PROJECT PHOENIX

NATIVE SEED TRANSFER ZONES IN AUSTRALIA

HOW FAR CAN SEED GO?

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Across all of our Project Phoenix activities and actions we pay respect to the Traditional Owners and Custodians of the lands and waters on which we work. We honour the resilience and continuing connection to country, culture and community of all Aboriginal and Torres Strait Islander people across Australia. We recognise the decisions we make today will impact the lives of generations to come.

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EXECUTIVE SUMMARY

Concerns regarding a lack of native seed supply have been raised within the Australian and global ecological restoration communities for several decades. Recent natural disasters such as the 2019–20 Black Summer bushfires in Australia exacerbate that concern. Many factors can contribute to supply shortages, including failed revegetation projects. Improved guidance on where to source native seed to reduce the possibility of maladaptation to the planting site offers one possible solution.

Seed transfer zones (STZs) provide clarification on where seed can be geographically transferred with little disruption of genetic patterns or loss of local adaptation to support better restoration outcomes.

The aim of this report is to identify the use of STZs and the level of prescription of seed movement in Australia and internationally, and to report on research or actions that have contributed to or is currently underway that may assist with consensus for and the development of STZs.

This report found that prescribed or enforced policy on seed movement and/or the use of STZs in Australia and the United States of America (US) is rarely generated from the top levels of governments or their agencies. Instead, decision making comes from the various offices of the agencies (a bottom up approach, rather than top down) but often with guidance from the respective agency. The level of guidance and enforcement can vary within agencies. It is uncommon for policy on seed sourcing to be mandatory, instead, guidance is often provided. By contrast, in many European countries, there is a top down approach where governments provide clear seed sourcing guidelines (in some cases legislated) and there is a high level of cooperation between countries to achieve major restoration goals and improve current practices.

This report is the first to qualify individual organisations' practice and policies on prescribed native seed movements in Australia. In addition to government bodies, representatives from knowledge providers, the mining industry and other NGOs were interviewed on their seed movement/seed sourcing practices. At the state and territory government department level, the strictest form of prescription is found in the State of Victoria. The Department of Environment, Land, Water and Planning (DELWP) in Victoria has developed new Delivery Standards for revegetation, currently in draft form. Once finalised, where DELWP invests money into projects in public land, the Standards will be prescriptive and their use encouraged where funding is provided on private land.

The strength of encouragement by the state departments to use locally collected seed (local provenance) is greatest in Tasmania (Tas), South Australia (SA) and the Northern Territory (NT) where the use of local seed is an expectation, rather than a rule. In Victoria, a 'combination' provenance approach that incorporates a 'climate-adjusted strategy' into the current strategy of using local provenance will be recommended. The definition of local provenance is often not defined in the guidance provided, but examples range from 'as close as possible to the revegetation site' to 'the catchment'. While some agencies expect the sole use of local provenance seed, others are using a 'climate-ready' approach and incorporating local seed with seed from locations currently experiencing the climate projected for their region.

For the mining industry, local provenance seems to be preferred and seed sourcing requirements outlined in rehabilitation plans must be adhered to. Other NGOs comprise a mix of practices; some use only locally collected seed and others source more widely, predominately because of climate change. The definition of 'local provenance' ranges widely among the organisations from 'on the site' to 'the region'. From reviewing the current guidance from knowledge providers, it appears that over the last few decades, there have been subtle paradigm shifts in the guidance of where native seed should be sourced.

The lack of prescription for seed movement affords a degree of flexibility that is helpful to counter issues such as seed shortages and may assist in the event of the development and implementation of STZs. Apart from Western Australia, few existing STZs were found in Australia. By state, the following STZs were found:

- Western Australia has hundreds
- New South Wales has approximately 20
- Tasmania has general seed zones for Eucalyptus commercial forest species and
- South Australia has zones for 17 grass species spanning 13 botanical regions.

Internationally, the US has many species-specific STZs for forestry species and is developing STZs for some grass and forb species. Similarly, in Europe, several countries have species-specific STZs for forestry species as well as legislated STZs for grassland species.

Within the native seed/ecological restoration community in Australia, there is support for the development of STZs. However, not all academics or practitioners think that STZs are necessary in Australia. For consensus to be reached, it will require multiple agreements and negotiations, with wide consultation among stakeholders on the many characteristics of potential STZs (i.e. the type of STZs — general or species-specific) suitable for Australia.

There are many research projects currently underway, existing STZs, and theory (in both Australia and internationally) that can contribute to the development of STZs and present an opportunity to build on these.

The information gathering process of this report (direct interviews rather than anonymous surveys) was time consuming. For some sections of the report, the number of interviews was smaller than that desirable to represent all stakeholder groups. The number of researchers, for example, may not adequately represent this group's views and additional information may be warranted to expand upon these findings. However, the interviewees are identified by their organisations, so knowledge gaps or opinions can be easily identified and therefore revised. The small sample sizes also reflect COVID-related issues and the time constraints imposed on many working within the ecological restoration community. Resources must be made available to allow the involvement of those with the expertise needed to develop and implement STZs within Australia, along with the appointment of a coordinating central body such as the federal government.

GLOSSARY

PHRASE/WORD	DEFINITION/INTERPRETATION
Admixture provenance strategy/approach	A wide variety of seed sources with no spatial relationship to the planting site are mixed together. The aim is to increase populations' ability to evolve (evolutionary potential).
Assisted gene flow	The managed movement of individuals or gametes between populations within species ranges to mitigate local maladaptation in the short and long term.
Assisted migration	Involves removing individual plants from an area that has, or will become, unsuitable (i.e. due to climate change), and moving them to a new site where conditions will be more suitable.
Climate-adjusted provenance strategy	Captures adaptive responses to climate in the face of uncertainty, by combining in situ plastic responses, adaptation, and selection occurring in the local gene pools, with genetic material that has evolved in environments more similar to projected futures of the restoration site.
Climate-informed seed transfer zones	Seed transfer zones informed by climate similarities.
Combination provenance strategy/approach	The incorporation of a climate-adjusted provenance strategy into a local provenance strategy. Seed for a local species is sourced from various locations across the climatic gradient in the direction of projected climate change.
Common garden experiment	A study where different genotypes or populations are grown together in the same environment. Because the growing conditions are similar, the environmental effects on the species' traits are minimised, thereby allowing any genetic differences to be detected.
Composite provenance strategy	The mixing of a small proportion of genotypes from non-local high quality and genetically diverse populations with local seed sources. The aim is to reinstate historical gene flow and address inbreeding and adaptive potential issues.
Empirical seed transfer zone	Seed transfer zones that are developed by empirical methods for specific species across their distribution. Various methods are used i.e. (i) common garden or reciprocal transplant experiments that investigate fitness, morphological, phenological and/or physiological traits, or (ii) modelling that links genetic variation across the species distribution with or without climate change projections.
Ecoregion	Regions of relative homogeneity in ecological systems or in relationships between organisms and their environments.
Forest reproduction material (FRM)	Parts of a tree that can be used for reproduction.
Genetically appropriate plant materials	Native plant material environmentally adapted to a restoration site that are likely to establish, persist, and promote community and ecological relationships. Such plants would be sufficiently genetically diverse to respond and adapt to changing climates and environmental conditions; unlikely to cause genetic contamination and undermine local

	adaptations, community interactions, and function of resident native species within the ecosystem; not likely to become invasive and displace other native species; not likely to be a source of non-native invasive pathogens; and likely to maintain critical connections with pollinators.
Inbreeding depression	A reduction in reproductive fitness of offspring in a population due to inbreeding (the mating of related individuals, reducing genetic diversity).
Local provenance	Over time, the definition of 'local provenance' has undergone many changes; from one which described a narrow distance-based seed collection radius from the planting site (i.e. 5kms) to a definition of an area where the climate and environment of the source material relative to the planting site are similar (sensu Erikson & Halford 2020). However, the definition is context specific; it will differ between species, locations, and the type of restoration activity.
Maladaptation	The failure or inability to adjust adequately or appropriately to a particular environment.
Outbreeding depression	A reduction in reproductive fitness of offspring after the crossing of populations, relative to the fitness of the offspring of the local population.
Provenance	Origin or source. Or more specifically, it is used to describe the location of the stand from which the reproductive material was collected.
Provisional seed zone	The first step, or attempt, in defining seed transfer zones or guidelines.
Reciprocal Transplant	A study to test the presence of local adaptation. Different genotypes or populations are planted at different sites that include the home site and sites representative of the environmental conditions experienced across the target species' range.
Region of provenance	A region identified by climatic similarity that can be ascribed to planting stock as an aid to sourcing suitable plant material.
Seed transfer zone (STZ)	Geographical areas (zones) within which seed can be transferred with little disruption of genetic patterns or loss of local adaptation. The term is often interchangeable with 'seed zones' but in the UK, for example, seed zones are a non-statutory sub-division of the statutory Regions of Provenance.
Seed collection zone	Geographical areas (zones) within which seed can be collected with little disruption of genetic patterns or loss of local adaptation.
Source-identified seed	Seed, seedlings, or other propagating materials collected from natural stands, seed production areas, seed fields, or orchards where no selection or testing of the parent population has been made. The source is verified by a third party, the Association of Official Seed Certifying Agencies (AOSCA). Source-identified seed may be from either a single remnant source or from several sources pooled together as a regional source. Sometimes referred to as 'yellow tag' seed. Term used in the US.
Yellow tag seed	Native seed where the source has been verified by the (AOSCA). See 'source-identified seed'. Term used in the US.

1 INTRODUCTION

1.1 Seed supply and seed sourcing

For several decades, concern has been raised that the scale of ecological restoration needed to address environmental issues, rehabilitate mine sites, and respond to 'natural' disasters (i.e. the recent 2019–20 Black Summer bushfires) that will deplete native seed supply (Mortlock 2000; Merritt & Dixon 2011; Broadhurst *et al.* 2015a; Hancock *et al.* 2020). Examples of suggested solutions to mitigate seed shortages include the expansion of seed production areas to increase supply (Nevill *et al.* 2016), more seed banks for bulk storage and other services (Merritt & Dixon 2011), the formation of an industry body to oversee seed collection and standards' utilisation (Broadhurst *et al.* 2015a; Hancock *et al.* 2020), and the development of flexible strategies and coordinated leadership to improve seed supply etc. (Broadhurst *et al.* 2015(b)).

Native seed supply concerns are also evident in other countries. Large-scale restoration efforts such as the UN Decade on Ecosystem Restoration (2021–2030) are likely to exacerbate current supply problems. To address the issue of how to supply adequate quantities of genetically appropriate seed, in the US, the *National Seed Strategy for Rehabilitation and Restoration* (NSS) (PCA, 2015) and its *Making Progress Report* (PCA 2018) provide the framework for working towards their vision of providing 'the right seed in the right place at the right time'.

In Europe, there is an increasing demand for native seed supply, particularly from countries such as Germany that have required the use of native seeds for all restoration of grassland areas since 2020 (De Vitis *et al.* 2017; Bucharova *et al.* 2019). The recent creation of the European Native Seed Producers Association aims to help produce and provide seed of appropriate origin and quality, but importantly, contribute to establishing policy frameworks that support the growth of the native seed industry in Europe.

> Many factors compound seed supply issues. Failed revegetation efforts are one source of exacerbation and the success of revegetation is multi-faceted. One of the determinants of that success or failure is the appropriate selection of the seed source used at the planting site. The decision of where suitable seed should be sourced is complex and involves the appraisal of factors such as seed availability, economic realities, and sometimes social expectations.

Separate decision making is necessary for each planting project and depends on the project site (i.e. the position of the site in relation to the species' distribution), the purpose of the planting (i.e. rehabilitation of degraded sites or the augmentation of natural populations) and the species used (i.e. widespread or narrowly distributed). Therefore, considerable time and effort is repeatedly expended to maximise revegetation success.

1.2 Seed transfer zones

One strategy where economies of scale can be applied to the decision-making process is to have well-defined seed transfer zones (STZs). STZs are areas within which reproductive material can be transferred with little risk of being poorly adapted to their new location.

STZs can enhance restoration outcomes by identifying which seed sources are best suited to the planting site. The use of STZs can improve outcomes by generating efficiencies, economies of scale, stability, and predictability in seed production systems and seed collection enterprises (Erickson & Halford 2020).

STZs replace arbitrary borders (state or local government) or geographical distances from which to source seed. Therefore, supply constraints can be improved and reductions made in overall restoration costs (Erickson & Halford 2020). Conversely, STZs are costly in terms of time and money and are not the panacea for all supply problems. STZs are informed by field trials (common garden experiments or reciprocal transplant studies) and/or genetic analysis (molecular or landscape-scale) and link a species' adaptive trials and climate (Johnson *et al.* 2004). Considerable time and resources are required to develop these zones that ideally cover the species' entire range and are long term in tenure.

A recent survey in the US found that if plant material is not available from within the designated zone, recommendations to use the prescribed seed will be disregarded, despite policy or guidelines (Tangren & Toth 2020).

1.3 Project aims

The aim of this report is to review the prescriptiveness of Australian and international native seed movement practices and to identify established STZs. Australian federal, state and territory governments (and a sample of their agencies), and non-government organisations (NGOs) are interviewed regarding their policies and/or practices on the sole use of local provenance, the level of prescriptiveness, and the definition of 'local provenance'. Internationally, the level of prescriptiveness of native seed movement is explored with examples of species-specific and general STZs provided from the US, Europe and the Americas.

In preparation for future stakeholders' meetings to discuss the development of STZs in Australia, Australian researchers are interviewed to identify the studies (including their own) that may contribute to the development of STZs. Details of relevant field trials currently underway are also sought from non-academic sources. The aim is to report on what further action or information is needed to generate consensus on the development and implementation of STZs in Australia.

2 METHODS

Information was sought on the following aspects of native seed movements (seed sourcing) in Australia and internationally:

- level of prescription (i.e. enforced policy/code of conduct/guidance)
- basis of the prescription
- underpinning research
- benefits and issues (if applicable) and
- examples of STZs.

The locations from which the information was sought was geographically extensive: Australia, the US, Europe and Latin America. This information was obtained by conducting interviews with appropriate representatives within each organisation from each country, and/or by reviewing the grey literature (with a focus on web-based material). This was not a systematic review of peer-reviewed literature. Rather, websites of targeted organisations were reviewed.

In Australia, most interviews with practitioners were conducted by phone (and a small number by email), with a transcript of the interview approved by the interviewee. Interviews conducted with overseas contacts were by email or video conferencing, primarily using Webex or Microsoft Teams. More detail on the sampling frames used per country is detailed in the appropriate sections.

To identify research or action that has contributed to or is currently underway that may assist in the development of STZs, Australian researchers that are known to work in relevant fields of study were identified. A sample of researchers were then selected to represent different expertise and geographical location (by state). These representatives were emailed and invited to participate in an interview. The interviews were conducted by video conferencing (Webex or Microsoft Teams).

In addition, non-academic interviewees were asked to identify any relevant field trials currently underway that may assist with STZ development. Information gathered from these sources (academic and non-academic), together with the documents and literature reviewed for other sections of this project, formed the basis of an understanding of what actions or information is required to gain consensus on the development of STZs in Australia.

3 RESULTS AND DISCUSSION

3.1 Prescribed native seed movement in Australia

To obtain information on prescribed seed movement within Australia, websites were searched for relevant documentation of governments at the federal, state and territory level, and their agencies, and for selected non-government organisations (NGOs). Once the appropriate department was found, a representative was invited to be interviewed about their department's or organisation's seed sourcing policies and/or practice. This information gathering exercise in itself was a major undertaking because contact details for the relevant people is rarely publicly available. Other contacts were recommended via the interviewees or through other Project Phoenix relationships, and/or existing contacts known to the authors.

This review did not find any enforced policies or legislation regarding the movement of native seed for ecological restoration purposes.

Guidance is often provided, with flexibility, resulting in different seed sourcing strategies practiced among departments and among its agencies/authorities, and within offices of those entities. For example, one office of a state national park may adopt the practice of sourcing all seed locally, whilst another office may source a proportion of seed non-locally. Several interviewees described this flexibility as a 'bottom up' approach, rather than 'top down'.

The bottom up approach and the autonomy of the many decision makers has meant that the number of potential interviewees is too large to adequately cover those below the 'top down' level during the time frame of this report. The interview process started at the level of departments within the governments (i.e. one or more department per state and territory) and progressed through a number of agencies and their offices. More time was spent interviewing and reviewing seed sourcing approaches within government than in the NGO sector. This decision was made due to time constraints, and the fact that governments are the biggest seed purchasers in Australia (Hancock *et al.* 2020) where the level of seed movement prescriptiveness should be detected.

3.1.1 National/Federal government

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the fundamental environmental legislation of the Australian Government. Among other aims, the legislation provides a legal framework to protect biodiversity and to protect and manage nationally important flora, fauna and ecological communities of national environmental significance. The Act does not direct or prescribe native seed sourcing, although some species-specific recovery plans may.

There is an overarching framework that is relevant to 'nature': *Australia's Strategy for Nature 2019–2030*. This Strategy covers all national, state and territories' strategies, legislation, policies and actions that target nature. Guidance or policy on seed sourcing is not provided in this Strategy.

At the national level, the 2012 Council of Australian Governments (COAG) Standing Council on Environment and Water's *Australia's Native Vegetation Framework,* does provide guidance on seed sourcing (Appendix 1).

Australian Governments cooperated in the development of the Framework and its use is also encouraged for 'natural resource managers regionally, catchment-wide, non-government organisations, and individual land users and managers'. Appropriate seed sourcing is defined as one that 'maximises the genetic diversity, evolutionary potential and the adaptedness of revegetation'.

The Department of Agriculture, Water and the Environment (DAWE), who represent the national environmental interests, do not have an overarching policy or guidelines on native seed movement (Appendix 1). The Department oversees many programs and funding opportunities, including bush fire recovery funding that involves revegetation using native seed. One of the largest more recent programs is the *20 Million Trees* program (2014–2020), administered by Landcare Australia. Generally, guidance is for local provenance to be used, but advice is context dependant and flexible (Appendix 1).

The National Landcare Network, to which the state and territory Landcare Associations belong, does not provide specific seed sourcing guidance to their members. Individual groups make their own decisions, but it is noted that using local provenance is often the default. There are several publications available online that reflect the different levels of expertise among the groups. An example is the six Landcare groups in New South Wales that engaged Greening Australia to write revegetation guidelines for their districts. The advice given on seed provenances is general and states that plant material and high genetic quality seed should be sourced from 'large' populations. If seed is sourced non-locally, it should match the planting site's environmental conditions (Appendix 1).

The Department of Defence undertakes large revegetation projects from time to time. Local environmental approvals often require local provenance seed, but the final decision is made by the Department's local environmental staff and is context dependant (Appendix 1).

3.1.2 State and territory governments and their agencies

3.1.2.1 Prescribed seed movement/seed sourcing

Each state and territory government in Australia makes their own decision about seed sourcing, independent of each other (Appendix 2). Within each state government and territory, often there is more than one Department that has an involvement with revegetation practice. Involvement may be via grants and funding programs, rehabilitation of mine sites, national parks management, and/or the protection of threatened plants or flora in general, to name a few. There is no consistency across states or territories as to where governance of the different forms of revegetation sits. As an example, a large user of native seed is the mining industries' rehabilitation of mine sites. In the Northern Territory, mining sits in the [Department of Industry, Tourism and Trade](), separate to the [Department of Environment, Parks and Water Security,]() the protectors of the environment and natural resources in the territory. In contrast, in NSW, mining and environmental guardianship sits within the one department, the [Department of Planning, Industry and Environment]().

There are no overarching policies or legislative requirements that prescribe native seed movement (seed sourcing) at the state department levels. At the department level, the strictest form of prescription is (or will be) found in Victoria. The Department of Environment, Land, Water and Planning (DELWP) in Victoria has developed new Delivery Standards for revegetation, currently in draft form. Once finalised, where DELWP invests money into projects in public land, the Standards will be prescriptive and their use encouraged where funding is provided on private land. In Western Australia, some guidance is provided, generally and also for specific species. In South Australia, although not stated, the default position is to use seed sourced locally. No guidance is provided by the other states.

Within a Department, there are many agencies that have different recommendations on and approaches to seed sourcing, and different levels of prescription. Within agencies, seed sourcing recommendations can differ between offices (the bottom up approach). Whilst there are guidelines, standards, and information on best practice at the agency level, these are not enforceable.

Several documents contained the word 'policy' in their titles but in the body of the document, policy is described as guidance. For example, of the states' and territories' translocation of threatened species documents that were viewed, if the 'policy' prescribes where seed should be sourced from, non-adherence to the policy is allowed on a case-by-case basis, if it can be justified. The flexibility in seed sourcing guidance counters some of the issues experienced when sourcing seed i.e. a lack of local seed, or where maximisation of genetic diversity is the goal.

3.1.2.2 The use of local provenance

The strength of encouragement by the departments to use locally collected seed (local provenance) are greatest in Tasmania, South Australia and the Northern Territory where the use of local seed is an expectation, rather than a rule. In contrast, in Victoria, the current information sheet and new Standards recommend a 'combination' provenance approach that incorporates a 'climate-adjusted strategy' into the current strategy of using local provenance. The definition of 'local provenance' is often not given but examples range from 'as close as possible to the revegetation site' to 'the catchment'. While some agencies expect the sole use of local provenance seed, others are using a 'climate-ready' approach and incorporating local seed with seed from locations currently experiencing the climate projected for their region.

Where the sole use of local provenance seed is encouraged, the expected benefits include the avoidance of maladaptation and genetic contamination. Where a combination approach is taken (the inclusion of non-local and local seed), the expected benefits also include the avoidance of maladaptation (due to climate change) and maximising genetic diversity.

3.1.2.3 Seed transfer zones in Australia

Some STZs have been developed in Australia (Appendix 2). In Western Australia, species-specific empirically-based STZs are available for over 100 plant species. It is beyond the scope of this report to list and discuss them all but some are further discussed in section 3.5. These STZs are not mandatory but it is believed that the specificity of the guidance is particularly helpful to some in the mining industry who voluntarily use the STZs, where available.

In New South Wales, the Royal Botanic Gardens (RBG) is developing the Restore and Renew web-based tool for a limited number of species and their NSW distribution. The zones are based on genetic and climate data (Appendix 2).

In South Australia, general STZs are available for 17 grass species, using a botanical regional approach. Technical notes provide a list of 13 botanical regions where the species occurs in that state. Some trials were undertaken to inform the recommendations. Local provenance use is preferred but where circumstances arise where this is not possible, a regional seed sourcing strategy is recommended (Appendix 2).

General eucalypt STZs based on elevation, matched with coldness and dryness have been developed by Sustainable Timber Tasmania (formerly Forestry Tasmania) for that state. There is some consistency among the states' forestry departments (Tasmania, Victoria and Western Australia) on where seed should be sourced from to revegetate harvested areas. Seed should be sourced from the immediate surrounds of the revegetation site, graduating away from the zone but restricted to within the forestry area. Where this is not possible, strict conditions apply for the geographical area from which to source seed (Appendix 2).

3.1.3 Non-government organisations' policy and practice on seed sourcing movements

To represent non-government organisations (NGOs), the sectors chosen to represent the sampling frame were grouped into:

- knowledge providers
- the mining industry and
- large-scale ecological restoration service providers (including Natural Resource Managers (NRM)) and other NGOs.

3.1.3.1 Knowledge providers

The term 'knowledge providers' is used here to describe organisations that collate, integrate and disseminate information. In the context of this project, the knowledge providers are those who have disseminated information from researchers or academics (and sometimes practitioners) and provided this knowledge in a form that is accessible to and in an appropriate language for a wide audience.

There are many guidelines at the national level to inform seed sourcing approaches (Appendix 3). The relevant sections of the publications were reviewed to assess the consistency of seed sourcing advice. The publications reviewed were:

- Australian Association of Bush Regenerators (ABBR): several online publications
- Australian Network for Plant Conservation (ANPC): Guidelines for the Translocation of Threatened Plants in Australia
- *FloraBank Guidelines*, second edition (new version due 2021)
- Revegetation Industry Association of Western Australia (RIAWA): online publications
- Society for Ecological Restoration Australasia (SERA): National standards for the practice of ecological restoration in Australia. Edition 2.1.

All of these documents are guidelines or offer suggestions on seed sourcing. AABR, however, is not involved in on-ground work, nor is there is one person who can speak for AABR's approaches. Each operator will have different viewpoints and practices. RIAWA, also a provider of information, does not offer guidelines on seed sourcing but their revegetation standards suggest that the provenance requested by a client must be adhered to.

Where more specific advice is given, all documents point out the importance of considering genetic diversity and in all but one publication, also highlight the effects of climate change on revegetation practice. Generally, the advice is to include a broad range of genetic material to increase adaptive potential. The SERA standards, while acknowledging that using local seed maintains local adaptations, it notes that 'the paradigm of collecting very close to the restoration site is no longer considered useful'.

The *FloraBank Guidelines*, originally published in 1999, was nominated by interviewees as the most commonly referred to source of guidance for native seed collection and use. These *Guidelines* are generally accepted as a leader in providing best practice protocols in the native seed sector (Hancock *et al.* 2020). Since the original publication, 20 years of practical experience and research has led to new information about seed sourcing. The second edition, currently in production, will comprise of 15 modules, one of which is on seed sourcing. This module describes the various seed sourcing strategies,

3.1.3.2 The mining industry

Mining companies are legally required to rehabilitate mine sites at the completion of the mining project (DIIS 2016). Each state and territory has their own requirements and processes for assessing mine rehabilitation. In order to cover as many jurisdictions as possible in this report, the companies included in the sampling frame were selected from the five top metals and mining companies by market capitalisation as listed on the Australian Stock Exchange. None of these companies have mining operations in Victoria and the response rate was poor. Therefore, gaps were filled with relevant information found on websites, and by interviewing and inviting other operators known to be active within the native seed sector (Appendix 4).

The mining industry is a large user of native seed in Australia (Merritt & Dixon 2011; Mattiske 2016). While there are legislative requirements to rehabilitate mine sites upon completion of the operation, plant selection, and by default, seed sourcing selection depend on the rehabilitation objective. Objectives can be to restore original native ecosystems (ecological restoration), return to original ecosystems as much as possible (rehabilitation), or to some other 'prescribed' land use (Lamb *et al.* 2015; DIIS 2016). Therefore, the decision of where to source seed is on a case-by-case situation with the environmental condition at the site and input from the local community influencing seed sourcing selection.

From the limited interviews conducted, it appears that using seed collected locally is the default seed sourcing strategy. Each mine has its own rehabilitation plan and definition of local. Local is defined as 'as close as possible to the mine site' to 'within the bioregion' by interviewees.

While not interviewed, these findings are reinforced by Fortescue Mining's use of local provenance seed at the Solomon Project mine and the intention to use local provenance seed at the Christmas Creek mine. Fortescue has defined the seed sourcing range as 'within a suitable maximum distance of the proposal area as agreed by the CEO of the EPA and on advice from the Department of Environment', for the Solomon mine, and as a 'broad vegetation formation or community representative of the area that has been rehabilitated' for the Christmas Creek mine. Seed collection and management is informed by guidelines, such as the *FloraBank Guidelines*, and other research and development activities for the Christmas Creek Mine.

Interviewees noted that a lack of local seed hinders the attainment of using locally collected seed. This finding is corroborated by Lamb *et al.* (2015) who also reported that it is often cheaper and easier to buy whatever is available from local suppliers, which may not achieve rehabilitation goals if local seed is not appropriate.

The small number of interviewees makes it difficult to determine the level of prescription in the mining industry. However, it appears that when the rehabilitation plans are developed, with input from stakeholders, including the regulators and the local community, the agreed seed sourcing strategy must be adhered to.

3.1.3.3 Large-scale ecological restoration service providers and other NGOs

Examples of where seed sourcing decisions are made within an organisation are the 56 regional Natural Resource Management (NRM) organisations in Australia (Appendix 4). The NRMs have different models in each state and are a mix of government agencies and NGOs. In some states, regional NRM bodies are statutory. In other states, such as Queensland, they are completely independent with their own governance structures, constitutions and legal status. For the purposes of this report, NRMs are grouped into the NGO category as large-scale ecological restoration service providers. Some regions are not directly engaged in revegetation works and outsource to third parties that may include Landcare groups or commercial contractors (pers. comm. Samantha Morris, Rangeland NRM Alliance, 2/12/2020). The NRMs also deliver projects under the Regional Land Partnerships.

