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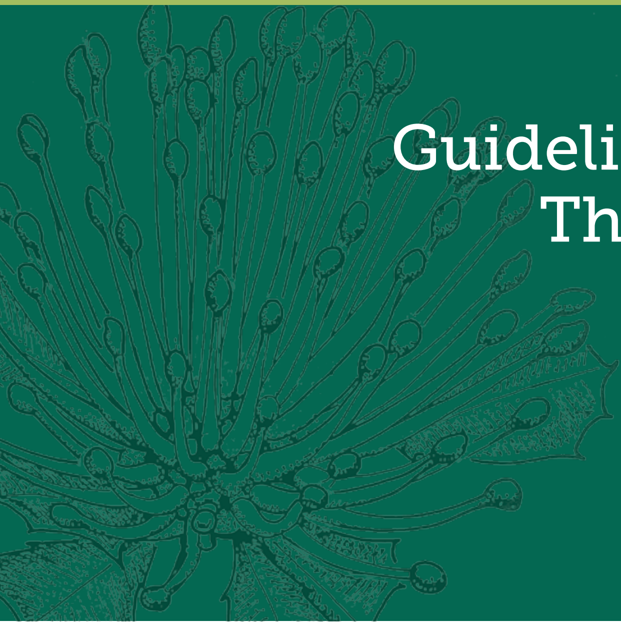

Guidelines for the Translocation of Threatened Plants in Australia

Third Edition

Editors: L.E. Commander, D.J. Coates, L. Broadhurst,
C.A. Offord, R.O. Makinson and M. Matthes

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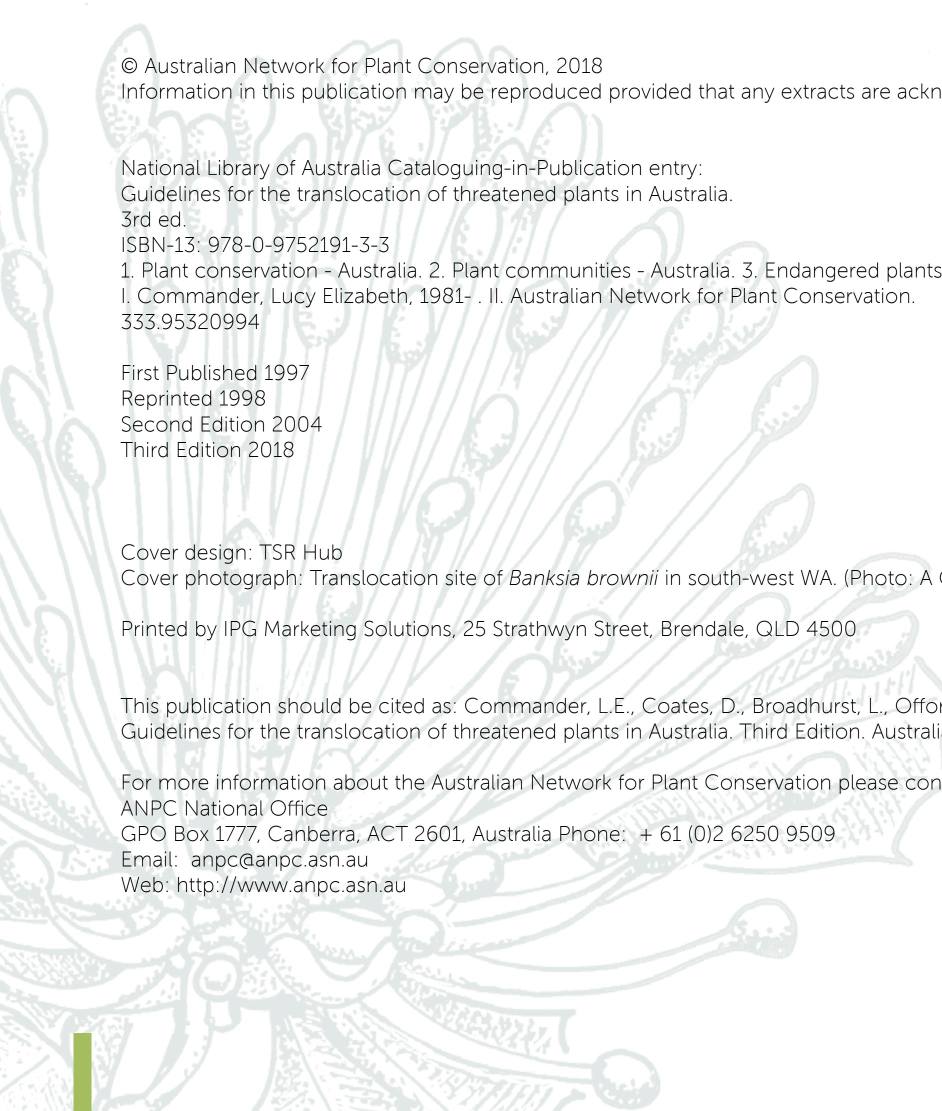

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Foreword

In the midst of immense global change, knowing plant reintroduction can effectively reduce extinction risk gives me solace. But truthfully, I didn't always have confidence in the process. In my early years of practice, I expected instant gratification and rapidly established populations that would thrive thanks to my intervention. My experience showed me that rare species did not work that way. I had to learn a different metric for success. I had to learn to be patient. Very patient. I also had to learn the fine art of preparation.

In South Florida in the early 2000s, new information about sea level rise hit the press, very active hurricane seasons erupted, and the U.S. endangered Key Tree Cactus (*Pilosocereus robinii*) population in the Lower Keys plummeted. My colleagues and I searched for answers. One suggested reintroduction, so I pulled out my copy of the 2nd Edition of the Australian Plant Conservation Network's Guidelines for Translocation. I remember going through the checklists related to pre-translocation preparation in the outdoor patio. 'Let's see now. Has an established recovery team assisted with the pre-translocation assessment…? Are relevant aspects of the taxon's reproductive biology and ecology understood? Has the need for a genetic assessment been conducted…?' After we honestly answered 'no' to the first three questions, we realized that we were not ready to reintroduce the species. The guidelines helped us set our course for the next several years. We started with convening a recovery team, which included government agency personnel who were anxious to take action, and researchers who could address some of the information gaps. Going through the process together helped us all realize that we were not ready and helped us outline actions needed before we would be prepared to conduct a reintroduction for the species. We conducted experiments related to potential threats, we conducted genetic analyses, we maintained an *ex situ* collection and propagated hundreds of plants from seeds and cuttings, and we researched potential recipient sites. Eventually by 2012, we installed the first of three reintroductions for the species. That pre-translocation process sparked off my admiration of these guidelines.

My admiration has not subsided. I am delighted with the 3rd edition, which embodies years of experience of the authors and recognises new threats, new technologies available to solve problems, and expanded sections on areas of new research. Akin to the Center for Plant Conservation book, Restoring Diversity (Falk *et al*. 1996), this volume forewarns practitioners to be wary of translocations motivated by mitigations, which often do not allow the time needed for proper preparation. As a result, they may waste time, resources, and fail to help the rare plant species. In contrast, reintroductions done with a sound plan, good commitment, adequate funding, appropriate site selections, removal of and protection from threats, adequate understanding of species' biology and horticulture often can succeed when given enough time.

Experimental examples in this edition illustrate the breadth of collective experience the Australian plant conservation community has achieved. From inception through implementation, following these guidelines can help practitioners improve the success of their reintroductions. Documenting that success is essential if we are to improve our practice worldwide. Expanded details about the importance of monitoring – how to develop a monitoring plan with conceptual diagrams, identifying the key plant and recipient site attributes to monitor to evaluate reintroduction success and recording changes to the recipient site, whether negative (pests, weeds, *Phytophthora*) or positive (improved forest structure or ecosystem function) are a nice addition in this edition. Asking whether management actions helped improve success of the reintroduction is important for honing efficiency and effectiveness of linking monitoring to management.

It is important that we develop an 'inclusive spirit' to continue to build reintroduction science, because our practice is not yet perfect. Involving recovery teams and communities of scientists and citizens, sharing our successes and failures, recognizing our achievements, our partners, the cultural context of the work we are doing, and knowing that rare plant populations will establish incrementally with time are only some of the messages I have taken from this edition.

Plant conservation is awesome work. I offer sincere thanks to those who strive to save plants across the world.

-Joyce Maschinski-
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Dedication

This publication is dedicated to the children and grandchildren of the authors, and all those devoting their lives to saving threatened species from extinction.

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Chapter 1 – Introduction

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1.1. Definition of translocation

Translocation is the deliberate transfer of plants or regenerative plant material from an *ex situ* collection or natural population to a new location, usually in the wild. It includes reintroduction, introduction, reinforcement, assisted migration and assisted colonization. Translocations involve a diverse range of methods including: seed collection and propagation; propagation via cuttings or tissue culture; planting of containerised plants; direct seeding; transplantation of whole plants from one site to another; and the transfer of soil, leaf litter, brush or pollen. It may also involve, as in the case of some terrestrial orchids, the movement of associated organisms such as mycorrhizae essential to the growth and establishment of the species or (limited cases to date) translocation of associated fauna including pollinators. The term reintroduction is often used to broadly cover all types of translocations but here we refer to reintroductions as a specific category of translocation (see Section 1.3.1).

The term translocation has been used to describe both the transfer of individual species and the transfer or reconstruction of ecological communities. These guidelines have been prepared to provide guidance on the translocation of individual threatened plant species only. Reconstruction of ecological communities is not discussed in these guidelines as the issues involved with this process are many and significantly more complex than those associated with single species translocation. If reconstructing threatened ecological communities we recommend restoration guidelines (such as Greening Australia 1999; Ross 1999; Standards Reference Group 2017) be consulted. There is still very little evidence that threatened ecological communities can be reconstructed, as opposed to restored *in situ*, and the process should, at this stage, be considered experimental (but for a recent study see Commander *et al.* (2017)).

1.2. Objectives and content of these guidelines

The main objectives of these guidelines are to:

- demonstrate that translocation is not a simple solution to the dilemma facing many threatened plants, and to minimise the occurrence of inappropriate translocations;
- highlight that translocation may be an expensive and time-consuming process that should be under early and continued consideration in recovery planning (it should not remain un-scoped until the situation is already critical), but implemented only with caution as a counter to anticipated or actual declines that cannot be countered by other means; it should be used when necessary to maximise the persistence of a population or taxon in the wild: translocations are optimally a supplement, not an alternative, to *in situ* conservation;
- provide guidance on how to decide whether translocation should, or should not, be implemented;
- provide guidance to evaluate and improve the success of translocation projects;
- provide information to assist in the development of comprehensive translocation proposals;
- highlight the need, and provide guidance for discussion between conservation agencies, regulatory agencies, researchers, botanic gardens and the broader community prior to and during a translocation project; and
- emphasise that translocation should be conducted under the guidance of a recovery team or similar team that brings together the necessary expertise and key stakeholders to improve the likelihood of success.

This document provides best-practice guidelines for conservation translocations, based on accumulated Australian and international experience. The formation of best practice is, however, a living process. There will be occasional cases where best practice may require variance from these guidelines. In such cases it is strongly recommended that the need for such variance be explicitly identified and justified in either the initial translocation proposal, or in subsequent documentation, and subjected to some form of peer review.

Since the publication of the original guidelines (Translocation Working Group 1997) and the 2004 update (Vallee *et al.* 2004), an increasing number of translocations have been implemented and our knowledge of many facets of translocation has increased. These guidelines bring together this knowledge and information to provide a step-by-step guide for plant translocations.

Chapter 2 discusses how to assess whether translocation is an appropriate management option for a particular threatened species, and outlines the factors to consider when determining whether to translocate a population or species. The necessary pre-translocation assessment of biology and ecology, including identifying propagation methods, is discussed in **Chapter 3. Chapter 4** provides advice on selecting source and recipient sites, including site selection for species where emerging threats may play a role in the success of a project, and preventing unintended consequences at recipient sites. **Chapter 5** outlines policy and permit issues and provides guidelines for the preparation of a translocation proposal. **Chapter 6** details the pre-translocation preparation required with tips on designing an experimental translocation. **Chapter 7** considers the procedures involved in implementing a translocation program and ongoing adaptive management. **Chapter 8** outlines the required actions following translocation, including monitoring, evaluation, documentation and dissemination of results. **Chapter 9** discusses the value of community involvement.

Each chapter is supported by case studies, box examples and explanations and checklists. The case studies have been used to illustrate particular points and the boxes provide additional information on topics or concepts. Checklists have been included in some chapters to summarise the required process. The use of technical terminology has been avoided as much as possible, but if used, definitions can be found in the glossary at the end of this publication. These guidelines are not a substitute for consultation with experts and therefore a list of useful contacts is also provided at the end of this publication (project proponents should not limit themselves to this list). An Australian Plant Translocation Database, documenting previous translocations, is currently being developed by the Threatened Species Recovery Hub and is likely to be published online in the future. The case studies are excerpts from articles that have been (or will be) published in Australasian Plant Conservation, the ANPC's Bulletin, and back copies can be ordered from ANPC.

In these guidelines we have used the term 'species' rather than 'taxon' for simplicity, and also because species is generally used in legislation. However, in these guidelines, species can include other taxonomic categories for example subspecies or varieties.

1.3. Objectives of translocation programs

Translocation programs for threatened plant species are implemented for two broad reasons: to assist in the management and conservation of threatened plant species (here termed Conservation Translocation); and to ameliorate the impacts of urban, agricultural or industrial development on a threatened species (here termed Mitigation Translocation). Conservation and Mitigation Translocations may use similar techniques in terms of propagation and recipient site selection. However, the main difference in the case of Mitigation Translocations, is that the source population is under immediate threat of destruction and needs to be moved. These Mitigation Translocations are often done as 'offsets' to compensate for residual, unavoidable impacts and should provide a net positive outcome for biodiversity and would be expected to have an important role in the conservation of populations and species. The issues associated with the use of translocation as an ameliorative measure for development are discussed in Chapter 2, particularly Section 2.2.3.

Irrespective of the reason behind implementing a translocation program, or the type of translocation being implemented, **the objective of all translocation programs should be to directly support the conservation of the target species, and to establish or maintain one or more self-sustaining populations capable of surviving in the long term (i.e. years, decades or hundreds of years depending on species longevity).**

For a population to persist in the short term there needs to be:

- a sufficient number of propagules to establish a viable population and protect against genetic (see Section 3.3), demographic and environmental stochasticity;
- good survival and establishment of the translocated individuals;
- management and control of threats; and
- flowering, fruiting and natural recruitment at rates similar to natural populations.

For a population to persist in the long term it also needs to possess sufficient genetic diversity to retain its evolutionary potential to adapt to long-term environmental change or infrequent extreme events. Satisfying this requirement is discussed in more detail in Section 3.3.

1.3.1. Types of translocation actions

Translocation actions can be categorised by their source population and recipient site (adapted from Botanic Gardens Conservation International 1995; IUCN/SSC 2013; Translocation Working Group 1997; Vallee *et al.* 2004).

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.

Introduction: An attempt to establish a population in a site where it has not previously occurred but is within the known range of the species and provides similar habitat to known occurrences.

Assisted migration: An attempt to establish a species, for the purpose of conservation, outside its indigenous range in what is considered to provide appropriate habitat for the species based on climate change or habitat change predictions. Such translocations are potentially high-risk projects with success often difficult to predict, and should only be carried out after an extensive risk assessment has been conducted. Also known as assisted colonization. (Further discussed in Chapter 4.)

Note: These definitions differ slightly from the IUCN definitions, which encompass both plants and animals. They provide a subtle difference between two types of translocations within the known range of the species reintroduction: establishment of a population where it previously occurred, and introduction: establishment of a population where it did not previously occur. These definitions are likely to only be applicable to plants, given that animals are able to move around their known range, whereas plants (generally) are known in specific locations.

1.3.2. Sources of plants for translocation

Translocations can also be categorised by the way in which plants are sourced.

Translocation of nursery-grown plants: The planting of seedlings or cuttings grown under *ex situ* conditions.

Translocation using seed: Direct sowing of collected seeds or other diaspores.

Whole plant translocation: The transplantation of mature plants or seedlings from an area due to be affected by development to an unaffected area. Also referred to as transplantation, mitigation translocation, salvage dig, or rescue dig. As outlined in Section 2.2.3, there are risks and disadvantages associated with this technique that need to be considered.

Soil seed bank translocation: The movement of the soil stored seed bank from one place to another.

1.4. Translocations: why, when, where, what, who and how?

1.4.1 History of plant translocation in Australia

The prevalence and imperative for plant translocations is growing in response to the increasing numbers of species threatened by habitat loss and degradation, disease and climate change. However, the intentional movement and nurture of plants to increase their range and/or abundance has been practiced for millennia, encompassing species with food, medicinal, narcotic, and ceremonial values. A recent review of the ethnographic, archaeological, biogeographic and phylogenetic record (Silcock 2018) identified more than 50 plant species that have been deliberately translocated by Aboriginal Australians, spanning a range of lifeforms and much of the continent. The vast majority were, and in some regions still are, important food species, while others were valued for plant materials. Over one-third had (or have) ceremonial or cultural importance, with translocations of these often occurring as part of specific ceremonies.

Introductions (see definitions in Section 1.3.1) were the most common type of Aboriginal translocation, documented for 31 species. Reinforcement planting into existing populations, often accompanied by *in situ* nurture of plants and their habitats, were documented for 23 species, while assisted migrations into new areas outside the apparent original range of the species were documented for 19. Ten records involve post-contact translocations, mostly of important food or ceremonial plants taken back to gardens to maintain connection with sites where they grow in the absence of regular visits. The Mediterranean south-west, tropical north and Western and Simpson Deserts stand out as having relatively high numbers of translocations documented.

The ethnographic record is fragmentary, often difficult to verify and prone to overlooking brief and inconspicuous practices like small-scale plantings, and we will never know the full extent and nature of plant translocations in Aboriginal Australia. However, combined with biogeographic and, increasingly, phylogenetic insights, there is sufficient evidence to place modern translocations in a much older context of human-plant interactions. Although biodiversity conservation as we define it today was not an explicit objective, the goals of Aboriginal translocations would appear broadly similar to present-day conservation initiatives: to create and maintain populations of important and valued plants. Success of translocations can only be evaluated after many years of monitoring – up to several decades depending upon generation time of the species – and it is too early to judge for the majority of contemporary conservation translocations. However, it seems that numerous Aboriginal translocations over the past 50,000 years have indeed been successful, and manifest today as unusual distributions of some species. This is no doubt due to factors which underpin modern translocation success, including detailed knowledge of species biology and habitat preferences, and learning from failed 'experiments'.

When habitat destruction accelerated across Australia's agricultural regions in the 1950s, concerned local residents like Vera Scarth-Johnson near Bundaberg (Australian National Herbarium 2015) rescued plants from areas that were about to be cleared and replanted them in their gardens or safe patches of bush. These acts of private citizens can be regarded as Australia's first modern conservation translocations, but today it is unknown what species were involved or whether plantings were successful.

1.4.2 Overview of plant translocations: where, who, why and how?

The first documented conservation translocations were carried out in Victoria in the late 1970s, in response to similar pressures. Since then, there have been more than 1,000 translocations involving almost 380 taxa; 85% of these have occurred since 2000, and more than half since 2010. The following summary is given by Silcock *et al.* (in prep.), who provide a detailed analysis of translocations in Australia and their performance. Silcock *et al.* (in prep.) collated data on as many translocations of plants of conservation concern that have occurred in Australia as possible, through literature review and extensive consultation with practitioners. Despite efforts at comprehensiveness, it is certain that some translocations have been missed. There is likely to be a bias towards larger, more recent and more successful translocations, as well as those done by government agencies and conservation groups rather than consultants.

