Gondwana Link

connecting people...connecting nature

TOWARDS ACHIEVING QUALITY RESTORATION IN SOUTH-WESTERN AUSTRALIA

Rev 1.2

Version 1.2: This version draws on numerous discussions and workshops, research and practical experience, along with an extensive review of the published literature and the approaches adopted by colleagues elsewhere. While a complete document that is ready for use, we are keen for it to be improved through ongoing discussion and experience.

COMMENT SOUGHT: We welcome your feedback and input. Please send any feedback, including comments on the document in revision mode, to bradby@gondwanalink.org

Authorisation

This Version 1.2 document is authorised by the Chief Executive Officer, Gondwana Link Ltd, who accepts any responsibility for errors and misinterpretations.

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Cover illustration: This 'desired future' image was produced by a Landscape Architecture student at UWA during a workshop at Nowanup in about 2005. We apologise for no longer being able to identify the name of the student.

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Gondwana Link's work involves many aspects of life – the land, the people, the nature

Gondwana Link

Since its establishment in 2002 the Gondwana Link program has grown and developed as a collaborative venture building a cohesive, focused, and strategic approach to on-ground restoration activities in south-western Australia. We recognise that large-scale ecosystem restoration can only be achieved through the endeavours of a wide spectrum of organisations and individuals. We work through partnering, either formally or informally, with many organizations and individuals who share the vision for an ecologically resilient landscape across south-western Australia. We exist because south-western Australia is a special place, and we aim to keep it that way.

Our overall goal is to achieve:

"**Reconnected country, from the wet forests of the far south west to the woodland and mallee bordering the Nullarbor, in which ecosystem function and biodiversity are restored and maintained**".

1. Acknowledgements

This initial Guide is largely focused on the Noongar country of south-western Australia, though it also touches on, and may be applicable to, some of the Yamatji, Wongi and Ngadju lands. We acknowledge the wisdom and foresight of the First Nation communities that kept this country healthy and resilient since time immemorial, and express our commitment to respecting that legacy by working with your communities to return as much of the country to health and resilience, and to you, as we can.

Preparation of this initial Guide was made possible by a grant from the Western Australian State Natural Resource Management program and a generous anonymous donation arranged through the Koorabup Trust. Support from the Ian Potter Foundation for the broader Gondwana Link program was timely in enabling some of the key discussions. We also drew on core Gondwana Funds to cover some of the time involved. Our sincere thanks for all this support.

This document draws heavily on the original Gondwana Link Standards, brought together in 2010 by Paula Deegan and Justin Jonson, as well as the National Standards for the Practice of Ecological Restoration first produced by the Society for Ecological Restoration Australasia in 2016, and then later that year the international standards of the same name published by the Society for Ecological Restoration. These are all significant bodies of work, representing the product of long standing collegial and cooperative efforts and we are grateful to the many, many people who contributed to their creation.

Development of this region-specific guide has also benefited from many years of involvement with restoration programs, but most particularly by the generously shared experience of a number of key practitioners. We would like to particularly thank:

Nic Dunlop – whose approach to monitoring has yielded many valuable insights into the importance of structure and design in achieving ecological outcomes, particularly in facilitating the return of wildlife to planted areas.

Justin Jonson – who led a significant increase in ecologically focused restoration practices in south-western Australia from 2006 onwards, documenting that work and his overall approach in numerous papers.

Sylvia Leighton and Peter McKenzie – for openly sharing their experiences of successes and failures over many decades of experience restoring biodiverse belts of vegetation across working farmland, and for hosting the conservation landholders network Field Day in June 2023, where we heard many additional comments and insights of value.

Peter Luscombe – one of the most experienced practitioners and astute set of eyes it has been our privilege to know, and who provided many examples of best practice, underlined the importance of local provenance and the risks of ignoring it, and provided some of the oldest examples of effective and innovative restoration of vegetation and habitats.

Blair Parsons – science and design manager at Greening Australia who contributed to a number of specific discussions and shared his overview and experience.

Jenni York – who fixed many of the punctuation, spelling and type bloopers (reckon we’ve hidden a few more in here though)

Development of the Guide has benefited from many discussions over many years with many other key practitioners who have willingly and generously shared their experiences, and we specifically thank Paula Deegan, Barry Heydenrych and Glen Steven.

We are also grateful for the discussion and comments received after the WA Landcare Network’s ‘Landcare Checks-In’ online forum on the topic of ecosystem restoration, held in 2023.

Recognising that we have no doubt missed many of the colleagues whose advice has helped over the years, we look forward to being corrected on this and many other points as we discuss, revise and improve this initial Guide.

You are welcome to join others in the Acknowledgements section by sending us comments on this Version – that would be much appreciated.

2. Introduction

With many challenges and ecological catastrophes facing the world, we are poised at a moment in history where we appear to be have one last chance to repair our world, and ourselves with it, if we are to avert disastrous outcomes. But as we progress into the United Nations Decade on Ecosystem Restoration, it is important to acknowledge that our understanding of the natural world, and of how to repair the damages we have caused, is imperfect. But it is important to do the best we can with what we do know, and always strive to do better.

The reality of economic drivers like the emerging carbon market are that a great many trees are being planted around the world, but even well-intentioned tree-planting without adequate planning can lead to perverse outcomes. There's enough knowledge out there to suggest we should try and restore the ecosystems around us as best we can.

This Guide brings together information that can help improve the practice of ecosystem restoration in south-western Australia. We hope this guide will assist to better identify the value of various restoration approaches and practices and highlight clearly why achieving quality restoration outcomes is so important in our part of the world.

Early in its establishment, a group of us working to achieve Gondwana Link saw the risks of proceeding with clumsy, simplistic revegetation approaches. Since then, we have been on a journey of steady learning and improvement: in 2004 we identified a suite of key issues in a workshop on 'restoration not revegetation'; by 2008 we were supporting detailed cultural and ecological planning before the commencement of any seeding or planting activities; and in 2010 we produced an initial set of Restoration Standards[1] which aimed to provide clarity on what approaches produced good ecological results. More recently, a similar process has been underway both nationally and internationally. We supported our colleagues at Society for Ecological Restoration Australia (SERA) in the consultative development and production of a broad set of ecological standards to guide the practice of ecological restoration, published in 2016[2], and watched with delight as this document was further developed by the international Society for Ecological Restoration (SER) to produce a set of global restoration standards in the same year[3] that were then revised in 2019[4]. Importantly, these standards recognise that different ecological recovery activities to repair environmental damage, regardless of their complexity or specific goals, occur along a spectrum SER has termed the

[1] Gondwana Link, 2010. Gondwana Link restoration standards, Version 1.1. Available at: https://gondwanalink.org/resources/

[2] McDonald, T., Jonson, J. and Dixon, K., 2016. National standards for the practice of ecological restoration in Australia (vol 24, pg S1, 2016). *Restoration Ecology*, *24*(5), pp.705-705.

[3] McDonald, T., Gann, G.D., Jonson, J., Dixon, K.W., Aronson, J., Decleer, K., Hallett, J., Keenleyside, K., Nelson, C., Walder, B. and Wickwire, L., 2016. International standards for the practice of ecological restoration–including principles and key concepts.

[4] Gann, G.D., McDonald, T., Walder, B., Aronson, J., Nelson, C.R., Jonson, J., Hallett, J.G., Eisenberg, C., Guariguata, M.R., Liu, J. and Hua, F., 2019. International principles and standards for the practice of ecological restoration. *Restoration Ecology. 27 (S1): S1-S46.*, *27*(S1), pp.S1-S46.

‘restorative continuum’ which recognise restorative activities such as revegetation and rehabilitation, that aim to enhance natural habitats or improve ecological functioning, as complementary to ecological restoration; but ecological restoration aims for the highest possible level of recovery in an ecosystem, relative to an appropriate native reference ecosystem. More on this, and how the approach applies in south-western Australia, in the next section.

The release of the SER Standards in 2016 was serendipitously timed, as they preceded the announcement and launch of the United Nations (UN) Decade on Ecosystem Restoration[5]—a rallying call for the global community to address the urgency and scale at which ecosystems around the world must be restored. As is identified in both the SER Standards and the UN Decade on Ecosystem Restoration guidelines, while terminology can vary among regions or initiatives (i.e., ecological restoration and ecosystem restoration) restoration activities should be aspirational in their goals, broad in their scope, and utilise the most effective ecological recovery methods available.

The guidance on the design and implementation of revegetation for ecosystem restoration provided in our initial 2010 Standards aimed to help provide clarity on what was needed to be ecologically effective, given the very broad range of revegetation that was being described at the time as ‘biodiverse’. It included a table for ‘scoring’ various planning and implementation practices. However, in our experience very few people in south-western Australia properly measure what they do when they undertake restoration, or monitor how successful it is, which makes it challenging to know whether their attempts have worked. This means we aren’t necessarily learning from the mistakes and successes of the past. Traditional, simplistic metrics such as vegetation cover or the number of stems per hectare of a particular species are useful things to monitor, but there’s so much more we need to examine to know whether restored ecosystems are biodiverse, functional and resilient.

Our intention with this Version 1.3 is to reflect what has been learnt, over many decades of revegetation and restoration projects across south-western Australia, from various practitioners, organisations, individuals and researchers, and to merge this knowledge with the widely accepted and adopted national and international standards.

This document has been developed from two decades of experiences undertaking restoration activities in south-western Australia and is intended to provide advice and useful reference material, rather than be prescriptive or impose our views. It is intended for anyone involved in ecosystem restoration in south-western Australia: individuals, landcarers, community groups, carbon farmers, government departments, NGOs, Friends groups, the mining industry, farmers, environmental enterprises. For many of these people restoring our exceptional ecosystems, there’s little or no regulatory framework or guidance available that speaks to the unique context and challenges of our corner of the world.

[5] https://www.decadeonrestoration.org/

3. Why this Guide

With a broader self-assessment system now available in the national SERA guidelines, and some significant improvements in ecological knowledge and restoration techniques over the past 12 years, it is time for a broader document that incorporates recent knowledge and sets out specific principles and approaches that apply across south-western Australia.

As we set out in Section 5, south-western Australia is very different place to many of the world's other eco-regions. You can learn ecological principles derived from centuries of global studies, but in the words of one of our most distinguished Professors, and current global Chair for the Society for Ecological Restoration, Kingsley Dixon, 'You will see many things here that contradict your knowledge of life on Earth'.[6]

For us in south-western Australia there is a world of difference between revegetation, the planting of trees with perhaps a few shrubs, and ecosystem restoration. Planting trees and other simplistic revegetation programs may help physically stabilise degraded and unvegetated soils through reducing erosion by wind and water, can assist in mitigating dryland salinity and other challenges, and can produce commercial products. However, ecosystems are incredibly complex. A few trees does not an ecosystem make. We must consider soils, water, climate, microorganisms, plants, animals, and all the innumerable interactions and relationships between these components.

While we still have a long way to go, both our cultural and ecological awareness has developed greatly in recent decades. We are now moving rapidly into an era where the need for restorative practices is broadly recognised, and such practices are better supported and understood. Yet, while our knowledge of ecological functioning and the species-level richness and the amazing levels of localised endemism in southwestern Australian ecosystems has improved, we are still at an early stage of understanding how these ecosystems can be restored to our damaged and degraded landscapes. Importantly, we must recognise and appreciate the wide range of specialised mechanisms that organisms have developed over a long evolutionary history in response to the unique southwestern Australian conditions, and how restoration must facilitate the return of conditions supporting these specialisations.