Several NRMs and other large ecological restoration service providers from different states were invited to be interviewed. Unfortunately, time constraints did not allow for a follow up on invitations and therefore, the sampling effort is inadequate to confidently summarise this group. From the responses received and from a sample of relevant documents found on websites, the information suggests that each NRM office and ecological restoration business makes their own decisions around seed sourcing (Appendix 4). As with the government sector, there is a mix of the sole use of locally collected seed and those who are sourcing more widely, predominately because of climate change.

N.B. To easily identify the research underlying the interviewees' decisions on seed sourcing (Appendices 1–4), these references are listed separately to this report, in Appendix 5.

3.1.4 General discussion and observations

This review found that there are no overarching policies at the departmental levels of governments in Australia prescribing where seed should be sourced. Any form of prescriptiveness is mostly applied at the operational level and usually with a certain amount of flexibility. The advantage of the flexibility is that if the location(s) of the prescribed seed is unavailable, other suitable seed can be sourced.

Anecdotally, the interview process revealed that at times, projects have been delayed due to a lack of the prescribed seed. This finding is reinforced by survey results that found that when local provenance plants are not available, the diversity of plant species is reduced, other seed sources are found, the project is deferred, or a combination of those actions (Hancock & Hughes 2012), with mostly detrimental effects for biodiverse restoration outcomes.

However, the downside to the flexibility is that its success relies on the officer (the decision maker) having the ecological and biological knowledge of determining suitable seed source locations. With little specific information to guide those decisions, successful planting outcomes can be compromised, as experienced by the US Forestry Service many decades ago (Johnson *et al.* 2004).

In addition, the various stances on provenance taken by the different entities (public and private) makes it complex for seed collectors and growers to navigate the systems.

During the course of the interview process and the web-based searches, some general observations were made by interviewees and are recorded below.

3.1.4.1 Paradigm shifts

Over the last few decades, there have been subtle paradigm shifts of where seed should be sourced. Traditionally, seed for a planting site was sourced from within the site, no matter the size of the site. This may be one reason why the term 'local provenance' is difficult to define and spatial descriptions given by interviewees ranged from as 'as close as possible to the planting site' to the 'region'.

Over time, a general trend has emerged where seed from large, healthy populations from outside of the traditional 'local' proximity is incorporated with local provenance seed to increase genetic diversity (Broadhurst *et al.* 2008). Many interviewees have further refined their practice to include seed from locations that are currently experiencing the climate projected for their site, as a climate change risk aversion approach.

3.1.4.2 The price of native seed

Price is often a big factor in determining where seed comes from. This issue means that at times, inappropriate (cheap) seed will be used, contributing to planting failure. However, some interviewees said that they are prepared to pay a premium to obtain the seed sources that they require. This practice also occurs in the US (Tangren & Toth 2020).

To make seed more affordable, entrenched problems within the native seed sector, such as addressing dormancy and germination issues, and increasing the supply of native seed, need to be addressed.

Programs such as the Seeds of Success program in the US to increase the supply of seed (collect, warehouse and produce native seed) may seem ambitious in Australia but possible if enacted at the federal level.

3.1.4.3 Online publications

A number of old publications (i.e. > 10 years), and relevant websites were found to be out of date and in some cases the owner was unaware that the information still existed. Publications should be reviewed and updated every five years or so to avoid mixed messaging.

3.1.4.4 Traditional landowners

Traditional landowners are increasingly supplying seed for projects such as mining rehabilitation. Traditional owners must be included in discussions surrounding the native seed sector, i.e. seed supply, production and the development of STZs.

3.2 Prescribed native seed movement in the US

3.2.1 Characteristics of the US native seed market

The native seed industries in Australia and the US differ in many ways. Differences are often due to the much larger size and capacity of the US markets. In the US, there are well developed seed production/seed farming entities that can grow crops of hundreds of species of grasses and forbs (Gibson-Roy 2018). In comparison, in Australia, the majority of seed production areas tend to grow fewer than 50 species (Hancock *et al.* 2020).

The types of plants used in the revegetation of natural areas in the US also differs to Australia. As a result of a severe drought, the 'Dust Bowl Era' of the 1930, the Natural Resources Conservation Service (NRCS) was established to develop plant materials for natural resource conservation through nationwide centres (NASEM 2020). In addition to a focus on introduced and native plants, desirable traits of native plants were selected and developed into cultivars. The Agricultural Research Service (ARS) has also been instrumental in the research and development of grasses and legumes, native and introduced (NASEM 2020). The result today is that native plants are available as cultivars or from wild-sourced plants.

To differentiate between products, the terms 'genetically appropriate seed' and 'source-identified seed' are commonly used. 'Genetically-appropriate seed' (or plant materials), should not be genetically modified and the term is used to indicate that these seeds are appropriate for use in a particular seed zone. 'Source-identified seed', or 'yellow tag seed', originates from wild seed, (i.e. these are not cultivars or come from genetically modified plants).

Many guidelines and seed sourcing standards encourage the use of genetically appropriate seed and detailed identification of the seed source (PCA 2015).

The terms 'cultivar', 'native', 'local', 'locality-specific' and 'local ecotype' are also often used in the US to refer to native plant material. Several surveys have found that there is some confusion within the industry as to exactly what these terms mean and they are often used interchangeably (Tangren & Toth 2020). The term 'native plant' can also cause some confusion among users (Tangren & Toth 2020) which may be due to the uncertainty of the plant's origins, or perhaps the use of cultivars with similar names to the parent or founding plant. A recent survey confirms the perception that land managers are changing from a reliance on cultivars of native species toward the use of local ecotypes (Tangren & Toth 2020). In this report, we limit the information provided to native plant materials (seeds) that have been derived from stands of wild populations, that have not been modified.

3.2.2 The sampling frame: US land managers

Land managers is the US comprise the federal and state governments, tribal, county/provinces, non-government organisations and private landowners. Where to concentrate the sampling effort for this project was informed by the National Seed Strategy for Rehabilitation and

Restoration (NSS) (PCA 2015). The NSS was initiated by 12 federal agency members and over 300 non-federal partners of the Plant Conservation Alliance (PCA) (PCA 2015). Almost 30% of US land is managed by the Federal Government (PCA, 2015), who is also the largest user of native seed (NASEM 2020). The five largest federal land managers are the Bureau of Land Management (BLM), the US Forest Service (USFS), the US Fish & Wildlife Service (USFWS), the National Park Service (NPS) and the Department of Defence (NASEM 2020). All of these Agencies, apart from the Department of Defence, are on the PCA committee list, and the 12 Agencies listed as contributors formed the sampling frame for this project (Appendix 6).

The question of how other tiers of government and non-government should be sampled was answered by the NASEM (2020) report that recommended that collecting qualitative data would best be achieved by methods such as individual interviews or focus groups.

Given the large number of users of native seed in the US (760 people responded to a recent survey in a relatively small proportion of the country) (Tangren & Toth 2020), a representative sampling group beyond the 12 federal agencies was not achievable in the short time frame of this project. In addition, NASEM (2020) advises that for the large agencies, decisions regarding native seed buying are probably made at multiple levels. Indeed, this proved to be the case and therefore, this report only contains information derived from the 12 federal agencies listed as contributors to the NSS (PCA 2015). A summary of the 12 federal agencies in regard to their conservation activities and their role in the NSS is listed in Appendix 6.

The NSS listed the personnel within each agency that had contributed to the strategy. At least one representative from each agency was invited to participate in an interview with the authors. Several representatives have since left their organisation and/or did not respond. The information contained in this report therefore comprises direct communications and reviews of the grey literature (web-based).

3.2.3 Seed transfer zones

STZs have been used in the US since the 1920s when it was perceived that trees from different geographic origins differed in traits for growth and hardiness. Extensive provenance testing ensued and since the 1960s, forestries, particularly in the US Pacific Northwest (Oregon and Washington) have used seed zones for replanting, resulting in fewer failed plantings (Johnson *et al.* 2004). The original seed zones have been replaced with updated information.

Over time, the results from common garden experiments and genetic field trials have allowed zones to be broadened and it was recognised that different seed zones are needed for different species (Johnson *et al.* 2004). For example, seed zones are relatively small and many are for Douglas-fir (*Pseudotsuga menziesii*), but larger and fewer are for Western red cedar (*Thuja plicata*) (Erickson & Halford 2020). The differences in the spatial scale of STZs compared to their specialist or generalist characteristics of some forestry species are provided by Erickson & Halford (2020) and Johnson *et al.* (2010). These studies show large differences in the size of STZs for different evolutionary modes and confirms the importance of species-specific STZs.

Over time, federal agencies other than the US Forest Service (USFS) have developed STZs to guide revegetation. There is now a limited but growing number of species-specific empirical seed zones, mostly for grasses and forbs (see Appendix 7 for recent examples. N.B. the examples in Appendix 7 do not include the large number of STZs used for tree species by the USFS).

The use of species-specific seed transfer guidelines is widely encouraged (Johnson *et al.* 2004; PCA 2015), and sought after (NASEM 2020), due to species' differences in patterns of adaptive genetic variation and in the spatial scale of adaptation across environmental conditions (Kilkenny 2015). One of the objectives of the NSS is to develop seed zones, using genetic research, for key restoration species (PCA 2015). Apart from the STZs for forestry tree species, currently, species specific empirical seed zones and general information on seed is focused in western US, particularly the Great Basin and the Colorado Plateau (Appendix 7) (NASEM 2020; Tangren & Toth 2020).

The requirement for native seed in the US is split into three broad but very different regions: western — where 40% of all land is managed by the federal government; eastern — where users are much smaller entities; and the Midwest (NASEM 2020).

3.2.3.1 Provisional or generalised seed zones

When empirical STZs are not available, provisional or generalised seed zones are often used. These seed zones are typically based on the assumption that climate variation serves as a proxy for evolution and local adaptation (Shryock *et al.* 2018). Provisional seed zones are improved if other environmental factors such as soil characteristics of the planting site and seed collection sites are included. These more complex zones are not generally available (but see (Gibson *et al.* 2019)). Provisional seed zones are a compromise, but they are relatively easy to use and can be applied to all plant species over all geographic areas.

Examples of provisional STZs as provided by Johnson *et al.* (2010) include:

- **USDA Cold hardiness Zones** (Cathey 1990). Used for species and populations where minimum temperature is the main influence of fitness to protect plants from cold damage;
- **Ecoregion Maps** (Omernik 1987; McMahon *et al.* 2001). Broad zones that identify sites with common floristic and soil attributes. Can be at a broad scale (Level III) or narrower (Level IV);
- **Plant Adaptation Regions** (Vogel *et al.* 2005). Composite STZs where ecoregions have been merged with USDA Cold Hardiness zones; and
- **Biogeoclimatic Regions** (Hargrove & Hoffman 2004). Multivariate clustering is used to develop ecoregions based on fine spatial resolution maps of elevation, temperature, precipitation, soil characteristics and solar inputs.

The most widely used provisional seed zones are those developed by Bower *et al.* (2014). These zones are easily accessible and the work is highly cited. The zones are based on high-resolution climatic data (winter minimum temperature and aridity) and reflect the USDA plant hardiness zone map (Bower *et al.* 2014). The result is the delineation of 64 provisional seed zones that represent areas of relative climatic similarity for any plant species in the continental US. To identify areas that are climatically similar but ecologically different, Omernik's level III ecoregions (Omernik 1987) can be superimposed over the seed zones (Bower *et al.* 2014). However, this action may result in too many zones to be practicable so using the ecoregions inside the provisional seed zones is recommended (Bower *et al.* 2014).

More recently developed examples of provisional STZs are:

- Species-specific zones within an ecoregion (Miller *et al.* 2011). Common garden trials investigated whether populations differed in morphological and phenological traits due to geography, climate or habitat with the Willamette Valley ecoregion (Appendix 7). The trial found that the ecoregion can serve as STZs for four of the five species investigated; and
- The Colorado Plateau Native Plant Program provides 20 provisional STZs, and climate-based, species specific STZs for 11 priority species (ArcGIS credentials required to log into the latter STZs).

3.2.3.2 Climate informed STZs

For the majority of empirical and provisional STZs, future climate change has not been incorporated. Climate modelling will be important to include in STZs where habitats of existing species and populations are projected to decline. Examples of STZs that have incorporated climate change projections include:

- Kilkenny (2015) expanded upon seed zones produced by Bradley St. Clair *et al*. (2013) to model projections of suitable habitat for *Pseudoroegneria spicata* (Bluebunch Wheatgrass) to enable better targeting of plant material use;
- Eastern states STZs (Pike *et al.* 2020). These zones were generated by combining plant hardiness and Bailey's ecoregion (not Omernik) layers, resulting in 245 seed-collection zones for 37 states. These zones allow seed suppliers to bulk collections within seed collection zones, enabling the user to mitigate the effects of climate change by combining non-local and local seed with a reduced risk of maladaptation (Pike *et al.* 2020). Genetic considerations are not factored into the zones; and
- Shryock *et al.* (2018), using 12 climate variables, developed provision seed zones for four desert regions (with continuous borders) in the south west US: the Mojave, Sonoran, Colorado Plateau, and the Southern Great Basin. The model produced 41 zones. In recognition that site-specific guidance is preferable to general zones, a web-based interactive decision support tool, the Climate Distance Mapper was also developed to match seed sources with planting sites (Shryock *et al.* 2018).

Other web-based tools, as described in section 3.2.4.2, include:

- The Seedlot Selection Tool (SST)
- The Climate-Smart Restoration Tool
- The SeedZone Mapper.

3.2.4 Level of seed movement prescriptiveness

The agencies of the Departments of the Interior (DOI) and Agriculture (UADA) have policies on the use of native plants in ecological restoration, but these do not necessarily prescribe native seed movement (Appendix 8). Among and within the agencies, the policies on the use of native seed and the prescriptiveness of native seed movement differ depending on their missions, and their management objectives for particular rehabilitation or restoration projects (BLM 2008).

At the national level, over time, there have been many initiatives to improve ecological restoration outcomes. These initiatives are not reviewed in this report, but the most relevant documents are briefly summarised. In response to an increase in the demand for native seed after wildfires in 1999 and 2000, the US Congress directed the BLM and the USFS to respond by establishing two new programs: the Native Plant Materials Development Program and the Native Plant Restoration Program (BLM 2008). These programs have enabled the development of STZs to guide the selection of genetically appropriate seed, thereby increasing the likelihood of revegetation success.

The most recent initiative is the National Seed Strategy (NSS) (PCA 2015) and its progress report (PCA 2018). This Strategy was developed in response to the destruction caused by Hurricane Sandy in the east, and wildfires in sagebrush habits in the west, to improve the availability and use of native seed with 'the right seed at the right place at the right time'.

Its mission is to ensure the availability of genetically appropriate seed to restore viable and productive plant communities and sustainable ecosystems (PCA 2015).

For any STZs to work, there needs to be a supply of readily available, appropriate native seed. Demand for seed for a diverse range of native seed and appropriate genetic provenance outstrips supply in the US (Oldfield 2019).

3.2.4.1 Bureau of Land Management

The largest federal agency land manager is the Bureau of Land Management (BLM), managing approximately 99 million hectares of land (NASEM 2020). To counter the supply demand imbalance, the BLM administers two programs designed to increase the supply of genetically appropriate native seed: the *Seeds of Success* program, and the *Native Grass and Forb Seed Increase Indefinite Delivery Indefinite Quantity (IDIQ) Contract*. The *Seeds of Success* program is part of the national *Native Plant Materials Development* Program (BLM 2008).

Seed is collected under this program and warehoused and can be used to support the development of geographically appropriate native plant materials for restoration, emergency fire rehabilitation, support conservation in general, and for research. (BLM 2008). All seed collections are of high quality, accurately identified, well documented, and comprise a significant representative of the genetic variation within the sampled population (BLM 2008). A proportion of the warehoused seed is contracted to private growers to on-grow the seed, making more seed available for projects in the appropriate seed transfer zone.

The BLM does not have an enforceable policy on native seed movement. The Integrated Vegetation Management Handbook 1740 (BLM 2008) is used as a guide to assist decision makers at the local level (Appendix 8).

3.2.4.2 The US Forest Service (USFS)

The second largest federal agency land manager is the US Forest Service (USFS), managing approximately 78 million hectares of land (NASEM 2020). The USFS has a policy on native seed movement which states: 'Base determination and selection of genetically appropriate plant materials on the site characteristics and ecological setting, using the best available information and plant materials' (USFS 2008) (Appendix 8). There is flexibility in this policy such as in the case of emergency requirements of large and unavailable quantities of native seed. As support for the policy, a framework — the *Native Plants Materials Policy. A Strategic Framework* — was developed in 2012. This Framework provides guidance and states: 'Ensure genetically appropriate native plant materials are given primary consideration'.

Adherence to the policy differs depending on the sector and district of forest management (i.e., the National Forest System, Range Management, Forests and Grasslands, and District Rangers). For example, in the Pacific Northwest, the USFS has explicit and specific guidance (STZs) for many of the most economically important timber trees and a number of commonly used restoration-relevant species. In California, close observance of tree seed zones that were adopted in the USDA forest seed policy of 1939 has historically been recommended (US Forest Service 1948).

The first rule of using seed is 'whenever possible, use seed from the zone in which planting or seeding is to be done'. The policy also states that trees should not be planted outside of their 500-foot elevational differences. However, the appropriateness of these rules is being challenged due to climate change. Experiments are underway to detect the suitability of using seed sources from hotter drier locations and/or sourcing seeds from lower elevations.

Not all within the USFS or the wider USDA agencies agree with non-adherence to the 1939 seed sourcing policy. For the majority of restoration activities, decisions are made from local district offices (Appendix 8). Generally, where specific seed transfer zones (empirical or research based) are not available, the Bower *et al.* (2014) provisional STZs are used. Recently, provisional STZs were developed for the eastern states of the USA (Pike *et al.* 2020).

The USFS partners with other organisations to develop web-based tools to add to the mix of seed selection information sources. The Climate-smart Restoration Tool, still under development, allows the user to match current seed sources with future climate conditions. The Seedlot Selection Tool allows users to map current or future climates based on different climate scenarios. The tool can be used to identify seed source locations that are appropriate for planting on a particular site or conversely, which planting sites are appropriate for a particular seed source.

3.2.4.3 Summary

While some of the agency documents cited for this report contain the word 'policy', its application is in the form of guidance rather than a directive. Generally, each federal agency has its own 'policy' and there is flexibility at most levels within a department, agency and their offices. This finding concurs with that found in recent survey in eastern states (Tangren & Toth 2020). A review of each agency's policy or guidelines, the level of its prescription, its basis, the underlying research and the benefits and issues are shown in Appendix 8.

> Similar to Australia, decision making in the US comes from the various offices of the agencies (a bottom up approach, rather than top down), often with guidance from the respective agency.

It was not within the scope of this report to delve any further into seed movement prescription at multiple levels. However, if a more detailed review of native seed users is warranted, it may be wise to wait until this information is more readily available (NASEM 2020). No doubt there are many documents to uncover, at multiple jurisdictional levels, i.e. the Nevada Seed Strategy and the Forest Preserves of Cook County Seed Source Policy and Guidelines.

3.3 Prescribed native seed movement in Europe

The information for this section was obtained by searching the internet and peer-reviewed journals (often provided in different languages e.g. French and Spanish) and by interviewing the different government agencies of European countries, practitioners and researchers. However, not all who were contacted replied or accepted our invitation to be interviewed. Most of the delays or declined invitations were related to the COVID-19 pandemic. For example, several contacts were on leave or their offices were temporarily closed.

Free movement and commercialisation of seeds within the European Union (EU) is permitted, however legislation and guidelines for seed sourcing vary between countries. This includes different bilateral agreements among countries for seed movement. For example, Finland buys seeds from Sweden that are grown in Estonia and then seedlings are sent to Finland. There also several differences in terms of seed sourcing guidelines for woody species (particularly forest species with commercial value) including shrubs, herbs, and grass species. There is considerably more information (legislation, multinational organisations and guidelines) for forest reproduction material (FRM) than for herbs and grasses. Therefore, much of the information presented here is mainly focused on woody species.

3.3.1 Seed transfer zones and provenance guidelines

Since the foundation of the EU, there has been multiple efforts for the conservation of genetic resources including multilateral agreements and guidelines for the use of FRM and seed provenance in general. For example, the General Declaration of the Lisbon Conference (1998) preferred the use of native species and local provenances for reforestation and afforestation. Subsequent agreements (e.g. Vienna General Declaration in 2003) aimed to maintain and promote the conservation of forest genetic resources. Most national laws regulate only production and commercialisation of FRM, but not its use.

In other EU countries, forest administrations make recommendations for the use of provenances in different regions. They mostly rely on the concept of provenance regions (or seed transfer zones), which are areas within which reproductive material can be transferred with little risk of being poorly adapted to their new location. For example, the UK Forest Commission established provenance regions early in 1977 based on climatic and geological data which were subsequently divided into seed zones later on to provide seed sourcing recommendations (Appendix 9). These zones are generally based on the results from provenance trials and the long-term experiences of practical forestry.

In many European countries, the provenance recommendations are given for either all or only a subset of species. The form of publication of the recommendations varies among countries. Some are paper documentation and others have internet-based interactive decision tools linking the planting site in an ecological zone with recommended seed provenance or FRM available in a nursery.

In Germany, forest administrations of the different states provide forest owners with recommendations for seed provenances, generally recommending local provenance (e.g. Bavaria). More recently, the Federal German Government has developed new guidelines and legislation for seed sourcing for herbaceous plants (Prasse *et al.* 2010; Bucharova *et al.* 2019). This includes generalised seed transfer zones for more than 50 species and seed zone-specific species lists across all states (Appendix 9). These STZs were developed based on climate, geology and vegetation data. The seed sourcing strategy is called ‘regional admixture provenancing’. The aim of this approach is to ensure a mix and match approach, i.e. seeds are sourced from multiple populations within the same region as the target locality and mixed prior to use, ensuring consistency of this method across the country. This system is possible due to an established private market of seeds in the country. This approach does not consider, however, any flexibility around seed sourcing or the potential effects of climate change.

In France, recommendations for the use of French FRM are published on the government agency website. Species-specific STZs and seed sourcing recommendations exist for several tree species. The recommendations are based on common garden experiments, provenance trials, and genetic and phenotypic studies for more than 50 species of tree and shrub species. Currently, a revision of these recommendations is underway to consider the effects of climate change.

Interactive decision tools or internet-based tools are becoming more common to provide recommendations for seed sourcing in different European countries. These applications are able to link plant sites in ecological zones with recommended seeds available by seed suppliers. In Austria, an online platform was created by the Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) to support forest owners in seed provenance selection.

Similarly, in Denmark, the Danish Nature Agency of the Ministry of Environment, in cooperation with the University of Copenhagen, provides seed provenance recommendations through a web-based tool that guides users to select appropriate FRM suitable for the locality. The system contains a database where information about species and seed sources is available, and a recommendation function for selection of species and seed sources.

Norway has an internet-based recommendation system, which is hosted by the Norwegian Forest Seed Centre. Customers can choose their planting location and elevation and will get suggestions for suitable seed lots, with differentiation between optimal and usable (according to the internal Norwegian transfer rules). After choosing a certain seed lot, the customer is provided with information about which nursery is producing plants from that lot at that time. The suggestions for seed lots from stands are made according to current legislation, and no climate change effects are considered.

3.3.2 Seed provenance actions under climate change

To ensure potential for adaptability under climate change, high levels of genetic diversity need to be maintained (Frankham *et al.* 2014). Therefore, it is critical that reproductive material with high levels of genetic diversity is chosen to maintain local adaptability. This might be particularly true at the edges of species' ranges, where local conditions might already be extreme. Thus, the EU and different European countries have started revising their current seed provenance guidelines to consider the effects of climate change.

Projects funded by the EU such as SUSTREE have been developed as a response to improve current seed provenance practices across Europe in the face of climate change. SUSTREE is a particularly interesting project that addresses the problem of seed provenances and movement of seeds between countries.

Currently, regions of provenances (i.e. large seed transfer zones), seed use and transfer are regulated mainly on the national level within the frame of the Council directive 1999/105/EG. Thus, information about provenances and reproductive material is mainly available in national languages and databases are not accessible for international users.

As European tree species do not follow national borders but track large biogeographic patterns, this creates problems when selecting appropriate planting materials for reforestation using assisted migration and assisted gene flow. SUSTREE outcomes show that coordinated transnational management of forest seeds are vital to support the adaptation of forests under climate change. The development of computer/phone apps and database tools by this project also facilitate the choice of seed sourcing following recommendations based on vulnerability assessments. Vulnerability assessments are developed considering multiple factors such as climate modelling, tree species distributions and seed transfer models.

3.3.3 Alternative approaches for delineation of seed transfer zones under climate change

The most common approach for seed transfer regulation has been a geographical one, based on seed zones or regions of provenances, which should contain populations with identical or similar adaptive features. Seed zones were often delineated based on environmental (mainly climatic) homogeneity rather than genetic variation patterns.

Novel approaches for the delineation of seed zones or regulation of seed transfer consist of a 'floating principle' meaning that seedlings can be planted outside their seed transfer zones, provided 'the transfer is within the adaptive limits of the seed source' predicted by a statistical model (e.g. Wu & Ying (2004)). The model defines the degree and direction of local optimality along longitude and elevation.

New improvements of statistical models and software allow the conversion of physical to climate distance. Hutchinson (2004) and Wang *et al.* (2006) including climate variables in seed transfer rules. On this basis, the seed transfer rules in British Columbia (Canada) were revised and changed in light of climate change (British Columbia Ministry of Forests, Lands and Natural Resource Operations, various dates). Now, most species in most areas are allowed to move 100 to 200m upwards in elevation.

3.3.4 Summary

In summary, Europe has made extraordinary progress for the development of STZs, the conservation of forest genetic resources, and the development of interactive tools for seed provenance decisions that facilitate the interactions between governments, EU agencies, seed suppliers (e.g. the European Native Seed producers Association), NGOs and private owners.

It is important to highlight that European countries have managed to coordinate efforts to improve seed provenance recommendations in the light of climate change, overcoming problems of national jurisdictions and legislation.

Similar approaches will be necessary in Australia to unify efforts across states and provide the best seed movement recommendations.

3.4 Prescribed native seed movement in Latin America

Information about seed provenance practices and legislation in Latin America (including Mexico, Central and South America) is scarce and not easily accessible as few countries have information available online. However, information was collected from Mexico and Chile about current seed provenance practices through online searches.

Mexico has established seed provenance recommendations for forest species including tree species of commercial value. This practice is legislated and STZs were determined using physiographic and geological information.

In Chile, currently there are no seed provenance practices either legislated or recommended by the Chilean Government. Most forest restoration efforts are of small geographical scale (i.e. <1 ha), with few initiatives in large areas (i.e. >100 ha) (Smith-Ramírez *et al.* 2015) and are mostly monitored only for a short-term period. However, there is a new Forestry Policy (2015–2035) that aims to comply with international commitments (Paris Climate Agreement COP21, New York Declaration of Forests, Initiative 20×20), plus restoring 500,000 ha of degraded or fragmented ecosystems within priority areas (CONAF 2015; Bannister *et al.* 2018). Chile, however, seems to face several problems to achieve the aforementioned restoration goals as it does not have established seed transfer zones, there is no seed supply chain or standards for seed collection, and the availability of native seeds is poor (León-Lobos *et al.* 2020).

3.5 Developing seed transfer zones in Australia

More than 20 researchers from across Australia were contacted to collect information on research that they have contributed to, or is underway, that could assist with the development of STZs in Australia. However, only seven researchers were interviewed; most researchers did not reply to the email invitations.

The difficulty of getting researchers to participate in the interviews reflects the potential obstacles that may occur in the future to reach a consensus on the implementation of STZs.

There are multiple studies published in peer-reviewed journals by Australian researchers that could assist in the development of STZs in Australia (Table 1). These studies include research on conservation genetics, landscape genomics, seed production areas, biogeography and provenance trials. While a comprehensive literature review was not conducted, the studies recommended by the interviewees provide a valuable starting list of available resources in the event of the implementation of STZs in Australia.

This list of recommended research is also provided as a separate bibliography (Appendix 10) for ease of accessibility and expansion when and if STZs are developed in Australia. Also included in Appendix 10 is an extensive list of relevant research relating to species-specific and general STZs, accessed from the Western Australian Department of Biodiversity, Conservation and Attractions' library. This list was generated by searching the library catalogue for relevant publications for three Western Australian researchers: Byrne, M., Krauss, S. and Millar, M.

