Florabank Guidelines

Module 1

Introduction

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The update of the Florabank Guidelines was funded by the New South Wales Government through its Environmental Trust, as part of the Healthy Seeds Project, and administered by the Australian Network for Plant Conservation (ANPC). It was overseen by the **Healthy Seeds Consortium** consisting of representatives from the ANPC, Australian Association of Bush Regenerators, Australian Seed Bank Partnership, Centre for Australian National Biodiversity Research, Greening Australia (GA), NSW Department of Planning Industry and Environment, Royal Botanic Gardens and Domain Trust, and the Society for Ecological Restoration Australasia. The **Florabank Consortium** which will oversee implementation of the Guidelines consists of the Australian National Botanic Gardens, ANPC, CSIRO and GA.

Key points

The Florabank Guidelines are a set of best-practice guidelines for the collection and use of native Australian seeds in restoration, and other related activities.

This version of the Guidelines (version 2) updates the original Guidelines, published in 1999.

Guidelines are required to ensure that seed collection has minimal impact on wild populations, and that high quality, appropriately sourced seeds are supplied.

A sound understanding of species ecology and adequate surveys are required to select species for restoration, and hence develop species lists for seed supply.

The revision and update of the Guidelines have been funded by the NSW Environmental Trust, through the Healthy Seeds Project, administered by the Australian Network for Plant Conservation and a consortium of seven other organisations.

The Guidelines are a result of a large collaboration between organisations and individuals across Australia and globally.

Florabank Guidelines: version 2

The first edition of the Florabank Guidelines (1999) was a set of 10 documents which consolidated existing information on seeds and practices at seedbanks across Australia. Florabank was originally a partnership between Greening Australia, CSIRO Forestry and Forest Products through the Australian Tree Seed Centre and the Australian National Botanic Gardens, with funding from the Bushcare program of the Natural Heritage Trust. Its aim was to support the increasing activities in plant and ecosystem restoration in Australia. The Guidelines are widely used, and were the most influential guidelines for seed collectors and native nursery workers surveyed by Cooper et al. (2018). Florabank Guidelines are cited in:

- NSW Seed Collection licence conditions;
- Revegetation Industry Association of WA (RIAWA) Seed Industry standards;
- National standards for the practice of ecological restoration in Australia (Standards Reference Group SERA, 2017);
- IUCN Guidelines for Seed Conservation website;
- roadside vegetation management plans; and
- documentation demonstrating adherence to good practice in native nurseries (e.g. https://plantsandlandscapes.com.au/nurseries/ and https://www.nativeplantswa.org.au/local-native-plants/).

This second edition of the Florabank Guidelines, allowing an update and enhancement of the original document, has been funded by the NSW Environmental Trust, through the Healthy Seeds Project. The project is administered by the Australian Network for Plant Conservation and a consortium of seven other organisations (Australian Association of Bush Regenerators; Australian Seed Bank Partnership; Centre for Australian National Biodiversity Research; Greening Australia NSW Government; Society for Ecological Restoration Australasia; The Royal Botanic Gardens and Domain Trust).

In these Guidelines, the sourcing and use of seeds for restoration and other conservation purposes is comprehensively outlined. The second edition updates the original Guidelines, incorporating new information generated by a further 20 years of research and practice, including:

- Advances in seed technology, direct seeding equipment and plant establishment.
- Information about seed collection, handling, storage and germination.
- Improvement in understanding provenance choice.
- Greater establishment of seed production areas.
- Improved understanding of the ecology of plant species and ecological communities.
- Updated policies and licence requirements.

Maintaining and restoring natural systems in Australia: the need for seeds

The Australian landscape has been modified and managed for at least 60,000 years, however, change and degradation have accelerated in the past 250 years since European colonisation. Clearing, land-use change, management practices and other threats to biodiversity are some of the main pressures affecting the environment (Jackson et al. 2016). Some areas of native vegetation are relatively intact, but require ongoing management of threats to maintain biodiversity (including soil seedbanks) within them. Other areas of vegetation no longer support several ecological functions (e.g. pollination, dispersal), nor provide ecosystem services (e.g. food and habitat for fauna, clean water). A number of areas have been completely cleared of vegetation, and soil may have been removed or replaced.

Areas that might require restoration include (Figure 1):

- degraded sites – urban and regional (e.g. abandoned farmland, saline land, remnant bushland, riparian areas, wind breaks, remnant roadside vegetation, previously cleared areas, road batters, coastal dunes);
- degraded or altered water courses (e.g. drains that can be converted into living streams);
- fire-affected areas unable to recover without intervention (i.e. too frequent fires, already degraded sites);
- sites impacted by mining and quarrying activities (e.g. borrow pits, waste rock dumps, tailings facilities);
- areas recovering from selective logging and intensive timber harvest operations;
- development offsets and carbon offsets; and
- areas supporting the native food sector.

Areas which may be prioritised for restoration include:

- sites with important ecological roles in landscape conservation (habitat, dispersal or migration pathways etc);
- areas of biodiversity significance, such as habitat for threatened species, threatened ecological communities and Key Biodiversity Areas; and
- areas of cultural/historic significance.



Figure 1. Areas that might require restoration include (left to right) former agricultural areas; degraded coastal dunes in urban areas; sites impacted by mining. (Photos: L Commander)

If plant species are unable to naturally regenerate, for instance from the existing **soil seedbank** or seed dispersal from surrounding areas, and need to be reintroduced, then re-establishment of vegetation is generally most efficient and effective using seeds of target species. Most plants produce seeds as their regeneration unit. Seeds may germinate once sown into the appropriate substrate, provided there is adequate moisture and the temperature is right, although some seeds require specific environmental conditions to alleviate dormancy before germination. Direct application of seeds also immediately provides some capacity for re-establishment or tolerating disturbances, although this capacity may be limited when compared to natural seedbanks in functioning ecosystems. If properly sourced, seeds should provide sufficient genetic diversity to allow effective ecosystem restoration and ongoing persistence of taxa. In some instances, seeds are directly placed into the landscape through hand or mechanical means of direct seeding. In other instances, seeds are used to grow **tubestock**, which are then planted out (Figure 2). These two methods (seeding and planting) can be used simultaneously at a site.

