Linear population shape reduces ecological and genetic function in a bird–pollinated plant

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Theme: Ecosystem Services and Environmental Offsets

Linear strips of native vegetation are prominent features in agricultural landscapes and revegetation projects, yet there has been little study of the impact of linear geometry on ecological and genetic function. We used microsatellite markers, field surveys and fitness trials to investigate the effect of different aspects of habitat fragmentation on the mating system, pollen dispersal, reproduction and progeny fitness in remnant populations of Banksia sphaerocarpa var. caesia, a common bird-pollinated shrub in the southern agricultural region of Western Australia. We found population linearity to be as important as population size in relationships with variables that could potentially affect population viability. Plants in linear populations had smaller seeds and lower seed germination. As population linearity increased, mating neighbourhood size decreased and pollen pool differentiation increased, indicating a decline in genetic function mediated through changes in bird foraging patterns. Neighbourhood size was highly correlated with seed weight, which in turn was highly correlated with measures of seed and seedling fitness, suggesting a strong effect of paternal diversity on progeny fitness. In contrast to these detrimental effects, plants in linear populations were larger and had more inflorescences, cones and follicles than those in non-linear populations, suggesting that increased resource availability in linear populations may partly compensate for negative effects on the mating system and progeny fitness. We suggest that when planning restoration projects, more consideration be given to the potential impacts of linear population shape on ecological and genetic function and consequent long-term population viability.

Ecosystem restoration of a trial landform constructed with hard waste-rock materials at Ranger Uranium Mine, Northern Territory

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Theme: Mine Restoration

In 2009, a trial landform was constructed at Ranger Uranium Mine (Ranger), which is located 250 km east of Darwin in the wet-dry tropics. Ranger is surrounded by, but separate from, the World Heritage-listed Kakadu National Park. The trial landform of ~8ha was constructed to test ERA's ability to successfully build and rehabilitate mine landforms with the ultimate goal of establishing self-sustaining ecosystems. The experimental design of the trial landform was based on the outcomes of extensive past research, including characterization of analogue habitats and past revegetation trials on waste-rock stockpiles at Ranger. The trial landform comprises three equally-sized areas, (1) primary rock, (2) a 2 m-thick growth medium comprising a mix of lateritic materials and primary rock overlying primary rock, and (3) a 5m-thick growth medium as in (2). The areas are further split to determine the success of direct seeding and tubestock re-vegetation methods and irrigation. Ongoing monitoring of the trial landform includes flora, fauna, whole-tree water use (xylem sap flow), soil moisture levels, erosion rates, run-off water quantity and quality, radon exhalation and weather: 3.5 years worth of results will be presented. Temporal changes in these parameters will be critical for determining the time required for the final landform to stabilise. and the rate at which self-sustainable ecosystems are re-established. There are significant implications from the trial landform in the context of final landform design methodologies, the rates at which ecosystems re-establish and trend towards agreed final closure criteria.

The value to invertebrates of snipped wood applications in rehabilitated bauxite mines in South-Western Australia

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Theme: Mine and Fauna Restoration

Woody debris and leaf litter are important components of forest ecosystems, providing habitat for many invertebrate species. The action of these saproxylic invertebrates in the decomposition of woody debris also returns a significant amount of nutrients to the system. In jarrah forest areas rehabilitated after bauxite mining, it can take many decades for this debris to build up to levels equivalent to the surrounding unmined forest, and hence many of the species associated with fallen wood and litter may be slow to return to rehabilitated areas. Alcoa of Australia has trialled a new technique involving the spread of snipped wood waste onto the surface of areas rehabilitated following bauxite mining prior to seeding and planting. In 2008, nine test plots with three different treatment levels of snipped wood (0t/ha, 100t/ha and 300t/ha) were established. To determine the effectiveness of this method in encouraging the return of saproxylic invertebrates, in 2012 the now 4-year old rehabilitated plots were surveyed by means of seasonal pitfall trapping, Tullgren funnel litter extraction and hand collection. We compared the differences in the fauna between treatment levels and between unmined forest controls. Here, we present the results of these surveys and discuss whether the application of fine woody debris during early stages of rehabilitation is an effective technique for restoring an invertebrate fauna which is similar to that of unmined natural forest.

Restoration of a snow gum woodland: 60 years on...

Elizabeth MacPhee

National Parks and Wildlife Service

Theme: Forest and Woodland Restoration

The construction of the Snowy Hydro Scheme in SE Australia resulted in over 400 sites of disturbance in what is now Kosciuszko NP. These sites all contravened at least one regulation of National Parks and some were considered to have extreme environmental issues with instability, steep slopes, threatened species impacts, weeds and some a complete lack of biological function. Snowy Hydro was corporatised in 2000 and by doing this thay gave back the environmental liability to NPWS. Funding was contributed by Snowy Hydro to National Parks and is to be used specifically for this restoration work. The sites range from spoil dumps, quarries, old towns, stream guaging stations, roads etc. In 2004, a small rehabilitation team was created within NPWS and so far have rehabilitated over 100 sites and managed the planting of 800,000 native tubestock and have removed over 80km of woody weeds in high altitude waterways. Sub-alpine landscapes in particular Snow Gum woodlands were altered and destoyed through the construction of the scheme. A primary goal of the former sites project is to restore this type of woodland. This paper will outline the process of restoration for one site, Snowy Adit; where over 100,000 seedlings have been planted with nearly 100% survival. The techniques used for site assessment, the restoration methodology used; i.e. engineering design, compost production, planting technique, tubestock management, use of organic mulches, timing issues, the success of the techniques and the application of these techniques to other woodland restoration projects will be discussed.

Is 37 years sufficient for full return of the ant biota following restoration?

Jonathan Majer[1], Elliot Hughes[1], Lewis Mounsher[1], Andrew Grigg[2]

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Symposium: Novel ecosystems in restoration and rehabilitation; Innovative planning or lowering the bar?

To provide an assessment of ecosystem recovery in 1975-bauxite mined areas, the ant fauna of one area to be planted with Corymbia calophylla, one to be seeded with mixed native species, one to be topsoiled but unrehabilitated, and a forest control was sampled monthly, and latterly annually, between 1976 and 1989. In this 'long-term' study, it was concluded that although composition of the ant fauna had converged on that of the forest over the 14-year period, differences still persist. A companion 'short-term' study was performed in 1979 in 30 bauxite mines of different ages and rehabilitated by a range of different methods, plus three forest controls. As with the long-term study, the rate of fauna return, and the type of ants present, varied with the methods of rehabilitation used and no plots had converged on the forest in terms of the ants present. In order to examine the assertion that the observed differences between rehabilitated areas and forest controls will lessen with time, both sampling programs have been repeated in 2012, using identical sampling methods, although only four of the rehabilitated areas from the short-term study were resampled. This presentation compares the current fauna with that observed in the original surveys to see whether differences in outcomes between the different rehabilitation prescriptions persist and whether the passage of considerable periods of time is an effective means of ensuring that fauna recovery does take place.

Borrow site restoration within the Shark Bay World Heritage Area

C. Ellery Mayence

Botanic Gardens and Parks Authority

Theme: Mine Restoration

Restoring landscapes degraded by mining activities can be labour-intensive and financially costly. Such settings, however, provide unique opportunities to develop and test novel approaches to restoring native plant communities. At Shark Bay Resources, a evaporative solar salt facility within the Shark Bay World Heritage Area, Western Australia, a innovative approach to creating habitat islands or patches of vegetation is being trialled to revegetate substrate borrow sites. The trials include two large factorial experiments employing two substrate materials (borrow site substrate and reference area topsoil), three seeding approaches (no added seed, addition of untreated seed, and addition of pre-treated seed), and two seedbed protection approaches (no protection and installation of a partially-buried cardboard windbreak). Prior to experimental set-up, each trial site was deep ripped to approximately 1 m to alleviate compaction, an impediment to past restoration attempts. For this study it was hypothesised that no significant benefit will be gained by seeding into reference area topsoil as opposed to borrow site substrate (based on a preliminary substrate and soils investigation), that pre-treated seed will exhibit greater germination success compared to untreated seed as a result of dormancy-breaking pre-treatments (e.g., hot water, smoke water), and that cardboard windbreaks will benefit seed germination and seedling establishment through protection from wind and blowing sand stress, increased soil and substrate moisture retention, and decreased small mammal herbivory. It is envisioned that results from these studies will increase the restoration capabilities of Shark Bay Resources, thereby benefiting the ecological integrity of the surrounding World Heritage Area.

Adaptive management for effective restoration of an urban bushland in Kings Park

Catherine McChesney

Kings Park and Botanic Garden

Symposium: Banksia Woodland Restoration

Kings Park and Botanic Garden, located in Perth, Western Australia, is internationally renowned for having a large area of bushland within close proximity to a capital city. Despite being subjected to a range of past and ongoing disturbances since European settlement, a rich diversity of flora, fauna and fungi persists. The goal of ecological restoration in Kings Park is to reverse the degradation of native biological diversity to the point where the ecosystem becomes autonomous, as much as is possible in an urban bushland setting. An adaptive management framework, incorporating a simple conceptual model of Kings Park, was outlined. Key factors driving the restoration approach were identified and included:

- Permanent ecological disconnection from surrounding bushland remnants – requires ongoing system inputs;
- restoration occurs within the existing bushland structure – restricts abiotic interventions; capitalizes on in situ native biotic resources and controls introduced biotic resources;
- resource constraints – focuses on direct introduction of plants and improving habitat for fauna and fungi;
- limited regional species pool – requires ongoing revegetation with local native species;
- biodiverse region – maximizes species richness of the revegetation mix;
- propagation techniques unavailable for many species – reduces species richness of the revegetation mix;
- harsh growth conditions for plants/ limited local native propagules – favors tubestock plantings over direct seeding;
- high visitation – promotes biodiversity conservation; minimizes adverse effects of recreation and risk management on biodiversity;
- lack of reference sites – incorporates value judgments because of the difficulty of defining meaningful, measurable targets;
- permanent staff – combines monitoring with informal observations during regular on-ground operations to evaluate progress; and
- complex ecosystem – requires ongoing scientific research to underpin ecological restoration.

Native species mine revegetation at goro in New Caledonia: strategies and challenges for industrial scale restoration

Stéphane McCoy

Vale New Caledonia

Theme: Mine Restoration

New Caledonia is renowned as a biodiversity hotspot because of its high level of diversity and endemism. These laterites also represent 25% of the world known nickel reserves and have been mined for over a century. Mine overburden previously dumped into valleys causing coastal pollution is now the focus of revegetation operations. These operations aim to produce vegetation similar to surrounding habitats because the peculiar properties of ultramafic soils exclude future agricultural or pastoral land uses. Revegetation efforts of mined lands have focussed since the 1990 on the diverse assemblage of endemic species from surrounding maquis heathlands tolerant of mine site conditions to generate pioneer vegetation suited to seedling colonisation from surrounding areas. Small scale germination and plantation trials have shown promising results for many pioneer endemic species. However there are numerous challenges in their large scale implementation on mine sites. A main hurdle in large scale seedling production is the annual variation in seed availability of target pioneer species, their viability, and storage and germination requirements compared to the diverse assemble of secondary species. To date, 230 endemic species have been produced from seed at Vale New Caledonia native species nursery. 50 pioneer species belonging to the families Myrtaceae, Cunoniaceae, Casuarinaceae, Cyperaceae and Proteaceae show promising growth results. However a ranking of the frequency in which these species have been produced over the past 16 years, indicates that the annual seed production and subsequent availability for revegetation of many key pioneer is highly variable leading often to an over representation of secondary maquis heathland species that are slower growing. Strategies to ensure that large scale native species restoration resemble the composition of surrounding vegetation include mass production of robust pioneer species by satellite nurseries in neighbouring communities to ensure quantities are available for restoration and seed priming for sedge species with poor field germination for direct seeding techniques.