TABLE 1. INTERVIEWS WITH AUSTRALIAN RESEARCHERS TO IDENTIFY (1) STUDIES (INCLUDING THEIR OWN) THAT HAVE CONTRIBUTED TO OR ARE CURRENTLY UNDERWAY, AND (2) FURTHER ACTIONS OR INFORMATION NEEDED TO GENERATE CONSENSUS ON THE IMPLEMENTATION OF SEED TRANSFER ZONES (STZ)

NAME OF RESEARCH INSTITUTION	WHAT STUDIES DO YOU THINK HAVE CONTRIBUTED TO STZS?	HAS ANY OF YOUR RESEARCH CONTRIBUTED TO STZS?	WHICH STUDIES THAT ARE CURRENTLY UNDERWAY DO YOU THINK WILL CONTRIBUTE TO FUTURE STZS?	WHAT FURTHER ACTION OR INFORMATION DO YOU THINK IS NEEDED TO GENERATE CONSENSUS ON THE IMPLICATION OF STZS?
Australian Tree Seed Centre (ATSC), Australian Capital Territory	Studies in *Eucalyptus regnans* (Mountain ash) and *E. delegatensis* or *E. camaldulensis* (not STZ per se). Local collection of seeds within NSW by forest service or within certain forests. Not many genetic studies, only very old tests of provenance trials done by forest service.	Work in seed provenances of *Eucalyptus globulus* and other Eucalypt species from the ATSC	Recent study on landscape genomics of yellow box (*Eucalyptus melliodora*) by Supple *et al* (2018 eLife 7: e31835). ATSC's study in *E. blakelyi*. Another study on *E. viminalis* with Linda Broadhurst and Dave Bush. Study with Brad Potts about provenance with Tasmanian species. Species like Jarrah in WA (provenance studies). There are many provenance studies that could be useful for STZ development.	No impetus or need to establish STZs. The forestry service has not seen the need to do STZs, forestry is happening in Australia with genetically improved seeds. Mining industry is good at getting seeds. Not convinced that STZ are broadly necessary because where there has been revegetation they used 'local is best'. It has changed a bit in the last years, moving seeds from drier places. Mainly dogmatic decisions, not research underpinning decisions. It is more complicated for threatened species (i.e., Mountain and Alpine Ash, *E. delegatensis*).
CSIRO, Australian Capital Territory	Research studies by Sally Aitken in Canada (i.e., AdapTree), North American seed provenance studies, research work by Siegy Krauss and Maurizio Rossetto. Paper about Genetic diversity in Australian species (Broadhurst *et al.* 2017). Andrea Premoli population genetic and restoration work in South America. Nick Gellie and Martin Breed ecosystem restoration work (Breed *et al.* 2019).	Paper of Australian plant genetic diversity (Broadhurst, *et al.* 2017) looking at commonalities between Australian plant species. Conservation genetic papers. Landscape genomics paper on Yellow Box Supple *et al.* (2018). Seed Production Area paper on *Dodonaea viscosa and Acacia montana* (Broadhurst *et al.* 2017).	Maurizio Rossetto's restore and renew project, ground breaking because it will be species rich. Working species by species is complicated for STZ work. Peter Harrison's seed provenance work in Tasmania.	Policy, research and practitioners sitting together in the same room to reach an agreement about STZ. Particularly practitioners (NRM and NGOs). May be examples in WA (REARWA). Big challenges are that NRM and NGO needs to be paid for this work. An Envirofund allocated to do a project like this one could be helpful. Federal government would be keen to get an agreement, biosecurity can be a problem or barrier; it would make life easier if we have a national program. Climate change: mechanism to track seed transfer and success of restoration. Flexibility is important in legislation around STZ. We need a systematic protocol for genetic data acquisition (DarT not enough) across Australia. To determine the causes of and to prevent future extinctions for species with similar life-history undergoing similar threats, genetic information from extinct populations and species needs to be incorporated to develop STZ and improve restoration work.

NAME OF RESEARCH INSTITUTION	WHAT STUDIES DO YOU THINK HAVE CONTRIBUTED TO STZS?	HAS ANY OF YOUR RESEARCH CONTRIBUTED TO STZS?	WHICH STUDIES THAT ARE CURRENTLY UNDERWAY DO YOU THINK WILL CONTRIBUTE TO FUTURE STZS?	WHAT FURTHER ACTION OR INFORMATION DO YOU THINK IS NEEDED TO GENERATE CONSENSUS ON THE IMPLICATION OF STZS?
Curtin University, Western Australia	Development of Seed Production Areas (SPA) in Europe. Advanced SPAs are in operation in Germany in response to European legislation (De Vitis *et al.* 2017; Abbandonato *et al.* 2018; Mainz & Wieden 2019). Also studies and programs from USA such as 'seeds for restoration success' (Shaw *et al.* 2020).	Work related to seed collection and SPAs, including that as a founder member of the European Native Seed Producers Association (De Vitis *et al.* 2017; Abbandonato *et al.* 2018; Pedrini *et al.* 2020).	The work developed by Martin Breed and Linda Broadhurst.	Species-specific approach is not enough. It is important to get STZ early and then it can be improved or revised accordingly. The development of STZ needs to be safe and viable genetically and economically. A national shared STZ is required. Practitioners and government will benefit from having STZs due to the development of a seed supplier market, as well as facilitating the efficiency of restoration work. Native seed distribution hubs will benefit from the establishment of seed supply markets in Australia and provide large volume of seeds as required. However, to reach that goal, to establish STZ, seed collection and production areas must be developed first.
Flinders University, South Australia	Studies from four different topics: 1) Meta-analysis papers and theoretical papers in evolutionary biology (e.g. Charlesworth & Charlesworth 1987; Frankham *et al.* 2011); 2) Literature about the impact of global changes (e.g. CSIRO reports, meta-analyses about habitat fragmentation); 3) Opinion-based papers, (e.g. Boshier *et al.* 2015; Breed *et al.* 2019); 4) Empirical studies about local adaptation in plants, seed quality, and the importance of climate as a driver of local adaptation in plants (Aitken & Whitlock 2013; Bucharova *et al.* 2017; Supple *et al.* 2018).	Review article about genomic approaches for ecosystem restoration, used in a forecasting context (Breed *et al.* 2019).	Quantitative review on seed provenance trials underway (not peer-reviewed yet, led by Peter Harrison). There is also another study in preparation investigating the best predictors of seed germination.	1) Exemplar leadership and collaboration underpinned by scientific evidence, 2) Coordinated efforts to improve research/forecasting 3) far better integration of the three main stakeholders (researchers, practitioners and end users (e.g. policy people, GA, CSIRO).

NAME OF RESEARCH INSTITUTION	WHAT STUDIES DO YOU THINK HAVE CONTRIBUTED TO STZS?	HAS ANY OF YOUR RESEARCH CONTRIBUTED TO STZS?	WHICH STUDIES THAT ARE CURRENTLY UNDERWAY DO YOU THINK WILL CONTRIBUTE TO FUTURE STZS?	WHAT FURTHER ACTION OR INFORMATION DO YOU THINK IS NEEDED TO GENERATE CONSENSUS ON THE IMPLICATION OF STZS?
Kings Park and Botanical Garden, Western Australia	STZ based on geospatial mapping and climate, e.g. STZ work from US (Bower *et al.* 2014). Population genetics and provenance trials studies (e.g. O'Brien *et al.* 2007; Krauss *et al.* 2013), which are of critical importance to test hypotheses.	Population genetic studies on multiple plants from WA investigating how local is local (e.g. on Jarrah forest species) as well as studies on mining restoration (Krauss *et al.* 2013; Stingemore & Krauss 2013; Ritchie *et al.* 2019). Also provenance trials studies on several species (e.g. *Eucalyptus marginata, Corymbia calophylla*) (O'Brien *et al.* 2007; O'Brien & Krauss 2010).	ARC Linkage grant (GA71446-V1) project: 'Optimising seed sourcing for effective ecological restoration' with Martin Breed and Suzanne Prober which will develop new knowledge that links plant and environmental genomics, plant physiology, seed and soil biology in embedded experiments at post-mining rehabilitation sites. The project will produce industry guidelines that refine seed sourcing strategies for ecological restoration for current and future climates. Besides this project, long-term provenance trials for several WA species are being developed that will be useful for future STZ.	Researchers working with practitioners to engage with the practice. Engagement with government and other stakeholders. Use work on STZ from USA and Europe. There seems to be a benefit on having a national strategy. However, southwestern WA might need specific refinements. Hierarchies of geographic scale; i.e. applying different recommendations and STZ depending on the region, would be important for a STZ strategy. Important to consider climate change into development of STZ (Ramalho *et al.* 2017). Multiple companies form part of a seed supply market in WA due to mining restoration (e.g. RIAWA). Establishing long term provenance trials could slow down the progress of developing or refining STZ.
Royal Botanic Gardens, New South Wales	Studies in the USA & Europe — STZs well established in Forestry. Restore & Renew (R&R) (Rossetto *et al.* 2019)	Yes, 40 species completed through Restore & Renew (Rutherford *et al.* 2018, 2019; Fahey *et al.* 2019; Bragg *et al.* 2020; Rossetto *et al.* 2020).	Royal Botanic Gardens, NSW, working on publications now. Currently trying to define a 'meaningful', replicable representative area for a broader vegetation type/functional group/etc (NSW).	General STZs will not work on a large scale. The Australian landscape is too heterogeneous. Climate or biogeographic might work but will depend on many factors. However, there should be a place for empirically defined seed transfer zones. The important thing is not to rely on a 'one-type-fits-all' approach, but in identifying general trends and patterns that are meaningful and replicable, as well as defining different objectives for those zones. R&R provides the ideal dataset to develop, test, and apply the concept across multiple regions and groups of species. R&R's existing data could be used to establish some preliminary hypotheses and expectations for sets of species that don't have data by using simulations, and then test them out by collecting real data. Depending on the outcome, a sampling strategy can be identified across vegetation types that would provide the information necessary to develop more and more geographically and environmentally meaningful zones.

NAME OF RESEARCH INSTITUTION	WHAT STUDIES DO YOU THINK HAVE CONTRIBUTED TO STZS?	HAS ANY OF YOUR RESEARCH CONTRIBUTED TO STZS?	WHICH STUDIES THAT ARE CURRENTLY UNDERWAY DO YOU THINK WILL CONTRIBUTE TO FUTURE STZS?	WHAT FURTHER ACTION OR INFORMATION DO YOU THINK IS NEEDED TO GENERATE CONSENSUS ON THE IMPLICATION OF STZS?
University of Sunshine Coast, Queensland	Mainly conservation genetics and outbreeding depression studies. Conservative approach for species with narrow distributions, different from revegetating large areas. Broad biogeographic areas for revegetation can be considered as a better guide to inform seed movement than a geographic distance approach, particularly where there are no genetic studies. Allow movement of seeds according to environmental change.	Not specifically, many studies on conservation genetics for movement of genetic material, for offsetting, and the delineation of zones for specific species (e.g. *Philotheca*).	Margaret Byrne's group and Siegy Krauss are doing work in that direction. Linda Broadhurst's work on restoration ecology and conservation genetics.	We need consensus on whether or not we need to apply the concept of STZs. STZs are not necessarily backed up by science partly due to problems demonstrating outbreeding depression or not. We need to differentiate between threatened and non-endangered species for the development of STZ.

The wealth of information provided by the interviewees is particularly encouraging, showing numerous population genetics studies across Australia for multiple plant species. It seems clear that novel genomic tools based on high-throughput sequencing techniques, can facilitate or improve the availability of empirical data to support provenance-sourcing decisions. These techniques can also provide insights into adaptive processes (Supple *et al.* 2018; Rossetto *et al.* 2019; Carvalho *et al.* 2021).

Genomic approaches in conjunction with the latest methods used for species distribution modelling are excellent tools to guide the development of STZs in Australia (Breed *et al.* 2019).

A great example of this is the 'Restore and Renew' project of Rossetto *et al.* (2019), which provides a framework and webtool platform to collect, analyse, and interpret data (genetic, climate, and geographic) to assist provenance decisions considering current and future climate. This webtool has the potential to include other layers of information (e.g. seed suppliers, codes of practice and provenance trials) in future developments.

Another example of an important study that will be useful for development of STZs in Australia is by Harrison *et al.* (2017), who investigated the importance of climate on provenance for 83 woody plant species and tested the 'local-is-best' paradigm. They found that local provenance plants did not perform better in most cases than non-local provenance.

Similarly, international projects such as AdaptTree in Canada, existing STZs in the US, and seed-associated practice in Europe were mentioned as examples of research and practice that can provide crucial information to guide restoration policies and practices for uncertain future climates. Similar approaches could be adopted in Australia.

Overall, most researchers agree that STZ guidelines from USA, Canada and Europe as well as studies about provenance trials and population genomics of Australian plants will be useful for the development of STZs in Australia. More specifically, guidelines based on climate-informed STZs, both current (e.g. Bower *et al.* 2014) and future (e.g. Shryock *et al.* 2018) could be useful in Australia as a starting point (i.e. a provisional STZ) and later refined with genetic information.

Climate-informed STZs are helping restoration efforts in the western US (Chambers *et al.* 2017) as they provide clear guidance for seed movement (Massatti *et al.* 2020). Although, the research on species-specific genetics and provenance trials is very important for developing STZs, some researchers interviewed think that working species by species will be difficult for developing STZs. Thus, some suggest developing STZs for large number of species (e.g. ~ 50 species) based on climate and biogeography (bioregions) as is done in Europe and the US (Prasse *et al.* 2010; Chambers *et al.* 2017; Bucharova *et al.* 2019). While not mentioned by Australian researchers specifically, the National Seed Strategy in the US (PCA 2015, 2018) provides guidance on how to coordinate and deliver STZs.

There are several NGOs in Australia that are conducting field trials or research that will be helpful in the development of STZs (Table 2). Of note is that all of the current work investigates the effects of climate change on seed sourcing (provenance) and/or species selection. These trials are in early stages but highlight the importance to practitioners of the consideration of climate change in the development of STZs.

TABLE 2. PRACTITIONER-LED RESEARCH/TRIALS CURRENTLY UNDERWAY THAT MAY CONTRIBUTE TO THE DEVELOPMENT OF SEED TRANSFER ZONES (STZS)

NAME OF ORGANISATION UNDERTAKING TRIALS	NAME & LOCATION OF TRIAL	DETAILS OF STUDIES OR FIELD TRIALS THAT ARE CURRENTLY UNDERWAY THAT MAY CONTRIBUTE TO FUTURE STZS
ACT Government and the Australian Tree Seed Centre	Ginninderra *Eucalyptus blakelyi* provenance trials (ACT)	CSIRO is partnering with the ACT Government and Greening Australia to conduct trials supporting the long-term survival of *Eucalyptus blakelyi*. CSIRO's ecologists and scientists from the Australian Tree Seed Centre and the ACT Government are carrying out these 'provenance' trials at CSIRO Ginninderra and among three other sites. 2019–2030. https://ginninderraproject.com.au/ginninderra-trials-helping-blakelys-red-gum-beat-dieback/ https://www.australiasnaturehub.gov.au/action-inventory/blakelys-red-gum-dieback-provenance-trial-planting-7000-trees.
Bush Heritage Australia	Nardoo Hills project, central Victoria	Provenance trials with *Eucalyptus melliodora* and *E. microcarpa*. There are nine replicated blocks for the two species. Within each block the five provenances (for each species) are planted in five plots each with 25 plants. The blocks are spread over two sites (approx 8km apart) in central Victoria. Each seedling is barcoded to identify its species, provenance and family, which will allow comparisons of tree survivorship and growth. https://www.bushheritage.org.au/places-we-protect/victoria/nardoo-hills.
Department of Planning, Industry and Environment (DPIE) NSW	Climate-ready revegetation trials (NSW)	DPIE and Landcare provenance trials in NSW: Yass (three species) and Richmond Valley (several Eucalypt species). Seed sourced locally and from locations currently experiencing the climate projected for the planting site. Trials starting in 2021.
Greening Australia, Melbourne	Climate Future Plots, Victoria	Climate-adjusted provenance trials: 50 Climate future Plots in Tasmania, two in the ACT, one in WA and one in Victoria
Hort Innovation, Macquarie University, Western Sydney University, Hawkesbury Institute for the Environment, and the NSW Government	Which Plant Where project, Australia wide	Habitat suitability modelling for approx. 960 native species using 2030, 2050 & 2070 future climate projections using variables of temperature and rainfall. Project due for completion in 2021. https://www.whichplantwhere.com.au

3.6 Generating consensus on implementation

As part of the interviews shown in Table 1, researchers were asked what further action or information is required to generate consensus on the implementation of seed transfer zones in Australia. This question was the most contentious subject for some of the interviewees.

Although, most of the researchers that were interviewed think that STZs would be beneficial, there was some questioning as to whether STZs are necessary.

Practitioners were not specifically asked about their thoughts on the implementation of STZs, but indirect feedback gave mixed opinions with some commenting that other priorities should be developed first (i.e. germination and dormancy issues) while others think that STZs would be helpful. The sample size for the interviews was small so further consultation with stakeholders (researchers and practitioners) to establish the acceptance of the development of STZs is the obvious first step.

Many interviewees commented that they would like to be involved in the development of STZs, or at least be kept informed of its progress, and they advise that any steps taken should involve wide consultation. Even from the small sample size of researchers interviewed, there is an impressive array of expertise available from which to begin discussions on the implementation of STZs.

3.6.1 Types of seed transfer zones

Of those who would like to implement STZs, there are mixed opinions about how STZs should be established. Some argue that general STZ at a large geographical scale might not work and using biogeographical and climate information might be useful but with limitations. The provisional STZs developed by Bower *et al.* (2014) are highly regarded in the US and may be a template upon which to consider general zones in Australia. However, climate change is not considered in this model and the spacial heterogeneity of Australia, the banded ironstone region of south west WA for example, must be considered.

Other avenues of improvement include splitting species into functional groups, concentrating on keystone species (i.e. Eucalypts) and/or dividing the continent into topographically complex regions (i.e. suitably scaled ecoregions/IBRA regions (Doherty *et al.* 2017).

Others argue that each species needs to be analysed separately to establish its STZ. Species-specific STZs depend on genetics, environmental distance and future climate, all of which need to be incorporated, at least starting with one (Durka *et al.* 2017; Rossetto *et al.* 2019). Species-specific STZs are expensive so improving general STZs with the introduction of a separate web-based tool such as the Seedlot Selection Tool to match seed sources with future climate may be a starting point.

There are many methods by which STZs can be developed, requiring further consensus from the developers.

3.6.2 Consensus among stakeholders

Most researchers agree that there is a need to create consensus among the stakeholders: researchers, government representatives (all levels) and practitioners (including seed suppliers) to reach agreements and adequately integrate knowledge, policy and limitations. Consultation must be wide among the groups but also within the groups to reflect the different opinions and experience. One of the problems mentioned by the interviewees is that there is a major gap between what researchers and practitioners do, i.e. between theory and practice.

There also has to be a balance between the economic viability of the restoration work using STZs (e.g. size of seed supplier market) and the empirical information available (e.g. genetic information, provenance trials) necessary to refine STZs and improve restoration success.

An important comment from one researcher regarding the ecological impact of the quantity of seed collected from natural populations highlights the necessity of careful thought on how damaging effects can be prevented.

Major obstacles to finding agreement among stakeholders include the misalignment of rewards systems e.g. differences in key performance indicators (KPI), and the translation and accessibility of research results (Cook *et al.* 2013). The problem in the different expectations in KPIs of researchers and practitioners will need to be addressed if STZs are to be developed.

The development and implementation of provisional and species-specific STZs is expensive and time consuming and the time spent by individuals will require funding from an external source. To expect individuals to volunteer their time will delay and perhaps impede the development of STZs. This comment is substantiated by the disappointing (but understandable) responses received from some researchers when asked to contribute to the interview process of this report. A publicly accessible repository for all information on all species already studied should form part of the STZ development process.

However, practitioners and researchers can and do work very well together, as evidenced by the partnerships outlined in Table 2 and the numerous collaborations that have occurred in the past. It could be argued that due to the dire state of the environment (i.e. fragmentation and climate change) and funding gaps currently being experienced by universities, the need for collaborations between practitioners and researchers has never been greater.

A comment from Bush Heritage succinctly portrays how science and practice need to work together:

> *'Our recommendation is that as land managers we maintain an open mind on seed provenances. In the face a significant environmental challenge with climate change, we can choose to allow ecosystems to adapt as they can and potentially transform, and we can also consider and trial managing ecosystems/species to try to maintain their current structure, diversity, and function. If we choose the latter then interventions may be needed to build species' resilience to climate threats. In the worst case, we may need to consider ecological surrogates for retreating species, with*

Further comments from interviewees on research or field trials currently underway that may contribute to the development of or provide consensus for STZs are provided below:

- The Science Saving Rainforests program was nominated by Firewheel Rainforest Nursery (restoration services arm) as important research to guide the implementation of STZs. Species-specific genetic testing and provenance trials are needed to generate consensus on STZs.
- To gain consensus we need to learn by doing and prepare for failure by taking a risk-based approach. Continued academic involvement essential. Nominated by Greening Australia, Eastern Australia and Tasmania.
- Many parts of the business contribute to research that will increase the success of seeds in rehabilitation and revegetation with the ultimate aim of fewer seeds being needed to achieve the same rehabilitation results. This may be done with support from Traditional Owners and/or local universities.

  Examples include research trials for precision seeding and flash flaming of Spinifex species, work to understand how to break dormancy of specific target species, and trials (nursery and field) to determine the most effective seeding rates. Nominated by an anonymous interviewee.
- Retain wild collection samples for later genetic testing to examine genetic character of seed production (SPA) output. Nominated by Kalbar Operations.
- The Industry is in transition — policy/guidelines versus the operation reality.
  - Demand for seed on large projects is outpacing the reality of being able to strictly adhere to inflexible guidelines that do not come under a regulatory framework.
  - New research developed for users, such as modelling using the ALA and/or other advance delineation of species-specific seed zones, must be easily accessible and cost effective to access.

- Researching the genetics of each species is not a realistic approach for a floristic provenance with 8000+ species.
- A better approach would be to improve data collection opportunities from seed collections in the field to feed back into species distribution models and make this available to practitioners to better inform their knowledge of the ecology of the region, and the suitability of a specific species to be seeded at a given planting site.
- Better tools to map species environmental envelopes and better presentation of information on primary pollination vectors and dispersal mechanisms would be helpful in assessing seed sourcing, rather than seed zones determined by genetic analysis alone.

Nominated by Threashold to gain consensus.

- Sources of studies or actions that can be used to inform STZs in Australia (and not previously mentioned in Tables 1 and 2) are: existing STZs in the US, regional vegetation guides in NSW, established bioregions, and genetic studies for species such as *Banksia marginata* by Maurizio Rossetto. There is a sizeable disconnect between theoretical and scientific notion and practice with the theory ahead of the native seed sector's capacity. Coordination of seed movement is ad hoc (at best).

  A systematic approach is needed so that there is regional coordination across state borders and bioregions. Regional understanding is necessary for seed suppliers i.e. where a species is common across bioregions. Regional vegetation guides could be the mechanism to guide STZs.

  Focus for STZs should be on species commonly used in restoration. Prescriptive seed movement methods (including STZs) need to be in the form of guidance, not legislation so that all native seed users can make decisions around the guidance i.e. the availability of the prescribed seed. There should, however, be standards and quality requirements for seed supply. Nominated by an Australian Network for Plant Conservation's (ANPC) officer.

3.6.2.1 Seed movement across jurisdictions

A potential obstacle to the implementation of STZs is related to legislation, specifically cross-jurisdictional issues.

> Most researchers agree that the development of STZs needs to be guided and coordinated at the national level. The movement of seed across jurisdictions is an issue that needs further exploration and discussion before consensus on STZs can be reached.

To fully explore the potential problems across jurisdictions, biosecurity personnel within the relevant federal, state and territory governments should be consulted.

The people interviewed for this project are not involved in biosecurity departments but they did offer the following relevant comments:

- There are more (biosecurity) restrictions around the movement of live material than seed i.e. problems associated with Myrtle rust.
- There may be biosecurity risks involved in seed imported from overseas plantations (i.e. Eucalypts).
- The movement of native species' seed may allow the species to become weedy in new areas.
- Seed sourced from other jurisdictions (or non-local) may contain contaminants in the seed mix (i.e. gamba grass).
- Some organisations in Tasmania are concerned about the potential disease and pest risks associated with plants and plant products brought into the state (*Plant Quarantine Act 1997* (Tas)).
- Movement across jurisdictions may increase the likelihood of mixing populations from different evolutionary histories.
- Plant material brought into Western Australia has to adhere to strict biosecurity laws and any plant material is subject to quarantine assessment. However, species are often endemic to Western Australia and together with adherence to the local provenance paradigm, seed does not usually come from interstate.
- Generally, in the commercial seed sector, there does not appear to be too many restrictions on seed movement. For example, seed can be ordered from Victoria or Western Australia for use in New South Wales.
- Where seed collection is made across several jurisdictions, there can be political issues i.e. different private and public entities have varying policies on seed provenance collection and use.

In summary, consensus for the implementation of STZs is not ubiquitous but is possible and not without some difficulties. Moreover, it will require multiple agreements and negotiations among stakeholders to reach consensus with the coordination of a central body such as the Federal Government.

Many basic characteristics of the type of suitable STZs will require much thought and input through wide consultation, a process that will be time consuming and will require strong and fair leadership. However, there is an inspiring amount of existing research and field trials underway that will form a basis from which to begin the process and several researchers and practitioners are keen to be involved.

3.7 Assessment of the suitability of international prescribed seed movements and seed transfer zones for Australia

In Australia, apart from Western Australia, only a small number of existing STZs were found at the departmental and agency level of state governments. To move from the current situation in Australia where little is known about the extent of which seed can be moved with little risk of maladaptation, to one of more certainty, requires the development and implementation of STZs. Species-specific STZs are recommended in the US but they are expensive and time consuming to develop, particularly in Australia with ~21,000 plant species.

Minimum estimated costs of the molecular work (genotype by sequencing) for a single species could be approximately between $15,000 and $20,000 (for example, using DArT Pty Ltd) depending on the quantity of samples (pers comm F. Encinas-Viso, 2021). These costs exclude other expenses such as collection of samples and labour costs for the genomic data analysis.

There are different types of STZs but they should be of a duration long enough that differences in seed provenance become evident i.e. >25 years (Prober *et al.* 2016) and that the plants experience an extreme or 'once in a decade event' (Germino *et al.* 2019). In addition, it is critical that STZs include climate change projections to account for future habitat suitability.

Recent studies in the US that found widespread presence of local adaptation in the Great Basin (Baughman *et al.* 2019) and advantages of retaining the current gene pool (Massatti *et al.* 2020), warn that environmental disturbance could outpace the ability of species to adapt, negating the present superiority of locally sourced seed.

In Europe, seed sourcing guidelines are currently being reviewed to consider the effects of climate change. Development of decision tools (web-based or apps) to provide seed sourcing recommendations and assess vulnerability for different climate change scenarios, such as SUSTREE developed by the EU, can be highly efficient platforms to unify efforts in Australia at the national scale.

> The obvious places to begin the development of species-specific STZs are for those species for which information is already available (i.e. genetics, traits, and provenance trials) and to expand existing research.

As discussed, Western Australia has developed over 100 STZs for use in that state. Some species-specific advice is also available through the RBG Restore and Renew web-based tool for a limited number of species and their NSW distribution (Rossetto *et al.* 2019, 2020). Results from the Science Saving Rainforests program, also run by the RBG, will be informative but this program does not include reciprocal transplant trials.

The various state forestries are an important source of information where provenance trials have been conducted (Johnson & Stanton 1993). If STZs are to be developed, a more rigorous search of forestry literature should be undertaken.

With constrained funding, it will be necessary to look for innovative ways to embed the research necessary to develop STZs into revegetation activity. Collaboration between those officers planning large-scale revegetation and research institutions is an obvious connection (i.e. S.A. Water and Gellie *et al.* (2016)). Other avenues may include working with grant providers where a condition of the funding is to conduct the planting in an experimental fashion. New partnerships may present opportunities to establish trials to develop STZs i.e. the newly announced Cooperative Research Centre for Achieving Sustainable Mine Closure led by the University of WA and the University of Queensland, and the new NESP hub (Resilient Landscapes), hosted by the University of WA.

Knowledge providers are steering revegetation activity towards incorporating local and non-local provenances. Together with acknowledgments from several organisations that climate change projections must be included in species and seed source selection, guidance on species-specific STZs is important and perhaps urgently required.