Figure 2. Seeds can be used to grow tubestock, which are then planted into the restoration area. (Photo: L Commander)

Seeds of native species are also used for research purposes (e.g. to investigate questions relating to seed ecology or community ecology, under laboratory, glasshouse or field conditions), plant breeding, ex situ conservation (i.e. in ex situ seedbanks), in Botanic Gardens, and amenity horticulture (i.e. parks and gardens) (Figure 3). Information and knowledge generated from these activities can be used to inform restoration and conservation, in particular seed storage and propagation (Figure 4; see also Martyn Yenson et al. (2021)).

Figure 3. Seeds can also be used in Botanic Gardens and amenity horticulture. (Photo: L. Commander)

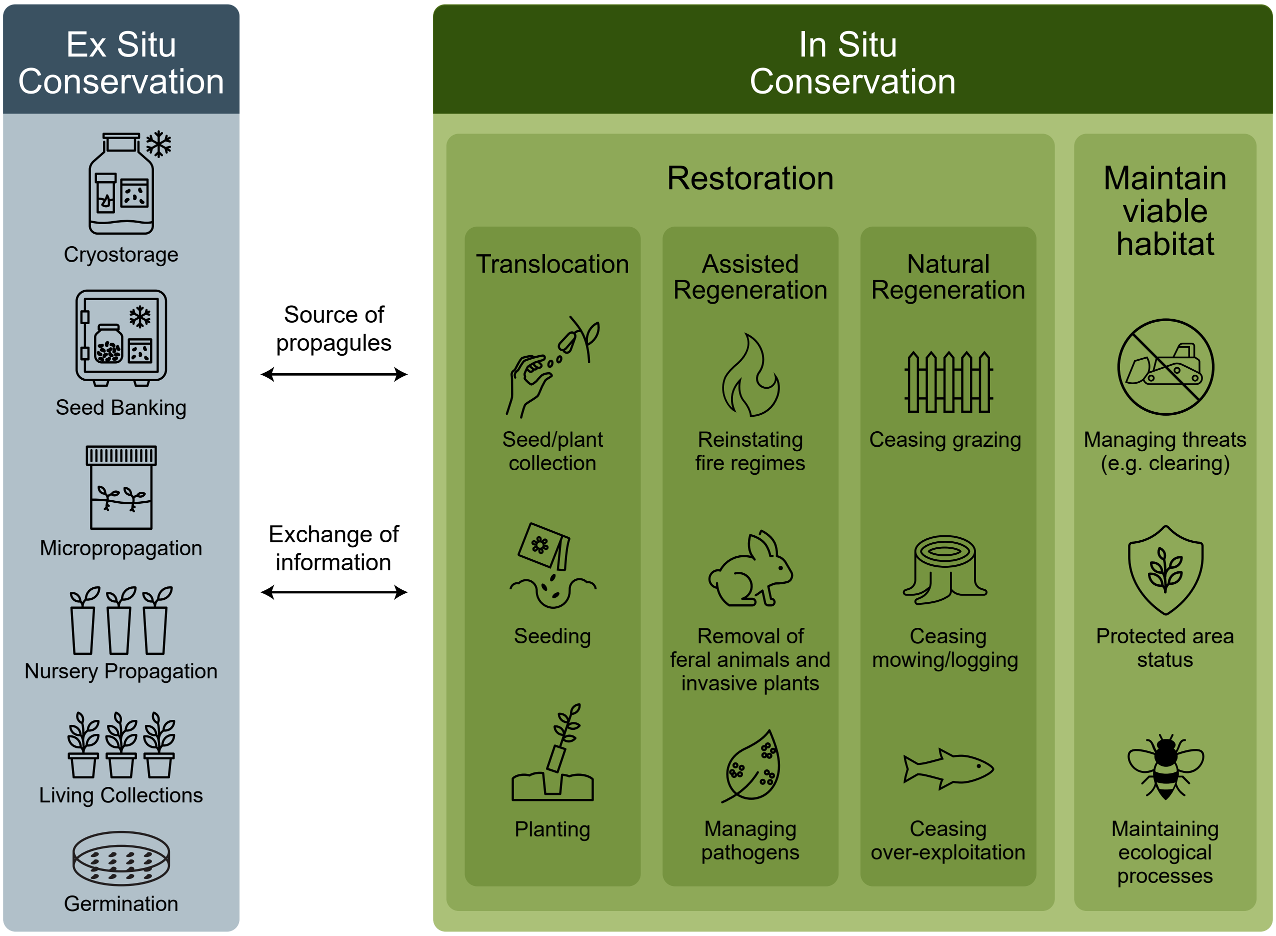


Figure 4. In situ and ex situ activities can support each other, for instance, ex situ research on germination can support actions like seeding and planting, and in situ seed collection can support ex situ seedbanking and living collections. (Figure prepared by Craig Miskell, CAM Graphics)

Box 1. What do we mean by 'conservation' and 'restoration'?

Conservation is the protection, care, management and maintenance of ecosystems, habitats, wildlife species and populations, within (**in situ**) or outside (**ex situ**) of their natural environments, in order to safeguard the natural conditions for their long-term permanence. **Ecological restoration** can contribute to conservation, as it is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Throughout these Guidelines, we use the term 'restoration' to encompass both **rehabilitation** and ecological restoration, as they are both **restorative activities**; that is, they are approaches that seek to address ecosystem damage. Planting and seeding are considered to be **reintroductions/reinforcements**, and are an appropriate approach when **natural regeneration** or **assisted regeneration** is low or not possible. **Translocation** is the deliberate transfer of plants or regenerative plant material from an ex situ collection or natural population, usually in the wild, and is often used in the context of threatened species. Hence, these Guidelines are applicable to all activities using native Australian plants to improve environmental conditions and reverse ecosystem degradation and landscape fragmentation. For more information on ecological restoration, see Gann et al. (2019).

Restoration does not replace preservation or protection

Despite the advances in knowledge and technology, and the resulting improvements made to the success of restoration, the ability to restore should never be used as a justification for activities that negatively impact plant communities and the ecological processes that allow their ongoing persistence (Figure 5). Protecting plant communities from threats is likely to be more effective and less expensive than restoration, and restoration can have a higher risk of failure depending on the scale of degradation. Hence, these Guidelines should not be used to encourage modification of existing natural plant communities; rather, they should be used to encourage the repair of historical damage.

Figure 5. The ability to do restoration does not replace the need to protect and manage threats in plant communities. The in situ protection of plant communities, including the management of threats, should take priority over restoration which can be performed as a complementary action. (Photo: L. Commander)

Regeneration versus reintroduction: the role of seeds?