Unsurprisingly, translocations are concentrated in areas with high numbers of threatened species and where there are ongoing threats to habitats and plants such as south-western and south-eastern Australia, and along the east coast (Fig. 1.1). Shrubs are by far the most common type of plant translocated (465 documented translocations), followed by trees and perennial herbs (about 140 of each) and ground orchids (81 documented translocations). Asteraceae, Myrtaceae, Proteaceae, Orchidaceae and Fabaceae are the most translocated families.

Most conservation translocations are conducted by State Government agencies, including Botanic Gardens, sometimes in conjunction with not-for-profit conservation groups, Natural Resource Management bodies and volunteer groups. A relatively small number of translocations are led by not-for-profit groups (e.g. Nature Glenelg Trust in South Australia, Trust for Nature in Victoria) and Universities, with a handful conducted by private landholders.

Development-related translocations are typically carried out by ecological consultants on behalf of property developers, main roads or water authorities, or mining companies. These often involve transplanting whole plants and/or blocks of soil from locations before development occurs to safe alternative sites.

The vast majority of translocations have been introductions, with a substantial number of reinforcements (see definitions in Section 1.3.1). Most projects used nursery-grown seedlings and cuttings, although there have been 80 whole plant transplantations and some examples of direct seeding. The majority of translocations involved some form of site maintenance including a combination of watering, weeding and grazing protection, and some three-quarters are still being monitored.

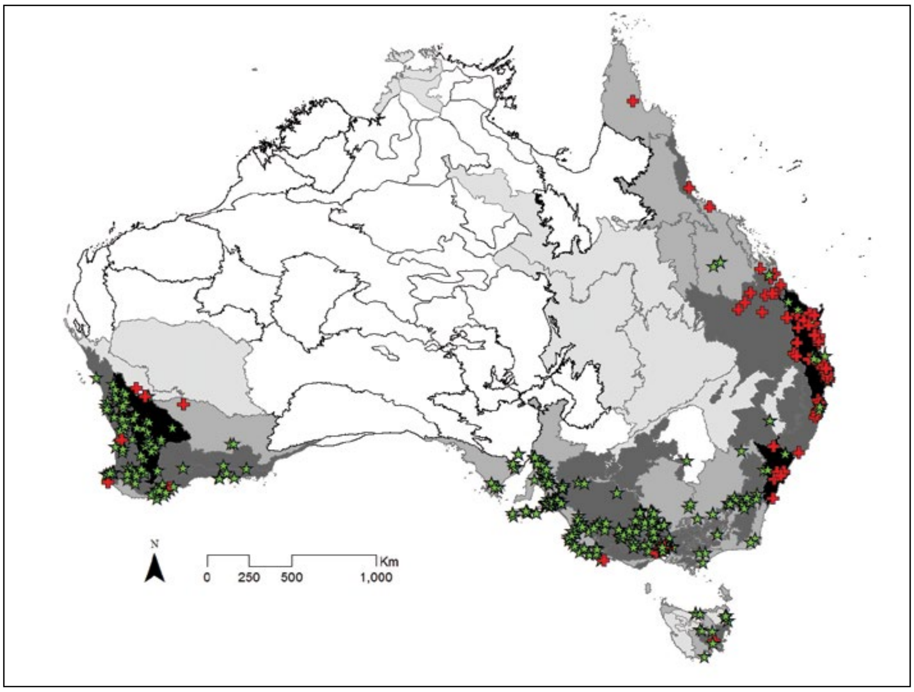

Figure 1.1 Map showing plant translocations across Australia. Green stars are conservation translocations, red crosses are those done as part of a development (mostly infrastructure and mining projects). IBRA biogeographic regions are shaded according to number of threatened species occurring in them (the darker the shading the more threatened species within the region) (Silcock et al. in prep).

1.5. Past translocation successes

Despite the massive increase in the number of translocations since the last edition of these guidelines (Vallee *et al.* 2004), there remain relatively few documented examples of translocation programs that have created self-sustaining populations. For some translocation programs, particularly those involving long-lived shrubs and trees, it is still too early to determine success. However, there are many examples where, despite large investments of time and effort, translocations have been unsuccessful.

Attempts to translocate threatened plants have generally been unsuccessful for several reasons, including:

- Loss of propagules within the first year of planting: 45% of all translocations documented had <50% survival after one year. The most common reasons for plant death were hot, dry summers in southern areas and frost damage in colder regions. Issues with planting technique also contributed to high mortality in some cases. Some translocations were affected by flooding, fire, herbivory (by both native and introduced domestic and/or feral species, both vertebrate and invertebrate) and disease.
- Too few plants were translocated to establish a viable population that allowed for natural attrition over time– for example, 370 translocations documented had <50 propagules.
- Failure to adequately control or manage the original threats affecting the species or habitat.
- Poor site selection, e.g. inappropriate habitat or threats present at the site.
- Lack of adequate consideration or understanding of the biology and ecological requirements of the species, including mycorrhizal fungi, pollinators, seed/fruit dispersers, seed germination biology and associated plant and animal assemblages.
- Use of inappropriate translocation methods, for example the use of whole plant translocation (i.e. salvaged/excavated mature plants) when the use of seeds or cutting material may have been more successful.
- Poor quality or inappropriate plants being used, for instance pot-bound, too young, too old.

- Lack of disturbance to stimulate, or provide opportunities for, recruitment into the population; this has been the most common reason for failure of grassland forb translocations, and is perhaps the biggest hurdle to achieving successful translocations.
- Absence of ongoing commitment of resources to monitoring, evaluation and follow-up maintenance.
- Failure to consider genetic variability, which may influence chances of translocation success in both the short and long term.

On the other hand, successful translocations are typically characterised by:

- Sufficient number of propagules planted – 50 at an absolute minimum.
- Development of a sound and detailed translocation proposal that provides for all aspects of the translocation program including collection, implementation, ongoing management, monitoring, evaluation and documentation.
- Commitment and collaboration of numerous individuals and organisations, ensuring the project receives the required expertise. Translocation is a complex process and requires an expert understanding of horticulture, experimental design, ecology, genetics, and restoration ecology.
- Sound site selection.
- Removal and ongoing control of threatening processes.
- Watering of plants during dry periods in climates with a seasonal rainfall deficit, at least over the first year or two.
- Protection from grazing and trampling where there are high numbers of native or introduced herbivores.
- Financial commitment to ongoing maintenance, monitoring and evaluation.

Even when translocations are 'failures' in terms of plant survival and recruitment, an experimental approach and commitment to monitoring mean that much can be learnt to inform future attempts. Even if the translocation fails, it fails further if nothing is documented. Some of the most successful translocations are those that have learnt from and applied lessons from past translocations.

Chapter 2 – Deciding whether to translocate

Authors: Tony Auld, Marc Freestone, Linda Broadhurst, Heidi Zimmer, Nigel Swarts, Rachael Gallagher

Conservation of species and ecological communities (including those that are threatened) requires a range of different strategies operating together. These will range from on ground measures such as reservation and habitat protection, amelioration of threats, management of disturbance regimes, restoration of habitat and at times enhancement or establishment of new populations through translocation (Fig. 2.1). Translocation is a key element within this framework, but all components need resourcing for successful conservation. This section discusses the range of contexts within which translocation may serve as a conservation management option.

Habitat protection
Stop clearing
Protected area expansion
Off reserve protection
Management of threats

Building resilience
Management of threats
Management of disturbance regimes
Restoration of habitats
Refugia, stepping stones

Managing migration
Retention of remnants
Key dispersal agents
Enhancing connectivity

Assisted conservation
Ex situ conservation
Translocation

Figure 2.1 Essential strategies for effectively managing biodiversity under a range of threats including changing climate. Translocation can be used to directly build resilience and to promote migration.

2.1. Conservation actions for species recovery, and how translocation may be part of a broader strategy

Threatened plant species are subject to a diverse range of threats including: land clearing; habitat fragmentation and degradation; weed, pest and pathogen impacts; inappropriate fire regimes; demographic, ecological and genetic consequences of small population size; along with a changing climate. Conservation of threatened species must then incorporate a variety of options for effective management (Fig. 2.1).

The type of translocation strategy needed for each individual threatened species will depend upon the extinction risk, the threats impacting on the species and other legislative requirements (e.g. offsetting) (see Case Study 2.1). As per global best practice for minimising impacts on biodiversity through a mitigation hierarchy (Arlidge *et al.* 2018), including offsetting (Maron *et al.* 2012; Maron *et al.* 2016), it is important that management options requiring the least intervention (and involving lower levels of risk) are considered first. Translocation can be relatively costly and time consuming, and successful outcomes are not guaranteed due to potential risks associated with the technique. In some cases, translocation may be conducted when all other conservation management options are deemed inappropriate or have failed. It is important that sufficient resources are directed towards conserving existing populations *in situ* through habitat protection and/or habitat restoration measures, and through the control of threatening processes (Fig. 2.1). Translocation may be necessary (in conjunction with a range of conservation management actions) to reduce the extinction risk in species that have been reduced to very low population levels or to only a few remaining locations, but scoping and preparation for translocation should not wait until this is the case, if that can possibly be avoided. Translocation may also be enforced for social or political reasons through legislation that promotes impact minimisation as a 'conservation' mechanism. In situations where translocation is being considered as an ameliorative or compensatory measure, advice regarding alternatives to translocation can be sought from your State conservation agency (Appendix 1).

2.1.1. Management options available for threatened plants

Management for the conservation and recovery of threatened plant species must address the threats impacting on the species:

Habitat protection: Some species at risk from ongoing habitat loss and/or degradation may require little active management if their remaining and recolonisable habitat is protected to ensure their survival. Habitat protection may be achieved through formal protection within a conservation reserve and through joint management with Indigenous land owners. Some habitat protection on private lands may be achieved through, for example, threatened species legislation, covenants, or other conservation agreements such as Voluntary Conservation Agreements (contact your State conservation agency for additional information, see Appendix 1). However, for most threatened plant species such formal reservation will not be sufficient to achieve their long-term conservation, nor will it be achievable or practical.

Managing migration: Retaining and connecting remnants builds ecosystem resilience, while also enhancing or maintaining gene flow by pollinator movement and seed dispersal. These factors can facilitate plant recruitment and establishment in new areas or recolonization of formerly occupied areas.

Building resilience: Habitat rehabilitation and removal of threatening processes: Effective management of most threatened species requires mitigation of often multiple threats which may act in concert and be complementary (Auld and Keith 2009). For example, this may involve control or removal of environmental weeds, adverse grazing impacts, or pathogens such as *Phytophthora cinnamomi*, limiting human disturbance (restrict vehicular or pedestrian activity) and implementation of appropriate disturbance regimes such as fire (for example, fire control measures or ecological burns).

Assisted conservation and active management: Threatened species characterised by just a few remaining populations or individuals may not respond to habitat protection and rehabilitation or the removal of threatening processes. Such species require more active management to increase population size, ensure ongoing recruitment of new individuals or create new populations to spread the risk of having all plants in one or a very few locations. Given that active management involves manipulative techniques and directly influences the survival of individual plants or populations, this approach can affect a species' genetic structure and thus its evolutionary development (Frankham *et al.* 2017). Consequently, it is important that such techniques be used only when necessary and that these are based upon sound knowledge.

Active management options can be ranked according to the level of manipulation involved (which often directly relates to the level of potential risk to the population or species). It is desirable to consider the feasibility of less evolutionarily disruptive techniques (see Section 3.3) first and then move onto 'higher risk' options if required. Low risk techniques aim to manipulate or restore natural processes to increase recruitment in the target population.

Such techniques include:

- promoting increased seed set (hand pollination, reducing the impact of flower and seed predators);
- restoring disturbance regimes such as fire (burning) or grazing (slashing) that allows recruitment and persistence;
- excluding adverse disturbances and native or exotic grazers (fencing);
- preventing clearing; and
- promoting seedling recruitment from a soil seed bank (soil disturbance or application of a germination promoting cue such as fire).

The advantage conferred by such techniques is cost effectiveness and the least evolutionary disruption (Hogbin and Peakall 2000) (see Section 3.3). But for those species characterised by extremely low numbers or few populations, such actions may be insufficient, and higher risk techniques such as translocation may be required. Translocation may involve high or uncertain risks in the immediate or longer terms, and may involve a high initial cost and significant ongoing costs for maintenance and monitoring. It is therefore not a preferred option, but may be a prudent one when the trends for *in situ* survival are on a downward trajectory. However, it is important to note that translocation must include management of existing threats.

2.1.2 Factors driving translocation

Generally, there are two broad types of factors driving translocations. These are:

i. conservation actions needed to reduce extinction risk and hence, maintain species or populations of species (conservation translocations); and

ii. amelioration measures that may help to mitigate habitat loss (mitigation translocation, development translocation, rescue dig, offsetting, salvage, enforced translocation). Translocation is often proposed as a mitigating, ameliorative or compensatory measure for the loss, or potential loss, of individuals or populations of a threatened species because of a development activity. Given the uncertainty of success of a translocation program, the potential use of translocation as an ameliorative measure should not be treated as a relevant deciding factor when determining the potential impact of a development (i.e. translocation does not effectively or reliably decrease the significance of an impact). In recent years, there has been an increasing number of development approvals issued by local and State governments that include the translocation of a threatened plant species as a condition of approvals and several States now have an offsetting mechanism established within planning legislation. For threatened species, one of the major priorities is ongoing protection and management of the remaining habitat where the species occurs. This is the best way to conserve the species in the long-term and **translocation is not an alternative to** *in situ* **conservation** nor should it be considered a suitable ameliorative, compensatory, or mitigating measure for development, although it may be a necessary measure once the preferable *in situ* options are excluded.

If there is strong economic or social justification for a development proposal and an impact is demonstrated to be unavoidable, translocation is one option that may be used to conserve genetic material. The major issue with such translocations is that the original habitat (source site) is lost or degraded. Hence, most translocations associated with development approvals will likely increase the extinction risk of the species as losses may not be able to be compensated and any such losses precede future management actions, including any translocation actions (Maron *et al.* 2012; Maron *et al.* 2016). However, the reality is that ongoing development pressure will continue to occur along with mitigation translocations. These translocations come with a series of risks, similar, but in addition to normal translocation risks (see 2.2.3). These risks are exacerbated because the source site is usually being lost or degraded. A mitigation translocation approval should not be granted unless and until:

- all possible measures have been taken to avoid and minimise impacts (as per global best practice offsetting guidelines (Maron *et al.* 2012);
- destruction or serious modification of the natural population is not to occur until the translocation program has been deemed successful or, if time is limited, at the very least until a sufficient number of plants and/or regenerative material is stored in an *ex situ* collection and detailed information on species ecology and propagation is known (see Chapter 3);
- it can be demonstrated with acceptable certainty that there will be no irreparable harm to the species;
- it is to be implemented, managed, monitored, and evaluated following the procedures outlined in these guidelines;
- if there is a possibility of time constraints, pre-approval preparation for translocation (see Chapters 3 and 4) is undertaken as a contingency, rather than leaving the preparation process to a time-constrained post-approval period;
- adequate time and funding have been provided for project development, monitoring, management and evaluation, and, if possible public dissemination of results; and
- relevant experts are involved.

Development or clearing approvals that are granted and specify mitigation translocation, but which do not satisfy the above conditions, cannot be considered in accord with best practice.

2.2. Benefits and risks associated with translocation

2.2.1. Benefits

Translocation, if implemented effectively, may assist in ensuring the persistence of threatened plant species *in situ*, and for some species may be the only means of ensuring the species' survival in the wild. It is also a tool for reducing the extinction risk or at least minimising increases in extinction risk in a threatened species. For those species represented by few populations, the creation of additional secure populations may reduce extinction risk by decreasing susceptibility to catastrophic events, environmental stochasticity and unsuitable future climatic conditions, or by providing additional sites that may have fewer threats than existing sites or may make the species more robust to predicted changes in climate. For small populations of threatened plant species that may be subject to declining population size or negative fitness effects associated with high levels of inbreeding (see Section 3.3.2c), successful population enhancement may increase population stability and hence long-term viability.

Protection of remaining individuals and their habitat should always be the primary priority in the conservation of threatened species, but there may be cases where development pressures enforce a translocation (e.g. salvage, offsetting) in order to try and reduce the subsequent increase in extinction risk that inevitably occurs with habitat loss. While there may be a limited benefit in trying to reduce extinction risk in these cases, this type of translocation is inherently risky as habitat loss usually precedes any effective compensatory translocation actions and hence the loss of individuals precedes any successful establishment of plants at another site.

2.2.2. Conservation translocation risks

Despite the potential benefits of translocation, there are possible risks associated with the technique that need to be considered when deciding whether to translocate. For example:

- The translocated plants may not survive, resulting in wasted resources (i.e. risk of failure) (Fig. 2.2). This risk will be site and species specific (see Case Studies 2.2 and 2.3).
- It may not be possible to eliminate the major threats to the species and hence, ongoing persistence is compromised and resources may be wasted.
- The mixing of individuals from different populations may in some cases lead to outbreeding depression, a reduction in fitness associated with mating among individuals adapted to different environmental conditions. However, the risks of outbreeding depression can be minimised (Frankham *et al.* 2011) and in some cases, the mixing of individuals may be beneficial as it will reduce inbreeding effects (Ralls *et al.* 2018) (see Section 3.3).
- The introduction of diseases, pests or pathogens to natural populations or habitat if appropriate phytosanitary techniques are not applied (see Sections 6.4.3 and 7.3.1).
- The introduction of a species into a habitat where it has not occurred previously, or where it has not occurred for a long time, may in some cases lead to the displacement of non-target species or may influence the structure and composition of the vegetation community.
- Activities associated with translocation (such as planting, soil preparation, fencing, watering, increased pedestrian activity) may impact detrimentally on other species either directly through destruction and trampling, or indirectly by altering ecological processes.
- Pollinators and symbiotic organisms may not be present in the new environment which may limit the long-term persistence of the new populations.

Figure 2.2 Dead translocated Wollemi Pine. (Photo: H. Zimmer)

In some circumstances, the risks to the species or the site may be too great to allow a translocation to go ahead. For example, where there are no pathogen free sites available, or there is very little likelihood of establishing a viable population. In these cases, it is important to ensure that there is a robust *ex situ* conservation program (Section 6.4) for the species that includes a nursery and/or a seed bank/germplasm store.

2.2.3. Mitigation translocation risks

Risks include those above and:

- Extinction risk for the species will increase as losses virtually always precede potential actions for benefits or compensation. Should the translocation fail, there is no effective compensation for the loss of the original habitat and individuals of the species.
- The success of a translocation cannot be guaranteed as a minimization (preventative) action to mitigate impacts due to the uncertainty of species' establishment and persistence (see Case Studies 2.3 and 2.4). Many translocations have now established populations of species on secure sites that are flowering and fruiting, but most have not yet recruited.
- There are potential risks to the translocated species if the translocation is not conducted appropriately.
- Novel constructed ecosystems have unknown ecological value and do not compensate for the loss of naturally occurring habitats or populations of species.
- Translocation is not a simple gardening exercise involving the movement of plants or plant material from a development site to an area not impacted by the development. The conservation of a species also requires the supporting context of its habitat and the continuation of natural ecological processes, along with the abatement of threats and overall reduction in extinction risk.

2.3. Factors to consider when determining whether translocation is necessary

Given the long-term (years, decades) commitment required to implement a successful translocation program, and that even after considerable effort success may not be guaranteed, it is important that the need for translocation is thoroughly evaluated prior to commencing a translocation program. In particular, careful consideration needs to be given to mitigation translocations (proposed as an ameliorative or minimisation measure for development, Section 2.1.2). Detailed consideration of the following aspects of the target species' biology and related factors will assist in identifying potential problems and deciding whether translocation is an appropriate technique. A decision to translocate should not be made until the issues identified in the checklist below have been addressed.

