pipes and taps" filtered reservoir water for prolonged drought; rehabilitation of incised stream channel for reconnection of floodplain; enhancement of riparian zone to prevent bank erosion and minimize channel sedimentation; and installation of flap gate to prevent invasion of alien species through back flow from reservoir spillway. All restoration options will be considered holistically with the whole-catchment plan. Restoration priority of the proposed solutions will consider relevant issues, e.g. funding availability, cost effectiveness, stakeholders and public perceptions.

Operation Crayweed: Restoration of underwater forests

Alexandra Campbell[1], Ezequiel Marzinelli[2], Adriana Verges[2], Melinda Coleman[3], Peter Steinberg[4]

[1]**University of the Sunshine Coast, Queensland**

[2]**University of New South Wales, New South Wales**

[3]**Department of Primary Industries, Australia**

[4]**Sydney Institute of Marine Science, New South Wales**

Seaweeds are the "trees" of the oceans, providing food and habitat that supports coastal marine biodiversity and underpins a wide range of ecosystem functions and services on temperate coastlines around the world. Key species of seaweeds

are, however, declining from many temperate reefs around the world and although conservation in a preventative sense is an important partial solution to the challenge of habitat degradation, the status of many of the world's ecosystems clearly demonstrates that it is not sufficient by itself. We use the seaweed Phyllospora comosa, or "crayweed", which disappeared from the Sydney coastline in the early 1980's, as an example of the potential of marine habitat restoration. We have been doing research on the ecological restoration of this species for the past 5 years and we have shown that the conditions in Sydney are now suitable for the re-establishment of crayweed populations and their associated biodiversity, which is specific to crayweed and not supported by other, extant species of seaweeds in the area. Furthermore,we have developed methods for the successful reintroduction of crayweed onto high energy, shallow subtidal reefs, which become self-sustaining populations after 6-12 months. Restored sites resemble reference sites with regards to multiple components of biodiversity after several years. We have now scaled-up and initiated restoration of this crucial habitat at the scale of the degradation - which is rarely done in marine systems. Most importantly, we believe that this is a great project to involve the general public and enhance people's awareness of important issues affecting their "marine backyard".

Walking to scale up soil restoration by cyanobacterisation in drylands

Yolanda Canton[1], Beatriz Roncero[1], Raul Roman[1], Pilar Aguila[1], Miriam Muñoz-Rojas[2], Cinthia Gómez[1], Maria José Moro[3], Maria de Los Angeles Muñoz[1], Pilar Mateo[1], Gabriel Acién[1]

[1]**University of Almería, Spain**

[2]**University of Western Australia, Western Australia**

[3]**University of Alicante, Spain**

Soil inoculation with cyanobacteria has become a promising biotechnological strategy for restoring soil function in degraded drylands due to their capacity to survive under water stress, facilitate succession and their crucial role increasing soil fertility and preventing erosion. Moreover, cyanobacteria can be cultured ex-situ to produce high amount of biomass to face large-scale land restoration projects. Our goal is to demonstrate that cyanobacterisation can be an effective strategy to reinstate soil function in large- scale rehabilitation, and favour vegetation establishment. To achieve this goal, our first step was to identify and isolate soil cyanobacteria strains from different Mediterranean ecosystems in Spain, and the selection of three key strains. Under laboratory conditions, we compared the effect of these strains on different soil types under diverse inoculation strategies. Results showed an excellent performance of Nostoc commune and a mixture of three cyanobacteria species in developing a new biocrust and improving key soil properties of all soils in the short term. To produce the necessary biomass for field inoculations, our next step focused on optimising its production. Cyanobacteria were cultured in reactors with traditional chemicals-made media in comparison to fertilizers-made media as a strategy to reduce production costs The quality of the produced biomass to be used in restoration projects was also evaluated demonstrating that fertilizers-made media allow cyanobacteria reaching higher growth rates and promoting higher soil improvements than conventional ones.

The following step was to evaluate the effects of cyanobacterisation on soils under field conditions. Despite experimenting under different climatic conditions, our first attempts to promote a biocrust after direct inoculation of cyanobacteria cultures on soils were not successful, with the inoculum being removed by wind or water erosion or not surviving before its establishment. However, we are obtaining very promising results by applying strategies that reduce environmental stresses during inoculation.

Tailings dam rehabilitation - a new perspective

Carmen Castor[1], Michael A. Cole[1]

[1]**CSER RESEARCH P/L, Australia**

Ecological rehabilitation of tailings dams from mining has been of interest for many years both in Australia and overseas. In the 80's and 90's some attempts were made and met with relative success. Nevertheless, ecological rehabilitation of tailings has not made it into best practice treatment of these mining legacies.

One reason for this is that the perceived risk by regulators for people and the environment remains long-term after closure. Standard practice (in NSW and Qld) is to cap dams with meters of inert spoil which is then rehabilitated using standard methods. This approach is not without problems; it can cost millions of dollars to realise and requires reworking of an area that could already be rehabilitated and sustainable.

This talk aims to describe the water dynamics inside tailings dams and why this is a safety concern. We will also present the first stages of an ecological rehabilitation program that seeks to address these issues by using a natural water pump. Data on crust resistance of one dam under study, experimental setup and treatments trialled, preliminary survival and transpiration rates will be shown.

This project has obtained ACARP funding (C27009).

From little things, big things can grow back again: Pumicestone Shellfish Habitat Restoration Project.

Susie Chapman[1]

[1]**Healthy Land and Water**

Shellfish reefs were once common estuarine features, however they are now considered functionally extinct ecosystems in Australia (Beck, 2011) and Pumicestone Passage (Diggles, 2013). Traditional Owners, fishing groups, oyster farmer, local government, utilities, research institutions and the regional NRM group have been working together for three years to establish a monitored shellfish habitat restoration trial in Pumicestone Passage near Brisbane. This trial supported by two innovative community projects of shell recycling and oyster gardening uses live and dead shell in a variety of subtidal reef structures.

The intent is to restore shellfish habitat to enhance fish stocks, and to protect Aboriginal cultural heritage values. If self-sustaining subtidal oyster reefs accompanied by improvements in fisheries production can be established, these data can be used to inform restoration efforts elsewhere in Moreton Bay.

Installed in December 2017, this trial features a variety of reef structures including patch reefs of shell, steel cages with shell, and a biodegradable potato starch matrix (BESE- Elements) developed by Bureau Waardenburg, used here for the first time in Australia.

Preliminary monitoring results are promising with fish mapping by University of the Sunshine Coast showing a doubling of total fish abundance, species richness and harvestable fish abundance at the reefs site. The BESE-Elements reefs were consistently surrounded by a higher average diversity and abundance of fish, and fish distributions across Pumicestone Passage have been modified slightly following the installations of the reefs. More data is needed before we can properly analyse these broad, seascape-scale effects.

The international movement of oyster reef restoration is in its infancy in Australia, and the complexities of local physical and governance contexts must be carefully navigated with trials before scaling up to significant impact. This modest trial shows promise for the future of this positive collaborative approach to marine ecosystem restoration in SEQ.

Seedling growth responses to species, neighbourhood and landscape scale effects during tropical forest restoration

Lachlan Charles[1], John Dwyer[1], Tobias Smith[1], Sophie Connors[1], Petra Marschner[2], Margaret Mayfield[1]

[1]**University of Queensland, Queensland**

[2]**The University of Adelaide, South Australia**

Central to the success of restoration plantings within abandoned pastures is the appropriate selection of species that can establish and grow rapidly to form canopies to suppress grasses. However, species selection can be difficult, largely due to combinations of biotic and abiotic factors operating across multiple spatial scales that can affect seedling growth rates. Here we present results from a large replicated restoration experiment in Australia's Wet Tropics, where we evaluated seedling growth rates of 24 native rainforest species commonly used in local restoration efforts over the first 31 months post planting. We investigated the influence of landscape, site and planting conditions on early-stage seedling growth and whether functional traits and surrounding neighborhood density and composition explain variation in seedling growth rates. Seedling growth rates were influenced by numerous stem-, species-, plot- and climate-level factors, with the strength of these effects strongly dependent on the size of the seedling. Specifically, the wood density and seed mass of the focal plants and the size and diversity of neighboring plants had consistent significant effects on growth in height and diameter throughout the 31-month monitoring period; species with low wood densities, larger seeds and seedlings surrounded by larger and taller neighbors consistently grew faster. In response to plot-scale and climate factors,

larger seedlings consistently displayed faster growth, demonstrating the benefits of initial seedling size for seedling success. Our study highlights that early-stage seedling growth can be influenced by many factors, operating across multiple spatial scales. Importantly, we demonstrate that planting larger seedlings may improve seedling growth and that developing strategies to increase the survival of fast growing low wood density species are crucial to ensure plantings can achieve canopy closure and improve early to mid-term trajectories of tropical forest recovery.

When the funding finishes - continuing conservation efforts through community connections

Samantha Colbran[1], Anna Markula[1], Daniel Cole[2]

[1]**Logan City Council, Queensland**

[2]**The Water & Carbon Group, Australia**

The Slacks Creek Restoration project was a five year project funded by the Federal Government under the Caring for Our Country funding that ran from mid-2013 until mid-2018. The goals of the project were to:

- revegetate and restore 25 hectares along Slacks Creek to increase habitat for wildlife, improve habitat quality, and reconnect areas of existing vegetation;
- improve water quality, bank stabilisation and pollutant mitigation; and
- increase knowledge and engagement of the community to better conserve, manage and protect natural resources.

The delivery of this project had a strong community engagement approach and as such multiple social outcomes were achieved, which in turn enhanced the environmental outcomes. The purpose of this presentation is to discuss the outcomes for the community and to ask 'What happens next?'

A focus on community engagement and education was embedded into the project. A community engagement strategy was developed and key groups were consulted throughout the project. These initiatives were complimented by a range of community workshops and events. Additionally, a community survey was run at the beginning, during and end of the project to gain insight on the community's knowledge, interests, and participation in environmental activities in the Slacks Creek area and changes over the project duration.

Engaging the community from the onset of the project has had multiple benefits, both to the community and the project. The community connections established during the project has since been utilised to encourage further community involvement and ensure that the restoration of Slacks Creek continues beyond the Federal funding.

Restoring tree cover in the Ramsar-listed Koorangie Marshes through an indigenous partnership

Damien Cook[1], Laura Kirby[2]

[1]**Wetland Revival, Australia**

[2]**Barapa Barapa Land and Water, Australia**

The Koorangie Marshes are a 3000 ha system of wetlands at the end of the Avoca River in north central Victoria and are of extremely high cultural and ecological significance.

Poor land and water management in the later half of the 20th century caused rising saline water tables and prolonged water-logging which killed the canopy of River Red Gum (Eucalyptus camaldulensis) and Eumong (Acacia stenophylla) over a large area of the marshes.

Improved irrigation practices and the millennium drought lowered the local water table and created suitable conditions for tree canopy species to re-establish, however regeneration has been limited because of the lack of a soil seed bank.

The North Central Catchment Management Authority, in partnership with the local Barapa Barapa traditional owners, have implemented a restoration program that has resulted in the planting of 11,000 trees over 1000 ha of the Marshes. Planting followed the draw-down of the 2016 flood using a technique that required no herbicide use and resulted in very high tree survival rates.

This paper will be presented by both the ecologist who helped design the restoration program and one of the traditional owners who participated in its implementation.

Local provenancing in subtropical rainforest restoration: for better or worse? A review of practitioners' perspectives

Sally L Cooper[1], Claudia Catterall[2], Peter C Bundock[2]

[1]**Tweed Shire Council, New South Wales**

[2]**Southern Cross University, New South Wales**

The adaptive potential of restored communities is important to their long-term sustainability, particularly in the face of changing environmental conditions such as climate change. The genetic diversity of rainforest plants in restoration projects, and their suitability to current and future environmental site conditions, are important considerations for restoration practitioners and seed suppliers. Presented here are the results from a survey of rainforest restoration practitioners in North East NSW and SEQ, Australia. The survey canvassed practitioners' perspectives on local provenancing, genetic diversity and other aspects of restoration that have the potential to influence the long-term success of restored rainforest communities. All respondents to this survey typically included a planting component in their restoration projects (whether for reconstruction or to supplement assisted regeneration). Planting represents an anthropogenic selection and translocation of genotypes to a restoration site. As a result, considerations of genetic origin and the potential implications to the restored community are relevant to most restoration projects. This industry survey's results showed that genetic diversity and local provenancing are concepts of importance to practitioners. However, there seems to be a lack of clarity within the industry about how to define local provenance and how the concepts of local provenancing and genetic diversity influence each other. The results indicated that local provenancing remains the preferred provenancing strategy amongst practitioners, with inclusion of non-local provenance seed not regarded as an effective means of improving genetic diversity. This is despite researchers highlighting the limitations of local provenancing, particularly in highly fragmented landscapes, and despite the publication of numerous alternative provenancing strategies. Rainforest restoration may benefit from practitioners questioning the appropriateness of local provenancing to their restoration projects and considering that in some circumstances exclusive reliance on local provenance stock may in fact be worse, not better, for the long-term sustainability of restored communities.

Responses of fauna to mine site restoration

Sophie Cross[1], Sean Tomlinson[1], Michael Craig[2], Kingsley Dixon[1], Bill Bateman[3]

[1]**Tweed ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

[2]**University of Western Australia, Western Australia**

[3]**School of Molecular and Life Sciences, Curtin University, Western Australia**

Globally increasing rates of mine site discontinuations are resulting in the need for immediate implementation of effective biodiversity and conservation management

strategies. Over 60 000 mines across Australia have been identified as discontinued, yet despite restoration being a legislative requirement, the number of these sites confirmed as restored and officially closed is extremely low. Monitoring vegetation structure and condition is a common method of assessing restoration success, however monitoring animal responses is relatively uncommon. Animals are generally assumed to return to pre-disturbance abundances following the return of vegetation (Field of Dreams hypothesis; 'build it and they will come'). In practice, recovering animal biodiversity and community structure can be some of the most difficult components to achieve and asses following the restoration of degraded sites.

Using remote sensing (camera trapping), we assessed fauna recolonisation and responses to mine site restoration at a Mid-West Western Australian mine. Numbers of animal detections significantly increased with increasing distance from the active mine pit, regardless of whether the site was a restoration or reference site. Restored sites were of the same age, however both species diversity and abundances were significantly higher in the site farthest from active mining activities. Feral species (cats, wild dogs, and rabbits) were detected across all sites, but large, native predatory animals such as Varanus species were detected almost exclusively at the reference and restoration sites farthest from the active mine pit.

Global map on the ecological uncertainty of forest landscape restoration success

Renato Crouzeilles[1]

[1]**International Institute for Sustainability, Brazil**

Several international commitments have emerged to boost forest and landscape restoration worldwide supported by an estimated US$18 billion. Yet the restoration cost and the uncertainty of the success of ecological restoration may constrain the flow of financial capital to restoration initiatives due to the high risk associated. Here we conduct a global meta-analysis over 135 study landscapes to map the global ecological uncertainty of forest landscape restoration success for biodiversity. We identify for the first time landscapes where restoration approaches are most likely to foster biodiversity recovery to similar levels found in old-growth or less-disturbed forests. Our global pattern of exponentially decreasing the ecological uncertainty of forest restoration success as the amount of forest cover increases is strongest within a buffer of 5 km radius around a landscape. Despite the large amount of deforested lands worldwide, most of the forested biomes still keep a low ecological uncertainty of landscape restoration success. This key message provides a strong rationale for continued investment in forest landscape restoration initiatives. Starting the implementation of large-scale forest restoration in landscapes with lower ecological uncertainty can be a key strategy to unlock the flow of financial investments to the ambitious restoration commitments.

Improving broad-scale post-mine ecological rehabilitation using landform heterogeneity

Anand Datar[1], David Mulligan[1]

[1]**The University of Queensland, Queensland**

The extractive phase of broad-scale mining involves significant alteration of topography and associated ecosystems. Post-mining ecological rehabilitation typically starts with reconstructing topography using simple and repetitive landform elements such as plateaus, terraces, and gentle slopes for stabilisation purposes. However, this approach leads to uniform landforms that do not reflect natural landscapes. Previous research in undisturbed and agricultural landscapes shows that ecological attributes and diversity in microclimates are positively correlated with landform heterogeneity. We investigated if those findings are still valid at post-mining rehabilitating landscapes where rehabilitation starts right from constructing the landforms. At the mineral sands mine rehabilitation at North Stradbroke Island in Queensland, landform heterogeneity was measured using remote sensing and GIS through variance in three landform elements (relief, slope, aspect), and ecological patterns were represented by ecological indicators (e.g. species richness) measured through field surveys. The results showed correlations between landform heterogeneity indices and ecological indicators with sensitivity to the spatial scale of investigation and rehabilitation history. In some cases, landform heterogeneity explained up to 77% of the variance in particular ecological measures. Landform heterogeneity emerged as a major significant contributor in explaining the variance case of all ecological variables when some of the other dominant drivers of rehabilitation, such as rehabilitation practices, soil characteristics and seed mix were included in the analysis. While some of the primary drivers of post-mining ecological rehabilitation (such as climate, substrate and rehabilitation practices) are difficult to control or condition over extensive areas and extended time periods, landform heterogeneity may provide a simple and effective tool to indirectly control the micro-environmental parameters that may encourage an improved rehabilitation outcome. Apart from broad-scale post-mining landscapes, this approach is adaptable to other ecological restoration projects that have a capacity to influence landform shape and dynamics.

Upscaling best practice: a 300 ha dry shrubland restoration within an irrigated farm landscape matrix

Nicholas Dickinson[1], Rebecca Dollery[1], Mike Bowie[1]

[1]**Lincoln University, New Zealand**

Within a 7,000 ha plantation pine forest to pivot-irrigated dairy farm conversion in lowland Canterbury, New Zealand, 187 ha of land has been developed for ecological restoration. In less than 5 years, 27 new reserves have been integrated into the landscape matrix, with linkages through ecological corridors. The few

local remnant benchmark communities consist of Kunzea serotina (Myrtaceae, Kānuka, tea tree) with an understory of smaller shrubs and an almost continuous ground cover of Hypnum moss. Our studies have drawn attention to the importance of soil physico-chemistry and have shown the moss layer to have an important functional role, both in moisture conservation and for seedling establishment. Nutrient spillover from farmland favours adventive weeds, but tolerance of native plants to drought stress provides some advantages once they become established. Management of noxious weeds (gorse and broom) and animal pests (rabbits and hares) is particularly critical. Our restoration strategy has been to establish research plots within the reserves, each of which has an established perimeter planting of Kunzea as protective buffer zones. Research activity focuses on the second stage of the restoration trajectory. This paper describes the results of experimental trials of soil acidification, mulch amendments, the efficacy of tree guards, how to restore the moss layer, the role of nitrogen fixers, and faunal colonization. Natural colonization by some native plants provides some surprising findings, but the range of species is restricted by a lack of sources of propagules at distances that allow native birds to disperse seeds. Current attempts to introduce inoculants and to embed small biodiversity pods within the restoration plots are discussed. We show how the economics of upscaling requires different approaches to ecological restoration practice.

Soil imprinting combined with an artificial soil crusting agent dramatically increases broadcast seed emergence

Mark Dobrowolski[1]

[1]**Iluka Resources, Australia**

Seedling emergence rates from broadcast seed are notoriously low in restoration. At Iluka Resources Limited's Eneabba mine in the Mid West of Western Australia, eight-fold more seedlings emerged under ideal nursery conditions in 2015 than when that seed was broadcast in the field. Unlocking this potential in broadcast seed is critical to establishing the desired plant density and species diversity of the restored kwongan shrubland vegetation, and is one focus of R&D at Iluka's Eneabba mine.

Erosion, both wind and water, is a major factor affecting seedling emergence in newly prepared restoration sites. To control wind erosion at Eneabba, Iluka applies a crust of dilute, non-toxic bitumen emulsion to the sandy soil surface. This crust degrades over a few years but does not inhibit germination. It allows seedlings to emerge and establish under windy conditions, common at Eneabba, holding the seed in the soil matrix for germination to occur and eliminating the sand-blasting that kills newly emerged seedlings. Combining this crust application with ripping-mounding to prevent water erosion in 2016 increased seedling establishment almost two-fold.

Soil imprinting, a technique developed in the 1970s, reduces rainfall run-off and increases infiltration and nutrient/organic matter accumulation thereby improving seedling emergence and establishment. However, the imprints erode too quickly in sandy soils such as found at Eneabba. A trial combining soil imprinting and bitumen emulsion crust improved seedling emergence more than two-fold for broadcast seed and three-fold for topsoil derived seed.

Data from large-scale field trials of these restoration techniques and the innovative combinations of them will be presented to illustrate their effectiveness and applicability to other restoration projects.

How ecological restoration can help facilitate a nature conservation culture

Todd Dudley[1]

[1]**North East Bioregional Network, Tasmania**

Ecological restoration and bush regeneration have only been a significant part of the nature conservation landscape for a relatively short time (since the 1970's). Advances in the science and practice of ecological restoration and bush regeneration during this time have been considerable. At the same time the attention paid to the cultural value of these practices has been relatively minimal.

Authors such as Joseph Sax (Mountains Without Handrails) have identified that human relationships with nature are influenced by their working environments (for better or worse).

In this talk I will discuss the opportunities ecological restoration and bush regeneration provide to embed a nature conservation culture and ecological conscience and literacy in the community. Some examples from work in a remote rural community in North East Tasmania will be used to demonstrate that relatively rapid changes in values can be achieved as part of on ground ecological restoration practice. Ecological restoration projects which explicitly incorporate ethics and values such as the intrinsic value of nature into their activities can generate a deeper, more meaningful experience.