Plant species in natural systems often rely on seeds for both dispersal and recruitment of new plants to replace those that die. Canopy or **soil seedbanks** buffer the species against declines and losses in above ground plants, with such declines often driven by dry conditions, fire, flood and other disturbances. Natural disturbances often promote recruitment from a seedbank but the success of this process can be affected by changes to natural disturbance regimes (e.g. altered fire frequency and/or intensity) and threats to the survival of recruiting plants (e.g. grazing by feral herbivores, competition from weeds).

In many instances, natural ecosystems recover after disturbance provided sufficient viable seeds are available in the seedbank, and/or plants can resprout, and the threats are mitigated. In these circumstances, additional provision of seeds is not required for restoration or recovery after disturbance. For instance, if degradation is caused by overgrazing, but the soil seedbank is largely intact, or it is possible for plants to regrow from buds in stems or from underground organs, then fencing may be the best option to initiate restoration in combination with a plan to manage grazing levels in the future. This restoration strategy is called **natural regeneration**. If invasive species are outcompeting natives, and if methods of invasive species control that effectively reduce this adverse impact are used, then the native species may recover. This restoration strategy is termed **assisted regeneration**, and apart from threat mitigation, does not require seed input from human intervention.

However, if threats are pervasive and ecological processes are disrupted, not all species may be able to recover naturally from their existing seedbanks (or dormant buds) or via dispersal of seeds from other intact habitats. In such cases, when there is limited potential for natural regeneration or assisted regeneration, **reintroductions** will be needed. For instance, when ecosystems become very degraded, or are cleared completely, soil seedbanks may be depleted, certain species may have become locally extinct, or the populations are isolated and regenerative material is unavailable for colonisation (i.e. it is too far for seed dispersal from other populations). Seed inputs into such degraded habitats are considered **reintroduction** (if target species cannot colonise without assistance), or **augmentation** or **reinforcement** (where genetic diversity and the number of individuals is not sufficient without intervention). In cases where an ecosystem has been completely destroyed, full reconstruction of the ecosystem may be needed, relying entirely on **reintroductions** (Gann et al. 2019).

A comprehensive site assessment will help inform restoration strategies, and whether a regeneration approach or minor or major levels of reintroduction are more appropriate. Assessments may require multiple years to accurately determine the correct strategy when several threats are present, and assessments of the soil seedbank may need to be done in a particular season (e.g. for annuals), in response to sufficient rainfall (e.g. ephemerals) or under ex situ conditions.

Why do we need native seed-use Guidelines?

There are multiple decisions that need to be made when using native seeds for restoration. Guidelines can help to help inform these decisions. These decisions may include:

- Which species to collect?
- Can we collect enough species?
- How can we increase species diversity?
- How can we ensure the correct species can be collected at the right time, and within the required timeframe?
- Are there enough seeds, or is demand greater than supply?
- What level of seed depletion from wild habitats can be tolerated before natural systems are themselves degraded and become less resilient to disturbances and threats?
- Ideally, from which locations should the seeds be sourced, and practically, where are they available?
- What licences and authorisations do we need?
- What hygiene protocols are needed to prevent spread or introduction of pathogens or weeds species?
- How do we know the quality of the seed we're buying?
- Has the seed been sourced sustainably, i.e. with no detrimental impacts on natural populations?
- Do seeds need a pre-treatment to germinate? Which pre-treatment(s)?
- How do we store seeds?
- How and when (i.e. which season) do we sow seeds when undertaking restoration?
- How do we monitor restoration, and what ongoing management is required?

What is the Australian native seed industry?

The Australian native seed industry comprises both individuals and businesses who supply and use seed. A recent review gives us a snapshot of the Australian native seed industry (Hancock et al. 2020). Most seed purchasers (48%) are employed by local or state government, while most seed collectors are employed within commercial organisations (43%), or non-government organisations (23%) (Figure 6). Most seed collectors are sole operators or employ fewer than five people. However, a small proportion of companies employ many people (Figure 7). The mining industry requires large volumes of seeds (Merritt and Dixon 2011).

Native seed is mostly sourced from private land, public reserves and roadside tenures (Hancock et al. 2020). As a significant proportion of seed collecting is not done under licence, it is difficult to capture the full extent of harvesting, and therefore to adequately assess the sustainability and impacts of harvesting across the industry, particularly impacts on resilience of native habitats (which themselves depend on their seedbanks for persistence). Sustainable harvesting practices are crucial to supply seed for restoration, along with protecting the native vegetation on which seed collection relies.

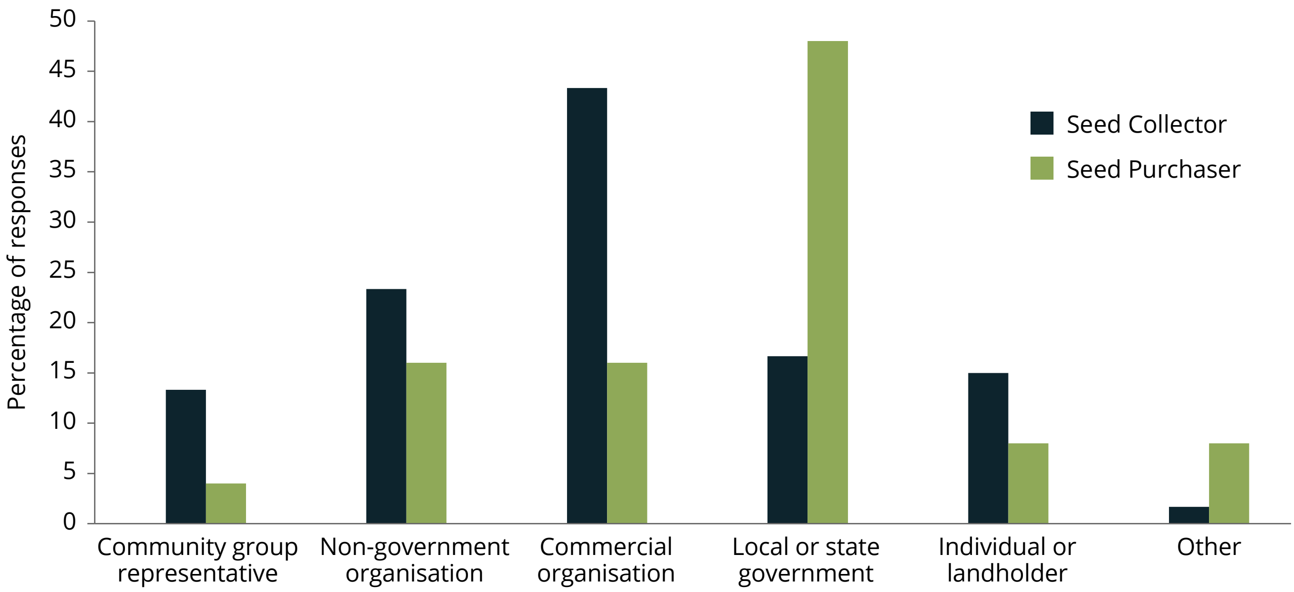


Figure 6. Who's who in the seed industry. Percentage of seed collectors and seed purchasers in each sector (community group, NGO, commercial, government, individual or landholder, other) who responded to the Seed Survey. From Hancock et al. (2020). Used with permission.