The sheer number of plant species in Australia, and the time and cost involved in developing species-specific STZs, renders the option of providing species-specific guidance at the scale required unworkable in the short-term. Therefore, consideration should be given to providing general STZs based on biogeography, geology and current climate.

For general STZs, there are many obstacles to overcome, including the appropriate spatial scale and the different requirements of the various governing bodies within a general STZ. An example was given by an interviewee from the tropics. Tropical regions in the Northern Territory are so different to other tropical regions in Australia that seed sourcing guidelines developed in the most similar regions (i.e. parts of Western Australia) are not applicable to the Northern Territory tropics.

Therefore, multiple general STZs are required for 'the tropics'. Examples of systems that may be useful for general STZs are the IBRA bioregions/subregions, overlaid with climate maps (aridity/temperature), or plant hardiness zones. The development of STZs must be developed in consultation with all users of native seed (government, non-government and academia) and at multi levels (government departments through to the office or project level).

4 CONCLUSION

This report is the first to qualify individual organisations' practice and policies on prescribed seed movements in Australia. Now, armed with the knowledge that seed sourcing decisions are generally made at the local project level, steps can be taken to identify how best to provide consistent and relevant seed sourcing guidance. On the positive side, the current lack of prescription at a departmental level means that decisions can be made on a case-by-case basis and should provide the most appropriate seed for the project. It also allows for a seed sourcing strategy to be altered as conditions change. However, the downsides include:

- the local operator not having access to resources outside of the local area
- difficulties in new information reaching all levels of decision making
- the loss of knowledge when the officer leaves that position and
- a possible loss of economies of scale by not centralising seed sourcing decisions at some sort of regional level. How many times do groups in the same region i.e. one group funded by an office within a state department and another funded by a federal agency, independently spend time trying to source seed from the same locations? This scenario is also played out within the state and agency levels.

Examples from international practice suggests that species-specific STZs afford better ecological restoration outcomes than where STZs are not practised. In Australia, some progress has already been made for species-specific STZs in Western Australia and New South Wales.

If STZs are to be developed in Australia, the logical first step is a continuation of existing work and the expansion into keystone or dominant species, in all states.

As an interim measure, consideration could be given to determining if dominant tree species (i.e. Eucalypts) can be grouped into genetic generalists and specialists (Johnson *et al.* 2010; Erickson & Halford 2020) and/or pollination and seed dispersal generalities to provide STZs for groups of species. For the reasons outlined in the report, climate change projections must be included in STZs.

Given the economic impediments to establishing species-specific STZs, consideration should be given to developing general or provisional STZs.

These general zones will not be perfect but they should be easily accessible and simple to use. The additional benefit of developing these zones is that it may help to determine 'what is local' and bring some consistency across the various users of native seed. It may also help to bring down the cost of seed if there is more confidence that seed can be sourced more widely and from different suppliers.

Any STZs (species specific or general) should include interactive decision tools and/or be internet-based.

The development of STZs, species-specific and general, will require input from researchers and practitioners to agree on determinants such as the choice of ecoregion (IBRA or other), climate change variables, and the methods used for common garden experiments (Kilkenny 2015).

Further work is still needed to reach consensus on the need for the implementation of STZs in Australia. However, the small number of interviews conducted indicate that consensus may be achievable. One of the unintended and welcomed outcomes of this review was the amount of information that interviewees shared with the authors. It is obvious that there are many passionate and committed people working in the ecological restoration industry and we were heartened by, and thankful for, the responses this report received from the national and international native seed communities. We note that several people expressed a desire to be involved in this project, which bodes well for future projects and collaborations.

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APPENDIX 1 — NATIVE SEED MOVEMENT/SEED SOURCING

Practice and policies of Australian federal government departments and Landcare organisations

Policies or guidance documentation used by the department or organisation, the level of prescription of seed movement imposed by the department or organisation, the basis of the seed movement prescription, the underpinning research for and the benefits and issues of the seed movement approach.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Department of Agriculture, Water and the Environment		There are no policies, guidelines or codes of practice related to native seed collection or use. Some EPBC listed threatened species recovery plans/conservation advice may contain high level advice for seed collection but this would be case by case.				
Department of Defence. Department of Defence estate — national		Local environmental approvals often require local provenance seed, but prescription is on a case by case basis. The heterogeneity of the estate needs flexibility rather than prescription. Whilst the expectations are that local provenance will be used, the final decision is driven by the local Defence Department environmental staff, and the context of the rehabilitation/restoration activity.	The default position on seed sourcing is to use local provenance. In order of preference: (1) obtain seed from the surrounding planting site; (2) source from the local area, and if locally-sourced seed is not available; (3) source from the sub-IBRA bioregion. For threatened species, the best practical source is used.	Guidelines from Greening Australia and other peak industry and government bodes; species-specific references; personal and locally-sourced knowledge		

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Landcare Australia, 20 Million Trees program. Australia wide (context dependent)		Context dependent and flexible i.e. local Landcare groups are best placed to make their own decisions. Sub-contractors for large projects (i.e. 20 million trees) are given direction to collect within 50km of project site.	Restoration is based on a local reference ecosystem. Restoration inputs are dictated by level of resilience and degradation. When restoration inputs are required, generally local provenance is used; the approach is to collect from populations closest to the site and then move further away. However, collections must be made observing best practice such as collecting from ≥ 250 plants to optimise genetic diversity and fitness. Some consideration is given to climate change by collecting a proportion of 'climate-adjusted' seed sources (northwards/drier).	National standards for the practice of ecological restoration in Australia, 2018.	Local genetic stock represented in restoration and adapted to local conditions.	
Landcare. Individual guidelines for 6 Landcare groups in NSW. Six Landcare districts within southern NSW. One example given here	Local Native Seed Supply Strategy for the Central Tablelands Landcare District, 2012, Greening Australia Capital Region.	Guidelines, written by Greening Australia.	Provenance (sic) plant material and high genetic quality seed sourced from large populations should be used. Can be sourced non-locally but should match the planting site's environmental conditions	http://www.florabank.org.au	Plants are genetically adapted to local environments; able to adapt to changing environmental conditions; increased plant survival; improved landscape function including interdependence with local fauna and fungi; fertile and vigorous progeny; decreased risk of 'polluting' the local flora gene pool.	Occasionally, different provenances of the same species cannot interbreed, so mixing them will reduce restoration success

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
The National Landcare Network. Australia wide			The National Landcare Network (NLN) brings together all the state and territory associations under one network. There are several thousands of groups and the NLN does not set rules or standards on seed sourcing/provenance selection. The group or the project funder usually make the decision about seed sourcing. The decision making process differs, depending on the group's access to information and their expertise. Decisions are constrained by price and information, not by standards. The default position on provenance choice, generally, is one of using local provenance, particularly in S.A. The big project deliverers, i.e. the 20 Million Trees program create their own standards. If asked for advice on seed sourcing, the SERA Standards are recommended.			
Documentation	Australia's Native Vegetation Framework. A national framework to guide the ecologically sustainable management of Australia's native vegetation. COAG Standing Council on Environment and Water 2012, Australia's Native Vegetation Framework, Australian Government, Department of Sustainability, Environment, Water, Population and Communities, Canberra.	The framework is not prescriptive or binding but acts as a strategic document to 'promote better management of Australia's native vegetation while acknowledging differences in approach and activity between jurisdictions'. It is a cooperative effort between all Australian Governments. In-principle, Victoria supports the Framework but at the time of the publication, the state's vegetation regulations were under review. The framework also encourages and supports 'the approaches taken by natural resource managers regionally, catchment-wide and locally, non-government organisations, and individual land users and managers'.	Appropriate seed sourcing is defined as the maximisation of genetic diversity, evolutionary potential and adaptedness of revegetation, which 'will be important for revegetation efforts, and for building the resilience of native vegetation to climate change and other drivers'.	Broadhurst *et al.* 2008		

N.B. References are detailed in Appendix 5

APPENDIX 2 — NATIVE SEED MOVEMENT/SEED SOURCING

Practice and policies of Australian state and territory government departments and their agencies

Policies or guidance documentation used by the department or agency, the level of prescription of seed movement imposed by the department or agency, the basis of the seed movement prescription, the underpinning research for and the benefits and issues of the seed movement approach.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
AUSTRALIAN CAPITAL TERRITORY (ACT)						
Environment, Planning and Sustainable Development Directorate		**There are no formal guidelines for seed collection or use in the ACT**				
ACT Parks & Conservation Service. ACT Parks — example 1 of a unit within Parks	No policy or guidelines within the Parks & Conservation Service	No written specifications. Different Park managers have big differences between their requirements and therefore their approach for seed movement differ. An example of one Park is given here.	In the past, Parks have been focused on using local provenance but some units are now thinking about how climate change will impact on restoration activities. Using the Climate Change in Australia analogue tool to guide species and provenance selection. Approach is to use 50% seed from local and 50% from more western locations.	(1) Hancock *et al.* 2018. (2) Prober, 2015. (3) Climate change in Australia. (4) Stevens *et al.* 2020.	Non-local provenance plants should be better adapted to future climate than local provenance plants. Better restoration outcomes.	(1) Potential for non-local species and plants to become invasive. Weed risk assessment undertaken to minimise this risk. (2) Can be difficult to obtain non-local seed. (3) Takes longer to obtain non-local seed than local seed. (4) Cannot always access species specific information i.e. recent work by Stevens et al on *Themeda triandra*
Icon Water (the Territory's water utility)	No specifications	No written specifications	Use local seed. The species present at the sites managed by the Utility are monitored and audited and are reported to be in good condition. Therefore it is economically prudent to, and no visible reason not to, engage seed collectors to collect seed from their properties for their own use.	Based on experience in the field.	Win/win situation. Seed collectors get extra seed to use, the Water Utility gets seed collected & germinated for their use.	In a changing climate, local species and local seed may not perform well and a mix of seed sources may perform better. *Eucalyptus blakelyi* being an example — not doing well locally. Changing environments mean that historical management techniques may not be appropriate.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
NEW SOUTH WALES (NSW)						
NSW. Department of Planning, Industry and Environment		There is no overarching government policy or code of practice regarding the movement of seed, nor is there any co-ordination of seed movement. However, some agencies within the government, or programs funded by the government, may have their own rules or guidelines. Guidelines found online are listed below	Not applicable	Not applicable		
NSW. Department of Planning, Industry and Environment. NSW state	Translocation operational policy. State of New South Wales and Department of Planning, Industry and Environment. 2019.	Guidance. Provides guidance to NSW DPIE officers and decision-makers, other relevant government agencies (such as local governments), non-government organisations, and private individuals and community organisations on the Department approach to assessing translocation proposals for plants and animals	This policy does not specify where seed should be sourced from — 'Empirical evidence of local seed source (provenance) superiority is equivocal and is often performed under local conditions, rather than being future-focused. Provenance strategies are increasingly looking to maximise genetic diversity and adaptive capacity These strategies recommend the inclusion of non-local provenance with local provenance germplasm for better restoration outcomes, especially over broad geographic scales and under climate change'. Applicants are asked to justify the seed sourcing approach in the application. Note that the policy acknowledges that assisted colonisation and genetic rescue are important management tools.	Frankham *et al.* 2011, Pickup *et al.* 2012; Hancock *et al.* 2013; Hancock & Hughes 2014; Breed *et al.* 2016; Gellie *et al.* 2016; Broadhurst *et al.* 2008; Breed *et al.* 2013; Prober *et al.* 2015.	Allows for flexibility, to be context specific, and to still be current with new provenance strategies. Expected benefits — the flexibility of seed sourcing increases the likelihood of increased genetic diversity and adaptive potential, arresting inbreeding.	Possible risks — adverse impacts on the source population (as well as other biota at the source site) e.g. outbreeding depression, although this can be predicted.

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NSW. Environmental Trust. NSW state — grants funded by the Environmental Trust	Environmental Restoration and Rehabilitation 2020 Program Guidelines. 2020. Environment, Energy and Science Department of Planning, Industry and Environment Locked Bag 5022, Parramatta NSW 2124.	For environmental grants, the applicant or grantee states in the grant application how native seed will be sourced. The Trust, using their own knowledge, reference material, and the advice from a relevant subcommittee, either accept the seed sourcing strategy nominated on the application, or recommend that a successful grant application will require an alternative method of seed sourcing.	For revegetation projects to be eligible for grant funding, local native species must be planted. Consideration must be given as to how the selection will be impacted by climate change and applicants are strongly encouraged to follow guidance provided in the publication 'Climate-ready Revegetation'. Using endemic plants is generally best, but where disturbance is large, native plants that can cope with the planting site's conditions may be appropriate (Ongoing riparian care). FloraBank #16 states the importance of using local indigenous plants in revegetation and rehabilitation work because these provenances (sic) ecologically and genetically complement other plants and animals in the area.	(1) Hancock *et al.* 2018. (2) Stock and Waterways: A NSW Manager's Guide. (3) *FloraBank Guidelines*. 2016	Adopt an appropriate provenance strategy to ensure climate change resilience is considered. Use local plants (and provenance) to ecologically and genetically complementing other plants and animals in the area.	None stated
Documentation, state wide	Conservation Management Notes Managing bushland and wildlife habitat. Seed collecting. 2011. Office of Environment and Heritage, Department of Premier and Cabinet NSW. 59–61 Goulburn Street, Sydney.	Guidelines	Generally best to match environmental conditions (such as ridgetop, floodplain, clay or sandy soil) at the planting site with those of the collection site. Mentions using local seed/provenance that is indigenous to the area. What constitutes local varies on how the species disperses seed & pollen.	*FloraBank Guidelines*	'The use of local native seed and other propagation material retains any unique characteristics of local genetic populations, which may be important for their long-term survival.'	Compromised genetic diversity If species from which seed is be collected is low in number, care must be taken not to encourage too narrow a gene pool.

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Documentation, state wide	Conservation Management Notes Managing bushland and wildlife habitat. Revegetation. 2011. Office of Environment and Heritage, Department of Premier and Cabinet NSW. 59–61 Goulburn Street, Sydney.	Guidelines	Use local provenance seed (i.e. are found in the local area).	Several references provided but none specifically attributed to seed use.	Retain the unique character of the area.	None reported
NSW Biodiversity Conservation Trust. NSW (state wide) landowners partnered with the BCT	(1) Biodiversity Conservation Trust Restoring Native Vegetation. 2019. (2) Biodiversity Conservation Trust Revegetation plan template. Template for guiding best practice revegetation. Guidelines for assisted regeneration and revegetation. 2020. NSW Government, NSW Biodiversity Conservation Trust.	Management plans are developed by BCT staff in consultation with landholders and should align with best-practice guidelines.	Seed should be sourced locally and from healthy populations growing on similar sites within the same bioregion. Some flexibility is applied in circumstances such as the unavailability of local seed. There may be cases where climate change may necessitate the planting of non-local native species.	(1) Greening Australia 'A revegetation guide for Eucalypt Woodlands'; Rawlings, K., Freudenberger, D., Carr, D. 2010. A guide to managing box gum grassy woodlands, Commonwealth of Australia. (2) *FloraBank Guidelines*. (3) Restore and Renew Project Webtool	Using locally-sourced seed means that the plants will be adapted to the planting site	
National Parks Landscape Restoration Team (NPWS). NSW — for revegetation in NSW Parks	Translocation operational policy. 2019.; Whole Plant Sustainable Management Plan 2018–22. 2011.; Seed collection management notes. 2017.. Department of Planning, Industry and Environment; Environment Energy and Science, National Parks and Wildlife Service	There is no formal policy or direction but internal documents used for some guidance. Some autonomy within Parks to make decisions.	Where possible, NPWS sources seed of local provenance for use in revegetation projects. In the context of NPWS operations, 'seeds of local provenance' refers to seeds obtained from local soil seed banks at, or in reasonable proximity to, the proposed revegetation site, and which are derived from endemic species. In most cases, seeds are germinated and subsequently grown into tubestock by locally and/or regionally based suppliers. The experience and expertise of NPWS staff, local suppliers and contractors is used to inform the source of seeds used in revegetation projects. These decisions are also informed by a review of reference material including vegetation mapping, and site inspections. NPWS acknowledges that climate change may necessitate its current seed sourcing strategy to change. For example, non-endemic flora species may prove more		Not given	Not given

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			adaptable to climate change and hence, seeds will need to be sourced from different vegetation communities than those that currently occur locally. N.B. In the Whole Plant Sustainable Management Plan, for the 'protected plants', where seed is authorised to be collected from the NSW estate, seed can only be used for planting activities in, surrounding, or adjacent to the NPWS estate.			
Web-based tool developed by the Royal Botanic Gardens, Sydney. NSW state wide	Restore and Renew. 2019. Rossetto *et al.* 2019:	Guidelines/information	A web-based tool that combines genetic, environmental and ecological data to create seed transfer zones for up 100 species in NSW (information currently only available for 40 species).	See publication reference list	Maximises genetic diversity and future proofs for better restoration outcomes. Advises on seed sourcing to be representative of the species (esp. for threatened species). Methodology is updated as more species' seed transfer zones are developed.	No feedback on the efficacy of the tool. Only NSW mapped, not the species' entire distribution. No patterns across species have been found — the 'seed transfer zones' are not replicable.

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NORTHERN TERRITORY (NT)						
Department of Environment, Parks and Water Security. territory wide		There are no revegetation policies or guidelines on where to source seed from				
Department of Industry, Tourism and Trade. territory wide	There are no requirements imposed by the Mines Division within the Department of Industry, Tourism and Trade					
Parks & Wildlife Commission. NT Parks & Wildlife — territory wide.	No policy or guidelines	No formal policy or guidelines	There is not a lot of revegetation undertaken in the NT. Whilst there is no revegetation policy, the expectation is that seed used in revegetation will have been collected from the Park where the planting occurs.		Sourcing locally means that there will be no detrimental effects on established populations	
Rum Jungle Project, NT. The former Rum Jungle mine site, NT	No specifications	No written documentation on seed sourcing	Seed collection is as close as possible to the planting site but can be collected anywhere within the catchment. Some flexibility is required due to high rainfall variability. If areas within the catchment seed poorly, collection may be made from another catchment.		Catchment-wide sourcing gives a greater likelihood that enough seed can be sourced, and for the required number of species. It also allows for better hygiene control i.e. the introduction of invasive species such as Gamba Grass can be avoided	

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QUEENSLAND (QLD)						
Department of Environment and Science		In Queensland, there is no overarching policy that applies state-wide for seed sourcing				
[The Private Protected Area Program]() — state wide — conservation agreements		No formal policy but conditions can be inserted into the agreement surrounding local provenance to improve restoration and ecological outcomes. Used by private landholders in Queensland who voluntarily enter into an agreement with the Queensland government to protect biodiversity on their property. Usually, the departmental officer provides advice to the landholder re seed sourcing.	The use of local provenance is recommended and encouraged. It is recommended to landholders that seed is sourced from the nature refuge area of the property (the Land), or the property. If this cannot be achieved, seed may be sourced from the local region to ensure local provenance. Landholders are not encouraged to source from other provenances or interstate. Conditions that can be inserted into agreements with landholders are: (1) When conducting any revegetation works such as planting or direct seeding, in consultation with the state, use local provenance plant propagation material, preferably sourced from the Land; or (2) Use local provenance propagation material preferably sourced from the Land, when planting or direct seeding.	The Private Protected Area Program follows the industry standard of the benefits of local provenance, and encourage its practice as such.		
[Community Sustainability Action]() grant program			No direction is given on where seed should be sourced from, apart from the recent rounds that related to threatened species where it was asked that the proposed project activities align with a recovery plan, conservation advice or threat abatement plan or are supported by strong scientific evidence such as a scientific paper. The recent 2020 rounds included the Koala Applied Research South East Queensland and the Threatened Species Recovery and Resilience grants			
Queensland Parks and Wildlife Service	It is believed that there are no policy or guidelines on where seed should be sourced.	Whilst it is believed that there are no policy or guidelines on where seed should be sourced, local provenance is encouraged to be sourced from the Park where the restoration project is undertaken				

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SOUTH AUSTRALIA (SA)						
Department for Environment and Water		In SA, there is no overarching policy that applies state-wide for seed sourcing. Although not stated, the view is that the seed source should be local unless there is justified reason to include other sources.				
SA Native Vegetation Council (or its delegate) for use where approval for clearing is given if significant environmental benefit (SEB) can be achieved by revegetation A form of biodiversity offsetting. SA — state wide	Policy for a Significant Environmental Benefit Under the Native Vegetation Act 1991 and Native Vegetation Regulations 2017. 2020. State of South Australia through the Department of Environment, Water and Natural Resources.	The document is policy but flexibility regarding seed movement is allowed if justified in a Management Plan. Part of that justification may be the issue of climate change. Generally in SA, although not stated, the view is that the seed source should be local unless there is justified reason to include other sources.	For non-threatened species, seed sourcing is not mentioned but 'like for like' is expected i.e. 'offsets should seek to maintain or improve the same habitat type that occurs at the site of impact'. However, departure from this rule may be allowed if vegetation with a 'higher conservation value' can be achieved. For threatened species or habitat for threatened species, refer to specific requirements set out in the 'Guide for calculating a Significant Environmental Benefit' (SEB Guide).'The restored ecosystem should simulate the natural condition, or some other native ecosystem appropriate for the new conditions of the landscape. Ecological restoration should broadly be undertaken in accordance with the 'Habitat Restoration Planning Guide for Natural Resource Managers' (DEWNR 2010)' — taken from Guide for calculating a Significant Environmental Benefit. Under the Native Vegetation Act 1991 and Native Vegetation Regulations (SEB Guide), 2017, State of South Australia through the Department of Environment, Water and Natural Resource, 2016, p 13.	No references documented	Like for like ensures that vegetation species/communities and critical habitats are not systematically degraded or lost from the landscape. Departure from the 'rule' may achieve higher conservation outcomes.	

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General guide for revegetation activities in SA. Native Vegetation Council recommend its use for general revegetation and offsetting agreements where threatened species involved. SA — state wide	Habitat Restoration Planning Guide for Natural Resource Managers. 2010. Clarke, I. Stokes, Z. and Wallace, R., 2010, Habitat Restoration Planning Guide for Natural Resource Managers, Government of South Australia, through Department of Environment and Natural Resources, Adelaide.	Guidance	Maximise adaptive potential to allow adaptation to climate change by maximising population size and introducing genetic variants via 'composite provenancing (p 21).	No references attributed to 'composite provenancing' but Broadhurst 2017 & 2018; and Lowe 2010 cited with 'provenance' listed in the bibliography. The composite provenancing issue was championed by Professor Andrew Lowe (pers comm 3/11/20 from one of the authors). For species movements under climate change — Lindenmayer and Burgman 2005.	The emphasis on using local provenance material is 'under scrutiny'. Using a range of genetic material may give the best chance of climate change adaptation particularly for revegetation in areas where genetic diversity in seed sources may be limited by vegetation fragmentation and isolation, however a risk assessment should be carried out.	Possible issue: the introduction of maladapted genes and possible production of sterile hybrids.
SA Water. SA Water land holdings	No specifications written yet	Contractors must follow SA Waters' specifications	Incorporate local and two non-local genotypes from intermediate and extremities of the species range along a rainfall gradient. This will increase the genetic diversity of the recruitments and therefore adaptability to climate change. Source from populations with ≥ 100 adult individuals (genetically healthy populations).	Broadhurst *et al.* 2008; Breed *et al.* 2013; Gellie *et al.* 2016.	Reported benefit — less herbivory and measurably taller stems on non-local *E. leucoxylon* seedlings. Expected benefits — recruitment plants will have greater genetic diversity because of the mixing of the parents. Recruits can overcome risks associated with reproduction in a highly fragmented landscape (e.g. reinforcing maladaptations in local sub-populations due to climate change).	Mixing individuals from very different environments (e.g. coastal/inland, alpine/lowland) may not be successful due to genetic differentiation/ specialisation to unique environmental settings.

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Documentation. Department of Planning, Transport and Infrastructure (DPTI). For use by local (SA) revegetation groups, the Native Grasses Resource Group, DPTI and contractors.	Native Grasses Technical Notes.	Level of prescription not documented.	Provides a list of 13 botanical regions within SA where 17 native grass species occur. Regional or local provenance use is preferred. 'Identifying sources for the purchase of native grass seed is dependent on the provenance requirements for sourcing seed for a particular project. Although using local provenance seed is considered desirable it may not be possible to obtain commercial quantities of seed to satisfy this requirement. Little information is available on the genetic variation between provenances of native plants in general, and more so for native grasses. The dispersal mechanisms for many grass seeds would tend to imply broad seed distribution and possibly extensive ongoing mixing of genotypes. Further research is required here, but the 'fit for purpose' rule is applicable, particularly for permanently modified environments.'	The majority of the information contained in the Technical Notes have been drawn from trials (since 1998) to establish native grasses using direct seeding methods that have been funded by DPTI. Much of the research conducted in the Mid-North (undertaken primarily by the SA Temperate Grasslands Group) and the grassy woodlands of the Mt Lofty Ranges (undertaken primarily by the Native Grasses Resources Group). No specific references attributed to the seed sourcing section.		

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TASMANIA						
Department of Primary Industries, Parks, Water and Environment. Tasmania — state wide	N/A	There is no overarching policy or guidelines on seed sourcing	Whilst there is no overarching policy or guidelines, it is generally accepted that local provenance seed will be used in revegetation. Nurseries tend to keep good records of seed collections and apportion appropriately for revegetation. The Translocation Policy for all conservation translocations is not available publicly (it expired in 2015) but may be used for guidance in some circumstances. There is an absence of government-generated information on seed sourcing. There is not a lot of revegetation untaken in Tasmania (apart from a few industries such as mining) as natural regeneration rates are high and planting is unnecessary. The state government publication, National Heritage Strategy for Tasmania Securing Our Natural Advantage, 2013–2030, dated September 2013,does not specifically mention native seed movement. However, the Strategy states that climate change adaptation will need to be incorporated into management strategies of Tasmania's natural heritage.	N/A		
Tasmania Parks & Wildlife Service. The Code applies to all land-based reserves managed under the *National Parks and Reserves Management Act 2002*, to forest reserves under the *Forestry Act 1920*, and to certain public reserves under the *Crown Lands Act 1976*.There are different types of land tenures so can be context specific (i.e. private land for conservation or Aboriginal heritage property)	Tasmanian Reserve Management Code of Practice. 2003. Parks and Wildlife Service, Forestry Tasmania and Department of Primary Industries, Water and Environment 2003, Tasmanian Reserve Management Code of Practice, Department of Tourism, Parks, Heritage and the Arts, Hobart.	Reserve managers are not required to adhere to the section on revegetation in the Code. There is no overarching policy on seed movement except that seed is generally not sourced from the mainland	Any activity within the state's parks and reserves must be consistent with the Park's Plan of Management, undergo a risk assessment, and is guided by (1) the policy and procedures of the Translocation of native animals and plants for conservation purposes (document not publicly available), and (2) The Tasmanian Reserve Management Code of Practice. The latter states that local provenance should be used in revegetating a site but will need to be interpreted on a site-specific basis. Seed from within 20km of the site (and preferably the same altitudinal range, geology, soil type and climate) is generally acceptable if closer sources are unavailable. Generally, seed will not be sourced from the mainland to avoid using genetically distinct populations that have separately evolved.	No research attributed	The aim of using local provenance is to avoid introducing stock from genetically different populations. Not using seed sources from the mainland eliminates the risk of genetically contaminating the local populations by introducing germplasm that has evolved separately.	Potentially, short supply of seed in Tasmania after large disturbances (i.e. fire)

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Sustainable Timbers Tasmania (formerly Forestry Tasmania). state forests, Tasmania	Forestry Tasmania (2010). Eucalypt Seed and Sowing, Native Forest Silviculture Technical Bulletin No. 1, Forestry Tasmania, Hobart. 2010. Division of Forest Research and Development, Forestry Tasmania, 79 Melville Street, Hobart.	The level of prescription could not be ascertained from the document supplied	Ideally, all harvested coupes should be sown with 100% on-site seed. Where this is not possible: • On-Site Seed (ONS) is seed collected from the coupe or from any immediately adjacent coupe that has similar topography, elevation, aspect, parent material and forest type. • In-Zone Seed (INZ) is seed collected from the same seed zone as the nominated coupe. • Out-of-Zone Seed (OOZ) is seed collected from outside the seed zone of the nominated coupe. If supplies of on-site and in-zone seed have been exhausted, out-of-zone seed should be obtained from the closest available similar seed zone, Seed Zones are shown in Appendix 3 of the bulletin. The seed zones are based on an assessment of the prevailing environment: altitude, dryness and coldness are the principal attributes used to distinguish between zones. Zones have been drawn up for all parts of Tasmania except for the Tasmanian Wilderness World Heritage Area.	There is an extensive bibliography but no citations directly linked.	On-site seed is highly desirable as it maintains gene pools and ensures that regeneration is adapted to the site.	