Tree dominated agriculture for environmental services and sustainable livelihoods in Sri Lanka

Kamal Melvani

Neo Synthesis Research Centre

Theme: Planning Restoration and Measuring Success

Forest cover in Sri Lanka is less than 25% of her land extent of which less than 9% is primary forest while 91% is naturally regenerated or plantation forest. Loss of forest cover has negative impacts: non availability of wood, reduced biodiversity, increased soil erosion, changes in hydrological productivity and reduced carbon sequestration. These impacts are already felt and will intensify if sustainable alternatives are not adopted. However the alternative selected must consider that large tracts of land are unavailable and forest restoration may need to happen in agricultural landscapes where home gardens are converted to forest gardens. Such restoration must include a 'livelihood' component that goes beyond the provision of environmental goods and services. The Neo Synthesis Research Centre has practiced a system of 'regenerative agriculture' in Sri Lanka for the past 20+ years. It focuses on tree cropping that ensures long term, risk free income and the cultivation of annual crops in a section of the garden kept as open space that provides rural households with income and food security in the short term. The diversity of crops and the adoption of biological methods of cultivation ensures wholesome food, non toxic environment for biodiversity and clean water amongst other benefits. While many applications of regenerative agriculture have been practiced successfully in diverse ecozones in Sri Lanka there is the need is to assess their efficacy in social, economic and ecological terms in order to test their scientific validity and replicability. This paper seeks to describe such assessment.

Ecological and population genetic implications for conservation and restoration of a rare orchid

Myles Menz[1], Kingsley Dixon[1], Rod Peakall[2]

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Symposium: Pollinators in Ecological Restoration

Orchids are one of the world's most diverse plant families and are well known for forming complex and specialised ecological interactions. One of the most specialised pollination interactions is sexual deception, whereby the orchid co-opts a male insect into mating with it, thus affecting pollination. Here we use the rare, sexually deceptive terrestrial orchid *Drakaea elastica* as a case study highlighting the need for intimate ecological knowledge in conservation or restoration programs involving specialised pollination interactions. We determined that *D. elastica* requires microhabitat patches of open, bare sand and low density ground-level vegetation. The majority of genetic variation lies within populations, with a relatively low overall FST = 0.03, however this was significant on a regional scale. We found differences in the pollinator attracted to some flowers, revealing the presence of different chemotypes within *D. elastica*. This was further corroborated with GC-EAD analysis which revealed differences in the response of some pollinators to compounds in the odour bouquet of *D. elastica*. A mark-recapture experiment on the specific pollinator, *Zaspilothynnus gilesi*, revealed that the majority of movements were less than 100 m, and that *Z. gilesi* does not occur in agricultural pasture. Consequently the majority of pollen movements should occur within populations of *D. elastica*, with potential for movements between adjacent populations within natural habitat. We conclude that conservation projects aiming to protect or augment populations of rare orchids, in particular those forming specialised interactions need to consider microhabitat requirements, mycorrhizal and pollinator associations.

Applying ecohydrology in mining restoration projects: lessons from ecological succession of mine slopes for future research

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Theme: Physiology and Hydrology for Mine Restoration

Mining restoration is a complex activity with natural abiotic processes developing interactively with ecological succession within newly constructed environments. Ecohydrological processes are imperative for the functioning of such ecosystems, with the behaviour of slopes in particular playing a significant role in the evolution of restored landscapes. Slope behaviour and its influence on processes such as runoff and erosion can dramatically affect the constructed environment as well as adjacent undisturbed ecosystems. In previous slope research in a post-coal mining environment, overland flow was identified as a key driver of ecological succession, notably that overland flow volume directly influenced the control of water resources, and hence, successional processes. The identification of overland flow as a driver of both abiotic and biotic processes calls for it to be more widely considered as an ecological factor in restoration projects. This previous research is presented as a foundation to the development of a new experimental approach for post-mining restoration on banded ironstone communities in semi-arid Western Australia. The scarcity of topsoil resources, a common problem throughout the mining industry with respect to restoration, encourages research aimed at identifying alternative growth media. Incorporating hydrology into this research will yield data that informs restoration decisions and benefits restoration success.

Managing seed longevity and dormancy release during the seed banking phase

David Merritt

Kings Park and Botanic Garden

Symposium: The Australian Seed Bank Partnership: a national network to advance seed management for conservation and restoration

Seed banking is a fundamental step in the restoration of degraded habitat. Seed banks can establish and maintain genetically and geographically representative samples of plant germplasm able to be used years, decades, or even centuries into the future as a resource for large-scale restoration projects. However, all seeds have a finite lifespan. Even under ideal storage conditions the longevity of seeds varies greatly between species. Recent research across Australia highlights that seed longevity varies by at least four orders of magnitude, and has identified many species that are short-lived and that require more considered storage procedures. Experimentation on alternative storage technologies, such as cryostorage, shows promise for short-lived seeds, but some seeds, particularly those of orchids, remain challenging to manage. Correctly managing seeds during the storage process requires knowledge not just of seed storage behaviour, but also of seed dormancy type and germination requirements. For some seeds, it is clear that dormancy can be manipulated and alleviated during storage by varying the storage environment. But can (and should) seed dormancy be broken prior to storage, without impacting on the longevity of seeds? Or should dormancy be broken after storage, immediately prior to delivery of seeds to restoration sites? These questions remain only partly answered. Planning ahead for the end use of the seeds and providing for flexibility in the storage environment is one key to ensuring seeds are ready to be used when needed. This paper will outline new research findings and future directions in Australian seed banking.

Connectivity and restoration in *Acacia woodmaniorum* (Maslin and Buscomb), a rare endemic of the Yilgarn Banded Ironstones

Melissa Millar, Margaret Byrne

Department of Environment and Conservation

Symposium: Seed Sourcing Guidelines for Restoration Success

Restoration ecology science is increasingly recognising the importance of contemporary evolutionary processes that maintain genetic connectivity for achieving successful long term restoration outcomes. The negative genetic impacts of reduced connectivity and mate limitation are well recognised and have been shown to be especially relevant to species that exhibit a degree of self incompatibility. In order to inform post-mining restoration practices we assessed historical and contemporary levels of genetic connectivity, as well as aspects of the contemporary mating system for Acacia woodmaniorum, an EPBC listed species of the Western Australian Banded Iron Formations. While fine scale genetic structure is observed, estimates suggest historical gene flow has been more than sufficient to maintain adaptive connectivity across the species range and largely negate any impacts of increased inbreeding in small, disjunct populations. A highly outcrossed contemporary mating system suggests a genetic self incompatibility mechanism. Immigration of outcrossed pollen combats mate limitation and results in large effective population sizes even in small, disjunct populations, but suggests a high dependence on dispersal of outcrossed pollen for reproductive success. Alteration to pollinator numbers, assemblages or behaviour that negatively affects the introduction of outcrossed pollen is likely to have significant affect on production of viable seed and reproductive success. The pattern of genetic structure also suggests an influence of wind on insect mediated pollen dispersal. Establishment of restored populations with high levels of diversity may alleviate any affect of mate limitation and placement of restored populations in the landscape will be critical for this taxon.

Current practice fails to provide adequate data to plan or assess restoration in relation to targets of species richness and community type as set by law

Ben Miller, Erin Picken

Kings Park and Botanc Garden

Theme: Planning Restoration and Measuring Success

In Western Australia, as elsewhere, Government approval for mining and other activities impacting on natural ecosystems with significant conservation value is often granted with a proviso of post-impact restoration. While varying on a case-by case basis, development approvals often specify targets for biodiversity reinstatement which appear to be increasing in precision and rigor. A precedent recently set with approval for a mine impacting a Threatened Ecological Community in Western Australia's Mid-west demands the re-establishment of pre-existing vegetation communities, and sub-communities incorporating ≥70% of the original species diversity. The setting of these targets creates a challenge to restoration practitioners and consultants to develop an adequate baseline of realistic and usable data. This is a challenge as the measurement and definition of species richness and community types is not straightforward. Observed species richness varies with measurement scale as well as successionally and seasonally. Community definition varies significantly between the several most commonly employed approaches (including numerical classification), each of which is also dependent on the details of sampling design, and is ultimately subjective. Here we examine the data and analyses typically employed, and those required, to set and test targets of species richness and community definition for ecological restoration. We illustrate the restoration implications of inappropriate baseline establishment and offer some recommendations to increase the utility and repeatability of approaches to baseline target establishment.

Threatened plant translocations in Western Australia: lessons learnt

Leonie Monks, David Coates

Department of Environment and Conservation

Symposium: The role of plant translocations in restoring and maintaining biodiversity: policy, planning and practice

Translocations are increasingly being used in an attempt to prevent extinction or to restore population viability of threatened plant species. For translocations to be effective in achieving these goals they must be carefully planned, implemented and monitored. Long term monitoring is essential as this allows practitioners to accurately assess success or failure and, where necessary, to take corrective action to avert failure. Recently, there has been an increasing interest in the use of translocation as a tool to aid in climate change adaptation. If translocation is to be effective at mitigating species decline under likely climate change scenarios then previous plant translocations must be examined closely and the lessons learnt shared. The Western Australian Department of Environment and Conservation has implemented translocations for more than 60 plant species over the past two decades. Using an adaptive management framework the knowledge and experiences gained from early translocations have been used to improve the success of later attempts. This talk will discuss some of the plant translocations underway in Western Australia and highlight the lessons learnt along the way.

Vegetation spatial pattern as a tool to measure restoration success

Cameron Mounsey[1,2], Gavan McGrath[1], Jason Stevens[2], Christoph Hinz[1], Waqar Ahmad[3], Kingsley Dixon[2],

[1]The University of Western Australia, [2]Kings Park and Botanic Garden, [3]CSIRO

Theme: Methods, Techniques and Technologies used in Restoration

The spatial structure or pattern of vegetation has been widely used as an indicator of ecosystem function in arid and semi-arid environments. Mediterranean environments, however, have received less attention. Furthermore, this spatial analysis is not commonly applied to assess attributes of restoration sites. This study utilised very high resolution, colour-infrared aerial imagery to examine the spatial pattern of restored Banksia woodlands on the sandy soils of the Swan Coastal Plain, in Perth, Western Australia, as they developed along a 20 year restoration chrono-sequence. Patch metrics and textural indices were assessed and used as indicators of function, and hence, restoration success. Field measurements of functional traits (hydrology, and soil physical and chemical properties) were taken to support image-derived information. The potential exists for this technology and methodology to become standard restoration monitoring practice in many environments, and holds particular promise in assisting to identify and target areas where further intervention and restoration management is required.

Translocation: challenges and policy responses

Simon Nally

Department of Sustainability Environment, Water, Populations and Communities

Symposium: The role of plant translocations in restoring and maintaining biodiversity: policy, planning and practice

The translocation of threatened species is increasingly used in Australia to meet conservation, animal welfare, social, and development offset objectives. Although historically applied in response to a threat to a species, its potential use for assisted colonisation in response to a changing climate has precipitated an expanded interest in translocation as a tool to manage threatened species. Conservation translocation protocols for threatened species, mostly for reintroduction, are well established within Australian States and at an international level. These protocols usually address; short term translocation purpose, animal welfare, biological and ecological needs of the organism, translocation methods, monitoring, and, increasingly, genetic considerations. Despite this well-established guidance, the success of translocations is often confounded by unclear objectives, unsuitable success criteria, or insufficient monitoring. The interplay of multiple objectives for a translocation and of its recipient site (e.g. ecosystem restoration, assisted colonisation, and iconic place protection) can further increase the risk of unclear objectives. Responding to the challenges of the differing objectives of translocation or of interstate or international movement may be assisted by a cohesive policy framework that addresses key gaps between existing protocols. In addition to supporting systems to balance and clarify translocation objectives, policy can help guide effective risk management, genetic management to maximise evolutionary potential, success criteria, the co-establishment of interdependent species, and community engagement. This guidance is likely to improve the targeting and success of this important conservation tool.

Forest restoration through capacity building and training

David Neidel, Pangestuti Astri

Environmental Leadership & Training Initiative

Theme: Education

Forest restoration is critical for conserving biological diversity and ensuring the adequate provision of fundamental environmental services. Restoration of degraded lands, however, has had minimal success, in terms of quality and extent, due to financial, technical, political, and socio-economic constraints. This presentation will explore some of the challenges to scaling up forest restoration efforts by examining the work of the Environmental Leadership and Training Initiative (ELTI). ELTI is a joint program of the Yale School of Forestry and Environmental Studies and the Smithsonian Tropical Research Institute aimed at increasing local capacity for forest conservation and restoration in tropical Asia. ELTI consists of two components: the Training Program works with a variety of research institutions to offer a variety of practical training events, while the Leadership Program works with Training Program alumni to ensure that the knowledge and skills learned through the trainings are implemented on the ground. This presentation will provide an introspective assessment of ELTI's work on forest restoration. It will discuss the array of strategies that ELTI is using to scale-up forest restoration, focusing particularly on our attempts to bridge the science-practice gap. It will explore some of the challenges that have arisen in this work and the key lessons learned. The importance of network building to overcome impediments to field implementation will particularly be discussed. Finally, it will present some of ELTI's achievements to date while underlining the difficulty in formulating and actualizing metrics of success.