As William Jordan III states in The Sunflower Forest "Restoration can emerge as a paradigm for learning about the natural landscape and for our relationship with it".

Artificially-constructed depressions provide insights into the role of soil disturbing animals in the recovery of degraded drylands

David Eldridge[1], Terry Koen[1]

[1]**New South Wales Office of Environment and Heritage, New South Wales**

Organisms that disturb soils while foraging for food or creating shelter (ecosystem engineers) can have profound effects on ecosystem functions and processes. In Australia, many of these mammalian engineers are now extinct or have severely reduced distributions. We used artificially-created pits, designed to emulate the natural pits of wild echidnas (Tachyglossus aculeatus), to provide insights into the processes activated by soil-foraging echidnas when they excavate surface soils. This novel approach using artificially-constructed pits enabled us to remove potential effects related

to different pit age, size, placement or morphology. We compared changes in litter decomposition and labile soil carbon, organic matter, seed and plant germinants differed between pits and their paired surface changed over 18 months.

We found significantly greater decomposition of Eucalyptus intertexta leaves in the pits (65%) than the surface (51%) after 18 months. Soil labile carbon declined immediately after pit construction, but after 18 months was significantly greater in pits than the surface. Pits trapped about seven-times more litter, six-times more seed, and three-times more richness of seeds than a surface of equivalent area. Twice as many plant species germinated in the pits but there were no differences in composition.

Using artificially-constructed pits allowed us to examine the potential roles of animal foraging in processes that are critical components of the recovery of degraded systems. We showed that artificial pits responded similarly to animal-created pits and could be useful for designing human-constructed analogues such as disk furrowers and land imprinters that are used to restore degraded drylands. Our pit infilling data suggest that pits would be almost indistinguishable from surface soil within 3 years, and may have application for restoring degraded soils in areas where soil disturbing animals are absent.

The capacity of restored urban forests to support native birds: Ecological or social restoration?

Elizabeth Elliot-Hogg[1], Bruce Clarkson[1], Ottilie Stolte[1], John Innes[2], Chaitanya Joshi[1]

[1]**The University of Waikato, New Zealand**

[2]**Manaaki Whenua - Landcare Research, New Zealand**

My ongoing PhD research combines ecological and social science to evaluate the contribution that restored native forests in New Zealand cities can make to native bird conservation and reconnecting urban residents with nature. The goal is to identify which factors among local habitat variables, landscape characteristics, site age and predation, determine the ability of native New Zealand bush birds to benefit from urban restoration.

Birds and predators were monitored at 43 sites in two North Island cities: Hamilton and New Plymouth. Sites represented three types of urban forest: unrestored (n = 6), restored (n = 26) remnant (n = 6), and the non-urban forest remnant nearest to each city (n = 6). Restored sites formed an age gradient of 1 to 73 years since initial planting.

Preliminary results reveal a trend for native bird species' richness to increase with the age of restored sites. The number of native bush bird species in Hamilton and New Plymouth is low (6 detected). Bird communities appear to shift from being dominated by non-native finches during the early stages of restoration, to supporting a greater number of native bush birds as the sites mature.

The qualitative, semi-structured interviews explored whether frequent use of restored forest can re-establish a relationship between people and native nature. Results reveal that parks dominated by native vegetation are valued for the opportunity they provide for observing nature and escaping the stresses of city life. Interviewees'

appreciation of native nature was ambiguous and complex, however, and reported preferences for native vegetation and birds did not result in increased plantings of native species in respondents' gardens. Our findings suggest that we cannot rely on urban gardens to support native biodiversity in the short term and stress the need for local authorities to invest more time and resources in urban restoration.

The Mokoan Project: The ecological renewal of an ephemeral wetland system in North-east Victoria

Lisa Farnsworth[1], Lance Lloyd[1]

[1]**Winton Wetlands Committee of Management Inc, Victoria**

A variety of woodlands, grasslands, swamps and wetlands were all flooded to make Lake Mokoan in 1970. Each of the Ecological Vegetation Classes EVCs had their own range of species and features which included terrestrial and wetland ecosystems such as Box woodlands, large open Cane Grass Swamps and River Red Gum wetlands. In 2010, Lake Mokoan was decommissioned and the site made a Special Features Reserve.

The ecological renewal of the 8,750 hectare Winton Wetlands Reserve is an ambitious project of national scientific, cultural and environmental significance, with a long term vision and plans stretching to 2036 and beyond. Located in north east Victoria, between the regional cities of Benalla and Wangaratta, the Winton Wetlands Reserve has 3800 Ha of wetlands surrounded by 4,950 Ha of red gum and box grassy woodlands, which includes 1850 Ha of grazing land.

The Mokoan Project has many aspects contributing to the establishment of a site of ecological, cultural, social and economic importance. The Ecological Renewal program has many inter-related elements for the restoration of both the aquatic and terrestrial environment:

- Water Quality Management and Improvement
- Aquatic and Terrestrial Vegetation Regeneration and Improvement
- Invasive species monitoring and management
- Community-driven projects to monitor and manage threatened or indicator species

The ecological renewal project at Winton Wetlands is guided by the Restoration and Monitoring Strategic Plan (Barlow 2011) and is supported by specific management plans that the current science team has developed for revegetation, fish, water quality, aquatic plants, weeds and feral animals. Our restoration program is supported by a high level science committee, an annual Science Forum, multiple research partnerships with regional and national universities and strong collaboration with community-based restoration groups.

This paper will discuss the restoration activities conducted to date, research undertaken and the ecological outcomes already achieved.

Leverage trust-based partnerships to implement stream restoration at scale: A CAREX case study

Catherine Febria[1]

[1]**University of Canterbury - Te Whare Wananga o Waitaha, New Zealand**

Scale continues to be one of the biggest challenges in both stream and river restoration. In Australasia and around the world, multiple stressors affect ecosystems simultaneously, and those stressors operate at varying spatial and temporal scales. Often, restoration actions and the spatial scales at which they are addressed are mismatched. For example, catchment wide issues such as water quality are addressed through local reach-scale actions such as riparian planting or in-stream habitat improvement. Temporally, assessment and monitoring are quite limited; restoration projects offer little to no baseline data, and post-restoration monitoring is often sparse and ends long before ecosystem health shows signs of recovery. Overall, there is a need for new ways to overcome social and ecological barriers preventing restoration success. Here we present learnings from the Canterbury Waterway Rehabilitation Experiment (CAREX), a ten-year project that has resulted in New Zealand's largest stream restoration experiment to date. Canterbury is grappling with water quality and ecosystem health issues due to agricultural land use and intensification. Stressors include nutrients, sediments and invasive aquatic weeds which together are influencing biodiversity, farm function and cultural health. We will discuss how we enacted a trust-partnership framework to unlock and overcome social barriers of working on privately-owned and managed farm waterways across the lowland Canterbury region. We hypothesized that trust-partnership between relevant actors (primarily farmers, scientists, governments and industry) fostered over time through co-development and co-design would enable the implementation of larger-scale, longer-term research on combinations of tools to address multiple stressors. This approach informed an experimental design involving nine-kilometres of waterway and more than 23 farming families, to implement 14 restoration tools at varying spatial and temporal scales. We will present social and ecological indicators of these trials and the resultant restoration outcomes that were achieved along a trust-partnership gradient.

Thirty years of ecological restoration of mining-degraded areas in New Caledonia:Comparative analysis and recommendations.

Bruno Fogliani[1], Simon Gensous[1], Hamid Amir[2], Alexandre Lagrange[3], Danielle Saintpierre[4]

[1]**New Caledonian Agronomic Institute, New Caledonia**

[2]**Université de la Nouvelle Calédonie, New Caledonia**

[3]**BotaEnvironnement, New Caledonia**

[4]**SIRAS Pacifique, New Caledonia**

During the few last decades, many revegetation/restoration projects on ultramafic areas degraded by nickel opencast mining operations have been performed in New Caledonia. A practical synthetic review became necessary to determine the state of know-how in this domain, highlight the most effective techniques and guide future research. Indeed, if many tests have been performed, results arising from the majority of these works are scattered and not all known. This was the aim of the CNRT RECOSYNTH project that has consisted of evaluating 35 restoration operations reflecting the maximum diversity of the field conditions and techniques used to establish recommendations.

Random quadrats (with variable size depending on the surface of the restored area) have been placed on the different studied zones (a same zone can include several assays) and variables measured to evaluate ecosystem productivity and dynamics. Based on 34 variables (calculated or directly obtained from field measurement), a stochastic algorithm permitted to select 12 variables, which have the most significant effect to compare the different used treatments. Results analysis was performed with hierarchical classification applied on ordination.

In terms of ecological restoration techniques, use of topsoil appears to be one of the most effective as it enhances both productivity and dynamics, thus guaranteeing the resilience of the ecosystem as it permits to enhance both productivity and dynamics. Without topsoil, differences exist regarding planted soil type, both in terms of success and of plant species behaviour and diversity. Using Acacia spirorbis, known for its capacity to fix nitrogen, can help restoration on ultramafic soils poor in nutrients. However, at the same time it blocks the ecological succession when used at high density. An evaluation done to establish effects of different inputs highlights that organic matter is essential for plant productivity. Finally, the use of windbreak systems plays a major role for restoration success in areas subject to main winds direction.

Illustration of the topsoil effects on right side on plant density and diversity at Goro, New Caledonia

Open Sessions

Maximising ecological restoration outcomes through threatened species management programs

Jen Ford[1]

[1]**Ecosure, Australia**

Numinbah Conservation Area is a 598 hectare site in the Gold Coast Hinterland managed by the City of Gold Coast's, Natural Areas Management Unit (NAMU). It contains 12 Regional Ecosystems, and ranges from highly degraded areas to remnant forest, connecting Springbrook and World Heritage areas with the Numinbah Valley. Previous disturbance consisted of logging and grazing, and despite being impacted by over 35 weed species including extensive infestations of Lantana camara, Passiflora species and exotic grasses, the site was considered to have an excellent capacity for recovery.

Detailed restoration and fire management planning commenced in 2007 when an opportunity arose to propagate and translocate 6 nationally threatened species that were being impacted by the raising of Hinze Dam. Involvement with the Technical Advisory Group, together with managing land within the catchment that directly suited the requirements of 4 of the 6 flora species, enabled negotiations, the development of plans and a budget that has spanned 10 years.

The detailed ecological restoration plan systematically guides works so each zone started builds on previous efforts. It also guides the management of the 1260 threatened species planted and makes up part of the contact between Council, Seqwater and the Commonwealth Government. The restoration plan aligns with fire plans developed for the project and broader site. Ongoing weed control maintenance continues to support the threatened species program as well as the broader recovery and management of surrounding vegetation. Regular monitoring and reporting continue and these events together with photographic monitoring, clearly demonstrate the assisted regeneration works being applied have had a massive overall benefit to the site. Currently more than 300 hectares are actively being restored and a number of these areas only require one to two visits per year to ensure weeds continue to be suppressed.

Scaling up - is it possible or an ongoing aspiration?

Jen Ford[1]

[1]**Ecosure, Australia**

The scaling up of ecological restoration is essential if we are to arrest the continued degradation and fragmentation of our ecosystems. We know increased funding and efforts are required in all aspects of ecological restoration from planning, implementation, monitoring and innovation but how do we scale up using current best practice standards? Moreover, how can we ensure good standards are applied to maximise our efforts and truly demonstrate what is possible, ecologically and economically?

This presentation focuses on two larger scale projects and demonstrates some of the successes and challenges with scaling up. The first project is restoring 205 hectares of a 960 hectare site to support koalas. This project is in its fifth

year and has not been without its challenges including planting 114,000 trees. Successes are supported by longer-term funding arrangements, good planning and the ability to apply a range of restoration approaches to maximise efforts.

The second project required the development of a practical ecological restoration plan that balances the rehabilitation of threatened fauna species and their possible relocation to the site; nature-based recreation; agriculture; the need for fire; and an array of other competing priorities across 4,800 hectares. Developing a plan that follows current best practice including recently adopted national standards, is easily understood by a range of stakeholders, has a long shelf life, and contains sufficient detail to guide on ground works, is a challenge. If the site and broader areas within the 750 square kilometre corridor are to be restored, numerous challenges including funding, remain. Solutions such as utilising and training a multi-disciplinary workforce of scientists, farmers, landholders, land managers and experienced Bush Regenerators who understand and are able to apply a range of restoration approaches including maintenance across very large areas are one of the solutions explored.

Coordinated recovery planning for threatened woodlands

Hannah Fraser[1]

[1]University of Melbourne, Victoria

Eucalypt woodlands constitute some of the most extensive and yet exploited ecosystems in Australia. There are 28 woodland communities listed as threatened under the Environment Protection and Biodiversity Conservation (EPBC) Act (15 Critically Endangered, 13 Endangered) but just 9 of these communities currently have recovery plans. Conservation and recovery plans are typically developed one at a time, and resources for conservation assessment and recovery planning are scarce. The question is, can we create a single generalized Recovery Plan to aid effective conservation management across all threatened woodlands without losing critical specifics of floristically or geographically distant woodlands?

Working together with woodland experts from across the country, we examined how similar the dynamics and threats are for geographically and floristically disparate woodlands in southern Australia. Through a series of surveys and a workshop, we developed a detailed State-and-Transition model describing how vegetation condition changes in these disparate woodlands, driven by different threats (e.g. grazing) and management actions (e.g. replanting).

Experts had different ideas about the definition of condition states, how threats varied across the geographic extent of Eucalypt woodlands considered in this project, and the most effective management actions to address these threats. We will present some of the similarities and differences from experts, and outline when these differences indicate multiple STM's are warranted to represent community dynamics in southern Australian eucalypt woodlands. Next steps are to develop a Recovery Plan to support the protection of Australia's southern eucalypt-dominated woodlands, including further research to incorporate faunal concerns, and exploring whether this framework can be expanded to other listed woodland communities.

Trialling stream rehabilitation tools to attenuate high nitrate loads in agricultural headwaters

Brandon C. Goeller[1], Catherine M. Febria[1], Helen J. Warburton[1], Hayley S. Devlin[1], Katherine E. Collins[1], Lee F. Burberry[2], Kevin S. Simon[3], Jon S. Harding[1], Angus R. McIntosh[1]

[1]**University of Canterbury, New Zealand**

[2]**Institute of Environmental Science and Research, New Zealand**

[3]**University of Auckland, New Zealand**

Networks of headwater ditches and subsurface tile drains that support agricultural production cause water quality problems by transporting excess nitrate across riparian protection networks. To inform management, we characterised drivers of headwater catchment nitrate fluxes and trialled stream rehabilitation tools as part of the Canterbury Waterway Rehabilitation project (CAREX; www.carex.org.nz). We quantified nitrate export in nine, one-kilometre-long lowland agricultural headwaters fed by tile and open tributary drains in a region with high groundwater nitrate (<1 to >15 mg L-1 NO3-N) over four years. In these waterways, the majority of variation in catchment nitrate fluxes was attributable to in-stream groundwater upwellings and tile drain inputs that by-pass riparian protection networks. Therefore, we tested the performance of three small (< 30 m3) denitrifying woodchip bioreactors implemented with riparian rehabilitation to intercept N sources along a single waterway. After accounting for variability in nitrate export caused by seasonal and longitudinal groundwater dynamics, we found that bioreactors and riparian rehabilitation significantly reduced downstream nitrate export by an average of -2 kg NO3-N d-1, or -5% of the mean daily stream load. To address the N loads not removed along the riparian corridor, we experimentally added in-stream wood in four waterways. Wood additions enhanced very dynamic nitrate removal patterns in 'hot times' and 'hot spots'. The nitrate removal associated with organic matter amendments was especially meaningful, given the overwhelming inputs of high nitrate from groundwater within the experiment reach. For a subset of the 'hot times', wood additions stimulated nitrate flux reductions of -10 kg d-1 NO3-N, equivalent to -20 % reductions in the mean daily stream load. Overall, the practical, cost-effective stream rehabilitation tools we trialled are recommended to address stream nutrient export while catchment-scale nutrient plans are developed to address losses from land.

Open Sessions

Addressing Indonesia's haze crisis through a multi-sector, interdisciplinary program based on accurate primary data field-research

Laura Graham[1], Grahame Applegate[2], Mark Cochrane[3], Bambang H. Suharjo[4], Daniel Mendham[5], Niken Sakuntaladewi[6]

[1]**Borneo Orangutan Survival Foundation**

[2]**University of the Sunshine Coast, AU**

[3]**University of Maryland, US**

[4]**Institut Pertanian Bogor, ID**

[5]**CSIRO, AU**

[6]**Ministry of Environment and Forestry, ID**

Indonesian tropical peatlands, some of the largest in the world, release huge volumes of green house and noxious gasses into the atmosphere following forest degradation, drainage and forest conversion through fire and oxidation. In 2015 Indonesia, and its neighbouring countries were blanketed in thick, noxious haze as a result of the degraded peatlands burning. The Indonesian Ministry of Environment and Forestry has partnered with Australia's International Centre for Agriculture Research to address the haze crisis. A new interdisciplinary, multi-sector project began in 2017 with five research objectives, including, 1) improved understanding of the causes of peatland fire, 2) identifying inclusive and sustainable livelihood options in rewetted peat localities, 3) quantifying restoration practices in relation to peat characteristics and water dynamics, 4) improving social and policy aspects of peatland restoration and fire prevention, and 5) supporting management and dissemination of knowledge on these topics.

This project is led by field-based Indonesian and Australian researchers, with rapid dissemination of findings to policy makers and on-the-ground practitioners and stakeholders. As an example, a NASA-funded project, the Maryland-IPB Peat Fire Research Project, initiated in 2014, has greatly contributed to the understanding of the causes of tropical peatland fires and their transition into the peat, and implemented a nation-wide program for monitoring peat fire behaviour. The ACIAR scientists are working together with the NASA funded scientists to upscale the study sites and replicates, increase the coverage of the nation-wide database and the coordination of the research outputs.

It is only by these kind of concerted and collaborative multi-sector efforts, building upon previous knowledge, collecting data directly, and sharing research findings quickly to assist with science based policy developments for immediate impact that this international crisis can hope to be resolved.

Open Sessions

Long-term research supports a reduced fertiliser application rate for minesite forest restoration in south west Australia

Andrew Grigg[1]

[1]**Alcoa of Australia**

Fertiliser is commonly applied in minesite restoration to promote rapid plant growth during the early establishment phase. However, the effects of different rates of fertiliser application at establishment on the longer-term characteristics and development of the post-mine ecosystem, especially where restoration of native plant communities is the goal, is less well understood. Alcoa has been undertaking forest restoration following bauxite mining in the south west of Australia since the late 1960's, and has adjusted and improved its restoration practices over time to better achieve the objective of restoring a self-sustaining jarrah forest ecosystem. Results from fertiliser trials and other research in restored mine pits over a 20-year period have shown that a reduction from previous fertiliser application rates at establishment of up to 80kg P/ha and 80 kg N/ha to the current rate of 20 kg P/ha and 20 kg N/ha leads to fewer exotic annual species and higher richness of native species, and benefits for slower-growing re-sprouter species that are important for community resilience. The latter two outcomes arise largely from a reduction in competition from vigorous legume species. The reduced fertiliser rates also have no negative impact on the longer-term growth rates of the dominant overstorey species of jarrah (Eucalyptus marginata). The current application rates can be viewed as optimising the shorter-term objective of promoting early growth (productivity) and the longer-term goal of achieving a restored forest ecosystem that is as close as possible to the reference jarrah forest (diversity). This presentation will provide an overview of Alcoa's restoration efforts and the findings of key research underpinning current fertiliser practice in striving for restoration excellence.

Achieving multiple benefits in ecological restoration for biodiversity conservation and carbon sequestration

Valerie Hagger[1], John Dwyer[1], Kerrie Wilson[1], Jacqui England[2]

[1]**The University of Queensland, Queensland**

[2]**CSIRO, Australia**

The potential for revegetation to deliver biodiversity co-benefits alongside carbon abatement has been a focus of much recent work however better assessments of the biodiversity values of revegetation, in particular for native fauna, and the potential synergies and trade-offs with carbon sequestration are required to inform decision making on where and when to invest in revegetation in order to maximise

outcomes for both biodiversity and carbon sequestration.

We undertook field surveys of revegetation sites across south-east Queensland to identify the diversity of woodland dependent birds, the above ground biomass in trees and shrubs, and the floristic diversity and structural attributes. Topsoil sampling was also undertaken and analysed for soil texture, macronutrients and organic carbon. Sites of different planting ages, sizes and landscape context were selected. We are analysing this data to explore (1) the relationship between productivity (above ground biomass) and biodiversity value (woodland bird diversity), (2) the influence of plant diversity, vegetation structure and habitat condition on biodiversity value, (3) the influence of landscape-level variables (age, size, landscape context and connectivity) on biodiversity value, and (4) the influence of soil and climatic variables on productivity.

We expect that plantings with more complex vegetation structure and higher floristic diversity will support a greater diversity of woodland dependent birds and have the capacity to store more carbon, delivering greater shared ecological and social-economic benefits.