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VICTORIA						
Department of Environment, Land, Water and Planning (DELWP). state wide	Biodiversity revegetation with provenance mixing for climate change adaptation. 2020. The State of Victoria Department of Environment, Land, Water and Planning.	An information sheet for ecological restoration & revegetation on cleared land (not forestry/silviculture)- not prescriptive. However, new Delivery Standards for revegetation are in draft form. These standards will be prescriptive when DELWP invests money into projects on public land and will encourage the use of the standards on private land (not prescriptive). The current information sheet and new standards recommend a 'combination' provenance approach.	A 'combination' approach — incorporates a climate-adjusted strategy into the current strategy of using local provenance. To ensure current and future revegetation works are suitable for a changing climate, incorporate seed sources from locations currently experiencing the climate projected for the planting site. This action should increase genetic diversity and therefore adaptability to climate change.	Jellinek, S., Bailey, T.G. 2020. Establishing Victoria's Ecological Infrastructure: A Guide to Creating Climate Future Plots. Greening Australia and the Victorian Department of Environment, Land, Water and Planning. Melbourne, Victoria. Guidelines_WEB-compressed.pdf (and the 42 references therein), and references cited within the Standards (not viewed at the time of this report).	Expected benefits: improved resilience and adaptation (increased genetic diversity). For species that are performing poorly (i.e. from dieback), by introducing new genes into the local gene pool, it may improve that species survival chances, thereby negating the need to replace with a non-local species & risking the chance that the new species will become invasive. Overall, the risks of not catering for climate change impacts on revegetation are likely to be greater than those involved with selection of alternative genetic sources.	Possible issues — outbreeding depression may occur, or new genes can be so pervasive that it leads to the extinction of the local genome.
Vic Forests. The Code and Standards apply to the planning and conducting of all commercial timber production and timber harvesting operations on both public and private land in Victoria.	Code of Practice for Timber Production. 2014. The State of Victoria Department of Environment and Primary Industries; Management Standards and Procedures for timber harvesting operations in Victoria's State forests, 2014. The State of Victoria Department of Environment and Primary Industries.	The Code is a prescribed legislative instrument under the Subordinate Legislation (Legislative Instruments) Regulations 2011. Under the *Sustainable Forests (Timber) Act 2004*, compliance with this Code is mandatory for any person planning for or conducting a timber harvesting operation on state forest. The Standards are subservient to the Code.	The Code states — 'Following timber harvesting operations, state forest must be regenerated (sic) with overstorey species native to the area, wherever possible using the same provenances, or if not available, from an ecologically similar locality. An ecologically similar locality for a species is from a similar elevation, aspect, soil type and/or climate, preferably as close as possible to the harvested area.' The Standards nominate the coupe (where timber is harvested in one operation) as the preferred seed source. If this seed is not available seed should be prioritised using the following criteria: (a)the collection site is within 25km of the coupe to be sown; (b) the mid-elevation of the collection site	Includes Nevill *et al.* 2010 and Nevill *et al.* 2014.	'The natural floristic composition and representative gene pools are maintained when regenerating native forests by using appropriate seed sources and mixes of dominant species.'	

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			is within 350m above to 150m below the mid-elevation of the coupe to be sown; (c) for slopes >10 ° the collection and sowing sites have similar aspect (separate between 'drier' aspects (W, NW, N, NE) and 'moister' aspects (SW, S, SE, E)); and (d) the collection and sowing sites are of similar soil type and parent material'. Where seed quantities within coupes are inadequate to meet requirements, application may be made to collect seed from trees in other coupes. N.B. in times of seed shortage, e.g. after the 2006/07 and 2018/20 fire seasons, more flexibility, according to the interim seed transfer guidelines, was given for Alpine Ash.			

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WESTERN AUSTRALIA (WA)						
Department of Biodiversity, Conservation and Attractions	The majority of this information is published in the scientific literature and therefore not always available to the public. A small proportion of this work has been recorded as Information Sheets (which are available on the Department's website), reports to mining companies, or other stakeholders, or in the case of threatened species, in recovery plans or interim recovery plans. Where research has been accepted in peer-review journals, the information is not always couched in the terms of provenance or seed transfer zones which may make finding this information more difficult. However, a long list of relevant information has been gathered by this project.	The Department does not practice or manage ecological restoration — they provide research. There is no overarching corporate policy or policy statement containing principles and rules that outline the Department's position and which guide decisions and actions in the conduct of the revegetation activities. However, there are several sources of information that can guide seed sourcing for revegetation. A large body of work is available that provide empirically-based seed transfer zones. Overall, there is species-specific data available for over 100 species, including threatened species, where genetic work has been conducted. Due to the sheer number of species-specific reports, they cannot all be listed here but one example is given (Provenancing for landscape restoration in the Midwest). Where species specific recommendations are not available, some general seed sourcing guidelines are provided. Throughout, there is emphasis that seed transfer zones are context dependent — rehabilitation sites that are badly degraded have different requirements to an ecological restoration site in a less degraded state. The Department does not monitor whether their recommendations are taken up or not.				
Department of Parks and Wildlife for threatened species recovery. 2015. Primarily delivered by Species and Communities Branch and the Plant and Animal Science Programs in Science	Corporate guideline no. 36 Recovery of threatened species through translocation and captive breeding or propagation. 2015. The Government of Western Australia. Department of Parks and Wildlife	Guidelines	No specific reference to seed sourcing but two general comments: (1) species from threatened flora can be moved outside its extant range if required. It is inferred from this sentence that seed used to establish these flora could be moved outside of its range. (2) the principals of conservation genetics should be considered: if mixing populations is requested, evidence needed that biodiversity will benefit & details of	No references supplied	Translocations will not detrimentally impact on ether source populations or their habitats, or plants and animals at the translocation site.	

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
and Conservation Division, Regional and Fire Management Services Division and Forest and Ecosystem Management Division in WA state wide			proximity to close relative (s) must be provided.			
Used by those managing native forest across private and public land within the mapped area, south west WA. Includes state forests, timber reserves & conservation reserves (nature reserves, national parks). South west WA	Forest Management Plan 2014–2023. 2013. Conservation Commission of Western Australia.	Prescription for seed sourcing is context dependant (i.e. forestry or mining)	The Management Plan has different criteria, depending on the context, e.g. (1) where regeneration is possible for timber production, first preference for seed sourcing for revegetation is from propagules of local native species from within the area targeted for rehabilitation, from the same landscape management unit (LMU), or where seed is not readily available from this LMU, then use seed from adjacent LMUs. However, some flexibility may be necessary to achieve self-sustaining populations to counter factors such as disease or drought. In this case, mixed seed sources to maximise genetic diversity may be appropriate. (2) where regeneration is not feasible, and where data are available on the underlying genetic diversity through genetic analysis and an understanding of life history traits, this information can be used to inform choice of areas from which seed is sourced. (species-specific information (and appropriate seed transfer zones) are available for some species i.e. jarrah, karri, Kennedia and Allocasaurina. Where the above data is not available, use as the first preference, seed or plants propagated from seed collected from the same LMU as the area to be rehabilitated, or where seed is not readily available from this LMU, then using	No research specifically attributed	The creation of a self-sustaining population will have a higher chance of success if the seeds used for revegetation are collected from the area surrounding the site (LMU) to be rehabilitated. An LMU is defined as Landscape Management Unit, based on vegetation complexes. In the past, anecdotally, 'local' was thought to be around 15km. The LMU map provided shows that the LMUs often cover a distance greater than 15km but few are greater than 80km and often half that distance.	Local seed collection may not achieve the aim of self-sustaining populations if seedlings propagated from local seed are detrimentally affected by disease and other damaging agents, or cannot adapt to climate change

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
			seed from adjacent LMUs. Subject to a process of approval by the Department, based on assessment criteria agreed between the Department and the Conservation Commission, where climate change, impact from damaging agents, or some other identified management need requires it, using other seed sources, flexible options will be considered.			
To be used for all DEC, local government and Main Roads WA operations and included as contract conditions for DEC and FPC contractors.	Guidelines for the Management and Rehabilitation of Basic Raw Material Pits. 2008. Department of Environment and Conservation.	Guidelines	For planting activities associated with rehabilitation: Seeding — seed mixes relevant to the surrounding forest type are to be utilised and must be sourced from the seed zones appropriate to the site. Planting — use plants propagated from seed sourced from the appropriate seed zone.	No research specifically attributed	None stated	None stated
Practitioners/ managers in post-mining landscapes of the Midwest WA. Midwest region of Western Australia	Provenancing for landscape restoration in the Midwest. 2019. Department of Biodiversity, Conservation and Attractions/Biodiversity Conservation Science. MA Millar, DJ Coates, M Byrne, D Roberts, Department of Biodiversity, Conservation and Attractions, The University of Western Australia.	Recommendation	Empirical seed transfer zones for *Grevillea paradoxa*, *Melaleuca nematophylla*, *Grevillea globosa*, and *Mirbelia* sp. Bursarioides in highly altered post-mining landscapes of the Midwest WA. To assess the distribution of genetically divergent lineages and historical and contemporary patterns of genetic structure and gene flow, sequencing of chloroplast DNA regions and genotyping with nuclear microsatellite loci was conducted. This information was integrated with species specific relevant life history traits that affect demography and gene flow and simulation modelling to develop provenance approaches to capture and maintain genetic diversity through subsequent generations.	Millar *et al.* 2016; Millar *et al.* 2017; Millar *et al.* 2019.	Restoration is likely to be achieved because this approach acknowledges divergent evolutionary lineages, genetic diversity, historical and contemporary patterns of genetic structure, gene flow, the life history traits of plant species and current and potentially altered future ecogeographic conditions.	None stated

N.B. References are detailed in Appendix 5

APPENDIX 3 — NATIVE SEED MOVEMENT/SEED SOURCING

Practice and policies of Australian knowledge providers

Policies or guidance documentation used by the organisation, the level of prescription of seed movement imposed by the organisation, the basis of the seed movement prescription, the underpinning research for and the benefits and issues of the seed movement approach.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Australian Association of Bush Regenerators (ABBR). Australia wide, planting in bushland	AABR's Guiding Principles for Ecological Restoration and Rehabilitation (draft). 2013. Australian Association of Bush Regenerators (NSW) Inc.	Information document.	Environmental change, particularly climate change, means that the traditional use of pre-existing species and genotypes may no longer be appropriate for ecological restoration and needs to be determined on a case-by-case basis. Where climate envelopes are broad and /or there is high connectivity across the landscape, pre-existing species and genotypes may still be viable. Where climate envelopes of key species have moved due to climate change, and where habitats are fragmented or tightly circumscribed (making migrations impossible), alternative species composition and genotypes will need to be considered. Identifying appropriate genetic selection where reintroductions or introductions are necessary for common and less common species requires sound scientific information and collaboration between practitioners and researchers.	Society for Ecological Restoration (2004) SER International Primer on Ecological Restoration. Society for Ecological Restoration International Science & Policy Working Group (Version 2, October 2004).	Expected benefits — optimise capacity for adaptation.	Possible issues: loss of ecological integrity. Unstated risks of rapid and radical introduction of new species.
(ABBR). Australia wide, planting in bushland	Planting and Revegetation. Undated, accessed 9/11/20.	Information document.	Genetic guidelines are most important to ensure your community develops appropriate genetic diversity.			

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Australian Network for Plant Conservation (ANPC). Threatened species, Australia wide	Guidelines for the Translocation of Threatened Plants in Australia. Third Edition. 2018. Australian Network for Plant Conservation, Canberra.	Chapter 4 provides broad guidelines for selecting source populations.	Where species have continuous distribution without large habitat variability, to maximise genetic diversity, source seeds from multiple populations. To enhance adaptation to climate change, include adaptive genes across the climate gradient. Where populations are genetically differentiated, keep seed sources separate.	Breed *et al.* 2013; Broadhurst *et al.* 2008; Byrne *et al.* 1999; Jordan *et al.* 2017; Llorens *et al.* 2015; McLean *et al.* 2014; Prober *et al.* 2016; Sgro *et al.* 2011; Steane *et al.* 2017; Steane *et al.* 2014; Weeks *et al.* 2011.	Maximise genetic diversity and adaptive potential.	A good understanding of the source populations' geographic distribution should be understood, and some understanding of its genetic structure is helpful. Seed sourcing for climate adaptation requires modelling of current and future planting sites which do not account for the large amount of uncertainty associated with climate projections and species distribution modelling.
Documentation for use Australia wide. N.B. This document is still in draft form, with expected release early 2021	*FloraBank Guidelines*, Second Edition. Commander, LE (ed) (in prep) *FloraBank Guidelines*, Second Edition.	Guidelines.	Local provenancing has been widely adopted, but alternative strategies address concerns associated with habitat fragmentation, maintaining or maximising genetic diversity, and climate change. The choice of provenance strategy depends on the purpose of the restoration, the degree of disturbance at the restoration site, the landscape context of the restoration site, the state of the local seed source, the biological properties of the species itself, and resilience of the local provenance to future climate change. The overarching objective is to pursue a seed-sourcing strategy that delivers short- and long-term success in a changing environment.	Viewing of the references was not available at the time of this report.	There are likely to be restoration benefits from capturing greater genetic diversity in seed collections by sourcing seed from as many well-spaced plants across a population as is practicable. Numbers and locations of seed sources will depend on the provenancing strategy for that species.	It is important to keep seed collections of different provenances separate and record the source details of each collection. This will help facilitate selection of provenances once a provenancing strategy has been chosen, as well as provide the source material for embedding experiments within restoration activities to understand the costs and benefits of alternative seed sourcing strategies.
Revegetation Industry Association of Western Australia (RIAWA). Western Australia/ Australia	(1) RIAWA Standards Review Paper. April 2006; (2) Seed Supply Standards Review Guidelines. April 2006	Standards suggested by RIAWA	Guidance is not given on seed sourcing apart from (1) Requested provenance plant material must be used to produce seedlings and (2) Provenance must match the stated client requirements. Refer to *FloraBank Guidelines* – 'Keeping Records On Native Seed'.	FloraBank *Guidelines* – Keeping Records On Native Seed.		

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Australian Association of Bush Regenerators (ABBR). Australia wide, planting in bushland	AABR's Guiding Principles for Ecological Restoration and Rehabilitation (draft). 2013. Australian Association of Bush Regenerators (NSW) Inc.	Information document.	Environmental change, particularly climate change, means that the traditional use of pre-existing species and genotypes may no longer be appropriate for ecological restoration and needs to be determined on a case-by-case basis. Where climate envelopes are broad and /or there is high connectivity across the landscape, pre-existing species and genotypes may still be viable. Where climate envelopes of key species have moved due to climate change, and where habitats are fragmented or tightly circumscribed (making migrations impossible), alternative species composition and genotypes will need to be considered. Identifying appropriate genetic selection where reintroductions or introductions are necessary for common and less common species requires sound scientific information and collaboration between practitioners and researchers.	Society for Ecological Restoration (2004) SER International Primer on Ecological Restoration. Society for Ecological Restoration International Science & Policy Working Group (Version 2, October 2004).	Expected benefits — optimise capacity for adaptation.	Possible issues: loss of ecological integrity. Unstated risks of rapid and radical introduction of new species.

N.B. References are detailed in Appendix 5

APPENDIX 4— NATIVE SEED MOVEMENT/SEED SOURCING

Practice and policies of Australian non-government organisations (NGOs), large-scale ecological restoration service providers and mining companies

Policies or guidance documentation used by the organisation, the level of prescription of seed movement imposed by the organisation, the basis of the seed movement prescription, the underpinning research for and the benefits and issues of the seed movement approach.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
NGOS AND LARGE-SCALE ECOLOGICAL RESTORATION SERVICE PROVIDERS						
Bush Heritage Australia. Australia wide properties		The decision on seed provenance(s) is made on a case-by-case basis — depending on what structural or function elements of a landscape are being lost, and where effective alternatives may be found. In the future we are likely to assess our seed sourcing on a case-by-case basis depending on the goals to be achieved. It is likely that local provenance will continue to be an element of most seed sourcing projects including where other provenances are being trialled.	Up until the Nardoo Hills project in Victoria and our realisation of the very real and immediate threat from climate change and its associated extreme events, the approach of local provenance was adopted to maintain the regional/local genetic characteristics of plants. However, in the new climate change paradigm, we are realising that we will have to think more laterally and creatively if we are to retain the ecological function and structure of our landscapes. This Nardoo trial used the climate-adjusted provenancing principles (Prober *et al.* 2016) to assess whether provenances of the same species but from trees found in hotter and/or drier locations, will help us to achieve those ends.	The Climate Ready Revegetation trial at Nardoo Hills is led by Drs Garry McDonald and Matt Appleby. The trial aims to evaluate and encourage cross-pollination between five provenances of two eucalyptus species, where the provenances were selected drawing on the principles of the climate-adjusted provenance approach. To identify regional sources of possible provenances, we set 50–70 year climate scenarios for Nardoo Hills in the BoM Climate Analogues Explorer and used species' distribution maps within the Australian Virtual Herbarium to select the few existing provenances that aligned with identified analogues. Commercial seed collectors and people with local floristic knowledge collected 5g of seed from each of 10 mother trees per provenance.	The trial should diversify the gene pool of local grey box and yellow box eucalypts, drawing on pre-adapted traits from hotter/drier regions. The intended benefit is to increase the resilience of local trees to changing climates, particularly heat waves and dry autumns. Without doubt, we seek long term (>50 year) benefits and will attempt to assess for genetic suitability and resilience in the short, medium and long-term.	The main issue has been finding adequately diverse climate-adjusted provenances. And once the provenances were located, the drought conditions in NSW and SA during 2018–19 meant few trees had seed capsules remaining on the trees and no fresh seed production.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Cape York Natural Resource Management Limited (Cape York NRM), Queensland. Cape York Peninsular bioregion, Queensland		There are no guidelines within the Rangeland NRM Alliance for the collection and transfer of seeds. Direction on seed sourcing for the Cape York NRM is supplied by an independent botanist/consultant.	Cape York NRM have been running a community seed collection wing within our organisation for the last three years. Local Traditional Owners source and collect native grass seed from their Traditional Lands in the southern Cape to supply mining companies in the north western Cape for revegetation purposes. At this point, seed sourced locally is not supplied outside of the Cape York Bioregion. Local provenance is the whole Cape York bioregion.		The community collection brings significant benefit to the local community through providing an income stream from Traditional Lands and allows for the passing down of Traditional Knowledge. Hand-picked seed (as done here) has higher viability than machine stripped seed. The reoccurrence of a surplus of collected seed may prove advantageous if the enterprise is expanded in the future.	Seed sometimes has to be stockpiled if too much is collected
Central Tablelands Local Land Services (NSW Government). Central Tablelands LLS region	No formal LLS guidelines but FloraBank Guidelines used if direction is requested by native seed users. (Guide 10 Seed collection).	The *FloraBank Guidelines* are not included in the revegetation plan given to landholders with an agreement with the LLS. Rather, known suppliers who collect locally are recommended.	The use of locally-collected seed is recommended for (1) landholder incentive projects and (2) large partnership plantings. For the former, a revegetation plan is developed for each agreement outlining species recommendations and suppliers. Using locally collected seed isn't a contractual requirement as it isn't always possible to source the seed within the project timeframe. An example of one of the few large partnership plantings is in the BirdLife planting in the Capertee Valley. All seed is sourced from within the Capertee Valley. Direct seeding, regardless of the project, is guided by *FloraBank Guidelines*; local seed is used	There is a strong focus on local provenance. Attempts are being made to introduce a more climate-ready approach	Sourcing seed locally supports local volunteers, NGOs, local businesses and private enterprises	Not including a climate-ready approach may be an issue if climate change effects revegetation success.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
			where possible but non-local has been used in the past when local not available.			
Firewheel Rainforest Nursery (restoration services arm). NSW North Coast Region	Guidelines are being rewritten, not available yet	The owner of the business (the nursery) makes the decision on where seed will be sourced for revegetation work	Due to inbreeding issues with the local subtropical rainforest species, seed sources are mixed for revegetation projects. Seed has been collected from a radius of approximately 200km north & south and 100km east & west of the Big Scrub. There has been a shift in general advice from using seed from within a planting site to one that incorporates seed from the region to increase genetic diversity. Current advice is that wider collection than regional may be required to address climate change and inbreeding issues.	Australian Rainforest Seed. A Guide to Collecting, Processing and Propagation; Genetics and the endangered. A guide for practitioners; and the results from the Science saving Rainforests program is informing seed sourcing strategies.	Reduce inbreeding depression and increase genetic diversity and thereby increase the likelihood that plantings will be self-sustaining	Seed sourcing strategies are species specific. For some (local) species, genetic diversity is an issue, for others it is not. The science is fast moving and there are more unanswered questions than there are answers.
Greening Australia. Eastern Australia & Tasmania	No internal guidelines. FloraBank under review		Seed sourcing approach is often dictated by where large quantities of seed is available. Operatives have flexibility in seed sourcing and seed selection is often based on operative experience. Generally, Victoria and the ACT are aware of climate-adjusted seed but tend to use local seed (local is the whole bioregion), because of constraints in accessing seed. Tasmania have a long history of a climate-adjusted approach and work extensively with UTas on climate-adjusted plots. Qld are not as active in revegetation as the other states and in NSW, reveg is largely delivered through the ACT team, as above. Recently, climate change was added as a risk factor to the internal risk register due to	Historically, the *FloraBank Guidelines* and internal mentors were used to guide seed source selection. There is no consistent evidence-based research to guide seed sourcing (the absence of consistency is not the issue, we need to learn by doing). For some time now, guidance is coming from ~ 50 climate-adjusted field trials in Tas (with UTas) and a few trials in the ACT, WA & Vic. Research by Ary Hoffman, Carla Sgro, Prober *et al.* 2016, and Hancock *et al.* 2018 are also informative. Broadhurst, Lowe and Breed have also contributed over time to climate-adjusted discussions at GA.	Reducing the risks associated by not incorporating climate adaptation into planting projects (failed plantings). Increasing the awareness of the risks of climate change. The appetite for climate adaptation in revegetation is increasing — increases the likelihood of successful plantings into the future.	Availability of seed from the desired location. Cost of purchasing non-local seed. Lack of expertise to plan where seed should be sourced from for a climate-adjusted approach — need dedicated resources. Establishing seed from analogue climate locations now, where conditions might not be quite appropriate — determining how to optimise the timing of planting non-local seed from climates currently more extreme than

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
			the increased risk (actual and perceived) of increased failure of plantings in a changing climate and we recommend therefore the seed sourcing approach should adopt a more risk-based approach. A risk-based approach has decreasing quantities of local seed and increasing quantities of seed collected from climate analogues and considering species traits etc (e.g. 70% local seed, 20% from hotter/drier regions & 10% from a climate analogue location.) As more evidence becomes available, the approach may work toward reducing the 70% local and increasing the 10% analogue proportions.			local. Reputational risk in the short term if failure rates are high.
Northern and Yorke Natural Resources Management Board (Government of South Australia)	Native plant seed collection In the Northern and Yorke Region. 2011	Fact sheet	The Fact Sheet concentrates on seed collection activities other than where seed should be sourced. It is inferred that local provenance is preferred — 'By collecting the seeds yourself you can ensure that they have come from the local area and that they were collected sustainably'.			
NQ Dry Tropics Ltd (NRM organisation). NQ Dry Tropics NRM region, North Queensland		No written specifications	There is no prescription as to where seed should be sourced for revegetation undertaken by the NRM or for revegetation projects funded by grants. Plants are generally sourced from local business who tend to collect seed locally.		The NRM region covers 146,000km^2 & 4 biomes. Some species are so widespread that genetic differentiation within these species, in the region, is likely to be minimal	

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Threshold Environmental			The process of selecting seed source locations is project/site specific and reflects local knowledge of species distributions and regional occurrences. Guided by science and best practice, but operationally dictated by availability, price and other operational realities. Benefits from ongoing dialogue with local seed collectors. Seed sourcing primarily follows a 'composite', and sometimes an 'admixture' provenance strategy depending on specific species being sourced. The proportion of local (i.e. within a 10km radius of the planting site) often depends on the availability and quality of the seed and is administered on a case by case basis.		This method provides a balance of gene flow that avoids inbreeding while also allowing for adaptive potential. The approach has structure yet is flexible, constrained by knowledge around plant genetics and flow theory yet considers local conditions and distributions on a case-by-case basis. The approach supports the capacity of restored species assemblages to persist into the future with a measured balance of both local genetics and those from further afield, providing respective adaptive capacity due to the genetic composition of the seeded mix.	Lack of well-presented species distribution maps for the southwest of Western Australia. Poor state Herbarium mapping, species distribution delineation and provision of associated environmental envelopes.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
MINING INDUSTRY						
Anonymous. Australia wide operations. This questionnaire was answered with input from sites located in WA, NT, and QLD.	Mine closure plans are published by state mining regulators and often contain seed commitments.	There is no single reference document for seed sourcing in the business. Each operation produces an internal seed management procedure that is agreed to with relevant regulators. Seed management procedures can form part of an approval, a general management plan, or a closure plan. The procedures generally include collection areas and typically stipulate that native seed will be sourced locally wherever possible. Local is defined on a case by case basis. Each state and territory has specific licensing requirements for seed collection.	Most operations source seed locally. 'Local' is not defined because it depends on (1) the bioregion of the mine site (i.e. local in the Pilbara could be 10's of kms), (2) the availability of seed, (3) the aim of the rehabilitation (i.e. return to farm land or native vegetation), (4) the ecology of the site, (5) availability of access to land for collection (e.g. pastoral lease vs national park), and (6) the ability of the seed to remain viable when stored. If seed is not available locally and is purchased, seed suppliers are contracted to source to the operation's specifications and full provenance and collection details are required.	Some operations have undertaken or contributed to research into local seeds. For example, some species-specific research done by Kings Park Botanical Gardens has informed seed sourcing.	Advantages of using local seed: (1) returns the site to a pre-disturbed vegetation structure with plants that have grown in the site's conditions (i.e. climate and soil), (2) enables engagement including employment with traditional owners due to their proximity to nearby seed, and (3) provides easy and timely access to the land for seed collection (if the mine has land holdings that are not actively being mined).	There are many challenges to sourcing seed locally. Limiting collection to a given area amplifies the unpredictability of seed set (some plants do not set seed every year), timing of ripe seed, finding the target species (at the right time), and the availability of the quantity of seed needed. Some seeds only have a short storage life (such as Spinifex grasses) so it is difficult to plan ahead and limits the value in collecting extra when the season is good.
Kalbar Operations. Kalbar Operations 'Fingerboards Project' mine site, East Gippsland, Victoria	Fingerboards Mineral Sands Project Environment Effects Statement. August 2020. Kalbar Operations Pty Ltd. (Chapter 11.5.5). Kalbar Operations 'Fingerboards Project' mine site, East Gippsland, Victoria	The Company develops a seed sourcing strategy as part of its rehab and closure planning. This plan is developed as part of the EES process. Specialist consultants prepare individual plans but these are reviewed and receive comment from independent experts and key stakeholder groups (appointed by DWELP). The final rehabilitation and closure planning document is then included as part of the company's Environmental Effects Statement (EES). This is made publicly available for comment. Once the EES statement is approved by the regulator, the plan, and the specified seed sourcing action must be followed.	The EES states 'Tree seed or seedlings will be, as much as possible, provenance material sourced from within, or close to, the project area'. Seed sourcing is extended from local — regional (a 150km x 60km radius around the site) to ensure that genetically healthy populations, that are also representative of local genetic structure, can be returned to the mine site.	Frankham *et al.* 2011; Prober *et al.* 2015; Hancock *et al.* 2018; Rossetto *et al.* 2019.	Fulfils stakeholder and community expectations for local seed. Regional collections give enough populations across the Gippsland region to genetically represent the species.	Obtaining permits to collect seed. Need to extend collection to the regional level to obtain the species diversity. Lack of seed volume from wild populations means that seed production approaches will have to be used to develop seed resources in the quantities and quality required for the scale of the restoration project.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Yancoal Australia, NSW. NSW operations, other states may differ		No written guidelines. Seed sourcing strategy is determined by each office branch. Each state may have different requirements	Seed sourcing strategy depends on the context but generally locally collected seed is preferred. For threatened species or endangered ecological communities, a seed mix may be used with seed from locations where the climate and soils are similar to the planting site, so not necessarily all local. Seed collectors are paid a premium to collect local seed. Seed is used that comes from seed production areas where the original source is known.	Walkworth Sands provenance trials (C.L. Gross, UNE, paper not sighted)		