A central theme of this Guide is perhaps the most fundamental concept underlying environmental management for many decades: the precautionary principle. The primary globally accepted definitions, results from the work of the Rio. Principle 15 of the Declaration of the Rio Earth Summit in 1992 notes: *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."*[7] This concept has been clarified in Australian Law as: *"If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reasoning for postponing measures to prevent environmental degradation. In the application of the principle... decisions should be guided by: (i) careful evaluation*

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[6] Quoted in Woodworth, Paddy (2013) *Our Once and Future Planet: Restoring the world in the climate change century.* University of Chicago Press. p214

[7] UNEP. "Rio Declaration on Environment and Development".

to avoid, wherever practicable, serious or irreversible damage to the environment; and (ii) an assessment of risk-weighted consequence of various options".[8]

We argue for the more widespread use of the precautionary principle in ecosystem restoration because we typically must operate from a point of considerable scientific ignorance on key factors that likely affect the success of our activities. For example, we still do not fully understand the importance of local provenance when sourcing seed or plant material, or even what constitutes 'local' for many species. Additionally, there is evidence that poorly planned revegetation efforts can cause environmental harm, such as through introduction of 'native weeds' that dominate systems and through increased populations of opportunistic and aggressive bird species arriving and overwhelming other, less robust species. We consider that good planning and forethought enables caution to be used in plantings and removes the need to take riskier approaches, such as using seed and seedlings from a range of different provenances.

However, we recognise that there is a balance to be struck with what can be achieved, safely, in a degrading environment facing accelerated climate change. The imperative to move rapidly is upon us, as is also the imperative to proceed cautiously. But too few people are putting sufficient thought and planning into restoration before getting stuck in, even though much of this thought and planning is similar regardless of the vision or intended outcomes. This document is intended to offer a set of guardrails, laying out key things to consider when planning restoration and acknowledging the different landscapes and contexts in which restorative activities are undertaken in our contested landscape.

Finally, we assume here that biodiversity is always a, if not the, core consideration, and that any activities aim toward an outcome of some improvement to the integrity, resilience, diversity, and functioning of an ecosystem. However, this does not mean we assume all activities intend to return the landscape to a pre-European native ecosystem; biodiversity outcomes can be achieved even in intensive agricultural and urban settings, and we consider any activity that aims to improve the ecosystems around us to be of merit.

4. What is this thing called restoration?

Ecosystem restoration (here synonymised with ecological restoration, as defined in the SER Standards) is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed[9]. It is not about trying to exactly replicate some pre-existing state or assemblage or organisms—trying to return to a pre-Captain Cook Australia, as it were. Instead, restoration recognises that ecosystems and the species they harbour have inherent value, and they are the most resilient and suited to the local conditions. Pioneering restoration ecologists James Aronson and Andre Clewell explain this as **"***Restoration is not akin to civil engineering, where each task has a highly predictable outcome, nor is it like gardening or farming, where local conditions can be tightly controlled until crops are harvested... It is more like raising children… [with] unexpected*

[8] Hon. Justice Brian J Preston, (2006), 'Telstra Corporation Limited v Hornsby Shire Council [2006] NSWLEC 133', *Land and Environment Court of New South Wales*. Paragraphs 125-183. https://www.caselaw.nsw.gov.au/decision/549f8a6b3004262463ad5606
[9] Society for Ecological Restoration 2004

circumstances that necessitate prompt resolution using ingenuity and audacity."[10] As mentioned above, the peak international body SER recognise a 'restorative continuum' of activities that aim to repair the damages caused by humans to the natural world. So what distinguishes ecosystem restoration from these other activities?

Most importantly, restoration always strives towards the full recovery of an ecosystem. It recognises that the most reliable and effective way of helping ecosystems recover is to assist natural recovery processes, supplementing them where they have been impaired. Crucially, restoration requires an appropriate local native reference ecosystem and understanding of this ecosystem's attributes from which goals and objectives for recovery can be established – things like soil type and chemistry, rainfall and climate, the number of types of native plants and animals present, and how these organisms interact so that the ecosystem functions properly. But a reference ecosystem isn't used to establish some inflexible historical condition to be replicated; rather, its purpose is to show what healthy ecosystems were composed of and to help us understand and prepare for the changes that are always underway. This gives restored habitats, and the wildlife they support, the best foundations upon which they can adapt and survive in dynamic, ever-changing environments.

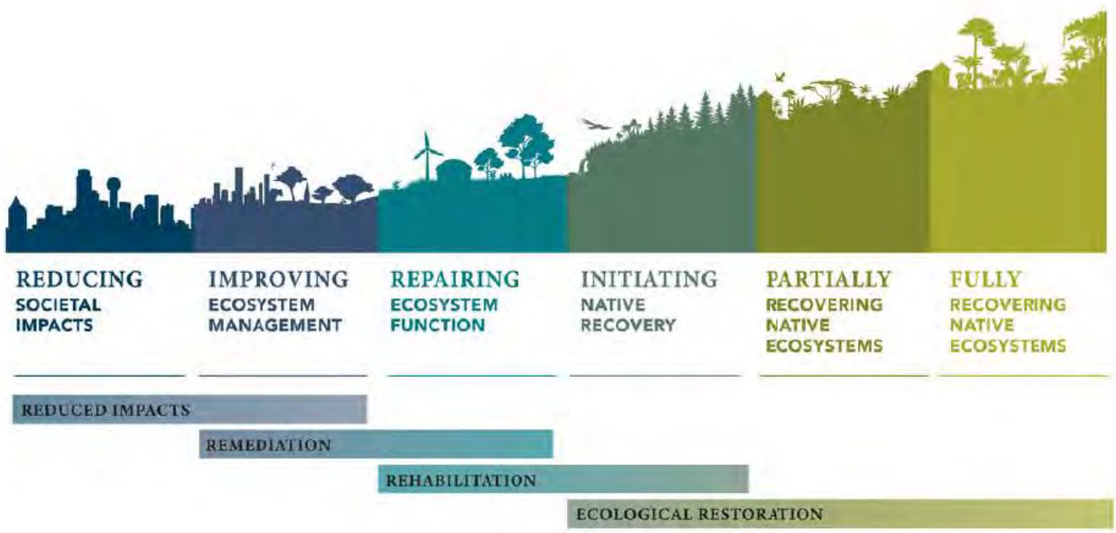

Figure 1: The continuum of restoration activities recognized by the Society for Ecological Restoration[11]

Restoration also recognises that ecosystems are extremely complex. A key aim of restoration is to assist not only in the return of specific species and biodiversity in general, but also the ecological functioning that underpins and supports that biodiversity. This means considering every aspect of an ecosystem, as well as how these interact with all its non-living parts like soils and water (although

[10] Andre F. Clewell & James Aronson (2007*) Ecological Restoration: Principles, Values and Structure of an emerging profession.* Island Press. Washington.

[11] George D. Gann, Tein McDonald, Bethanie Walder, James Aronson, Cara R. Nelson, Justin Jonson, James G. Hallett, Cristina Eisenberg, Manuel R. Guariguata, Junguo Liu, Fangyuan Hua, Cristian Echeverría, Emily Gonzales, Nancy Shaw, Kris Decleer, and Kingsley W. Dixon (2019) International Principles and Standards for the Practice of Ecological Restoration. Society for Ecological Restoration, Second Edition: November 2019

recognizing that both of these have living parts!). Plants often need insects to pollinate flowers or to disperse seeds, and many rely on soil fungi for nutrient uptake or have very specific water or soil chemistry requirements and cannot establish or survive if these requirements are not met. Microbes and invertebrates play important roles in breaking down organic matter and returning nutrients to the soil. Animals need places to shelter and hide from predators, as well as other resources such as food and water. If all of this complexity is not recognized and returned during restoration, it is unlikely that an ecosystem will have sufficient ecological resilience – capacity to continue functioning in the face of disturbance or change[12]. Ultimately, restoration is about recovering ecosystems that, once established, will no longer require our assistance or intervention to survive and will still exist in a hundred or a thousand years.

5. Restoration in south-western Australia

Given that all ecosystems are special, why do we think this one is so special? Australia is recognised as one of the 17 'megadiverse' countries, as it harbours incredible biodiversity and remarkable levels of endemism (species that are found nowhere else). Western Australia contains over half of all currently recognised National Biodiversity Hotspots[13], and south-western Australia is recognised as one of the world's 36 global biodiversity hotspots[14]. South-western Australia is a Mediterranean-climate refuge of >300,000 km^2, island-like as it is bordered on all sides by ocean or desert. It is inhabited by an estimated 8,400 native plant taxa, of which some 47% can only be found in this area and 49% have been named scientifically since 1970[15], underlying how rapidly knowledge of the flora has grown in recent decades. There are around 500 species of native mammals, birds, frogs, and reptiles[16]. It is one of the oldest regions on the planet and has an old, climatically-buffered infertile landscape (OCBIL)[17], with the plants and animals of its ancient landscapes having experienced evolutionary processes under a relatively stable climate for some 250 million years—a tad more than the ~100 million years suspected for eastern Australia, or 12,000 years for the Great Plains region of the Central United States and other young, often disturbed, fertile landscapes (YODFELs). And, importantly, there are several hotspots of species richness within the broader Southwest Australia hotspot. Some are within protected areas, such as the 329,000 ha Fitzgerald River National Park that alone harbours an astonishing 1,800 species of flowering plants[18], while some, as the inset map demonstrates, occur across what are now largely agricultural landscapes.

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[12] Wallington, T. J., R. J. Hobbs, and S. A. Moore 2005. Implications of current ecological thinking for biodiversity conservation: a review of the salient issues. Ecology and Society 10(1): 15. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art15/

[13] Auditor General Western Australia (AGWA). 2009. *Rich and rare: conservation of threatened species*. Report 5. Office of the Auditor General, Perth.

[14] Myers, M., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B. and Kent, J. (2000). *Biodiversity hotspots for conservation priorities*. *Nature*, 403, 853-858.

[15] Gioia P & Hopper S D 2017. A new phytogeographic map for the Southwest Australian Floristic Region after an exceptional decade of collection and discovery. *Botanical Journal of the Linnean Society* **184**, 1–15.

[16] Rix, M.G.,, Edward D.L., Byrne M., Harvey M.S., Joseph, L., and Roberts, J.D., (2015) Biogeography and speciation of terrestrial fauna in the south-western Australian biodiversity hotspot. *Biological Reviews* 90 (2015) 762–793

[I presume Rix is the better reference here]

[17] Hopper, S.D., 2009. OCBIL theory: towards an integrated understanding of the evolution, ecology and conservation of biodiversity on old, climatically buffered, infertile landscapes. *Plant and Soil*, *322*(1), pp.49-86.

[18] Auditor General Western Australia (AGWA). 2009. Rich and rare: conservation of threatened species. Report 5. Office of the Auditor General, Perth.