The recovery of functional diversity with restoration

Sophie Hale[1], Jason Tylianakis[1]

[1]**University of Canterbury, New Zealand**

There is an increasing urgency to successfully harness restoration to safeguard biodiversity and yield functioning ecosystems, resilient to global change. In measuring biodiversity, approaches that incorporate species' functional traits (i.e. measures of functional diversity) crucially link biodiversity with ecosystem functioning in ways richness-based measures alone cannot. However, there lacks a comprehensive global assessment of the effectiveness of restoration in recovering functional diversity. We conducted a meta-analysis of 30 restoration projects by extracting species lists from published studies and matching these to publicly available trait data. We compared actively and passively restored sites with degraded and pristine control sites, with respect to functional richness, evenness and dispersion. We conducted separate analyses for longitudinal studies (which monitored control and restoration sites through time) and space-for-time substitutions, which compared control sites with restoration sites of different ages at one point in time. Overall, restoration appeared to be effective in space-for-time studies, with restored sites improving across multiple diversity measures over time. However, longitudinal data did not find sustained benefits of restoration for any measure of functional diversity, suggesting that the positive results found in space-for-time data may have been an artefact of the inability of the study design to control for regional changes across all sites. Further, active measures (i.e. guided recovery) were no better than passive measures (i.e. unassisted regeneration) at restoring functional diversity. Patterns were consistent across the six taxonomic groups, six ecoregions and two realms (freshwater and terrestrial) included in this work. Therefore, we stress the indispensability of including degraded controls in ongoing monitoring to distinguish the consequences of restoration efforts from unassisted temporal changes. Additionally, the failure of active restoration to outperform passive restoration suggests that allocating resources towards less intensive measures over larger areas may be a successful strategy to optimise gains for functional biodiversity.

Integrating climate change and local adaptation to inform species and provenance choice for woodland restoration

Peter Harrison[1], Rene Vaillancourt[1], Tanya Bailey[1], Brad Potts[1]

[1]**University of Tasmania, Tasmania**

The long-standing 'local-is-best' paradigm in ecological restoration is being increasingly questioned in the face of global climate change in terms of both species and provenance choice. We here explore the application of future climate models to the prediction of species and provenance suitability for future climate habitats. We focus on the eucalypt tree flora of Tasmania and an area targeted for restoration by Greening Australia in the Midlands of the island. Habitat suitability models developed for 27 of the 30 native eucalypt species show that 63% of species records will be outside of modelled suitable habitat. This trend was most evident in the Midlands, but our modelling identified one non-local and ten regionally local candidate species that are likely to be suitable candidates for the future climate habitat of the region. A framework was subsequently developed to (i) identify provenances of targeted restoration species likely to be best adapted to the future climates of restoration sites for seed sourcing, and (ii) test and implement climate-adjusted provenancing. The generic software developed (Provenancing Using Climate Analogues) matched current and future climate predictions for restoration sites to known provenances of the target species that are already growing in analogous climates for 2020, 2050 and 2080 projections. To experimentally test assumptions of our framework and the effects of provenance translocation, 45 provenances of Eucalyptus ovata were grown in the glasshouse and common-garden field trials embedded within restoration plantings in the Midlands. The glasshouse study revealed that functional trait differentiation was associated with two independent climate gradients which represented home-site aridity and frost prevalence. Early growth and survival in the field trial showed that provenances originating from sites matching the future climate analogues of the restoration site can establish under current climate conditions, an initial requirement for the implementation of a climate adjusted provenancing strategy.

Monitoring understorey from UAV-derived data: A review and future directions for monitoring ecosystem restoration

Lorna Hernandez-Santin[1], Peter Erskine[1], Renee Bartolo[2]

[1]**Centre for Mined Land Rehabilitation, University of Queensland, Queensland.**

[2]**Environmental Research Institute of the Supervising Scientist, Department of Environment and Energy, Darwin, Australia.**

Woodland understorey species are generally more diverse than the overstorey strata and they also play a critical role in nutrient cycles, soil carbon accumulation and ecosystem functioning. However, most vegetation classifications and remote sensing has been restricted to overstorey species, which are detectable from the air at relatively coarse resolutions. The emergence of Unmanned Aerial Vehicles (UAV) has the potential to alleviate the high costs of traditional vegetation surveys and increase the resolution of remote sensing. Our goal was to assess the potential and feasibility of monitoring understorey vegetation in natural environments and in restoration projects using UAV technology. We reviewed original research that used UAV-related technology to assess understorey vegetation, especially examining attributes that may allow or impede successful monitoring (spatial resolution, spectral sensitivity, spatial extent, and temporal frequency at which a sensor acquires data). We also assessed the feasibility of identifying some phonological attributes of three flowering ground cover species in open savanna using UAV-derived multispectral imagery at different heights. We found that the high spatial resolution of UAV-related technology has already started to revolutionise remote sensing and its ability to monitor understorey species. However, there appear to be different levels of success related to the inappropriate choice of methods or sensors given the interaction of the different system-derived attributes. Considering flower detection at different heights, we found that a pixel resolution between 15 and 30 mm per side was ideal, whereas by 89 mm/pixel (30 m height in our case) large flowers were barely discernible. With current technologies, remote sensing based on UAV delivery systems can be used to monitor local-scale understorey vegetation in open environments such as savannas, a range of open ecological restoration communities, and potentially under the overstorey canopies of more closed forest types.

Applying the SERA standards to large-scale restoration in Gondwana Link (south-western Australia) - challenges and approaches.

Barry Heydenrych[1], Blair Parsons[1], Glen Steven[1], Keith Bradby[2]

[1]**Greening Australia, Australia**

[2]**Gondwana Link Ltd., Australia**

Greening Australia and other key partners in Gondwana Link have been undertaking broad scale ecological restoration in the Great Southern Region of WA for over 15 years. In the early stages there was no "roadmap" to guide practitioners from the practice of rehabilitation into genuine ecological restoration for landscape connectivity and the creation of habitat. Without a restoration roadmap, the likely outcome is simply more trees in the ground, rather than regaining some degree of ecological function or tracking and guiding progress towards a destination of true ecological restoration.

To achieve the best possible ecological outcomes various guidelines and approaches, including Gondwana Link Restoration Standards, have been developed and "road-tested". The most recent guidelines - the National Standards for the Practice of Ecological Restoration in Australia (SERA 2017) - have been applied by several restoration practitioners working across Gondwana Link. Use of these standards is increasing as practitioners are keen to track ecological restoration against stated objectives both within and between restoration sites.

In this presentation, we will explore Greening Australia's journey from revegetation to ecological restoration using SERA standards. Using project examples from Gondwana Link we will explore how the outcomes required by a goal of ecological restoration have changed our thoughts and practices. We will discuss the challenges of working at a landscape scale - 100s to 1000s of hectares per year - and constraints associated with achieving genuine ecological restoration within the current revegetation industry framework. We will also discuss the application of the SERA standards, and offer some ideas for increasing the rigour of the evaluation criteria, including adding time frames into those criteria, and how the standards can be used for communicating messages about landscape-scale.

Figure 1. Time series of landscape-scale ecological restoration at Greening Australia's Nowanup property (L - 2004, R - 2018, Photographs: Barry Heydenrych, Greening Australia)

Open Sessions

From remediation to ecological engineering: The paradigm shift in concepts and technology of tailings rehabilitation

Longbin Huang[1]

[1]University of Queensland, Queensland

Metal mining and mineral processing cause a range of negative environmental and long-term ecological impacts on the mined and surrounding environments, ranging from bio-disturbed /degraded, contaminated, and mine wastes storage facilities (i.e., waste rock dumps and tailings /residue dams). The domains of residue/tailings storage facilities pose by far the greatest challenges in rehabilitation, in terms of technical difficulties and economic costs. Progressive rehabilitation of tailings domain is rather slow and limited by current technology and practices, which is to cap tailings by using the expensive conventional cover design. On the other hand, low-cost and direct phytostabilization have only achieved no more than short-term "re-greening", rather than non-polluting and ecologically sustainable outcomes, because of the pitfalls of applying "soil remediation" and hyperaccumulater plant species in the wrong context. The present talk aims to highlight the recent paradigm shift from remediation (by wrongly treating tailings as soil) to holistic ecological engineering of mine wastes. By using this holistic approach, these wastes are treated as novel parent materials, from which functional technosols may be eco-engineered with effective and targeted organic and inorganic inputs under local climatic conditions (such as subtropical monsoonal and semi-arid Mediterranean). The present talk draws research findings from literature and our own research projects over the past decade (2008-2018), in example cases of copper, lead-zinc, iron ore and bauxite mines and refineries. The important roles of tolerant microbes (including bacteria and fungi) are particularly emphasised in the initiation of soil formation via catalysing mineral weathering and transformation, using three representative examples of benign magnetite-Fe-ore tailings, sulfidic Cu/Pb-Zn tailings and bauxite residues. From here, tailing-soil development would be advanced by rhizosphere interactions of pioneer plant species (i.e., very important biopedoturbation factors) towards novel soil types compatible with ecophysiological requirements of keystone plant species concerned.

Monitoring plant survival in revegetated agricultural landscapes

Sacha Jellinek[1]

[1]Greening Australia and the Arthur Rylah Institute, Australia

Land clearing, habitat fragmentation, and landscape degradation are major factors causing the loss of biodiversity throughout the world. To maintain biodiversity in highly fragmented landscapes such as agricultural areas, extensive habitat restoration via methods such as revegetation is necessary. Although restoration has the potential to maintain native animal and plant communities, information about how to achieve good outcomes from restoration, or how to maximise restoration survival is lacking.

Here we propose a monitoring method, used on a landscape scale restoration project in south-eastern Australia, to assess restored terrestrial landscapes, and show how different biotic and abiotic factors influence plant survival. We show that there is a consistent decline in plant survival from those plants surveyed in Spring (directly after planting) to those surveyed in Autumn (after the first Summer) over a 5 year period. This may be partly due to climatic impacts (rainfall and temperature), although factors such as planting stress, weed competition and grazing pressure are likely to play a more significant role. Soil type, especially in areas that have deep sands, also substantially impacts plant survival. Overall, plant community composition substantially changes from those plants initially planted, to those that survive after the first Summer, ultimately changing the communities we are trying to restore. This study highlights the importance of a robust monitoring method to assess restoration survival, and the factors that are likely to influence plant survival directly after planting and after the first Summer, and how this may influence community composition into the future.

Engaging schools and the community in riparian restoration - A Wilsons River case study

Georgina Jones[1]

[1]Envite Environment, Australia

The Wilsons River Tidal Pool Riparian Restoration project is a Rous County Council project funded by the NSW Environmental Trust which involves students and teachers from participating schools and stakeholders including Landcare taking part in the regeneration of sites within the Wilsons River Tidal pool. The project is a continuation of a previous grant successfully implemented from 2012-2014 working with six schools in the Wilsons Catchment restoring riparian vegetation and educating about catchment health.

The projects have been successful in achieving and exceeding objectives, strengths include:

- Working with committed environmental volunteers and expert organisations to increase school student's skills, knowledge and awareness of local environmental issues.
- Working with schools to empower students to make a real difference to their local environment.
- Professional bush regenerators working to implement best practice restoration in partnership with land managers, schools and the local community.
- Environmental education providers supporting participating schools to implement environmental sustainability into curriculum outcomes in Human Society and Its Environment (HSIE) and science classes through activities including vegetation monitoring and professional development programs for teachers.

By holding events over six years, good relationships between project co-coordinators and teaching staff have been established and students, teachers and school community members have been able to see trees become well established providing habitat for birds and other wildlife.

Rous Water bush regenerators have had a mentoring role working alongside agricultural students at Kadina, Woodlawn and Richmond River High schools teaching techniques in bush regeneration and working alongside students on sites restoring native vegetation.

Rous County Council have committed a large number of on-ground bush regeneration hours during the course of the project on site preparation including weed control and site maintenance after plantings were undertaken by schools. This is funded by Rous County Council and is key to successful establishment of riparian plantings.

Habitat restoration or creation - a feasibility assessment for reuse of dredged marine sediment

Kevin Kane[1], William Glamore[2], Paul Erftemeijer[3], Judith Wake[4]

[1]**North Queensland Bulk Ports Corporation, Queensland**

[2]**University of New South Wales, New South Wales**

[3]**University of Western Australia, Western Australia**

[4]**Central Queensland University, Queensland**

North Queensland Bulk Ports Corporation (NQBP) has undertaken a Comprehensive Beneficial Reuse analysis, to see if there are productive ways to use the marine sediments that accumulate in the port's navigational areas and which must be removed by undertaking maintenance dredging.

The restoration or establishment of marine habitat was identified as a potential beneficial reuse option, which needs further investigation to properly assess its feasibility. NQBP has brought together a number of scientific experts to determine if it is feasible to beneficially reuse dredged maintenance material to restore or create marine habitat, around the Port of Hay Point.

The role of the scientific advisory group will be to ensure the scope for each work phase is clearly defined, review and evaluate all technical reports, assist with engagement and ensure best practice standards are maintained.

Although its infancy the project will be delivered in six key phases, each phase representing a 'feasibility gate' which will ultimately determine progression to the implementation of a pilot habitat or restoration program using dredged maintenance material at the Port of Hay Port.

The feasibility and first steps of restoring Australia's disappearing giant kelp (Macrocystis pyrifera) forests

Cayne Layton[1], Ceridwen Fraser[2], Scott Hadley[3], Catriona Hurd[3], Matthias Schmid[3], Victor Shelamoff[3], Brian Von Herzen[4], Jeffrey Wright[3], Craig Johnson[3]

[1]**University of Tasmania, Tasmania**

[2]**Fenner School of Environment and Society, Australian National University, Canberra**

[3]**Institute for Marine and Antarctic Studies, University of Tasmania, Tasmania**

[4]**The Climate Foundation, United States of America**

Kelp forests are the foundation of the Great Southern Reef, Australia's continent-wide temperate reef system that supports high levels of biodiversity, endemism and economic value. Unfortunately, in Australia and elsewhere, kelp forests are experiencing habitat loss due to climate change, overgrazing from herbivores, and coastal development and pollution. Globally, some of the most dramatic declines have occurred in south-eastern Australia, where 95% of Australia's giant kelp (Macrocystis pyrifera) forests have disappeared in recent decades. The feasibility of ecological restoration of these underwater giants - which can reach heights greater than 35 m and grow 50 cm per day - is being assessed as a potential key element of the conservation of kelp forests. Here we outline the key drivers of loss of Australia's giant kelp forests - increasing ocean temperatures and destructive overgrazing by sea urchins - and discuss the approach to assess restoration efforts. We present novel methods to overcome and alleviate the drivers of giant kelp forest loss, including identification and selection of the most thermally tolerant genotypes, acclimation of these genotypes to current/future conditions, and intervention to minimise effects of grazers and competitors after outplanting. Additionally, we illustrate how Integrated Multi-Trophic Aquaculture (IMTA) and permaculture may facilitate kelp growth and habitat restoration, while simultaneously providing environmental benefits through bioremediation of excess nitrogenous waste from finfish aquaculture. Finally, we discuss the broader management implications of our findings, and the potential to restore resilience to the sparse remaining giant kelp forests in Australia.

Germination, cultivation and ex situ conservation of an extremely rare palm endemic to New Caledonia

Pierre Loslier[1], Bruno Fogliani[1], Gildas Gateble[1], Stéphane McCoy[2], Joseph Manaute[3]

[1]**New Caledonian Agronomic Institute, New Caledonia**

[2]**VALE NC, New Caledonia**

[3]**Province Sud, Direction de l'Environnement Parc Provincial Rivière Bleue, New Caledonia**

Saribus jeanneneyi is a narrow endemic palm of New Caledonia, located in the south of "Grande Terre". It is critically endangered (IUCN criteria) due to the tiny number of individuals (one mature and fifteen immatures) in the localised natural population sheltered in a Natural Reserve close to the Vale NC plant. This decline results from intensive harvesting by convicts of a penal colony for its edible heart and extensive logging of rainforest remnants during late 19th and early 20th Centuries. The South province Government initiated an ex situ conservation plan of its rarest and only endemic palmate palm species in partnership with Vale NC and New Caledonian Agronomic Institute in 2009. The objective of this collaborative project was to evaluate seed germination and cultivation in order to produce seedlings for ex situ conservation.

Fruits protected from predators / dispersers by baskets were collected. Measurements were realised on fruits and seeds to characterise and evaluate optimal stage of collection. Several pre-treatments (scarification GA3) were assayed in controlled (cultivation room) or semi-controlled (greenhouse) conditions to optimise germination and assess dormancy. Seeds were implanted in situ under natural conditions to evaluate species ecology. Finally, seedling cultivation was also studied.

Eighteen seedlings have been produced since 2009 and planted in areas of the Park, with similar environmental conditions to in situ population. However, germination, seedling development and survival issues still need to be resolved. Optimal fruit collection stage and controlled conditions for germination have been identified. Results on buried seeds in natural in situ environment will also be presented.

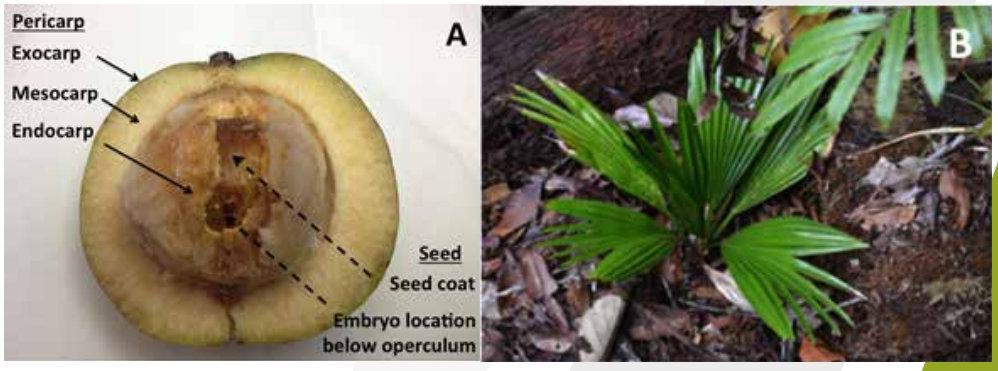


Figure 1. A/ Photo of dissected fruit showing structure and seed embryo position; B/ 5 year old seedling planted at the Parc Provincial de la Rivière Bleue (South Province National Park)

Open Sessions

Investigation on proximate and underlying causes of deforestation to identify remedial measures (Case study: Ywangan Township, Shan State, Myanmar)

Phyu Phyu Lwin[1]

[1]**Forest Research Institute.**

Deforestation has become one of the most challenging problems faced by many developing countries that can hinder sustainable forest management, and in turn, sustainable development. In mountainous areas of Myanmar, shifting cultivation had been practiced by hill-tribe people as their major livelihood. As population increased and modern agricultural practices developed, farmers tended to abandon their traditional agricultural practice by transforming their shifting cultivated areas to sedentary farmlands. This pattern of land-use change was the proximate cause of deforestation in mountainous areas because fallow forests at the era of shifting cultivation currently transformed to farmlands. Therefore, we conducted this study with the main objective of exploring the patterns of land-use/land-cover (LULC) change in upland areas of Shan State in Myanmar by investigating their proximate and underlying causes in order to explore the most reliable remedial measures to recover deforested areas. This study firstly analyzed three decades of LULC change at two periods; 1988 as initial state and 2016 as final state. The major LULC change was disappearance of forested areas and increment of farmlands by 47% in 2016 than areas of 1988. The result also revealed that farmers were willing to clear fallow forests located in more accessible areas. The main underlying causes of deforestation were aggregated results of social, economic and political factors. As the entire area is located in a hilly region where forests are important not only to support local livelihood but also to provide ecosystem services as the primary sources of water springs, deforestation became the most challenging problem to be tackled at the most earliest time. Forest Department has been trying to introduce a community forestry programme by means of agroforestry technique in deforested areas whereas conservation and enrichment planting measures are being conducted for other remnant forests.

This study proposed the potential reforestation approaches based on the results of remote sensing analysis in combination with several discussions with relevant stakeholders including local farmers, local government, NGOs and CSOs in the study area. Therefore, the result of this study can provide fundamental information in developing integrated land management plan by policy makers to ensure the sustainability of montane forest ecosystem and the security of livelihoods for local people.

‘Creek Heroes’ are winning the battle in the City of Onkaparinga urban watercourse restoration project

Nikola Manos[1], Ben Moulton[1]

[1]**City of Onkaparinga, South Australia**

When asked to take on the management of watercourses in the largest metropolitan council in South Australia, the City of Onkaparinga Natural Areas Conservation Team saw an opportunity to expand native vegetation restoration works to a landscape level to help build ecosystem resilience and enable native plants and animals to disperse and adapt within the fragmented urban environment. After gathering data, mapping watercourses and prioritising on-ground works the team secured a five year watercourse restoration grant (2013-2018) for $2.125 million from the Australian Government and Adelaide and Mt Lofty Ranges Natural Resources Management Board.

Community support was critical to the success of this large scale ecological restoration project in an urban area. Previous small scale efforts had resulted in negative reactions to the removal of certain invasive plant species. This inspired the team to develop its own branding for an ‘Urban Creek Recovery’ Project along with a creative communication strategy based on ‘Creek Bullies and Heroes’, a play on the universally recognised ‘good versus evil’ theme. A range of brochures and posters have proven extremely popular with all ages. Instead of education, the focus was on involving the community in a range of activities which has led to greater acceptance of weed removal efforts and a better understanding of creek ecology.

Ecological restoration works are now being undertaken along 62 km of creeks, including 144 parcels of land totalling 530 Ha. Nearly 136,000 seedlings have been planted with over 120 different species.

More than 4,500 people have already visited creeks for discovery tours, youth forums, workshops, litter clean-ups and planting. The Project was even featured on an episode of Network Ten’s ‘Totally Wild’ children’s TV program.

An internally developed spatial weed mapping tool is accurately reporting project outcomes at a landscape level. Results are shared with the community through an interactive online StoryMap.

Open Sessions

Remediation of legacy acid sulfate soil disturbance: East Trinity case study

Michelle Martens[1], Evan Thomas[1], Doug Smith[1]

[1]**Queensland Department of Environment and Science, Queensland**

In May 2000 the Queensland State Government purchased the 770 ha East Trinity property to address the severe acid sulfate soil issues and protect the green tropical backdrop to Cairns in northern Queensland. With conventional remediation approaches deemed cost prohibitive and impractical, a Lime-Assisted Tidal Exchange (LATE) treatment strategy was implemented- ironically, by modifying the tidal gates that lowered the water table and caused the pyrite oxidation and acidification in the 1970's.