Variable spatial genetic structure in three co-occurring riparian tree species (*Eucalyptus camaldulensis*, *Eucalyptus victrix* and *Melaleuca argentea*): implications for seed sourcing and conservation

Paul Nevill

Kings Park and Botanic Garden

Symposium: Seed Sourcing Guidelines for Restoration Success

The concept of local provenance is widely applied in native plant community restoration, revegetation and conservation, where the local provenance is typically defined using a combination of climate, geomorphological and genetic information. Where information on the spatial distribution of genetic diversity and the extent of gene flow between locations is not available, predictions are often made based on the life history traits of the species. However, this is problematic as species with very similar life history traits can have very different spatial genetic structures, due for example to different histories of range expansions and contractions. Here we investigate genetic variation at nuclear and chloroplast markers in populations of three co-occurring Pilbara riparian tree species: *Eucalyptus camaldulensis*, *Eucalyptus victrix* and *Melaleuca argentea*. Bayesian clustering, maximum likelihood estimates of migration rates, as well as genetic variance partitioning based methods were used to assess the spatial genetic structure of these three riparian species and in particular, contrasting the extent of differentiation within and among creek systems. Critically, genetic structuring was found to vary significantly between the three study species, which highlights the importance of species-specific studies on the geographic distribution of genetic variation. This study generates novel data on landscape drivers of genetic structuring in the Pilbara, and provides restoration practitioners with a solid genetic basis to guide seed sourcing for optimal restoration and biodiversity conservation outcomes.

Management of *Hydrocotyle ranunculoides* in Europe

Jonathan Newman

Centre for Ecology and Hydrology

Symposium: Aquatic Ecosystems: Restoration Interactions

Hydrocotyle ranunculoides is known to be present in at least 5 countries of North West Europe. Despite its limited distribution, where it occurs it forms very dense floating mats that block waterways, with the consequent loss of most submerged macrophytes, restriction of marginal habitat, simplification of habitat structure and significantly increased potential flood risk. Methods of control of this species range from exclusively mechanical removal (harvesting) in the Netherlands to a combination of methods including mechanical control of large floating mats followed by application of glyphosate based herbicides combined with the aquatic approved sticker adjuvant TopFilm, followed also by hand pulling of fragments. No single method of control has proved successful at completely eliminating this species and the only sites in the UK where eradication has proved successful are where dedicated water managers have ensure continued control efforts over a period of years. The most successful regime at the moment appears to be hand pulling in early spring to remove as many of the small marginal mats as possible, followed by more hand pulling or application of herbicides, followed by mechanical removal if required followed by more hand pulling and herbicide application. This process goes on between early spring and late autumn. Restriction of trade in the species at specialist aquatic nurseries has limited the increase in distribution in the UK since about 2005, but further action is required to ensure a complete ban on the sale of this and other nuisance aquatic macrophyte species.

An industry perspective on achieving biodiverse banksia woodland return

Vern Newton[1]

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Symposium: Banksia Woodland Restoration

Perth sits at the centre of one of the world's 25 global biodiversity hotspots. A key resource centre (silica and building products) operated by Rocla is located 30km north-east of Perth (Gnangara) on the Swan Coastal Plain on the suburban outskirts of Perth. The development of metropolitan Perth is highly dependent on the significant sand resources that are generally restricted to isolated pockets in specific geological units within the metropolitan regions' Bassendean dune system. As a result, the company impacts the Banksia woodland plant communities in the path of the mine, which are supported by the deep siliceous Bassendean dune sands. The process of sand extraction requires clearing of the Banksia woodland vegetation from undulating hill-sites, stripping the topsoil and removing the underlying white and yellow quartz sand horizons constituting 18–40m of the sand profile, thereby reducing the resultant sand profile depth by at least 20m. A major priority of the company is to restore the post-sand extracted sites with a plant community closely resembling the pre-sand extracted Banksia woodland plant community. Devoid of any existing restoration information, Rocla over the past 18 years has developed, in collaboration with Kings Park and Botanic Garden, procedures to ensure >75% of species return in their restoration sites. This presentation will highlight some of the key advances in planning and restoration implementation that have enabled these industry leading restoration outcomes.

Reconstructing a native forest ecosystem at Mount Owen Mine

Yvonne Nussbaumer, Carmen Castor

The University of Newcastle

Theme: Mine Restoration

Mount Owen open-cut coal mine is passing through 50% of Ravensworth State Forest in the Hunter Valley NSW. As a consequence, Thiess Pty Ltd and Xstrata Coal, together with the University of Newcastle, has initiated the Forest-Woodland Reconstruction Research Program in the spoil placement area and a Biodiversity Offsets Research Program, using the Ravensworth State Forest remnant as the reference community. Research on the soil placement area has focused on using forest or pasture topsoil as a growth medium, as well as finding topsoil substitutes. Experiments to date have looked at the use of biosolids, municipal waste compost, chitter and pasture subsoil, as well as the application of fertilizer and gypsum. Forest topsoil has consistently produced the best outcomes in terms of plant density and species richness, while pasture topsoil has performed worse than bare spoil due to high weed and grass competition. Capping pasture topsoil with either chitter or subsoil reduced competition long enough for native species to become established. Pasture subsoil was the best of the media trialled to date, while biosolids produced mixed results due to high weed and grass competition in the field. Inoculation of plants growing in these substrates with rhizobia bacteria improved plant growth. Long term monitoring of experiments provides insight into their resilience to environmental stresses such as drought and therefore the likelihood for long-term sustainability.

Fauna colonisation of newly established mine rehabilitation at a mineral sands mine in arid southwest New South Wales

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Theme: Mine and Fauna Restoration

This study assessed colonisation by birds, small mammals, reptiles and amphibians of a newly rehabilitated mine waste dump, OB3 (Overburden Stockpile 3), at the Bemax, Ginkgo Mine in far southwest NSW. The construction of a large mining void to facilitate a sand mining operation has resulted in the establishment of a permanent 34ha elevated hill feature. The vast majority of overburden at OB3 is comprised of overburden sands and clays which have been capped with 20cm of calcareous subsoil followed by 20cm of topsoil, representative of the surrounding region. The landform has been cross-ripped with woody debris placed over batter areas to reduce erosion. Revegetation commenced in mid 2009 involving direct seeding along with some targeted areas of tree and shrub tubestock planting. Flora surveys conducted in May 2010 and September 2011 have established the floristic and structural composition of OB3. In 2011 we began fauna surveys of pads and batter slopes at OB3 as well as in surrounding remnant vegetation which was separated by approximately 100 m of cleared land. Our surveys consisted of pit-fall trapping for small mammals and herpetofauna and timed observations for bird species. Both birds and herpetofauna showed greater species richness within the remnant habitat, although some species were found exclusively within OB3, including the only amphibian recorded, *Neobatrachus sudelli*. Pit-fall trapping revealed a bias towards certain mammal species, namely Fat-tailed Dunnart (*Sminthopsis crassicaudata*) and House Mouse (*Mus musculus*) within OB3, while Common Dunnarts (*Sminthopsis murina*) were the dominant within the remnant habitat.

Seed quality and management of plant genetic resources in fragmented landscapes

Kym Ottewell[1], Mike Gardner[2], Andrew Lowe[2]

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Symposium: Seed Sourcing Guidelines for Restoration Success

Identifying appropriate sources of seed for ecological restoration is a complex, yet critical, process. In fragmented landscapes, reduced stand density and changed plant-pollinator interactions can lead to changes in individual plant mating patterns, for example, through increased inbreeding or reduced pollen diversity. These mating patterns drive immediate gains or losses of genetic diversity in populations and are expected to directly impact the fitness of future generations. Through a review of the literature we provide a meta-analysis of the general effects of habitat disturbance on mating patterns of animal-pollinated trees and shrubs. We demonstrate these effects using several case studies of mallee and woodland eucalypts in southern Australia. Through microsatellite analysis of open-pollinated progeny arrays collected from isolated trees, remnant patches and 'intact' forest we show that the mating patterns of these trees show a correlation with stand density and pollinator mobility. We then explore the fitness consequences of these altered plant mating patterns in a common garden experiment and find that pollen diversity is a significant predictor of progeny fitness, in addition to outcrossing effects. The findings of this work have applications to management of plant genetic resources. We focus on the implications of these findings for the use of plant genetic resources in restoration and revegetation.

Riparian wildlife habitat mapping with LiDAR and high resolution imagery

Chong-Hwa Park, Seung-Gyu Jeong

Seoul National University

Theme: Methods, Techniques and Technologies used in Restoration

Drastic change of stream topography and vegetation after flooding makes riparian corridor surveys obsolete frequently. Advanced remote sensing technologies could be employed for the mapping and monitoring of stream renovation projects. The objective of this paper is to produce accurate riparian wildlife habitat maps by merging high resolution multi-spectral data and canopy height obtained from LiDAR. Such maps can be used to evaluate wildlife habitat and to connect fragmented riparian wildlife passages of river corridors in urban areas of Korea. Land cover classification based on OOC was carried out by merging spectral data of high resolution imagery and vertical data of LiDAR. Spectral bands of the DMC digital high resolution are RGB, and NIR, and spatial resolution is 0.2 m. First, riparian land cover map was produced tree, shrub, grass, bare earth, and water surface. Overall accuracy was 66.25%, and those of water and bare earth classes were 82.5% and 70%, respectively. But the accuracies for shrub and grass classes were less than 54% due to the confusion with each other class. Second, Canopy Height Model were produced based on the LiDAR data. Threshold values between bare earth, grass and shrub, and tree were set at 3m and 5m, respectively, for the data fusion of spectral and height data. Third, land cover classification based on the data fusion and OOC was carried out. The classification accuracies for the two classes, shrub and grass classes, were improved to 60% level. The classification accuracy may be improved by adjusting the height threshold based on the phonological stage of the remotely sensed data, too. Finally, wildlife habitat maps for above mentioned bird and mammal communities were produced.

Evaluation of native Australian grass species for tolerance to sodium sulphate salinity in bauxite processing residue sand

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[1]The University of Western Australia, [2]Murdoch University

Theme: Mine Restoration

Introduced grasses are currently used as temporary vegetation cover on bauxite residue storage areas (RSA) to suppress dust and erosion. Native Australian grass species are ecologically preferable, but their tolerance to the alkaline, sodic, and saline soil conditions of bauxite residue is unknown. Twenty-seven native grass species were pre-screened for their requirement of gibberellic acid and smoke water to break seed dormancy, a common problem for establishment of these species. Thirteen species were then compared with two currently-used, introduced grass species for their ability to emerge in bauxite residue sand pre-treated with gypsum, washed, then amended with Na_2SO_4 to produce salinity (ECe) ranging from 2 -12dS/m. Austrostipa scabra and Chloris truncata showed the greatest tolerance to salinity with no inhibition up to 10dS/m. Neurachne alopecuroidea displayed a moderate-high tolerance to salinity with a 20% decrease in emergence over the treatment range. *Microlaena stipoides* and *Themeda triandra* exhibited moderate inhibition and *Bothriochloa bladhii*, *Brachyachne convergens* and *Enneapogon polyphyllus* displayed low tolerance to salinity. No native species had emergence exceeding 50% and none exceeded the emergence of the introduced species, *Lolium rigidum*. This investigation highlights the need to test the germinability of seed and dormancy-breaking requirements prior to use. *Austrostipa scabra*, *C. truncata* and *N. alopecuroidea* show potential as early-stage rehabilitation species, while *M. stipoides* and *Themeda triandra* could be established when salinity has declined. Field performance, including productivity and competition of these grasses compared with introduced species, remains to be tested on bauxite RSA.

Novel ecosystems: a necessary consideration for restoration planning in the 21st century

Michael Perring, Kristin Hulvey, Lori Lach, Tim Morald, Rebecca Parsons, Rachel Standish
The University of Western Australia

Symposium: Novel ecosystems in restoration and rehabilitation: Innovative planning or lowering the bar?