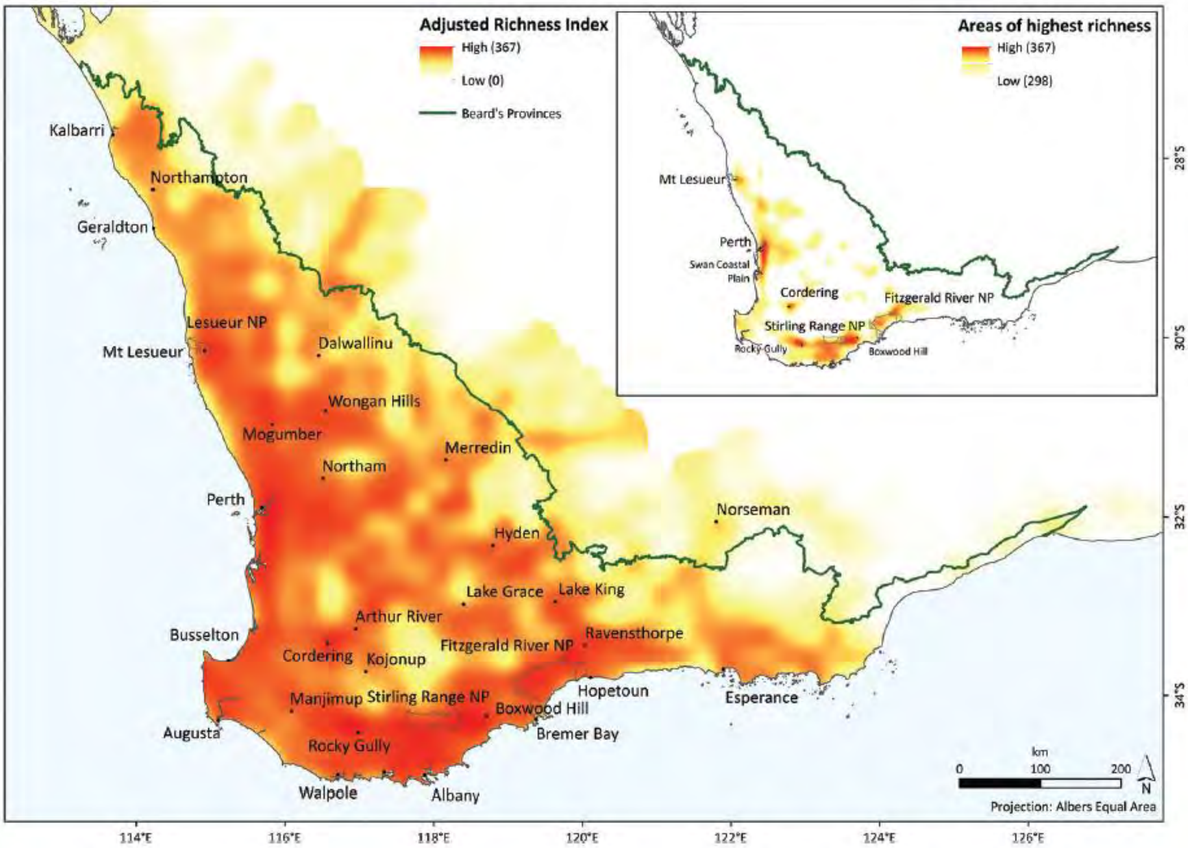

Figure 2: This map was produced by Paul Gioia and Stephen Hopper in 2017. It shows an *"Adjusted richness index, based on mean richness from all data subsamples. Index values are mapped from low (0) to high (367) onto a white–yellow–red colour ramp. Inset emphasizes just areas of highest richness (c. top 20% of values using same colour ramp)".* For further detail and explanation we strongly recommend reading the entire paper[19].

While we can catalogue and marvel at the intricate richness of this biodiversity, we should not pretend we know much, yet, about how these ecosystems evolved and how they function or interact (though let's enjoy the voyage of discovery we are on). Landmark studies such as Mark Burgman's 1986 work[20] showed that many south-western Australian ecosystems are characterised by rapid changes in species assemblages (known as high turnover of species), and, thus, probably in genetic structure, at very short intervals. This is especially true for island-like habitats such as granite outcrops and rocky ridges, where different outcrops can harbour completely different species despite being only hundreds of metres or kilometres distant. Indeed, species turnover even in forests and woodlands can be remarkable, and as Burgman noted: "*stands in mallee formations include substantially different suites of species at distances greater than 15 km*". In contrast to the ecosystems present in geologically younger regions, such as the extensive and relatively uniform conifer forests of the northern hemisphere, such rapid changes in the species present across a landscape are rather incredible. As might be expected for a place harbouring such high biodiversity, there is also a richness of ecological interactions in Southwest Australia rarely encountered elsewhere on the planet, let alone in other relatively dry and flat Mediterranean and temperate

[19] Gioia P & Hopper S D 2017. A new phytogeographic map for the Southwest Australian Floristic Region after an exceptional decade of collection and discovery. *Botanical Journal of the Linnean Society* **184**, 1–15.

[20] Burgman, M.A. (1988) *Spatial analyses of vegetation patterns in southern Western Australia – implications for reserve design*. *Australian Journal of Ecology* 13, 415-42.

climate landscapes. This functional diversity prompted a recent study to proclaim Southwest Australia 'one biodiversity hotspot to rule them all'[21].

Unfortunately, following colonialisation by Europeans the extensive cultural and ecological damage caused by a mixture of exploitative and careless practices became another feature of Southwest Australia. Many of the ecosystems have suffered greatly from habitat loss, land-use change, invasive species, disease, and poor management. South-western Australia is behind only southeast Queensland as the most cleared area of Australia, as over 90% of primary vegetation in the region, and over 97% in areas like the central Wheatbelt, has been removed. Indeed, being recognised as a biodiversity hotspot is as much about acknowledging how much has been lost as it is about the value of what remains, as biodiversity hotspots are defined as regions "where exceptional concentrations of endemic species are undergoing exceptional loss of habitat". Estimates suggest that over 2,500 species of plants (>30%) in south-western Australia were of conservation concern by the early 2000s[22], but the number of species recognised as threatened has increased much faster than the number of species being less threatened in the intervening two decades since this assessment[23]. It is now thought that this number might be a significant understatement.

Unlike many other countries where histories of agricultural practice can stretch back thousands of years and have irrevocably changed the landscape, it's not too late for us to restore large areas to a high degree of ecological integrity. While south-western Australia is, undoubtedly, an ecologically damaged place, it has been very recently damaged. Most fundamental changes to its landscapes have occurred in the last 100 years, not the last 1000 years— with over half of all vegetation clearing in Southwest Australia occurred between 1945 and 1982[24]. While many mammal species have been permanently lost to extinction, together with the roles they played in ecosystems, patches of largely intact original habitat remain in many areas. Importantly, we shouldn't be viewing these remaining habitat patches as 'remnants'—these are the strategic building blocks from which functioning and resilient ecosystems can be rebuilt at scale across the damaged Southwest Australian landscape through ecosystem restoration.

But that means moving on from the approaches used since colonisation. Broadacre agriculture was undertaken despite the techniques used being poorly suited to the soils, climate, and biodiversity of this special place. Recent years have seen increased levels of understanding on the catastrophic long-term impacts of these practices, and a realisation that we must both change the systems by which we commercially utilise the land, and ecologically restore at vast scales to reverse the damages caused and strengthen the core ecosystem functions that provide resilience in the face of change. To do this we need to improve on current restoration practices, which were largely built from early revegetation practices which, in their turn, drew heavily from the same playbook and patterns of behaviour as colonial era settlement — inadequate knowledge and consideration of

[21] Brundrett, M.C., (2022) *One biodiversity hotspot to rule them all: southwestern Australia—an extraordinary evolutionary centre for plant functional and taxonomic diversity*. Journal of the Royal Society of Western Australia, 104: 91-122, 2021.
[22] Hopper, S. and Goia (2004). *The Southwest Australian Floristic Region: Evolution and Conservation of a Global Hot Spot of Biodiversity. Annual Review of Ecology, Evolution, and Systematics, 35* (1), 623-650.
[23] Auditor General Western Australia (AGWA). 2009. *Rich and rare: conservation of threatened species*. Report 5. Office of the Auditor General, Perth.
[24] Saunders, D.A. (1989). Changes in the avifauna of a region, district and remnant as a result of fragmentation of native vegetation: the wheatbelt of Western Australia. A case study. *Biological Conservation*, 50, 99-135.

southwestern Australian ecosystems and biodiversity, and a desire to ensure damage was mitigated in a manner that would enable existing exploitative land uses to continue.

Similarly, 'standard' restoration approaches derived from experiences in Prairie grasslands, tropical rainforest, or temperate conifer forests simply do not work in this unique place. There is no "one-size-fits-all" approach to ecosystem restoration, and this is becoming widely understood around the world, but there are few regions where this concept is more applicable than in Southwest Australia. Restoration in the many and varied ecosystems of Southwest Australia needs guidelines that developed from experience - trial and error, and success.

5.1. What was that about YODFELs and OCBILs?

When planning for restoration, one of the most important things to consider for any site is situation: its geographical location, its climate and soils, and how these have influenced the distribution of species throughout geological time and space. Relatively geologically young landscapes, like those of post-glacial Europe or the coastal dunes of the Margaret River region, often support very different assemblages of species than do ancient landscapes such as the Banded Ironstone Formations of the Mid West region. OCBIL Theory[25] outlines what drives these differences, and is a neat way of understanding how situation really influences the sorts of ecosystems that occur across Southwest Australia.

OCBILs are Old, Climatically Buffered, Infertile Landscapes, the bulk of Southwest Australia, while YODFELs are the Young, Often Disturbed, Fertile Landscapes. Globally, OCBILs are rare - predominantly Southwest Australia, South Africa's Greater Cape, and Venezuela's Pantepui Highlands. They are centres of endemism and biodiversity, where millions of years of weathering under relatively stable climate have leached soils of nutrients leaving plants to adapt in many extraordinary ways so they can thrive despite the limited resources. In response, over millennia, many species have evolved remarkable adaptations for survival and coexistence—time and competition for limited resources is one of the best recipes for high biodiversity. OCBILs typify much of inland Southwest Australia, as might be expected from a 3.5-billion-year-old landscape, though perhaps the best examples are granite outcrops. These island-like habitats represent ancient bedrock that has slowly eroded over millions of years, leaving only shallow and nutrient-impoverished soils in gnamma (rock holes) and apron areas in which plants have found ways to survive.

YODFELs are geologically young places, perhaps only tens or hundreds of thousands of years since they were last disturbed. Sometime the soils are relatively fertile (at least, compared to OCBILs), such as along a river bank, or they may be extremely infertile, such as a young sand dune on the coast. YODFELS generally support relatively fast growing species that can colonise large areas quickly and out-compete slower-growing species. This results in ecosystems dominated by only a few common and widely-distributed species. Coastal dune ecosystems in Southwest Australia are examples of YODFELs: most range from 2000–120,000 years old and are species-poor compared with ecosystems further inland, and the same groups of species can often be encountered right along the

[25] Hopper, S.D., 2009. OCBIL theory: towards an integrated understanding of the evolution, ecology and conservation of biodiversity on old, climatically buffered, infertile landscapes. *Plant and Soil*, *322*(1), pp.49-86.

coast from Kalbarri in the northwest to Esperance in the southeast[26]. Another example from Southwest Australia, though smaller in scale, are the relatively young soils generated from the underlying granites after the Pallinup River carved through the Pallinup siltstones, which were themselves deposited some 34–56 million years ago in the Eocene era. These granite derived soils once supported riparian and woodland ecosystems stretching from Borden in the north to where the Pallinup crosses the South Coast Highway at Boxwood Hill.