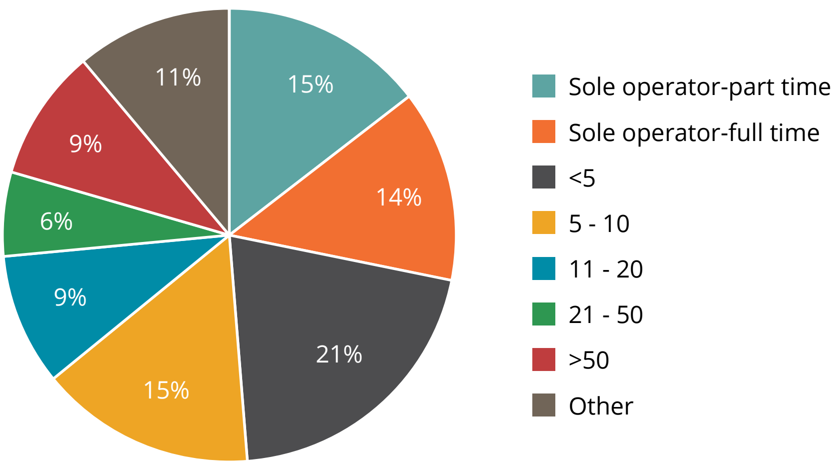


Figure 7. Percentage of respondents to the Seed Survey in each staffing category. Size of businesses in the seed industry ranged from sole operators to over 50 employees. From Hancock et al. (2020). Used with permission.

The key issues in the seed industry

The native seed industry is an important part of the ecological restoration sector, and the challenges that need to be addressed by restoration also impact on the availability of seed for collection. These challenges include land clearing, fire, erosion, vegetation fragmentation, climate change, overgrazing and invasive species (Hancock et al. 2020) as all these factors limit seed availability and quality.

A recent survey (Hancock et al. 2020) has highlighted a number of issues in the Australian seed industry that affect the use of seeds in restoration of habitats. These include, but are not limited to:

- a lack of seed available for a broad range of species being used for restoration;
- the majority of seed collections or seed purchases made annually are small in volume (i.e. usually <5 kg) suggesting that overall native seed volumes (supplied or purchased) are modest in quantity and may not be sufficient to support large-scale restoration;
- inconsistent and unpredictable demand for native seed;
- native seed is not commonly tested to determine its quality attributes;
- seed price does not cover the true cost;
- a small workforce which has training requirements;
- current provenance range stipulations are considered too restrictive;
- a large proportion of the seed harvested by seed suppliers comes from geographic ranges that greatly exceed those considered to be 'local provenance'; and
- currently, seed purchasers require a greater amount of species diversity than seed collectors are able to supply; and seed purchasers often accept seed from locations much farther away from the planting site than is commonly thought.

These Guidelines address some of these issues by providing advice on how planning informs species selection for seed-based restoration (this module), options for seed sourcing (Module 5), how to undertake quality testing and interpret quality tests (Module 10). The issues surrounding demand for native seed (volume, unpredictability, sustainability) may need to be addressed by medium to long term (5–10 year) coordination and planning of restoration at a regional level, and by including all sectors of the restoration community (government, NGO, mining, consultants, practitioners and volunteers) (Driver and Commander, in prep). To achieve medium to long term planning, funding terms for restoration projects may need to be increased, and extended across multiple years, rather than funded on an annual basis, as can sometimes be the case. This type of planning would inform development of Seed Production Areas (Module 7) and regional requirements for seed storage (Module 9). Results from nursery propagation (Module 13) and direct seeding (Module 14) could also then more easily be shared. By increasing predictability around seed supply through better restoration planning, seed collectors would have more secure employment, and may be able to better develop and retain a trained workforce. Furthermore, reduced wastage of seed through appropriate storage conditions (temperature, humidity, packaging, duration of storage etc.), as well as more efficient use of seed in propagation and direct seeding is likely to lead to improved restoration outcomes.

Who should read the Guidelines?

The Guidelines aim to promote seed literacy for all those involved in the native seed industry, whether it is directly on the ground (e.g. seed collecting, planting or direct seeding); ex situ (e.g. seed storage, testing or research facilities); or in decision making roles (e.g. writing or implementing policy, licencing, or offset terms).

Specifically, we hope to reach:

- Bushcare and Landcare organisations.
- Commercial operators (e.g. those planting tubestock, direct seeding).
- Community groups, including community restoration groups (such as 'friends of' groups) and community native nurseries.
- Ecological consultants involved in restoration.
- Ecologists without a seed science background.
- Farmers doing restoration or setting up seed production areas.
- Home gardeners.
- Landcare groups.
- Mining and development companies.
- National, state and regional park rangers.
- Native plant nursery industry.
- Native plant products (e.g. bushtucker, skincare products, tea) industry and enthusiasts.
- NGOs doing seed-based restoration on their properties.
- Restoration practitioners.
- Seed collectors.
- Seed end-users.
- Seed processing and storage facilities.
- Seed purchasers.
- Seed testing facilities.
- State and federal government regulators, policy and licencing staff.
- Students.
- Volunteer groups, including those working with Botanic Gardens.
- Wildflower societies.

What's in the Guidelines? Where should you start?

The Guidelines roughly follow the seed supply chain, including the associated information and activities that provide input into the supply chain, such as seed assessment and utilisation of seeds in restoration areas (Figure 8). Working with Indigenous Australians: Seed Knowledge, Partnerships, Intellectual Property and Permissions (Module 2) and Approvals, Principles and Standards for Seed Collection (Module 3), both inform collection practices and outline permissions needed. Throughout the supply chain, quality record keeping is essential (Module 4). Module 5 is concerned with seed sourcing, and describes options for where to obtain seeds of the species selected. These seeds can either be wild collected (Module 6) or collected then increased in seed production areas (Module 7). Seeds that are wild collected or collected from production areas are then processed and cleaned (Module 8), dried and stored (Module 9), quality tested (Module 10), germination tested or pre-treated to overcome dormancy (Module 10), and finally, there is an option for seed enhancement (Module 12).