N.B. References are detailed in Appendix 5

APPENDIX 5 — REFERENCES (PEER-REVIEWED) FOR APPENDICES 1–4

Research for the seed movement approach cited by federal government, state and territory governments, knowledge providers and NGOs

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APPENDIX 6 — US FEDERAL AGENCIES PARTICIPATING IN THE NATIONAL SEED STRATEGY, 2015–2020, AS PART OF THE PLANT CONSERVATION ALLIANCE (PCA)

NAME OF AGENCY	SUMMARY OF OPERATION	WEBSITE/INFORMATION SOURCE
Agricultural Research Service (ARS)	The **ARS** is the chief scientific in-house research agency of the US Department of Agriculture (USDA). The ARS is organised into four National Programs, which includes the 'Natural Resources and Sustainable Agricultural Systems'. Research activities in this program include enhancing conservation, restoring ecosystems, developing germplasm for conservation, and enhancing natural resource stewardship. For ARS, seed zones are not part of any directed policy. Similar to the Natural Resource Conservation Service (NRCS), the ARS approach to native plant restoration has largely been to select plant traits within and among wild seed collections and develop widely used germplasm and cultivars. Neither Agencies have emphasised seed zones.	https://www.ars.usda.gov/
Bureau of Indian Affairs (BIA)	The Bureau of Indian Affairs has several programs that conserve and improve the land and natural assets. Programs include the Agriculture & Range program, the Natural Resources Damage Assessment and Restoration Program, and the Endangered Species program. The BIA has 12 regional offices and 83 agencies.	https://www.bia.gov/
Bureau of Land Management (BLM)	The BLM is a bureau within the US Department of the Interior and manages public lands for a variety of uses, often with shared stewardship and partnerships. The BLM administers and leads many conservation programs, including those with an emphasis on native seed and seed transfer zones. Examples include the Native Plant Materials Development Program (to increase the quality and quantity of native plant materials available for restoring and supporting resilient ecosystems), Seeds of Success (collect wildland native seed for research, development, germplasm conservation, and ecosystem restoration), initiatives to collect and supply locally adapted plant material from the eastern seaboard in the aftermath of Hurricane Sandy, and programs to develop species-specific seed transfer zones i.e. The Great Basin Native Plant program, the Colorado Plateau Native Plant program **and the Mojave Desert Native Plant Program.**	https://www.blm.gov/ https://www.blm.gov/programs/natural-resources/native-plant-communities/native-seed-and-plant-material-development https://www.blm.gov/sites/blm.gov/files/SOS_Protocol_10.18.18_2020.pdf; https://www.blm.gov/programs/natural-resources/native-plant-communities/native-plant-and-seed-material-development/ecoregional-programs

NAME OF AGENCY	SUMMARY OF OPERATION	WEBSITE/INFORMATION SOURCE
Federal Highway Administration (FHWA)	The Federal Highway Administration (FHWA) allocates funding from the US Department of Transportation (DOT) and provides technical guidance to interstate, state, municipal and country highways for roadside revegetation projects using native plants (NASEM, 2020). There are some legislated components to funding (i.e. section 319 of title 23, US Code, specifying the use of native plants), but no evidence of policy or legislation regarding seed movement or the use of seed transfer zones were found, For seed sourcing, guidance is given by DOT/FHWA's publications *Pollinators and Roadsides: Best Management Practices for Managers and Decision Makers* and *Vegetation Management: An Ecoregional Approach* (see spreadsheet for details of these publications). The Office of Federal Lands Highway (FLH) was established to protect and enhance the Nation's natural resources (amongst other reasons). There are many programs with many different partners, administered by the FLH and aspects of the programs are context specific. No mention is made of seed sourcing requirements in the Project Development and Design Manual (Environmental Stewardship). For projects that receive funding from DOT's **Transportation Alternatives Program, seed must be ordered from the** state wide coordinator who organises the bulk purchase of locally grown native seed. This may be viewed as being 'prescriptive' but individual states differ in their application of the program guidelines. One example is the Iowa Integrated Roadside Vegetation Management (IRVM) Program.	https://highways.dot.gov/ https://highways.dot.gov/federal-lands/about#:~:text=The%20Office%20of%20Federal%20Lands%20Highway%20(FLH)%2C%20of%20the,and%20enhance%20our%20Nation's%20natural https://tallgrassprairiecenter.org/irvm/transportation-alternatives-seed.
National Institute of Food and Agriculture (NIFA)	The National Institute of Food and Agriculture (NIFA) is a federal agency within the US Department of Agriculture (USDA), and is part of USDA's Research, Education, and Economics mission area. NIFA administers federal funding to address agricultural issues and invests in and advances agricultural research, education, and extension to help solve national challenges in agriculture, food, the environment, and communities.	https://nifa.usda.gov/about-nifa
National Park Service (NPS)	The National Park Service (NPS) is a Federal Agency within the Department of the Interior that manages land comprising over 400 geographically and ecologically diverse units. These units vary in size, landform and function: from natural landscapes to historic and cultural sites. The Park's mission is to protect and enhance America's National Park system for present and future generations.	https://www.nps.gov/index.htm
Natural Resources Conservation Service (NRCS)	The Natural Resources Conservation Service (NRCS) is an agency of the US Department of Agriculture (USDA) that provides technical assistance to farmers and other private landowners and managers. The NRCS has offices throughout the US and most often in every county. Demand for seed is wide ranging, from erosion control, creating pollinator habitat, to biodiversity conservation, through many different programs. The NRCS operates 25 Plant Materials Centres that cultivate and select plants that are released to commercial growers, who then increase them for natural resource conservation and restoration projects. The plants grown at Plant Materials Centres test new selections under a variety of climates and soil types to ensure they will perform as needed. Currently, very few NRCS plant releases are genetically manipulated and most are selected to maximise genetic diversity. The NRCS does not have an overarching policy on seed transfer zones (STZ) or seed collection or use. State offices have recommended plant species lists for different conservation practices, and these recommendations & the species and seed source(s) may vary across the state depending on the natural resource concern being addressed. Conservation Practice	https://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/

NAME OF AGENCY	SUMMARY OF OPERATION	WEBSITE/INFORMATION SOURCE
	Standards are available for different resource conservation activities each with different recommendations ranging from the use of cultivars to pre-varietal germplasm such as source identified materials.	
Smithsonian Institution (SI)	Contribution to the NSS was communication/outreach to the public	https://www.si.edu/
US Botanic Garden (USBG)	The Gardens do not manage any federal lands (apart from their display gardens). Contribution to the NSS was via research (i.e. seed germination trials), education/communication.	https://www.usbg.gov/
US Fish and Wildlife Service (USFWS)	The US FWS is a bureau within the US Department of the Interior that is dedicated to the conservation, protection, and enhancement of fish, wildlife and plants, and their habitats. The FWS also manages the National Wildlife Refuge System. While the FWS does not have a national policy on seed transfer zones, some FWS offices are using seed transfer zones to inform seeding decisions. Decision making on seed sourcing is at the individual office level.	https://www.fws.gov/help/about_us.html
US Forest Service (USFS)	The USFS is an agency of the US Department of Agriculture (USDA). Their mission is to 'To sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. To meet this requirements management includes the protection, preservation and conservation of natural area.	https://www.fs.usda.gov/
US Geological Survey (USGS)	The USGS provides research to support many aspects of the native seed industry: seed transfer guidance, native plant material development, ecological restoration strategies, and web-based tools (i.e. https://seedmapper.shinyapps.io/climate_partitioning_app/)	https://www.usgs.gov NASEM, 2020

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APPENDIX 7 — RECENTLY DEVELOPED EMPIRICAL SEED TRANSFER ZONES FOR NON-TREE SPECIES IN THE US

Plant growth habits are according to https://plants.usda.gov/

SPECIES	GROWTH HABIT	TYPE STZ	LOCATION (DISTRIBUTION SAMPLED)
[1]*Achnatherum hymenoides*	Graminoid	Empirical — Common Garden Study	Western US (Great Basin & Colorado Plateau)
[2]*Achnatherum thurberianum*	Graminoid	Empirical — Common Garden Study	Western US (Great Basin)
[3]*Agrostis scabra*	Graminoid	Empirical — Genecology / Landscape Genetics	Idaho and Montana
[4]*Allium acuminatum*	Forb/Herb	Empirical — Common Garden Study	Western US
[5]*Andropogon gerardii*	Graminoid	Species and phenotype distribution models climate and change projections.	Current and future distribution
[6]*Artemisia tridentata* ssp *vaseyana*	Shrub/Tree	Empirical — Common Garden Study	Western US
[6]*Artemisia tridentata* ssp *wyomingensis* and spp *tridentata*	Shrub/Tree	Empirical — Common Garden Study	Western US
[7]*Astragalus lonchocarpus*	Forb/Herb	Climate-matched — climate & species distribution	Colorado Plateau
[7]*Bouteloua gracilis*	Graminoid	Climate-matched — climate & species distribution	Colorado Plateau
[8]*Bromus carinatus*	Graminiod	Empirical — Genecology / landscape genetic Study	The Blue Mountains of eastern Oregon
[9]*Bromus marginatus*	Graminoid	Empirical — Common Garden Study using (1) climate variables, & (2) climate and soil	Montana and Idaho
[7]*Cleome lutea*	Forb/Herb	Climate-matched — climate & species distribution	Colorado Plateau
[10]*Danthonia californica*	Graminoid	Empirical — Genecology / Landscape Genetics	W. Oregon

SPECIES	GROWTH HABIT	TYPE STZ	LOCATION (DISTRIBUTION SAMPLED)
[10]*Deschampsia caespitosa* var. *caespitosa*	Graminoid	Empirical — Genecology / Landscape Genetics	n.a.
[10]*Distichlis spicata*	Graminoid	Empirical — Genecology / Landscape Genetics	Range wide
[11]*Elymus glaucus*	Graminiod	Empirical — Common Garden Study	The Blue Mountain Ecological Province of northeastern Oregon and adjoining Washington
[7]*Elymus elymoides*	Graminoid	Climate-matched — climate & species distribution	Colorado Plateau
[12]*Ephedra nevadensis*	Shrub/Subshrub	Empirical (Landscape genetics Study	Mojave Desert
[13]*Epilobium densiflorum*	Forb/Herb	Empirical — Common Garden Study	Willamette Valley ecoregion
[13]*Eriophyllum lanatum* var. *leucophyllum*	Forb/Herb Subshrub	Empirical — Common Garden Study	Willamette Valley ecoregion
[10]*Festuca idahoensis*	Graminoid	Empirical — Genecology / Landscape Genetics	Idaho and Montana
[14]*Festuca roemeri*	Graminiod	Empirical — Common Garden Study	Pacific Northwest
[7]*Heliomeris multiflora*	Forb/Herb/ Subshrub	Climate-matched — climate & species distribution	Colorado Plateau
[15]*Holodiscus discolor*	Shrub	Emperical — Common Garden Study (1 site)	Pacific Northwest
[7]*Koeleria macrantha*	Graminoid	Climate-matched — climate & species distribution	Colorado Plateau
[16]*Leymus cinereus*	Graminoid	Empirical — Common Garden Study	Columbia Basin — Great Basin
[17]*Lotus utahensis*	Forb/Herb	Empirical — common garden study — Genetic — molecular	Southern Great Basin and Colorado Plateau
[18]*Lupinus latifolius*	Forb/Herb	Empirical — Common Garden Study	Mt. Hood National Forest
[7]*Machaeranthera canescens*	Forb/Herb	Climate-matched — climate & species distribution	Colorado Plateau
[19]*Penstemon deustus*	Forb/Herb/ Subshrub	Population genetic study	Great Basin region
[19]*Penstemon pachyphyllus*	Forb/Herb	Population genetic study	Great Basin region
[19]*Penstemon rostriflorus*	Forb/Herb Subshrub	Population genetic study	Great Basin region
[20]*Pleuraphis jamesii*	Graminoid	Genetic — molecular	Colorado Plateau and adjacent regions

SPECIES	GROWTH HABIT	TYPE STZ	LOCATION (DISTRIBUTION SAMPLED)
[7]*Pleuraphis jamesii*	Graminoid	Climate-matched — climate & species distribution	Colorado Plateau
[21]*Poa secunda*	Graminoid	Empirical — Common Garden Study	Western US
[13]*Potentilla gracilis* var. *gracilis*	Forb/Herb Subshrub	Empirical — Common Garden Study	Willamette Valley ecoregion
[22]*Pseudoroegneria spicata*	Graminoid	Empirical — Common Garden Study	Western US
[23]*Pseudoroegneria spicata*	Graminoid	Empirical — Genecology	North western US
[13]*Saxifraga oregana*	Forb/Herb	Empirical — Common Garden Study	Willamette Valley ecoregion
[12]*Sphaeralcea ambigua*	Forb/Herb/ Subshrub	Empirical (Landscape genetics Study	Mojave Desert
[20]*Sphaeralcea parvifolia*	Forb/Herb	Genetic — molecular	Colorado Plateau and adjacent regions
[7]*Sphaeralcea parvifolia*	Forb/Herb	Climate-matched — climate & species distribution	Colorado Plateau
[7]*Sporobolus cryptandrus*	Graminoid	Climate-matched — climate & species distribution	Colorado Plateau
[20]*Sporobolus cryptandrus*	Graminoid	Genetic — molecular	Colorado Plateau and adjacent regions

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APPENDIX 8 — NATIVE SEED MOVEMENT/SEED SOURCING

Practice and policies of US Federal Agencies

Policies or guidance documentation used by the agency, the level of prescription of seed movement imposed by the agency, the basis of the seed movement prescription, the underpinning research for and the benefits and issues of the seed movement approach.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Agricultural Research Service (ARS), country wide	No directed policy		The approach to native plants has largely been to select plant traits within and among wild seed collections and develop widely used germplasm and cultivars.		Compared to locally sourced germplasm, these releases still dominate the industry for several reasons including selection for traits that may promote establishment at restoration sites, seed production under cultivation, and an established presence in the market.	Diversity of species and types within species are often lacking. Ecologist have been concerned that this approach, leading to the use of just a few species and selections over large geographic areas, is at the expense of local adaptation and productive ecological interactions. Their widespread use conflicts with the local adaptation many prefer.
Bureau of Indian Affairs (BIA), country wide	No specifications	No legislated requirements	The tools or research used within the BIA to inform seed sourcing or to delineate seed transfer zones varies. Some offices use the USDA — Forest Service's (USDA-FS) TRM Seed Zone	The research underpinning the TRM Seed Zone map		

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
			Map (which has provisional STZs and some empirical STZs), others use US Environmental Protection Agency's (US EPA) Ecoregions.			
Bureau of Land Management (BLM), all BLM land, country wide	Integrated Vegetation Management Handbook 1740–2. 2008. US Department of the Interior Bureau of Land Management.	Provides a guide for the use of seed in restoration & other revegetation projects for decision making at the local level: local communities, stake holders, other landowners, tribes and other agencies. Aim of this approach is to avoid duplication of efforts, ensure consistency and improve public acceptance of vegetation management activities.	To re-establish vegetation, use genetically appropriate native vegetation (e.g. from the same seed zone & of similar elevation) to the area treated. Seed transfer zones should be used where available. When not available, use seed collected within or as close as possible to the project area (local) and within the same ecological regions. Use seeds/cuttings from local variants from unusual or extreme environments. For riparian species, collect immediately upstream or downstream, or within sub-watersheds within the same ecological site and at similar elevations. If local sources are unavailable, commercial sources of seeds (& native plants) may be used. Seed can come from germplasm releases made by USDA Plant Materials Centres where plants were grown out and multiplied, or it can be collected from wildland plants.	Research for empirical seed transfer zones, no specific references attributed.	Higher short-term and long-term establishment and survival rates will be achieved by using local genotypes that are adapted to the local environment.	Local seed may not always be available. Cultivars may not be adapted to the planting site and not appropriate.
Bureau of Land Management (BLM), all BLM land, country wide	Manual Section 6840. Special Status Species Management. 2001. US Department of the Interior, Bureau of Land Management.	Policy and guidance for the conservation of BLM special status species and the ecosystems upon which they depend on BLM-administered lands. Seed sourcing may be stated in the species' approved recovery plan, on a case-by-case basis.	Case-by-case basis — refer to the species' approved recovery plan.	No references specifically attributed		

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Federal Highway Administration (FHA), FHA roadside vegetation projects, country wide	Pollinators and Roadsides: Best Management Practices for Managers and Decision Makers. 2016. US Department of Transport. Federal Highway Administration.	Guidelines	Prioritise the use of locally sourced plant material. Where local sources are not available, regional designations may be acceptable.	[1]Gustafson *et al.* 2005. [2]Houseal & Smith 2000. [3]Lippit *et al.* 1994. [4]Norcini 2014.	Improve establishment and persistence of plantings and have higher value to pollinators. Local ecotype plant materials that originated in geographic proximity to the project site will generally establish and grow well because they are adapted to the local climatic conditions (Lippit *et al.* 1994). The phenology of non-locally sourced seed can also differ (Norcini *et al.* 2014; Houseal & Smith 2000; Gustafson *et al.* 2005).	
Federal Highway Administration, (FHA), FHA roadside vegetation projects, country wide	Vegetation Management: An Ecoregional Approach. 2013. Federal Highway Administration, USDOT, Washington D.C.	Guidelines	Use source-identified, or yellow tagged, and/or local ecotypes as much as possible. Use germplasm that originated as close to the planting site as possible. A minimum buffer of one-quarter mile is recommended for use of non-local seed sources, cultivars or varieties to protect native remnants & other seed production areas. For other purposes, source distance varies.	National Standards	To protect native remnants & other seed production areas.	
National Park Service (NPS), All NPS Units, countrywide	National Park Service Management Policies. 2006. The Guide to Managing the National Park System. National Park Service. US Department of the Interior.	NPS Management Policies provide overall direction for management issues. Parks follow these policies but these are not specific and they need to cover over 400 geographically and ecologically diverse units. Each of these units	Ecological restoration undertaken in parks is context dependant. 'The restoration of native plants and animals will be accomplished using organisms taken from populations as closely related genetically and ecologically as possible to park populations, preferably from similar habitats in adjacent or local area'. Deviation from this policy is allowed in certain situations i.e. the genetic diversity of a species within a	Restoration actions are 'based on clearly articulated, well-supported management objectives and the best scientific information available. All resource management actions involving planting or relocating species, subspecies, or varieties will be guided by detailed knowledge of site ecological	These actions assist with the fulfilment of the policy requirement to 'maintain the closest approximation of the natural condition when a truly natural system is no longer attainable'. It also allows the Service to use the best	Resources are lacking to conduct genetic analyses and for stock piling seed. Information on species-specific and general technical guidance developed by researchers can be

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
		has been established by its own legislation for its own unique purposes. Therefore, many/most on the ground decisions are context dependant and are made by the local unit manager (superintendent / park manager). There are no requirements to use seed transfer zones in the policies.	park has diminished and needs to be augmented, populations have become isolated, and/ or, populations of rare, threatened, or endangered species need to be enhanced. Where species-specific seed transfer zones are available, and are known about, they are used. However, few are available. As more become available, through the National Seed Strategy, their use will increasingly be encouraged.	histories and knowledge of local adaptations, ranges, and habitat requirements. Actions to transplant organisms for purposes of restoring genetic variability through gene flow between native breeding populations will be preceded by an assessment of the genetic compatibility of the populations'. Many small parks without technical staff may not have access to the most recent scientific literature and decisions may be made based on agricultural applications.	rule of thumb to work with the appropriate genetic stock without doing a lot of testing and research. The policy provides flexibility for individual parks to respond to their particular requirement and to be managed in the context of their larger ecosystems.	shared to overcome the information gap. The strategy doesn't work so well for common species in parks that are very isolated in, for example, urban or agricultural landscapes.
(USDA) Natural Resource Conservation Service (NRCS), country wide	Conservation Practice Standards are used to determine which species should be used and which seed sources are most appropriate, but that can be highly variable. The Standards do not determine seed transfer zones. The relevant Standards are: 340, 342, 512, 327, 512, 420, 643 & 550. US Department of Agriculture. Natural Resource Conservation Service. 2015–2020 (Conservation Practice Standards are updated every five years, therefore the majority are 2015–2020).	No national policy on seed sourcing for natural resource conservation programs. NRCS state offices make recommendations on seed sources, depending on the purpose of the practice. All NRCS programs are voluntary.	The Standards are available for different conservation activities each with different recommendations ranging from the use of cultivars or pre-varietal germplasm including source identified materials. Field trials test for adaptability to soil and climate.	The development of new plant materials is based on field trials that develop plant selections for a specific geographic area and then tests that material in other areas to see if it can be used in a wider geographic area than originally intended. Plant selections are often made to retain as much of the genetic diversity of the original population to the extent possible.	Successful plantings over a wide geographic area.	

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
US Fish and Wildlife Service (FWS). Fish and Wildlife Refuges country wide.	Fish and Wildlife Service Manual Series 601 FW 3 Biological Integrity, Diversity and Environmental Health, Section 3.15 Part C / Amendment 1, 601 FW 3. 2001, amendment 2006.	No national policy on seed transfer zones or seed sourcing. Where STZs are available, these are used as priority, but each office makes its own seeding decisions. Gradually moving towards having a centralised point of approving seed sourcing decisions. The FWS work closely with federal agencies (i.e. Bureau of Land Management and US Forest Service) in these circumstances to ensure consistency in terms of seed transfer guidance.	Native seed is used in ecological restoration. Genetically modified organisms are not used in refuge management unless it is determined that their use is essential to accomplishing refuge purpose(s) and the Regional Chief, National Wildlife Refuge System, approves the use. Where available, seed transfer zones are used to inform seeding decisions, otherwise each office makes their own decisions.	Empirical evidence for STZs (see Appendix 7 for list of Great Basin & Mojave Desert species).		
US Forest Service (USFS), All USFS administration units	FSM 2000 — National Forest Resource Management (Chapter 2070 — Vegetation Ecology) Amendment No. 2000-2008-1. 2008. US Forest Service. Washington, D.C.: US Forest Service National Headquarters.	Policy	Ensure genetically appropriate native plant materials are given primary consideration and base the determination and selection of genetically appropriate plant materials on the site characteristics and ecological setting, using the best available information and plant materials.	No references attributed but the USFS has a long history of using seed transfer zones for commercial forestry trees. More recently, empirical STZs have been established for some grasses and forbs.		

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
US Forest Service (USFS), All USFS administration units. The continental US	Native Plants Materials Policy. A Strategic Framework. 2012. USDA Forest Service, SW Washington, DC 20250-0003.	The Framework supports the Policy (FSM 2000 — National Forest Resource Management Chapter 2070 — Vegetation Ecology), aims and objectives, mainly for grasses, forbs & shrubs. 'The native plant materials policy directs national forests and grasslands (sic) to cooperate and coordinate the development and use of native plant materials across administrative units as well as with other federal agencies, states, tribes, non-governmental organisations, private industry, and other stakeholders'.	Use genetically appropriate native plant materials. Seeds should be sourced from similar environmental conditions (example given — coastal populations, no frost compared to inland locations with frequent frosts. Examples of species-specific STZs for grasses, forbs and a shrub are provided in Appendix 7.	No references attributed but the USFS has a long history of using seed transfer zones for commercial forestry trees. More recently, empirical STZs have been established for some grasses and forbs.	Plants have a better chance of survival if they are locally adapted to the area being revegetated. All plant materials used will be of known origin and any field production will follow standards to receive certification. The benefit of the policy is to capture the range of genetic variability adapted to different climates and soils.	

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APPENDIX 9 — NATIVE SEED MOVEMENT/SEED SOURCING

Practice and policies of European governments

Policies or guidance documentation used by the organisation, the level of prescription of seed movement imposed by the organisation, the basis of the seed movement prescription, the underpinning research for and the benefits and issues of the seed movement approach.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
German Federal Government	Prasse R, Kunzmann D, Schröder R (2010) Development and practical implementation of minimal requirements for the verification of origin of native seeds of herbaceous plants (in German). In cooperation with Verband Deutscher Wildsamen-und Wildpflanzenproduzenten. DBU, reference no. 23931. (Interview to Anna Bucharova)	This practice is legislated — specific directions for the use of seed of herbaceous plants in restoration and revegetation projects at the federal level defining seed transfer zones for all Germany. Aim of this approach is to ensure the mix and match approach (i.e. seeds are sourced from multiple populations within the same region as the target locality and mixed prior to use), ensuring consistency of this method across the country.	The STZ was first delineated by geomorphology, geology, hydrology and soil. The exact borders of the seed zones were discussed with the administration of the Federal States of Germany to ensure practical feasibility. To supply the market with regional seeds adapted to wider range of environmental conditions, the German system demands to collect seeds from at least five large populations across a seed transfer zone (Prasse *et al.* 2010). The seeds are then mixed and either directly used or, more frequently, propagated as crops on fields and sold for restoration projects (Rieger *et al.* 2014).	Research was done through multiple papers for herbaceous species considering genetics and climate. Prasse R, Kunzmann D, Schröder R (2010) Development and practical implementation of minimal requirements for the verification of origin of native seeds of herbaceous plants (in German). In cooperation with Verband Deutscher Wildsamen- und Wildpflanzenproduzenten. DBU, reference no. 23931. Rieger ER, Feucht BI, Wieden MA (2014) Agricultural propagation of native seeds and development of a certification procedure in Germany. In Kiehl K, Kirmer A, Shaw N, Tischew S (eds) *Guidelines for native seed production and grassland restoration*. Cambridge Scholars Publishing, pp 101–116	The benefits are an increase of the genetic diversity for future adaptation, while restricting seed origins to a regional scale to maintain regional adaptation.	Local seed may not always be available and legislation impose difficulties for future changes of STZ due to climate change.

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Ministry of Agriculture and Food — France	La politique nationale de conservation des ressources génétiques forestières (National policy for the conservation of genetic resources in forestry)	This code of practice is legislated. It established seed transfer zones for 50 woody species used in forestry (each species has a STZ), including different species of pine and oak. Movement of seeds is restricted to zones delineated to maintain high genetic diversity and phenotypic traits. This includes maintaining gene flow between species that might hybridise such as different Quercus species.	The basis of this STZs is underpinned by numerous genetic (population and quantitative genetics), phenotypic and climate studies done over more than 40 years of forestry research. The code strictly prevents the 'contamination' of foreign genetic material (including seeds and pollen) to maintain genetic diversity. The code of practice also defines populations of each species as Conservation Units based on genetic studies (molecular markers and phenotypic traits) and seasonality.	The research has been done through multiple papers on individual species. Some listed here: https://agriculture.gouv.fr/la-politique-nationale-de-conservation-des-ressources-genetiques-forestieres	The benefits are an increase of the genetic diversity for future adaptation, while restricting seed origins to a regional scale to maintain regional adaptation.	No specific reported issues, although some argue that STZ will not be necessary in the future due to climate change.
EUFORGEN (European Forest Genetic Resource Programme)	Use and transfer of forest reproductive material in Europe in the context of climate change. 2015. (interview to Michele Bozzano)	Not legislated, code of practice to be implemented by country members of EUFORGEN and particularly European forest owners	The Standards are available for different conservation activities each with different recommendations ranging from the use of cultivars or pre-varietal germplasm including source identified materials. Field trials test for adaptability to soil and climate.	The development of new plant materials is based on field trials (common garden and provenance trials) that develop plant selections for a specific geographic area and then tests that material in other areas to see if it can be used in a wider geographic area than originally intended. Plant selections are often made to retain as much of the genetic diversity of the original population to the extent possible.	The main benefits are for woody species in European forests that have transnational distribution and therefore seed sourcing is affected by different legislations. This project facilitates seed sourcing across Europe.	No reported issues

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
Theory	Cevallos *et al.* 2020. Seed transfer zones based on environmental variables better reflect variability in vegetation than administrative units: evidence from Hungary. *Restor Ecol*, 28, 911–918.	Guidelines	The STZs was based on a floristic map, a vegetation map, and a landscape map of Hungary. No genetics studies were used to delineate the STZ. A clustering analysis using the environmental data was used to make the STZs.	Published paper: Cevallos, D, Bede-Fazekas, Á, Tanács, E, Szitár, K, Halassy, M, Kövendi-Jakó, A, Török, K (2020) Seed transfer zones based on environmental variables better reflect variability in vegetation than administrative units: evidence from Hungary. *Restor Ecol*, 28, 911–918.	The benefits are: 1) improve seed transfer between jurisdictions within the country and 2) it only requires floristic and environmental data to delineate STZ.	These are generalised STZs therefore it might not be suitable for all species.
Theory	Jørgensen, MH, Elameen, A, Hofman, N, Klemsdal, S, Malaval, S, Fjellheim, S (2016) What's the meaning of local? Using molecular markers to define seed transfer zones for ecological restoration in Norway. *Evol Appl*, 9, 673–684.	Guidelines	Define STZ to preserve genetic diversity using neutral genetic markers to infer population structure from several species. This provides a scientific basis for the selection of local seeds for restoration of vegetation in alpine regions in Norway in compliance with the Norwegian Nature Diversity Act.	Jørgensen, MH, Elameen, A, Hofman, N, Klemsdal, S, Malaval, S, Fjellheim, S (2016) What's the meaning of local? Using molecular markers to define seed transfer zones for ecological restoration in Norway. *Evol Appl*, 9, 673–684		
Interreg Europe	SUSTREE: Conservation and sustainable utilisation of forest tree diversity in climate change. 2019.	A code of practice that aims to make policy changes at EU level	Climate change projections together with information of regional provenance based on genetics and provenance trials. The aim is to allow seed transfer across country borders for the utilisation of the best forest reproductive material that is fit for the challenges posed by climate change affecting the forests of the region.			
Forestry Commission — UK Government	Using Local Stock for Planting Native Trees and Shrubs. 1999.	Code of practice	A system intended to facilitate the identification of, and trade in, locally sourced stock for the planting of native species in Britain. The STZ are a non-statutory sub-division of the statutory Regions of Provenance (defined in 1977 for the marketing of reproductive material of commercially important species for timber). These regions have been sub-divided using	Salmela, MJ, Cavers, S, Cottrell, JE, Iason, GR, Ennos, RA (2011) Seasonal patterns of photochemical capacity and spring phenology reveal genetic differentiation among native Scots pine (Pinus sylvestris L.) populations in Scotland. *Forest Ecology and Management*, 262, 1020–1029. Salmela, MJ, Cavers, S, Cottrell, JE, Iason, GR, Ennos, RA (2013) Spring phenology	Locally sourced seeds maintain the genetic integrity and ecological diversity of woodlands. New guidelines are being developed to consider climate change effects.	