So, what does this mean for restoration? Many of the plants typically found in YODFELs are pioneers, rapid-growing species that are very good at establishing under a wide range of conditions and exploiting the opportunities that disturbance provides. In contrast, many of the plant species inhabiting OCBILs are highly-specialised, often slow-growing, and rarely occur except within a narrow range of conditions. This must be considered in restoration planning for several reasons:

- OCBIL habitats are generally much harder to restore following significant disturbance than YODFEL habitats, because the former typically harbour greater numbers of species and these species are usually highly specialized with particular requirements. Meeting these requirements in the restored environment can be very difficult.

- Species occurring in YODFELs are still sometimes represented in OCBILs, but often only by a few surviving individuals (or in the seed bank) in long-undisturbed areas where time has allowed other, slower-growing species to become dominant. In areas being restored after disturbance, without careful management these species can rapidly dominate and take over large areas—species of pioneer *Acacia* such as *A. saligna* are a great example, both here in the Southwest and in South Africa where they have been introduced, as their well-meaning use in restoration can result in these species rapidly and almost entirely out-competing other natives to develop thicket-like monoculture stands.

- Restoration in OCBILs is much more likely to be limited by soil conditions, because so many species exhibit adaptation to particular soil conditions typical of heavily weathered, ancient landscapes. Given the degree to which some disturbances, such as mining, alter soils (and the fact that these disturbances often specifically target ancient geological formations), any restoration in OCBILs must consider the implications of changed soil conditions on the achievability and timeframes required to attain restoration outcomes. For example, it might take thousands or millions of years for natural weathering processes to transform freshly processed mine tailings into something resembling the natural soils present before mining, which influences the species able to be successfully used in restoration over short time frames[27].

[26] Dixon KW. 2011. Coastal plants: a guide to the identification and restoration of plants of the Perth region. CSIRO Publishing, Perth.
[27] Cross AT, Lambers H. 2017. Young calcareous soil chronosequences as a model for ecological restoration on alkaline mine tailings. Science of the Total Environment 607-608: 168–175.

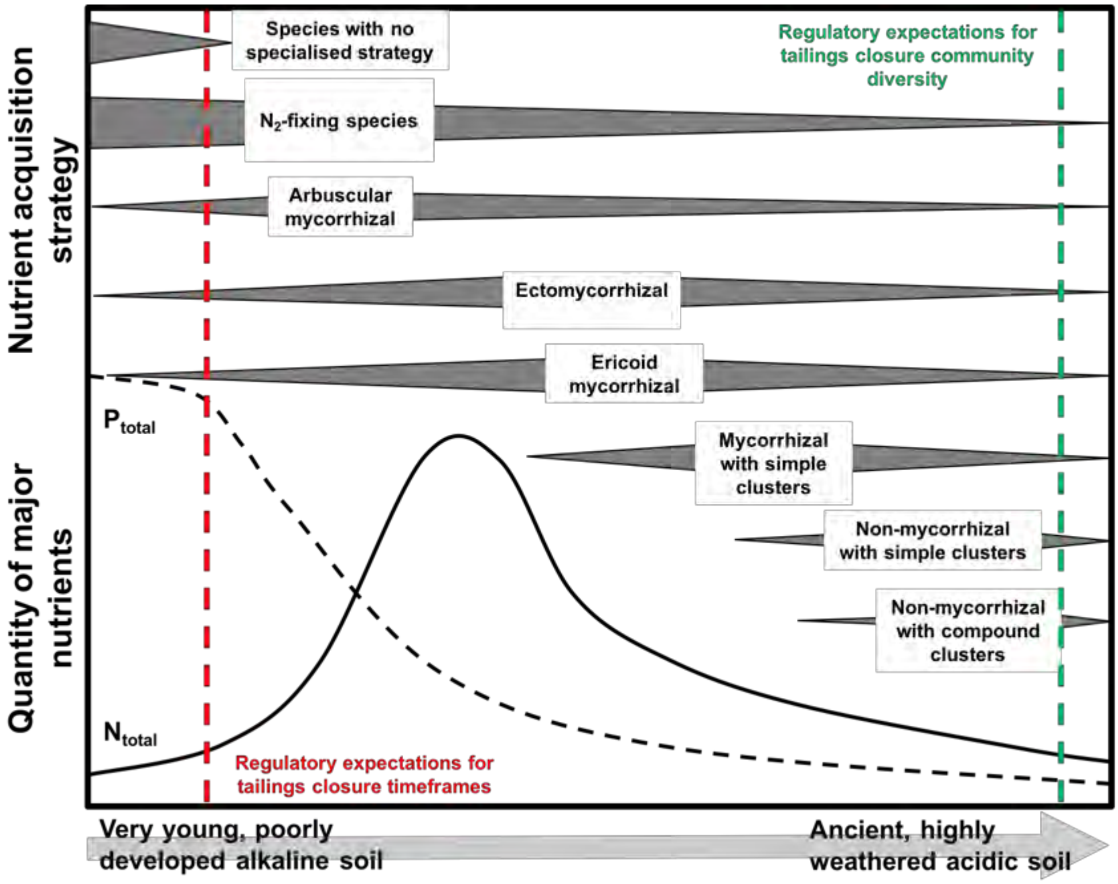

Figure 3. Changes in the comparative dominance of plant nutrient-acquisition strategies in relation to changes in total soil P and N from very young, poorly developed alkaline soils to ancient, highly weathered acidic soils—the time scale for these changes being hundreds of thousands or millions of years. Annotated are the regulatory expectations for the typical time frames in which restoration should be achieved on mine tailings (dashed red line), as well as the typical biodiversity targets that are established for these activities (dashed green line). Reproduced from Cross and Lambers 2017.

For all the reasons outlined above, restoration in OCBILs is not a simple, rapid process. It requires informed planning, a great deal of thought, and considerable preliminary information about many different aspects of both the area to be restored and the selected reference community. And, importantly, it takes time.

5.2. Considering climatic change

It seems sensible to tackle this thorny issue up-front. South-western Australia has long been predicted to experience a warmer, dryer climate, and those predictions are now becoming a reality. Annual rainfall across the region is already down 15% or more compared with long-term European records, with decreases of up to 38 mm per decade[28], and studies suggest annual average temperatures have increased by almost 1°C since 1910. Broadly, the climate zones of Southwest Australia recognised since European settlement are being shifted south-westward—the last two

[28] Philip, P. and Yu, B. 2020. Interannual variations in rainfall of different intensities in South West of Western Australia. *International Journal of Climatology*, 40: 3052–3071.

decades alone have seen some rainfall boundaries shift by over 150 km. Clearly, climate must be a consideration in our restoration thinking.

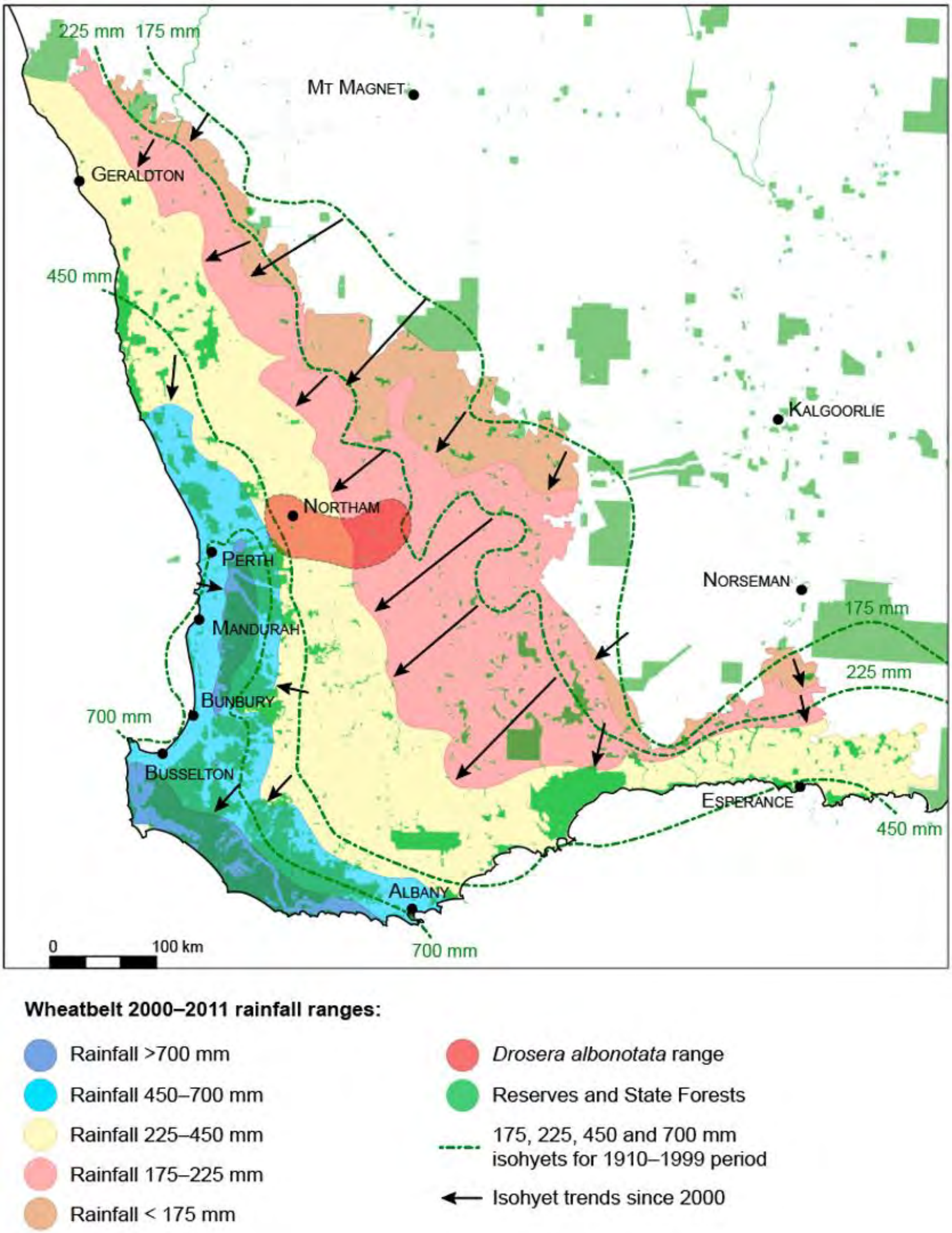

Figure 4. A map of south-western Australia with isohyets demonstrating the boundaries for average rainfall amounts in the 1910–1999 period, along with shifts in these boundaries for the 2000-2011 period illustrating the significant drying that has occurred in the region in recent decades. Reserves and State Forests of Western Australia are superimposed to illustrate the extreme habitat loss and fragmentation of native vegetation across the region, as is the approximate range of a recently-described species, *Drosera albonotata* (Droseraceae), indicating the significant potential impact of shifting annual

rainfall on species distributional ranges. Reproduced from Cross et al. 2020. Note that parts of south-western Australia are also experiencing changes in the seasonality of its rainfall.