Seed supply chain involves seed being passed from seed collectors to end users, possibly through a third party such as a testing facility, seed bank or native plant nursery.

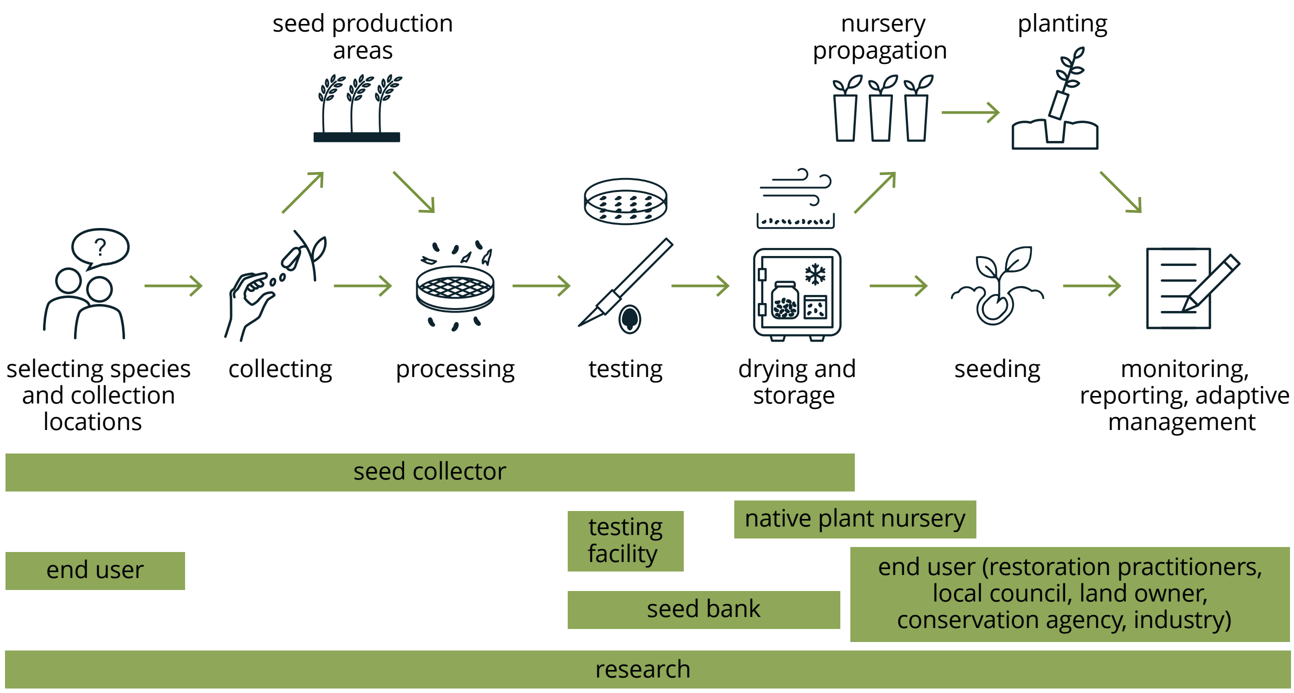


Figure 8. The seed supply chain involves collection through to end use (seeding or planting), after care and monitoring. It is governed by licencing and policy in the collection phase (state government regulations see Module 3) and the Nursery Industry (see Module 13). While other aspects of the supply chain may not be governed by legislation or industry standards, these Guidelines can act as information for best practice. Species selection should be informed by the restoration plan. Seed may be passed from user to user along the supply chain, or it may be collected and utilised in restoration by one user. Seed may need to be tested at various points along the supply chain, such as prior to collection to ensure it is mature, prior to seed production area development, nursery propagation and direct seeding to determine if pre-treatments are required, after processing to determine quality, at regular intervals during storage, and on retrieval from storage, to ensure seeds remain viable.

Seeds are then used either in a nursery to produce tube stock for planting (Module 13), or directly seeded in restoration areas (Module 14), and in both instances need monitoring. Some companies may follow this entire process from start (collection) to finish (seeding/planting/aftercare); however, many companies undertake an aspect of the seed supply chain (Figure 8). In this latter case, seed may travel through the hands of various companies i.e. seed collectors, quality testing labs, research institutions, storage facilities, production nurseries, landowners/site managers, and restoration contractors. Therefore, seed may be bought and sold one or more times. The final module lists some top tips for buying and selling seed (Module 15).

The reader can start from Module 2, then read all the modules sequentially. As the modules inter-relate, they are cross referenced so that more detail can be found about certain topics in other modules (Figure 9). Alternatively, the reader can start at the module which is most relevant to their area of work, and follow the cross referencing to other modules with related topics. Ideally, it would be best to eventually read each module to gain a comprehensive picture of the seed industry, and how the reader's role fits in with the whole seed supply chain.