Novel ecosystems are now widespread across the global biosphere, having arisen through abandonment of intensively used land or through human-caused biotic and abiotic changes to supposedly unaltered 'natural' systems. Thresholds (ecological, economic and social) present in these systems prevent the return of historically accurate species assemblages, a restoration goal that may be questioned in this era of multiple, rapid and pervasive environmental changes. Here, we present an alternative restoration goal of providing those processes and outcomes valued by humans i.e. ecosystem services. We discuss the background and design to the Ridgefield Multiple Ecosystem Services experiment, set up on former agricultural land in the highly fragmented wheatbelt of Western Australia. This experiment investigates how different native species assemblages provide desired ecosystem services (including carbon sequestration, nutrient cycling, soil erosion control, maintenance of biodiversity, and invasion resistance) and whether trade-offs exist among these services. Additionally, we ask whether novel components to the flora are detrimental to service delivery. This is a much needed experimental investigation of how novel ecosystems can contribute to appropriate restoration goals in certain circumstances. However, novel ecosystems are neither conservation nor restoration panacea and careful distinctions must be made between those novel ecosystems that have arisen inadvertently and require management action in the 21st century, and those that are planned, innovatively or otherwise.

The need for standardising quality assessments of seeds used in rehabilitation and restoration projects in Western Australia

Alice Quarmby
Western Botanical

Symposium: Seed Sourcing Guidelines for Restoration Success

As many mining projects progress towards mine site closure and evaluating rehabilitation success, the requirement for quality seed resources is on the rise. Currently there are no broadly accepted standards defining the quality of seeds that can be sold by seed merchants. The quality of seed needs to consider both the viability and the purity of the collection. These affect the sowing rates, amount of seed required, and ultimately the cost of rehabilitation projects. If a seed merchant does not provide information on the viability (seed fill) of the collections they are providing, a buyer is likely to assume that they have 100% healthy seeds. For some species, however, seed fill can be less than 50%. This would mean that you need double the quantity of seed (and cost) to deliver the same outcome as a collection with 100% seed fill. For particular species (e.g. from the Myrtaceae family) it is common for chaff material to be included in the seed collection. While chaff can be removed using various cleaning techniques, it is more common for it to remain in the collection due to time and effort required to separate the material. Depending on the sowing technique, e.g. direct seeding versus automated nursery machinery, the effect of impurities in the collection are either not important or cause considerable problems in the propagation results. It is therefore recommended that the seed purity and viability information are provided for all seed collections for sale.

Pastoral stream restoration through integrated farm management: how do responses match expectations over the first decade post-implementation in a New Zealand hill catchment?

John Quinn, Robert Davies-Colley, Glenys Croker, Kerry Costley
National Institute for Water and Atmospheric Research

Theme: River Restoration

Catchment rehabilitation has become a widely accepted approach for improving water and habitat quality of pastoral streams but long-term evaluation of its effectiveness is rare. In 2001, a farm scale Integrated Catchment Management experiment was established on a sheep and beef farm at Whatawhata Hill-land Research Centre, West of Hamilton, NZ, to evaluate effects on economic performance, biodiversity and aquatic ecosystem health of an integrated package of land management actions, developed by a stakeholder group, towards achieving long-term economic and ecological sustainability. We evaluated response trajectories of a range of stream ecosystem attributes (i.e., hydrology, water quality, channel morphology, shade, stream temperature, instream vegetation, macroinvertebrates and fish) to sub-catchment management changes. These involved a change in the livestock system and (i) pine afforestation with 10 m riparian planting setbacks in the steepest, most erosion prone, least productive, areas; (ii) cattle exclusion and riparian poplar planting and 30% upland afforestation, and (iii) native reforestation of riparian areas. Responses were compared with adjacent reference sites in native forest and pasture below native forest, in a BACI experiment from 1995 .Ten years after implementation, attribute responses have varied from 'step change' (e.g., for *E. coli*) to 'rubber band' (relatively rapid response as pressures decreased, e.g., for stream temperature and invertebrate community metrics) to highly lagged (for nitrate, channel width and large wood). Shade development, via riparian vegetation growth, was a key driver of several responses. The proximity to colonist sources has likely contributed to the relatively rapid response of macroinvertebrates to habitat improvement.

Spinifex microchemistry and mineral exploration potential

Nathan Reid
CSIRO

Symposium: Arid zone spinifex (Triodia) restoration

Spinifex (*Triodia* spp.) grasslands cover vast areas of arid Australia, across a variety of soils and landscapes. These grasses are deep rooted and long lived, hence have great potential as a biogeochemical sampling media for mineral exploration. The analysis of T. pungens and T. scariosa leaves from field sites over buried Au mineralisation (Coyote, Oberon and Tunkillia Prospects) shows that there is a multi-element anomaly in the vegetation over the projected mineralisation, the haloes are of different scales depending on the local landscape setting and dispersion potential of each element associated with mineralisation. The magnitude of the anomalies is similar for each site independent of underlying substrate. Overall, spinifex chemical composition has the potential to act as a point indicator of substrate geochemistry with very minimal dispersion (hundreds of metres only) that can delineate the extent of a potential ore deposit. *T. pungens* and *T. scariosa* also have Cr accumulation potential, discovered during the mineral exploration studies, from several field sites (Coyote, Oberon, Tunkillia and North Miitel Prospects). Triodia species are shown to be able to accumulate Cr up to potentially toxic levels independent of substrate concentration. This could be due to accumulation (active transport) or the lack of a barrier mechanism (passive uptake) within the plant.

The role of translocation in Victorian orchid conservation

Noushka Reiter[1], Richard Thompson[2], Rob Cross[2], Glen Johnson[3], Karen Lester[3], Julie Whitfield[4], Mary Argall[1], Gail Pollard[1], Ann Lawrie[5]

[1]Wimmera Catchment Management Authority, [2]Royal Botanic Gardens Melbourne, [3]Department of Sustainability and Environment, [4]North Central Catchment Management Authority, [5]RMIT University Melbourne

Symposium: The role of plant translocations in restoring and maintaining biodiversity: policy, planning and practice

Victoria is host to approximately 380 species of orchids, more than half of which are threatened. A major success of the Victorian Orchid Conservation program has been establishing ex situ symbiotic germination techniques for a number of these species. Currently 30 of these threatened orchid species are being propagated for reintroduction and approximately 150 in situ populations of 50 orchid species are being protected. The Victorian Orchid Conservation Project aims to implement a range of actions from the National Recovery Plans and Flora and Fauna Action Statements of 80 species of terrestrial orchids from across the state of Victoria. Using ex situ symbiotic germination and reintroduction, this collaborative project is a collaboration between the Wimmera Catchment Management Authority, Victorian Department of Sustainability and Environment, the Royal Botanic Gardens Melbourne, the Australasian Native Orchid Society, the University of Melbourne, RMIT University and many community groups. Summaries of five endangered orchid reintroductions and lessons learnt from these recovery work conducted on them over the past decade are presented. The work includes surveys, long term monitoring, propagation, habitat modification, re-introductions and mycorrhizal phylogenetic work. The species highlighted here are *Caladenia cruciformis*, *Caladenia robinsonii*, *Caladenia xanthochila*, *Diuris dendrobiodes* and *Thelymitra epipactoides*.

Measuring the success of banksia woodland restoration using ecological markers

Alison Ritchie

The University of Western Australia, Kings Park and Botanic Garden

Symposium: Pollinators in Ecological Restoration

The delivery of pollinator services is key to the functionality, self-sustainability and success of restored populations. The Southwest of Western Australia on a global scale, has a high proportion of bird pollinated species and diversity of pollinators. The importance of these pollinator guilds for outcrossing and production of genetically robust outbred seed in West Australian plant populations is known, however their implications for restoration success is rarely taken into account. To address these issues, pollination studies of *Banksia attenuata* and *Banksia menziesii,* two keystone tree species used in Banksia woodland restoration are being conducted. Pollination and mating systems of the summer flowering *B. attenuata* and winter flowering *B. menziesii* within post-mining restored populations are compared to natural fragmented and natural unfragmented populations. In this presentation I will focus on comparing and contrasting observed pollinator visitation rates, pollinator assemblages and foraging behaviour between the two Banksia species and between population types.

An effective way forward to understand, learn and respond to restoration actions

Julie Robert
SERCUL

Theme: River Restoration

South East Regional Centre for Urban Landcare (SERCUL), with 15 years extensive restoration experience, has an underlying philosophy to incorporate the scientific method, as fundamental to all project delivery, both ecological and social. Extensive experience in restoration projects has identified the ideal strategy for effective outcomes to be the incorporation of inclusive partnerships for ecological and social outcomes, utilising independent collaborative research driven from the bottom up, rather than top down from Research Institutions. To this end SERCUL restoration ecologists, practitioners and invasion ecologists developed a Framework (Fisher, 2011), to which SERCUL staff has contributed information based on their extensive experience in restoration projects. The outcome was a Monitoring Plan (Fisher, 2011) to respond to identified knowledge gaps utilising an ecosystem management approach to understand i) ecosystem interactions, ii) native and weed species interactions and iii) measurable outcomes of restoration projects. This Framework, incorporating all Project Partners, enables the willing conversion of evidence based techniques into standard practice without coercion, while adapting restoration methods based on new understandings of functional interactions and processes in complex often highly disturbed urban systems. The Monitoring Plan has been incorporated into the $A8.6 million Urban Waterways Renewal (UWR) project, with 11 Restoration Projects managed and implemented by SERCUL. This is the biggest project ever conducted by a community group in Western Australia, receiving $A4 million of Australian Government funding under the Water for the Future initiative. Other funding was provided by the Western Australian Department of Water, Water Corporation, Swan River Trust, and the Cities of Canning, Gosnells and Armadale. Current outcomes from the ecological interactions study, utilising an ecosystem management approach will be presented (Fisher JL (2011) Report to SERCUL).

Hydrocotyle and the management experience in Perth, Western Australia

Julie Robert
SERCUL

Symposium: Aquatic Ecosystems: Restoration Interactions

Hydrocotyle ranunculoides represents a major threat to the biodiversity and amenity of freshwater waterways in Western Australia. *H. ranunculoides* is listed as a declared weed, as priority P1 for containment and P2 for eradication, in the State of Western Australia requiring landholders to control and eradicate where possible. In 1991 Floating mats of Hydrocotyle covered large areas of the Canning River from bank to bank, with the eventual cleanup cost in excess of $A2 million dollars. A total of approximately $A4.5 million dollars has been spent removing *H. ranunculoides* from the Swan Canning river system, however large localized infestations remain causing a loss of biodiversity, damage to infrastructure and an increase in management costs. The Hydrocotyle Working Group (HWG), a stakeholder partnership formed in 2002, managed by South East Regional Centre for Urban Landcare (SERCUL) to coordinate the control and management of *H. ranunculoides* with members from the City of Canning, Water Corporation, Department of Environment and Conservation, Swan River Trust, Department of Agriculture, Local community and Catchment groups. The HWG recommends that consideration be given to funding a comprehensive research project utilising a knowledge acquisition and systems approach to understand its impacts on biodiversity and to enable the eradication of *H. ranunculoides* in the National Heritage listed Canning River Regional Park and wider Swan-Canning River catchment. The Symposium is designed to bring together experts to establish an effective way forward for the Research and management of this species.

The nuts and bolts of successful living stream planning and implementation

Julie Robert
SERCUL

Symposium: Living Stream Restoration

The South East Regional Centre for Urban Landcare (SERCUL) is a community organisation which has developed, and implemented projects to improve the health of our waterways and other ecosystems through the promotion and utilisation of an integrated approach to catchment management. SERCUL's primary area of river management is the most weed infested river in Western Australia, the Canning River a tributary to the Swan River. A major focus has been the development of Living Streams with the first being constructed in 2000 as part of the implementation of the Bannister Creek Management Plan, a tributary to the Canning River, with a further 11 Living Stream Restoration Projects currently under construction, managed and implemented by SERCUL, as part of the $A8.6 million Urban Waterways Renewal (UWR) project, receiving $A4 million of Australian Government funding under the Water for the Future initiative, in partnership with the Western Australian Department of Water, Water Corporation, Swan River Trust, and the cities of Canning, Gosnells and Armadale. The effective implementation of such projects in highly urbanised systems where the waterway has functions including stormwater conveyance and water detention within often straightened systems involves complex interactions and coordination between the doers and the neighbours. SERCUL Staffs' expertise in reaching agreement between engineers, state and local government agencies, environmental consultants, contractors and local people, and coordinating large scale machinery, site assessments, planning approvals and volunteers, provides the impetus for success which must be achieved before the restoration actions can begin.