Additionally, recent analysis of 700-year-old tree rings shows that Southwest Australia experiences drought periods of greater magnitude and duration than those recorded in the last 120 years. These include two 'megadroughts' of more than 30 years duration in the eighteenth and nineteenth centuries. By contrast, the twentieth century has been the wettest of the last seven centuries. The only conclusion that can be drawn from this data is that our agricultural experience, at least for inland Southwest Australia, 'does not capture the full scale of natural hydroclimatic variability and that the risk of prolonged droughts in the region is likely much higher than currently estimated'[29].

In the context of how we plan for a such a highly variable and exponentially changing climate in restoration, there are a few key factors worthy of consideration:

- While south-western Australia has experienced a relatively stable climate in comparison to other places on Earth over similar time periods (the climatically-buffered part of being an OCBIL), it still exhibits evidence of a long history of mild climatic variability.

- Despite historical climatic fluctuations, ecosystems in south-western Australia still exhibit a richness of biodiversity that has persisted through those fluctuations.

- Many species exhibit highly complex adaptations for survival in the face of change and uncertainty, and while they may appear to be finely-tuned to the environments they are currently in are also extremely adaptable. We simply do not understand the degree to which most species can tolerate or might respond to climatic changes; for example, the degree to which plasticity and bet hedging in seed dormancy and seed response to seasonal climatic cues might allow at least some seeds to germinate and establish even under very changed conditions.

- There is still considerable uncertainty over what will happen to global and regional climates in the next 100–1000 years. While we know that change is coming as a result of carbon pollution in the atmosphere, and that it is likely to be severe, a complex interaction of factors in various atmospheric fluxes mean that even the most robust statistical models contain uncertainty in determining the precise changes expected.

- These are dynamic systems and changes in species composition of different vegetation communities in different areas can be expected. Are we really smart enough to manage this, or is it best to let the system manage itself? We must recognise that none of us are cleverer than a 250-million-year-old complex system, and that tinkering without understanding effects of our actions can be catastrophic (think cane toads, Buffel grass and feral cats). The

[29] O'Donnell, A.J., McCaw, L.W., Cook, E.R., Grierson, P.F (2021) Megadroughts and pluvials in southwest Australia: 1350–2017 CE. *Climate Dynamics* (2021) 57:1817–1831 https://doi.org/10.1007/s00382-021-05782-0

goal is to restore ecosystems, to assist in their recovery, not re-design them based on our incredibly limited knowledge base.

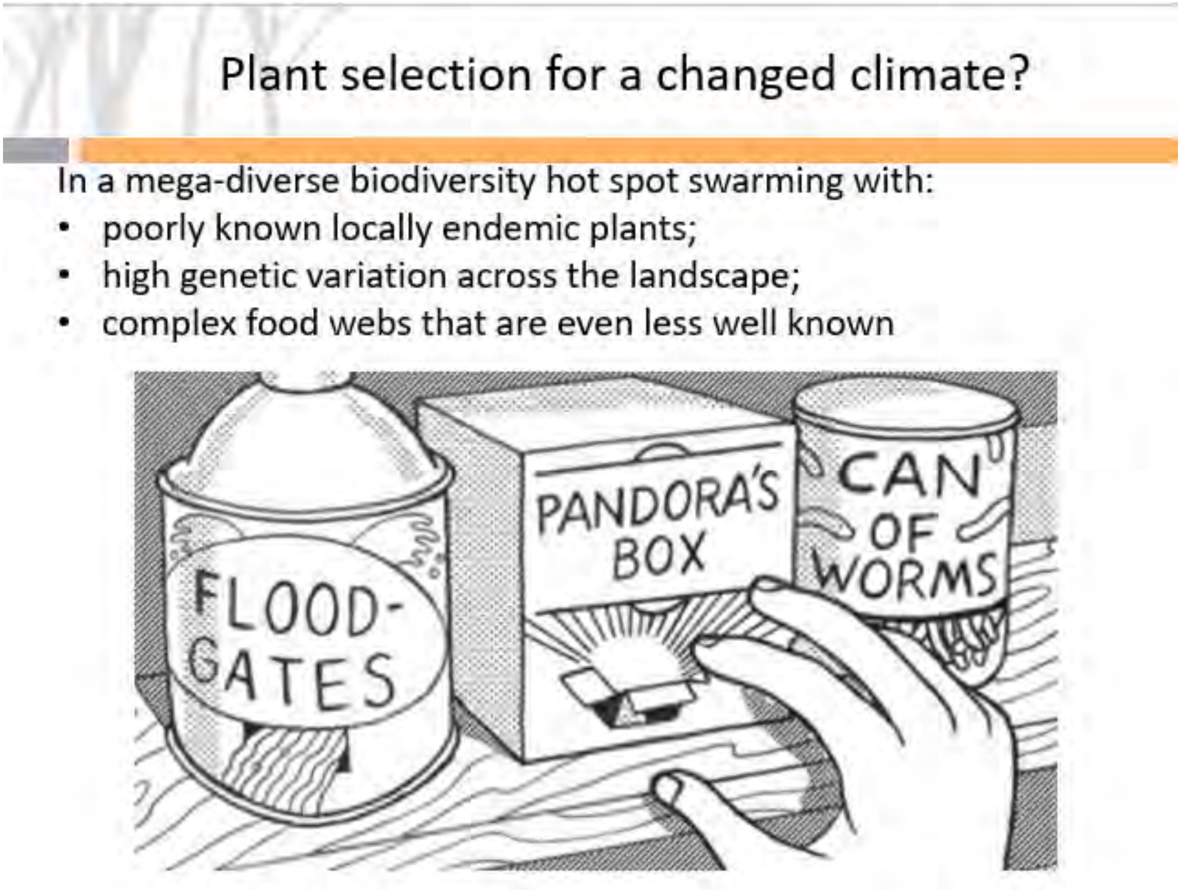

Figure 5. Planning for the future must acknowledge the considerable uncertainty about what the future will entail—even the most well-intentioned efforts can lead to catastrophe if we act without adequate knowledge and understanding of the impacts of our actions. [Please note – this reproduces a slide used by one of the authors (KB) in various presentations, with the key image coming from an internet source but we have been unable to identify its origin. We are keen to acknowledge its origins.]

What we are already facing, in hotter parts of south-western Australia at least, is difficulties in establishing local and other species due to the impact of the current climate changes. For example, over the summer of 2021-22 many plantings on sandy soils in the northern parts of the Swan Coastal Plain suffered badly as a record-breaking hot summer swept through the region. Dealing with these establishment issues is an urgent need, and techniques need to be rapidly developed, but this is a different issue from species selection and use of local reference sites for restoration.

In addition, we note that a number of geographically restricted species from specific areas of south-western Australia have become recognised weeds when planted in other areas. the classic example of this is *Kunzea baxteri*, known only from a small area east of Esperance, which is now well established in and clearly invasive of many natural areas in south-western Australia.

5.3. The need for, and other benefits of, restoration

History shows that, after clearing, many ecosystems in south-western Australia recover agonizingly slowly or, more often, not at all. That is the essence of being an OCBIL - as discussed in Section 5.1

these systems have not evolved to pioneer new areas, but to largely drop their seed where they stand. Land cleared for agriculture and then abandoned in places like Corrigin, Ravensthorpe and Forrestania looks little different now than when first cleared almost century ago—studies have found that most native species simply cannot naturally recolonize these disturbed areas[30]. Even with our assistance ecosystems can take many decades to recover, as was highlighted following the disastrous high-profile clearing undertaken for the proposed Roe-8 development[31]. However, slowly is far better than never, and there are a great many reasons why we should be intervening to repair the damaged and broken Southwest Australian landscape.

Firstly, we have a moral obligation to reverse the immense damage that our actions have caused and to try and protect what little nature remains. We are in the midst of a global biodiversity crisis, and Australia's track record for extinctions is already among the worst in the world—over 1700 species and ecological communities are at risk of extinction, at least 19 unique ecosystems around the country are at risk of complete collapse, and more than 10% of Australian land mammals have already been lost forever[32,33]. Good restoration can help imperiled species by improving the quality and quantity of existing habitat, by establishing protective buffers around habitat remnants, by re-establishing ecosystems to provide more habitat, and by reconnecting habitat remnants that have become fragmented and isolated to help species forage, find shelter, and reproduce. In a world where natural ecosystems have been removed at industrial scale and continue to be eroded daily, restoration represents the most effective biodiversity conservation strategy.

Restoration can also help maintain the ecosystem services that humans rely upon, and re-establish them in ecosystems where they have been compromised by degradation. The ecosystem services provided by nature are many and varied, from ensuring the water we drink is clean and protecting our towns and cities from the worst of extreme weather events like floods and tsunamis to providing natural products such as timber and fibres. Some communities are utterly reliant upon the ecosystems in which they exist for almost all aspects of day-to-day life; the value of ecosystem services to humanity is estimated at an unimaginable $US 350 trillion, of which up to $US 20 trillion continues to be lost each year[34]. There is also, therefore, a clear economic imperative to restore ecosystems.

But there's even more to it than the imperative to conserve biodiversity and maintain ecosystem services. Restoration is also considered one of the most effective tools in the fight against climate change, as natural ecosystems capture and store huge amounts of carbon and assist in regulating local and regional climate. Indeed, biodiverse natural ecosystems appear to store significantly more carbon than monocultures of one or a few species of trees in Australia[35]—and have the added bonus

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[30] Standish, R.J., Cramer, V.A., Wild, S.L. and Hobbs, R.J., 2007. Seed dispersal and recruitment limitation are barriers to native recolonization of old-fields in western Australia. *Journal of Applied Ecology*, *44*(2), pp.435-445.

[31] https://www.abc.net.au/news/2017-03-30/roe-8-environmental-damage-could-take-decades-to-restore/8402126

[32] https://www.awe.gov.au/environment/biodiversity/threatened/species

[33] Bergstrom, D.M., Wienecke, B.C., van den Hoff, J., Hughes, L., Lindenmayer, D.B., Ainsworth, T.D., Baker, C.M., Bland, L., Bowman, D.M., Brooks, S.T. and Canadell, J.G., 2021. Combating ecosystem collapse from the tropics to the Antarctic. *Global Change Biology*, *27*(9), pp.1692-1703.

[34] Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S. and Turner, R.K., 2014. Changes in the global value of ecosystem services. *Global environmental change*, *26*, pp.152-158.

[35] Hulvey KB, Hobbs RJ, Standish RJ, Lindenmayer DB, Lach L, et al. (2013) Benefits of tree mixes in carbon plantings. Nature Climate Change 3: 869–874.

of simultaneously improving soil health, reducing erosion, and providing habitat to native wildlife including the many insects we rely upon to pollinate many of our crops. The ‘tree planting’ exercises that have typified the carbon capture industry to this point are not sustainable, and nor are they ecologically sensible.

Finally, restoration can also improve the health and well-being of individuals and communities (a concept known as ‘ecohealth’, or an ecosystems approach to health). In addition to delivering significant economic opportunities restoration is also beneficial to public health, with studies showing greater access to nature can improve both mental and physical well-being as well as help protect communities from exposure to harmful infectious diseases[36]. Indeed, just the act of participating in restoration activities and spending time in the bush can be beneficial to your health. With mental ill-health in particular quickly becoming a national priority—currently costing the Australian economy more than $500 million *per day*[37]—restoration likely also represents a very cost-effective public health intervention. Restoration can offer fantastic opportunities for community engagement and involvement, as well as creating employment—often in regions where land degradation has limited other job opportunities. There are also many societal benefits from improving the health of the ecosystems in which we live[38,39], not only benefits to mental and physical well-being as noted above but also improving community cohesion, increasing cultural resilience, creating a stronger sense of place, and encouraging investment in local regions and businesses.