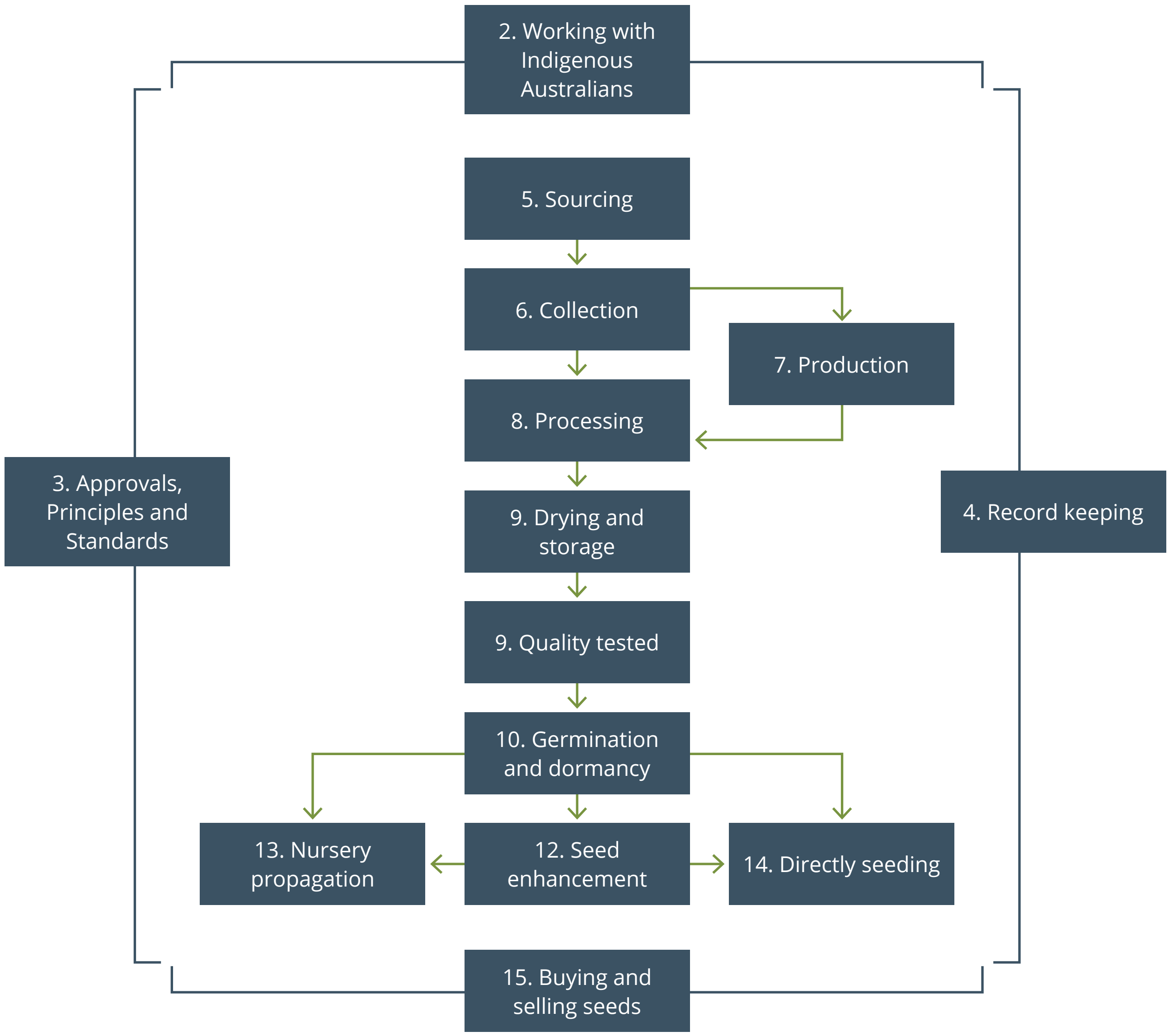


Figure 9. Format of the modules of the Florabank Guidelines which follow the Module 1 – Introduction, and how they inter-relate. The numbers refer to the module number.

Box 2. Complementary guidelines

The Florabank Guidelines focus on seed use in restoration. More detailed information on some aspects of restoration and **ex situ conservation** can be found in other documents. The Guidelines for the Translocation of Threatened Plants in Australia (Commander et al. 2018) provides more information about threatened species, including selecting recipient sites, translocation proposals, and monitoring. Plant Germplasm Conservation in Australia (Offord and Meagher 2009, Martyn Yenson et al. 2021) focuses on ex situ conservation, and thus provides more detailed information on vegetative propagation and different methods of germplasm storage, particularly for threatened species, and the practicalities of implementing these methods. These three guidelines complement each other to enable ex situ conservation to support **in situ conservation** and restoration of both threatened and non-threatened species and vegetation communities (see also Figure 4).

Detailed planning informs species selection for seed-based restoration

Underpinning species selection for seed collection is a comprehensive restoration plan. Before collecting or purchasing seed for restoration, the targets, goals and objectives of the restoration project must be identified (Gann et al. 2019). This plan may take some time to develop, particularly if vegetation surveys are needed to inform the plan. Despite comprehensive planning, there may be a difference between what is on the 'wish list' of species required for restoration, and what is realistically available. Therefore, species selection needs to be both ecologically appropriate, sustainable and practical. However, if there are barriers to species availability, seed sourcing strategies may need to be developed.

The first step in developing a restoration plan is to undertake an inventory of the site to be restored, to describe the composition, structure and function of the vegetation (if the site supports vegetation, i.e. is degraded, not cleared) as well as the landform and soil, along with threats that may need to be ameliorated. Then, identify target native **reference ecosystems** and develop an appropriate **reference model** (the site's expected condition if degradation had not occurred, including a species list, relative abundance of those species, and taking into account predicted environmental changes) using a suitable number of **reference sites** (sites which have similar attributes to the restoration site) (Figure 10). The goals can then quantify the level of recovery, for instance, how many species to return. Useful resources for planning restoration projects include: International Principles & Standards for the Practice of Ecological Restoration, 2nd Edition (Gann et al. 2019); Guidelines for Developing and Managing Ecological Restoration Projects (Clewell et al. 2005) and Project planning and management for ecological restoration (Rieger et al. 2014).

Also, keep in mind that restoration is not just concerned with restoring species composition, but also **structural diversity**, **ecosystem function** and external exchanges, such as provision of resources for pollinators, habitat for fauna, soil stabilisation or hydrological flows. Consideration of restoration of these attributes may also inform species selection. While these guidelines focus on plant replacement, they should be used in concert with other guidelines on replacement of non-plant species (e.g. animals, fungi, soil biota) (Morrison 2009), restoration of the abiotic environment, and social restoration (Egan et al. 2011).

Species lists of reference ecosystems may be developed from regional vegetation guides, Atlas of Living Australia or consultant's surveys. Information about Threatened Ecological Communities may be found in relevant state/territory or national regulatory planning documents, recovery plans and threatened listing determinations, or the Species Profile and Threats Database (SPRAT). These sources of information may give an indication of the species list (**species pool**), but may not (depending on their level of detail) provide enough information to develop goals.

One of the important points about selecting reference sites is that they need to be at the same scale as the restoration site (Figure 10), because the number of plant species in a site is scale dependant. This means that more and more species will be found as a survey area increases within a vegetation community, until all of the species are eventually identified (this concept can be graphed as a species area curve). So, a species list for the entire vegetation community (species pool) can be used to inform species selection for the restoration site, but the number of species required at the site depends on the number of species found in an identically sized reference site (or average of sites). Alternatively, if the restoration site is too big to survey in its entirety, select the same number of identically sized survey plots in reference and restoration sites, and use the average number of species per plot, and total number of species across all plots in the targets. This concept of scale-specific targets is essential for ecological restoration, as it informs the number of species required for restoration (Commander et al. 2017; Elliott et al. submitted).