2.3.1. Taxonomy

The taxonomic status of a species should be clear before translocation is considered. For example, is the species an undisputed formally described species, is it part of a species complex that requires further taxonomic study, or is it an undescribed species? In addition, taxonomic uncertainty may influence the sampling strategy and selection of source and recipient sites (Chapter 4). In cases where uncertainty exists, clarification should be sought from experienced taxonomists or population geneticists. Experienced researchers may be reached by contacting your State herbarium, conservation agency or university (Appendix 1).

2.3.2. Distribution

The distribution of the species needs to be determined through the collation of known records and targeted survey for additional populations (Box 2.1). Targeted survey may reveal additional populations, or the existence of more individuals than previously identified, thereby reducing or eliminating the need for translocation. In addition, as outlined in Chapter 3, a detailed understanding of the distribution and abundance of the species is required when selecting translocation source and recipient sites if translocation is to proceed.

Box 2.1 – Steps involved in targeted surveys for populations of threatened plants

Adapted from Keith (2000). See the original reference for further detail

Step 1: Collate existing records

Information about the target species should be sought from the literature, plant collections and databases held by various agencies, Atlas of Living Australia (www.ala.org.au) and individuals familiar with the geographic region or taxonomic group including taxonomists and seed collectors. Verify the records by checking the GPS locations with the location descriptions.

Step 2: Survey previous collection locations

Previously recorded localities could then be searched to confirm or refute the presence of the target species. Collection dates recorded on herbarium labels may indicate the time of year when plants are flowering, and hence most conspicuous in the field. Have some understanding of the ecology of the species, for instance, annuals may not be present all year round, and some species may only be present for a few years after fire.

Step 3: Collate habitat information

The next step involves the collation of information on habitat factors such as geological substrate, landform, elevation and vegetation structure from existing sources, as well as from collections and new observations gathered in the field during the previous step.

Step 4. Identify other potential sites

Habitat information can be used to infer patterns in the distribution of the species and predict additional locations where the target taxon may occur. These sites can then be searched, and a more comprehensive picture of distribution developed.

2.3.3. Drivers of extinction risk and threatening processes

Three main attributes are used to assess the extinction risk of species (IUCN 2017). Species are considered to be threatened if they have any one of: a high rate of decline (either in the past or projected into the future, e.g. through habitat loss); a restricted geographic distribution (combined with ongoing threats that cause decline) as species with small distributions have less capacity to avoid localised threats; or a low population abundance (e.g. species with small populations are more prone to disruption of pollinators/dispersers and adverse genetic consequences, Section 3.3). Translocations need to consider the reason for the threat status of a species along with management of the threats to the species. Translocations can be used to enhance population abundance in species with low numbers, or to create additional sites in species with highly restricted geographic distributions (see Section 4.2.1). At the same time, translocation should not be considered until the factors that limit the species' distribution and abundance in its natural range are understood (IUCN, 1987). Three questions are key here:

1. Which threatening processes are affecting the species? (e.g. habitat loss and degradation, inappropriate fire regimes, invasion by environmental weeds (Fig. 2.3), grazing pressure (Fig. 2.4), other biotic interactions (Fig. 2.5), climate change).
2. Can these threats be controlled or minimised on an ongoing basis?
3. Will the translocation effectively reduce extinction risk in the species by increasing population size and viability and/or by establishing new threat free locations?

Figure 2.3 *Grassy weeds around translocated* ***Acanthocladium dockeri*** *(grey leaf). (Photo: M Jusaitis)*

*Figure 2.4 Grazing damage caused by stock to translocated **Acacia cretacea**. (Photo: M Jusaitis)*

*Figure 2.5 Mouse diggings threatening translocated **Acanthocladium dockeri**. (Photo: M Jusaitis)*

For many threatened species, the removal or ongoing management of threatening processes may be sufficient to ensure population persistence and may lead to an increase in population size, hence negating or reducing the need for translocation.

It is also necessary to identify whether there are any potential recipient sites that are free of threatening processes, or if there are any sites where the threatening processes can be managed effectively. It may be of little use conducting a translocation program unless the threatening processes can be controlled adequately, or if it is not known why the natural populations are in decline (i.e. the threats to the species are not understood).

2.3.4. Recipient sites

Although final selection of suitable recipient sites is unlikely to occur until after the decision has been made to translocate (Section 4.2), the availability of potential recipient sites needs to be considered during the decision-making process (see Chapter 4).

Questions which need to be addressed include:

- Is there any suitable habitat available?
- Is any of the suitable habitat on lands that are protected, or have the potential to be protected?
- Can any threats to the species at the recipient site be mitigated?
- Will the translocation be likely to adversely affect any other species (including other threatened species)?
- Are essential mutualistic symbiotic species (i.e. pollinators, fungi) involving important biotic interactions (Section 3.4) present to ensure persistence of the translocation?
- Are landholders or managers of potential recipient sites likely to agree to translocation occurring on their land? There is no use proceeding with a translocation proposal if suitable recipient sites are unlikely to be available.

The type of translocation will also influence the choice of recipient site. If the primary issue for the species is low population abundance, then increasing plant numbers at the site via reinforcement will be the highest priority. However, if narrow geographic range with limited populations is the primary extinction risk, then repopulating depleted known sites and establishing new sites within the known distribution range should be prioritized assuming suitable habitat is available. Alternatively, if no suitable habitat can be found within the species known range, translocation to other potential habitat may be a viable option. Adoption of these scenarios is also dependent on the number of individuals available for translocation and consideration of longer term threatening processes.

2.3.5. Population persistence

Prior to implementing a translocation designed to increase the size of an existing population via reinforcement, clear justification is required which takes into account the ecology and biology of the species. Many threatened plant species are naturally rare and have restricted spatial distributions, occurring as small and isolated populations or with population fluctuations over time in response to rainfall, or disturbances such as fire and flooding. These small (and/or fluctuating) populations may not require any increase in population size to persist. In these cases, habitat protection and control of threatening processes may be sufficient to protect the species.

The need for active management or an increase in population size can be determined by gaining an understanding of population stability. If a population size is considered stable or increasing (considering natural fluctuations in population size), and the existing population size is considered sufficient to avoid both demographic and environmental stochasticity, then a population enhancement translocation will not be required. On the other hand, if a population is in decline, and/or population size is considered insufficient, then active management may be required to increase population size and stability. Alternatively, the establishment of new populations may be needed to allow the persistence of the species.

Determining whether a natural population is stable

The level of recruitment into the adult population, along with the factors that promote recruitment and plant longevity, are the primary determinants of ongoing population stability and persistence, although these factors may be disrupted by novel threats (e.g. new introduced pathogens). A population will be stable if there are sufficient new recruits surviving to adulthood to replace adult deaths (Harper 1977). In contrast, a population will decline if the number of new recruits is less than the number of adults that die. However, adult populations will fluctuate over time, especially in species with persistence soil seed banks that respond to climatic conditions or disturbances such as fires, floods or storms. Similarly, recruitment of new individuals may be constant or episodic. IUCN (2017) highlight the differences between natural population fluctuations and directional change (i.e. decline). Therefore, the stability of a population can be established by understanding the life history and demography (age specific survival) of a population. There are various means of gathering demographic information and the approach taken will be determined by the life history of the species concerned and the amount of time available. See Keith (2000), Menges and Gordon (1996) and Caughley and Gunn (1996) for a more detailed discussion of monitoring changes to population size.

Age/size class structure

The quickest and simplest means to obtain demographic information is to investigate the age/size class structure of a population at a single point in time (i.e. take a 'snapshot' of population structure). For example, a population that is made up of various size classes ranging from juveniles through to mature individuals could indicate that there is ongoing recruitment. However, such an approach has its limitations and will not provide meaningful information for all species. For example, a population of a fire sensitive species that is dependent upon fire to promote recruitment from a soil stored seed bank will typically be comprised of a single age class.

Monitoring through time

Demographic information can be obtained by following the fate of individuals in a population and making repetitive *in situ* measurements as outlined by Keith (2000). Such a process would be relatively simple to conduct for an annual or short-lived plant species. However, for many species it may be several years before such demographic monitoring provides the required information.

Reproductive and recruitment ecology

An insight into possible population stability may be obtained by investigating a species' reproductive and recruitment ecology. If such a study reveals no major limits to reproduction or recruitment (i.e. pollination is occurring, viable seeds are being produced which are capable of germinating, new recruits are observed and can survive to maturity), it may be inferred that the population is likely to be relatively stable, provided the population is large enough to avoid both demographic and environmental stochasticity. Alternatively, if major limits to recruitment are identified at a life history stage, then it may be assumed that the population would be in decline if the limit to recruitment continued over time (see Auld and Keith 2009).

2.3.6. Other means of increasing population size

If an increase in population size is deemed necessary, then all other means of increasing population size should be considered and/or attempted prior to commencing a translocation program. For example, if low seed production was apparent and pollinator limitation was found to be the cause, hand pollination or ways of increasing pollinator abundance could be examined. If low or no recruitment were apparent even though a large viable seed bank exists, investigating ways to stimulate seed germination may be needed, such as soil disturbance or burning or examining whether fencing may be needed to reduce impacts of grazers on the survival of recruits. Such active management options are likely to be more cost effective than translocation.

2.3.7. Success of past translocation projects

When deciding whether to translocate it is important to investigate whether the species (or a closely related species) has been translocated previously and if so to evaluate the reasons for success or failure. It is useful to explore the possible reasons for failure to ensure that the same mistakes are not made again, while the reasons for any success can be incorporated. It may be that the species is particularly difficult to translocate and it may not be sensible to attempt to do so again, unless new knowledge has been gained in the meantime. More guidance on monitoring and evaluation of translocation projects is provided in Chapter 8. The ANPC website will contain a database of translocation projects, and a series of case studies of past translocation projects has been and will be published in Australasian Plant Conservation (the ANPC Bulletin).

2.3.8. Resource availability and cost

The potential financial cost of a proposed translocation program and the availability of the required resources are important considerations when deciding whether to proceed with a proposed translocation program. How much will the proposed program cost, including monitoring, to establish whether the translocation has been a success? Is there sufficient logistical support (vehicle transport, equipment, trained personnel etc.) available? Would the funds be more effective if directed elsewhere?

2.4. Define the goals and objectives

Having clear goals and objectives is key to effective and efficient planning, implementation, and evaluation.

The IUCN Guidelines for Translocation (IUCN/SSC 2013) suggests defining goals, objectives and actions when planning for a translocation.

- 'A goal is a statement of the intended result of the conservation translocation. It should articulate the intended conservation benefit, and will often be expressed in terms of the desired size and number of populations that will achieve the required conservation benefit either locally or globally, all within an overall time frame.'
- 'Objectives detail how the goal(s) will be realised; they should be clear and specific and ensure they address all identified or presumed current threats to the species.'
- 'Actions are precise statements of what should be done to meet the objectives; they should be capable of measurement, have time schedules attached, indicate the resources needed and who is responsible and accountable for their implementation. Actions are the elements against which translocation progress will be monitored and assessed.' (IUCN/SSC 2013)

2.4.1. The ultimate goal

The ultimate goal of a conservation translocation is usually to establish a viable (self-sustaining) population (IUCN/SSC 2013), the persistence of which will reduce extinction risk of the species.

Further information on what constitutes a viable or self-sustaining population can be gleaned from the Guidelines for Using the IUCN Red List Criteria (IUCN Standards and Petitions Subcommittee 2017). These guidelines state that populations established by translocation cannot be included in IUCN extinction risk assessments for a species until the population produces viable offspring.

Goals of translocation may differ for mitigation translocations. For example, the goal here may be to retain genetic diversity, while at the same time minimising any increases in extinction risk.

2.4.2. Objectives and tracking progress

Meeting the goal of creating a self-sustaining population, or waiting until translocated plants produce viable offspring, may take many years, for example, *Banksia verticillata* from Western Australia has juvenile periods of 13-17 years (Monks 1994 cited in Department of Parks and Wildlife 2017), while juvenile plants of the Wollemi Pine (*Wollemia nobilis*) in the wild may survive for decades with little growth (Zimmer *et al.* 2014).

It is important to set objectives that make clear what needs to happen for the translocation to meet its overall goal. Detailed objectives allow the tracking of progress towards the translocation becoming a self-sustaining population.

Typical objectives for threatened plant translocations include:

- vegetative growth of individuals;
- survival of individuals with time (i.e. from one monitoring visit to the next, or weeks, months, seasons, years);
- survival of individuals to flowering;
- presence of reproductive structures (flowers and fruits) on individuals;
- presence/abundance of seeds;
- presence/abundance of second generation (seedling or vegetative recruitment); and
- capacity to successfully respond to future disturbances such as fire.

The answers to these questions may be referred to as 'short-term criteria for success'.

2.4.3. What 'number' constitutes success?

Unfortunately, this chapter cannot provide numbers (e.g. rates of survival) required to 'guarantee' the establishment of a self-sustaining population. While we do provide an overview of this issue in Section 4.1.2 with suggested numbers of plants for setting up a translocation, we emphasise that these numbers, also known as vital rates, vary greatly among species, and among sites and populations/subpopulations, and with threats and environments.

At the most basic level, the vital rates of a population are the number of births and deaths (or fecundity and mortality) during a given time period. Complexity is added when we consider that vital rates within a population vary with the life stage of individuals. In plants, mortality rates are typically higher at earlier (seedling) and later life stages (Harper 1977), while seed production may also vary with plant size and age. These variations are particularly relevant to plant translocation where, for example, there are often high rates of mortality in the immediate period following translocation. For translocation, knowing when first and peak reproduction (fecundity) are likely to occur (either in terms of size or age) is critical.

Vital rates can be used to conduct population viability analysis (PVA) (or other type of demographic modelling concerned with abundance), which can be used to estimate what number of propagules/seedlings are required (i.e. initial population size) for a translocated population to survive until maturity, based on expected mortality rates. Although PVA is often described as a quantitative conservation tool for assessing the fates of rare and endangered species, it is rarely applied for this purpose, especially for translocated populations (Menges 2008) or long-lived plants (Schwartz 2003).

While there can be challenges with the accurate estimation of vital rates critical for the development of a PVA, and this can be particularly acute for slow-growing, long-lived plants, PVA can be especially useful for projecting the probability that the translocated population will achieve a viability threshold (Monks *et al.* 2012). The establishment of a self-sustaining population will often be difficult to demonstrate but a well-designed monitoring program combined with a PVA can allow robust estimates of the long term trajectory of the translocation population providing one of the best estimates of translocation success.

2.4.4. Getting the most out of the translocation: Linking monitoring and actions

Translocations can be designed to answer questions about which conditions (e.g. microenvironment, initial plant size, management interventions) are more likely to lead to the desired outcomes (e.g. growth, survival, flowering), and to inform future translocations (see Section 6.5 and Chapter 8). Monitoring is also a great opportunity to learn more about the ecology of the target species. Key questions can become more detailed, and also inform future management, for example:

- To what extent is flower/fruit production in the translocated population higher in sunny or shady microsites?, or
- To what extent is plant survival in the translocated population higher in plants that received watering, or not?

This might also be considered as asking 'management-relevant questions' and applying adaptive management (Keith *et al.* 2011). It is very helpful where it is possible to apply adaptive management principles to inform translocations and future management actions. To conduct true adaptive management, two or more management strategies must be used in a comparative experimental framework, and the results of monitoring these alternate strategies are used in an established framework to guide future management (Keith *et al.* 2011). Because of the limitations typical of threatened plant translocation (e.g, small numbers of plants and suitable recipient sites), it may not always be possible to trial multiple management strategies on populations of appropriate numbers to allow statistical analysis of outcomes (Section 6.5).

2.5. Decision making framework

A simple decision tool to assist in deciding whether to translocate is provided in Fig. 2.6.

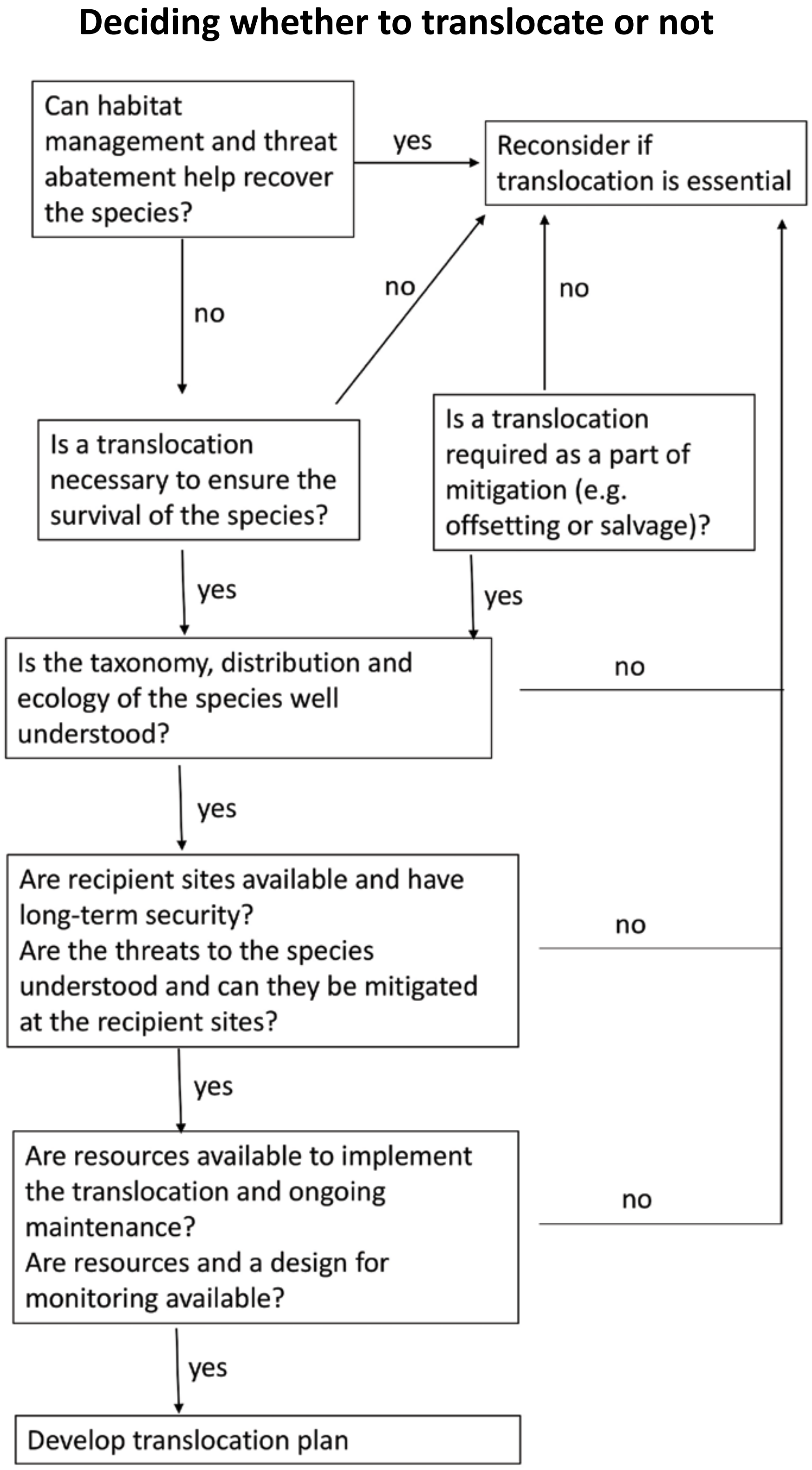

Figure 2.6 A decision tool to assist in deciding whether to translocate or not.