5.4. The sweet spots of scale

All ecosystems work best at scale, and Australian ecosystems probably more than most. Many Australian ecosystems are renowned for their ‘boom and bust’ ecological cycles, and many native wildlife and plants are well adapted to, and indeed are often reliant upon, these cycles. In south-western Australia many species have adapted to the challenging ecological conditions by staying put and conserving energy; not trying to colonise new, distant areas by throwing oodles of lightweight seeds into the wind, but simply allowing gravity to drop seeds below the canopy to ensure future generations persist in that suitable location. Similar ‘stick it out’ approaches have been adopted by many invertebrates, and even some larger fauna. However, other species can only thrive at scale by moving around landscapes to exploit seasonal conditions and resources. Emus once arrived into the early farms north of Albany with the dust of the Nullarbor on their wings[40], and many birds such as honeyeaters move seasonally between inland and coastal areas following vegetation flowering patterns. Indeed, one of our endemic birds, the purple crowned lorikeet, can swiftly travel from feeding in huge flocks on Karri blossoms in the far southwest to feasting on the flowers of eucalypts inland east of Kalgoorlie.

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[36] Reaser, J.K., Witt, A., Tabor, G.M., Hudson, P.J. and Plowright, R.K., 2021. Ecological countermeasures for preventing zoonotic disease outbreaks: When ecological restoration is a human health imperative. *Restoration Ecology*, *29*(4), p.e13357.

[37] https://www.pc.gov.au/inquiries/completed/mental-health/report

[38] Aronson, J.C., Blatt, C.M. and Aronson, T.B., 2016. Restoring ecosystem health to improve human health and well-being: physicians and restoration ecologists unite in a common cause. *Ecology and Society*, *21*(4).

[39] Elmqvist, T., Setälä, H., Handel, S.N., Van Der Ploeg, S., Aronson, J., Blignaut, J.N., Gomez-Baggethun, E., Nowak, D.J., Kronenberg, J. and De Groot, R., 2015. Benefits of restoring ecosystem services in urban areas. *Current opinion in environmental sustainability*, *14*, pp.101-108.

[40] Pers.comm. Peter Luscombe, from observation by early farmers

Ecosystem restoration actions are often undertaken at a single site, whether this be strip planting along a road or vegetating the corner of a bare paddock. But, while any effort to restore is good, small and isolated patches are always likely to decline as they suffer from edge effects and the relentless laws of island biogeography. Where possible, restoration is most effective where it considers, contributes to, and is part of achieving a larger change across landscapes that make up a functioning ecosystem—with the aim being to reach a point where the ecosystem is no longer reliant on constant human tinkering to mitigate disturbance. This is why Gondwana Link exists: to support good restoration practice at broad scales linking individual sites together towards a connected, resilient landscape.

The 'other' key sweet spot to consider is in relation to the cost of planting as it relates to your broader objectives, and where the 'sweet spot' sits between doing a stunningly impressive restoration of just a few hectares, or an effective restoration of a much larger number of hectares. This dilemma gets surprisingly little discussion, but is a factor in virtually every planting program. While every decision is influenced by available funds and the objective of the planting, for most plantings we suggest that it is important to find your project's 'sweet spot' where you will, for example, set the environmental trend of a bare area onto a course of steady improvement in ecological health over time. For example, for most of us, it is somewhat impractical to plant orchids, but they are known to find their way into good restoration after 20-40 years.

So the question is – at what level of restoration is an area secured against 'slipping back' to its original condition and positioned so that it will eventually become a healthy and self-sustaining part of the regional ecosystems.

Now let's think about restoration at the site level in a bit more detail – and how we can work better to make sure it adds up to ecosystem restoration.

6. Fundamentals for bringing back the bush

The fundamentals of good restoration in Southwest Australia are as simple as planting the right stuff the right way in the right place, and then giving it a few nudges along the path to being a self-maintaining ecosystem. An ecosystem is the interconnected relationships between animals, plants, the soil, air, water and fire. These relationships, ecological processes, include nutrient cycling, gene flow, predation, water movement. When undertaking ecosystem restoration, it is critical to consider the impacts you can have on all those relationships.

6.1. Respectful use of land

We live and work on someone else's land; it always was, and always will be. It's important to show respect, and avoid further damaging the many values of Boodja. While registered Aboriginal sites are few and far between on the maps of south-western Australia, sites where people once lived, worked, and celebrated are relatively common—if you know how to look or who to ask.

In our view, no 'reasonably sized' planting should commence without some consultation and cultural mapping, so that the richness of human connection with the landscape can be known and continued. In this manner, further damage can be avoided. A number of the groups restoring land across Gondwana Link have undertaken cultural mapping, and this has always been an enriching experience for everyone involved. Our preference is typically for a skilled archeologist to visit the property with local Elders and some young First Nations folk who can walk the property, seek evidence of past use and quite likely refresh memories of relatively recent use. Any such areas can then be easily avoided during the planting program (there's been enough grindstones turned up by ploughs already), and activities that must be undertaken in and around any important areas can be planned carefully with guidance from the Elders.

Allied to this is the increasing recognition that our contemporary Western approaches to fire management introduced in the last 150 years are clearly damaging the ecological values of south-western Australia ecosystems. Gondwana Link supports groups like Ngadju Conservation who are working to restore traditional Indigenous fire regimes across Country, though also recognising the need to adapt them so they cope with a hotter and dryer climate. Such approaches strive for complex mosaics of different burn ages at small scales, benefiting biodiversity, and appear much more effective than the wide-scale, short cycles of prescribed fire currently implemented using aerial incendiaries across our native ecosystems.

Figure 6: Restoring an ecosystem needs to be a respectful people centred activity. Here Noongar Elder Annette Woods is being supported to manage a cultural fire of grasslands in amongst a restored mallee ecosystem. Photo by Jim Underwood.

6.2. Laying the right foundations

Restoration is a complex process. Ecosystems are dynamic and we don't always understand how their parts all fit together (or, sometimes, what all these parts are). Lots of factors can influence how successful restoration activities are, and the time frames over which they can occur. With this in mind, the best thing possible is to build restoration programs from a solid foundation of knowledge that allows for flexibility. There are two important things required to create this solid foundation:

1. **Baseline**: information about the condition of the ecosystem at the point where restoration activities began—the starting point.
2. **Reference**: information about an appropriate reference system, selected as the goal towards which restoration activities at the site aim—the target point.

A baseline and a reference are important because they provide detail against which the development of the ecosystem over time can be compared and monitored. Without baseline information about the disturbed landscape and its history, it is very challenging to determine the most appropriate restoration actions needed and to determine how these actions have changed the landscape over time. A reference ecosystem is necessary because it gives a solid target to aim for and to compare changes to. Monitoring it as well as the restored ecosystem can show the effects of changes that might be occurring in the broader environment, such as climate change.

Baseline information should be gathered through biodiversity, environmental, and cultural surveys before starting restoration activities, particularly focussing on how degradation has influenced the ecological conditions of the site. Poor understanding of the conditions of the degraded site and how these might influence restoration can mean even the best-intentioned efforts lead towards undesirable outcomes that might not reflect a desired reference ecosystem (for example, one species dominating the vegetation and outcompeting others).

Choosing and gathering information about a reference ecosystem is more than just selecting a nearby vegetation assemblage, identifying the most dominant species, and estimating the percentage canopy cover. Ideally, the information should be as detailed as possible to allow for as accurate and precise monitoring of the restored ecosystem as possible. This information should ideally include detail about soils and water, microbiota, plants, animals, and ecosystem services and other human values, as well as the natural patterns and variation in these factors across the landscape. This information informs choices about important issues such as the most appropriate species to be seeded or planted, how many trees we might expect to establish in a given area, and how we know to expect certain animals to return.

Obviously not all projects have the luxury of being able to examine all these factors in detail, but even basic information on things like soil type can be extremely valuable because the goals for restoration activities are established from the reference: restoration actions should all work together to reinstate as many of the ecological and environmental characteristics of the reference ecosystem as possible, as well as possible.

Ecosystem restoration is a developing area of science and practice, and it is widely recognised that it is critical to learn from every experience and mistake so that methods and outcomes can be improved and made more efficient over time. The expected outcomes and goals of any project should be clearly stated at the outset so the project can later monitor and evaluate progress against them. This requires good documentation, and a mindset open to continuous improvement and adaptive learning.

6.3. The right preparation

While this Guide is focused on achieving ecological quality, and not intended as a technical instruction on the mechanics of planting programs, it is important to note that there are a number of site factors that can stop you from achieving even the best of intentions. For example, when restoring previously cleared land, some weed species will be present and will need to be managed to ensure effective germination and early growth of planted species, and to also ensure that subsequent spread does not occur. While reasonably standard techniques such as scalping before seeding or planting seedlings can deal with the competition from weeds for the first 1-2 years, failure to adequately deal with virulent weeds, such as African Lovegrass, Sydney Golden Wattle and Tagasaste, in the planting area will lead to serious difficulties in dealing with them once your restoration is established.

Similarly, it is important to assess both the presence of pathogens like Phytopthera and the risk of introduction, particularly for sensitive species on certain soil types. Is there Phytopthera nearby and what impact will it have on the area's restoration, are special measures needed to reduce the risk of its introduction, and so on.

6.4. The right seeds and plant material

By 'right stuff' we mean the best genetic material to achieve your restoration goals. This section aims to both set out the overall ecological criteria that should be used, and also gives some guidance on how to achieve 'the right stuff'. Regardless of whether restoration activities will be undertaken using direct seeding or the planting of nursery-grown seedlings, there are some important criteria to consider relating to the plant material used:

1. **Genetic variation.** For each species all seed used should be collected from a variety of plants to ensure genetic richness. Simple enough to do, and important you check on this with your seed supplier. Complexity arises if the seed came from an area that has already been planted out. In that case it is important to know that the original seed source of that area also came from a mix of species. Genetic studies on plantings in the Fitz-Stirling section of Gondwana Link indicates that effective pollen dispersal occurs across species in well designed restoration, effectively mimicking natural vegetation and contributing to long term species persistence and effective ecosystem function through integration into the broader landscape[41].

2. **Provenance:** We recommend the precautionary principle be adopted in sourcing seeds for restoration projects. Specifically, "If it ain't local, there is cause for concern". While in south-

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[41] Melissa A. Millar, David J. Coates, Margaret Byrne, Siegfried L. Krauss, Justin Jonson, Stephen D. Hopper. 2020. Evaluating restoration outcomes through assessment of pollen dispersal, mating system, and genetic diversity. *Austral Ecology*. doi: 10.1111/rec.13335
Melissa A. Millar, David J. Coates, Margaret Byrne, Siegfried L. Krauss, Justin Jonson, Stephen D. Hopper. 2019. Assessment of genetic diversity and mating system of Acacia cyclops restoration and remnant populations. *Austral Ecology*. doi: 10.1111/rec.13007
Melissa A Millar, Janet M Anthony, David J Coates, Margaret Byrne, Siegfried L Krauss, Matthew R Williams and Stephen D Hopper. 2019. Genetic Diversity, Mating System, and Reproductive Output of Restored Melaleuca acuminata Populations are Comparable to Natural Remnant Populations. *Ecological Restoration* Vol. 37, No. 4, 2019

western Australia a number of species appear to be genetically consistent over large distances, even within broadly-distributed species there can be significant genetic variation over very short distances, which may influence how individuals grow in different soils and respond to different stresses such as temperature and moisture. Population genetic studies done to date offer such widely contrasting results for different species, and even populations of the same species from different regions or habitats. This correlates with experience from the seed industry, where specific locations of some species are sought after for specific characteristics, such as salinity tolerance. So while in some instances broader provenance may be appropriate, there is limited evidence of this for most species. It seems virtually impossible to develop a one-size-fits-all strategy, so on that basis, the precautionary principle suggests it is always best to collect seeds locally from the same soils and vegetation types where possible.