Once the number of species required for restoration is known, selecting which species to restore is the next step. But how should these species be selected? It is helpful to have frequency and density information, in addition to a species list, when selecting species for restoration to determine which species are more common and which are less common. Some projects may aim to replace some/most/all of the common species, and representatives of all life forms (e.g. grasses, herbs, shrubs, trees). Other projects may aim to also replace some of the uncommon species which have a particular attribute that is required (i.e. habitat or food resources for threatened fauna). The aim of some projects may be to return a certain percentage of the total number of species. Projects may aim to also increase the numbers of a particular threatened plant species, in which case, the Germplasm (Martyn Yenson et al. 2021) and Translocation Guidelines (Commander et al. 2018) provide useful information, in addition to these general principles. Further information on how to identify reference ecosystems and set restoration goals is available in the International Principles and Standards for the Practice of Ecological Restoration (Gann et al. 2019).

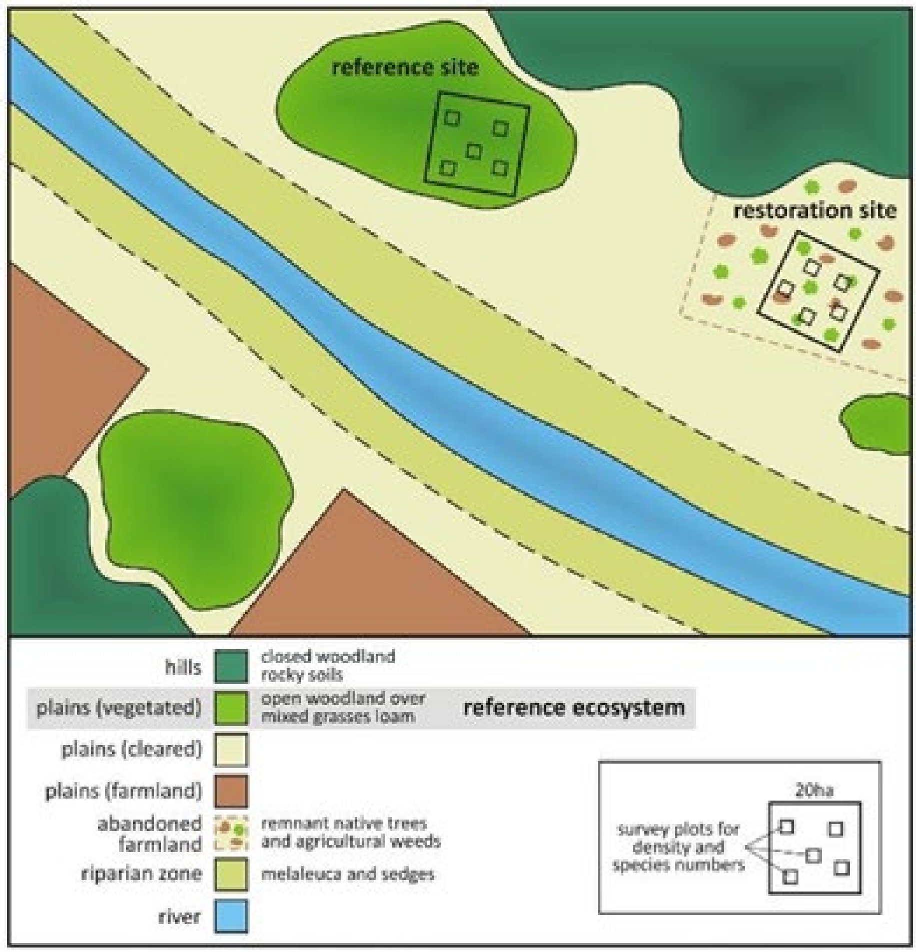
Box 3. Selecting a select a reference ecosystem and a reference site to inform species selection – a hypothetical example

Figure 10 shows a hypothetical example of how to select a reference ecosystem and reference site. The diagram shows a catchment, including river, riparian zone, plains and hills. The restoration site, farmland and remnant vegetation are situated on the plains. The remnant vegetation on the plains has been selected for the reference ecosystem, as it's on the same geomorphological unit as the restoration site.

As the restoration site is 20 ha, a reference site of an identical area (20 ha) has been marked within the reference ecosystem (2,000 ha). Within both the restoration site and the reference site, five, 20 x 20 m survey plots have been marked out. A species list for the reference ecosystem has been developed using regional vegetation guides, ALA and consultant's surveys (400 species). Within the reference site, the survey plots can be used to quantify ecosystem attributes, such as the expected number of species per plot, stem density of trees, etc. The survey plots within the restoration site can initially be used to quantify any existing vegetation (including weeds). Hence, the entire vegetation community, spread across a 2,000 ha area, consists of 400 species, as determined by regional surveys. However, as the restoration site is only 20 ha, either a 20 ha survey, or an estimate from a species area curve can be used to determine the number of species that would reasonably be expected to be restored to such an area, e.g. 50 species.

All the information from the reference ecosystem, reference site and restoration site, can be used to develop the reference model, and the goals, targets and objectives. The reference model is one that indicates the expected condition that the restoration site would have been in had it not been degraded. This condition is not the historical condition, but rather reflects background and predicted changes in environmental conditions. After implementation, the survey plots within the restoration site can be used to assess the trajectory of community development, and whether or not the goals, targets and objectives have been achieved.

This conceptual model is based on an existing reference site, however, a reference ecosystem can also be a conceptual representation of a non-degraded native ecosystem that is the target of ecological restoration which might have existed on the restoration site had degradation not occurred, and adjusted to accommodate changed or predicted environmental conditions (see Gann et al. 2019).