Closure cost modelling: benefits of forward planning

Jo Russell
Karara Mining Limited

Theme: Planning Restoration and Measuring Success

Historically mining companies have based the financial provision for closure and rehabilitation on unconditional performance bonds lodged with the Department of Mines and Petroleum (DMP). This can lead companies to be unprepared for the cost of closing a mine site, as bonds only cover a proportion of the cost of rehabilitation. In July 2011 the Guidelines for Preparing Mine Closure Plans were issued by the Department of Mines and Petroleum and the Environmental Protection Authority. These guidelines describe the standards required for the closure of mine sites which apply to both existing and new mining operations. Among the key changes is a requirement to include estimates of mine closure costs in the Mine Closure Plan to be submitted to Government as part of the project approvals process. The estimates must be supported by information on the costing method, assumptions made and financial processes used to estimate costs. Karara Mining Limited engaged SRK Consulting to develop a preliminary cost estimate for the implementation and management of rehabilitation and mine closure for the Greater Karara Project. Conceptual reclamation and closure methods were used to evaluate the various components of the mining operations and standardised cost modelling tools employed to prepare a closure cost estimate. Mine personnel provided user input data describing the physical layout, geometry and dimensions of project components. Along with this data, the model used first principle methods to estimate quantities, productivities, and work hours required for various closure tasks based on 2011 standardised industry unit costs for labour, equipment and materials. This methodology allowed KML to develop an increasingly accurate closure cost estimate that will reflect changes over the life of the project and assisted KML with fulfilling the requirements of the new Closure guidelines.

Developing a tool kit to maximise success in managing environmental assets degraded through altered hydrology

Jasmine Rutherford[1], Ryan Vogwill[2], Kevin Cahill[3]

[1]Department of Environment and Conservation, [2]The University of Western Australia, [3]CSIRO

Symposium: Toolibin Lake: a case study of wetland restoration

One of the main challenges in managing Toolibin Lake has been the development of a planning framework that allows for the prioritisation of investment in acquiring and interpreting data. This challenge has arisen as the hydrology was significantly altered prior to biophysical mapping and monitoring to assess water and salt fluxes. As a consequence, the main hydrological drivers of vegetation stress and death can only be identified through long term study and investment in both catchment and asset scale spatio-temporal datasets capable of mapping and explaining surface-groundwater dynamics. Datasets critical for the successful management of Toolibin Lake's hydrology are derived from a range of geophysical and remotely sensed techniques. Adopting an integrative approach allowed for the calibration and validation of data to produce a quantitative assessment of the lake's hydrology. Mapped outputs from this work form the foundation datasets for numerical modelling to underpin restoration at Toolibin Lake.

Restoration of an iconic canopy species with specific regeneration niche requirements during low-intensity prescribed burning

Katinka Ruthrof, Leonie Valentine, Giles Hardy

Murdoch University

Theme: Forest and Woodland Restoration

Regeneration is a necessity for long-term development and sustainability of forest ecosystems. Regeneration of the dominant canopy species, *Eucalyptus gomphocephala*, in many parts of its fragmented distribution in Western Australia, is nominal. Local extinction of the population could occur as older serotinous trees senesce or, more recently, succumb to massive canopy dieback. *Eucalyptus gomphocephala* has a specific regeneration niche, mass recruiting in ashbeds in canopy gaps. Ashbeds can be created by burning coarse woody debris (CWD) piles at high temperatures. However, burning individual CWD piles is too labour intensive for larger, intact forest areas. Furthermore, ashbeds may not occur naturally in intact forests following low-intensity, fuel reduction burns that are prescribed for many E. gomphocephala forests and woodlands. We investigated whether regeneration could be facilitated by creating CDW piles prior to a prescribed fire. Intervention techniques included: control (no CDW) gaps; control (no CWD) gaps+broadcast seed of *E. gomphocephala*; created ashbeds; and created ashbeds+broadcast seed. Results indicated that a) the majority of CDW piles burnt at high temperatures (>600Co), b) control plots, + broadcast seed, contained few seedlings, and c) ashbeds, especially those that were seeded, contained high numbers of seedlings. Thus, *E. gomphocephala* regeneration can be facilitated at an operational scale as part of prescribed fire activities, through creation of CWD piles and broadcast seeding. This research is applicable for managers working in forest systems that are subject to low intensity prescribed burns where key species have specific regeneration requirements.

A landscape neo-baroque: design as a cultural strategy for the restoration of urban ecosystems

Catharina Sack

FALVA, University of Western Australia

Theme: Urban Restoration

This paper presents a cultural strategy for ecological restoration. It rejects the culture/nature binary by presenting the baroque as a landscape design strategy aimed towards the restoration of novel ecosystems. The baroque creates an atypical armature for structuring scientific systems into the creation of the expanding suburban landscape mosaic. This paper elaborates on how baroque design strategies can overcome the creation of market-driven, water and nutrient craving landscapes. Baroque characteristics, seemingly pejorative and counter to the scientific methodology, are used to create resilient and ecologically productive novel ecosystems grounded in a critical and autochthonous aesthetic of botanical complexity. The paper focuses on Perth, Western Australia, a rapidly expanding settler-city located in an internationally recognized biodiversity hotspot. While uniquely high in plant endemism and species richness, the city's fringes are smoothed over and bulldozed with little regard. As are all landscapes, the landscape of Perth is the sum of its parts; the inimitable details of Perth's parts are, however, widely misunderstood. Part of the Southwest Australian Floristic Region, the landscape's extreme age and stability, its isolation and Gondwanan botanical heritage, and the ability of its plants to thrive in old, leached stable soils are some of the factors that account for this botanical richness. As are many Mediterranean places, it is a landscape that is dry, crunchy and not green. While the scientists continually strive to understand the specific, the inhabitants persistently crave the verdant picturesque. Without an acute and novel approach to modify current development practices, Perth's biodiversity is headed for extinction. This paper proposes one such approach.

Spatial optimisation of managed regrowth for fauna recovery in the brigalow

Leonie Seabrook[1], Martine Maron[2], Megan Evans[2], Tara Martin[3]

[1]Environmental Decisions Group, [2]The University of Queensland, [3]CSIRO

Theme: Delivering Large Scale Restoration

Investment in the carbon economy, such as carbon farming initiatives and investment in carbon offset schemes, is predicted to change attitudes towards broad-scale revegetation in agricultural regions. In Queensland, where energy extraction industries (coal mining and coal seam gas extraction) are rapidly expanding, investment by these industries in revegetation for carbon offsets may offer a viable alternative income stream to landholders. Revegetation offers benefits not only for carbon but also for biodiversity conservation, particularly if native vegetation is used for carbon sequestration. The Brigalow Belt bioregion in Queensland offers a unique opportunity to use managed regrowth to increase fauna recovery outcomes for a range of threatened fauna species. Many Brigalow (*Acacia harpophylla*) ecosystems are now endangered due to clearing for agriculture but a characteristic of this species is its ability to regrow from suckers when disturbed. Strategic identification of locations where restoration through managed regrowth can maximise opportunities for fauna recovery, while minimising economic costs and conflict with other land uses, is critical to increase the likelihood of success. This project applies spatial prioritisation techniques based on species occurrence, habitat suitability within existing remnant and regrowth vegetation, and landscape connectivity. We estimate opportunity costs such as land values, existing and potential land use, average agricultural income and potential income from alternative sources of land use. We use time steps to account for increasing use of regrowth vegetation by fauna as it matures. Results will identify priority areas to maximise potential fauna recovery outcomes from managed regrowth, while minimising opportunity costs.

The potential for classical biological control of *hydrocotyle ranunculoides* in Europe

Richard Shaw

CABI

Symposium: Aquatic Ecosystems: Restoration Interactions

Hydrocotyle ranunculoides, known as floating pennywort, has become one of the most feared aquatic plants by land and water managers in Europe despite being a relative newcomer. It has spread rapidly in its introduced range to cover still and slow-moving water bodies to the exclusion of native species and many leisure activities. It is also known to block drains and could exacerbate flooding. Current control relies mainly on mechanical removal in much of Europe but in the UK, innovative formulations of glyphosate can be effective. Nonetheless, *H. ranunculoides* is very unlikely to be controlled by conventional means so an alternative approach is required. More than 30 years ago, researchers in the native range of South America highlighted a weevil (recently renamed *Listronotus elongatus*) with an apparently restricted host range from Argentina as a potential biological control agent (Cordo et al. 1982). Research in 2006/7 confirmed the potential of this weevil amongst other natural enemies. Subsequently, a full biocontrol programme was initiated in the UK in 2010 and further potential agents have been revealed including a petiole-mining fly (*Eugaurax* sp.) and a Puccinia rust. This paper will consider the characteristics and likely host range of each of the most interesting natural enemies in turn. We conclude that there is excellent potential for the management of this weed by natural means in Europe and beyond. whilst classical biological control is a novel technique in Europe, floating pennywort is likely to be reunited with at least one of its natural enemies soon.

Conservation genetics and ecology of endangered swamp orchids *phaius australis* and *p. Bernaysii*: what are the implications for conservation in a changing world?

Laura Simmons, Robert Lamont

University of the Sunshine Coast

Poster Presentation

Swamp Orchids, *Phaius australis* and *Phaius bernaysii*, are some of the most iconic and beautiful plants in the coastal and littoral wetlands of east coast Australia. However, these orchids are endangered due to habitat loss, fragmentation and illegal collection. Future climatic change threatens to push such flora with small population sizes, limited connectivity and narrow environmental tolerances, to extinction. Little is known about the biology or ecology of Swamp Orchids and how they might respond to climate change: they occur in disjointed coastal areas from north Queensland to central New South Wales, on sand islands and in isolated western Queensland patches. Does the species have genetic variability or display plasticity across its range? Do population dynamics change over the climatic gradient? Would translocations assist survival of the species? This doctoral research will test theories for plants occurring over latitudinal gradients by undertaking population census, ecological and reproductive studies linked with climate, habitat and fragmentation. These results may be utilised in population dynamic modelling (RAMAS GIS), habitat modelling (Maxent) coupled with climate change models (SIM CLIM) to predict future range shift. Genetic variability and diversity across the species' range will also be assessed using microsatellite markers produced through NextGen Sequencing. This range-wide, holistic understanding of the species response to climate will result in an estimation of future viability, persistence and conservation implications. Outcomes will be presented to land managers and community groups to guide habitat protection, recovery and restoration plans including design of translocation programs, increasing the likelihood of long-term survival.

Measuring genetic diversity in a successful restoration site: implications for future seagrass restoration

Elizabeth Sinclair[1], Jennifer Verduin[2], Siegfried Krauss[1,3], Gary Kendrick[1]

[1]The University of Western Australia, [2]Murdoch University, [3]Kings Park and Botanic Garden

Symposium: Seagrass Restoration

Seagrass meadows are in decline globally. A number of experimental methods have been tested to help restore meadows. However, they have largely been unsuccessful in the long term, are usually monitored over the short-term, and often with little or no input from genetically based methods to ensure diversity, despite evidence to suggest that increased levels of genetic diversity increases intraspecific survival as well as overall diversity. Cockburn Sound, a natural embayment south of Perth, WA, has seen a 77% decline in seagrass cover since the 1967. In small, localised areas natural recruitment has been very successful, while other parts have not been able to recruit and recover naturally. A transplant trial was conducted between 2004 and 2008 as part requirement of a seagrass loss compensation measure mitigating the impacts of shell sand dredging. Sprigs (15–20 cm lengths of rhizome with roots and shoots) were planted in a bare sand area. We assessed genetic diversity in this transplant area and compared diversity to the original donor sites. Shoot samples were collected using a standard random coordinates method in March 2012, and genotyped using seven microsatellite DNA markers. Genetic diversity was very high in the restoration site and comparable to the donor sites. The spatial arrangement of the multilocus genotypes showed that transplant material for the restoration site was sourced from the same genetic provenance, although none of the same plants were sampled. The high level of genetic diversity and choice of site may have played an important role in the success of this restoration trial.

Spinifex-mallee revegetation at Wemen in semi-arid northwest Victoria: implications for the sand mining industry in the Murray-Darling depression bioregion of southeastern Australia.