A number of sources have suggested collecting within 15 kms of any planting site as a general rule of thumb. This appears to be based on a 1980s study[42] that while it was foundational in understanding the scale of species turnover in woodland ecosystems, did not have a genetic basis.

3. **Seeds or seedlings:** Direct seeding is now a proven technique in most areas and systems, aside perhaps from those with chronic weed problems (e.g., sites dominated by kikuyu grass). Broadcast or direct seeding is advantageous as it is usually cheaper per hectare than planting nursery-grown tubestock, it enables a diverse mix of species to be delivered together in a 'natural' assemblage, and it avoids the problems that can arise with planting seedlings such as poor root development or the introduction of weeds or soil-borne pathogens. However, examples from around the world suggest that <10% of broadcast seeds often result in an established plant in many ecosystems[43], particularly in drylands, and it can be challenging to collect enough seeds from already-fragmented remnant bushland to meet restoration requirements[44]. Restoration planning should always consider the availability of desired seeds to meet targets, and whether the required volume and diversity of seeds can be collected ethically. In many situations, particularly important or difficult-to-collect species are being propagated in dedicated 'Seed Production Areas' in an attempt to increase the availability of seeds for restoration activities.

   Ecosystem restoration has undergone a transformation in the last few decades. Direct seeding at scale only started in the 1980s and since then has moved from small scale to paddock scale machines, from being able to deliver one seed mix to delivering complex seed mixes in one pass with precision seed placement. Hand planting has been minimized and some planting systems can direct seed up to 20-30 hectares per day.

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[42] Mark Burgman (1988) Spatial analysis of vegetation patterns in southern Western Australia: implications for reserve design. *Australian Journal of Ecology* 13, 415-429

[43] Cross AT, Pedrini S, Dixon KW. 2020. Foreword: International Standards for Native Seeds in Ecological Restoration. *Restoration Ecology* 28: S216-S218. https://doi.org/10.1111/rec.13173

[44] Nevill P, Cross AT, Dixon KW. 2018. Ethical seed sourcing is key issue in meeting global restoration targets. *Current Biology* 28, R1378-R1379. https://doi.org/10.1016/j.cub.2018.11.015

While we strongly favour the use of direct seeding, planting nursery-grown seedlings can be a useful method in those areas not conducive to broadcast or direct seeding, such as rocky outcrops, awkward corners, stream banks or other sloping areas, and for areas where different treatments are useful. We note that for some soil and climate types, such as sands in the northern wheatbelt and even on the Swan Coastal Plain, the difficulty of getting seeds germinated and strong enough to withstand a long dry summer is leading to a preference by some groups for seedlings.

Additionally, many south-western Australia species considered key structural or functional components of ecosystems can be hard to collect seeds from, or produce seeds that are very difficult to germinate, or may be challenging to grow. A technique developed in Gondwana Link by Justin Jonson[45]is to plant these in 'nodes' across the direct seeded area, and recent monitoring has shown that these assimilate well, sharing pollinators and pollen with the same species in adjoining areas[46], and it is expected they will spread over time.

6.5. How many species, and where should they go?

Targets and goals around species diversity, and the methodologies employed in their establishment in a restoration area, are among the most important planning in ecosystem restoration. Getting these right, and properly considering how the conditions of the site to be restored might influence your targets and goals, and over which time frames, is crucial.

1. **How many species should we aim for?** There is no set figure, with the critical factor being, as discussed in 5.4 the number of species that can set the planting on a pathway towards full restoration as a healthy and functioning part of the local ecosystem.
   For restarting ecosystem functions on a site in south-western Australia we estimate at least fifty species need to be in the mix you plant, and these need to range across the layers of vegetation and time that were on your reference site. This relatively low number is predicated on there being existing habitats nearby, preferably adjoining, which over time are likely to 'leak' additional seed and genetic material into the planted site. For areas remote from other natural vegetation then the number may need to be much higher. Complex ecosystems survive and thrive through a mixture of interactions and synergies, some we have discovered in recent years, some we still can't even imagine. Simple ecosystems often simplify further, particularly where they have edge pressures.

2. **Site factors.** It is also important to consider how factors such as different patterns of soil types, hydrology, aspect, elevation and species interactions within a site an could influence

[45] Jonson, J.H. 2010. Ecological restoration of cleared agricultural land in Gondwana Link: lifting the bar at 'Peniup'. Ecological Management & Restoration 11:16-26 see also https://thresholdenvironmental.com/implementation/

[46] Melissa A. Millar, David J. Coates, Margaret Byrne, Siegfried L. Krauss, Justin Jonson, Stephen D. Hopper. 2020. Evaluating restoration outcomes through assessment of pollen dispersal, mating system, and genetic diversity. *Austral Ecology*. doi: 10.1111/rec.13335
Melissa A. Millar, David J. Coates, Margaret Byrne, Siegfried L. Krauss, Justin Jonson, Stephen D. Hopper. 2019. Assessment of genetic diversity and mating system of Acacia cyclops restoration and remnant populations. *Austral Ecology*. doi: 10.1111/rec.13007
Melissa A Millar, Janet M Anthony, David J Coates, Margaret Byrne, Siegfried L Krauss, Matthew R Williams and Stephen D Hopper. 2019. Genetic Diversity, Mating System, and Reproductive Output of Restored Melaleuca acuminata Populations are Comparable to Natural Remnant Populations. *Ecological Restoration* Vol. 37, No. 4, 2019

the fine scale mosaic of vegetation. The density of plantings will likely interact with these considerations, as most ecosystems show considerable variation in the densities of different species reflecting these and other factors. Where possible, restoration should have mosaic ‘patchiness’ incorporated into its design, and avoid regular and widely-spaced row plantings, to encourage spatial heterogeneity. It is also important to consider how the design of restoration areas might influence off-site ecosystems, and consider whether management is needed for hydrology and the movement of nutrients and soil or sediment by erosion or leaching. This helps ensure that the project will not contribute to ongoing degradation of adjacent ecosystems through the leaching of fertilizer, herbicide or insecticide that might contaminate native ecosystems and impact flora or fauna.

3. **Vegetation structure should develop over time.** Vegetation is much more than just an upper canopy, and vegetation structure is much more than just the different heights at which species grow. Vegetation develops in time and space, with disturbance recovery naturally resulting in vegetation transitioning from single-story cover of disturbance pioneer species, such as short-lived wattles, through to the plant elders of the future—species that without major disturbance will remain a key feature of the system for centuries, such as Jarrah or Karri. However, many of these species from the later stages of ecosystem development take time to establish or require facilitation from other species which must establish first. Including the right balance of pioneers in seed mixes has the advantage of building soil carbon and soil microbiota, as well as woody debris and leaf material on the ground, as they grow, die, and decompose. This improves soil health and microbial functioning which will likely assist future plant species to establish more successfully, as well as providing habitat for fungi and other decomposers such as invertebrates which also act as ecosystem engineers. An increasingly common principle in regenerative farming is to never leave soil bare to ensure it remains healthy and biologically active; the early establishment of pioneer species achieves this same outcome.

   Structural diversity is one of the most important characteristics of revegetation for enhanced fauna habitat. Having different layers in the vegetation provides different fauna habitats required for foraging, nesting, shelter, and predator evasion. For many vegetation communities, the emergence of all strata may take many years depending on the growth rates of the tallest structural components. This can be hastened in some cases by inclusion of seedlings as well direct seeding. Large woody debris such as hollow logs, as well as rocks, offer significant fauna habitat and can also provide micro-climatic conditions for seed germination in many species.

   These micro-habitats, and others created by remnant vegetation or rock outcrops should be retained where already present or replaced through active placement of such material if it can be obtained without harm to other areas to maximize the chances of fauna recolonization.

6.6. Planted the right way

The overall objective is to achieve vegetation communities that are self-sustaining, will continually recruit, and function as habitat for a wide range of wildlife. While that implies a system that will gradually become richer and more resilient over time there is arguably a more urgent need to create the habitat conditions that support those local wildlife species most adversely affected by current conditions.

A number of key requirements, such as ensuring a mix of habitat layers and placing the right seeds into the right soil types for the right vegetation communities, are covered in earlier sections. If planting by machine significant additional benefits are gained by narrow row spacings, so that by the time the plants are 4-5 years old they merge and rows disappear. It's important to minimize row width, to give above and below ground plant and wildlife synergies the best chance, to produce areas of the dense thickets that much wildlife needs, and to avoid creating hunting highways[47]. Foxes, and perhaps to a lesser extent cats, do not penetrate our dense (and generally prickly) bushlands easily, and prefer to hunt along tracks. Wide-spaced rows are perfect for then to hunt along and kill the wildlife attracted to your plantings. We have been heartened by the modification of farm machinery, such as by Threshold Environmental, that economically brings row spacing to ecologically desirable widths, such as around 1.4 metres.

Because restoration is about ecosystems and their function, it's important to note that even key local wildlife will avoid wide spaced open plantings. Many are shy and cryptic. Data from sites across Gondwana Link[48] has shown how quickly the full mix of wildlife can return to well designed and executed restoration plantings, much quicker than for simple revegetation areas. The same type of survey data, collected from plantation style revegetation, shows how very common, aggressive and opportunistic species can easily dominate. What's worse, these species can build up in revegetation areas and then spill into adjoining habitats, chasing shyer species away.[49] We term this avian pollution, and are keen to avoid it.

Another key issue in ensuring good seed placement, germination and growth is getting the seeds into the ground as a mixture of species (noting that seeds vary enormously in size) and planting them in the right conditions and at the right depth. We're not covering the specific techniques here, but there are now also a mix of machines and contractors that can achieve this.

Even though different seasons can give different levels of germination and hence density of plantings, we consider it important to consider your desired plant spacings along the rows carefully. Close dense early growth looks great, but can 'freeze' itself within a short number of years, and grow very slowly from then on. Wider spaced plantings may not look as good early on, but give the plants a much better opportunity to mature – as our colleague Justin Jonson once retorted to us "why didn't you tell me you wanted old growth, I can grow that quicker than I can young growth'. And he can!

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[47] We thank Justin Jonson for his initial observation, and succinct phrase, on this additional ecological impact of wide spaced rows.

[48] Collected by the Conservation Council of Australia's Citizen Science program, led by Nic Dunlop, over a number of years. We understand the data is being written up and will be published.

[49] Collected by the Conservation Council of Australia's Citizen Science program, led by Nic Dunlop, over a number of years. We understand the data is being written up and will be published.