Lime-Assisted Tidal Exchange involves the controlled re-introduction of daily tidal cycles, with the strategic addition of hydrated lime (Ca(OH)2) to both enhance the natural acid buffering capacity of sea water and prevent off-site acid and metal discharge. LATE keeps the soil wet and neutralises enough acidity to stimulate the activity of naturally occurring sulfate and iron reducing bacteria which proliferate in the high organic carbon conditions. Real-time water monitoring guides treatment activities, while a multi-disciplinary team studies key ecosystem changes.

The East Trinity ASS remediation has converted a highly acidified sugar cane development near Cairns into a healthy, managed tidal wetland. Strategic research has explained how, where, and importantly - why - these changes occurred so rapidly.

Studies have shown that the bulk of the remediation at East Trinity was due to the microbial and chemical reduction of iron and sulfate. In situ bicarbonate production, a by-product of this process, further neutralises soil acidity and promotes the beneficial microbial weathering of acid minerals. The process becomes self-propelling toward a stable, neutral and healthy soil-wetland system with good water quality.

LATE has transformed the East Trinity landscape while the biogeochemical understanding of LATE has transformed the legacy broad acre acid sulfate soil remediation paradigm.

A question of time; mycorrhizal community change along a restoration trajectory

Vicky McGimpsey[1], Cristina Aponte[1], Rebecca Miller[1], Fiona Ede[1]

[1]**University of Melbourne, Victoria**

Restoration success is underpinned by soil communities and microorganisms as they influence plant growth, establishment and survival. Symbiotic mycorrhizal fungi promote plant growth, nutrient acquisition, plant defence, water acquisition and buffer against toxic levels of trace elements in contaminated land, increasing a plant's ability to tolerate environmental stresses. Plant establishment and survival are closely related to mycorrhizal interactions which become increasingly

important in disturbed or degraded environments. The time that it takes for mycorrhizal communities to transition to their pre-degraded state is currently unknown.

The study was carried out in 6 catchments around Melbourne Victoria. At each catchment sites were selected, with a different vegetation status, along a restoration trajectory. Sites ranged from intact native riparian vegetation, to those revegetated within the last 5-10 years through to cleared sites, which were dominated by pasture grasses. At each site a 25 m x 25 m quadrat was established for soil collection and vegetation assessments. 27 soil cores were taken at two depths (0-10 cm, 20-30 cm), soil was then homogenised and sieved ready for genetic analysis and physicochemical analysis. Aboveground flora was assessed using the point centred quartered method (canopy layer, n=16), the line intercept method (sub-canopy/shrub layer, n=3 x 60 m), and by cover estimates in 1 m x 1 m sub-quadrats (groundcover, n=15).

Our research shows how the diversity and composition of soil mycorrhizal communities in riparian ecosystems differ along a restoration trajectory and how these changes relate to abiotic soil properties and vegetation attributes. These results will improve our understanding of the time scale required for restoration of the mycorrhizal community after degradation and contribute to the development of evidence-based guidelines for restoration practices that could increase our capacity to efficiently restore riparian ecosystems.

Measuring the recovery of coal mine rehabilitation following fire in Queensland using remote sensing and ground surveys

Phill McKenna[1], Peter Erskine[2], Stuart Phinn[3], Vanessa Glenn[2], David Doley[2]

[1]**The University of Queensland, Queensland**

[2]**Centre for Mined Land Rehabilitation, University of Queensland, Queensland**

[3]**Remote Sensing Research Centre, University of Queensland, Queensland**

In Queensland, many coal mines conduct progressive rehabilitation and are aiming to certify established areas prior to lease relinquishment. This can be achieved by meeting agreed completion criteria and demonstrating to regulators that the rehabilitation is safe, stable, self-sustainable and non-polluting. One approach to validating rehabilitation success is to show vegetation recovery to disturbance impacts such as fire. However, mine managers actively avoid fire on rehabilitation, and as a result have limited understanding of fire behaviour on revegetated landforms, the long term implications for site stability and the potential risk to site relinquishment. The aim of this project was to test the resilience of established rehabilitation by applying fire and measuring the vegetation response over the two years following the burn.

We used ground surveys (ten x 400 m2 plots) and WorldView-3 remote sensing assessments using the differenced Normalised Differenced Vegetation Index (dNDVI) to assess post-fire floristic recovery and record changes from pre-fire condition.

The experimental fire was conducted at a Central Queensland coal mine in May 2015, and burnt 117 ha of 19- to 21-year old rehabilitation. Ecological metrics such as species richness and understorey biomass recovered to pre-fire levels for both grassland and open woodland areas (Figure 1). This is supported by the dNDVI which showed high regrowth in grassland (82%) and open woodland (52%) within two years after the fire (Table 1). A large suckering response (mostly from Acacia spp.) resulted in a significant increase in woody density in the less than 2 metre height class, indicating a future shift in ecosystem structure. The results suggest that within the recorded conditions, this site is resilient to fire impacts, and has the capacity to recover to pre-fire levels within the first two years following the fire.

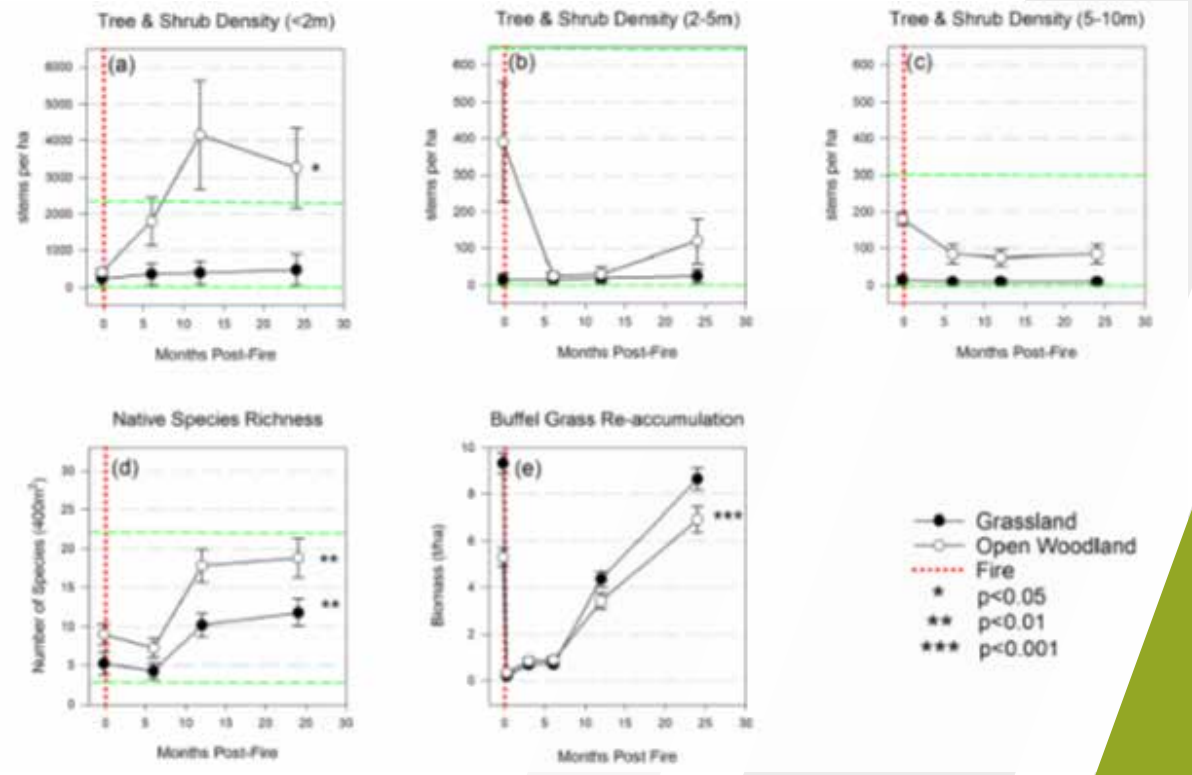


Figure 1. Vegetation metrics measured pre-and post-fire: (a) tree and shrub density height class <2 m (b) tree and shrub density height class 2-5 m, (c) tree and shrub density height class 5-10 m, (d) native species richness and (e) buffel grass re-accumulation following fire. Tests for statistical significance represent paired t-tests pre-fire v 24-months post-fire. Note the difference in scale between (a) and (b-c). Green horizontal dashed lines represent historical unburnt ranges (n=145).

Area results for fire impact classes for dNDVI severity map and 12-and 24-month post-fire recovery maps.

Map	Location	Metric	High Regrowth	Unburnt / Low Regrowth	Low Severity	High Severity	Total
Fire Severity	Whole Area	Area (ha)	-	30	30	57	117
		%	-	25.64	25.64	48.72	100
	Grassland	Area (ha)	-	4	8	26	38
		%	-	10.53	21.05	68.42	100
	Open Woodland	Area (ha)	-	26	22	31	79
		%	-	32.91	27.85	39.24	100
12 Month Fire Recovery	Whole Area	Area (ha)	59	58	-	-	117
		%	50.43	49.57	-	-	100
	Grassland	Area (ha)	27	11	-	-	38
		%	71.05	28.95	-	-	100
	Open Woodland	Area (ha)	32	47	-	-	79
		%	40.51	59.49	-	-	100
24 Month Fire Recovery	Whole Area	Area (ha)	72	45	-	-	117
		%	61.54	38.46	-	-	100
	Grassland	Area (ha)	31	7	-	-	38
		%	81.58	18.42	-	-	100
	Open Woodland	Area (ha)	41	38	-	-	79
		%	51.90	48.10	-	-	100

Table 1. Area results for fire impact classes for dNDVI severity map and 12-and 24-month post-fire recovery maps.

Forest gardens are a financially-sound land rehabilitation model

Kamal Melvani[1]

[1]**Charles Darwin University, Northern Territory**

Land rehabilitation in poor, densely populated, tropical countries is more successful when people who manage it gain value. In Sri Lanka, farmers adopt tree-dominant, forest gardens (FGs) to rehabilitate land because they reduce the economic vulnerability of farming enterprises.

To evaluate this claim, FG financial performance was investigated and compared with other components of farming enterprises in short (reference year, 2012-2013) and long-terms (beyond 2013). Farming enterprises comprise On farm (land uses including FGs, paddy, cash crops, plantations, swidden plots and livestock), Off farm (eg. employment, trading, grants) and household (farmer's family) components.

Farmers' values were collected for 85 farming enterprises in nine locations of the Intermediate zone using household income and expenditure surveys, floristic, timber and fuelwood inventories and area of land uses mapped. Data were quantified using accounting procedures.

Forest gardens occupied the largest area and had the highest floristic diversity of all land uses. Tree crops were more productive than seasonal crops despite multiple stressors including rainfall variability, animal pests and labour shortages. In the short-term, FGs contributed 29% to household food self-sufficiency, generated the highest profit and profitability, and were the most financially efficient land use in the On farm component. Average FG profit was greater than enterprise profit (Current assets) and composed the largest share. In the long-term, FGs had the highest number of timber and fuelwood species (biological assets) with the highest Net Realisable Value (NRV). Forest gardens contributed 90% of total NRV (all land uses) and were repositories of biological assets in enterprises. Occupying 68% of the study area, FG land and biological assets were significant Noncurrent assets. Current and Noncurrent FG assets collectively contributed 79% of farmers' equities.

Forest gardens have immense potential to rehabilitate land in poor, densely populated tropical countries because they improve farmers' livelihoods and are resilient to stress.

Recreating wallum wetland habitat for threatened 'acid' frog species

Ed Meyer[1], Mark Bayley[2], Mark Sanders[3], Clinton Heyworth[4]

[1]**Freelance ecologist, Australia**

[2]**Australian Wetlands Consulting Pty Ltd, Australia**

[3]**EcoSmart Ecology, Australia**

[4]**Tasmanian Fire Sevice, Tasmania**

'Acid' frogs are a specialized group of frogs inhabiting oligotrophic, acidic, ground-water-dependent wetlands in areas of 'wallum' habitat along Australia's east coast. The wallum habitat occupied by these species has been extensively cleared and modified through agroforestry, sand mining, and urban development. Development of urban areas and associated infrastructure remain a significant threat to areas of acid frog habitat on the southern Queensland and northern New South Wales coast. To address the ongoing loss of acid frog habitat in these areas, a number of attempts have been made to recreate/construct wetland habitat suitable for acid frog species with mixed success. In this paper, we examine some of the challenges associated with successfully recreating breeding habitat for acid frog species and consider the lessons learned from a number of different acid frog habitat recreation projects in southern Queensland. Determinants of successful creation of 'acid' frog breeding habitat, including biotic and abiotic factors such as soil structure and groundwater hydrology, are also discussed.

Community solutions to rehabilitating seabird breeding habitat on Big Island (Booirodoong), Five Islands Nature Reserve

Rowena Morris[1], Peter Button[1], Nicholas Carlile[2], Chris Lloyd[3], Kevin Mills[3]

[1]**New South Wales National Parks and Wildlife Service, Office of Environment and Heritage, New South Wales**

[2]**Science Division, Office of Environment and Heritage, New South Wales**

[3]**Friends of Five Islands, NSW National Parks and Wildlife Service, New South Wales**

Community involvement has been one of the driving forces to support the rehabilitation of seabird breeding habitat at the Five Islands Nature Reserve. Big Island is located 450 metres off the mainland at Port Kembla in New South Wales, Australia (34°29'24" S, 150°55'42" E). Rehabilitation efforts commenced in 2014 to control the extensive weeds impacting on the burrowing seabirds. White-faced storm-petrels Pelagodroma marina, Wedge-tailed shearwater Ardenna pacifica, Short-tailed shearwater A. tenuirostris and Little penguins Eudyptula minor suffer from weed entanglement and loss of burrowing habitat. Two key weeds, Kikuyu Grass Cenchrus clandestinum and Coastal Morning Glory Ipomoea cairica, were sprayed with a broad-spectrum systemic herbicide delivered aerially with the aid of helicopters and by on ground spot treatments. Plantings of native seedlings were undertaken by local contractors and volunteers.

Community involvement in the project has been extensive including local traditional knowledge, scientific expertise, plant propagation, marine transportation, university research and local volunteer members. Traditional knowledge was shared at the commencement of the project through circumnavigation boat trips by Dharawal elders and art workshops. Paid contracts with Berrim Nuru Environmental Services ensured the local Koori (NSW Aboriginal) community were involved. Guidance was obtained through a working group of dedicated volunteers and OEH scientific staff. Scientific support was also obtained by seeking assistance from retired academics, a volunteer seabird study group and the local university. Wider community involvement was achieved by working with the local Marine Rescue volunteers to provide transport to the island. Establishment of the volunteer group Friends of Five Islands ensured the success of the project. Analysis of the community input is measured using social, temporal and spatial indicators. The purpose of this presentation is to discuss how the social dimensions of the project are designed to ensure the long-term commitment and funding to the rehabilitation of seabird nesting habitats at the Five Islands Nature Reserve.

Assessing understorey vegetation diversity of savanna woodland to inform mine-site restoration in Kakadu National Park

Jaylen Nicholson[1], Mitchel Rudge[2], Lorna Hernandez-Santin[3], Natashe Ufer[3], Jon Schatz[4], Peter Erskine[3], Renee Bartolo[2]

[1]**Department of the Environment and Energy, Supervising Scientist Branch, Australia**

[2]**Department of the Environment and Energy, Supervising Scientist, Australia**

[3]**Centre for Mined Land Research, The University of Queensland, Queensland**

[4]**CSIRO Land and Water, Tropical Ecosystems Research Centre, Australia**

The Ranger uranium mine, surrounded by Kakadu National Park, is scheduled to close in 2026, with mining of stockpiles to cease in 2021. The Australian Government's Environmental Requirements for Ranger requires restoration to result in revegetation which is "similar to surrounds" in terms of species composition, structure, and ecological function. However, community structure and composition of understorey vegetation in savanna woodland surrounding Ranger had not been sufficiently described to guide mine site restoration. In order to derive closure criteria for ecological restoration, detailed measurements of the structure and composition of savanna understorey vegetation is required.

Eight 1 hectare plots were established within a 10 km radius of Ranger and sampled using the Ausplots Rangelands Survey Protocol late in the 2017/2018 wet season. At one metre intervals along ten 100 m long transects located within each plot, a measurement of species presence and height was made.

Understorey was highly diverse with 220 (out of a total 276) plant species recorded across all eight plots. However, 123 of these species were only found in one of eight plots indicating high beta diversity across the landscape. The six most abundant species made up on average over 75% of understorey cover. Multi-variate analyses revealed both clear groupings and separations in species composition and vegetation cover such that all sites were within 20% similarity of each other, and were completely dissimilar at 70% similarity (i.e. all plots are at least 30% dissimilar to each other).

Although understorey diversity is high, the majority of vegetation cover in each plot is consistently dominated by a few species. However, for restoration to be considered "similar to surrounds", the variability in understorey composition must be taken into consideration. Ultimately, a reference ecosystem will be created to guide and assess the success of restoration at Ranger.

Reverting the Brisbane River Estuary from brown to blue

Jesper Nielsen[1]

[1]**The University of Queensland, Queensland**

The Brisbane River no longer serves as the backbone of Brisbane's economy, providing no natural resources or passage to large vessels beyond the central business district. This is unusual for a river flowing through a capital city. Where cities around the world continue to engineer their rivers to support their respective economies, Brisbane has the opportunity to engineer the Brisbane River to improve its health and the amenity already provided to Brisbane's residents and guests.

The turbidity within much of the Brisbane River Estuary cycles on timescales of the ebb and flood tide, spring and neap tidal cycles and on an annual scale. Analysis of past data sets, the development of processed based numerical models and field monitoring has demonstrated that the annual cycling in the estuary's turbidity is driven by exchanges of fine sediments between the inter and subtidal zones.

For several months of the year spring high tides repeatedly occur during periods of calm winds, facilitating the net transport of fine sediment from the subtidal zone to the intertidal zone. Subsequently the turbidity gradually decreases to a minimum in September. An increase in the winds results in the erosion of the intertidal sediments, reintroducing them to the sub tidal zone where they are repeatedly suspended by the tidal currents and subsequently contribute to the estuary's turbidity (Figure 1).

Crinum pedunculatum (local native) responds well to assisted propagation, survives at the low tide limit and is of a form conducive to wave blocking. Thus mass planting of Crinum will result in enhanced settling of sediment in the upper intertidal zone where the existing vegetation (mostly Avicennia marina, Aegiceras corniculatum and Bacopa monnieri) would provide further stabilization. Assisted mangrove colonization of the rock walls which line much of the estuary would also act to reduce the turbidity, again by encouraging the fine sediment to settle and remain within the intertidal zone. Experiments to determine an effective means of achieving this colonization are underway.

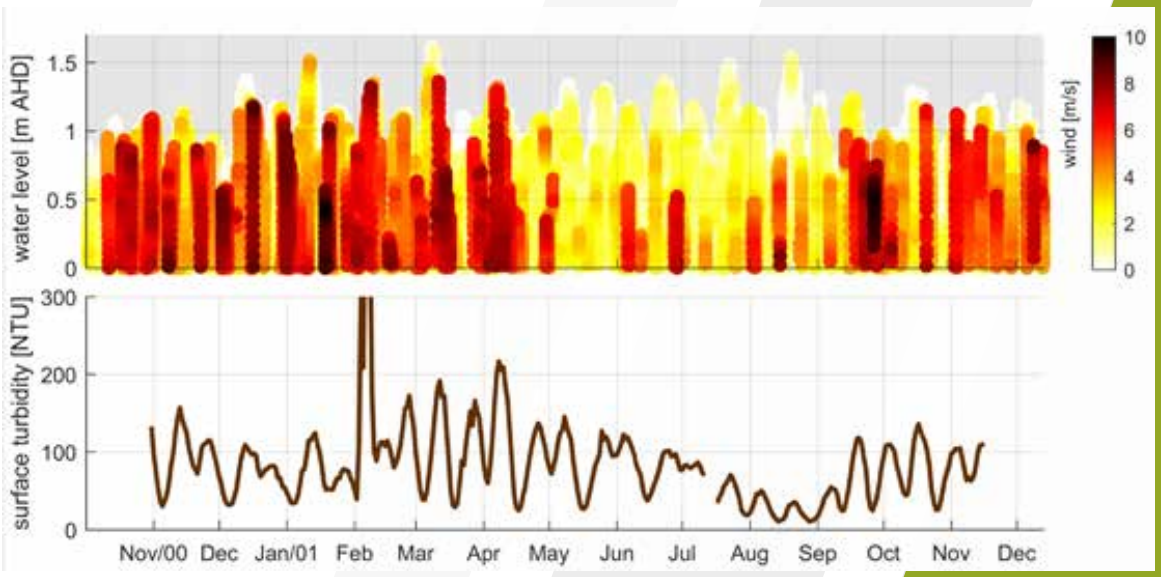


Figure 1.

Bungawalbin Catchment Endangered Emu Conservation through habitat enhancement, vertebrate pest control and community engagement.

Paul O'Connor[1], Dan Cox[1]

[1]**Envite Environment, Australia**

Envite Environment, Bungawalbin Landcare, Native Title Holders, local land managers and landholders have been actively working to conserve one of the subpopulations of the Endangered Emu within the NSW North Coast Bioregion. This has involved plan development, landholder engagement, strategic weed control in areas known or thought to be important for emu habitat and/or movement. Vertebrate Pest control works have generally occurred during spring/ summer and autumn and targetted wild dogs, foxes, feral cats and feral pigs. The control program has involved remote camera monitoring, 1080 baiting, trapping for pigs and wild dogs (soft jaw trapping/panel) and supplemental ground shooting.