2.6. Checklist

The following check list is a quick guide to help decide whether the translocation will be worthwhile or achievable:

- Have other conservation measures been tried (e.g. reducing existing threats) (Section 2.1.1 and 2.3.6)?
- Will extinction risk be reduced by the translocation or will it increase due to habitat loss?
- Can the threats to the species be ameliorated to a degree that allows the species to persist at the translocation site?
- Is the taxonomic status of the species well understood?
- Is the distribution of the species adequately understood as outlined in Section 2.3.2? Have adequate field surveys been undertaken to inform the conservation status of the species?
- Has a clear purpose and plan for the translocation been identified?
- Have suitable recipient sites been identified (Section 2.3.4)?
- Is the tenure of recipient site secure and is it likely to continue to be secure in the future?
- Are other species at the site likely to become threatened or adversely affected because of the translocation?
- Can the species be successfully established at the site?
- Can the threats be managed /ameliorated at the recipient site? (Section 2.3.4)?
- Are there any emerging threats/risks that need to be considered?
- If considering population enhancement, is there evidence of population decline as opposed to simply natural fluctuations (Section 2.3.5) and has alternative means of increasing population size been considered or attempted (Section 2.3.6)?
- Do necessary associated species (symbionts) i.e. pollinators occur at the site?
- Is there sufficient germplasm to carry out a translocation?
- Does the germplasm have sufficient genetic diversity for long term population persistence?
- How will success of the translocation be measured and monitored?
- How will assessing the translocation and its success be resourced?
- Has the success of any previous translocation programs relevant to the species being considered been investigated (Section 2.3.7)? (See ANPC website and back issues of APC.)

If the answer to any of the above questions is no, then the benefits and risks of proceeding without that information should be assessed prior to making a decision to translocate.

Case Studies

Case Study 2.1 - A Ministerial condition mandating translocation

Excerpt from Elliott et al. (in press).

Tetratheca erubescens has a single natural population in Western Australia covering just 3.5 ha. It is located north-east of Perth in the Koolyanobbing Banded Ironstone range. To mine an iron ore body under this range, Cliffs Asia Pacific Iron Ore (Cliffs) received a Ministerial Statement (1054) from the Western Australian government that agreed to the implementation of the proposal subject to a list of Conditions, including the conservation and protection of *T. erubescens*. One such condition (Condition 8 Stage 1 Offsets) stated that the company needed to 'establish a new self-sustaining population of at least 313 mature individuals of *Tetratheca erubescens* on a suitable landform that is suitable for the species'. Consequently, translocations would need to be carried out to achieve this Ministerial Condition.

As part of an offset package to mine and subsequently remove *T. erubescens* plants from banded ironstone habitat, Cliffs were required to conduct translocation research with the aim of contributing a scientific understanding of the long-term recovery and protection of this threatened species.

A translocation proposal was developed by Cliffs in consultation with Kings Park Science, using a template provided by the (then) Department of Parks and Wildlife (DPaW) to guide and provide justification for the translocation. The proposal was submitted to DPaW where it was assessed by several independent reviewers. The proposal met the policy requirements on plant translocations and was granted approval for the translocation to proceed as agreed upon. Translocation approval conditions included submission of an annual report that outlined the following year's translocation plan.

The first translocations were implemented in 2017 on natural and disturbed landforms in close proximity to natural populations. At this early stage, *T. erubescens* can be physically placed into its natural cliff habitat via cuttings with some level of short-term success and early research suggests that microhabitat placement, seasonal rainfall and access to supplementary water (irrigation) are essential for translocation success.

Figure 1 Images of ***Tetratheca erubescens*** *in the natural population and translocations.*
Top left: Mature plant in natural population at Koolyanobbing Range;
Top right: Flower of ***Tetratheca erubescens****;*
Bottom left: Cuttings planted at a translocation located on Koolyanobbing Range (2017 translocation);
Bottom right: Two-month-old translocated plant (cutting derived; 2017 translocation). (Photos: C Elliott).

Case Study 2.2 - Learning from translocation failure

Excerpt from Doyle et al. (in press).

Hibbertia spanantha is a perennial shrub known from just three locations in the Sydney basin. One of these locations, a bushland reserve, was near a development. The development posed no immediate threat to the population, however, there was a risk of accidental damage to the plants due to its close proximity. A translocation was proposed to provide insurance in the instance of unintentional damage.

Initially, direct seeding was planned, but no viable seeds could be located. Instead, plants were propagated from cuttings. Cuttings were collected from the reserve to propagate plants to be planted in the vicinity of the source plants. Twenty-seven cuttings were collected from three individual specimens (clonal) of which a total of 18 cuttings successfully struck. Eleven of those survived, 8 of which were supplied for translocation, 3 were retained by the Australian Botanic Garden, Mount Annan as part of *ex situ* conservation. Planting occurred in autumn 2015, and the soil was moist.

Monitoring of plants occurred for one-year post planting (concluding June 2016). Throughout autumn and winter of 2015 all plants were healthy. In September and October, four of the planted individuals died in bud or with partially opened flowers. One was recorded dead in April 2016 and another recorded dead in June 2016. At the time of the final monitoring, only one *Hibbertia* remained alive albeit with only very sparse basal leaves remaining. This plant has since died. Anecdotal observations suggested that soil nutrients and period of 'hardening off' may have a role in the survival of cuttings when planted back into their natural habitat.

The original aim, to augment the existing population of *Hibbertia spanantha* failed. All planted individuals eventually died. Observations during the first program have however provided insights into the behaviour of the plants which has posed further questions on potential for the propagation and translocation of this species. This has led to a second propagation and planting trial with cuttings due for planting in Autumn 2018. This trial aims to monitor the impact of growing medium, nutrient levels and hardening off on the survival of planted individuals. Lessons from the failed translocation and the new trial will be used to inform future propagation practice and hopefully improve long term survival success.

*Figure 1 Parent **Hibbertia spanantha**. (Photo: C Doyle).*

Case Study 2.3 - Success and failure – different outcomes at different sites

Excerpt from McDougall et al. (2018).

Pomaderris delicata is a perennial shrub endemic to New South Wales (Fig. 1). The species grows in dry open forest and is known at only two sites, a nature reserve and a roadside. Plants were translocated to these two known populations, and a translocation was planned to create a new population to reduce the extinction risk. The new population was established at Nadgigomar Nature Reserve, which is the closest protected area to the roadside population where propagation material was obtained.

Seed output has been observed to be poor. Cutting material was collected for propagation in Autumn – Winter. The Australian National Botanic Garden retained representatives of all clones in the Living Collection, in case of failure of the enhancement plantings, further decline in extant populations and as stock plants for future production for subsequent plantings.

Reinforcement plantings at both sites are surviving, flowering and producing seed, despite occasional deaths. The best survival and subsequent growth occurred when new plants were placed within the existing population at the roadside site, although survival was also surprisingly good on an exposed roadside batter comprising B horizon soils. No recruitment has been observed yet.

The translocation into Nadgigomar Nature Reserve failed rapidly. All plants had died by early October, two months after planting, despite favourable conditions for plant growth (i.e. soils were not especially dry during that time).

Finding a suitable planting site has been challenging. Survival seems to be better within existing sites in sheltered situations but has also been very good on an exposed road batter made up of subsoil.

Figure 1 ***Pomaderris delicata*** *under cultivation at the Australian National Botanic Gardens. This species grown from cuttings, flowered and set seed within 18 months. (Photo: J McAuliffe)*

Chapter 3 – Pre-translocation assessment of biology and ecology

Authors: Lucy Commander, Tony Auld, Maurizio Rossetto, Mark Ooi, Noushka Reiter, Nigel Swarts, Leonie Monks, Margaret Byrne

The considerations and information required when deciding whether to translocate a particular threatened plant species were discussed in Chapter 2. Once a decision to translocate has been made, further information - ecological, reproductive biology, genetic, environmental and logistical - is required to allow detailed plans to be developed and to enhance translocation success.

A translocation program should not commence or be approved until all of the following questions can be answered:

- Has an established recovery team for the species assisted with the pre-translocation assessment or has a suitable translocation working group been established as outlined in Section 3.1?
- Are relevant aspects of the taxon's reproductive biology and ecology adequately understood (Section 3.1, 3.2, 3.4, 3.5)?
- Have experts on the genus been consulted?
- Has an assessment of the need for genetic research been conducted in consultation with a population geneticist and has any necessary genetic research been conducted (Section 3.3)?
- Have propagation methods been determined (Section 3.5)?

3.1. Recovery team or translocation working group involvement

Translocation should only be considered as part of a holistic approach to managing a species. Ideally, in the case of a species that has been listed as threatened under State or Commonwealth legislation, a recovery team will already have been formed to implement the recovery plan (Australian Government Department of the Environment and Energy 2018) and direct the recovery actions. The recovery team should bring together people from a range of disciplines who have experience and/or an interest in conserving a species or group of species. A translocation should preferably be undertaken as part of a broader recovery process and should be undertaken in consultation with a recovery team, or similar team with the required expertise, or in the absence of these should include the formation of a specific project team, including relevant experts and consulted stakeholders, for the translocation phase.

A considerable amount of information is required before proceeding with a translocation. Much of the required information may be already available, or alternatively it may be necessary to gather additional information through observations and/or experimentation. In order to facilitate the gathering and collation of information it is vital that a range of individuals or organisations with the appropriate knowledge and expertise are involved, and these people may already be available through a recovery team. In cases where a recovery team does not exist an alternative may be to set up a translocation working group, which brings together people with the appropriate knowledge and expertise (Section 3.10.1).

3.2. Ecology

As part of the planning for a translocation, it is essential to have an understanding of the species' ecology, as this will influence all aspects of the project, from site selection, to the design of the monitoring program. Ecological understanding of the target species will also greatly increase the likelihood of translocation success. It is important to collate all available literature for the species, and talk to people who have relevant experience, to ascertain what is already known and where any knowledge gaps exist. However, for some species there will be little available information. In this case, the ecology of the species should be assessed as best as possible, potentially by using data from surrogate species such as closely related species (ideally within the same genus) with similar life-histories, distributions and habitat requirements.

It is recommended that the following information is gathered through collation of available data or research:

life history attributes

- longevity and average generation length, including whether the species is short- or long-lived, or is a component of a specific successional stage (e.g. disturbance opportunist) and time to reproductive maturity;
- primary mode of regeneration (seed or vegetative) and assessment of clonality (where necessary);
- typical age structure of the population (whether the population is even or multi-aged);
- breeding system (e.g. self-compatible or self-incompatible);
- pollination mechanisms (e.g. bird, insect, wind, combination of vectors);
- levels of flower and fruit production;
- season of seed maturation;
- seed dispersal mechanisms;
- seed viability, dormancy type, and germination cues;
- germination amount and speed;
- seed bank type (soil, canopy, transient, persistent) size, and potential longevity;
- season of seedling emergence;
- factors limiting natural population recruitment along with known means of controlling/managing these;

biotic factors

- associated flora and fauna and details of any potential inter-relationships between the species and other species, including rhizobia, mycorrhizae, pollinators or and seed dispersal vectors;
- habitat characteristics, for example whether the species occurs under a closed canopy or inhabits open areas, whether the site is exposed to salt spray or strong prevailing winds;

abiotic factors

- characteristics such as soil type and profile;
- water quality and water table depth, drainage characteristics;
- slope and aspect;
- landform;
- elevation;
- climate envelopes (precipitation, temperature and other climatic conditions);

disturbance and threat factors

- response to disturbance, e.g. fire sensitivity (e.g. re-sprouter or obligate seeder) and response to difference components of the fire regime, floods, storms;
- resilience to other disturbances or management techniques such as grazing or herbivory by native, domestic or feral animals;
- susceptibility of the target species and associated vegetation to disease (e.g. *Phytophthora* spp., Myrtle Rust), and potential to control the disease or prevent its introduction to the translocation site;
- resilience of the species and its habitat to weed infestation, and the effect of herbicides on the species and the associated vegetation; and
- resilience to a changing climate and associated threat exacerbation.

If conservation introductions are being planned, consideration must be given to whether there is potential for the species to impact on the ecology of other species at the recipient site, e.g. become a weed in the new habitat or hybridise with related species (see Section 4.4.3 and 3.3.2b). The likelihood of these events will largely depend on the biology of the species. Special considerations must be given to any planned conservation introduction of:

- aquatic species (IUCN 1987);
- families or genera that are known to be invasive in some habitats, e.g. Asteraceae, Myrtaceae, *Acacia*; and
- families or genera that are known to hybridise readily, e.g. *Persoonia, Eucalyptus, Verticordia*.

3.3. Conservation genetics

3.3.1. Background

Conservation genetics uses a range of continuously improving DNA-based tools to assess genetic diversity within populations and genetic differentiation among populations of species. This information can then be used to infer the impacts of small population size and range fragmentation on the long- and short-term viability of rare and threatened species, and other species of conservation interest, and can also provide information to assist in resolving taxonomic uncertainties. The type of information that can be obtained from conservation genetics studies includes: clarifying how evolutionary processes such as genetic drift, selection, and migration shape genetic and phenotypic variation of species and determine population structure; and describing the effects of low effective population size on genetic variation and overall species viability.

Genetics can be readily included in translocation planning and integrated with other pre-translocation research as well as included in monitoring to assist in assessing translocation success. Although the availability of significant expertise, technical automation, and lowering costs, make conservation genetics an increasingly accessible proposition, it is important to first determine the need for this research component during the planning phase for threatened plant translocations, as genetic issues are not pertinent to all species. There might be issues that need more immediate consideration (for instance if populations are about to be destroyed irrespective of other considerations), populations might be so small that all individuals can be translocated.

It is recommended to contact a conservation geneticist for advice and whether there is a need for genetic studies. Specialists at universities, Botanic Gardens, CSIRO, or State/Territory environment/conservation departments may be able to assist (Appendix 1).

3.3.2. Why is it important to consider genetic diversity?

Genetic diversity within populations and species contributes to the maintenance of fitness, and facilitates evolution and adaptation. Consequently, a decline in the number of individuals in a population can lead to increased genetic drift and loss of diversity, and increased inbreeding (particularly in preferentially outbred species), and increased vulnerability to change following the loss of broader adaptive potential.

Much has been written about how genetic studies can be applied in conservation and management, including translocation projects (e.g. Menges 2008). Consequently, this section does not aim to explore in detail the theory and practice behind conservation genetics, but rather to provide a brief summary of the main genetic issues that need to be considered within the context of threatened species' translocation. The following points do not represent definitive solutions, but they identify some of the major issues that need to be considered, provide suggestions on the use of genetic tools to investigate them, and highlight general interpretations.

a) Taxonomy and genetic differentiation

Issue: It is important that taxonomic entities are resolved and species / lineage boundaries are understood so that decisions on management strategies can be made. Defining species and other taxonomic categories that can be formally listed as threatened can be complex as a variety of interpretations and verification protocols exist. While listed threatened taxa are required to be formally taxonomically recognised or the entity clearly delimited based on genetic and biogeographical data, further genetic studies may reveal strongly differentiated lineages or extremely divergent populations (see Section (d)) representing cryptic taxa that are identified in need of urgent action, but the taxonomic identity of the new lineage cannot be verified by morphology alone. Genetic studies can sometimes identify strongly differentiated lineages that represent divergent evolutionary histories that also need to be considered in management and are better kept apart in translocation projects. Most of these cases involve species whose distributions include large geographical disjunctions or habitat variability with the divergent lineages characterised by the accumulation of substantial genetic or phenotypic differences among two or more population groups within the species over time) that may even represent cryptic taxa that when mixed will lead to sterility and/or reduced fitness in progeny. Therefore, unless there is genetic evidence that the populations across the disjunction are not substantially genetically differentiated, a precautionary approach is recommended where seed sources from populations across the disjunction are kept separate and not mixed (also see Section 4.1.1). In rare circumstances, mixing individuals from different populations that are not highly disjunct or come from very different habitats can also lead to a loss of fitness. This can be a consequence of mixing populations with polyploid chromosomal differences, or of disrupting co-adapted gene complexes (specific combinations of alleles with a beneficial effect on fitness), or of mixing lineages with different timing of life history traits (such as flowering time for example).

How & What: There are two options that can be considered if genetic studies reveal genetically divergent populations/lineages or a new taxon within an already identified threatened species. Firstly, the genetically divergent population/lineage or new taxon can be listed separately as threatened under legislation with the appropriate protection and management. Alternatively, formal listing might not be pursued and management options can be considered. Regardless, if uncertainty of the taxon's status is acknowledged, the new lineage (be it a single population or a more widely distributed lineage) can be placed into its evolutionary context by a comparative population genetics study that includes those related lineages it needs to be differentiated from. Where possible, it is advisable to rely on a combination of analytical approaches, extensive sampling and multiple lines of evidence (for example a mix of chromosomal, nuclear and plastid data). When chromosomal differences are suspected, cytological methods and chromosomal studies can efficiently identify differentiation present within or between populations. Additionally, the investigation of genetic structure across a species' range (this can be done at different hierarchical levels, via a range of technical and analytical approaches), and looking for associative patterns between genetic and environmental variation (modern genomic tools are increasingly informative – see following Section) can guide the identification of differentiated population units. Based on this information, decisions can be made in relation to the prioritization and planning of combined vs. separate management strategies.

b) Is hybridization a possible threat?

Issue: Some genera are particularly prone to hybridization (e.g. *Eucalyptus*) where differentiated species can interbreed and produce viable offspring. In extreme circumstances, admixture events have the potential to completely swamp genomes of rare species. In some cases, it can be difficult for translocation practitioners to select material that is not of hybrid origin. It is also important when selecting translocation sites to be aware of any closely related species in adjacent vegetation that could potentially hybridise with the translocated species. Unplanned hybridization events have the potential to reduce the overall fitness of translocated populations, as well as impact on natural populations located close to translocation sites.

How & What: If hybridization is considered a potential risk, genetic tools should be used to understand which species and populations are involved, and how common such events are. Generally, this can be achieved by analyzing a suitable number of adult individuals and progeny from the target threatened species, as well as a representative number of individuals from co-distributed, closely related species. This information will ensure that suitable (non-hybridized) material is selected for translocation projects and collections of propagules from hybrid sites are avoided. Furthermore, if genetic evidence suggests that natural hybridization can occur across species with overlapping distributions, selection of translocation sites must ensure that the potential for inter-specific admixture does not compromise translocation success. A risk assessment has been developed for revegetation and the same principles apply to threatened species translocations and such an assessment can be used to determine risk for threatened species (Byrne *et al.* 2011). Finally, genetic tools can contribute to long-term monitoring by verifying that the progeny of translocated plants have the expected genetic make-up.

c) Small population size and mixing populations

Issue: Extreme reductions in effective population size (bottlenecks) and loss of between-population connectivity (fragmentation) across the natural distribution of species often cause significant reductions in within-population genetic diversity and increases inbreeding. In naturally outbreeding species inbreeding can (but not always) result in the loss of fitness, reduced reproductive output, overall population decline, and increased extinction risk. Overall this effect is known as inbreeding depression and it is generally caused by the increased impact of harmful recessive alleles within inbred populations. These issues are valid for translocated populations. If the re-established genetic spectrum is not sufficiently broad, the self-sustainability and long-term viability of translocated population might be compromised with reduced capacity for adaptation, be it new diseases (e.g. Myrtle Rust), increased competition, or anthropogenic climate change. This is particularly problematic for long-lived species where the deleterious impact of inbreeding might not be fully apparent for decades.