Ian Sluiter[1], Ralph Mac Nally[2]

[1]University of Ballarat, [2]Monash University

Theme: Mine Restoration

Revegetation involving the hummock-forming grass Spinifex (Triodia scariosa) has to date, not been undertaken with success in the Murray-Darling Depression Bioregion. Revegetation success with Spinifex and mallee trees is an imperative with the impending prospect of new sand mines in Spinifex-Mallee vegetation communities across the Bioregion. We assessed hand-planting trials of tubestock incorporating a high proportion of Spinifex grass and mallee species in a cleared paddock at Wemen in northwest Victoria, adjacent to a former mineral sands mine (Wemen Mine). Botanical assessments of the Wemen trials were conducted in October 2011 after being established in June 2001. A Bayesian model was constructed to determine species-specific survival proportions relative to the overall average. The overall mean survival rate was 0.58. Species having substantially greater survival proportions were Mallee (*Eucalyptus* spp.) trees, Needlewood (*Hakea* spp.) trees and Spinifex. Species having substantially smaller survival rates than the average were mostly Wattle (*Acacia* spp.) taxa. The implications for sand mine rehabilitation with Spinifex and mallee species are discussed.

Environmental offsets: are they effective in promoting restoration?

Kane Smith

Ecofund Queensland

Theme: Ecosystem Services and Environmental Offsets

The increasing implementation of environmental offsets as government agencies seek to counterbalance unavoidable environmental impacts that result from development activities is showing them to be effective in achieving restoration outcomes. In Queensland, environmental offsets are a legislative requirement triggered by impacts on particular environmental values. Typically, the delivery of environmental offset projects involves the identification, protection and ongoing management of areas of land with a similar suite of environmental values to the land that is subject to development. Strategically implemented offsets support the restoration of degraded ecosystems, address threatening processes and restore and re-establish habitat for threatened species. Offset projects can also provide additional environmental benefits beyond project boundaries. Environmental resilience can be improved by strategically locating offsets to add to and buffer protected areas, establish biodiversity corridors and improve water quality in creeks and rivers. Environmental offset projects typically involve initial restoration groundworks (such as fencing, weed control, pest animal management and revegetation) and on-going maintenance (including fire management), which is coordinated under an offset area management plan. Ecofund engages experienced practitioners to undertake major on- ground works and negotiates financial payments to landholders for land management activities where appropriate. Offset management continues for the life of the project, which is typically until the vegetation has reached its pre-clearing condition. In Queensland, the responsibility for funding initial and ongoing management actions lies with the developer and failure to adequately manage offset sites can lead to compliance breaches and legal proceedings.

Should we change restoration strategy in the face of climate change? A case study from Western Australia

Ann Smithson

Kings Park and Botanic Garden, The University of Western Australia

Symposium: Seed Sourcing Guidelines for Restoration Success

Best practice restoration is usually based on the premise of local adaptation, such that locally sourced propagules (for example seed) are utilised to achieve high-quality restoration. However, with climate change predicted to impact restoration through altered survival and reproductive success, it has been suggested that our strategy should change from one of local sourcing of seed to one of maximisation of diversity of sources, perhaps even focus on seed sourcing from predicted climatic extremes. Specifically it has been hypothesised that for any one species restored, increased seed source diversity will increase survival, and thus restoration success, in an unpredictable climate. In this talk, I will present the results of an experimental study initiated in an exceptionally dry year where the survival and reproductive success of local and widely sourced seedlings was compared at multiple sites for two plant species, one of which is normally outcrossing and one of which is normally selfing. I will also contrast the genetic diversity of seed source populations, and test the relationship between genetic diversity and both survival rates and reproductive success. Can we predict the benefits and costs of local vs genetic-diversity seed sourcing in an unpredictable climate?

Digging deeper for woodland restoration: exploring the role of soil fungi

Rachel Standish[1], Georg Wiehl[2], Tim Morald[1], Chris Walker[1], Mark Tibbett[3]

[1]The University of Western Australia, [2]CSIRO Ecosystem Sciences, [3]Cranfield University

Theme: Forest and Woodland Restoration

Temperate eucalypt woodlands throughout southern Australia are in decline and yet there is limited understanding of how to intervene to promote their restoration. Woodland decline has been linked to livestock grazing, climate change and weed invasion among other factors. Fencing to exclude livestock grazing is one of few tools commonly used for maintaining and restoring remnant woodlands in Australia in agricultural landscapes. We begin this talk by describing our research to determine the benefits of fencing York gum woodlands in Western Australia's wheatbelt. While we observed clear benefits of fencing, it was the highly degraded sites that did not recover after fencing that stimulated our interest in soil properties, particularly soil fungi. Soil fungi could potentially improve the establishment and persistence of native plant species, and ultimately, contribute towards the functioning of the woodland ecosystem. We hypothesized that a combination of missing soil fungi, high soil nutrients and invasive weeds was preventing the recovery of more degraded woodland sites. So next, we present preliminary data on the presence and absence of soil fungi in woodland soils using different techniques including molecular analysis (T-RFLPs), spore counts and plant baiting. Finally, we present the results of a microcosm experiment designed to test the contribution of soil fungi to (weed) invasion resistance. We conclude by presenting a synthesis of our data and ask whether we have enough evidence to test a basic yet unanswered question in restoration ecology – do soil fungi facilitate restoration or follow it?

Aquaculture of *posidonia australis* seedlings for seagrass restoration programs: effect of sediment type and organic enrichment on growth

John Statton[1,2], Kingsley Dixon[1,2], Gary Kendrick[2]

[1]Kings Park and Botanic Gardens, [2]University of Western Australia

Symposium: Seagrass Restoration

Seeds of the seagrass *Posidonia australis* are desiccation-sensitive and since there is no seed dormancy seeds cannot be stored for use in restoration projects. To realize the restoration potential of seed-based restoration of Posidonia this study investigated preconditioning seedlings of Posidonia in aquaculture facilities prior to transplanting to extend the restoration window from a few weeks (for fresh seed) to months or even years (for preconditioned seedlings). Here, we tested two levels of organic matter addition, 0% and 1.5% sediment dry weight and three sediment types; two heterogeneous sediments typical of low-energy marine environments (i) unsorted calcareous and (ii) unsorted silica, and a homogeneous sediment typical of high-energy marine habitats (iii) well-sorted silica. We then evaluated seedling survival, biomass and development over a period of seven months in tank culture. There was 100% survival over the seven month experimental period for seedlings. Seedling leaf, root, rhizome and total biomass increased when organic matter was added to unsorted calcareous and unsorted silica sediment but not well-sorted silica sediment, though this increase was significant only after seven months of growth. The characteristics of the sediment also influenced seedling root length and architecture. Root length and number of lateral root branches was greatest in unsorted sediments and when organic matter was present. This study demonstrates that tank culture of *P. australis* enabled seedlings to be available for restoration purposes for at least seven months, and with modification of the sediment composition, larger *P. australis* seedlings with more substantial root systems can be produced.

Restoration ecophysiology: understanding restoration outcomes

Jason Stevens

Kings Park and Botanic Garden

Theme: Physiology and Hydrology for Mine Restoration

Restoration programs need to meet increasing public, regulatory and company expectations within reasonable time frames, highlighting the need to deliver effective and efficient restoration outcomes. In order to increase restoration efficiencies we need to capitalise on successes and minimise risks of failure, however currently the drivers underpinning these outcomes are often poorly understood. The question therefore remains – why is our restoration succeeding or failing to meet expectations? This presentation will outline how plant ecophysiology can be used by practitioners throughout the planning, implementation and evaluation phases of restoration programs to provide an efficient understanding of the restored system and its potential trajectories. Despite being a fundamental science for describing plant responses to environmental conditions, to date ecophysiology has been largely overlooked in ecological restoration programs, perhaps the result of a perception of relevance and/or prohibitive costs. By using ecophysiology, practitioners may gain a more subtle understanding of plant function in response to the restoration environment, develop proxies for community expectations, and have more rapid feedback loops (traditionally restoration performance indicators are <5 years) that may be modelled into longer-term restoration trajectories, all of which support traditional restoration monitoring approaches. With the continual development and refinement of physiological monitoring techniques for understanding plant function in intact reference species/systems and the development of real time remote plant monitoring systems, the gap between basic ecophysiology and the requirements of the restoration practitioner is closing.

Increasing seed-use efficiency of Australian native grasses

Jason Stevens[1], David Symons[1], Ian Chivers[2], Kingsley Dixon[1]

[1]Kings Park and Botanic Garden, [2]Native Grasses Pty Ltd

Symposium: Restoration with native grasses in Australia

There is an urgent need to identify perennial species that have the potential to be successful in the low to medium rainfall (<300–500mm) regions of Australia. Given the large genetic diversity that exists, there is large potential for the development of native perennial species (particularly grasses) that are already well adapted to the climatic and edaphic conditions of Australian farming/pasture systems. The overall aim of this program is to improve opportunities to introduce native grasses, through developing and testing seed enhancement techniques, allowing for the rapid scaling-up of sowing of native grasses onto a broad-scale. By lowering the establishment costs associated with increased germination performance it is anticipated that we will observe a greater use of native perennial grasses in, and production capacity for, Australasian restoration systems. This presentation will unpack the complexities associated with native grass germination and how germination enhancement (streamlining seed cleaning processes and testing a diverse range of dormancy alleviation techniques) is providing promising outcomes for increasing establishment success in several widespread native grass species.

Building and sharing our knowledge: how the hidden life of seeds can support restoration

Lucy Sutherland

Australian Seed Bank Partnership

Symposium: The Australian Seed Bank Partnership: a national network to advance seed management for conservation and restoration

Until recently, there has been little effective data sharing between Australia's conservation seed banks. These seed storage and research facilities gather and manage foundation scientific information on Australia's native flora, including seed species identification, origin and provenance, morphology, germination and dormancy requirements, storage characteristics, phenology and ecology. The work conducted on these ex situ collections generates scientifically verifiable information to support such activities as habitat restoration and plant conservation. The Australian Seed Bank Partnership is working with the Atlas of Living Australia to create a free on-line seed information hub to assist with sharing and linking data of the seeds and seed biology of Australian native plants. This hub enables conservation seed banks to manage their existing local databases, and allow them to upload and download data, creating a shared and integrated view of Australia's conservation seed bank resources. This paper introduces and describes the new seed hub and how it supports ecological restoration by providing authoritative information on the phenology of seed development and maturation of wild species and the spatial and temporal variation for these factors. Information from the seed hub can help overcome establishment issues such as seed storage, seed pre-treatments and suitable soil for seedling establishment. The hub offers future possibilities to expand the scope of seed information to cover on-line seed identification tools, spatial predictive modelling tools and online tool and workspaces for native seed related citizen science and community engagement.

Combining nature and technology to rehabilitate seagrasses in South Australia

Jason Tanner[1], Andrew Irving[1], Mandee Theil[1], Sue Murray-Jones[2]

[1]SARDI Aquatic Sciences, [2]DEWNR

Symposium: Seagrass Restoration

Over 5000ha of seagrass has been lost along the Adelaide metropolitan coast due to anthropogenic pollution and coastal development. Recently, however, there has been signs of natural regeneration in areas where sand movement is low, indicating that water quality has improved and that it may be an opportune time to investigate restoration. After earlier work using traditional transplanting techniques, we have had good success at facilitating natural recruitment at small scales using hessian sandbags in areas of relatively high water and sand movement. This technique relies on the viviparous seedlings released by Amphibolis, which have small 'grappling hooks' on their distal end which entangle in the hessian. Initial recruitment can be on the order of hundres of seedling per sq m, with rapid growth, and infilling between bags occuring on the order of 4–5 years. Interannual variability in recruitment has been high, however, and necessitated developments on 2 fronts to overcome. First, we started with little idea of the reproductive cycle of Amphibolis, and so had to better understand its biology. We have also been working with materials scientists to prolong the longevity of the hessian, which was prone to rapid breaking down, while still retaining an ultimately biodegradable product. More recently, we have been working to extend the technique to fruiting taxa such as Posidonia, as well as examining the influence of substrate characteristics such as grain size and organic matter content.