Community engagement activities have included: a questionnaire to assess local interest, knowledge and opinions of emu status / threats, involvement in NPWS community Emu counts, involvement in habitat enhancement works by Aboriginal contractors and other landowners, facilitating vertebrate pest control induction and training for landowners, provision of remote cameras to assist surveys for emus/feral predators on landowner properties, vertebrate pest control, workshops, field days to discuss/demonstrate ways to enhance habitat and manage threats.

Recent habitat enhancement work has involved 10 properties and vertebrate pest control over > 4500 ha of private land. NPWS, Forests Corporation and landowners are undertaking better co-ordinated pest control efforts. Over 330 ha of private and priority public land has been controlled for lantana using splatter technique. Camera monitoring results indicate that wild dogs are the most relatively abundant and widespread (50 % of detections and 79% of locations), followed by feral cats (19.5%/ 36 %), foxes (14.8 %/ 36 %). Emus were recorded on 25 or 6.8% of all detections and 29 % of all locations. Camera trapping is continuing to be used to guide location of pest control efforts and provide information on emu movements.

Balancing acts: Staged restoration of endangered species habitat in the Brickpit, Sydney Olympic Park 2006-2018

Jenny O'Meara[1], Andrew Jack[1]

[1]**Sydney Olympic Park Authority, New South Wales**

Sydney Olympic Park is a large urban park containing both remnant and constructed landscapes that underwent significant restoration in preparation for the 2000 Olympic Games. The challenge at The Brickpit, a disused quarry where invasive environmental weeds were allowed to establish large stands, is how to balance the removal of dominant invasive environmental weeds while retaining or

enhancing habitat for a diverse range of fauna species, including threatened species. Sydney Olympic Park's monitoring program provides important information on the ecology of target species, particularly species response to vegetation management within their habitat. This information provides direct input into an adaptive management program aimed at supporting future decisions. Regular monitoring, use of a multiskilled team and an adaptive management strategy are crucial to ensuring that vegetation management is improving, or at least retaining habitat values, and not having an adverse effect on the populations of key fauna species. Evaluation of progress through monitoring is an essential step to understand the degree of success in restoration of degraded ecosystems.

Scaling Up Reforestation: Lessons learnt from three different reforestation approaches in Myanmar

Thaung Naing Oo[1]

[1]**Forest Research Institute, Myanmar**

Deforestation occurred at an alarming rate in Myanmar for four decades due to many factors. Annual deforestation rate was the most serious during 2010 and 2015 and it amounted to 572,326 ha (1.7 percent). Reforestation is a cost-effective nature-based solution which promotes multifunctional landscapes and aims to regain a balance of ecological, social and economic benefits from forests and trees.

Restoration of degraded forests has been implemented with three different ownership approaches: government (Forest Department), private and community. Large-scale plantation forestry began in 1980 and about 30,000 ha of forest plantations have annually been formed since 1984. Furthermore, a Special Teak Plantation Programme was launched in 1998 and annually planting rate was about 8,100 hectares of teak plantations. In 2017, the Government of Myanmar launched 10-year Reforestation and Rehabilitation Programme (2017-18 to 2026-17) in order to restore degraded forests for fulfilling the timber demands, climate change mitigation and enhancing ecosystem services.

Community Forestry (CF) officially began in Myanmar in 1995 through issuing of the CF instructions (CFI 1995) and new CFI has been issued in 2016. It represents a significant policy breakthrough for participation in forest governance in Myanmar. CF will be extended up to 1 million ha (2.7 million acres) by 2030. At present, a total of 3,883 CFs covering 211,209 ha have been established throughout the country.

In Myanmar, The Government started to allow the private sector to invest in forest plantations in 2005. At present, private teak and non-teak plantations have been established 26,518 ha and 246,688 ha respectively. Since forest plantation is a long-term investment, there are many issues and challenges that the private investors have been facing.

This paper examines the lessons learnt (success and failure) from three different reforestation approaches in Myanmar, and provides the appropriate recommendations in relation to social, technical, economical and political perspectives.

Evolution of a riparian restoration project: Stabilisation and revegetation of the Damian Leeding Foreshore. Using large hardwood logs on the river bed for erosion protection, bank stabilisation and rehabilitation of mangroves along the foreshore

Marjolein 'Mars' Oram[1]

[1]**City of Gold Coast, Queensland**

In 2015, the Coomera River foreshore at Damian Leeding Memorial Park in the upper estuary was experiencing severe erosion, resulting in the significant loss of trees and destabilisation of the bank. This was resulting in increasing risk to the adjacent pathway, which had the potential to fall into the river, and risk of a break through into a large recreational rowing lake looked imminent. The City of Gold Coast's Catchment Management Unit undertook an assessment of the erosion which led to a foreshore stabilisation project of Damain Leeding Memorial Park and Regatta Parklands covering a 2.5 km riparian foreshore, a freshwater wetland and tidal tributary.

The complexity of the location of the project, coupled with the community's expectations and the immediate need for a solution to manage erosion, led to an innovative approach to stabilise and rehabilitate the foreshore. The project used a combination of hardwood logs (with root balls), hardwood marine piles, and extensive revegetation. The aims of the project are to provide a safe and stable foreshore bank to a popular public park, prevent a breach into the Regatta rowing lake, create resilience in the upper estuary against future floods, create mangrove habitat for erosion protection from boat waves, create habitat for fish, crab, benthic fauna and birds, improve water quality values and showcase a natural alternative to bank stabilisation other than rock.

The presentation will provide an overview of the project area and the erosion conditions, the methodologies used during construction (including the challenges and opportunities encountered), the outcome of the project (including the learnings from the planning and construction phases), and discuss the ongoing five-year monitoring program that is currently underway.

Establishing self-sustaining ecological mine rehabilitation that achieves recognised ecological communities

Travis Peake[1], Liza Hill[1]

[1]**Umwelt, New South Wales**

Regulatory agencies are increasingly requiring proponents to demonstrate that mine rehabilitation meets a certain level of ecological function and self-sustainability. While there is some policy and legislative provision for the use of ecological

mine rehabilitation to offset impacts, the quantum is usually restricted due to the significant knowledge vacuum that exists around likely rehabilitation success. Biodiversity offsets are costly and in many intensively mined areas (e.g. Hunter Valley NSW; Bowen Basin Qld.) they are hard to obtain, establish and maintain. This situation encourages mining proponents to minimise substantial and costly biodiversity offset obligations through the provision of ecological mine rehabilitation dedicated to offset biodiversity impacts. Previous studies have provided preliminary but encouraging indications that complex ecological mine rehabilitation is possible, but they have pointed to the need for more thorough investigations.

The function and self-sustainability of mine rehabilitation will be measured using an applicable metric approach, particularly in relation to threatened ecological communities listed under state and Commonwealth legislation. This will include the suitability of mine rehabilitation in providing substrates, habitat components and strata for the development of complex ecological communities and for threatened species. Existing mine rehabilitation will be measured against ecological function and recognisability success criteria.

Based on the review of existing outcomes, and collection of field metrics, this project will develop a set of establishment principles, monitoring guidelines, and performance/completion objectives and criteria to enhance ecological outcomes, measurability and reporting, together with the appropriate valuation of ecological mine rehabilitation in terms that provide improvement incentives to the coal mining industry as well as regulatory mechanisms for offsetting and mine site approvals.

The past, present and future of the native seed market in Europe

Simone Pedrini[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

An increased awareness of the importance of natural habitat and native species triggered the European Commission in 1992 to pass the Habitat Directive, the most significant legislation for biodiversity conservation in Europe to date. As a consequence of this directive, countless projects, research, and business opportunities for conservation and restoration were created in Europe.

Private companies began to farm native seed from locally sourced material to meet the demand for ecological restoration. Germany was at the forefront of the emerging native seed market, by structuring a national association of producers that guaranteed the provenance and quality of native seed. However, this market was not clearly regulated. The major agricultural enterprises dealing in fodder varieties, whose market share was affected by the competition of native seed producers, lobbied Brussels to pass a new Directive (60/2010). This legislation, in spite of being framed as "providing derogates for preservation mixtures", in reality posed serious limitations for the development of the native seed market.

In response to this legislation, the native seed producers across Europe are now rallying together and getting organised in a continent wide association to prove to the EU commission the real environmental and social values, and economic potential of a European Native Seed Market.

If successful, this model could be applied to other countries where the need of restorative activities will require a reliable source of native material.

Choosing appropriate seed sources: The importance of environment, genetics and demography for predicting restoration outcomes

Melinda Pickup[1]

[1]**Barton Group, Australia**

A central issue in ecological restoration is the choice of appropriate source material. This is increasingly important in the era of rapid environmental change, as the level of genetic variation in restored populations will determine their adaptive potential. Furthermore, having a diverse genetic base is essential because restored populations are often established in novel environments. Despite the importance of genetic variability to restoration outcomes, there are many questions about how the genetic composition of the founders may reduce establishment success due to maladaptation to local environmental conditions. Most traits underlying adaptation have a polygenic basis (i.e., quantitative traits), where adaptation is controlled by a very large number of genes which all have a small effect. Theoretical models based on quantitative traits can therefore provide the means of testing different seed sourcing strategies to examine the effects of environment, demography and genetics on restoration success.

Here we use simulation models to examine how distance from the environmental optimum, number of founders, sourcing from multiple populations (composite provenencing) and the size and level of inbreeding in the source population influence restoration outcomes.

Initial results suggest that both demography and genetics are important for population establishment and that these factors interact with the strength of environmental selection. We found that the probability of establishment was higher when the difference in the optimum trait value between the source population and restored site was smaller and when the population was established with more individuals. The strength of selection was also important with stronger environmental selection leading to a lower probability of establishment, especially when there was a greater difference between the optimum trait values in the restored and source populations. This model provides a new theoretical framework to assess the processes and outcomes of restoration for quantitative traits and may assist in optimising seed sourcing strategies for population restoration.

Determining restoration potential of livestock grazed Mediterranean shrublands using fenced grazing exclosures

Zoe Poulsen[1], Muthama Muasya[1], Timm Hoffman[1], Pippin Anderson[1], Odette Curtis[2], Samson Chimphango[1]

[1]**University of Cape Town, South Africa**

[2]**Overberg Renosterveld Conservation Trust, South Africa**

Renosterveld vegetation is one of the world's most species diverse Mediterranean type shrublands and forms part of the Fynbos Biome in South Africa's Cape Floristic Region (CFR). It is particularly known for its extraordinary diversity of geophytes. In the Overberg region there are four renosterveld types, all of which are Critically Endangered due to transformation for agriculture. Only 4-6% of its former extent remains. Continuous heavy grazing by domestic livestock is a significant threat.

This research aims to develop a protocol and conceptual model to use ecological thresholds and alternate stable states theory to evaluate restoration potential of overgrazed renosterveld and prioritise sites for restoration interventions. It also provides valuable baseline data on responses of renosterveld vegetation to varying degrees of livestock grazing. This is done using a series of 19 fenced grazing exclosures across three types of Overberg Shale Renosterveld monitored over three years.

Preliminary results suggest that species diversity is higher at sites subject to medium grazing and lower at sites with low and high grazing intensity. Sites degraded by continuous heavy grazing were often invaded by non-native grasses which may pose a challenge to effective restoration. Plant productivity of palatable Overberg Renosterveld species such as Aspalathus nigra and Themeda triandra was significantly decreased with increased grazing impact. Vegetation cover and height of palatable species increased at medium grazing intensity sites following erection of fenced grazing exclosures, whereas at sites with low to high grazing intensity there was little change. It is concluded that restoration potential using passive restoration is higher at sites subjected to medium grazing intensity whereas areas that have had continuous heavy grazing may need active restoration interventions to ensure their recovery.

Six years and $250,000 - what a community group learnt from implementing a major project

Suzanne Pritchard[1]

[1]**Coal Point Progress Association, New South Wales**

This presentation will showcase the outcomes and learning gained from a six-year, $250,000 Environmental Trust community bush regeneration project, The Threatened Species Last Stand on the Coal Point Peninsula, which was completed on 30th June 2018.

The Coal Point peninsula ridgeland and Carey Bay floodplain hold the remnants of a botanically bygone era. The ornamental gardens of early settlers from the 1800s had become environmental transformers. This project aimed to regenerate a 20.2 ha mosaic of public-private bushland along the Coal Point ridge and 8.7 ha of wetlands and catchment at Carey Bay.

A successful 17 year history of local landcaring, prior to the project commencing, inspired the Coal Point Progress Association landcarers to undertake a whole peninsula project to protect and preserve three endangered ecological communities, two endangered populations and five vulnerable species. Community communication in the form of a monthly newsletter, blog and social media supported community monitoring, participation and information sharing.

Over 23,000 hours of volunteer labour have been contributed to on-ground bush regeneration, hosting and delivering local events, community communications, flora and bird surveying and community meetings. The project has formally identified the presence of local threatened species and set multiple reserves on the bushland peninsula on a recovery trajectory. The roles and support of various community groups and Lake Macquarie City Council will be discussed.

Now the final report has been submitted, this presentation provides an opportunity to reflect on and share what has been an extensive, extremely satisfying and rewarding project for the local community and the bushland which surrounds us.

Case study of avifaunal diversity of wetlands in industrial and non-industrial areas, Vadodara, Gujarat, India

Jagruti Rathod[1], Amita Sankhwal[1], Deepa Gavali[1], Ishani Patel[2], Dhara Shah[3]

[1]**Gujarat Ecology Society, India**

[2]**J research Foundation, India**

[3]**Arvind Envi Sol Limited, India)**

Wetlands play an important role in the water cycle, maintaining water quality

and acting as a transition zone between terrestrial and marine habitats. It is important to manage the health of wetlands because it sustains many human lives. Avifaunal monitoring can be a useful indicator of condition to help design possible management strategies of wetlands. This study was conducted in two clusters of wetlands in the peri-urban areas of Vadodara city lying in the semi-arid region of Gujarat. The study objective included the impact of industrialization on avifauna and wetland ecology. One group of wetlands (4 sites) was studied in the industrial zone and the other group in the non-industrial zone (6 sites). Biological indices of birds were used to infer the quality of wetland and provide management strategies of wetlands.

The study revealed Barn swallow (Hirundo rustica) to be an indicator of the wetlands conditions. Wetland comprised of edges vegetation like Neem (Azadirachta indica), Pipal (Ficus religiosa), Acacia nilotica, Banyan (Ficus benghalensis), Typha spe. (aquatic plant), Ipomoea spe, etc. Apart from the avifaunal diversity, proper status of the wetlands was documented. The quantum of human interventions both positive and negative was assessed to help formulate management strategies. The paper presents different strategies that could be implemented for effective wetland management like creation of floating vegetation, installation of wood logs, prevention of solid waste dumping, leases for fishing and others. Implementing the right combination of strategies can restore and improve the conditions of wetlands and aid wetland conservation.

Bleaching mitigation and restoration of Micronesian Staghorn Acropora

Laurie Raymundo[1], David Burdick[2]

[1]**University of Guam Marine Laboratory, Guam**

[2]**Guam Long-Term Monitoring Program, Guam**

Prior to 2013, coral reefs in the Mariana Islands had not experienced major bleaching mortality despite global bleaching events beginning in the 1980s. However, moderate-to-severe bleaching events affected Guam's nearshore reefs in 2013, 2014, 2016, and 2017, with current sea surface temperatures on track for a significant bleaching event in 2018. Reefs were also subjected to extreme tides in 2015 and disease outbreaks in 2017. Staghorn Acropora, which form extensive stands on shallow reef flats in Guam, were particularly devastated, suffering >50% loss between 2013 and 2015. 2017 surveys determined that five out of 21 populations had disappeared. Four staghorn species have only been observed at a single location since 2013, with two each represented by a small cluster of branches. Dead stands have been reduced to rubble or have become recruitment substrates for genera, such as Pavona, Pocillopora, and Porites, which may be in the process of replacing staghorns. Recovery in remaining stands has not kept pace with successive, almost annual, bleaching, resulting in a net annual loss of coral cover.

The impacts of these catastrophic events on Guam's coastal ecology are unprecedented in recent history, and their influence on the island's tourism-dependent economy, culture, and climate change resilience is beginning to be realized. This highlights the need for urgent management responses to conserve remaining populations. Staghorns provide a tractable group of corals for management efforts, as they form discrete, accessible communities; are essential fish habitats; grow fast; and respond well to asexual propagation. A management plan has been developed which focuses on: 1) monitoring recovery of remaining stands; 2) determining environmental

attributes that could facilitate staghorn recovery; 3) using this information to guide identification of sites suitable for restoration; 4) culturing and propagating selected species for outplanting; and 5) developing and testing outplanting protocols.

Implementing strategic coastal wetland restoration on a catchment scale

Duncan Rayner[1], William Glamore[1], Jamie Ruprecht[1]

[1]**Water Research Laboratory, University of New South Wales, New South Wales**

Identifying sustainable floodplain restoration opportunities requires a detailed understanding of existing land uses and catchment wide estuarine processes. This is particularly relevant when considering restoration across the developed estuarine floodplains of south-east Australia. In many cases, management actions are focused on the most vocal proponents. To overcome short-term reactionary management, a holistic evidence-based approach is required. This is important when considering complex issues such as catchment impacts to estuarine health and the identification of poor water quality hotspots resulting from acid sulfate soil impacted coastal backswamps. Strategic restoration of degraded backswamps and wetlands that contribute most to poor estuarine health provides the greatest return for resource managers and catchment-wide ecology.

A methodology was developed to assess and prioritise the impact of degraded backswamps wetlands within coastal floodplains catchments and rank them based on their impact to the estuary. The prioritisation methodology uses a number of key factors including: floodplain drainage, sub-catchment hydrology, groundwater conductivity, groundwater quality, soil acidity, proximity to sensitive receivers, drainage asset condition, and climate change.

Following identification, priority restoration sites are assessed in detail using an approach that includes extensive site investigation and characterisation, long-term site monitoring, and detailed hydrodynamic/water quality modelling. Calibrated numerical modelling enables a range of restoration scenarios to be tested, with subsequent habitat extents quantified, impacts to adjacent landholders minimised, climate change impacts investigated and on-ground works requirements assessed. This proven approach focuses on utilising catchment and estuarine hydrology as the main driver for water quality improvement and ecological change. Examples of coastal wetland restorations implemented using these methods include Tomago Wetlands (Hunter River), Yarrahappini Wetlands (Macleay River), Big Swamp (Manning River), Everlasting Swamp (Clarence River) and Broughton Creek (Shoalhaven River).

Mapping reconstructed plant community types in cleared areas of NSW

Adam Roff[1], Vicki Logan[1], Matthew Hingee[1]

[1]**Office of Environment and Heritage, New South Wales**

The NSW Office of Environment and Heritage (OEH) is developing an approach to mapping the prior extent of Plant Community Types (PCTs) in cleared areas of NSW to deliver a state-wide map and estimates of pre-cleared vegetation for NSW. The information will better inform government, industry and the community.

Historical reconstructions of native vegetation across cleared lands face methodological challenges, data limitations and uncertainties. Working assumptions were made explicit. Decisions were made about extant communities which are considered 'derived'.

Our approach to prior extent reconstructive mapping is based on available current extant native vegetation mapping. Our primary tools include ARCGis, ADS40 imagery, floristic survey sites and imagery interpretation. Modelling is used initially to map 12 broad landscape-scale Patterns using Boosted Regression Tree Analyse followed by manual editing. At this stage, over 18 archival '1750' maps were consulted. Plant Community Types that had been assigned to each of the 12 landscape Patterns were modelled into the 12 Patterns. The final map is again manually edited.

This method has been trialled for the NSW Murray-Riverina and Western regions. The difference between the extant PCTs and the reconstructed PCTs provides statistics about the relative extent of loss or gain of native vegetation.

A different approach was taken to mapping reconstructed PCTs in the Western Region. Large areas of Western Region remain largely unmodified, with only small areas requiring native vegetation reconstruction. In this case, mapping of landscape Patterns was undertaken using manual visual interpretation.

Using data from drones to derive restoration targets for Ranger Uranium Mine

Mitchel Rudge[1], Timothy Whiteside[1], Jaylen Nicholson[1], Lorna Hernandez-Santin[2], Natasha Ufer[2], Peter Erskine[2], Renee Bartolo[1]

[1]**Department of the Environment and Energy, Supervising Scientist Branch, Australia**

[2]**Centre for Mined Land Rehabilitation, The University of Queensland, Queensland**

Ranger uranium mine is surrounded by the World Heritage listed Kakadu National Park. The mine operators plan to cease production by 2021 and finalise rehabilitation by 2026. The operators are required to establish an ecosystem similar to those in adjacent areas of Kakadu National Park, and restoration targets will be set

using a reference ecosystem approach. The vegetation of Kakadu is spatial variable and would not be fully captured by ground-based plot surveys. Drones represent an emergent technology that can enable rapid, cost effective measurement of vegetation at the landscape scale. The Supervising Scientist Branch are using drones to establish landscape scale reference ecosystems to develop restoration targets for Ranger. Here, we compare data from ground based plot surveys with data captured by drones to determine which vegetation attributes can be captured directly by drones and scaled accordingly.

We established eight one-hectare plots within a 10 km buffer around the mine using stratified, randomised site selection. During the 2017/2018 wet season, data including RGB, multispectral, hyperspectral and LiDAR were acquired at each plot using a range of drone platforms. During the same field campaign, ground based point intercept surveys were conducted at each plot using the Ausplots Rangeland Survey Protocol to quantify percentage cover per species.