ORGANISATION & LOCATION OF REFERENCE MATERIAL'S TARGET	SEED SOURCING REFERENCE MATERIAL, PUBLISHING DETAILS & WEBSITE	LEVEL OF PRESCRIPTION	BASIS OF SEED MOVEMENT PRESCRIPTION	UNDERPINNING RESEARCH — SEED MOVEMENT APPROACH	REPORTED BENEFITS	REPORTED ISSUES
			information about climatic and geological variation. Elevation should be considered as an additional factor using two levels — above and below 300m — because of the importance of elevation in influencing local climatic conditions. The seed zone number may be used to identify collections of seeds or cuttings made under the statutory regulations or the voluntary identification system. If no planting material is available from the same seed zone/ elevation band, then material from adjacent zones close areas (or same elevation band) within the same Region of Provenance should be used. Specific STZ exist for certain species, such as Scots Pine.	shows genetic variation among and within populations in seedlings of Scots pine (Pinus sylvestris L.) in the Scottish Highlands. *Plant Ecology & Diversity* DOI: 10.1080/17550874.2013.795627. (2) Herbert, R, Samuel, S, Patterson, GS (1999) *Using local stock for planting native trees and shrubs*. Forestry Commission Practice Note 8. Forestry Commission, Edinburgh.		

APPENDIX 10 — REFERENCES FOR TABLE 1

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TABLE 3. SPECIES SPECIFIC STZS — ADDITIONAL REFERENCES OBTAINED FROM THE WESTERN AUSTRALIAN DEPARTMENT OF BIODIVERSITY, CONSERVATION AND ATTRACTIONS' LIBRARY FOR BYRNE, M., KRAUSS, S., AND MILLAR, M

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Hart, A. J.	10 year results of river gum (Eucalyptus camaldulensis) provenance trials at 6 localities in agricultural areas of W.A.	by A.J. Hart	1982	Forests Dept.		
	A cryptic genetic boundary in remnant populations of a long-lived, bird-pollinated shrub Banksia sphaerocarpa var. caesia (Proteaceae)	Heidi M. Nistelberger, David J. Coates, Tanya M. Llorens, Colin J. Yates and Margaret Byrne	2015		Sourced from: Biological journal of the Linnean Society. - Vol. 115 (2015)	
Krauss, Siegfried	A molecular assessment of clonality in the critically endangered Grevillea pythara (Proteaceae)	Siegfried Krauss and Grace Zawko	2004	Botanic Gardens & Parks Authority		
Shepherd, Kelly A.	A rare, new species of Atriplex (Chenopodiaceae) comprising two genetically distinct but morphologically cryptic populations in arid Western Australia: implications for taxonomy and conservation	Kelly A. Shepherd, Kevin R. Thiele, Jane Sampson, David Coates and Margaret Byrne	2015		Sourced from: Australian systematic botany. - Vol. 28 (2015)	
	A threatened ecological community : research advances and priorities for banksia woodlands	Alison L. Ritchie ... [et al.]				
Millar, Melissa Ann	Acacia saligna as a sustainable agroforestry crop for southern Australia : a genetic assessement	Melissa Ann Millar	2008	M. Millar		
Schuster, C. J.	An initial study of provenance variation in karri (Eucalyptus diversicolor F.Muell.)	by C.J. Schuster	1979	Forests Dept.		
	An integrated genetic linkage map for Eucalyptus nitens.	M. Byrne... [et al.]	nd		In: Theoretical and Applied Genetics. - Vol. 91 (1995)	
Sampson, Jane F.	Assessing genetic structure in a rare clonal eucalypt as a basis for augmentation and introduction translocations	Jane F. Sampson, Margaret Byrne	2016		Sourced from: Conservation genetics. - Vol. 17 (2016)	
Millar, Melissa A.	Assessment of genetic diversity and mating system of Acacia cyclops restoration and remnant populations	Melissa A. Millar, David J. Coates, Margaret Byrne, Siegfried L. Krauss, Justin Jonson, Stephen D. Hopper	2019		Sourced from: Restoration ecology. - Vol. 27 (2019)	
Butcher, Penny	Assessment of genetic structure and pollen dispersal highlights potential impacts of mining on the rare ironstone endemic Tetratheca paynterae	Penny Butcher, Donna Bradbury, Siegy Krauss	2007	Conference Organising Committee	In: ESA 2007, program and abstracts : Ecological Society of Australia, Perth 2007 : Perth Convention and Exhibition Centre, Perth, Australia, 2007, Monday 26th November to Friday 30th November 2007	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Millar, Melissa A.	Assessment of population genetic variation and structure of Acacia woodmaniorum, and its phylogenetic relationship to other Acacia species : twenty four month report to Karara Mining Ltd by the Department of Environment and Conservation.	Melissa A. Millar and David J. Coates	2011	Dept. of Environment & Conservation		
Coates, David J.	Assessment of the genetic structure and levels of clonality in the critically endangered Banksia ionthocarpa subsp. chrysophoenix and its sister taxon Banksia ionthocarpa subsp. ionthocarpa	David J. Coates, Melissa Millar and Margaret Byrne	2009	Dept. of Environment & Conservation		
Millar, M. A.	Biogeographic origins and reproductive mode of naturalised populations of Acacia saligna	M.A. Millar and M. Byrne	2012		Sourced from: Australian journal of botany. - Vol. 60 (2012)	
Sampson, J. F.	Characterizing the radiation of subspecies of polyploid Atriplex nummularia Lindl. (Chenopodiaceae) using microsatellite markers	J.F. Sampson, M. Bryne	2010	Conference Organising Committee	Sourced from: Genetics Society of AustralAsia 2010 : annual conference, Canberra 4-8 July : programme and abstracts	
Byrne, M.	Chloroplast DNA diversity in Eucalyptus nitens	M. Byrne and G.F. Moran	nd		In: Population genetics and genetic conservation of forest trees / edited by Ph. Baradat, W.T. Adams and G. Mu¨ller-Starck	
Bradbury, Donna	Clonality, interspecific hybridisation and inbreeding in a rare mallee eucalypt, Eucalyptus absita (Myrtaceae) and implications for conservation	Donna Bradbury, Peter M. Grayling, Bronwyn Macdonald, Margaret Hankinson and Margaret Byrne	2016		Sourced from: Conservation genetics. - Vol. 17 (2016)	
Wallace, Mark J.	Complex genetic relationships within and among cytotypes in the Lepidosperma costale species complex (Cyperaceae) on rocky outcrops in Western Australia	Mark J. Wallace, Siegfried L. Krauss and Matthew D. Barrett	2019		Sourced from: Australian journal of botany. - Vol. 67 (2019)	
Sampson, J. F.	Confirming the genetic affinity of the Eyres Green saltbush cultivar as oldman saltbush (Atriplex nummularia Lindl.)	J.F. Sampson, M. Byrne, H.C. Norman and E. Barrett-Lennard	2014		Sourced from: Australian journal of botany. - Vol. 62 (2014)	
Millar, Melissa	Connectivity and restoration in Acacia woodmaniorum (Maslin and Buscomb), a rare endemic of the Yilgarn banded ironstones	Melissa Milla, David Coates, Margaret Byrne	2012	Conference Organising Committee	Sourced from: Society for Ecological Restoration Australasia Conference : Perth, Western Australia, Australia, 28-30 November 2012 : program and conference abstracts / L. Commander, J. Stevens and K. Dixon (eds.)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
	Conservation and genetic diversity of microsatellite loci in the genus Eucalyptus	M. Byrne ... [et al.]	1996		In: Australian journal of botany. - Vol. 44 (1996)	
Bezemer, Nicole	Conservation of old individual trees and small populations is integral to maintain species' genetic diversity of a historically fragmented woody perennial	Nicole Bezemer, Siegfried L Krauss, David G Roberts and Stephen D Hopper	2019		Sourced from: Molecular ecology. - Vol. 28 (2019)	
Nistelberger, Heidi	Contrasting evolutionary histories in two phylogeographic lineages of a widespread, woody shrub in Western Australia	Heidi Nistelberger, Margaret Byrne, Neil Gibson	2011	Conference Organising Committee	Sourced from: Genetics Society of AustralAsia, Annual Conference 2011 : Melbourne, July 10-13th 2011	
Levy, E.	Contrasting influences of geographic range and distribution of populations on patterns of genetic diversity in two sympatric Pilbara acacias	E. Levy, M. Byrne, D.J. Coates, B.M. Macdonald, S. McArthur, S. van Leeuwen	2016		Sourced from: PLoS one. - Vol. 11 (2016)	
Binks, R. M.	Contrasting patterns of clonality and fine-scale genetic structure in two rare sedges with differing geographic distributions	R.M. Binks, M.A. Millar and M. Byrne	2015		Sourced from: Heredity. - Vol. 115 (2015)	
	Correlations between species diversity and genetic diversity of Banksia attenuata (Proteaceae) in the presence of frequent seed dispersal between populations	T. He ... [et al.]	2007	Conference Organising Committee	In: ESA 2007, program and abstracts : Ecological Society of Australia, Perth 2007 : Perth Convention and Exhibition Centre, Perth, Australia, 2007, Monday 26th November to Friday 30th November 2007	
Millar, Melissa A.	Cryptic divergent lineages of Pultenaea pauciflora M.B.Scott (Fabaceae: Mirbelieae) exhibit different evolutionary history	Melissa Ann Millar and Margaret Byrne	2013		Sourced from: Biological journal of the Linnean Society. - Vol. 108 (2013)	
Millar, M. A.	Defining entities in the Acacia saligna (Fabaceae) species complex using a population genetics approach	M. A. Millar, M. Byrne and W. O'Sullivan	2011		Sourced from: Australian journal of botany. - Vol. 59 (2011)	
O'Brien, Eleanor	Delineating seed transfer zones to conserve genetic variation in restoration of southwestern Australian forest tree populations	Eleanor O'Brien	2007	Conference Organising Committee	In: ESA 2007, program and abstracts : Ecological Society of Australia, Perth 2007 : Perth Convention and Exhibition Centre, Perth, Australia, 2007, Monday 26th November to Friday 30th November 2007	
Millar, M. A.	Delineation of cryptic divergent lineages within Narrogin pea	M.A. Millar, M. Byrne	2012	Conference Organising Committee	Sourced from: Genetics Society of AustralAsia, Annual Conference, 2012: Melbourne, July 15-18 2012	
Byrne, M.	Detection and inheritance of RFLPs in Eucalyptus nitens	M. Byrne, G.F. Moran , J.C. Murrell, W.N. Tibbits	1994		Sourced from: Theoretical and applied genetics. - Vol. 89 (1994)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Kroiss, Lori	Development, characterization and transferability of microsatellite markers for Cullen australasicum (Leguminosae)	Lori Kroiss ... [et al.]	2009		Sourced from: Conservation genetics. - Vol. 10 (2009)	
Llorens, Tanya M.	Disjunct, highly divergent genetic lineages within two rare Eremophila (Scrophulariaceae: Myoporeae) species in a biodiversity hotspot : implications for taxonomy and conservation	Tanya M. Llorens, Bronwyn Macdonald, Shelley McArthur, David J. Coates And Margaret Byrne	2015		Sourced from: Biological journal of the Linnean Society. - Vol. 177 (2015)	
Millar, Melissa A.	Disparate patterns of population genetic diversity, structure and clonality in a critically endangered Banksia species	Melissa A. MIllar, Margaret Byrne, David Coates	2009	Genetics Society of AustralAsia	Sourced from: GSA 2009 : Brisbane, 7-10 July : programme and abstracts	
Barrett, Matthew	Distribution of Triodia cytotypes within Roy Hill seed collection zones	Matthew Barrett, Siegy Krauss and Pauline Grierson for Roy Hill	2016	University of Western Australia, Ecosystems Research Group		
Llorens, Tanya M.	Does population distribution matter? : influence of a patchy versus continuous distribution on genetic patterns in a wind-pollinated shrub	Tanya M. Llorens, Sarah-Louise Tapper, David J. Coates, Shelley McArthur, Margaret Hankinson and Margaret Byrne	2017		Sourced from: Journal of biogeography. - Vol. 44 (2017)	
Ritchie, Alison L.	Does restored plant diversity play a role in the reproductive functionality of Banksia populations?	Alison L. Ritchie, Paul G. Nevill, Elizabeth A. Sinclair, Siegfried L. Krauss	2017		Sourced from: Restoration ecology. - Vol. 25 (2017)	
Bamford, Bella Renee	Does sandalwood provenance selection influence early establishment of sandalwood?	Bella Renee Bamford	2001	B. Bamford		
Hart, A. J.	E. calophylla provenance trial, Harvey, 1976-1985	by A.J. Hart	[1985]	Dept. of Conservation & Land Management		
	E. microcarpa provenance trial : Boddington establishment report, RPP 10/88	organised by P. Brown	[1989?]	Dept. of Conservation & Land Management		
	Effect of genetic relatedness among parents on gain in salt tolerance in progeny of crosses of Eucalyptus occidentalis	by R. Hendrati ... [et al.]	2011		Sourced from: Silvae genetica. - Vol. 60, no. 2 (2011)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Butcher, T.	Eucalyptus globulus provenance trials in Western Australia	T. Butcher	1986		Reprinted from: Research Working Group No. 1 of the Australian Forestry Council, Forest Genetics : proceedings of the ninth meeting of representatives held at Somerset, Tasmania, 24 to 27 February, 1986 (1986)	
Anderson, Benjamin	Evolutionary diversity in spinifex grasses : an example from the Triodia basedowii E.Pritz. species complex	Benjamin Anderson, Matthew Barrett, Pauline Grierson, Siegy Krauss, Kevin Thiele	2014	Conference Organising Committee	Sourced from: Book of abstracts : Ecological Society of Australia, 2014 annual conference : 28 September-3 October 2014, Alice Springs Convention Centre	
	Extensive genetic connectivity and historical persistence are features of two widespread tree species in the ancient Pilbara region of Western Australia	Heidi M. Nistelberger ... [et al.]	2020		Sourced from: Genes. - Vol. 11 (2020)	
Millar, Melissa A.	Extensive long-distance pollen dispersal and highly outcrossed mating in historically small and disjunct populations of Acacia woodmaniorum (Fabaceae), a rare banded iron formation endemic	Melissa A. Millar, David J. Coates and Margaret Byrne	2014		Sourced from: Annals of botany. - Vol. 114 (2014)	
Binks, Rachel M.	Final report for assessment of genetic processes in Lepidosperma sp. Parker Range and Lepidosperma sp. Mt Caudan: final report to Cazaly Iron Ore Pty Ltd		nd			
	Fine scale genetic structure and gene flow in Banksia sphaerocarpa var. caesia in the fragmentated agricultural landscape of south-western Australia	Tanya Llorens ... [et al.]	2009	Genetics Society of AustralAsia	Sourced from: GSA 2009 : Brisbane, 7-10 July : programme and abstracts	
Hopley, Tara	Gene flow and genetic variation explain signatures of selection across a climate gradient in two riparian species	Tara Hopley and Margaret Byrne	2019		Sourced from: Genes. - Vol. 10 (2019)	
Byrne, Margaret	Genetic analysis of Eucalyptus bennettiae	Margaret Byrne	2003	M. Byrne		
Sampson, Jane	Genetic analysis to inform management of mallee box, Eucalyptus cuprea	Jane Smpson and Margaret Byrne	2009	Dept. of Environment & Conservation		
Coates, D. J.	Genetic and ecological consequences of habitat fragmentation in two woody shrubs (Calothamnus quadrifidis and Eremaea pauciflora) and the tree (Eucalyptus wandoo) in the Western Australian wheatbelt	D.J. Coates	2003		Reprinted from: Consequences of Habitat Fragmentation Workshop, 4th-5th July 2003 (2003)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Byrne, M.	Genetic and ecological consequences of population fragmentation in Eucalyptus wandoo in Western Australia	M. Byrne	2003		Reprinted from: Abstracts and posters : XIX International Congress of Genetics : Genomes, the Linkage to Life: 6-11 July, 2003: Melbourne Exhibition and Convention Centre, Victoria, Australia (2003)	
Coates, D.	Genetic and ecological consequences of population fragmentation in the bird pollinated woody shrub Calothamnus quadrifidis	D. Coates	2003		Reprinted from: Abstracts and posters : XIX International Congress of Genetics : Genomes, the Linkage to Life: 6-11 July, 2003: Melbourne Exhibition and Convention Centre, Victoria, Australia (2003)	
Moniodis, Jessie	Genetic and environmental parameters show associations with essential oil composition in West Australian sandalwood (Santalum spicatum)	Jessie Moniodis, Michael Renton, Christopher G. Jones, E. Liz Barbour and Margaret Byrne	2018		Sourced from: Australian journal of botany. - Vol. 66 (2018)	
Monks, Leonie	Genetic and mating system assessment of translocation success of the long-lived perennial shrub Lambertia orbifolia (Proteaceae)	Leonie Monks, Rachel Standish, Shelley McArthur, Rebecca Dillon, Margaret Byrne and David Coates				
Byrne, M.	Genetic and morphological analysis of multi-stemmed plants of tuart (Eucalyptus gomphocephala)	M. Byrne, A. Koenders, K. Rogerson, J. Sampson and E.J.B. van Etten	2016		Sourced from: Australian journal of botany. - Vol. 64 (2016)	
Byrne, Margaret	Genetic and taxonomic status of Eucalyptus absita populations : BankWest Landscope Visa Card grant report	Margaret Byrne and Peter Grayling	2005	Dept. of Conservation & Land Management		
Binks, Rachel	Genetic assessment of Aluta quadrata across the Western Range	Rachel Binks, Margaret Byrne and Stephen van Leeuwen	2019	Department of Biodiversity, Conservation & Attractions		
	Genetic congruence with new species boundaries in the Melaleuca uncinata complex (Myrtaceae)	L. Broadhurst ... [et al.]	2004		Sourced from: Australian journal of botany. - Vol. 52 (2004)	
Millar, Melissa A.	Genetic connectivity and diversity in inselberg populations of Acacia woodmaniorum, a rare endemic of the Yilgarn Craton banded iron formations	M.A. Millar, D.J. Coates and M. Byrne	2013		Sourced from: Heredity. - Vol. 111 (2013)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Coates, D. J.	Genetic consequences of population loss and reintroduction in the rare geographically disjunct Banksia brownii following pathogen driven local extinction	D.J. Coates, S. McAthur, M. Bryne	2010	Conference Organising Committee	Sourced from: Genetics Society of AustralAsia 2010 : annual conference, Canberra 4-8 July : programme and abstracts	
	Genetic differentiation among morphological variants of Acacia saligna (Mimosaceae)	Nicholas George ... [et al.]	2006		Reprinted from: Tree genetics and genomes. - Vol. 2 (2006)	
Hines, B.	Genetic differentiation between mallee and tree forms in the Eucalyptus loxophleba complex	B. Hines	2001		Sourced from: Heredity. - Vol. 87 (2001)	
Broadhurst, L. M.	Genetic divergence and phylogeny in the Acacia acuminata (Leguminosae: Mimosoideae) complex	L.M. Broadhurst	1999		Reprinted from: XVI International Botanical Congress: St. Louis, USA, August 1-7, 1999: abstracts (1999)	
Byrne, M.	Genetic diversity and conservation of the oleosa group of oil mallees	M. Byrne	1998	Conference Organising Committee	Sourced from: Abstracts : Society for Conservation Biology : Macquarie University, Sydney July 13-16, 1998	
George, N. A.	Genetic diversity and feed quality variation in Acacia saligna, implications for using the species in dryland salinity management	N.A. George, M. Byrne and G. Yan	2005	Conference Organising Committee	Reprinted from: International Salinity Forum : Managing Saline Soils and Water : Science, Technology and Social Issues : April 25-27, Riverside Convention Center, Riverside, California	
Byrne, M.	Genetic diversity and mating systems in eucalypt evolution	M. Byrne	2011	Conference Organising Committee	Sourced from: IBC2011, XVIII International Botanical Congress : Melbourne, Australia, 23-30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17-22 July, 2011, University of Melbourne : abstract book	
Sampson, Jane F.	Genetic diversity and multiple origins of polyploid Atriplex nummularia Lindl. (Chenopodiaceae)	Jane F. Sampson and Margaret Bryne	2012		Sourced from: Biological journal of the Linnean Society. - Vol. 105 (2012)	
Wheeler, M. A.	Genetic diversity and phylogenetic relationships within Eucalyptus marginata (Myrtaceae)	M.A. Wheeler	2002		Sourced from: Plant Breeding for the 11th Millennium : proceedings of the 12th Australasian Plant Breeding Conference, Perth, Western Australia : 15-20th September 2002 (2002)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Millar, Melissa	Genetic diversity and population persistence in a rare endemic	Melissa Millar and David Coates	2011	Conference Organising Committee	Sourced from: MEDECOS XII: Linking Science to Resource Management : the International Mediterranean Ecosystems Conference : September 6-9, 2011, Los Angeles, California, United States : abstracts	
	Genetic diversity and the utilization of Acacia species complexes in agroforestry	Margaret Byrne ... [et al.]	2001	Australian National University	In: Legumes down under : the Fourth International Legume Conference, 2-6 July 2001, Australian National University, Canberra, Australia : program and abstracts	
Byrne, Margaret	Genetic diversity in Acacia atkinsiana across the Pilbara : provenance zone implications	Margaret Byrne, David Coates and Stephen van Leeuwen	2012	Dept. of Environment & Conservation		
Coates, David	Genetic diversity in Aluta quadrata : implications for provenance seed collections and management	David Coates, Margaret Byrne and Stephen van Leeuwen	2012	Dept. of Environment & Conservation		
Byrne, Margaret	Genetic diversity in Eucalyptus leucophloia across the Pilbara : provenance zone implications	Margaret Byrne, David Coates and Stephen van Leeuwen	2011	Dept. of Environment & Conservation		
Byrne, Margaret	Genetic diversity in Isotoma petraea and Macrozamia riedlei	Margaret Byrne	1991	M. Byrne		
Byrne, M.	Genetic diversity in the cycad, Macrozamia riedlei	M. Byrne.and S.H. James	nd		In: Heredity. - Vol. 67 (1991)	
Byrne, Margaret	Genetic diversity in Western Australian sandalwood (Santalum spicatum) : report to the Forest Products Commission	Margaret Byrne	2001	Dept. of Conservation & Land Management		
	Genetic diversity of an Australian Santalum album collection: implications for tree improvement potential	by C.G. Jones ... [et al.]	2009		Sourced from: Silvae genetica. - Vol. 58 (2009)	
	Genetic diversity of tropical sandalwood (Santalum album)	J.A. Plummer ... [et al.]	2011	Conference Organising Committee	Sourced from: Combio2011 : proceedings of the Australian Society for Biochemistry and Molecular Biology, Cairns, Queensland, 25-29 September 2011	
Elliott, C.	Genetic diversity within and between natural populations of Eucalyptus occidentalis (Myrtaceae)	by C. Elliott and M. Byrne	2003		Reprinted from: Silvae genetica. - Vol. 52 (2003)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
	Genetic diversity, mating system and reproductive output of restored Melaleuca acuminata populations are comparable to natural remnant populations	Melissa A. Millar ... [et al.]	2019		Sourced from: Ecological restoration. - Vol. 37 (2019)	
Nistelberger, Heidi M.	Genetic drift drives evolution in the bird-pollinated, terrestrial island endemic Grevillea georgeana (Proteaceae)	Heidi M. Nistelberger, Margaret Byrne, David Coates, J. Dale Roberts	2015		Sourced from: Botanical journal of the Linnean Society. - Vol. 178 (2015)	
Binks, R. M.	Genetic entities and hybridisation within the Acacia microbotrya species complex in Western Australia	R.M. Binks, M. O'Brien, B. MacDonald, B. Maslin, M. Byrne	2015		Sourced from: Tree genetics and genomes. - Vol. 11 (2015)	
Krauss, Siegfried L.	Genetic impacts of habitat loss on the rare banded ironstone formation endemic Ricinocarpos brevis (Euphorbiaceae)	Siegfried L. Krauss and Janet M. Anthony	2019		Sourced from: Australian journal of botany. - Vol. 67 (2019)	
Butcher, P. A.	Genetic impacts of habitat loss on the rare ironstone endemic Tetratheca paynterae subsp. paynterae	P. A. Butcher, S. A. McNee, S. L. Krauss	2009		Sourced from: Conservation genetics. - Vol. 10 (2009)	
Moran, G. F.	Genetic mapping and breeding of temperate eucalypts in Australia	G.F. Moran and M. Byrne	nd		In: International Wood Biotechnology Symposium (IWBS): August 31-September 1, 1994 Tohyo, Japan	
	Genetic mapping of seedling traits in Eucalyptus nitens	G.F. Moran ... [et al.]	nd		In: Eucalypt plantations : improving fibre yield and quality : CRCTHF-IUFRO Conference, Hobart, Australia, 19-24 February 1995 / B.M. Potts (managing editor) ; N.M.G. Borralho ... [et al.] (co-editors)	
Byrne, Margaret	Genetic relationships in the E. kochii group of oil mallees	Margaret Byrne	1999		Reprinted from: Dinkum oil. - Vol. 13 (1999)	
	Genetic risk assessment to complement weed risk assessment in the selection and management of perennial species for agricultural systems in southern Australia	Christine Munday ... [et al.]	nd			
	Genetic structure in the priority one species genus sp. Yalgoo (J.M. Ward s.n. 11/7/1999)	David J. Coates ... [et al.]	1999	Dept. of Conservation & Land Management		
Byrne, Margaret	Genetic variation captured in dieback resistant jarrah clones : report to Alcoa Ltd	Margaret Byrne	2004	Dept. of Conservation & Land Management		