How & What: DNA-based analytical tools and techniques can provide information about the overall diversity present within and between populations, and support the selection of source material to be used in translocation projects. It is now widely acknowledged that, in many cases, this information can be used to reverse the detrimental effects of low genetic diversity and inbreeding in populations by mixing genetically distinct populations or by augmenting populations with genetically distinct individuals and providing new genetic variation. This process is known as 'genetic rescue' and can potentially lead to long term translocation success if population growth and size are appropriately maintained (Fig. 3.1) (Frankham 2015; Ralls *et al.* 2018).

In circumstances where clonality is an issue, genetic analyses will be needed to differentiate genets (genetically differentiated stems) from ramets (genetically identical stems) (see Binks *et al.* 2015; Millar *et al.* 2010). Such information can guide the establishment of new populations where clonal diversity is maximized and in some cases, sexual reproduction is re-established. Genetic information can also be used to verify and monitor the identity of propagated material (errors can and do occur in the identification of propagated material) (see Case Study 8.3 and Krauss *et al.* (2002), and to assess relatedness (kinship) among translocated individuals and offspring produced.

Protocols for ecological restoration are focusing less on the use of 'local' provenances only, and more on a range of carefully planned genetic mixes. It is now recognised that the advantages of increasing genetic diversity within populations far outweigh the potential risks involved (Broadhurst *et al.* 2008a). This is particularly the case for many threatened species where populations are small and isolated, and where focussing on local populations may lead to collections with limited genetic diversty or from plants subject to inbreeding (Breed *et al.* 2013; Broadhurst *et al.* 2008a; Ralls *et al.* 2018; Sgro *et al.* 2011; Weeks *et al.* 2011). A number of genetic augmentation scenarios have been developed to support restoration strategies (Prober *et al.* 2015), and similar strategies have been considered and implemented when planning the translocation of threatened species (see Weeks *et al.* 2011). For these strategies to be effective, it is preferable to obtain genetic information that defines the boundaries of genetic provenances, and how these relate to environmental / climatic conditions, as well as other important biotic and abiotic factors. For a more detailed overview of seed sourcing strategies see Section 4.1.1.

*Figure 3.1 Seedlings of two of the subspecies of **Schoenia filifolia** (threatened **S. filifolia** subsp. **subulifolia** two pots on the left; common **S. filifolia** subsp. **filifolia** four pots on the right). A glasshouse experiment was set up to cross these two subspecies to investigate whether genetic rescue was possible, however the experiment found that cross-pollinated flowers do not set seed. (Photo: L Monks)*

3.3.3. New tools, new opportunities

Traditionally, conservation genetics has relied on small numbers of molecular markers derived from allozymes, Amplified Fragment Length Polymorphisms (AFLPs), or microsatellites (SSRs). More recently the high-throughput sampling of nucleic acids derived from Next Generation Sequencing (NGS) has provided new opportunities for scaling-up to genome-wide inference (Bragg *et al.* 2015). Although traditional methods have still something to offer, genomic studies can provide greater power to detect genetic diversity and genetic structure, particularly where large sample sizes are not available for analysis.

While whole genome sequencing of multiple individuals across populations might still be beyond the budget and scope of most studies, reduced representation genomic methods allow tens of thousands of single nucleotide polymorphisms (SNPs) to be discovered and reliably genotyped at a significantly reduced cost. This is particularly beneficial for species of conservation concern where no previous genomic knowledge is available, and where limited resources and sampling constraints (i.e. few individuals are available) are the norm. The resulting availability of high density, genome-wide, variable SNPs is ideal for the study of evolutionary history, population dynamics, and inheritance processes. The ever-advancing technology and increasing availability of dedicated and affordable commercial services creates new opportunities for ecologists and conservation biologists (Rossetto and Henry 2014). Consequently, translocation practitioners, in collaboration with ecologists and conservation geneticists, can place greater emphasis on experimental design and data interpretation than on the technical requirements involved in the production of genetic data.

The analytical tools used in genome-wide studies are also increasingly suitable for identifying markers that reflect local adaptation, as well as genomic regions associated with inbreeding depression. Such information was often inaccessible to studies using traditional markers, and it has the potential to further guide the selection of plant material sources to be used in translocation projects.

While not commonly applied in threatened plant species as yet, other advanced NGS-based techniques may also be used to inform translocation projects in the future. For instance, the investigation of transcribed genes (the transcriptome) can more directly identify variability with gene families of interest (gene associated with disease resistance for example) and recent developments in gene editing may assist in producing plants with specific traits (Bortesi and Fischer 2015). However, these applications will require significant knowledge of particular genes influencing plant traits as well as advanced transgenesis systems, and are not likely to be readily applied to translocations of threatened plants in the near future.

3.4. Understanding biotic interactions

One possible factor increasing the likelihood of plant extinction is specialisation with a partner organism (Harcourt *et al.* 2002). Biotic interactions can come in the form of pollinators to facilitate reproduction, dispersal agents to facilitate the movement of seed, mycorrhizal fungi to improve plant nutrition and water uptake and bacteria/rhizobia for soil conditioning. It is likely that a range in specialisation/dependency of partner organisms exists with each scenario requiring unique consideration for translocation projects. Where plants with specialist interactions lose an essential symbiotic partner from part of their range e.g. pollinator (Robertson *et al.* 1999; Anderson *et al.* 2011; Pauw and Bond 2011; Reiter *et al.* 2017) or mycorrhizal fungi (Shefferson *et al.* 2005; Swarts *et al.* 2010), a range retraction is inevitable. Conversely, generalists are more likely to be robust to losing a symbiotic partner as they may be able to switch to another association in part of their range (Johnson and Steiner 1997). Plant conservation translocations require not only a thorough knowledge of the threats and threat management, but also a detailed understanding of the ecology (Reiter *et al.* 2016) of the partnering organisms e.g. pollinators (Reiter *et al.* 2017) and mycorrhizal fungal associations (Batty *et al.* 2001; Swarts *et al.* 2010). It may be necessary to symbiotically propagate the plant with mycorrhizae or rhizobia and, for plants with specialised pollination syndromes, determine the presence of the pollinator at potential translocation sites prior to the translocation of plants.

While some biotic interactions may benefit translocated plants, other interactions may be detrimental. For instance, competitive effects may influence population persistence. This is clear from invasive species but is also relevant for natives. Care needs to be taken to understand any likely adverse competitive interactions for a proposed translocation (e.g. overtopping or shading out by larger individuals of another species etc.).

3.4.1. Pollinators

Establishment of reintroduction sites and supplementation of small populations is critical to the recovery of many threatened plant species. Many Australian plants are reliant on specific species or groups of species of birds, mammals, bees, wasps or other insects for pollination. Often plants which require animals as a vector are specialized on a subset of the available pollinator community (Fenster *et al.* 2004; Rosas-Guerrero *et al.* 2014). For plants with specialized pollination strategies, understanding the spatial distribution of pollinators is essential for successful reintroductions. There are many examples, particularly in the Orchidaceae where pollinators have been patchy or scarce in the environment thus limiting potential translocation sites (e.g. Phillips *et al.* 2015; Reiter *et al.* 2017) (see Case Study 4.1). Outside of the Orchidaceae there are many plant families that utilise specialised pollinator associations, notably Fabaceae (see Pea and Bee literature). Therefore, it is important prior to translocation of a particular plant species to understand what pollinates the plant, if this is a specialised or generalist pollination strategy (i.e. associates with one or few pollinators or many) and if these are present at the recipient site.

3.4.2. Mycorrhizal and rhizobial associations

Over 80% of Australian plants have mycorrhizal associations and many others form unique associations with rhizobia (for example Wollemi Pine, many Fabaceae). An understanding of these associations may benefit both the propagation and translocation success of the species. There are many examples of nationally threatened species having improved growth by the addition of their symbiotic soil associations including *Borya mirabilis* (Boryaceae) (Reiter *et al.* 2013).

All Orchidaceae are reliant on mycorrhizal associations in order to germinate in the wild (Rasmussen 1995; Rasmussen 2002; Warcup 1971). Therefore, it is critical to ensure that the specific mycorrhiza is present in the proposed translocation site either through symbiotic propagation (Fig. 3.2) (see Reiter *et al.* 2016; Swarts and Dixon 2017) or through fungal baiting of proposed translocation sites (see Brundrett *et al.* 2003). New research in this area shows that mycorrhizal associations with particular species can be habitat specific and may need to be considered in potential translocation site selection (Linde *et al.* 2017; Reiter *et al.* 2018a).

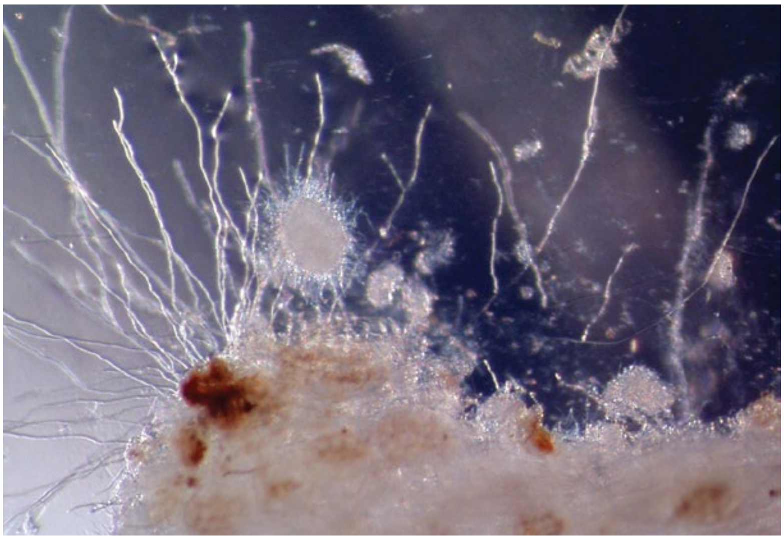

Figure 3.2 Mycorrhizal fungus isolated from ***Pterostylis arenicola****, used for symbiotic seed germination. (Photo: M Jusaitis)*

3.5. Sourcing plants for translocation

Information is required on the most appropriate method of obtaining plants for the translocation project. There are essentially two main choices, translocation with or without propagation. It is also useful at this point to consider the level of after-care the species will require once it has been translocated. After-care techniques are outlined in Section 7.4. Staff at germplasm storage or propagation facilities should be able to assist in choosing the most appropriate method of obtaining plants and developing a suitable after-care plan.

3.5.1. Identifying appropriate propagation techniques

Part of the information gathering phase is to decide how to source plants for translocation. Plants can be obtained in a variety of different ways (Case Study 3.1). Propagation methodology will depend on the biology of the species, and the time available. Information about sourcing material for propagation of threatened Australian species is found in Offord and Meagher (2009). In general, seedlings derived from germinated seeds are used as the main propagules for translocations, as these provide the cheapest and most effective source of germplasm as they are more likely to encompass a large proportion of a population or species diversity. Seed collections also occupy minimal storage space and can be stored for a period prior to propagation. However, some species produce limited amounts of seed, or seed germination is difficult as methods for overcoming dormancy may not be known. Seed production is also dependent on several factors including climate and pollinators, and some populations may not set viable seeds for several seasons.

For species where timing of fruit set and seed release are not available and for species with clonal reproduction, cuttings, division, grafting or using micropropagation techniques are alternative sources of propagules. These techniques can produce large numbers of propagated plants in a short period of time. However, unlike seed collections it is harder to capture sufficient diversity within large populations, and large cuttings collections are more expensive to maintain. Plants propagated from cuttings are also genetic clones of their source plant and so care must be taken in tracking source material to ensure one clone is not over represented in the *ex situ* collection. Tissue culture is a useful collection method for very rare species where genetic variability is not a major issue.

While tissue culture collections take up less space than cuttings collections, they are more expensive to set up and maintain as the procedure requires specialist equipment and techniques. Approaches that maximise genetic variation are relevant to both seeds and cuttings as propagules (see Section 4.1 for information on selecting source populations and collecting plant material). Plants can also be translocated without the need for propagation, such as direct seeding, transferal of the soil seed bank or of mature plants. All of these techniques can be used for both conservation and development translocations, although removal of mature plants is more common in development translocations. Costings will depend on the methodology chosen and the species (see table 3.1).

If the source population is to be removed due to development, collect regenerative material (seed, cutting material etc.) from the mature plants and propagate tubestock from this material. Ideally, the source plants should not be destroyed or removed until the success of the population at the recipient site has been determined. If there is an unavoidable time constraint, the source plants should not be removed until a large *ex situ* collection of germinable seed and/or tubestock exists.

Developing a timeline for obtaining plants is an essential part of the planning process (see Section 6.2). Some activities such as seed collection are seasonal and may have a small window of opportunity once per year. If seed germination methods are unknown, research into germination may take some time. Overall, plant production may take between a few months and several years.

3.5.2. Translocation via propagation and tubestock

Information about whether it is possible to propagate the species is required. This may require some trialing or experimentation if time allows. Often, information may be derived from closely related species (Table 3.1). This information should ideally include:

- seed collection season;
- seed germination requirements of the species, including any symbiotic relationships, presence of any dormancy mechanisms, and methods of overcoming dormancy (e.g. heat, warm or cold stratification, dry after-ripening, acid, nicking of seed coat, scarification, smoke);
- possible methods for vegetative propagation (e.g. division, cuttings, tissue culture);
- survival rates of the propagation methods, as they may differ (e.g. for some species, seed grown and cutting grown plants may have different survival rates); and
- any special establishment requirements for the species, for example many orchid species are dependent on mycorrhizal fungi for seed germination and survival, and legume species require rhizobial symbionts for nitrogen fixation and parasites and hemi-parasites require host plants.

Translocation usually involves propagation of regenerative material and planting of tube-stock. All propagation methods should be discussed with a specialist to determine species-specific requirements and refine techniques (see Appendix 1 for contact details).

Commonly used propagation techniques include:

Seed: Seeds can be pre-germinated under laboratory conditions (Fig. 3.3) and then transferred to the nursery, or seeds can be sown directly into seed raising mix at the nursery. Some seeds may need treatment to break dormancy. Seeds with physiological or morphophysiological dormancy are likely to have complex requirements to overcome dormancy, which may need to be investigated prior to commencing the translocation process (see Section 3.5.4).

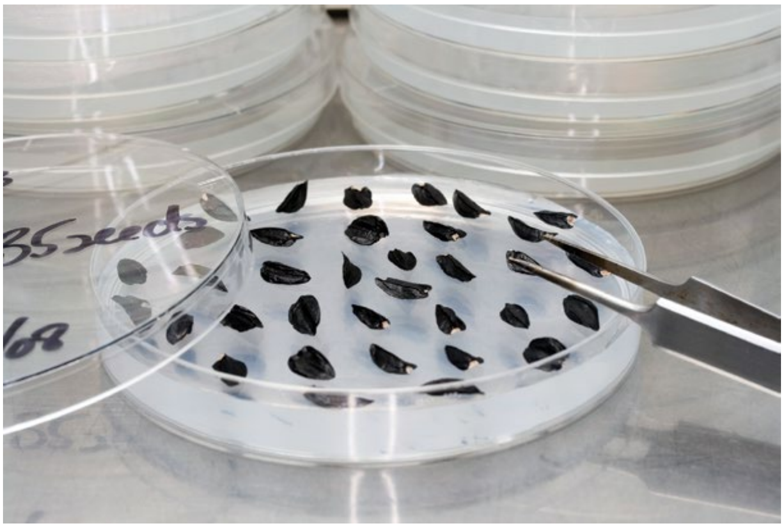

Figure 3.3 Seeds can be germinated on agar in petri dishes before being transferred to pots. (Photo: A Crawford)

Cuttings: Shoot material may be dipped in hormone solution or powder to encourage root development before being planted into cutting mix in trays or pots. Not all species can be propagated in this manner.

Division: Clumping plants may be separated into several plants. Plants that produce stolons or runners may also be propagated by removing the daughter plant. Tuberous herbaceous plants with larger tubers (i.e. older plants) are more likely to survive outplanting than plants with smaller tubers (Smith *et al.* 2009).

Grafting: Grafting involves splicing vegetative material of the target plant onto rootstock of another plant. This is a specialist method and evaluation of its application to the target species will need to be carried out prior to collecting the propagation material.

Micropropagation techniques (e.g. tissue culture, artificial seeds, embryo extraction): For species that are difficult to propagate using traditional methods, micropropagation may be an option (e.g. Bunn and Dixon 1992). Micropropagation techniques involve inducing small pieces of plant tissue to form a new plant (Figs 3.4, 3.5; Case Studies 3.2, 8.3). These techniques require specialised equipment, facilities and expertise.

Figure 3.4 ***Acanthocladium dockeri*** *in tissue culture ready to transfer to pots for hardening. (Photo: M Jusaitis)*

Figure 3.5 Tissue-cultured ***Acanthocladium dockeri*** *being hardened for out planting. (Photo: M Jusaitis)*

Propagation of symbiotic or parasitic plants: Some groups of plants require another organism in order to germinate or survive. For instance, terrestrial orchids require a mycorrhizal fungus to germinate. Seeds of parasitic plants may be able to germinate, but then require a host plant for growth, which could be planted in the same pot as the seedling, or separately at the planting site.

Topsoil seedbank: For soil-stored seed, topsoil from the source location can be spread in trays in a glasshouse or nursery, watered, and emerging seedlings potted up (Fig. 3.6).

*Figure 3.6 Top left: Singleton Mint Bush (**Prostanthera cineolifera**) was translocated during construction of the Woolgoolga to Ballina project using soil seedbank salvaged from the construction footprint. Fire was applied to stimulate seed germination;*
Top right: Three germination treatments were applied: control (no fire), low fuel (3 cm of litter) and high fuel (6 cm of litter). Much higher germination resulted from the third treatment;
*Bottom left: Close up of seed germination in treatment 3, including **P. cineolifera** seedlings;*
*Bottom right: **P. cineolifera** seedlings being grown-on in native tubes before planting out.*
(Photos: A. Benwell)

Table 3.1. Propagation categories used by The Royal Botanic Gardens and Domain Trust (NSW) (OEH Saving our Species Program 2016 – 2021) to highlight differences in the ease of propagation between species. The cost of propagation increases from Category A to D. Dormancy types are abbreviated as follows: ND: Non-dormant, PY: Physical Dormancy, PD: Physiological Dormancy, MPD: Morphophysiological Dormancy.

Category	Seed collection	Germination/ strike rate	Possible dormancy type	Growing time	Examples
A	Easy to collect and store long term.	High	ND, PY	6-12 months propagated from seeds (not cuttings)	*Acacia, Eucalyptus, Casuarina, Pultenaea.*
B	Moderately easy to collect but long term storage unreliable.	Moderately reliable ~50%	ND, PD	12-18 months propagated from seeds or cuttings	*Grevillea* (some), *Prostanthera, Hakea.*
C	Difficult to collect in quantity, repeat collecting trips needed. Processing and storage difficult more complex.	Often unreliable <50%	PD, MPD	12 -24 months	*Hibbertia, Persoonia, Zieria, Boronia, Pimelea*, Rainforest trees.
D	Difficult to collect and germinate. Seed storage and dormancy issues.	Difficult to germinate or strike – limited data. Require high technical input and research or germination trials	PD, MPD	~3 years	Rainforest species, Terrestrial orchids, *Epacris, Leucopogon, Persoonia.*

3.5.3. Translocation without propagation

Translocation may also involve methods that do not require a propagation step, such as direct seeding, transfer of soil stored seed, and transplanting of mature plants and seedlings. These methods may be done in combination with methods that require propagation, to maximise the chances of translocation success.

Translocation techniques that do not involve propagation include:

Direct seeding at the translocation site: This technique involves sowing seeds either by hand or using machinery. It will require considerably more seeds than growing tubestock from seeds because conditions in the laboratory and nursery can be controlled to maximise germination, whereas this may not be possible on-site. The conditions under which a species recruits in the wild should be considered when direct seeding, as these conditions will provide information to develop pre-treatments to overcome dormancy and promote germination (see Section 3.5.4).