The Ausplots ground survey results confirmed the spatial variability of ecosystems surrounding the mine, with species accumulation curves indicating that an unrealistic effort would be required to fully capture species variability. We are currently analysing RGB and multispectral data using machine learning with a Random Forest Classifier to obtain percentage cover of the dominant species (e.g. Sorghum spp., Eucalyptus miniata and Erythrophleum chlorostachys). Preliminary results support the use of drones to derive species composition and structural diversity metrics at the landscape scale to provide restoration targets for Ranger.

Using the YouTube platform to promote Gondwana Link eco-restoration projects

Basil Schur[1]

[1]**Green Skills, Western Australia**

Western Australian NGO Green Skills has partnered with local film makers to make YouTube short video documentaries that highlight various citizen science and other ecorestoration projects in Gondwana Link. These have proved to be an effective science and eco-restoration communication tool because they are easily assessible by a diverse audience, assist with networking and participation, are easily affordable, and allow for gathering of access metrics. In addition, such YouTube clips have proved to be very useful in crowd funding campaigns, acquittal reports, links in e-newsletters and feedback for citizen science participant volunteers.

Examples include: "The Living Wetlands of Gondwana Link: caring for Wilson Inlet & its catchment". This documentary outlines the significance of this Inlet and its wetlands for Noongar culture, as a hotspot for migratory shorebirds, and as a good example of community action for the environment **(https://www.youtube.com/watch?v=80lyV7LP6hc).**

Other Youtube videos focus on the citizen science program of Chingarrup Sanctuary near Boxwood Hill, **(https://www.youtube.com/watch?v=EjC2QZKCjeY),** and on Balijup near Tenterden **(https://www.youtube.com/watch?v=oLaxA5Lc1Sc)**. A fourth one focusses on the Lake Muir Unicup wetlands **(https://www.youtube.com/watch?v=qZcDcaqNWug).**

This paper will provide practical information on how others can use YouTube to communicate their science message.

Using Hooded Plovers to promote restoration of lake foreshores in WA's Great Southern

Basil Schur[1]

[1]**Green Skills, Western Australia**

This paper reports on an innovative program that links protection and rehabilitation of Salt lake foreshores with conservation of Hooded Plovers, a beach-nesting species at risk of becoming endangered. The paper will present a case study of collaborative foreshore and habitation restoration projects on broad acre farms in the Cranbrook area of WA's Great Southern. These form part of Green Skills' Gondwana Link wetland conservation program.

The aim of the project has been to expand the uptake by broad acre farmers of lake foreshore fencing and conservation assistance across the suite of wetlands in the area north of WA's Stirling Range National Park. This has been achieved through offering fencing subsidies, technical advice and revegetation assistance to farmers in collaborative lake conservation projects. Additional encouragement to landholders has come through inviting their involvement or interest in bird surveys focussing on Hooded Plover and other shorebird species for wetlands on their farms. There has been an increased uptake of support for foreshore works, in part directly linked to greater local awareness of the high value of these salt lakes for Hooded Plovers.

(Reference: https://greenskills.org.au/download/cranbrook-lakes-and-hooded-plover-report-v18-may-2018/).

How did we go? A genetic analysis of the Gossia gonoclada rare tree recovery program

Laura Simmons[1, 2], Tamara Taylor[3], Alison Shapcott[1]

[1]**University of the Sunshine Coast, Queensland**

[2]**Queensland Herbarium, Queensland**

[3]**Griffith University, Queensland**

Gossia gonoclada is an endangered tree that is restricted to extremely limited areas of remnant riparian rainforest in highly urbanised south-east Queensland. A recovery program was undertaken in the 1990s with the aim of arresting the decline of the species in the wild and maintaining viable in situ populations and included conservation genetic studies to inform propagation and planting of recovery populations. Natural attrition of individuals, concern of clonal spread and the significant threat of the invasive fungal plant pathogen myrtle rust, has prompted a re-assessment of the natural and recovery G. gonoclada populations to inform further recovery efforts.

21 polymorphic microsatellite markers developed from ddRADseq libraries were utilised to genotype each natural (23 of 26 remaining plants) and recovery (79 offspring) individual and assess genetic variation, diversity and levels of inbreeding in the natural and recovery populations (17 total).

Unique genotypes were identified, which will be useful in matching pedigrees with myrtle rust resistance information. Wild plants have retained relatively high levels of species genetic variation across all populations (As = 3.2) and we found little evidence of clonal spread within source populations with little genetic clustering or isolation of wild individuals and populations. All of the recovery populations had moderate to high levels of excess heterozygosity; however, these were similar to the largest wild population and expected given the limited gene pool for the previous recovery plan. The genetic diversity of the species has been captured in the recovery actions and is spatially well spread, with representation of the genotypic composition of the wild populations and increased average levels genetic diversity in recovery populations compared to the wild populations. Future restoration programs should focus on sourcing propagating material from genetically diverse wild and offspring individuals and continuing to capture the full genetic representation of G. gonoclada.

Defining the parameters of successful bush regeneration outcomes.

Brendan Stephen[1]

[1]**Natural Bushland Ecology, Queensland**

Bush Regeneration is a multi-faceted field of Restoration Ecology which has increased in profile and scope over the last fifteen years. There are many perceptions as to how we measure the results of projects and where we place importance and relevance. The aim of this presentation is to define and discuss these perceptions and to reinforce the importance of the role vegetation dynamics play in this process.

Through my 24 years of experience working and studying in the Restoration Ecology field and the observations I have made, we will discuss and define the priority objectives of Bush Regeneration projects and what is fundamentally important in their assessment and management. There are many approaches to restoring our bushland areas, but I believe it is essential to understand the vegetation dynamics of the communities we are working in, how we can incorporate this understanding into our delivery of Bush Regeneration works and what benchmarks and parameters we establish to effectively asses the success and effectiveness of projects.

Large scale restoration at small scale costs in Southwest Western Australia.

Glen Steven[1], Barry Heydenrych[1], Blair Parsons[1]

[1]**Greening Australia, Australia**

Globally, there is a significant need for cost effective solutions for revegetation to address the consequences of past over-clearing in fragmented landscapes. These consequences include biodiversity decline, land degradation, loss of resilience and reductions in productivity. A barrier to revegetation at scale is the perceived high cost of undertaking revegetation since there is little economic return for landholders in the short term. Although some landholders would pay for revegetation if it

was cheaper, many are willing to fence and prepare their degraded land for revegetation establishment.

Direct seeding has been used intensively for over 10 years by Greening Australia and it can be used very effectively at a large scale for revegetation of native species. Direct seeding has been a game changer or key enabler for ecological restoration because of its cost-effectiveness.

It has many other advantages over traditional revegetation techniques (e.g. tubestock planting) including the ability of seed to germinate when conditions are right, and the fact that seeds, once sown, can germinate over multiple years. The utility of direct seeding is further enhanced as practitioners can now establish plants successfully from seed in most soil types including typically difficult soils such as clays and deep sands, where seedlings were once a necessity.

In this presentation we will share and discuss our experiences using direct seeding to implement thousands of hectares of native revegetation on the south coast of WA. This has involved working on dozens of handpicked landholder properties and delivering via a number of major government revegetation grants. We will also explore differences in ecological outcomes between revegetation established using more expensive techniques and those that have been established at a lower cost.

How rapidly do litter decomposition and decomposer invertebrates return during rainforest restoration on disused pastures?

Marisa Stone[1]

[1]Griffith University, Queensland

Converting rainforest to pasture can have large impacts on ecosystem functioning. It could be expected that vegetation restoration should induce recovery of many ecological functions. However, evidence to test this proposition is scarce. We experimentally quantified litter decomposition, as the rate of mass loss from 1 mm mesh bags containing forest leaves, exposed in the field for 5-8 months. Bags were deployed in 25 sites, with replicate sites representing different stages of vegetation degradation and recovery: old growth forest, grazed pasture, unassisted regrowth (aged five years to several decades since livestock removal from former pasture), and assisted regeneration of similar regrowth 1-10 years after intervention. We found that decomposition occurred more slowly when rainforest had been converted to pasture, but that faster decomposition had returned within a few years following commencement of both unassisted and assisted restoration. Invertebrates are known to play an important role in decomposition. So, to investigate this role we also sampled potential decomposer communities at each site using extraction funnels to separate the invertebrates from litter remaining in the bags after field exposure, and also from independently collected samples of ground surface litter at all sites. Overall abundance of litter invertebrates in pasture sites was much lower than in old growth forest, but had substantially returned in all regenerating sites. Further results will be presented to assess the effect of excluding macro-detritivores on litter decomposition rate, by looking more closely at the abundance and functional composition of invertebrates within feeding guilds, in open versus closed bags across the different habitats. We consider whether decomposition in regenerating

sites occurs through different trophic pathways from those in old growth forest. Irrespective of possible variation in invertebrate contribution and composition, litter decomposition rates recovered more rapidly than did the structure and composition of the vegetation.

The case for a closer look at constructed wetlands for mine water treatment in Queensland

Dominique Taylor[1], Sue Vink[2]

[1]**Simtars, Queensland**

[2]**Sustainable Minerals Institute, Queensland**

In Queensland's coal industry, it is a common requirement to manage mine-affected water to prevent contamination of the environment. A number of conventional methods for bulk water treatment are available, which are typically expensive and require active management and ongoing maintenance. A passive, cheaper, alternative would represent a significant benefit to industry. Constructed wetlands have been successfully employed in the treatment of a variety of water contaminants from a wide range of industries around the world, including coal mines. Do they bear consideration as a viable option for sustainable water treatment in Queensland's coal industry? A review of literature and industry projects in the fields of phytoremediation and other passive water treatment technologies was conducted and compared to the prevalent water treatment requirements of active coal mines in Queensland. The typical profile of coal mine-affected water in Queensland includes high salinity, low pH and may also feature levels of other contaminants that are outside the required limits for release. The vast majority of successful constructed wetlands are located in the world's temperate zones, whereas Queensland's coal mines exist in a subtropical region. This poses real challenges in the form of high evaporation rates and cyclic extremes of rainfall and drought. However, the existence of native halophytic macrophytes, the potential availability of land and the significant benefit of aquatic habitat in terms of mine closure objectives, added to the potential cost efficiencies and improvement in sustainability of the industry, supports ongoing investigation into this ecotechnology. Much of the existing information in this area is highly technical and widespread. Further work is required to consolidate the information relevant to Queensland coal and begin to develop a plain-language manual to increase the utilisation of constructed wetland technology and its potential success through the development of scientifically sound design recommendations.

Addressing Kunzea robusta (kanuka) direct seeding constraints in New Zealand

Ana Magalhaes Teixeira[1], Paula Jameson[2], Timothy Curran[3], Colin Meurk[4], Ian Dickie[2], David Norton[1]

[1]**School of Forestry, University of Canterbury, New Zealand**

[2]**School of Biological Science, University of Canterbury, New Zealand**

[3]**Department of Pest-management and Conservation, Lincoln University, New Zealand**

[4]**Landcare Research, Lincoln, New Zealand**

Kanuka (Kunzea robusta) is a colonist pioneer species which presents a range of characteristics advantageous for direct seeding restoration projects, such as production of large quantities of seeds, rapid germination under favourable moist conditions, and retention of viability when dry. For this reason, kanuka has been included in many direct seeding restoration attempts across New Zealand. While germination of kanuka in the laboratory usually has a high success rate, in the field failure to germinate or establish is the most common outcome. In order to investigate what constrains kanuka establishment, seeds were sown in trays filled with soil collected on the Port Hills, in Christchurch, New Zealand. The site was burned in February 2017, and is currently being restored. The soil was collected from under three different burned vegetation types: areas formerly dominated by Pteridium esculentum (bracken), by Ulex europaeus (gorse), and native conifer-broadleaf forest (bush). Part of the soil collected was sterilised, resulting in six different treatments: sterilised and non-sterilised soil from each of the three vegetation types. Each treatment presented 10 replicates sown with the same amount of seeds (1 gram/m2). The trays were kept in a temperature-moderated glasshouse under controlled irrigation. Fifteen days after sowing, seeds had germinated abundantly in all the trays, and 45 days after that, the average number of seedlings in the sterilised treatments (165 to 182 seedlings) was substantially greater than the number in the non-sterilised treatments (21 to 31 seedlings). The vegetation type did not affect seedling establishment. These results suggest that sterilisation eliminated soil pathogens, benefiting the establishment of the seedlings in the glasshouse. A field trial is currently underway at the same study site in order to test the hypothesis that soil pathogens may constrain seedling establishment and play an important role in kānuka direct seeding outcomes.

Capturing genetic diversity for ecological restoration through seed collecting

Marlien van der Merwe[1], Patricia Lu-Irving[1], Jason Bragg[1], Maurizio Rossetto[1], Thomas Pyne[2]

[1]**Royal Botanic Garden, Sydney, New South Wales**

[2]**Macquarie University, New South Wale**

An aim of restoration ecology is to obtain information on how to build new populations that can adapt to change, are resilient and in the long term self-sustainable. It is well known that increasing genetic diversity in restored populations can assist in this process. Seed collecting forms a vital part of many restoration projects. Guidelines for collecting seed advises restoration practitioners to collect seed from several individuals spread out within a population. The assumption is that this optimises the genetic diversity captured through seed collecting while simultaneously representing 'local provenance'. However, there is little or no empirical data available on the relationship between genetic diversity of seed versus source populations particularly for widely distributed Australian native species (as is commonly used in restoration work). The aim of this presentation is to introduce a satellite project of Restore and Renew (Royal Botanic Garden, Sydney) in which we explore the relationships between source populations versus that of the seed populations. The project uses single nucleotide polymorphism data from seedlings and mother plants from multiple populations and species to address this knowledge gap. For this presentation we will explore the following questions using data for two species, Acacia suaveolens and Banksia serrata: 1. How does the genetic diversity captured through seed collecting represent the genetic diversity of the source population, 2. Is the genetic diversity captured through seed collecting similar across different populations. 3. Are germination and growth rate influenced by seed origin and how does this relate to genomic patterns of diversity. The implications of the results for restoration practitioners in particular seed collectors will be discussed.

Urban forest restoration has opposing indirect effects on litter decomposition and no effect on denitrification

Kiri Joy Wallace[1], Daniel C. Laughlin[2], Bruce D. Clarkson[1], Louis A. Schipper[1]

[1]**University of Waikato, New Zealand**

[2]**University of Wyoming, United States of America**

Forest restoration has potential to recover degraded ecosystem functions in urban environments. Leaf litter decomposition and denitrification are two critical steps in forest nutrient cycling often compromised by anthropogenic activities. When

exotic deciduous trees invade evergreen forests, decomposition rates may be accelerated due to faster breakdown of deciduous leaves. Fertilizer runoff can inflate nitrogen (N) availability, increasing the need for removal through denitrification, the microbial conversion of nitrogen from mineral to gaseous forms. As forest canopies develop following plantings, they may indirectly impact ecosystem functions by altering abiotic conditions. We aimed to determine whether forest canopy openness, topography, and soil sand content would indirectly affect litter decomposition and denitrification by regulating the microclimate, the herbaceous plant layer, soil chemistry and soil moisture.

Research occurred in restored native temperate rainforest patches in the New Zealand cities of New Plymouth and Hamilton. Decomposition rates were determined using mesh leaf litter bags and denitrification rates through denitrification enzyme activity assays. We used structural equation modelling to quantify the direct and indirect drivers of these two forms of nutrient cycling.

Decomposition rates were positively related to soil moisture, relative humidity, and herbaceous plant layer cover (Figure 1). Denitrification was negatively related to soil pH and positively related to soil moisture, but functioned independently of forest structure (canopy openness). Unravelling the drivers of ecosystem functions can improve the restoration of degraded urban ecosystems. The identification of opposing effects can improve management so that restoration actions focus on specific direct drivers that can elicit desired changes. Some ecosystem processes, like denitrification, are not affected by forest restoration, but are instead driven by edaphic and landscape factors. This demonstrates how abiotic properties can sometimes exert stronger control over ecosystem functions than the manipulation of vegetation structure and composition.

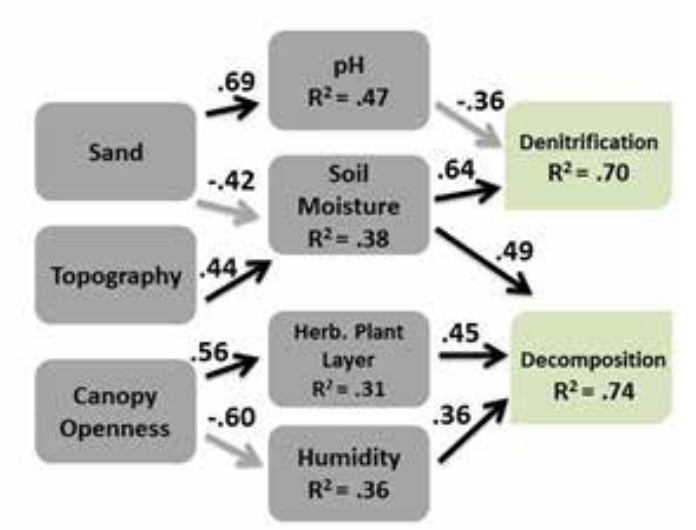


Figure 1. Decomposition rates were positively related to soil moisture, relative humidity, and herbaceous plant layer cover

Direct seeding to restore Drooping Sheoak Grassy Woodlands on Dakalanta Wildlife Sanctuary, Eyre Peninsula, South Australia

James Walsh[1], Shane Norrish[1], Keith Bellchambers[2]

[1]**Landcare Australia, Australia**

[2]**Australian Wildlife Conservancy, Australia**

Landcare Australia, in partnership with Australian Wildlife Conservancy has been undertaking broad acre revegetation work on Dakalanta Wildlife Sanctuary. Dakalanta Wildlife Sanctuary covers 13,600 hectares and occupies an ecologically important location on Eyre Peninsula, South Australia. The project was funded under the 20 Million Trees Program and aimed to restore 1190 Ha of degraded land and establish 595,000 plants.

Drooping Sheoak (Allocasuarina verticillata) Grassy Woodlands have been declining in South Australia for several decades and are listed as 'Rare' in South Australia, this project was designed to restore this community and help reverse that trend. The planning, logistics and materials required for delivering a project of this scale were extensive, with Landcare Australia collecting 1190 kilograms of seed from 50 local indigenous species. A custom built direct seeding machine designed to withstand the calcareous soils found on the project site was also constructed. In addition to this, Landcare Australia also developed and deployed an integrated pest management strategy which adopted a regional approach to addressing the various invasive species that were deemed a threat to the project's success.

Landcare Australia has worked closely with local farmers, community groups, State Government agencies and Aboriginal corporations in order to deliver this large scale restoration project. The exceptional results to date are reflective of Landcare Australia's planning, management and ability to collaborate across all sectors in order to achieve landscape scale restoration outcomes.

The 20 Million Trees project on Dakalanta Wildlife Sanctuary has been extremely successful, with 3 Million trees, shrubs and groundcovers currently estimated to be on site. The project concludes in June 2018 and is expected to well exceed its target of 595,000 trees and shrubs.

Reef Aid: Restoration of wetlands and gullies in priority catchments to improve water quality in the Great Barrier Reef

Lynise Wearne[1], Damon Telfer[2], Delwyn Windridge[1], Sunny Behzadnia[1], Merv Pyott[1]

[1]**Greening Australia, Australia**

[2]**Fruition Environmental, Australia**

As detailed in the 2017 Scientific Consensus Statement, many of the Great Barrier Reef (GBR) ecosystems continue to be in poor condition caused by an interaction between climate and other stressors. Of all these stressors, poor water quality is understood to be the greatest local threat to the future of the GBR beyond climate change. Greening Australia are working to halt the soil erosion, reduce sediments and improve water quality through innovative restoration techniques extending across the GBR catchments. The focus of Greening Australia's current program is on-ground practical restoration within both wetlands and high priority gully areas. To do this, Greening Australia are leading project partnerships, working with government agencies, corporate and philanthropic partners and Natural Resource Management bodies.

The current Reef Aid projects extend from Cairns to Rockhampton. Two wetland projects are working to restore 700 ha of priority wetlands in sites including the Mungalla Wetlands (Herbert River), the West Haughton, Fig Tree Lagoon (Mulgrave River), and the Fitzroy River. These restoration works range from constructed wetlands, installation of bioreactors, solar bores for weed control, and working closely with land managers to sign cooperative agreements and change grazing management practices.

The priority gully projects range from targeting hillslope erosion to restoration of large alluvial gully complexes across the Don, Burdekin and Fitzroy River catchments. A range of monitoring techniques have been implemented to determine reduction of sediment and particulate nutrient loads to the GBR and the costs of achieving those reductions based on different interventions. Phase 1 works were competed in 2017, and the initial results showed a greater than 97% reduction in suspended sediment concentration between treated and untreated alluvial gullies. The current paper will provide information about existing and future restoration works associated with the Reef Aid.

Spatio-temporal analysis of savanna woody cover to drive closure criteria for Ranger uranium mine

Tim Whiteside[1], Andrew Esparon[1], Renee Bartolo[1]

[1]**Environmental Research Institute of the Supervising Scientist, Australia**

As part of the Environmental Requirements provided by the Australian Government to Ranger uranium mine, there is a requirement that restoration of the mine site will provide an ecosystem that is similar to surrounding areas of Kakadu National Park. The surrounding areas are predominantly savanna woodland and open forest comprising of a Eucalypt dominated canopy and annual grass understorey. Proportional cover of these strata are both spatially and temporally variable. For mine close out, a range of closure criteria will be developed to ensure structural diversity similar to reference areas. Tree canopy cover (hereby referred to as woody cover) is a structural parameter that can be used for closure criteria and readily derived from the analysis of remotely sensed image data.