Reference Ecosystem	Reference Site	Restoration Site
e.g. Open woodland occurring on plains. Total 2,000 ha	e.g. 20 ha site within the reference ecosystem	e.g. 20 ha site within abandoned farmland with remnant trees
Compile species list from ALA and Regional vegetation guide	Install monitoring plots to measure number of species per plot and plant density, and determine common species. Estimate total number of species at the site from a species area curve, or survey the entire site.	List all species found. Install permanent monitoring plots
e.g. contains 400 species	e.g. contains 50 species	Aim to restore up to e.g. 50 species (some may already be present), but can select from species list of reference ecosystem, and processes that maintain these species.
Use all information to develop **Reference Model**		
Use Reference Model to develop **goals, targets and objectives**		

Figure 10. A conceptual diagram showing how to select a reference ecosystem and a reference site, and use them to develop a reference model, then goals, targets and objectives, to ensure that the restoration site has a realistic number of species, realistic plant density, and the species selection is suited to the environment. (Figure drafted by Craig Miskell, CAM Graphics)

To find out more

To find out more, visit the Australian Network for Plant Conservation (ANPC) website, follow ANPC on social media, become an ANPC member, subscribe to the ANPC free monthly newsletter, and attend an ANPC workshop or conference. Refer also to the complementary Guidelines such as Plant Germplasm Conservation in Australia: strategies and guidelines for developing, managing and utilising ex situ collections (Offord and Meagher, 2009; Martyn Yenson et al. 2021) and the Guidelines for the Translocation of Threatened Plants in Australia (Commander et al. 2018) (Box 2).

Technical and support networks include:

- International:
  - Botanic Gardens Conservation International (BGCI) https://www.bgci.org/
  - International Network for Seed-based Restoration (INSR) https://ser-insr.org/
  - International Seed Testing Association (ISTA) https://www.seedtest.org/en/home.html
  - International Society for Seed Science (ISSS) https://seedscisoc.org/
  - IUCN Seed Conservation Specialist Group https://seedconservationsg.org/
  - Millennium Seed Bank Partnership (MSBP) http://brahmsonline.kew.org/msbp
  - Society for Ecological Restoration (SER) https://www.ser.org/
- Australasia:
  - Botanic Gardens Australia and New Zealand (BGANZ) https://www.bganz.org.au/
  - Society for Ecological Restoration Australasia (SERA) https://www.seraustralasia.org
- National:
  - Australian Association of Bush Regenerators (AABR) https://www.aabr.org.au/
  - Australian Network for Plant Conservation (ANPC) https://www.anpc.asn.au/
  - Australian Seed Bank Partnership (ASBP) https://www.seedpartnership.org.au/
  - Australian Seed Federation (ASF) https://www.asf.asn.au/
- State:
  - Revegetation Industry Association of WA (RIAWA) http://riawa.com.au/wordpress/
- Europe:
  - The Native Seed Science, Technology and Conservation Initial Training Network (NASSTEC) https://nasstec.eu/home
- North America:
  - Center for Plant Conservation (CPC) https://saveplants.org/about-us/ https://academy.saveplants.org/
  - Seeds of Success (SoS) https://www.blm.gov/programs/natural-resources/native-plant-communities/native-plant-and-seed-material-development/collection

Glossary

Assisted regeneration: restoration at sites of intermediate or greater degradation requires removal of the causes of degradation and active interventions to correct abiotic and biotic damage and trigger biotic recovery.

Augmentation: (see Reinforcement)

Conservation: the protection, care, management and maintenance of ecosystems, habitats, wildlife species and populations, within or outside of their natural environments, in order to safeguard the natural conditions for their long-term permanence.

Ecological restoration: the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.

Ecosystem functions: the workings of an ecosystem arising from interactions and relationships between biota and abiotic elements. This includes ecosystem processes such as primary production, decomposition, nutrient cycling and transpiration and properties such as competition and resilience.

Ex situ conservation: the conservation of the components of the biological diversity outside of their natural habitats.

In situ conservation: the conservation of the ecosystems and natural habitats and maintenance and recovery of viable populations of species in their natural environments and, in the case of tame and cultivated species, in the environments where they have developed their specific characteristics.

Natural regeneration: Germination, birth, or other recruitment of biota including plants, animals and microbiota, that does not involve human intervention, whether arising from colonization, dispersal, or in situ processes.

Reference ecosystem: a representation of a native ecosystem that is the target of ecological restoration (as distinct from a reference site). A reference ecosystem usually represents a nondegraded version of the ecosystem complete with its flora, fauna, and other biota, abiotic elements, functions, processes, and successional states that might have existed on the restoration site had degradation not occurred, and adjusted to accommodate changed or predicted environmental conditions.

Reference model: a model that indicates the expected condition of a restoration site had it not been degraded (with respect to flora, fauna and other biota, abiotic elements, functions, processes, and successional states). This condition is not the historic condition, but rather reflects background and predicted changes in environmental conditions.

Reference site: an extant intact site that has attributes and a successional phase similar to the restoration project site and that is used to inform the reference model. Ideally the reference model would include information from multiple reference sites.

Rehabilitation: management actions that aim to reinstate a level of ecosystem functioning on degraded sites, where the goal is renewed and ongoing provision of ecosystem services rather than the biodiversity and integrity of a designated native reference ecosystem.

Reinforcement: Adding individuals of a species into an existing population with the aim of enhancing population viability by increasing population size, genetic diversity and/or representation of specific demographic groups or stages. This may be part of the process of restoration or reconstruction of a site where the species occurs but requires population manipulation to ensure the maintenance of a viable population. Also referred to as enhancement, re-stocking, enrichment, supplementation or augmentation.

Reintroduction: An attempt to establish a population in a site or habitat type where it no longer occurs (locally extinct). This may be part of the process of restoration or reconstruction of a habitat where the species was previously known to occur. Also known as re-establishment.

Restorative activities: any action, intervention, or treatment intended to promote the recovery of an ecosystem or component of an ecosystem, such as soil and substrate amendments, control of invasive species, habitat conditioning, species **reintroductions** and population **reinforcements**.

Soil seedbank: seeds within or on the soil.

Species pool: all species that could potentially colonise and inhabit an area.

Structural diversity: diversity of key structural components, including demographic stages, trophic levels, vegetation strata and spatial habitat diversity.

Translocation: the deliberate transfer of plants or regenerative plant material from an ex situ collection or natural population, usually in the wild, and is often used in the context of threatened species. Translocation actions can include **reinforcement**, **reintroduction**, introduction, and assisted migration.

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Online resources

Atlas of Living Australia
www.ala.org.au

IUCN Guidelines for Seed Conservation
https://seedconservationsg.org/guidelines-for-seed-conservation

NSW roadside vegetation management plans
https://www.rms.nsw.gov.au/documents/about/environment/rec-rmp-guidelines.pdf)

Native nurseries
e.g. https://plantsandlandscapes.com.au/nurseries/ and https://www.nativeplantswa.org.au/local-native-plants/

Species Profile and Threats Database (SPRAT)
https://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

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