The other role of direct seeding is to create or re-create a persistent soil seed bank in any new translocation. In such cases this may be in addition to planting individuals and the roles of the seeds being added is not to have immediate germination and growth, but to buffer the population to any future disturbance, e.g. fire, grazing etc.

Transfer of soil containing seed: For some species the mechanical disturbance during moving of the soil may result in a flush of germination from a soil-stored seed bank. Any movement of soil may transport diseases such as dieback (e.g. *Phytophthora cinnamomi*). It is recommended that translocation by this method is only used where the site is adjacent to the area from where the soil has been removed, or the soil has been tested to ensure that it is free from disease.

Salvage of mature plants or seedlings: If plants are to be removed due to a development, they can be dug up using shovels or large earth moving equipment and the plant and soil moved to a new site (see Chapter 6). Seedlings can be dug up with trowels or a bulb planter (see Case Study 7.2). Salvage of mature plants should only ever be considered as a last resort in situations where the source site is to be destroyed immediately and/or there is considerable evidence that it is the most appropriate technique. Care needs to be taken to ensure that pests and diseases are not transferred with the plants or associated soil. Whole turves of soil and plants may be transplanted (Case Study 3.3).

3.5.4. Highlighting the role of seeds in translocation

Seeds are clearly very useful for restoration and potentially provide the most efficient means by which plants can be translocated. However, there is an imperative to understand the dormancy and germination mechanisms of each target species (Turner and Merritt 2009), both for propagating seedlings *ex situ* or direct seeding, so that seed collections are not wasted.

When studying the ecology of a target species, identification of the dormancy type is an important starting point. For example, species with physical dormancy (e.g. Fabaceae, Sapindaceae, Malvaceae) need to have seeds scarified or heated before germination can occur. In contrast, species with physiological dormancy (e.g. Ericaceae, Rutaceae, Lamiaceae) generally require specific seasonal temperatures or a period of dry after-ripening to break dormancy and, in fire-prone regions, application of a smoke cue before germination should occur. Identifying dormancy type can therefore provide a clear direction identifying techniques for germinating seeds and increases the chances of success of propagation or field emergence.

If a species targeted for translocation is seed limited, due to small population sizes or difficulty in obtaining seeds (as is often the case for many threatened species), seed propagation in the nursery may be the more cost-effective method. However, for suitable species, direct seeding may provide an equally efficient approach. In the past, results from direct seeding projects have not always been considered as successful as other approaches, but it is essential that a broader understanding (and further or more focused research) of the seed ecology of a species is needed both to determine how and when to sow seeds, and how to measure the chances of direct seeding success. For example, in remote areas with sporadic rainfall, planting seedlings may not always be practical, and direct seeding prior to the wet season may be a more efficient approach for species that aren't seed-limited.

In general, natural germination and seedling recruitment drivers determine when emergence occurs in the field. Natural recruitment rates (i.e. seedling survival) are usually low, and seeds sown may not germinate but remain in the soil seed bank for subsequent recruitment opportunities. To increase recruitment from direct seeding (if that is the aim), all of these factors need to be considered. Sowing should be timed to match natural recruitment windows, and supplementary watering could be conducted (if feasible) during early seedling emergence stages for smaller-scale projects. Assessment should also be taken over subsequent recruitment periods, as seeds play a role in bet-hedging, particularly in disturbance-prone systems. In fact, another aim of seeding may be to establish a persistent soil seed bank, in which case, factors affecting persistence must be understood (Long *et al.* 2015).

Case Studies

Case Study 3.1 - An experimental translocation identifies the best propagation method

***Excerpt from Emery** et al. 2018*

Persoonia pauciflora, a woody shrub endemic to the Hunter Valley, NSW, was threatened by urban development and habitat fragmentation. A small-scale experimental planting trial in 2015 was considered as the most appropriate 'first-step' target objective, before subsequent large-scale translocations, for the successful recovery of the species.

The aims of the experimental translocation were to understand which propagation material (seedlings vs cuttings) was more successful for translocation, and whether fencing improved success. A schematic of the initial planting design is illustrated in Figure 1. At each of the three sites, twenty-four plants (evenly split by propagation type: seedlings and cuttings) were randomly planted in six blocks over an area of 10 × 16 m (a total of 72 plants). Each block contained two cutting-propagated plants and two seed-propagated, and three randomly assigned blocks were fenced off to exclude macropod predation. Each block was 4m^2 with plants placed 1 m from the edges to avoid contact with the fence and/or adjacent conspecifics. Several juvenile plant deaths from frost damage prompted us to protect younger plants with tree guards. Refinements to the experimental design were subsequently made for the 2016 and 2017 plantings.

Plant health (including signs of physical damage, foliage loss and changes in foliage colour), survival, growth (plant height and width), flowering and fruiting was monitored. The monitoring schedule was initially intensive, weekly for the first month (to detect signs of translocation shock), fortnightly, monthly, quarterly and eventually half-yearly. By 2018 (30 months post-planting), survivorship among the initial three planting sites was 67–71%. Monitoring plants in the initial translocation enabled the evaluation of fencing and propagation method. Survival was slightly higher for fenced plants (72%) compared to unfenced plants (63%), and plants propagated from cuttings (81%) compared to seedlings (58%).

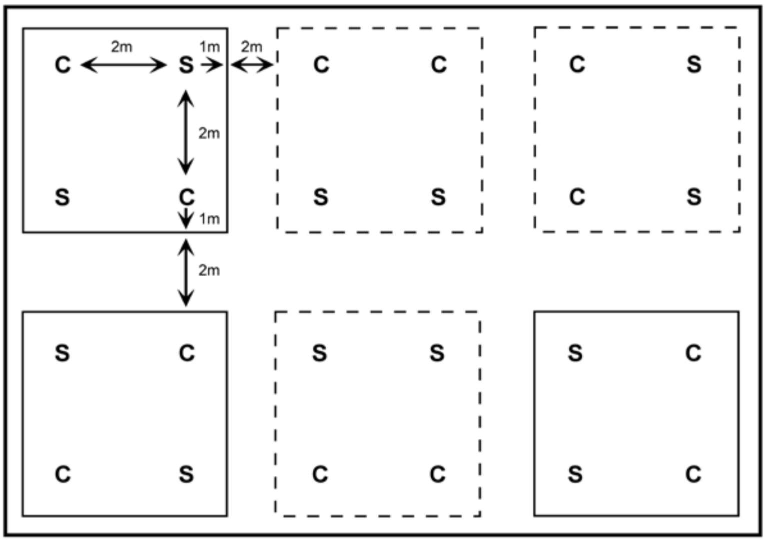

Figure 1 Site design of the initial translocation (plant and block positions were randomised at each site). Dotted line indicates an unfenced block, solid line represents fenced. C: plant cultivated from vegetative cutting; and, S: plant cultivated from seed.

Case Study 3.2 - Using tissue culture to propagate plants for translocation

Excerpt from Bunn and Turner (in press).

Symonanthus bancroftii is a dioecious perennial shrub endemic to south-west Western Australia (Fig. 1). The species was thought to be extinct in the wild with the last known sighting dating back to the 1940's. In 1997 a single (male) plant was found in an area previously used for road aggregate storage near the wheatbelt town of Ardath in south-west WA., followed by another (female) plant in 1998 after an intensive search. Both plants were tissue cultured (Panaia *et al.* 2000), and a third (female) plant was produced from in vitro germinated seeds (harvested from an *ex situ* container collection of micropropagated original male and female plants grown in Kings Park) in 2001. It was considered that even with only three genotypes it was worth the risk of translocation in the event that more plants may be found in the future and such information as could be gleaned from a trial translocation would be worth the effort.

Micropropagated plants were produced via tissue culture at BGPA and grown in pots to about 4 months old, hardened off in full sun, then taken to translocation sites to be planted during winter 2002. Later translocations (2005, 2006, 2007 and 2008) were also carried out using micropropagated plants, although from 2006 onwards, seedlings generated from *ex situ* collected seeds (Fig. 2) began to be increasingly utilised at the translocation sites along with some micropropagated plants. The first translocations (prior to 2004) required a motorised post-hole auger to drill holes ~100-120 mm in diameter and 150-180 mm deep. Following ripping in 2004, digging holes for planting was then able to be done much more easily using hand trowels.

Symonanthus bancroftii was difficult to initially establish in tissue culture until the correct protocols were devised, then micropropagation was successful (Panaia *et al.* 2000). Reliable irrigation was essential to maximise plant or seedling survival during summer in the first two years following transplanting to sites. Precocious flowering was observed after only 2-3 years growth, with pollinating insects frequenting both male and female plants and abundant seeds were produced (Ye *et al.* 2007). Emerging evidence from seed burial experiments suggests that seeds of *S. bancroftii* germinate following after-ripening in soil in response to gibberellic acid or smoke (Shane Turner, pers. comm.). Based on observations of translocated plants of both male and female *S. bancroftii,* if *S. bancroftii* is to be protected in the future from threats such as more frequent and intense drought (implicated in climate change models), weeds and feral animals, more needs to be known about its fire ecology and impacts on natural recruitment dynamics. A new population of *S. bancroftii* has been recently discovered (Greg Keighery, pers. comm.) and while its conservation status has now significantly improved, this trial translocation has provided valuable information about the biology of this species and the value of tissue culture techniques in propagation of some species for translocation.

Figure 1 Native butterflies visiting female plant of ***Symonanthus bancroftii.*** *(Photo: G. Messina)*

Figure 2 Seedlings of ***Symonanthus bancroftii*** *being raised at Kings Park and Botanic Garden for translocation. (Photo: E Bunn).*

Case Study 3.3 - Translocation of whole turves

Excerpt from Shapcott (in press-b).

Approximately 15 hectares of coastal heath (10 ha 'dry', 5 ha 'wet' heath) was threatened by a housing development. The area including habitat for Ground Parrot (*Pezoporus wallicus*), Lewin's Rail (*Rallus pectoralis*), vulnerable Acid Frogs (*Crinia tinula, Litoria freycineti, Litoria olongburensis*) and five plant species that were listed as vulnerable or rare within Queensland at the time the project commenced: *Acacia attenuata* (vulnerable), *Acacia baueri, Boronia rivularis, Blandfordia grandiflora, Schoenus scabripes*.

The five listed plant species all regenerate after fire from seeds and only two were known to resprout after fire and this shaped some of the methods later selected and ongoing management. Relatively few of the species recorded as present in the heath to be translocated were known to have been propagated either by seeds or by cuttings previously and so translocation of the existing heath species was determined to be the best way to maintain the species composition in the compensatory habitat. Preliminary trials and studies had demonstrated that translocation of whole turves rather than just topsoil would result in higher success rates and significantly lower ongoing management of weeds.

The University of the Sunshine Coast (USC) was selected as an appropriate receiver site after initial site assessments for compatible drainage, proximity, habitat suitability, and soil types.

The site was scraped clean of weeds and topsoil prior to placement of the turves to remove weeds and to lower the soil level to minimise changes in drainage. There were distinctive management sections created within the translocated site according to different parts of the donor site. These divisions were maintained to enable fire breaks between different management units within the site. The turves were moved from the donor site and placed on the same day on the receiver site (Fig. 1). Shade cloth was used to line the truck tray wall to reduce wind damage. The receiver site was fenced to keep out kangaroos and the fence also lined with shade cloth to reduce grass seeds entering the site from adjacent playing fields.

After the final assessment against the performance criteria was made by the independent ecologist, the project was deemed to have been successful and the site was handed over to USC for ongoing management. The use of large whole turves leads to much lower ongoing management, particularly of weeds.

Figure 1 Systematic placing of whole turves using modified machinery. (Photos: Stocklands Bundilla)

Chapter 4 – Selecting source and recipient sites

Authors: Nigel Swarts, Nola Hancock, Linda Beaumont, Joslin L. Moore, Stephen Van Leeuwen, Margaret Byrne

4.1. Selecting source populations(s) and individuals for translocation

4.1.1. Selecting source populations

The geographic distribution of the species should be adequately understood before selecting source populations for the translocation (Section 2.3.2). The selection of source populations will depend upon the purpose of the translocation, the location of recipient sites and the amount of genetic diversity within the source populations. Some knowledge of the species' genetic diversity and structure is helpful in designing seed collection strategies (see Section 3.3, Case Study 4.2). Unless there is a specific reason for genetic analysis to be conducted (e.g. disjunct distribution, disrupted breeding systems), general guidelines can be followed.

Much consideration has been given to seed collection strategies in recent years. Previously there was a strong focus on collecting seeds from local plants or populations (local provenance), based on assumptions that local genotypes are best adapted to local environmental conditions (Leimu and Fischer 2008; McKay *et al.* 2005). More recently, provenance strategies have concentrated on situations where populations are small and isolated, and have identified that focussing on local populations may lead to seed collections with limited genetic diversty or from plants subject to inbreeding (Breed *et al.* 2013; Broadhurst *et al.* 2008a; Sgro *et al.* 2011; Weeks *et al.* 2011). It is well accepted that maximising genetic diversity is important for long term persistence of populations, and this can be achieved by sourcing seeds (or cuttings – see below) from multiple populations.

Currently, provenance strategies give consideration to the factors that might influence the persistence of populations in the face of changing climate conditions. These strategies recommend maximizing genetic diversity as well as including genes that may enhance adaptation to changing climate. A number of different provenancing strategies have been proposed. A composite provenance strategy uses seeds from multiple populations with a focus on populations close to the translocation site with decreasing contributions from populations further away designed to mimic patterns of gene flow (Broadhurst *et al.* 2008a) whereas admixture provenancing advocates using seeds from multiple populations in equal proportions (Breed *et al.* 2013). Predictive provenance strategies aim to identify source populations that have the same current climatic conditions as the recipient populations in the future (Sgro *et al.* 2011). These strategies require species distribution modelling in relation to current and future population sites under future climate conditions (see Section 3.5), but does not take into account the large amount of uncertainty associated with future climate predictions and species distribution modelling. Climate adjusted provenance strategies advocate sourcing seeds from multiple populations in the direction of projected climate change (without explicit site/climate matching) to include adaptive genes from across the climate gradient (Prober *et al.* 2016). This strategy is based on accumulating evidence for presence of adaptive genes within species across climate gradients (Jordan *et al.* 2017; McLean *et al.* 2014; Steane *et al.* 2017; Steane *et al.* 2014).

Provenance strategies that use mixed seed sources are appropriate for species whose distributions do not include large disjunctions or habitat variability. Geographic disjunctions in species distributions may indicate that the species has divergent lineages where substantial genetic or phenotypic differences have accumulated among two or more groups of populations over time. These populations may have been historically isolated or may even represent cryptic species (i.e. different species that cannot interbreed but contain individuals that are morphologically identical (see Section 3.3.2); and (see Byrne *et al.* 1999; Llorens *et al.* 2015 for examples of species with historical disjunctions)). Consequently, unless there is genetic evidence that the populations across the disjunction are not genetically differentiated, it is recommended to keep seed sources from these types of populations separate. See Chapter 3a Section 3.3.2 for reference to genetic mixing considerations including when to mix and when not to mix.

4.1.2. How many separate individuals?

The number of plants required to be propagated for translocation will vary considerably between different taxa as well as the purpose of the translocation (e.g. establishment of a new population or supplementing an existing population) (see Section 2.4.3). As the goal of translocation is to establish a viable self-sustaining population, the initial number of individuals required to achieve this goal needs to be estimated. Pavlik (1996) proposed nine characteristics to consider when considering population viability: longevity, breeding system, growth form, fecundity, ramet production (i.e. whether the species can reproduce vegetatively), survivorship (attrition), seed longevity, environmental variation and successional status. Species could then be scored against these characteristics and a minimum viable population size between 50 and 2500 individuals can be estimated. For example, for the characteristic of longevity, Pavlik (1996) asks whether the species is a perennial or an annual as annual species require larger population sizes. These numbers may be impractical for threatened perennial species. Research across Australia confirms that small populations show reduced genetic and demographic outcomes in perennial species (Broadhurst *et al.* 2008b; Llorens *et al.* 2012; Llorens *et al.* 2013; Yates *et al.* 2007a; Yates *et al.* 2007b; Young and Brown 1999) and suggests that populations of around 200 to 250 plants are required to minimise these effects. See also Table 2.1 in IUCN Standards and Petitions Subcommittee (2017) for information about how the number of individuals in the entire population determines the threatened category. While we suggest that translocated population sizes of around 200 to 250 plants are a useful initial target, it is important to note that others (Frankham *et al.* 2014) suggest that the genetically effective population size should be $\geq$ 1000 to maintain evolutionary potential.

4.1.2.1. Plant material collection and sourcing

The aim should be to sample a number of individuals to capture the bulk of the genetic variability represented in the source population. The number of individuals sampled will depend on the:

- conservation purpose of the translocation;
- the number of reproductive individuals in the source population(s); and
- the type of material used as the propagule source (i.e. seeds vs cuttings vs mature plants for transplanting).

Good seed collection practices recommend collecting across the whole population, avoiding collection from neighbouring plants, and only taking a proportion of seed crop (Fig. 4.1) (Brown and Marshall 1995; Cochrane *et al.* 2009; Guerrant *et al.* 2004). Seed collection permits for threatened species will usually include conditions limiting collections to 20% of the seeds from any individual and from a proportion of individuals in each population depending on the abundance and distribution of the species. This is to ensure that the seed collection does not impact on the fecundity of the source population.

There are a variety of approaches for sampling which will depend on the species and the information that is available:

- Sample all individuals. For some threatened species with population size less than 50 plants it may be possible to sample all, or the majority, of individuals, and therefore a large proportion of the total genetic diversity available will be captured. If it is not possible to sample all individuals then the objective should be to sample as many individuals as practical with a recommendation of 50 individuals as a general rule.
- If there is information regarding genetic variation within the population, it is advised to aim to capture 95 percent of the alleles with frequency greater than 0.05 (Brown and Marshall 1995; Falk and Holsinger 1991). If it is not possible to sample the majority of individuals, the populations should be sampled systematically to avoid collecting from related individuals. One approach could be to divide the population into units (e.g. 10 m by 10 m squares or 5 m wide strips etc.) and choose a predetermined number of individuals from each unit.
- Seed collections from each plant should be kept separate where possible in order to maximise opportunities for experimental work.

- For most species, wild harvested seeds have been the main source of germplasm for translocations. However, in cases where seed production is limited or natural populations are difficult to access, seed production areas (Broadhurst *et al.* 2015; Nevill *et al.* 2016) may be established to provide a source of seeds for translocations. Establishment of seed production areas using collections that maximise genetic diversity is essential otherwise these will be subject to inbreeding. For clonal species, genetic analysis may be required to determine the spatial extent of clones and differentiate genets (e.g. Binks *et al.* 2015; Millar *et al.* 2010) (see also Section 3.3).

Figure 4.1 Collecting seeds of ***Jacksonia velveta.*** *(Photo: A Crawford)*

4.1.2.2. How many plants to propagate

After estimating the desirable population size, the aim should be to propagate enough plants to reach this size. However, the number of propagated plants may be significantly more than the desired size as death of plants, particularly after translocation, can be high. For example, Guerrant and Fiedler (2004) investigated population dynamics in several translocation projects in the United States using computer modelling. Results from one study indicated that, to account for high losses, 67,000 seedlings would need to be planted to achieve the minimum viable population of 1,000 reproductive plants. Therefore, a general rule of thumb would be to propagate as many plants as resources will allow.

There are also a number of other factors to consider when deciding how many plants need to be propagated. These include:

- amount of propagation material available;
- number of trained staff and volunteers available for planting and monitoring;
- funding available for propagation;
- funding available for equipment needed to maintain the plants; and
- size and number of the proposed translocation site.