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Wood, C.	Genetic variation within and between populations of Posidonia sinuosa Cambridge and Kuo	Wood, C., Walker, D.I. and Byrne, M.	1997	Conference Organising Committee	Sourced from: Conference abstracts : proceedings of the 44th Annual Conference of the Genetics Society of Australia Inc. held in the Weatherburn Lecture Theatre ... 1997	
Byrne, Margaret	Genetic works to delineate threatened flora species for recovery priority setting : Dryandra mimica (Banksia mimica)	Margaret Byrne and Melissa Millar	2008	Dept. of Environment & Conservation		
Byrne, Margaret	Genetic works to delineate threatened flora species for recovery priority setting : Pultenaea pauciflora	Margaret Byrne and Melissa Millar	2008	Dept. of Environment & Conservation		
Byrne, Margaret	Genetics and ecology of plant species occurring on the banded iron formations in the Yilgarn, Western Australia	Margaret Byrne	2019		Sourced from: Australian journal of botany. - Vol. 67 (2019)	
Byrne, Margaret	Granite outcrops as ancient islands in old landscapes : evidence from the phylogeography and population genetics of Eucalyptus caesia (Myrtaceae) in Western Australia	Margaret Byrne and Stephen Hopper	2007	Dept. of Environment & Conservation		
Byrne, M.	High genetic identities between three oil mallee taxa, Eucalyptus kochii ssp. kochii ssp. plenissima and E. horistes based on nuclear RFLP analysis	M. Byrne	1999		Reprinted from: Heredity. - Vol. 82 (1999)	
Millar, Melissa A.	High levels of gene flow but low levels of hybrid progeny in genetically divergent taxa in the Acacia saligna species complex of southwestern Australia	Melissa A. Miller, Margaret Byrne	2007	Conference Organising Committee	Reprinted from: Evolution 2007, Christchurch, New Zealand.16-20 June, 2007	
	High levels of genetic contamination in remnant populations of Acacia saligna from a genetically divergent planted stand	Melissa A. Millar ... [et al.]	2012		Sourced from: Restoration ecology. - Vol. 20 (2012)	
	High levels of outcrossing in a family trial of Western Australian sandalwood (Santalum spicatum)		2007		Reprinted from: Silvae genetica. - Vol. 56 (2007)	
Byrne, M.	High nuclear genetic differentiation, but low chloroplast diversity in a rare species, Aluta quadrata (Myrtaceae), with a disjunct distribution in the Pilbara, Western Australia	M. Byrne, D.J. Coates, B.M. Macdonald, M. Hankinson, S.M. McArthur and S. van Leeuwen	2016		Sourced from: Australian journal of botany. - Vol. 64 (2016)	
	High outcrossing and random pollen dispersal in a planted stand of Acacia saligna subsp. saligna revealed by paternity analysis using microsatellites	M.A. Millar ... [et al.]	2008		Reprinted from: Tree genetics and genomes. - Vol. 4 (2008)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
	How does the post-fire facultative seeding strategy impact genetic variation and phylogeographical history? : the case of Bossiaea ornata (Fabaceae) in a fire-prone, Mediterranean-climate ecosystem	Donna Bradbury, Sarah-Louise Tapper, David Coates, Margaret Hankinson, Shelley McArthur, Margaret Byrne	2016		Sourced from: Journal of biogeography. - Vol. 43 (2016)	
	Identification and mode of action of quantitative trait loci affecting seedling height and leaf area in Eucalyptus nitens	M. Byrne... [et al.]	nd		In: Theoretical and applied genetics. - Vol. 94 (1997)	
	Identification of quantitative trait loci influencing frost tolerance in Eucalyptus nitens	M. Byrne... [et al.]	nd		In: Theoretical and applied genetics. - Vol. 95 (1997)	
Ayre, Bronwyn	Impact of nectar-feeding birds and European honeybee's on Anigozanthos manglesii's reproductive success	Bronwyn Ayre, Siegy Krauss, David Roberts Janet Anthony, Ryan Phillips, Stephen Hopper	2018	Conference Organising Committee	Sourced from: Book of abstracts : annual conference, Ecological Society of Australia, 25-29 November 2018, Royal International Convention Centre, Brisbane, Qld: Ecology in the Anthropocene	
Ayre, B.	Importance of pollen dispersal distance on the reproductive success of the bird-pollinated Anigozanthos manglesii	B. Ayre, S. Krauss, D. Roberts, J. Anthony, R. Phillips, S. Hopper	2017	Conference Organising Committee	Sourced from: EcoTAS 2017, the joint conference of the Ecological Society of Australia and the New Zealand Ecological Society, 26 November-1 December 2017, Cypress Lakes Conference Centre, Hunter Valley, NSW	https://protect-au.mimecast.com/s/JPfLCp81gYCl2NE8FkIZ71?domain=kaigi.eventsair.com
Krauss, Siegy	Inbreeding and outbreeding depression in Stylidium hispidum : implications for mixing seed sources for ecological restoration	Siegy Krauss, Kristina Hufford, Erik Veneklaas	2018	Conference Organising Committee	Sourced from: Book of abstracts : annual conference, Ecological Society of Australia, 25-29 November 2018, Royal International Convention Centre, Brisbane, Qld: Ecology in the Anthropocene	
	Increased ecological amplitude through heterosis following wide outcrossing in Banksia ilicifolia R.Br. (Proteaceae)	B. Heliyanto ... [et al.]	2006		Reprinted from: Journal of evolutionary biology. - Vol. 19 (2006)	
Miranda, Isabel	Influence of provenance, subspecies and site on wood density in Eucalyptus globulus Labill.	Isabel Miranda	2001		Reprinted from: Wood and fiber science. - Vol. 33 (2001)	
Coleman, P.	Intracontinental orogenesis in the heart of Australia : structure, provenance and tectonic significance of the Bentley supergroup, western Musgrave Block, Western Australia	by P. Coleman	2009	Geological Survey of W.A.	In: Geological Survey of Western Australia products, 2009-10	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Byrne, M.	Intraspecific phylogeography and genetic structure in eucalypt species	M. Byrne	1999		Reprinted from: Program and Abstracts: Symposium on Molecular Genetics of Eucalypts: University of Tasmania, Hobart, Tasmania, 4-5th February, 1999 (1999)	
	Isolated with persistence or dynamically connected? : genetic patterns in a common granite outcrop endemic	S.-L. Tapper ... [et al.]	2014		Sourced from: Diversity and distributions. - Vol. 20 (2014)	
Annels, A. R.	Karri provenance trials	A.R. Annels	1977		In: Forest notes. - Vol. 15, no. 2 (1977)	
Butcher, P. A.	Life on the edge : conservation biology of the ironstone endemic Tetratheca paynterae	P.A. Butcher and S.L. Krauss	2005	Dept. of Conservation & Land Management	In: Advances in plant conservation biology : implications for flora management and restoration : symposium program and abstracts 25-27 October 2005 / Dept. of Conservation & Land Management, Botanic Gardens & Parks Authority (WA)	
Butcher, P. A.	Limited pollen-mediated dispersal and partial self-incompatibility in the rare ironstone endemic Tetratheca paynterae subsp. paynterae increase the risks associated with habitat loss	P. A. Butcher, D. Bradbury, S. L. Krauss	2011		Sourced from: Conservation Genetics. - Vol. 12 (2011)	
	Linear population shape reduces ecological and genetic function in a bird-pollinated plant	Tanya Llorens ... [et al.]	2012	Conference Organising Committee	Sourced from: Society for Ecological Restoration Australasia Conference : Perth, Western Australia, Australia, 28-30 November 2012 : program and conference abstracts / L. Commander, J. Stevens and K. Dixon (eds.)	
Wheeler, M. A.	Little genetic differentiation within the dominant forest tree, Eucalyptus marginata (Myrtaceae) of south-western Australia	M.A. Wheeler	2003		Sourced from: Silvae genetica. - Vol. 52 (2003)	
	Local provenance and identification of historical refugia in Eucalyptus leucophloia in the Pilbara	Margaret Byrne ... [et al.]	2012	Conference Organising Committee	Sourced from: Society for Ecological Restoration Australasia Conference : Perth, Western Australia, Australia, 28-30 November 2012 : program and conference abstracts / L. Commander, J. Stevens and K. Dixon (eds.)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Sampson, Jane F.	Long-term islands in the landscape : low gene flow, effective population size and genetic divergence in the shrub Hakea oldfieldii (Proteaceae)	Jane F. Sampson, Maggie Hankinson, Shelley McArthur, Sarah Tapper, Margaret Langley, Neil Gibson, Colin Yates and Margaret Byrne	2015		Sourced from: Botanical journal of the Linnean Society. - Vol. 179 (2015)	
	Maintenance of high pollen dispersal in Eucalyptus wandoo, a dominant tree of the fragmented agricultural region in Western Australia	Margaret Byrne ... [et al.]	2008		Reprinted from: Conservation Genetics. - Vol. 9 (2008)	
Hart, A. J.	Marri provenance trials, Clarks Road, Harvey	by A.J. Hart	1978		Sourced from: Forest notes. - Vol. 16, no. 1 (1978)	
	Mating system studies in jarrah, Eucalyptus marginata (Myrtaceae)	M.A. Millar ... [et al.]	2000		Sourced from: Australian journal of botany. - Vol. 48 (2000)	
Krauss, Siegy	Measuring and managing genetic erosion in plant translocation: lessons from Grevillea scapigera	Siegy Krauss, Bob Dixon, Bronwyn Ayre, Janet Anthony	2018	Conference Organising Committee	Sourced from: APCC12 abstracts : 12th Australasian Plant Conservation Conference 2018, 11-15 November 2018, CSIRO, Canberra	
George, N.	Mixed mating with preferential outcrossing in Acacia saligna (Labill.) H.Wendl. (Leguminosae: Mimosoideae)	by N. George, M. Byrne and G. Yan	2008		Reprinted from: Silvae genetica. - Vol. 57 (2008)	
Byrne, M.	Molecular genetic diversity in the oleosa group of oil mallees and implications for conservation	M. Byrne	1998		Reprinted from: Biodiversity, Biotechnology & Biobusiness: 2nd Asia-Pacific Conference on Biotechnology: Perth, Western Australia, 23-27 November 1998: Programme and Abstracts (1998)	
Ayre, Bronwyn M.	Near-neighbour optimal outcrossing in the bird-pollinated Anigozanthos manglesii	Bronwyn M. Ayre, David G. Roberts, Ryan D. Phillips, Stephen D. Hopper, Siegfried L. Krauss	2019		Sourced from: Annals of botany. - Vol. 124 (2019)	
Mazanec, R.	Nine year results from a Eucalyptus camaldulensis Dehnh. provenance trial in the Wellington catchment of Western Australia	R. Mazanec	1999		Sourced from: Australian forestry. - Vol. 62 (1999)	
Bezemer, Nicole	No evidence for early inbreeding depression in planted seedlings of Eucalyptus caesia, an anciently fragmented tree endemic on granite outcrops	Nicole Bezemer, Siegy L. Krauss, David G. Roberts	2019		Sourced from: Plant ecology. - Vol. 220 (2019)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Binks, Rachel M.	Not all rare species are the same : contrasting patterns of genetic diversity and population structure in two narrow-range endemic sedges	Rachel M. Binks, Melissa A. Millar, Margaret Byrne	2015		Sourced from: Biological journal of the Linnean Society. - Vol. 114 (2015)	
	Patterns of genetic diversity in two key understorey species, Allocasuarina humulis and Kennedia coccinea, used for forest rehabilitation in Western Australia : implications for seed sourcing	David Coates ... [et al.]	2012	Conference Organising Committee	Sourced from: Society for Ecological Restoration Australasia Conference : Perth, Western Australia, Australia, 28-30 November 2012 : program and conference abstracts / L. Commander, J. Stevens and K. Dixon (eds.)	
Sampson, Jane	Persistence with episodic range expansion from the early Pleistocene: the distribution of genetic variation in the forest tree Corymbia calophylla (Myrtaceae) in south-western Australia	Jane Sampson, Sarah Tapper, David Coates, Maggie Hankinson, Shelley McArthur and Margaret Byrne	2018		Sourced from: Biological journal of the Linnean Society. - Vol. 123 (2018)	
Byrne, M.	Phylogenetic relationships between two rare acacias and their common, widespread relatives in south-western Australia	M. Byrne	2001		Reprinted from: Conservation genetics. - Vol. 2 (2001)	
Byrne, M.	Phylogenetic structure in the York gum complex, Eucalyptus loxophleba, E. gratiae and E. blaxelliit	M. Byrne	2000		Reprinted from: Genetics Society of Australia : 47th Annual Meeting (2000)	
Elliott, C. P.	Phylogenetics and the conservation of rare taxa in the Eucalyptus angustissima complex in Western Australia	C.P. Elliott & M. Byrne	2004		Sourced from: Conservation genetics. - Vol. 5 (2004)	
Funnekotter, Anna V.	Phylogeographic analyses of Acacia karina (Fabaceae) support long term persistence of populations both on and off banded ironstone formations	Anna V. Funnekotter, Melissa Millar, Siegfried L. Krauss and Paul G. Nevill	2019		Sourced from: Australian journal of botany. - Vol. 67 (2019)	
Byrne, M.	Phylogeography and conservation of three oil mallee taxa, Eucalyptus kochii ssp. kochii, ssp. plenissima and E. horistes	M. Byrne and B. Macdonald	2000		Sourced from: Australian journal of botany. - Vol. 48 (2000)	
Millar, M. A.	Pollen contamination in Acacia saligna: assessing the risks for sustainable agroforestry	M.A. Millar & M. Byrne	2007	WIT Press	Reprinted from: Ecosystems and sustainable development. VI / editors, E. Tiezzi ... [et al.]	
	Pollen dispersal, pollen immigration, mating and genetic diversity in restoration of the southern plains Banksia	Melissa A. Millar ... [et al.]	2020		Sourced from: Biological journal of the Linnean Society. - Vol. 129 (2020)	
Hevroy, Tanya H.	Population genetic analysis reveals barriers and corridors for gene flow within and among riparian populations of a rare plant	Tanya H. Hevroy, Michael L. Moody, Siegfried L. Krauss	2018		Sourced from: AoB plants. - Vol. 10 (2018)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Coates, D. J.	Population phylogeny, genetic structure and the mating system of endangered Lambertia orbifolia (Proteacea) [i.e. Proteaceae] : implications for conservation	D.J. Coates	1998		Reprinted from: Conference Abstracts: 45th Annual Meeting of the Genetics Society of Australia Inc. at the University of Sydney, Thursday October 9-Sunday October 12, 1998 (1998)	
	Population-size effects on seeds and seedlings from fragmented eucalypt populations : implications for seed sourcing for ecological restoration		2007		Sourced from: Australian journal of botany. - Vol. 55 (2007)	
Krauss, S.L.	Preferential outcrossing in the complex species Persoonia mollis R.Br. (Proteaceae)		1994		Reprinted from: Oecologia. - Vol. 97 (1994)	
Bezemer, Nicole	Primary pollinator exclusion has divergent consequences for pollen dispersal and mating in different populations of a bird-pollinated tree	Nicole Bezemer, Stephen D. Hopper, Siegy L. Krauss, Ryan D. Phillips and David G. Roberts	2019		Sourced from: Molecular ecology. - Vol. 28 (2019)	
Binks, Rachel	Progress report for assessment of genetic processes in Lepidosperma sp. Parker Range and Lepidosperma sp. Mt Caudan	Rachel Binks, Melissa Millar and Margaret Byrne ; report submitted to Botanica Consulting and Cazaly Iron Ore Pty Ltd	2012	Dept. of Environment & Conservation		
Gray, Friday	Provenance modulates sensitivity of stored seeds of the Australian native grass Neurachne alopecuroidea to temperature and moisture availability	Friday Gray, Anne Cochrane, Pieter Poot	2019		Sourced from: Australian journal of botany. - Vol. 67 (2019)	
Mazanec, R. A.	Provenance trials of four exotic eucalypts in bauxite mines in Western Australia	R.A. Mazanec	[1994]		Sourced from: Workshop 3 : Revegetation of Mine Sites using Appropriate Species (1994)	
Carnegie, A. J.	Provenance variation in Eucalyptus globulus in susceptibility to Mycosphaerella leaf diseases. Paper		nd			
Breidahl, Richard	Provenance variation in karri	Richard Breidahl	1983	Conference Organising Committee	Sourced from: Research working group no. 1 of the Australian Forestry Council : forest genetics : proceedings of the eighth meeting of representatives held at Perth, Western Australia, 14 to 19 November, 1983 : prepared by Paul Cotterill, chairman	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Mazanec, R. A.	Provenance variation, genetic parameters and potential gains from selection for biomass and cineole production in three-year-old Eucalyptus loxophleba subsp. gratiae progeny trials	R.A. Mazanec, P.M. Grayling, J. Doran, B. Spencer and C. Neumann	2020		Sourced from: Australian forestry. - Vol. 83 (2020)	
	Recent range expansion in Australian hummock grasses (Triodia) inferred using genotyping-by-sequencing	Benjamin M. Anderson ... [et al.]	2019		Sourced from: AoB plants. - Vol. 11 (2019)	
	Regional genetic differentiation in Western Australian sandalwood (Santalum spicatum) as revealed by nuclear RFLP analysis	M. Byrne ... [et al.]	2003		Sourced from: Theoretical and applied genetics. - Vol. 107 (2003)	
Hart, A. J.	Report on Euc. camaldulensis (River gum) provenance trial for insect resistance (W/P28/68)	A.J. Hart	[1968]	Forests Dept.		
Millar, M.	Risk assessment for Acacia saligna agroforestry	M. Millar	2005	Dept. of Conservation & Land Management	Sourced from: Advances in plant conservation biology : implications for flora management and restoration : symposium program and abstracts 25-27 October 2005 / Dept. of Conservation & Land Management, Botanic Gardens & Parks Authority (WA)	
Teixeira da Silva, Jaime A.	Santalum molecular biology : molecular markers for genetic diversity, phylogenetics and taxonomy, and genetic transformation	Jaime A. Teixeira da Silva, Mafatlal M. Kher, Deepak Soner, M. Nataraj, Judit Dobránszki, Melissa A. Millar	2018		Sourced from: Agroforestry systems. - Vol. 92 (2018)	
Bezemer, N.	Sex on the rocks : recruitment genetics of a tree endemic on granite outcrops	N. Bezemer, S.D. Hopper, S.L. Krauss and D.G. Roberts	2018	Royal Society of Western Australia	Sourced from: The Royal Society of Western Australia Symposium, 27-28 July 2018 : Landscapes, Seascapes & Biota: Unique WA: Past, Present & Future : program & abstracts, July 27 & 28, 2018, University Club, the University of Western Australia	
Bezemer, N.	Sex on the rocks: genetic consequences of recruitment after wildfire in a granite-endemic tree	N. Bezemer, S. Hopper, S. Krauss, D. Roberts	2017	Conference Organising Committee	Sourced from: EcoTAS 2017, the joint conference of the Ecological Society of Australia and the New Zealand Ecological Society, 26 November-1 December 2017, Cypress Lakes Conference Centre, Hunter Valley, NSW	https://protect-au.mimecast.com/s/JPfLCp81gYCl2NE8FkIZ71?domain=kaigi.eventsair.com

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Krauss, S. L.	Short- and long-distance seed dispersal in a metapopulation on Banksia hookeriana (Proteaceae)	S.L. Krauss	2004		Reprinted from: Ecology, conservation and management of Mediterranean climate ecosystems : proceedings of the Tenth MEDECOS Conference (2004)	
Coates, David J.	Significant genetic diversity loss following pathogen driven population extinction in the rare endemic Banksia brownii (Proteaceae)	David J. Coates, Shelley L. McArthur, Margaret Byrne	2015		Sourced from: Biological conservation. - Vol. 192 (2015)	
	Significant population genetic structure detected for a new and highly restricted species of Atriplex (Chenopodiaceae) from Western Australia, and implications for conservation management	Laurence J. Clarke ... [et al.]	2012		Sourced from: Australian journal of botany. - Vol. 60 (2012)	
Millar, Melissa A.	Spatial genetic structure in a rare banded ironstone endemic: implications for restoration	Melissa A. Millar and David J. Coates	2010	Australian Network for Plant Conservation	Sourced from: Australian Network for Plant Conservation Inc. : 8th National Conference: Planning conservation to achieving restoration, 28 September to 1 October 2010, Perth, W.A. : program & abstracts	
Wang, Weihui	Species and provenance selection for Eucalyptus leaf oils production	Weihui Wang	1997		Sourced from: Forest research. - Vol. 10 (1997)	
Anderson, B. M.	Taxon delimitation in the Triodia basedowii E.Pritz. species complex	B.M. Anderson, M.D. Barrett, K. Thiele, P. Grierson and S. Krauss	2013	Conference Organising Committee	Sourced from: Systematics without Borders: 1-6 December, 2013, Sydney, Australia	
	Temporal patterns of genetic variation across a 9-year-old aerial seed bank of the shrub Banksia hookeriana (Proteaceae)	Luke G. Barrett ... [et al.]	2005		Reprinted from: Molecular ecology. - Vol. 14 (2005)	
	Tetratheca erubescens translocation, annual research report 3 for Mineral Resources Limited, March 2019 to March 2020	Carole Elliott ... [et al.]	2020	Department of Biodiversity, Conservation & Attractions		
Millar, Melissa	The complex issue of the Acacia saligna species complex	Melissa Millar, Margaret Byrne, Wayne O'Sullivan	2011	Conference Organising Committee	Sourced from: MEDECOS XII: Linking Science to Resource Management : the International Mediterranean Ecosystems Conference : September 6-9, 2011, Los Angeles, California, United States : abstracts	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
	The conservation consequences of promiscuity in a Banksia pollinated by nectar-feeding birds	Siegy Krauss ... [et al.]	2007	Conference Organising Committee	In: ESA 2007, program and abstracts : Ecological Society of Australia, Perth 2007 : Perth Convention and Exhibition Centre, Perth, Australia, 2007, Monday 26th November to Friday 30th November 2007	
Dixon, Bob	The Corrigin grevillea : 12 years of recovery	Bob Dixon and Siegy Krauss	2006		Sourced from: Western wildlife. - Vol. 10, no. 2 (2006)	
Van der Kroft, Tayla	The critical role of honeyeaters in the pollination of the catspaw Anigozanthos humilis (Haemodoraceae)	Tayla van der Kroft, David G. Roberts, Siegfried L. Krauss	2019		Sourced from: Australian journal of botany. - Vol. 67 (2019)	
	The evolutionary and conservation consequences of promiscuity in a Banksia pollinated by nectarfeeding birds	Siegy Krauss ... [et al.]	2007	[Conference Organising Committee]	In: MedEcos XI : conference program, information & summary abstracts : the International Mediterranean Ecosystems Conference, Perth, Western Australia, Australia, Sunday 2-Wednesday 5 September 2007	
Millar, M. A.	The maintenance of disparate levels of clonality, genetic diversity and genetic differentiation in disjunct subspecies of the rare Banksia ionthocarpa.	M.A. Millar, M. Byrne and D.J. Coates,	2010		Sourced from: Molecular ecology. - Vol. 19 (2010)	
Krauss, Siegfried L.	The potential impact of mining on population genetic variation in the banded ironstone formation endemic Tetratheca erubescens (Elaeocarpaceae)	Siegfried L. Krauss and Janet M. Anthony	2019		Sourced from: Australian journal of botany. - Vol. 67 (2019)	
Byrne, M.	The role of genetics in the conservation and utilization of Acacia	M. Byrne	2001	Shire of Dalwallinu	In: Acacia Symposium: the Conservation and Utilisation Potential of Australian Dryland Acacias: 13-14th July, 2001, Dalwallinu, Western Australia	
Mazanec, R. A.	Thirteen year results from a spotted gum provenance trial in the Wellington catchment of Western Australia	R.A. Mazanec	1999		Sourced from: Australian forestry. - Vol. 62 (1999)	
Johnson, I. G.	Thirty years of eucalypt species and provenance trials in New South Wales : survival and growth in trials established from 1961 to 1990	by I.G. Johnson and R.R. Stanton	1993	Forestry Commission of N.S.W.		
Dixon, Bob	Threatened plant translocation case study: Grevillea scapigera (Corrigin grevillea), Proteaceae	Bob Dixon and Siegy Krauss	2019		Sourced from: Australasian plant conservation. - Vol. 27, no. 3 (2019)	

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE	URL
Anderson, Benjamin M.	Untangling a species complex of arid zone grasses (Triodia) reveals patterns congruent with co-occurring animals	Benjamin M. Anderson, Matthew D. Barrett, Siegfried L. Krauss, Kevin Thiele	2016		Sourced from: Molecular phylogenetics and evolution. - Vol. 101 (2016)	
Anderson, Benjamin	Using genotyping by sequencing to resolve evolutionary relationships in a species complex of Australian arid zone grasses (Triodia)	Benjamin Anderson, Matthew Barrett, Pauline Grierson, Siegy Krauss, Kevin Thiele	2015	Conference Organising Committee	Sourced from: Australasian Systematic Botany Society annual conference, Canberra 2015 : Building our botanical capital : program and abstracts	
Nistelberger, H. M.	Using measures of genetic diversity to identify terrestrial islands of conservation value in semi-arid Australia	H.M. Nistelberger, D. Coates, D.J. Roberts, N. Gibson, M. Byrne	nd			
Millar, Melissa A.	Variable clonality and genetic structure among disjunct populations of Banksia mimica	Melissa A. Millar, Margaret Byrne	2020		Sourced from: Conservation genetics. - Vol. 21 (2020)	
Wills, Allan	Variation across provenance regions and families for damage to Eucalyptus globulus leaves by chewing insects	Alan Wills and Tom Burbidge	1995	Dept. of Conservation & Land Management		
Pryor, L. D.	Variation and taxonomy in Eucalyptus camaldulensis	by L.D. Pryor and C.R. Byrne	1970		Reprinted from: Silvae genetica. - Vol. 18 (1969-1970)	
Wheeler, M.	Variation in cpDNA haplotypes of Eucalyptus marginata	M. Wheeler	2003		Reprinted from: Abstracts and posters : XIX International Congress of Genetics : Genomes, the Linkage to Life: 6-11 July, 2003: Melbourne Exhibition and Convention Centre, Victoria, Australia (2003)	
Ritchie, Alison L.	Wide outcrossing provides functional connectivity and resilience to habitat fragmentation for old and new Banksia populations	Alison L. Ritchie, Rodney J. Dyer, Paul G. Nevill, Elizabeth A. Sinclair, Siegfried L. Krauss	2019		Sourced from: Oecologia. - Vol. 190 (2019)	
		Elizabeth A. Sinclair ... [et al.]	2018		Sourced from: Molecular ecology. - Vol. 27 (2018)	

TABLE 4. GENERAL INFORMATION ON PROVENANCE AND SEED SOURCING — ADDITIONAL REFERENCES OBTAINED FROM THE WESTERN AUSTRALIAN DEPARTMENT OF BIODIVERSITY, CONSERVATION AND ATTRACTIONS' LIBRARY FOR BYRNE, M., KRAUSS, S., AND MILLAR, M

AUTHOR	TITLE	RESPONSIBILITY	DATE	PUBLISHER	SOURCE
Ramalho, Cristina E.	A climate-oriented approach to support decision-making for seed provenance in ecological restoration	Cristina E. Ramalho, Margaret Byrne, Colin J. Yates	2017		Sourced from: Frontiers in ecology and evolution. - Vol. 5 (2017)
	A diverse flora : species and genetic relationships	Margaret Byrne ... [et al.]	2014	UWA Publishing	Sourced from: Plant life on the sandplains in southwest Australia : a global biodiversity hotspot : kwongan matters / Hans Lambers, editor
	A framework for the practical science necessary to restore sustainable, resilient and biodiverse ecosystems	Ben P. Miller ... [et al.]	2017		Sourced from: Restoration ecology. - Vol. 25 (2017)
	A manual on species and provenance research with particular reference to the tropics	compiled by J. Burley and P.J. Wood	1976	Commonwealth Forestry Institute, Dept. of Forestry	
Byrne, Margaret	A molecular journey in conservation genetics	Margaret Byrne	2018		Sourced from: Pacific conservation biology. - Vol. 24 (2018)
Ramalho, Cristina E.	A spatially explicit approach to support the decision-making process on seed provenance for ecological restoration in a climate change context	Cristina E. Ramalho, Margaret Byrne, Colin Yates	2016	Dept. of Parks & Wildlife	
	Adaptation to climate in widespread eucalypt species : climate-resilient revegetation of multi-use landscapes: exploiting genetic variability in widespread species	Margaret Byrne ... [et al.]	2013	National Climate Change Adaptation Research Facility	
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	Assessing genetic connectivity across a fragmented landscape	T.M. Llorens ... [et al.]	2007	Conference Organising Committee	Sourced from: ESA 2007, program and abstracts : Ecological Society of Australia, Perth 2007 : Perth Convention and Exhibition Centre, Perth, Australia, 2007, Monday 26th November to Friday 30th November 2007
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