Towards a mechanistic approach to pollinator restoration

Sean Tomlinson[1,2], Raphael K. Didham[1], Kingsley Dixon[1,2]

[1]University of Western Australia, [2]Kings Park and Botanic Garden

Symposium: Pollinators in Ecological Restoration

There has recently been a general recognition that conservation and environmental management programs would benefit from a more scientific approach and a mechanistic understanding of critical processes underpinning the systems in question. We pursue these concepts using the parable of the Honey possu , Tarsipes rostratus. The Honey possum is an obligate nectarivore, known to feed on plant species from only the Myrtaecaea, Proteaceae and Epacridacae. We investigated how the population fluctuated in response to rainfall and fire over a 20-year period, and also changes in energetics, diet and movements during a period of decreased food availability in late summer. Populations increased with increased flowering rates of Banksia illicifolia and winter rainfall two years prior to trapping. Burnt habitats were associated with low populations. During the late summer food gap, the entire energetic requirement of the Honey possums is met through access to two species of plant, but estimated home ranges required to supply these resources average 6 hectares. Understanding the requirements of the Honey possums suggests that longterm management of the pollination services provided by this species is dependent upon the management of Banksia illicifolia, Beaufortia sparsa and Adenanthos meisneri populations, and the reduction of broad-scale fires. Using these concepts as a template, we intend to expand our techniques into studies of insect pollinators in order to understand crucial aspects of ecological restoration in Banksia woodlands on the Swan Coastal Plain. We present preliminary data on Honey bees Apis mellifera as a proof of concept for insect systems.

Bannister Creek living stream: restoring a more natural hydrology and channel structure to improve stream health

Antonietta Torre

Department of Water

Symposium: Living Stream Restoration

A major cause of degradation of urban waterways is the change in catchment hydrology resulting from conventionally drained urban areas. Flows become more frequent and variable and peak flows become larger. The complex interactions between surface flows, groundwater hydrology, water quality, channel form, aquatic habitat and riparian vegetation characteristics of a waterway are dramatically disturbed by the alterations to the flow regime. An objective of stormwater management is to ensure a more natural catchment hydrology is maintained or restored. Approaches to detain flows and reduce flood peaks and 'flashiness' have been successfully implemented in the Bannister Creek catchment. However, there are limitations to the feasibility of retrofitting an urbanised catchment to restore a more natural hydrology. In combination with catchment works, intervention to the stream channel itself can improve the resilience of the channel to erosion and increase the hydraulic diversity of the channel, and hence the biodiversity. Bannister Creek is located on Western Australia's Swan Coastal Plain, where there is a superficial aquifer and high connectivity between surface water and groundwater systems. Bannister Creek was originally a chain of wetlands, which were channelised to drain the land and enable urban and agricultural development. Drainage channels in the Bannister Creek catchment commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Understanding these factors and their implications for flow regime and nutrient transport was essential to planning and designing the Bannister Creek Living Stream. Rehabilitation efforts in the Bannister Creek catchment have focused on mimicking natural systems and restoring key hydrologic processes and features of the waterway as the foundation for ecological recovery.

Mapping modified vegetation in order to assist restoration prioritisation in the Galapagos Islands

Mandy Trueman, Rachel Standish, Richard Hobbs

The University of Western Australia

Theme: Island, Coastal and Marine Restoration

In highly modified ecosystems it is difficult to decide where limited conservation dollars can best be spent in order to maximise restoration and conservation outcomes. The novel ecosystems conceptual framework can assist in making such pragmatic decisions. Our study aims to use the novel ecosystem framework to in the Galapagos Islands to help prioritize sites for restoration in the Galapagos Islands, based on plant species assemblages. We surveyed vegetation in the National Park area of the humid highlands that has been heavily invaded by introduced plants. We are now assessing the difference between the modified vegetation and reference conditions in order to classify ecosystem types as historical (same as or similar to reference conditions), hybrid (somewhat dissimilar to reference) or novel (very dissimilar to reference). We will look for indications of thresholds by correlating the proportions of vegetation cover made up of native and exotic plants with the native and exotic plant species richness across our sites. We will also map current vegetation across the landscape. The spatial extent of novel ecosystem types can then be compared to a model of pre-disturbance vegetation to help prioritize sites for restoration action.

Moving house: can we relocate the trap door spider *Idiosoma nigrum*?

Alexa Tunmer

Curtin University

Poster Presentation

The declared rare shield-backed trapdoor spider (*Idiosoma nigrum*) is endemic to Western Australia and occurs in fragmented populations in the midwest and Wheatbelt areas. It threatened by feral animals, natural disasters (flooding, fire) and from development (such as agricultural and mining). Adult females mature at 5 years and live for up to 30 years, producing multiple broods during their lifetimes and never leaving their burrows. It is thought that mature females are unable to rebuild their burrows after the original is destroyed, only repair slight damages. Little is known about the behaviour of the species and if representatives of an at risk populations can be translocated to other suitable environments prior to development or disturbance. Translocation has never been trialled with *I. nigrum* and rarely with any trapdoor spider. This study trials translocation of spiders from within the footprint of the Jack Hills Iron Ore mine, 800km north of Perth, to artificially created burrows nearby. Our trials have translocated 80 spiders to test the life stage and burrow conditions needed for success (size of burrow, use of original door, and presence of spiders under the same vegetation type). Individuals have also been established in pots in a laboratory to allow detailed observations of their response to translocation. Initial field results show high survival (75% of translocated spiders), and we will present results 5 months after translocation.

Seed ecology of two endangered West Australian plant species: *Androcalva perlaria* (malvaceae) and *Symonanthus bancroftii* (solanaceae)

Shane Turner, Christine Best, Bob Dixon, Kingsley Dixon

The University of Western Australia, Kings Park and Botanic Garden

Theme: Threatened Species, Populations and Communities

Long-term conservation of threatened flora requires the input of different research fields to ensure the maximum likely-hood that a species will not disappear. A thorough understanding of the key factors regulating in situ germination enables managers to predict the longevity of the soil seed bank and what factors are required to stimulate germination. To develop management tools the aim of this study was to investigate different seed biology attributes of two threatened species as a means to better manage in situ populations. The seed ecology of *Androcalva perlaria* and *Symonanthus bancroftii* was investigated. *Androcalva perlaria* has fewer than 80 plants remaining while *Symonanthus bancroftii* is only known from two plants. Using seeds a series of different experiments have been performed including water uptake studies, responses to different germination conditions, dormancy loss requirements, rapid seed ageing and in situ seed burial to ascertain the key variables that regulate in situ recruitment. Seeds from both species were found to be highly dormant though dormancy could be removed by the use of hotwater (*A. perlaria*) and afterripening (*S. bancroftii*). Seeds of *S. bancroftii* were also observed to become highly Kar1 responsive during afterripening and soil storage. Seed burial has also confirmed that seeds maintain high viability (~90%) during soil storage for at least 18 months to 2½ years. The seeds of both species are dormant when fresh and both appear to require fire to stimulate in situ recruitment though both are triggered by different fire components ie heat (*A. perlaria*) and smoke (*S. bancroftii*). The seeds of *A. perlaria* possess physical dormancy while the seeds of *S. bancroftii* possess physiological dormancy. In addition, both appear to have the capacity to persist for significantly longer than 12 months in the soil seed bank.

Responses of biodiversity to prescribed burning in urban woodlands

Leonie Valentine[1], Katinka Ruthrof[1], Leonie Stubbs[2], Barbara Wilson[3]

[1]WA Centre of Excellence for Climate Change, Woodland and Forest Health, [2]Friends of Paganoni Swamp, [3]Department of Environment and Conservation

Theme: Forest and Woodland Restoration

Bush remnants in urban landscapes hold a wide range of social and ecological values, but maintaining these values can be challenging. Prescribed burning to reduce fire risk to human life and infrastructure is often necessary within bush remnants, and fire may be an important restoration tool for target species and communities. We used a transdisciplinary approach, involving community groups, land and fire managers and researchers, to understand the impacts of prescribed burning on non-target biodiversity attributes in an urban bush remnant. Paganoni Swamp woodland reserve (700ha) has high biodiversity values within the Perth Metropolitan Region, and contains one of the few remaining large populations of tuart (*Eucalyptus gomphocephala*). The area had been unburnt for more than 30 years, and a prescribed burn to part of the reserve was administered by the Department of Environment and Conservation following consultation with community groups and researchers. We established five paired monitoring sites in the burnt and unburnt regions. At each site we examined floristic composition, vegetation structure and reptile community composition. Within the first year of the prescribed burn, floristic composition was significantly different between burnt and unburnt sites and vegetation cover was lower in the burnt sites. Fewer reptile species and abundances were detected in the burnt sites. In addition, fewer juveniles of the common dwarf skink *Menetia greyii* were detected in burnt sites. We hope that the continued collaboration between community groups, researchers and land managers will facilitate an adaptive management strategy for prescribed burning within bush remnants.

Distinguishing invasive hydrocotyle ranunculoides from non-invasive congeners by DNA barcoding

Clemens van de Wiel[1], Leni Duistermaat[2], René Smulders[1]

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Symposium: Aquatic Ecosystems: Restoration Interactions

Among invasive exotic plants, a number of aquatic species pose a particular ecological threat to water bodies, as in the worst case, they may obstruct water flow by their profuse growth. Therefore, one would opt for preventing them from entering a country or area. However, often related species are commercially traded, and distinguishing invasive from non-invasive species based on morphology alone can be hard at a vegetative stage. Thus, DNA barcoding could be an alternative for reliable identifications, for which the CBOL Plant Working Group proposed the chloroplast sequences rbcL and matK. We additionally tested the trnH-psbA locus, as it is more variable than rbcL and more reliably amplified for sequencing than matK. Using trnH-psbA alone, we were able to distinguish the invasive *Hydrocotyle ranunculoides* from at least six other species from the genus *Hydrocotyle*.

Defining plant functional types to inform arid land restoration

Erik Veneklaas

The University of Western Australia

Theme: Physiology and Hydrology for Mine Restoration

Restoring biodiversity does not guarantee adequate ecosystem functioning. Adequate representation of key plant functional types in restored plant communities is essential. When original plant communities are poorly known or restored communities are faced with severely altered abiotic conditions, knowledge of plant functional types helps design restoration targets and monitor restoration success. This presentation will summarise findings from a number of projects in Australian arid zones where physiological ecological methods were used to define and understand plant functional types.

On the study of New Caledonian dormant native seeds for ecological restoration after mining impact using hydroseeding on the Massif du Koniambo

Matthieu Villegente, Alexis Carteron, Antoine Leveau, Bruno Fogliani
University of New Caledonia

Theme: Mine Restoration

Dealing with mining and ecosystem restoration is always a challenge. It becomes even harder when the country has the incredible honour of belonging to the top ten listed countries for biodiversity preservation. New Caledonia is one of those. It has a very rich and diverse flora composed of 3,371 species, with an endemism rate of 75%. These are due to several factors with, in particular, ultramafic soils that are rich in heavy metals, including nickel, for which New Caledonia has 13% of the worldwide mineral deposit. This valuable economical resource often prevails upon flora richness, leading to destruction of huge areas to access the exploitable soil. The ultramafic Koniambo massif is under the mining activity of Koniambo Nickel SAS. The company currently rehabilitates the massif by hydroseeding as a technique of choice for large-scale rehabilitation. In the recent past, the lack of studies on native seeds, in particular Cyperaceae, has lead to the use of non-native seed species, including common graminoides during hydroseeding. Our initial research aims to characterize dormancy types of technical pioneer native species seeds to find easily applicable pre-treatments to release dormancy. It allowed for example to reduce latency time (15 days instead of 55) and increase germination rate for some Cyperaceae in laboratory conditions. Our main challenge is to apply our laboratory results in the field. Therefore, we performed last February, a hydroseeding experiment to test the effectiveness of our pre-treatments on seed germination and plantlet establishment, using only natives species, including 3 Cyperaceae and 4 woody species.