This followed work by Justin to measure the rate of carbon sequestration in remnant and biodiverse plantings across Gondwana Link. His data showed that some species had high resilience to self-thinning and when planted at high stocking rates could 'lock up' - that is plant growth would slow considerably as the plants competed with each other for nutrients and moisture[50]. Restoration plantings should aim to include both highly stocked areas and well-spaced areas to account for this and to maximise growth and productivity, given that ecological productivity includes not only carbon, but also flowering and nectar, seed production, habitat and overall vigour.

Similar processes, where considerable periods of time are required for closely spaced seedlings to reach maturity after fire, has been documented in the eucalypts of the Great Western Woodlands[51].

6.7. And monitored the right way

Studies suggest monitoring is most informative if it can be undertaken over decades at least; monitoring only once or twice gives little opportunity to identify and correct any problems that arise, and many south-western Australia ecosystems take decades to mature. However, having such time periods is often a luxury, and for projects with more limited scope the aim should be to simply monitor as much as possible, as often as possible. There are a few important points to consider in monitoring:

1. Many projects monitor very simple metrics, like the presence or absence of one or a few indicator species or the percentage of vegetation cover. While this is cheap and easy, it's far from ideal: they tell us almost nothing about the integrity, complexity, or ecological functioning of the ecosystem. Monitoring should ideally examine as many different parts of the ecosystem as possible, in as much detail as possible, to provide an accurate picture of how things are developing and changing over time. This might mean engaging with experts to ensure flora and fauna surveys are as accurate as possible, for example, or undertaking such surveys in more than one season and across multiple years to ensure annual plants or migrating animals are recorded.

2. The composition of species present is just as important as the total number of species present, as different species play different roles in ecosystems and all contribute to complexity and functioning. Monitoring should always aim to determine which species have established in restoration, not just how many or the total amount of vegetation cover.

3. Don't forget the wildlife! Ecosystems are much more than just the plants that are present, and many restoration projects forget to examine how animals return to the landscape.

4. It's also important to look at more than just which plants and animals are present in a restored ecosystem; factors such as how soils develop, how water is moving through the landscape, how animals are behaving, what's happening in the soil and whether plants are flowering and setting seed are also crucial in figuring out how the ecosystem is developing.

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50 Jonson, J. (2007) Succession, Resistance, and NPP for an Obligate Re-seeder in the southwest region of WA. Poster. MEDICOS XI Conference, Perth, WA.

51 Gosper, C.R., Yates, C.J., Prober, S.M. (2013) *Floristic diversity in fire-sensitive eucalypt woodlands shows a 'U'-shaped relationship with time since fire*. J. Appl. Ecol. doi: 10.1111/1365-2664.12120

For example, restoration activities in wetlands and riverine areas might also need to examine variation in the quality and amount of seasonal water flow, and how the ecosystem connects with other waterbodies nearby–these factors can influence how, when, and what types of aquatic plants can establish. Without fungi functioning in your soil you are unlikely to see orchids return, but when soil fungi is plentiful and healthy, you may be surprised by what starts growing.

5. Think about the tools that are available for monitoring, and how they can be best used to capture as much information as possible to support monitoring efforts. Loads of new approaches are becoming available and accessible, from drones to DNA metabarcoding, but they each have their limitations as well as their strengths. For example, sampling environmental DNA can give an excellent, rapid, and cheap assessment of which species are present in an area if done well, and may offer information about their abundance but tells us little about their behaviour or development.

6.8. Restoration should always occur in the right place

A key element in achieving quality restoration is where and how it happens within the broader landscape, cultural, social and ecological contexts. Geographically, the ideal is a restoration site on one of those magic sweet spots that connects two existing habitat areas, making those two areas into one larger and much more viable piece of habitat - the bigger the bush patch the better. However, by establishing restoration sites so they adjoin bushland on at least one side, you will provide buffer areas to the remnant bushland as well as help your restoration site establish more rapidly and facilitate the quicker arrival of wildlife. And of course, that site is now a better candidate for connecting up with other sites in the future. While improving connectivity is so crucial in our fragmented and cleared landscapes, establishing isolated restoration sites is still of high value. Indeed, such areas can act as stepping-stones between larger, more connected areas, and all bush is valuable to nature—from paddock trees to huge national parks.

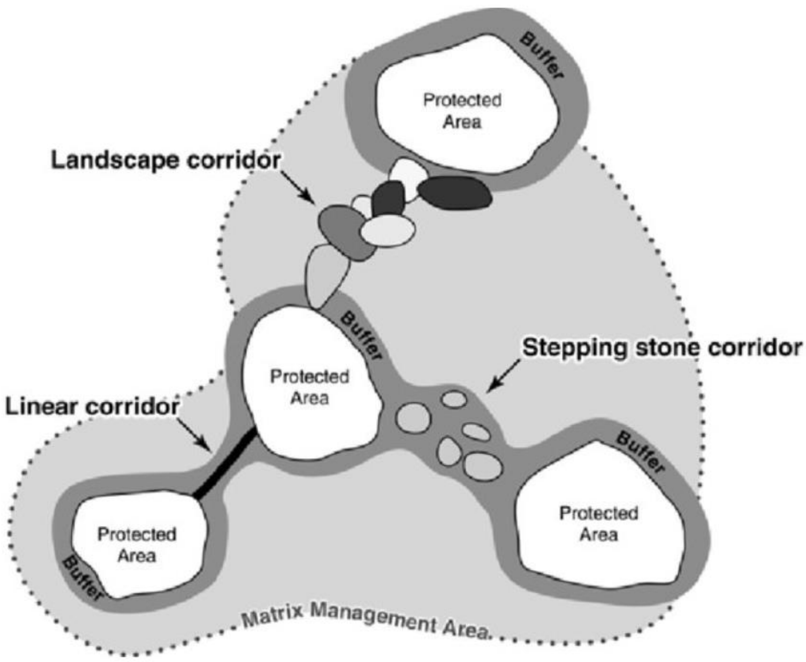

Figure 7: Some of the conceptual elements that comprise connectivity conservation spatial planning: core protected areas, the landscape-wide matrix management area, native vegetation that serves as 'stepping stones' and linear corridors of native habitat[52]

The best, and likely most successful, locations for restoration are places where the original native vegetation is at least somewhat intact and whatever has caused degradation of the ecosystem, such as grazing by sheep or cattle, can be prevented. Even considerably degraded vegetation can recover from the seed bank provided the degradation has not been too prolonged or severe. However, remnant vegetation is desperately scarce in the huge areas of south-western Australia cleared for agriculture, and restoration must now increasingly look to the revegetation of bare, completely degraded areas such as old paddocks and salinity-affected land. The challenges of restoration in these highly-altered areas are exponentially greater, but so too are the rewards and ecological implications of success.

Another element of place is who else shares that place. Maintaining good relationships with neighbours and other local stakeholders helps maintain a local license to operate for restoration projects. This might include the management of weeds and feral animals, maintenance of boundary fences, and contribution to fire preparedness and local fire-fighting capability.

Finally, the long-term tenure of the site should be considered. Revegetating land to meet ecological objectives requires a long-term commitment to maintaining its ecological values, requiring mechanisms to ensure this can continue to occur regardless of the future ownership of the land or changes to the institutions responsible for its management.

6.1. Clarity and Contracts

In the discussions that informed the development of this Guidebook we had some landholders show us plantings they were disappointed with. The reasons for their disappointment were many, and often key factors were issues already covered – a difficult season, poor weed control etc. But it was also striking that there were a number of examples where what germinated and grew included plants very different from what the landholder expected. In at least one case this has led to plants from one part of south-western Australia, different from the planting area, becoming a pest species and needing to be eradicated over a number of seasons.

While recognizing that there are a number of variables in any planting program, beyond the control of both the landholder and the planting organisation or contractor, there are a number of factors that can be better managed. The plant species used are one of these, be they direct seeded or planted as seedlings.

We suggest that as a very minimum landholders should seek a written outline of how the plantings will be undertaken, along with a list of the species that will be planted on their property. Additionally, in relation to the species used it seems sensible for this understanding to be in the form of a contract, with the organisation or individual implementing the planting program guaranteeing

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[52] From Bennett, G 2004, *Integrating Biodiversity Conservation and Sustainable Use: lessons learned from ecological networks*, IUCN, Geneva.

that if species different from those agreed to emerge from their planting work over a 1-5 year period, then those plants will be removed at their cost.

7. Know what's happening and enjoy success

Ideally, restoration activities are considered successful when the planted area has become self-sustaining and requires minimal ongoing human management. However, achieving such a target is challenging and can take many, many decades. Restoration doesn't stop once seeds have been sown or tubestock planted. Sites need management and careful monitoring, often over long periods, to know what's happening and ensure that they continue developing in the way desired. Monitoring is one of the most crucial aspects of restoration and effective, appropriate monitoring is one of the most important keys to success—indeed, the only way to know if restoration efforts have been successful or not is to watch the restored area develop over time. Even after active restoration interventions are finished it is important to plan for at least a decade of what we call 'nudge' management—management that is subtle, undertaken only when required to keep things on track, and provides only a few little nudges to ensure the trajectory of the system remains self-sustaining.

At some of Gondwana Link's restoration sites, we've worked with volunteer and community groups to survey restored areas using 'functional bird guild' techniques to assess how wildlife is returning (we're expecting a paper to be published soon outlining this approach). It's pretty exciting to see tangible evidence of success happening within just a few years following planting. Indeed, this underlines an important fact to remember: as restoration areas age and develop, and the degraded landscape begins to flourish and recover, you will have the pleasure of watching it all happen. A walk through the bush watching wildlife can be relaxing and invigorating—but even more so when that walk is through bush that you grew, to watch wildlife that you attracted back and provided a home for. And, importantly, watching new life establish in the bush brings hope and healing to us, too. Being involved in restoration, just like spending time in the bush, is good for anyone's health and well-being.

8. Help is available!

Plenty of guidance material and advice is freely available online from national and international restoration organisations. These include guidance and a simple check wheel against which your restoration processes and monitoring can be compared in the International Principles and Standards for the Practice of Ecological Restoration), and loads of advice on the most successful and appropriate ways to collect, store, and use native seeds in the International Standards for Native Seeds in Ecological Restoration (https://onlinelibrary.wiley.com/toc/1526100x/2020/28/S3). Ecosystem- and habitat- specific advice can be found for many Australian ecosystems, such as the River Restoration Manual (https://www.water.wa.gov.au/water-topics/waterways/managing-our-waterways2/river-restoration-manual), and help with threatened species and translocations can be found in Guidelines for the Translocation of Threatened Plants in Australia (https://www.anpc.asn.au/translocation/).

9. The final summary

The continuum of biodiversity and ecological values[53]

★ ★★ ★★★ ★★★★ ★★★★★

Low biodiversity value	High biodiversity value
Few species	Many species
Introduced species	Species all occurred naturally on this site
One structure (eg all canopy trees)	Diverse structure (many layers)
Spatially homogeneous (eg evenly spaced rows)	Diverse habitats (litter, tree hollows, logs...)
Few habitat types	Spatial heterogeneity ("patchiness")
No management	Dieback, ferals, weeds managed
Short lived	Durable (can self-replicate within reasonable period)
Isolated, small, no strategic connections	Part of a strategic context: corridors, stepping stones,

[53] Gondwana Link Ltd (2010) Restoration Standards Version 1.1 (Eds. Paula Deegan, Justin Jonson and Keith Bradby)