If it is not possible, due to resource limitations, to propagate sufficient plants in one year to achieve the desired numbers, then consideration should be given to propagating plants and staggering planting over several years as this reduces the need for resources. Planting over multiple season also spreads the risk of adverse weather impacting the project as well as selection processes that may happen unexpectedly (see Section 6.2.2).

4.2. Selecting recipient sites

4.2.1. Site selection to decrease extinction risk

The aim of translocations is to decrease the risk of extinction for the translocated species, so consideration must be given to how the site selected for translocation will achieve this. This consideration will influence where (i.e. inside or outside the species known habitat range, or both) and how many recipient sites should be selected given the characteristics of the translocated species and the type of translocation being implemented.

Extinction risk for plants includes three major elements: the rate of decline, the reduction in geographic distribution, and reduction in population abundance (IUCN Standards and Petitions Subcommittee 2017) (see also Section 2.3.3). The IUCN have developed detailed criteria for the assessment of extinction risk for both plants and ecosystems that factors in each of the above elements and their interactions (IUCN Standards and Petitions Subcommittee 2017). Accordingly, species most at risk of extinction are allocated to either 'critically endangered', 'endangered' or 'vulnerable' extinction risk categories. Importantly, new populations arising from plant translocations are included by the IUCN in the species extinction risk categorization process as long as the following criteria are met (IUCN Standards and Petitions Subcommittee 2017):

- the known intent of the translocation was to reduce the extinction risk;
- the recipient site(s) is in close geographical proximity to the natural range of the plant species;
- there is evidence of natural recruitment arising from translocated plants;
- at least five years have passed since the translocation.

Therefore, a good understanding of how the site(s) selected for translocation addresses the three elements of extinction risk is required. This information is likely to be well captured in listing statements or recovery plans for the species. Most plants facing the highest risk of extinction have highly restricted geographic distributions with ongoing population decline and exposure to threatening processes, as well as few populations with small numbers of individuals. Thus, threat identification and management are essential components of any site selection rational.

4.2.2. Identifying potential recipient sites

The purpose of the translocation will impact the selection of recipient sites (Figs 4.2-4.7). For most translocations the aim is to establish a new population in a secure site where the threats are either not present or can be controlled. Sites where the target species occurs or is known to have occurred in the past are most likely to support a translocated population in the long term, and should be considered in the first instance. However, sometimes such sites may not be suitable – if threats affecting the species cannot be removed or controlled (e.g. climate change, *Phytophthora*) (Case Study 4.2), or if detrimental impacts on existing populations are foreseen. In such cases it will be necessary to investigate other areas that have similar habitat (soil, associated vegetation type and structure, aspect etc.), within the known range of the species if possible. It may also be necessary to consider degraded, highly modified, or reconstructed landscapes, or those likely to be more climatically suitable in the future. However, such sites will likely require considerable site preparation and post-translocation habitat management. Once potential areas have been identified, suitability will need to be assessed at a more detailed level as discussed over the page.

Figure 4.2 *Receival site for lowland rainforest species translocated during the Yelgun to Chinderah highway project. This is the site established on open grazing land after approximately 5 years. (Photo: A Benwell)*

Figure 4.3 *Receival site for* ***Dendrobium melaleucaphilum*** *in* ***Melaleuca styphelioides*** *–* ***Casuarina glauca*** *swamp forest, Nambucca Heads to Urunga project. (Photo: A Benwell)*

Figure 4.4 *Ardath reserve, south-west WA, translocation site for* ***Symonanthus bancroftii****. (Photo: E Bunn)*

Figure 4.5 *Translocation site of* ***Daviesia ovata*** *at Mt Manypeaks, WA. (Photo: L Monks)*

Figure 4.6 *Translocation site of* ***Banksia brownii*** *in south-west WA. (Photo: A Cochrane)*

Figure 4.7 *Translocation site for* ***Grevillea humifusa*** *near Jurien Bay, WA. (Photo: D Coates)*

4.2.3. How many recipient sites?

Ultimately the number of recipient sites will need to be decided on a case by case basis taking into account the goals and aims of the project and the resources available. In some cases, the habitat of the species may be highly specialised and occur in a landscape that has undergone substantial modification, limiting the number of sites available. In other cases, the number of available propagules may limit the number of sites at which the desirable population size can be reached. It may also be sensible to focus effort and resources at one site to increase the chance of success. Alternatively, spreading the risk over several sites may be preferred to reduce the risk of a catastrophic event causing the entire translocation to fail.

In the case of mitigation translocation, in which plants at the source site are to be moved or destroyed, additional consideration as to the number of recipient sites may be required. Moving plants may not necessarily address the possible increase in extinction risk due to the loss of the source population. There may be a need to consider establishing additional sites in this case.

4.2.4. Assessment of potential recipient sites

A number of factors affect the suitability of a site including the following:

- habitat is matched as close as possible to source location (Case Study 4.3);
- the microclimate is appropriate (Case Study 4.4);
- future climate projections and the sustainability of the species and population(s) at the site;
- determining that ecological functions identified in Chapter 3 are present such as pollinator services, particularly for species with highly specific pollinator relationships and /or soil mycorrhizal fungi critical for establishment of mature plants and new recruits (e.g. orchids) (Case Study 4.1);
- whether the habitat area is large enough to support a self-sustaining population, and whether ecological requirements of the species are met;
- history of past land uses and degree of disturbance at the site (e.g. whether the site has been used for cropping or grazing and presence of weeds or erosion);
- ecosystem functional status, or the ability of the ecosystem to regenerate without intervention once pressure is removed;
- processes impacting soil health and stability;
- ongoing threat management that may be required, and whether any threats present at the site can be controlled or eliminated, e.g. fire management regimes in circumstances of multiple use sites;
- potential risk from threats that may not currently be evident, including landscape-level threats such as salinity and water table changes, and diseases such as *Phytophthora* spp. and *Armillaria* spp. (Case Study 4.2);
- security of land tenure - long-term security of the site is essential to ensure that the translocated plants are protected, otherwise there is potential for damage or destruction of the site resulting in the waste of resources. Long-term security on private land can be achieved through the signing of covenants or conservation agreements with the landowners, and help should be sought from State conservation agencies or agriculture departments and non-government organisations (see Appendix 1 for contact details);
- the compatibility of current and future management of the site with managing a translocated population (e.g. whether any proposed fire management is compatible with translocation, or whether the site is within a recognised asset protection zone). In some circumstances the recipient site could be part of a ‘restoration’ site and the translocation could link to restoration ecology principles implemented at the site;
- whether any adjacent land uses impact on the translocation site, and a buffer may need to be left or constructed between the site and the adjacent land, such as vegetation or a shade-cloth barrier;

4.3. Additional site selection considerations for translocations beyond the known range

While translocations within the native range are likely to be most appropriate, translocations beyond the known range of the species, may be necessary if the threats within the known range are not able to be controlled (e.g. climate change or dieback), or if there are no suitable sites within the known range (e.g. due to land clearing or other impacts of development).

Translocations of plant species due to the threat of climate change may be necessary where the environment is altered to such an extent that the persistence of the species is projected to become unsustainable (Hancock and Gallagher 2014; Vitt *et al.* 2016). Under these circumstances, the selection of a recipient site becomes more complex because decisions need to be made regarding an uncertain future climate at the proposed planting site (Harris *et al.* 2013). In addition, sites with suitable projected climates may not be located within the species' known range, making site selection even more complex. Consideration of these sites must balance projected future climates with habitat availability and the presence (or absence) of key biotic interactions such as pollination (herbivory or disease) (Case Study 4.1). The human-assisted movement of organisms beyond their known range to counteract adverse climate effects is termed assisted migration (also called assisted colonization or benign introduction) (Gallagher *et al.* 2015b; Harris *et al.* 2013; IUCN/SSC 2013).

If the species to be translocated (or its habitat) is threatened by climate change it is useful to evaluate the projected climatic suitability of any proposed recipient sites. In addition, site selection might incorporate information regarding projected future climates by preferentially selecting sites that are predicted to change least into the future (see 3.3.3). It is likely that the climate conditions represented by the species' occurrence records (i.e. its realised climate niche) do not span the full range of conditions that the species can tolerate and reproduce in (i.e. its fundamental niche). For example, a species may be physiologically adapted to a wide range of climatic conditions, yet occupy only a subset of these due to other limiting factors such as competition, herbivory or disease. As such, the selection of recipient sites needs to consider abiotic and biotic suitability of other factors in addition to climate change. Projections of future climate and climate suitability have high degrees of uncertainty, and we recommend that this uncertainty be incorporated in decision making processes (Harris *et al.* 2013).

Apart from forestry, there are few published case studies of assisted migration of plant species that could be used as templates to guide site selection for translocation under climate change (see Torreya Guardians; Vitt *et al.* 2016), although reintroduction case studies may provide some information (Dalrymple *et al.* 2012). An experiment-based approach is therefore desirable to monitor the focal species' survival and growth rates at the recipient site, potential mismatch in the species' phenology and that of associated pollinators as well as any effect of the focal species on species already resident at the site (see Case Study 4.1).

Despite the lack of empirically tested site-selection methods under climate change, there are predictive tools and approaches to support the selection of recipient sites and source populations and the assisted migration decision-making process. The use of species distribution models (SDMs, also referred to as habitat suitability models or niche models) can be used to project and map the distribution of suitable habitat (Booth *et al.* 2012; Ramalho *et al.* 2017). In addition to species distribution models, another such approach involves visualising concordance between the species' realised climate niche and the climate space of the proposed recipient site under future climate scenarios (climate envelopes) (Hancock *et al.* 2018).

Expert assistance using climate envelopes and SDMs is recommended since interpreting these complex models can be challenging – see Case Study 4.5 Climate envelopes and SDMs do not include microclimatic conditions that operate on a spatial scale less than that considered by the models, nor do these account for other variables not included in the model such as soil type, resource availability, presence/absence of competitors, pollinators, herbivores, diseases which will also influence site suitability. Further, climate change will disrupt interactions between species and this is of particular concern for species whose survival is strongly reliant on a subset of other species. Hence, while climate envelopes and SDMs can identify coarse characteristics of potential sites, these sites will require greater investigation at finer scales to evaluate other habitat requirements.

4.4. Preventing unintended consequences / impacts at the recipient site

When selecting recipient sites the risk of negative impacts to the site should also be considered. Negative impacts may be caused by the translocation process or through ecological interactions between the translocated population and resident species. These impacts may affect cultural as well as biodiversity values and may have ecological, socio-economic or financial consequences. A formal evaluation of the risks, costs and benefits of a translocation helps to clarify the critical issues for any given situation (Byrne *et al.* 2011; Gregory *et al.* 2012; Harris *et al.* 2013). A structured decision approach clearly identifies the values, trade-offs and key knowledge gaps underlying the decision to translocate or not (Gregory *et al.* 2012).

4.4.1. Impacts due to the translocation process

The translocation process may cause negative impacts through the transfer of weeds, soil pathogens or other diseases that are introduced along with the target population (e.g. through soil plugs, translocating diseased individuals or introduction of seeds/pathogens on the clothes of the translocation team). Conduct a risk assessment to determine potential risks and a strategy to implement control measures. In addition, increased human activity at the recipient site and ongoing monitoring and management may heighten impacts. Careful consideration of potential impacts and close attention to procedures aimed at limiting the unintentional introduction of pests or pathogens is crucial, especially if the recipient community is itself threatened or sensitive to human disturbance (see example below).

4.4.2. Impacts on cultural values

Where cultural values are present at the recipient site consideration needs to be given to any potential damage to such values or subsequent restrictions on the use of the recipient site for customary activities imposed by the translocation and any follow-up monitoring and management programs. These considerations should include recognition of the Indigenous bio-cultural values of sites with intrinsically high biodiversity value. Careful consideration of potential impacts and their mitigation may be achieved through the engagement of Traditional Owners in the co-design of the translocation process, especially the selection of the recipient site(s).

4.4.3. Ecological impacts

A successful translocation will result in a new population at the recipient site that will form part of the recipient ecosystem and interact with the resident community. Hence, it is important to consider the ecology of the translocated species and potential consequences for the recipient ecosystem prior to the translocation taking place. A prominent concern is that the species may become invasive in its new location, spreading rapidly and/or causing negative impacts, especially if the species is translocated outside of its known range (see Ricciardi and Simberloff (2009)for a discussion of possible risks). The potential consequences are many and varied. In addition to direct competition, invasion biology has documented a wide range of impacts including changing soil nutrient status, disrupting pollination networks, changing water tables, altering disturbance regimes (e.g. changing fire frequency or intensity), acting as reservoirs for pests or disease or hybridizing with closely related residents.

Using the invasion literature as a guide, we pose five questions that may be useful to structure and guide the assessment of ecological impacts on the recipient community. If the answer to any of these questions is 'yes', additional evaluation is warranted.

1. **Is the species or a closely related species invasive elsewhere?**
   If yes, there is a heightened risk that the translocated species will become invasive at the recipient site.

2. **Does the species display any traits that may facilitate invasion in the context of the recipient site?**
   While no universal set of traits that reliably predict whether a species will invade or not has been identified (but see Van Kleunen *et al.* (2010) for a recent meta-analysis and Gallagher *et al.* (2015a) for a recent analysis in the Australian context), many invasive species have traits in common. These include broad habitat requirements, fast-growth, high seed production, dispersal potential, the ability to reproduce clonally and generalist pollinators.

3. **Was the species historically widespread, dominant or abundant?**
   If yes, these species could become widespread, abundant or common if the threat is removed. This is most likely in cases where habitat loss or changes to disturbance regime have substantially reduced habitat or disrupted population processes. In these cases it is recommended that there be an assessment, on whether inspections on population abundance have been made and the potential and consequences of spread into nearby available habitat.

4. **Is there potential for interference between the translocated species and closely related or functionally similar resident species?**
   The translocated species may interfere with closely related species through hybridisation or disruption of pollination (e.g. if the species share a pollinator) (see Section 3.3.2b and Case Study 4.1). Field *et al.* (2011) highlighted the risks of hybridisation in *Eucalyptus aggregata* when populations become small and the changes to the genetic integrity of seed crops produced by these populations. Byrne *et al.* (2011) provide a genetic risk framework for ecological restoration that can also be applied to translocations. Functionally similar species are most likely to be negatively impacted through direct competition for resources and/or transfer of pests or pathogens.

5. **Is there any potential for the species to transform ecosystem structure or function?**
   Species might transform an ecosystem if these introduce novel attributes into a community (e.g. a new growth form, taller individuals, nitrogen fixing) or disrupt current processes (e.g. changed flammability). Further investigation is recommended if the translocated species introduces a novel, potentially ecosystem changing attribute into the community.

Case Studies

Case Study 4.1 - Pollinator rarity limits conservation translocation sites in a rare orchid

Excerpt from Reiter** et al.* ***(2018b).

Caladenia hastata is a sexually deceptive orchid reliant upon a single wasp species *Lestricothynnus hastata* (Brown and Vleck 2010) for pollination (Fig. 1). In order to establish new populations, the presence of the pollinator at potential translocation sites needs to be confirmed. Without the pollinator translocation populations will not be viable in the long term.

The criteria for *C. hastata* conservation translocation sites were:

- pollinator is found at the translocation sites,
- reserved or permanently protected land managed for ecological purposes,
- vegetation is a match with known sites of the species,
- located within the natural range of the species,
- low or no weed/invasive species present,
- accessible for monitoring,
- vegetation appears healthy and intact,
- naturally occurring wild fires are still a possibility,
- location is not impinged on by man-made infrastructure, and
- the site is large enough to support a self-sustaining population.

Pre-translocation sites were assessed against the above selection criteria. Pollinator presence was assessed using the standard baiting method for sexually deceptive orchids (Bower 1996). A total of 233 sites were assessed for the presence of the pollinator species, *Lestricothynnus hastata* (Reiter *et al.* 2017) but the pollinator was only detected at five sites. Of those five sites, only two sites had vegetation structure and composition similar to existing wild extant populations (Reiter *et al.* 2017). These two sites were chosen as the conservation translocation recipient sites.

In total, 446 plants were planted across the two sites where the pollinator was present. An average survival rate of 83% has been observed across the two sites. Flowering and seed set has been recorded at both sites and the conservation translocations are on track against long-term performance goals for each site.

As a result of this study, we found the pollinator for *Caladenia hastata* is the main limiting factor for selecting sites for conservation translocation of this species. We have shown an essential step prior to translocation is ensuring the presence of the pollinator in any potential translocation site.

Figure 1 Flowering ***Caladenia hastata***
12 months after conservation translocation:
(Photo: N Reiter)

Case Study 4.2 - Using population genetics to inform site selection

Excerpt from Coates** et al.* ***(2018).

Banksia brownii (Proteaceae) is highly susceptible to the introduced soil-borne pathogen *Phytophthora cinnamomi* (dieback). Twelve of the 30 known populations are presumed extinct due to dieback, and eight of the remaining populations have <10 individuals. Genetic diversity studies indicate that some 38% of total genetic diversity has been lost from *Banksia brownii* due to *Phytophthora* dieback (Coates *et al.* 2015).

Population genetic studies (using microsatellite genotyping) have demonstrated significant levels of differentiation among populations of *B. brownii* corresponding to the three geographically and historically isolated disjunct population groups; Stirling Range National Park (SRNP), Milbrook-Waychinicup and Vancouver Peninsula. These isolated population groups also display ecological differences occupying contrasting habitats in terms of substrate, associated vegetation and climate. The three population groups are therefore considered to be discrete conservation units important for the management and recovery of *B. brownii* (Coates *et al.* 2015). The aim of the translocation was to successfully establish three viable populations covering the three genetically and biogeographically distinct conservation units recognised in *B brownii* (Fig. 1). For each population the objective was to establish at least 200 mature adult plants in secure sites where threats, in particular *Phytophthora* dieback, were absent.

Each translocation was established with seedlings grown from seed collected from natural populations which has been stored in the Department of Biodiversity, Conservation and Attractions (DBCA) Threatened Flora Seed Centre covering the three genetically and biogeographically distinct regions. As it was not possible to locate a translocation site within areas of suitable habitat in the SRNP which was not affected by *Phytophthora* dieback, Site 1 was located north of the Porongurup Range within 26 km of *B. brownii* populations in the SRNP. After 10 years, survival at site 1 is 20%, After an initial three years of good health and survival at site 1, extended dry periods resulted in a decline of plant numbers, indicating the site has become unsuitable for this species. Site 2 was located within remnant vegetation similar to the species natural habitat and site 3 was located within 4.3 km of the natural population at the Vancouver Peninsular. Survival at site 2 is 49% and site 3 is 50%.