Woody cover over a 66 year time frame was analysed using historical aerial photography and very high resolution satellite imagery. Estimates of woody cover were extracted using an object-based image analysis and were scaled to percentage cover per 1 ha and per land unit polygon. In addition, a number of landscape analysis metrics (including object fate metrics) were applied to the woody cover data. As expected, analysis shows change in cover is variable in both space and time and that the difference between dates is significant. The measured variability can be used to define an envelope of woody cover proportions considered typical for the surrounding areas. This spatio-temporal reference will help inform revegetation standards for the mine. There are a number of potential drivers for this variability including climate, extreme weather events (e.g cyclones), fire, feral animal impact, land use and tenure. Future research includes the inferential analysis of what the primary drivers are and likely future impacts.

Microbial biobanking: Cyanobacteria-rich topsoil facilitates mine rehabilitation

Wendy Williams[1], Mel Schneemilch[1], Angie Chilton[2], Stephen Williams[1], Brett Neilan[3], Colin Driscoll[3]

[1]**The University of Queensland, Queensland**

[2]**The University of New South Wales, New South Wales**

[3]**University of Newcastle, New South Wales**

Restoration of soils post-mining requires key solutions to complex issues because the removal or disturbance of topsoil incorporating soil microbial communities can alter ecosystem function. This research was in collaboration with Iluka Resources at Jacinth-Ambrosia (J-A) mineral sand mine located in a semi-arid chenopod shrubland in southern Australia. At J-A assemblages of microorganisms and microflora inhabit at least half of the soil surfaces and are collectively known as biocrusts.

This research encompassed a polyphasic approach to soil microbial community profiling focused on 'biobanking' viable cyanobacteria in topsoil stockpiles to facilitate rehabilitation.

We found that cyanobacterial communities were compositionally diverse topsoil microbiomes. Cyanobacteria were central to soil micro-processes, strongly supported by species richness and diversity. Cyanobacteria are moderately resilient to stockpiling at depth and over time, with average species richness greatest in the top 10 cm of the stockpiles of all ages, and more viable within the first six weeks, indicating potential for biocrust re-establishment. In general, the resilience of cyanobacteria to burial in topsoil stockpiles in both the short and long term was significant, however in an arid environment recolonization and community diversity could be impeded by drought. Overall, there was no significant difference in cyanobacterial community structure across soil types. Cyanobacteria were a significant component of all three successional stages with 21 species identified from ten sites. Known nitrogen-fixing cyanobacteria comprised more than 50% of the species richness at each site and 61% of the total community richness.

Biocrust re-establishment during mine rehabilitation relies on the role of cyanobacteria as a means of early soil stabilisation. At J-A mine operations do not threaten the survival of any of the organisms we studied. Increased cyanobacterial biomass is likely to be a good indicator and reliable metric for the reestablishment of soil micro-processes.

Acoustic recording to monitor bird song after aerial 1080 operation from an indigenous Maori perspective

Richard Witehira[1], Isabel Castro[2], Stephen Marsland[3]

[1]**Tauahika Ltd, New Zealand**

[2]**College of Agriculture and Environment, Massey University, New Zealand**

[3]**Victoria University of Wellington, New Zealand**

The toxin 1080 is very controversial in New Zealand especially for Maori. Most of the anti-1080 movement is based on out right misinformation and even lies that cast doubt on what we know from scientific studies. One of such falsehoods is that the forest falls silent after a 1080 operation and that we lose most of our native species. In NZ, 1080 is the main "tool in the tool box" that is applied to stop the collapse of biodiversity values, both fauna and flora, in our native forests. For example, introduced predators together with habitat degradation are responsible for 40% of our native birds, which are taonga (treasures) for our people, being endangered. Maori are very active in clawing back their rights as kaitiaki (guardians) of the natural world. However, many have been highjacked by the "anti 1080" movement as activists see Maori as a powerful weapon to fire the bullets on their behalf. It is important to use methods that can bring the positive results of 1080 to the people. Acoustic recording using autonomous recorders is a tool that can produce credible data to prove that this controversial toxin does work.

To use 1080, we went through a long marae (meeting house) based communication process. We have provided training and support for hapu (tribes) from the Bay of Islands to use autonomous acoustic recording to monitor the sounds of the birds before and after a poison drop.

This presentation will show for the first time the process we underwent, and the results of our monitoring before and immediately after a 1080 drop on tribal

lands. The overall project will take three years, so we will also present our plans for the future.

It has been a journey of many challenges, but all worthwhile.

Geochemical and mineralogical factors limiting soil structure formation in magnetite iron ore tailings

Songlin Wu[1], Longbin Huang[1]

[1]**Centre for Mined Land Rehabilitation, Sustainable Minerals Institute, The Univeversity of Queensland, Queensland**

The present study has investigated physicochemical and mineralogical characteristics of magnetite iron (Fe) ore tailings, compared to native soil, at Karara Mine, West Australia. Iron speciation and localization were examined in Fe-bearing minerals of the tailings. The results showed that the tailings was extremely alkaline (pH > 9.0), with high abundant phyllosilicates (like biotite), low organic matter and poor physical structure. The tailings sampled from a long-term tailing plot trial at the foothill of the tailings storage facility did not exhibit much significant changes in physicochemical properties and physical structures even after 4 years of revegetation trial, compared those of fresh tailings recently sampled. Iron (oxy)hydroxides (e.g. hematite, goethite, magnetite) were abundant in both aged tailings and soils based on the bulk chemical extraction and spectroscopic analysis (e.g., X-ray direction (XRD) and synchrotron based Fe K edge X-ray absorption fine structure spectroscopy (XAFS) analysis). BSE/SEM-EDS examination showed that the Fe mineral distribution and morphology in the aged tailings were different from those in the soil. Specifically, Fe bearing-minerals morphologically exhibited sharp edges, and did not interact with other minerals (Si/Al minerals) in the aged tailings, but Fe minerals in soil appeared rounded, randomly distributed and closely amassed with Si/Al bearing minerals. The lack of labile organic matter and alkaline-saline conditions may have prevented/ significantly slowed down the weathering/bioweathering of Fe minerals and biogenic Fe mineral formation, limiting soil structure development in the tailings. The study also indicated that native pioneer plants could facilitate the bioweathering of Fe bearing minerals in the tailings. Based on these initial investigations, it is thus proposed that organic carbon accumulation, together with microbial and pioneer plant driven bioweathering of the Fe bearing minerals should be stimulated to initiate soil formation in the tailings into functional technosol.

The new Index of Biodiversity Surveys for Assessments improves access to Western Australian biodiversity information

Mike Young[1], Chris Gentle[2], Bridget Hyder[1]

[1]**Department of Water and Environmental Regulation, Western Australia**

[2]**Western Australian Biodiversity Science Institute, Western Australia**

Substantial amounts of biodiversity information, including species records, vegetation maps and habitat maps, are collected annually to support environmental impact assessment in Western Australia. This information is often used only during the assessment for which it was collected, and is not consolidated or publicly shared.

This leads to inefficiencies, such as the re-collection of existing information and the time-intensive gathering of widely dispersed information. It also means that contextual information can exist outside the knowledge of proponents and regulators, and thus go unused in assessments. Ultimately, it can increase the time taken for assessments, the costs borne by industry and the level of uncertainty in decision-making.

The Index of Biodiversity Surveys for Assessments (IBSA) is a new tool launched in May 2018 in response to these issues. IBSA was developed by the Government of Western Australia in collaboration with the Western Australian Biodiversity Science Institute.

IBSA is a system by which biodiversity information collected to support assessment and compliance processes under the Western Australian Environmental Protection Act 1986 will be captured and indexed in a central location. IBSA comprises a set of policy statements, technical instructions and data standards that facilitate information capture, and an online portal by which this information can be publicly shared - free of charge and without access restrictions.

IBSA will open a substantial amount of previously inaccessible biodiversity information to researchers, industry, environmental practitioners and other users. Among other benefits, this will facilitate development of better pre-disturbance datasets for restoration projects, improve access to regional data to inform management and promote transparency in evaluating progress toward restoration targets.

Here we present an overview of IBSA and discuss some of the lessons learnt during its development. These lessons are not unique to IBSA, and should be considered during the development of information management systems in other contexts.

Resilience isn't always healthy: using stressors to overcome negative resistance and resilience in stream restoration

Isabelle Barrett[1], Catherine Febria[1], Angus McIntosh[1], Kristy Hogsden[1], Elizabeth Graham[2], Jon Harding[1], Helen Warburton[1]

[1]**University of Canterbury, New Zealand**

[2]**National Institute of Water and Atmospheric Research, New Zealand**

Resistance and resilience are terms commonly used to describe the capacity of an ecosystem to withstand and recover from a disturbance. Community resistance and resilience often form the basis of restoration goals, and are associated with good ecological health. However, degraded ecosystems can also be resistant and resilient to disturbances (negative resistance and resilience) making them restoration-resistant. In New Zealand, many aquatic ecosystems are degraded and locked in restoration-resistant states. Using freshwater ecosystems as a model system, we present a framework to test and overcome negative resistance and resilience.

We hypothesise that resistance to restoration is a consequence of degraded communities becoming dominated by species with traits which enhance food web stability (e.g. trophic generalism), thereby increasing resistance to restoration actions (negative resistance). Whilst individual species' inherent tolerance to specific stressors can be tested on a species by species, stressor by stressor basis, this neglects the trophic and species interactions which become evident when considering a community perspective. Although often acknowledging the importance of considering disturbance response on a community scale, most research fails to consider the potential for this to vary between different communities (e.g. a nutrient and fine sediment-stressed agricultural stream community versus a flood-prone braided river community). Here we present a series of stream channel mesocosm experiments to test if responses to stressors depend on context. Understanding how different community types respond will be vital for the end goal of overcoming negative resistance and resilience, using stressors to destabilise degraded communities. This research will provide the groundwork for a "biotic restoration toolbox" which will build upon the existing abiotic restoration tools that are currently used in stream restoration, and enable suggestions to be made for biologically-focussed restoration which aims to work with environmental stressors as agents for community change.

Posters

Objectives, measures of success and outcomes of marine and coastal restoration

Shantala Brisbane[1], Elisa Bayraktarov[1]

[1]**University of Queensland, Queensland**

Marine and coastal ecosystems provide a range of ecosystem services and are important habitat for a vast number of organisms, yet they face large scale loss and degradation. Restoration activities have been undertaken in a range of coastal and marine settings in Australia and internationally, however these activities have had varying success and are often expensive (with a median cost of US$80,000 to restore one hectare of marine coastal habitat). In addition, objectives of restoration projects are not always clearly stated, there is a lack of consistent reporting on restoration outcomes, and there is uncertainty around which variables best measure success. In this study, we analysed a database of published restoration projects in five marine/coastal habitat types (mangroves, seagrass, saltmarsh, coral reefs and oyster reefs), assessing the ecological and/or socio-economic objectives, variables measured, and reported outcomes of the restoration projects. Preliminary analysis of mangrove restoration projects found that restoration objectives were frequently related to biodiversity enhancement, coastal protection and improving restoration techniques. Ecological variables were, as expected, measured much more frequently than socio-ecological variables, and the most common variables included survival of restored mangroves and various measures of growth. In comparing the studies from published literature to the six Key Concepts of the SER International Restoration Standards, we found that very few studies were consistent with all six. Here, we will present the results of these analyses, and discuss relevance to scientists and practitioners of marine and coastal restoration.

Indigenous biocrust cyanobacteria promotes seedling recruitment of plant species native to the Pilbara, Western Australia

Melissa Chua[1], Todd E. Erickson[1], David Merritt[2], Angela Chilton[3], Mark Ooi[3], Miriam Muñoz-Rojas[1]

[1]**University of Western Australia, Western Australia**

[2]**Kings Park and Botanic Gardens, Western Australia**

[3]**University of New South Wales, New South Wales**

Up to 25% of land has been degraded globally to date and with on-going large-scale anthropogenic disturbances and climate change, this figure will increase. Ecosystem restoration in degraded dryland environments is rarely successful due to the high temperatures and low rainfall compounded by the lack of topsoil and poor natural plant recruitment. Cyanobacteria from soil biocrust are photosynthetic bacteria present in most dryland regions and can survive extreme environmental conditions. These organisms have shown potential as bio-fertilisers and plant

promoters and can enhance soil function and structure. However, few studies have investigated the effects of bio-priming seeds with cyanobacteria on early plant survival. We present a case study in the Pilbara floristic region, Western Australia, a hotspot for large-scale mining activities comprised of arid and semi-arid environments, to investigate the effects of seed bio-priming with a mix of cyanobacteria species on the germination and early survival of plant species native to the Pilbara.

Cyanobacteria species (Leptolyngbya spp., Microcoleus spp., Nostoc spp., Scytonema spp.), previously isolated from soil biocrust samples collected in the Pilbara region, were cultured and used for bio-priming seven plant species native to the Pilbara and used in landscape restoration. Germination rates were recorded daily, and shoot and radicle measurements were taken on 10-day old seedlings.

Our results showed that shoot and radicle lengths of Grevillea wickhamii and Triodia wiseana seedlings bio-primed with cyanobacteria were significantly longer than their control counterparts. No significant inhibitory effects on germination rates and seedling growth were observed. Longer roots may provide seedlings with more structure to establish and increase surface area for nutrients absorption, reducing high mortality rates. However, many factors could contribute to seedling mortality following germination. Thus, future studies investigating seedling emergence and establishment are required to understand longer-term effects of cyanobacteria on native plants.

Culturally modified (Aboriginal scarred) trees: Sharing knowledge to improve management of veteran cultural trees

Dan Cole[1], Gregory Siepens[2]

[1]**The Water and Carbon Group**

[2]**The Hut Environmental and Community Association (THECA)**

Traditional Owners of Australia valued trees for a range of cultural purposes as have Europeans. In many fields of endeavour, veteran trees are not usually valued highly and are generally lost during development of properties, areas and regions, including road and rail corridors. The project aim was to increase awareness and knowledge on culturally modified trees and specifically Aboriginal scarred trees which now exist as veteran trees in fragmented landscapes through a series of workshops and field visits.

Scarred trees are significant to Aboriginal culture as they were a source of material for construction, craft and have important intangible values (e.g. spiritual beliefs). Scarred trees now provide information to modern cultural groups on artefact manufacture and are of irreplaceable value as these remnants provide knowledge and links to past practices. The need exists to mitigate developmental impacts and other encroachment pressures in association with increased conservation efforts to ensure scarred trees are not vulnerable and remain a viable part of our cultural heritage until natural senescence.

The need to create more awareness about veteran trees, especially scarred trees had been identified by the non-Indigenous authors for some time. Five educational workshops discussing the management of these significant trees were developed

and held in North & South East Qld, and northern NSW and funded by the Bjarne K Dahl Trust.

The planning and delivery of the project was co-managed with Indigenous groups and their representatives. The focus of the workshops was the convergence of Indigenous Ecological Knowledge and Western Scientific Knowledge to explore ways of managing veteran and scarred trees.

The authors will present a number of examples that will include veteran tree management options that integrate Indigenous values and cultural management and touch on important considerations that are crucial to engaging with Indigenous groups.

The Slacks Creek Restoration Project: Planning urban restoration projects to deliver ecological assets for communities

Dan Cole[1], Gregory Siepens[2]

[1]**The Water and Carbon Group**

[2]**The Hut Environmental and Community Association (THECA)**

Slacks Creek traverses through a highly modified landscape. The riparian restoration project was initiated to increase both terrestrial and hydrological connectivity in the creek corridor. The Slacks Creek Restoration Project (SCRP) was funded by the Australian Government and delivered by Logan City Council through partnerships with The Water and Carbon Group, CSIRO and Griffith University.

The project commenced in 2013 and concluded this year. The planning and successful delivery of several sub-projects have engaged the community and stakeholders, whom are now supporting the ongoing restoration of these key sites. In early 2018 the Slacks Creek Catchment Restoration Group was established to coordinate ongoing community participation and to maintain momentum for restoration beyond the project's primary funding.

Several degraded sites identified for restoration were nominated to achieve additional outcomes such as providing assets for the broader community. The planning phase then became critical to the design of restoration projects to deliver these ecological and community assets. Examples include:

1. The establishment of a 9.5 hectare Arboretum at the Griffith University Logan campus which adjoins Slacks Creek. The contemporary Arboretum represents a range of local vegetation communities and includes threatened species that now forms a valuable conservation resource for the Logan region. This restoration project has now created a land-based asset with ecological, educational and recreational benefits.

2. A stormwater wetland system was designed and constructed in 2014 at Shailer Pioneer Park. The wetland is now a valued community asset improving water quality and enhancing biodiversity.

The successful and ongoing outcomes of SCRP highlight the importance of designing and delivering urban restoration projects that identify and integrate

a diversity of values for the benefit of local communities. Planning, partnerships and stakeholder engagement have been integral to the success of the project and to fostering connections within the diverse communities of Logan City.

Disturbing times in the Westonia Commons

Haylee D'Agui[1], Lucas Moynihan[1], Richard Harris[1]

[1]**Curtin University, Western Australia**

Agriculture has significantly affected global landscapes, with widespread clearing of native vegetation resulting in fragmentation of natural habitats. The temperate eucalypt woodlands of WA's wheatbelt have been reduced to small isolated fragments, resulting in altered ecological processes, including fire regimes, with fire now infrequent, or totally suppressed in areas historically exposed to regular burning, reducing recruitment in dominant tree species. The 3,500 ha Westonia Commons in the wheatbelt has a long history of fire suppression, and a species poor, sparse understorey.

The re-introduction of disturbance to increase the recruitment and biodiversity of the woodland was investigated using eight 4 m x 4 m plots established within the woodland, each containing four randomly allocated treatments (Control, Fire, Mechanical Disturbance, Fire and Mechanical Disturbance) within 1.5 m x 1.5 m sub-plots. A greenhouse trial was conducted simultaneously using soil taken from each of the eight plots treated with Fire, Disturbance, Smoke-water, Heat, and Gibberellic Acid, to determine the contents of the soil seed bank.

Results from both field and greenhouse experiments indicated no clear treatment response, with richness and abundance of seedlings significantly different between plots but not treatments. Seedling species composition from the germinated soil seed bank differed from that of the extant plant community, with only chenopods, Eucalyptus sp., Melaleuca pauperiflora and Calandrinia eremaea being present in the extant vegetation and emerging from the soil seed bank. The number of seedlings from both the field and greenhouse experiments were lower than expected, as was species richness, likely due to low winter rainfall. Soil analysis indicated high aluminium content and low pH; factors that when combined, are known to be toxic to plant growth. Several other factors including seed viability, temperature, and duration of the study are all possible contributing factors to the low seedling yields of the experiment.

Temporal dynamics of urban forest restoration plantings

Katherine de Silva[1]

[1]**Victoria University of Wellington, Wellington, New Zealand**

Urban forest restoration programmes have become a key tool globally over the last few decades to improve ecosystem services, function, resilience and biodiversity. However over decadal timescales, the trajectory and success of restoration plantings in degraded urban environments can be hindered or altered from abiotic and biotic influences. Studies completed at the local scale, have reported conditions such as micro-climate, canopy cover, competition and propagule source

as key determinants of natural regeneration in restored urban landscapes. However, research into these factors at a regional scale and across wide latitudinal gradients are rarely studied. Using a chronosequence approach, whereby space is substituted for time, I determine how temporal dynamics of restoration plantings change over latitudinal and forest age gradients. I established permanent plots at 45 urban planting sites in five cities, aged 5 to 58 years since planting from bare ground. The structure, composition, and environmental conditions were quantified. This presentation will include preliminary results on the impact of latitude, micro-climate, canopy composition and canopy age on the development of restored urban forests, with a focus on the regeneration potential of native trees. Research outcomes may show regeneration drivers in a temporal context, providing guidance towards more effective urban restoration policies, priorities and activities.

Assessing the effectiveness of understory prescribed burning for managing fire risk in Mediterranean landscapes (Northeastern Spain)

Beatriz Duguy Pedra[1]

[1]University of Barcelona, Barcelona, Spain

The occurrence of large intense fires increased in northern Mediterranean countries in recent decades, particularly due to extensive fuel buildup. This situation may worsen under climate change resulting in increasing ecological and socio-economical negative impacts.

Proactive landscape-scale forest management/restoration strategies considering the use of fire are needed. Understory prescribed burning (PB) is a fuel reduction treatment that may also maintain, even promote, diversity. It is still poorly applied in the Mediterranean region. Its effectiveness for controlling fire propagation and behavior at the landscape scale depends on spatial aspects of the planning process (i.e. landscape-specific optimal extents and locations), and temporal aspects (since the vegetation changes over time).

We implemented a fire modeling-based approach for assessing if understory PBs can significantly control fire spread and behavior under extreme weather conditions in a landscape dominated by Pinus halepensis forests (El Perello, Northeastern Spain). Based on previous research conducted in that area, we described the custom fuel models corresponding to the pre-burning (Control), the short- and the medium-term (1 and 5 years, respectively) post-burning understories. We designed a set of alternative fuel scenarios considering several spatial configurations of PBs (random or based on the historical fuel reduction treatment locations) and different treatment extents. We took into account the temporal aspect by creating scenarios in which all burnings were either very recent, or medium-term, and some mixed scenarios as well (i.e. combining short- and medium-term custom fuel models). We then simulated fire growth and behavior in all fuel scenarios with FARSITE model under extreme summer weather conditions.

Results show that the spatial configuration of the burnings is particularly relevant in relation to fire spread. When fuel discontinuities created by PBs are scattered in the landscape, fire propagation is strongly disrupted. Besides, it appears that PB may modify the understory in the medium term.