Toolibin Lake 2012, catchment and asset scale ecohydrolgoical modelling to explain the response of biota to management interventions

Ryan Vogwill[1], Blaire Coleman[2], Rachel Tarplin[1], Christoph Hinz[1], Janaine Colletti[1], Matt Hipsey[1]
[1]The University of Western Australia, [2]DEC

Symposium: Toolibin Lake: a case study of wetland restoration

Altered hydrology due to changed land use threatens the native biota of Toolibin Lake. In addition to revegetation and surface water management in the catchment, interventions at Toolibin Lake include inflow control and pumping of groundwater from beneath the lake bed. Original hydrological targets for recovery of lake floor vegetation included a depth to groundwater greater than 1.5m across 80% of the lake bed, when no surface water was present in spring; and inflows be diverted unless their salinity is below 1,000mg/l. Fifteen years later these targets have been met most of the time, but the level of vegetation recovery has not been uniform, widespread or fully met expectations. There has been some salt flushing in the upper part of the profile but not in the root zones of trees. HYDRUS 1D and WET-OD modelling have helped us understand asset management and re-evaluate hydrological targets. Based on current analyses, a depth to groundwater greater than 8m is required to allow salt flushing to reduce soil ECs to less than the 5 ds/m required for full recovery. Coupled catchment-asset models have allowed testing of management scenarios based on land use changes. Detailed assessments of management feasibility require multidisciplinary investigations integrating hydrology and plant ecophysiology. To achieve this, advanced techniques such as numerical ecohydrological modelling, geophysics and remote sensing have been developed and applied. At Toolibin Lake, good planning, long term monitoring, innovative science and iterative management have been essential to recovery of biodiversity assets.

Recovering Toolibin Lake: an uncertain life

Ken Wallace

Department of Environment and Conservation

Symposium: Toolibin Lake: a case study of wetland restoration

Research suggests that, in the south-west of Western Australia, altered landscape hydrology threatens some 850 native plant and animal taxa with global or regional extinction. Most of these taxa occur in wetlands and remnants of native vegetation on valley floors. Replacement of native perennial vegetation with annual crops and pastures drives the hydrological changes. This has led to extensive salinisation of surface soils and waters, a process termed secondary salinisation. Recovering the remaining, native valley-floor ecosystems requires consistent effort over decades with significant uncertainty attached to outcomes. Management and recovery work in agricultural areas of the south-west has focussed on six catchments, termed natural diversity recovery catchments. In this case study we describe the management approach adopted at the oldest recovery catchment, Toolibin Lake, an ephemeral freshwater wetland listed as a Wetland of International Importance under the Ramsar Convention. Secondary salinisation has exposed Toolibin Lake to increasingly saline surface water and rising saline groundwater. As a result the native biota of the wetland have declined and are under serious threat. To halt degradation of the lake, an integrated package of management tools has been implemented including engineering works and revegetation. Many of the key works have been undertaken on privately-owned farmland, which adds an important social dimension to management. Although evidence suggests we have halted the decline of the lake biota and achieved vegetation recovery in some areas, management continues to be challenging. After outlining the management approach, a number of the factors critical to management success are discussed.

Restoration of semi-arid rangelands through the control of total grazing pressure and rotational grazing management

Cathleen Waters, Gavin Melville, Trudie Atkinson

NSW Department of Primary Industries

Theme: Restoration in Production Landscapes

Within pastoral areas of the semi-arid rangelands considerable incentive funding has been directed toward exclusion fencing to control total grazing pressure (TGP), particularly goats and kangaroo populations. It is assumed that TGP fencing will result in increases in ground cover and help to achieve minimum catchment ground cover targets of 40% in western New South Wales. To date this assumption has not been tested. In this paper, we describe the results of a pilot study undertaken in western New South Wales to assess the impact of TGP fencing in conjunction with alternative grazing management strategies. We examined the effect of TGP fencing on ground cover and floristic diversity using three replicate 0.5ha plots within each of three contrasting management treatments; long- (>5years) and short-term (<2 years) TGP fenced paddocks with rotational grazing (current best practice) and non-TGP fenced paddocks with set stocking (historical district practice). Significant differences in ground cover ($P<0.05$) were found between TGP and non-TGP fenced paddocks, in some cases a two fold increase in ground cover was found within TGP fenced areas. TPG fenced areas also supported a greater number of desirable native perennial grasses and herbaceous species. We discuss these results in terms of native, feral and domestic grazing intensity and long-term impacts on biodiversity and livestock production. These results indicate that the control of external grazing pressure, combined with rotational grazing provides a means for restoring native perennial grasses and achieving catchment ground cover targets.

Ecosystem functioning and rehabilitation of a mosaic landscape

Justin Watson[1], Eileen Campbell[2]

[1]Charles Sturt University, Australia, [2]Nelson Mandela Metropolitan University, South Africa

Poster Presentation

The semi-arid landscape at the locality known as Grassridge in South Africa consists of a unique mosaic of bushclumps and grassland (colloquially termed Bontveld). This mosaic is confined to the ridges that are characterised by shallow soils overlying an extensive calcrete layer (i.e. karst). The grassland has a combination of dwarf shrubs and grasses while the bushclumps have deeper soils (dolines) and support a moderately tall thicket community. The surrounding lowlands and gullies support a tall thicket community. This patchy landscape supports a diversity of endemic flora and fauna that play an essential role in the functioning and dynamics of this ecosystem. The calcrete limestone is sought after for the production of cement. Opencast limestone mining has the potential to significantly alter this landscape. Rehabilitation and monitoring of vegetation cover and composition, soil, fauna and microclimate were compared to natural vegetation to determine appropriate management strategies to reinstate the mosaic landscape. Of the 32 treatments, subsoil and topsoil treatments produced relatively high plant cover and species richness comparable to the natural grassland. Other landscape features including edaphic parameters, microclimatic conditions and invertebrate communities where comparable to the natural grassland. Whilst recreating a functional post-mining grasslands appears relatively simple (and rapid); the establishment of the bushclumps is more complex and requires a more creative and proactive approach. Without active intervention to re-establish the bushclump component of the ecosystem, the functioning and dynamics of the mosaic (Bontveld) landscape has the potential to be lost for eternity.

Clematis pubescens: ex situ propagation and restoration in bauxite mine rehabilitation in the jarrah (*Eucalyptus marginata*) forest of South-western Australia

David Willyams

Alcoa of Australia ?, The University of Western Australia

Poster Presentation

Clematis pubescens Endl. is a geophytic vine species, common throughout the Jarrah forest. *C. pubescens* was a model species during a larger study on geophyte restoration in disturbed lands. Geophytes comprise 33% of the upland Jarrah forest flora and constituted many of the species seldom found in Alcoa of Australia's bauxite mine rehabilitation. By using a combination of phenological and germination research the hypothesis that seed factors caused establishment failure was discounted. Collecting fully ripe seed was critical for propagation success. Ex situ plant manipulations enabled the production of same age plants with 3 shoot and tuber sizes: small, medium or large. The hypothesis that a higher percentage of initially-larger-tuber plants would survive planting in the mine rehabilitation and reproduce was demonstrated. Nearly all initially-small plants with small tubers died during the first summer drought, whereas 67% of plants with large-at-start tubers survived for 3 years. Bare-rooting initially-larger-tuber plants was equally as effective thus allowing large numbers of plants to be easily carried, reducing planting effort and cost. The surviving plants produced seed in the 3rd summer, dispersing it into the surrounding restored forest. Broadcast seed germinated but died during the first summer drought, probably due to inadequate tuber growth and storage. This was also demonstrated with 12 other Jarrah forest geophyte species. These concepts may be globally applicable to the restoration of Mediterranean climate-type geophytes in disturbed lands. Integrated studies of adaptive biology, ex situ propagation and revegetation offer considerable potential for establishing absent geophyte species in mine restoration.

Adoption and refinement of agricultural practices to enable the scaling up of restoration activities in southern Australia

Geoff Woodall

CENRM, UWA

Theme: Delivering Large Scale Restoration

Agriculture is supported by a large national and international research budget that has delivered improved equipment and cultivation systems. The annual area planted with agricultural crops and pastures is large but the number of species grown is small. In contrast, the terrestrial restoration industry operates with a minimal research and development budget, currently operates at a small scale but involves the establishment of an enormous diversity of plant species on cleared agricultural land. This paper aimed to determine whether agricultural technologies can be applied to restoration. A number of agricultural innovations were found to have application to restoration and the refinement and adoption of these agricultural innovations is of paramount importance if large scale restoration is to be achieved. The study clearly showed that agricultural seeding equipment, herbicides, pesticides and nutritional supplements can improve the uniformity and reliability of restoration activities and enable broad scale restoration to be achieved in southern Australia. Several limitations to the use of agricultural practices for restoration activities were identified. This body of work has led to the developed new equipment and approaches that are now being widely adopted by restoration practitioners in southern Australia.

The conservation of the floristic biodiversity in New Caledonia: assessment and challenges to come in a hotspot of biodiversity

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Theme: Threatened Species, Populations and Communities

New Caledonia is a territory that has the delicate mission to conciliate an exceptional floristic diversity and quick development of human activities impacting natural habitats. It is one of the main hotspots of the terrestrial biodiversity on Earth because of its richness in endemic plant species. The threats impacting these species and more generally the natural environments, such as fires, urbanisation, introduction of invasive species, but also the increasing development of mining industry, with the tripling of the production of nickel planed for 2013–2015, have increased recently. Fortunately, New Caledonia has the chance to have well-developed research facilities (UNC, IAC, IRD) enabling precise data collections leading to management priorities. They also bring up methods to increase ecological restoration success. These recommendations are taking into considerations by local authorities and mining companies. Then international and local NGOs sensitize the public in order to increase their awareness on the various threats impacting natural habitats. All these actors met during a workshop in April 2012 and the results from the exchanges will be presented here. They first identify the various actions that were undertaken for the conservation of plant biodiversity in New Caledonia. Moreover outside contributors brought their experience to this event, placing the conservation in a more global context. Following that, wills and objectives of each other were exposed in order to plan the various actions to be carried out in the future to preserve this unique natural heritage.

Successful re-colonisation, by vertebrate and invertebrate fauna, of rehabilitated mining areas in Western Australia's Pilbara region: a case study

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Theme: Mine and Fauna Restoration

Assessment of mine site rehabilitation tends to focus on the return of vegetation as an indicator of success. In the Pilbara region of Western Australia, few studies have investigated whether rehabilitated areas provide adequate habitat for fauna. Here we document fauna presence in rehabilitated areas at two of Rio Tinto Iron Ore's Pilbara operations – Brockman 2 and Tom Price. The objectives of this study were to assess which fauna were present at rehabilitation sites, how their assemblages compared to those at adjacent, unmined reference sites and, if fauna were absent, what barriers might exist. We surveyed three rehabilitation sites and three reference sites at each of Brockman 2 and Tom Price, in spring 2011. Methods included trapping and searching for vertebrates, and wet-pitfall trapping for invertebrates with a focus on ants. Habitat assessments used a protocol intended to document characteristics most relevant to fauna. Of the 106 species of native vertebrates recorded, 83 were found at reference sites and 85 at rehabilitation sites. Although vertebrate assemblages differed between study areas and between reference and rehabilitation sites, species lists at rehabilitation sites were broadly comparable to those at reference sites. Of the fauna groups compared, ants appeared to most closely reflect habitat characteristics in their community composition. These findings suggest that rehabilitated areas in the Pilbara can be re-colonised by fauna. However, the absence of particular species at rehabilitation sites suggests barriers to re-colonisation may exist. Further investigation may identify improvements to rehabilitation that remove barriers or limit their impact.

Delineating the potential provenance boundaries of rehabilitation species at Ranger Uranium Mine, Northern Territory

Anja Zimmermann

Energy Resources Australia Ltd

Symposium: Seed Sourcing Guidelines for Restoration Success

Ranger Mine's conservative 30km seed collection zone poses a major risk to revegetation, as there may not be enough seed available at closure. Some of the revegetation species are naturally low or erratic seed producers. In addition, fires frequently whip out entire harvests and can cause delays in flowering and hence seed production. This study investigates the provenance boundaries of Ranger Mine's revegetation in order to possibly extend the 30km seed collection zone. A non-genetic approach was adopted, which assessed environmental factors, gene flow and species traits known to influence genetic variation in plants to identify zones of least likely genetic variation. In identifying the environmental factors, the provenance assessment took into account the unique growing conditions on the constructed final landform, which are unlike those found in the natural surrounding ecosystems. The resulting zones match the eco-geography of the Ranger Mine area and hence maintain the 'home site' advantage of local plants. Some genetic diversity that may be present in more distant seeders is welcomed, as it allows plant populations to respond to environmental changes such as climate change. This so-called 'composite provenancing' approach ensures that the genetic diversity is maximised while the risk of genetic pollution and outbreeding depression is minimised. The outcome of the investigations provides a strong case for changes in the seed collection zone and hence reducing a major risk at mine closure.