Saving Sphagnum moss: Restoring populations following wildfire

Lee Jeffery[1], Bec Duffield[1], Julie Schofield[1]

[1]**Conservation SA**

Sphagnum moss (Spahagnum novo-zelandicum) is known to occur in two regions of South Australia (South-east and Fleurieu Peninsula). The South Australian Sphagnum is a minor component of wet heath communities dominated by tall shrubs and sedges. A 2006 survey of Sphagnum in South Australia recommended that Sphagnum be listed as a threatened plant in SA due to its limited distribution and isolated occurrence (Whinam et al. 2008).

Stipiturus Conservation Park on the Fleurieu Peninsula contains Glenshera Swamp, approximately 30 hectares of high quality Fleurieu Peninsula Swamp. A number of nationally listed endangered flora and fauna species occur across the site. This swamp is one of the few sites that Sphagnum moss remains and is typically distributed on narrow trails that are shaded by sedges and shrubs.

In October 2017 an ecological burn at Stipiturus CP to enhance habitat for threatened plants, over-achieved the intended burn area, and most of the known Sphagnum sites were impacted. Sphagnum was easily located post fire and its occurrence was wider than previously recorded. Due to the upcoming summer there was concern about desiccation and long-term survival of the Sphagnum, and a trial to examine the effectiveness of shading individual patches of Sphagnum was implemented.

Initial results support the need to protect Sphagnum populations from desiccation after a fire. There were greater live Sphagnum populations in areas that had been covered when compared to those that were exposed.

Maintaining wetland habitats under climate change - Prioritising management actions for the Gippsland Lakes

Sacha Jellinek[1]

[1]**Greening Australia & the Arthur Rylah Institute**

Under a changing climate, it is essential that habitat restoration planning to enhance ecological systems take full account of modelled climate futures in Australia. In this presentation, we provide an example of resilience planning at the landscape-scale. This project focusses on the Gippsland Lakes landscape in eastern Victoria, which includes internationally recognised Ramsar wetlands. This diverse landscape consists of over 2,000 wetlands of varying salinities (fresh to hypersaline) and water regimes, and it is predicted that these wetlands will become increasingly saline over time, or disappear under hotter, dryer conditions. To determine how target waterbird and frog species would be influenced by Climate Change to 2050,

we modelled how connectivity would affect these species, and how different management actions could ensure their persistence over time. Results suggested that connectivity under climate change had a much greater impact on frogs than it did on waterbird species. The most effective management actions for waterbirds were excluding grazing, undertaking revegetation and managing water regimes, while frogs benefited most by excluding grazing, managing water regimes and preventing clearing. While management interventions were similar for these species, the locations that provided the highest benefits for these taxa were different.

This approach offers a quantitative and reproducible approach to strategic natural resource management for organisations. It shows how decision support tools can be used by practitioners to support efficient and effective management of wetlands and other landscapes.

A global review of invertebrate conservation translocations

Rachel Lee[1], Michael Magrath[2],Euan Ritchie[1]

[1]**Deakin University, Victoria**

[2]**Zoos Victoria**

Invertebrates are the most speciose group of organisms on Earth, but despite their importance for ecosystem health and human persistence, the 'other 99%' are often neglected in research and conservation programs. Limitations in invertebrate conservation are associated with a lack of public and policy maker awareness, challenges with research methodology, and an overall taxonomic bias toward more charismatic species. The translocation of invertebrates to new or previously occupied environments is challenging, with a lack of information regarding what constitutes best practice protocols and indicators and measurement of a successful translocation. To provide recommendations for what is likely to increase the success of future translocation programs, we performed a global systematic review and meta-analysis of published and grey literature on invertebrate reintroduction programs. We collected information for over 300 terrestrial, fresh water and marine invertebrate species. We discuss outcomes of this comprehensive assessment of invertebrate conservation translocations; identify and contrast the reasons for successful/unsuccessful invertebrate translocations with invertebrate species invasions and highlight key considerations for improving the likelihood of successful invertebrate translocations in the future.

Indigenous forest-based livelihoods and bauxite mining: A case-study of the Weipa-Aurukun region, Northern Australia.

John Meadows[1], Mark Annandale[1]

[1]**University of the Sunshine Coast, Queensland**

Bauxite mining operations are increasingly sited on Indigenous-owned land, particularly in tropical areas including Northern Australia. The environmental impacts of bauxite mining are profound. A mine-site's native vegetation cover is cleared and commercially valuable forest resources are typically windrowed and burnt. For Australian Indigenous landowners, the mining activity creates much concern about cultural, community health and livelihood impacts associated with the loss of traditional resources and the ability to 'care for country'. Improved pre-mining resource utilisation and effective mine-site rehabilitation are key areas of Indigenous community concern about bauxite mining projects on their country. Past mine-site rehabilitation attempts to restore forest cover including native forest ecosystems and to support Indigenous businesses and employment have had mixed outcomes. This paper explores the potential to improve outcomes in these areas by integrating Indigenous community forestry into bauxite mine management and rehabilitation. Through a qualitative case-study, we investigate the opportunities and challenges for incorporating pre-mining forest product salvage harvesting and multiple-use mine-site rehabilitation into the whole-of-life of bauxite mining projects in the Weipa-Aurukun region in North Queensland, Australia. In this context, we review previous natural and cultural resource development initiatives implemented as part of the management and rehabilitation of bauxite mines, and the processes and outcomes of Indigenous community consultation to determine a multi-purpose pre- and post-mining land-use vision for bauxite mine-sites. We present insights into an Indigenous community's sustainable forest-based livelihood strategy associated with bauxite mine-sites. The findings can inform policymakers and mining industry professionals in the design and implementation of mine-site relinquishment criteria and associated pre- and post-mining management plans and strategies that will improve environmental outcomes and socio-cultural benefits for impacted Indigenous communities.

Constructed "habitat stacks" for fauna recovery within vegetation offset projects

Steven Milner[1]

[1]**Sunshine Coast Council, Queensland**

Bush restoration has few documented terrestrial examples of constructed ground habitat as an essential component that facilitates accelerated restoration and ecosystem recovery. Most of the current literature on this topic describes the installation of course woody debris (CWD) and habitat pods in marine, estuarine and freshwater ecosystems. Terrestrial habitat recovery is an essential emerging practice.

CWD can take centuries to develop on the forest floor. Micro-organisms and insects use CWD as a substrate to enrich the soil and increase fertility as well as building food webs for the new ecosystem. Five years ago Sunshine Coast Council (SCC) commenced delivering vegetation offset projects onto ex-livestock or sugar cane paddocks which were devoid of CWD. Salvaging large tree stumps and stem timber from the likes of civil works projects has now been identified as having immense ecological value. Subsequently, SCC commenced constructing "habitat stacks", using a 6 tonne excavator with a log grab to artificially construct a useable habitat and installed infra-red motion detection cameras to monitor the stacks.

These cameras have proved to attract a large range of fauna well within 12 months of construction and for reptiles, as soon as overnight. This method very quickly increases the biodiversity of an area and accelerates fauna establishment compared to sites reliant on natural recruitment of native fauna.

Fauna use these "habitat stacks" as stepping stones to traverse and populate a previously open space. Where possible this process is now being incorporated into SCC's delivery of broad scale revegetation projects and vegetation offset projects as an important element of advanced habitat restoration.

Using a common sampling frame to organise monitoring of an urban restoration project

Rachel Omodei[1], Tom Atkinson[1]

[1]**Emerge Associates, Australia**

Establishing a monitoring program that is sufficient to allow the later evaluation of goals and objectives is a challenge for all restoration projects. Invariably the resources available for monitoring will be limited and so monitoring methods must avoid being onerous whenever possible. In the early stages of a project, some objectives may not yet have been determined and the specific parts of a project site or range of indicators that require monitoring may not be known. This poster outlines a methodology applied in the establishment of a monitoring program for a relatively long term, urban restoration project in Perth, Western Australia. The project aims to restore native bushland that was cleared along the proposed alignment of the now suspended 'Roe 8' highway extension. A monitoring program was needed to inform and evaluate the adaptive implementation of the project over a ten year period. Data was required that met the expectations of interested community members, academic researchers and the management authorities tasked with coordinating project implementation. The broader goals of the project also required that citizen science participants and interested stakeholder organisations, who have varying levels of expertise, could participate and/or lead monitoring activities. Our approach was to prepare a common sampling frame with some basic stratifications through which a variety of monitoring tools could be applied. Protocols for sampling and measurement were established to help control data quality and enable systematic evaluation of outcomes against the project's goals and objectives. The resulting methodology allows detailed evaluation of ecological outcomes and project progress reporting requirements, as well as lower intensity observations of anything of interest within the project site. Crucially, the approach makes it possible to adapt the focus of monitoring and introduce new stratifications, tools or indicators should the information requirements or circumstances of the project change over time.

Treatments to improve native understory establishment in mine waste rock material in northern Australia

Megan Parry[1], Sean Bellairs[1], Ping Lu[2]

[1]**Charles Darwin University, Northern Territory**

[2]**Energy Resources of Australia, Australia**

Re-establishment of vegetation is an important component of mine rehabilitation and is critical for recovery of fauna and ecological processes. Understory plants, such as grasses and legumes, are an integral component of rehabilitated ecosystems as they can improve soil fertility, promote erosion control, and supply resources for fauna. Establishment of understory plants in mine waste material can often be challenging due to its physical, chemical and microbiological characteristics that impact seedling establishment and plant growth. This project aims to address the knowledge gap in protocols for optimal techniques for understory species establishment in mine waste rock at the Ranger uranium mine in the seasonally wet-dry tropics.

Several treatments have been applied to amend mine waste rock material to assess if any of the treatments improve plant establishment and growth. Treatments include the addition of: incorporated organic matter, surface litter, sand, fertiliser and a combination of sand, fertiliser and surface litter. A range of native understory grass and legume species have been established in waste rock material in situ at the Ranger mine as well as in pot trials in a shade house at Charles Darwin University. The effects of the treatments on the emergence, survival and growth of various grass and legume species are being assessed. So far the surface litter treatment has been particularly effective, but substantial differences in establishment success has occurred between species. As well as the characteristics of the media, other challenges have included sourcing seeds and weather conditions.

International Network for Seed-based Restoration

Simone Pedrini[1]

[1]**ARC Centre for Mine Site Restoration, Curtin University, Western Australia**

Nearly two-thirds of ecosystems world-wide are degraded and native plant seed supplies are critical for their restoration. Ecological restoration is a growing sector valued in excess of a trillion dollars annually; of which seed collection and cultivation industries are important components. Thus there is a critical need to develop native seed technology and certification to achieve restoration goals.

The goals of the international network for seed based restoration (INSR) are:

- Promote international collaboration to develop standards for native plant seed testing and regulation.
- Foster understanding and advancement of seed ecology, conservation, and seed-based restoration of degraded systems.

- Serve as an emergency expert panel on disaster relief issues related to germplasm conservation, seed technology, seed farming, and seed-based restoration.
- Support education, outreach, and research globally to provide seed-based solutions for restoration.

INSR aims to engage a wide range of stakeholders and promote ecologically and socially acceptable collection, regulation and use of native seed. Through these efforts, we hope to increase effectiveness of seed-based restoration world-wide.

The aim of the poster is to promote INSR activities and expand its membership.

Community mangrove restoration and livelihood improvement in Ayeyarwady delta, Myanmar

Sang Phan[1], Ammar Abdul Aziz[1], Toe Aung[2], Bo Ni[2], Catherine Lovelock[1]

[1]**The University of Queensland, Queensland**

[2]**Myanmar Forest Department, Myanmar**

The Ayeyarwady (Irrawaddy) Delta in Myanmar is one of 11 large river deltas of the world. The Ayeyarwady has extensive mangrove forests which have large Blue Carbon stocks and also provide important natural resources that support the livelihoods of rural communities and provide protection from extreme weather events. Between 1978 and 2011, nearly two-thirds of the 262,000 ha of mangroves in the delta have been deforested and converted to other land uses. The remaining mangroves are severely degraded due to illegal harvesting of timber and fuelwood for households and for preserving fish catch.

Rehabilitating the mangroves of the delta is a high priority for the Forest Department (FD) of Myanmar, but how this can be most effectively achieved is not known. Management of mangroves is conducted by 1) the Forest Department who restore mangroves on their lands, 2) community groups who sometimes work in partnership with non-government organizations, and 3) by individual households under community forestry certificates. To assess the effectiveness of management of these three arrangements we evaluated mangroves at 109 sites across the Ayeyarwady Delta. We found that mangroves under the management of community groups and households have significantly higher density of trees, tree biomass, canopy cover and natural regeneration of seedlings than mangroves under the FD's management. Although mangrove plantings initially succeeded for all three management arrangements, mangrove plantations on community group and small-holders land have higher levels of longer term success, while many of the FD plantations have been lost due to illegal cutting of trees and land conversion. Our socio-economic surveys revealed that families involved in community forestry in the delta had more livelihood options compared to other households which included sale of timber and non-timber mangrove products. Our results suggest that decentralized management of mangroves is a pathway to successful mangrove restoration in Myanmar.

Joining the dots versus growing the blobs: optimal targeting of ecological restoration

Maksym Polyakov[1], Fiona Gibson[1], David Pannell[1], Geoff Park[2]

[1]**University of Western Australia, Western Australia**

[2]**Natural Decisions Pty Ltd, Australia**

The primary causes of biodiversity decline worldwide are habitat destruction, alteration and fragmentation resulting from human economic activities such as agriculture or property development. Public- and private-sector organizations allocate considerable resources to slow down biodiversity decline by developing conservation networks that preserve the remaining habitat. In this study we use simulation to compare several strategies to spatially target ecological restoration effort to create conservation networks, on private lands in a fragmented agricultural landscape. The evaluated targeting strategies are aggregation and connectivity. The effectiveness of these targeting strategies is compared to the effectiveness of ecological restoration without targeting. We allow for heterogeneity of landowners' willingness to participate in restoration projects and explicitly assume that not all parcels within target areas will be restored. We model the probability of participation in restoration projects as a function of the private benefits of ecological restoration captured by the landowner. The results of the simulation are analyzed using regression analysis. Our results suggest that effectiveness of the targeting strategies depends on landscape characteristics (level of fragmentation) and species characteristics (habitat requirements and area of home range). On average, when uncertainty about whether landowners will participate is considered, targeted strategies outperform untargeted. When conservation effort is low and in cleared landscapes, the aggregation strategy outperforms the connectivity. However, with greater conservation effort and in less fragmented landscapes, the connectivity strategy performs better. Accounting for the landowners' behavior through a private benefits function improves the biodiversity outcome for most species.

Posters

Evaluating the capabilities of hyperspectral and SENTINEL-2 information for quantitative chlorophyll estimation on induced biocrusts

José Raúl Román Fernández[1], Emilio Rodríguez Caballero[1], Pilar Águila Carricondo[1], Borja Rodríguez Lozano[1], Beatriz Roncero Ramos[1], Sonia Chamizo de la Piedra[2], Yolanda Cantón Castilla[1]

[1]**University of Almería, Almería, Spain**

[2]**Univisity of Florence, Florence, Italy**

Despite significant efforts to restore dryland ecosystems worldwide, the rate of success of restoration is extremely low in these areas. In recent years, soil inoculation with pioneer biocrust-forming cyanobacteria has become one of the most promising biotechnological strategies for restoring soil functionality in degraded drylands because of their critical role in increasing soil fertility and preventing erosion. Chlorophyll concentration is a well-proven proxy of biocrust development commonly used to assess the success of biocrust rehabilitation tasks. However, laboratory methods for chlorophyll analysis require destructive sampling and are expensive and time consuming, limiting its applicability to punctual measurement that may not represent inherent spatial and temporal variability of induced biocrust communities in large scale restoration projects. Indirect estimation of chlorophyll by means of soil surface reflectance analysis has been demonstrated to be an accurate, cheap and quick alternative for chlorophyll retrieval in plants. However, its application in biocrust is yet to be harnessed. For this reason, we evaluated the potential of soil surface reflectance measurements for non-destructive chlorophyll quantification of artificially induced biocrusts under laboratory conditions over three different soils. Our results revealed that in a similar way as it was observed in vascular plants, spectral reflectance at both hyper- and SENTINEL-2 spectral resolution can be used to estimate induced biocrust chlorophyll concentration and, therefore, development status. From the different methods and techniques for spectra transformations, first derivate of reflectance and continuum removal were more accurate in CHL retrieval than single reflectance values. Normalized difference values in the red-edge region and common broadband indices (NDVI, SR, MSR, SAVI and OSAVI) also were sensitive to changes in chlorophyll concentration, highlighting the feasibility of using spectral information as an alternative for non-destructive and reliable chlorophyll quantification in artificially induced biocrusts. Our approach of employing different soil textures increases the transferability of the results to assess the success of biocrust rehabilitation on assisted restoration activities in Australia.

Posters

Implementing nation-wide tropical peat fire monitoring in Indonesia

Andri Thomas[1], Laura Graham[1], Grahame Applegate[2], Erianto Indra Putra[3], Kevin Ryan[4], Bambang H. Suharjo[3], Mark Cochrane[5]

[1]**Borneo Orangutan Survival Foundation, Inodnesia**

[2]**University of the Sunshine Coast, Queensland**

[3]**Institut Pertanian Bogor, Indonesia**

[4]**US Forest Service, Missoula Fire Sciences Laboratory (ret), USA**

[5]**University of Maryland,, Maryland, USA**

Indonesia hosts some of the world's largest tropical peatlands, but in the last 30 years, a high proportion have been logged, drained and converted to agriculture. Once degraded, tropical peatlands become fire prone, and when a peatland surface fire transitions into the peat, large volumes of carbon-based and noxious gases are released. Indonesia has one of the world's highest green-house gas emissions rates with a large percentage due to tropical peatland emissions. There remains a research gap, however, in studies on tropical peat fire behaviour, related emissions and improved approaches to land management and human activities on peat.

In response to this, in 2014, the NASA-funded Maryland-IPB Peat Fire Research Project was established. It pioneered research methodologies in Central Kalimantan for monitoring tropical peatland fires, including human activities relating to burning, understanding how and why surface fires transition to the more harmful peat fires, and quantifying peat fire behaviour and fire emission factors.

Phase II of the project commenced in 2017 focusing on implementing these methods at three new research locations; Riau and Jambi in Sumatra, and West Papua, in additional to continuing data collection in Central Kalimantan. The project also works with an ACIAR-funded project that will implement these methods with the Indonesian Forest Research Agency in South Sumatra and another location in Central Kalimantan. This research therefore now covers five of the seven Indonesian Government targeted fire-prone provinces which have been prioritised for tropical peatland restoration. The data being collected is managed in a central database and will improve tropical peat fire carbon emissions calculations at a nation-wide scale, and will enable development of regionally-appropriate fire management practices. The project partners include the Indonesian Government, to ensure the outputs are quickly disseminated at the national level, and to practitioners on the ground.

Posters

Strategic identification of simple management tools to solve complex restoration puzzles.

Alexi Williams[1], Brett Howland[1], Chloe Sato[1]

[1]**Australian Capital Territory Government**

Jarramlee is an environmental offset for the threatened Golden Sun Moth (GSM) and critically endangered Natural Temperate Grassland (NTG) community. Across Jarramlee, GSM and NTG have survived in fragmented patches despite a history of agricultural management, pasture improvement and extensive non-endemic tree plantings, resulting in a legacy of exotic-dominated landscapes.

As the current land managers, ACT Parks and Conservation Service has commitments under the EPBC Act to maintain and enhance GSM and NTG across Jarramlee. To meet these commitments, a clear strategy underpinned by an adaptive management framework has been developed for implementing restoration actions across Jarramlee.

Developing this strategy involved several steps including: (1) understanding targets set by national and territory policy documents and strategies; (2) characterising potential restoration sites by mapping vegetation composition, testing soil nutrients, researching site history and using spatial analysis to identify connectivity gaps and habitat values; and (3) synthesizing available literature to compile a 'library' of existing restoration methods for GSM and NTG. Additional factors challenging restoration and management efforts for GSM and NTG also have been considered as part of the strategy, including managing historical tree plantings that provide woodland bird habitat, addressing erosion along the creek, and social interaction with the urban interface.

Using this process, simple yet creative restoration techniques will be implemented. These include: (1) broad-scale burning; (2) mowing to reduce soil nutrients and invasive grasses coupled with raking to remove litter and planting Kangaroo Grass to enhance degraded grassland, (4) trialling weed burners to remove introduced grasses (such as Phalaris) and Kangaroo Grass thatch; and (5) planting islands of native species to facilitate seed dispersal. A site-specific grazing management plan and feed budget will further support restoration actions, and ongoing monitoring will be used to evaluate the success of each project, and provide direction for future restoration actions.

Who owns the land containing the remaining key natural environmental features in Queensland?

Yi Zhang[1], David Pullar[1]

[1]**The University of Queensland, Queensland**

It is recognised that National Parks and reserves do not adequately protect on an area basis natural parts of the environment, so what is the state of ownership of other land containing natural environmental features such as native vegetation and waterways? It is clear that some of the intact natural lands are owned by the government, such as national parks, and some of the others are owned by private landowners (e.g. individuals and conservation non-governmental organisations). However, except for government and private landowners, there are huge intact natural lands owned by other groups. Identifying the owners who hold the intact natural lands, could help researchers and policymakers understand land use decisions and plans made by various landowners. Afterwards, policies and incentives can be generated for effectively engaging these landowners in vegetation conservation and restoration, in order to prevent land degradation. This presentation will identify the intact natural landowners in the South East Queensland region, by combining vegetation remote sensing data with the land tenure spatial data.

Posters

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