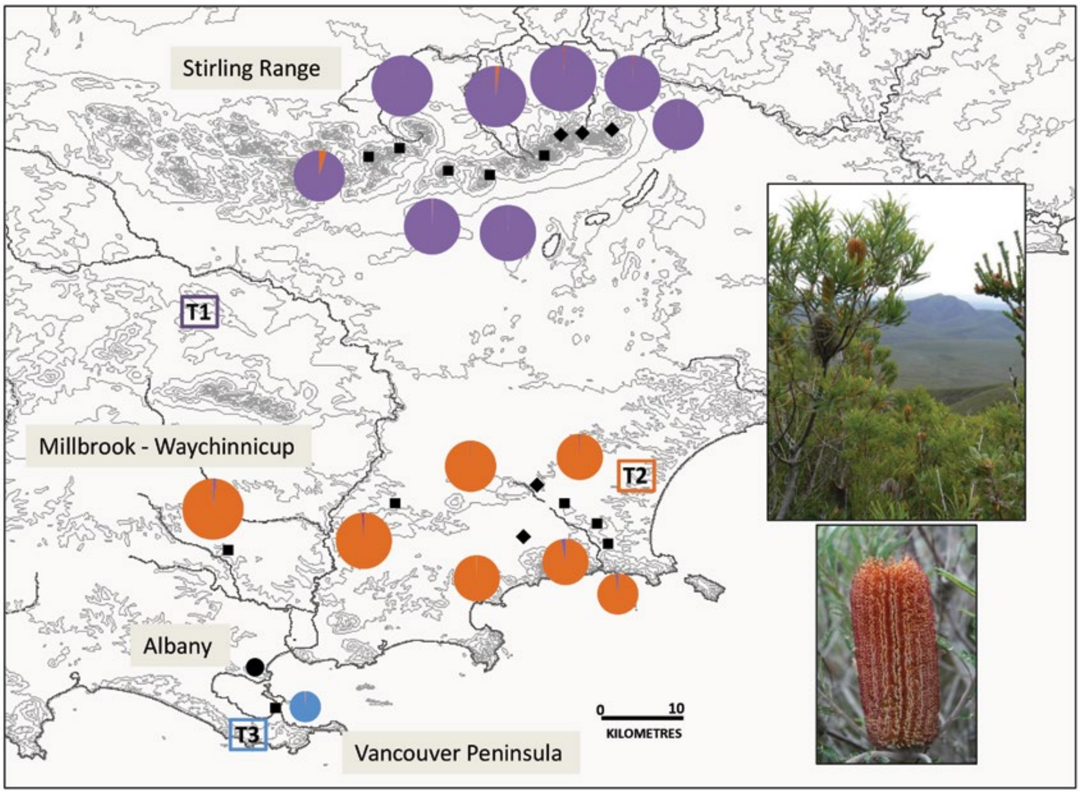

Figure 1 Mean q-matrix membership proportions of ***Banksia brownii*** *populations (pie charts) when K=3 from a STRUCTURE analysis (see Coates et al. 2015). The size of pie charts is relative to the level of genetic diversity. Extant populations ■. Germinated seeds from extinct populations ♦ was initially used to establish two separate translocated populations (T1 and T2) in disease free areas. Translocated population T3 was established with seeds from the single Vancouver Peninsula population.*

Case Study 4.3 - The importance of site selection

Excerpt from Turner** et al. **(in press).

Androcalva perlaria is a shrub endemic to Western Australia restricted to fringing vegetation around wetlands and known from only seven populations with the second largest occurring within a proposed mine site. Due to likely mine impacts in the future as well as a lack of long-term protection within any reserve, two experimental translocations were implemented at different locations.

The first location selected was Mettler Lake Nature Reserve (~400 ha), which is within 8 – 20 km of natural *A. perlaria* populations. The specific location within this reserve reflected the natural attributes of *A. perlaria* sites such as similar soil, adjacent to a wetland and a ~60% vegetation similarity. The second (Southdown) translocation site selected was at the proposed mine site, adjacent to natural *A. perlaria* plants. This second site was selected because the natural *A. perlaria* plants at this site were in good health and thus the use of this location provided an opportunity to test two different planting environments. At both sites, a series of identical treatments were assessed to determine whether the poor results observed in a preliminary trial at the Mettler Reserve were due to specific site problems or other causes.

Interestingly, plants at the second site performed much better in terms of overall survival (91.3 ± 3.1%), plant health (4.5 ± 0.6) and growth (100 ± 39 cm wide) compared to the first (Mettler) site where plants performed much more poorly i.e. lower survival (41.3 ± 11.8%), poorer plant health (2.8 ± 0.5) and smaller growth (33 ± 14 cm wide). Within both sites consistent and significant treatments effects were noted. Hence, poor site selection was by far the biggest single factor affecting translocation success in this species. Plants at the proposed mine site have grown at rates similar to plants observed in natural populations (Turner *et al.* 2013). Plants performed exceptionally well in suitable habitat (in this case a site where *A. perlaria* plants occur naturally) so spending the time to carefully identify suitable planting sites based on floristic assembly, soil types, aspect and landform is likely to be a good investment of resources.

Figure 1
*Top: Proposed Southdown mine site where **Androcalva perlaria** plants are found naturally (large plant in the foreground) and where a research translocation was implemented for this species in 2014 (the location is indicated in this image by the presence of the bamboo stakes and white pin flags in the background);*
*Middle left: Six month old translocated **A. perlaria** plant at the Mettler Nature Reserve site that is indicative of the poor health of the majority of plant found at this location;*
*Middle right: Six month old translocated **A. perlaria** plant at the proposed Southdown mine site that is indicative of the excellent health of the majority of plant found in this location;*
*Bottom: healthy 18 month old translocated flowering **A. perlaria** plant at the proposed Southdown mine site. (Photos: S Turner)*

Case Study 4.4 - The importance of microclimate in site selection

Excerpt from Zimmer** et al. **(in press).

The Wollemi Pine is a Critically Endangered conifer, endemic to a single catchment in Wollemi National Park, NSW (Fig. 1). There are fewer than 100 mature Wollemi Pines remaining in the wild. They are up to 42 m tall and occur in warm temperate rainforest in deep gullies. It is likely that the creation of canopy gaps would increase Wollemi Pine recruitment, as in many rainforest trees.

Our main aim was to determine the effect of light availability and plant size on translocated Wollemi Pine growth and survival. We focused on the influence of light because of known positive effects on seedlings in the wild (Zimmer *et al.* 2014) and in greenhouse experiments (Offord *et al.* 2014). We investigated the influence of plant size because size is often positively correlated with growth and survival in translocation and because the available seedlings varied in size. The particular questions we asked were:

1. How does growth and survival of translocated Wollemi Pines vary along a light gradient?
2. How does the effect of light on Wollemi Pine growth and survival vary with plant size? (Zimmer *et al.* 2016) and
3. How do soil properties and soil microbial communities influence translocation? (Rigg *et al.* 2017)

We found greater survival in sites with more light. This was largely due to high mortality in deeply shaded sites during the first winter post-translocation, associated with infection by the native pathogen *Botryosphaeria* sp. – an opportunistic fungus that attacks stressed plants. Growth and survival have been highly variable, with most of the variation attributed to the two plant suppliers, and differing plant condition at the time of planting. We found that plant condition is key. Plants should be acclimatised before translocation in conditions as close as possible to that of the recipient site.

The effect of plant size has been difficult to disentangle. Of the Australian Botanic Garden Mt Annan plants, larger individuals had high survival rates and grew fast, whereas small plants from the commercial supplier had high survival rates, but grew very little (Zimmer *et al.* 2016).

In addition, we found that Wollemi Pines developed their own species-specific microbial communities after two years, and this unique community was linked to plant health and condition (Rigg *et al.* 2017).

***Figure 1**. Wollemi Pines in the wild. (Photo: H Zimmer)*

Case Study 4.5 - Using Species Distribution Modelling to identify suitable habitat

Excerpt from Shapcott (in press-a).

Macadamia jansenii is endangered and only known in the wild from a single population estimated to be 60 plants (1 m or taller) distributed over 1 km along a single creek within Bulburin National Park, Queensland, 180 km north of other Macadamia species. Population genetic studies indicated moderate genetic diversity and no significant inbreeding which was not expected given the very small population size.

Species suitable habitat distribution modelling (SDM) within the local region was used to identify areas most likely to be suitable for reintroduction (Shapcott and Powell 2011). Potential sites were then ground truthed for ecological and practical suitability and accessibility for planting. Two sites within Bulburin National Park in collaboration with local QPWS rangers were selected; one at a higher altitude than the existing population in order to allow for anticipated climate change (Powell *et al.* 2014). Two sites were also selected within land owned and managed by the Gidarjil Cultural Heritage Corporation representing traditional owners which is located close to the wild population. All sites were located within the potential range of long distance dispersal of pollen by insect pollinators, among themselves and the wild population, based on genetic estimates (Neal 2007).

Plant identification codes that were used in the original population genetics study (which carried out a complete genetic survey of the entire population) (Shapcott and Powell 2011) were also given to cuttings used for propagation. To propagate the plants, cuttings were taken from all plants larger than a minimum size specified by the EPA permit. The four new populations were planted, each with a complete set of clones, representing approximately 85% of individuals in the wild population greater than the minimum height. 'Mother plant clones' were established in the nursery, so that when at each planting the survival of previous plantings was documented, lost plants were replaced with the same individual plant clone. Prior to the fourth/last planting in 2017, 40 plants had been successfully established across the four sites (an average 10 per site).

There is a high mortality of young plants less than 1m tall both in wild populations and in reintroduced populations; we found it takes two years for plants to become established. A project that repeatedly introduces plants over a period of time is more likely to be successful in the long term and a two-year period is needed to assess if plants will become established. Projects should plan for replacement of plants as a high mortality rate of young plants is common in natural as well as introduced populations in the wild.

Figure 1 ***Left:*** *QPWS ranger for Bulburin National Park, Gidarjil Caring for Country (CRC) rangers, and Macadamia propagators;* ***Right:*** *Collecting plant material for cuttings from the wild population with Macadamia propagators. (Photos: A Shapcott)*

Chapter 5 – Policy, approvals and translocation proposals

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This chapter outlines the nature of approvals or standards required under policy and legislation for translocations, and provides a translocation proposal template with the information required to assess whether an approval is granted. In addition to making the case for approval, the translocation proposal can be used as the key planning document for the intended translocation, hence its preparation should be commenced as early as possible.

The translocation proposal sets out the objectives, explains how risks will be managed, identifies who is involved and responsible, and outlines the methods intended to be used at each stage of the translocation. The proposal is also an important communication document, on which the merits of the translocation will be assessed and judged, both before and after the translocation occurs.

5.1. Translocation policies

Policy documents provide insights into the priorities, concerns and factors that are considered by approval authorities when assessing applications. Proposals that are consistent with policy are more likely to be supported or approved. In this context a 'policy' is a non-statutory document that explains or guides how a government authority or agency will process or consider proposals to translocate.

IUCN's *Guidelines for Reintroductions and other Conservation Translocations* (IUCN/SSC 2013) is an important reference point for the development of policy, and is often cited by government conservation agencies in policies and procedures.

5.1.1. Translocation policies relevant to plants

There are few government policies in Australia that specifically address plant translocation. The New South Wales and Western Australia governments identify these ANPC guidelines as the primary reference, and indicative of their policy. At the time of publication, several governments were in the process of preparing policies, or were trialling policies and procedures specifically targeted to informing approval decisions, and improving the standard of translocation practice.

The Australian Government has policy relating to approvals under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and the Australian Government Policy Statement 'Translocation of Listed Threatened Species—Assessment under Chapter 4 of the EPBC Act' provides advice on the circumstances under which approval may be required for conservation translocation under the EPBC Act, and how mitigation translocation will be considered in the assessment process (www.environment.gov.au/system/files/resources/c0463a3b-cf06-44a7-a7c6-76b488321561/files/epbc-act-policy-translocation.pdf).

Where more than one translocation policy applies (e.g. two adjacent States, or State and Commonwealth), the recovery team should develop a single translocation proposal, and the relevant government departments should facilitate a single assessment process.

Because of the increasing use of translocation, either for threatened plant populations affected by change of land use, or from more interventionist conservation planning strategies, a consistent and efficient approval process guided by policy is required.

5.1.2. Other policies relevant to threatened plant translocation

Policies that relate to the management of threatened species are both the best guide to planning a translocation and are strongly influential on government conservation agencies asked to approve translocation proposals. Recovery plans, action statements, regional biodiversity strategies, or species management programs are key examples of policies that aim to describe what is necessary to protect and manage threatened species.

At the national level, recovery plans and Conservation Advice documents are policy documents required by national environmental law, and provide detail on the key actions necessary for the conservation of nationally-listed threatened species. The Threatened Species Strategy also identifies priorities for conservation action.

In addition to the national policies, each State or Territory has its own policy framework to plan for the conservation of threatened, at risk, or otherwise significant species. The NSW Biodiversity Conservation Program includes the Saving our Species Program, which is informed by recovery plans for some species. In Queensland, priority actions are identified for each Natural Resource Management (NRM) region in the form of 'Back on Track: Actions for Biodiversity' documents.

South Australia and Western Australia use recovery plans to identify the conservation needs of nationally-listed threatened plant species to inform NRM program planning. In the Northern Territory, species profiles summarise conservation objectives and necessary management actions, and recovery plans provide more detailed information where necessary. Similarly, the ACT uses Threatened Species Action plans to detail threatened plant conservation needs. In Victoria, threatened species are provided for by Action Statements, Recovery Plans and Catchment Management Strategies, and *Protecting Victoria's Environment – Biodiversity 2037*, under which the specific needs of endangered threatened plants may be identified.

The policies identified above should be considered the primary conservation plan(s) for the target species. It is important to clearly identify this plan (or plans) early in planning, as a key reference point for planning and making decisions about the translocation.

Natural Resource Management plans, regional threatened species, conservation action plans or biodiversity management plans, and park or reserve management plans also often form part of the policy framework relevant to the translocation of threatened plant species. Operational policies relating to the issuing of licences and permits mentioned above are sometimes available to clarify and guide applications or assessment of proposals.

These policies are generally available on request from or on the website of the State or Territory government conservation agency (Appendix 1).

In addition, there is a range of other policies that may be indicative of an approver's response to a plant translocation proposal. For example, policies relating to the translocation of vertebrate fauna are more common and can be useful in understanding the principles by which government agencies consider translocation proposals.

5.2. Requirements for approval

Legislation (law) defines what activities are prohibited, require approval, or are permitted without any approval. Persons who carry out activities that are prohibited or do so without the necessary authority may be fined or penalised. Law regulates activities so that personal and public interests are protected. An approval allows an activity to be carried out in a way that accounts for those interests, and can be used as a defence if there are concerns raised by persons affected by the approved activity.

The pre-translocation assessment will identify what approvals, authorisations, licences or permits (approvals) are required to conduct the translocation. If there is uncertainty surrounding the approvals required, please review the steps outlined in previous chapters or sections.

In some circumstances, more than one approval will be required, possibly from different levels of government, and unfortunately, one approval rarely negates the need for another. For example, having an approval to collect seeds of a threatened species from a national park may not remove the need for an approval to transport seeds interstate or to even possess, germinate, or grow the plants. Similarly, having an approval under threatened species law to carry out an ecological burn for site preparation does not negate the requirement for approval from the local fire service or environment protection agency who consider other matters like risks to the community from bushfires or pollution. In some circumstances, an agency may facilitate a process that generates multiple approvals, but this rarely happens across different types of laws or between levels of government.

The types of approvals required may relate to impacts on biodiversity or the environment, the use and occupation of land, or the protection of human safety and health. Variably, an approval may address aspects of all of these, or focus on one element.

Factors that influence which approvals are required include:

- Land tenure - private, Crown, reservation type, planning zone category, mining tenure.
- Native Title status - exclusive possession vs non-exclusive and/or extinguishment, determination of access rights, joint management.
- The environmental sensitivity of the donor and recipient sites and the species involved - value or status of biodiversity assets; visibility and landscape value, stability of soils, maintenance of water quality.
- Effect on people or their livelihoods - other land users, impact on customary activities, effects on neighbours, risks to biosecurity.

Different levels of government are responsible for regulating these factors at different scales, so the types of approvals required can also be categorised in this way:

- Commonwealth: approval to take action likely to cause significant impact on threatened species or ecological community, permit to take, possess, move from/on Commonwealth land.
- State/Territory: permit/licence to collect/possess/move protected/threatened species, authority for import/export of protected species, authority to release to the wild, authority to enter and for activity on national park/reserve, authority for activity on Crown land, approval to conduct ecological or hazard reduction burn.
- Local Government: approval to use or develop (build structures on) land, approval to carry out activity on Crown land managed by local government; approval to conduct burning or other management activities.

In the majority of situations, approval from the relevant State or Territory conservation agency to conduct the translocation will be required. Agency websites provide information about relevant legislation, policies and permits (see Appendix 1 for contact details and key web links). In addition, the Australasian Legal Information Institute provides a searchable database of State and Commonwealth legislation in Australia (www.austlii.edu.au).

It may also be necessary to refer the translocation proposal to the Commonwealth government under the *EPBC* Act 1999 if the translocation is likely to have a significant effect on a threatened species, other Matters of National Environmental Significance (e.g. Ramsar wetland or National/World Heritage listed property) or on the environment on Commonwealth land.

Finally, proponents should also consider heritage and cultural factors involved with species or sites and whether consent from traditional owners is required. Such consent may be mandated through legislation or required to conform with the indigenous engagement policies and guidelines of Commonwealth and State agencies, research institution and universities, and NRM bodies (see http://www.environment.gov.au/epbc/publications/engage-early, http://www.environment.gov.au/system/files/pages/2f561690-b47e-4bf2-b028-d18739b3486f/files/nesp-indigenous-engagement-guidelines.docx, http://www.nrm.gov.au/indigenous-nrm/increasing-participation). Consent is required in instances where the species or the site(s) occur on land for which exclusive possession Native Title has been determined. Similarly, on land where no-exclusive possession Native Title has been determined, consent will be required if the translocation proposal impacts of the Native Title rights granted to the traditional owners, especially for matters that impact on the use and benefit of the land to the traditional owners and where the proposal may impact on the pursuit of customary activities. In cases where Native Title has been determined to be extinguished it is still prudent to consult with traditional owners regarding access to land as heritage and sacred site considerations still need to be considered. The National Native Title Tribunal (http://www.nntt.gov.au) mapping service provides an up to date coverage of the status of Native Title across Australia.

Aboriginal Land Councils and Prescribed Body Corporates (https://www.nativetitle.org.au/) can provide guidance on navigating land access and Traditional Owner engagement. It is particularly important to ensure proponents of translocation proposals engage and co-design proposals with the 'Right People - Right Country' and in most instances a co-design approach will ensure that the proposal has the cultural imperative to proceed and the proponents have the cultural authority to work on Country. Having the cultural authority to work on Country is a critically important consideration in the recipient site selection process as it may influence who can access a recipient site(s) when that site(s) may be culturally sensitive and accessible only to men or *vice versa* only women. Similarly, knowledge of possible access restrictions for a recipient site(s) during lore time or ceremonial periods will ensure that plans for monitoring or management activities can be co-designed into a translocation proposal.

In many jurisdictions the conservation estate and/or Traditional Owner lands (e.g. Indigenous Protected Areas) are managed jointly either through Indigenous Land Use Agreements (ILUA) between the Native Title holders and the Crown or through arrangements with not-for-profit conservation organisations (e.g. Bush Heritage Australia, Australian Wildlife Conservancy). In instances where joint management is founded on an ILUA proponents of translocation proposals need to obtain the approval of both parties to access the recipient site(s). In the majority of situations, the relevant State or Territory conservation agency should be able to advice on the best way to navigate the approval process for jointly managed lands.

The potential for several levels of permission, some conditional on others, and for permit processing delays, can mean that time frames for final approval and implementation of translocation proposals are lengthy. Where actions are time-critical, this can have serious consequences. Very early consideration by proponents of possible permit needs is therefore advisable. Contingency workshopping between biodiversity management work units and permit authorities, of potential future permit needs and decision processes, is prudent.

5.2.1. Approval process

Translocation can often involve a series of on-ground activities, such as site survey and preparation works; studies on associated species such as pollinators and mycorrhizae; seed, propagule, plant and associated species collection; introduction of the translocated plants or material; maintenance and monitoring. It is important to identify the first activity that requires approval, and to have the approvals in place before this stage is reached. Ideally, one type of approval is issued for the suite of activities proposed, but the applicant may elect or be requested by the regulator to submit different applications for different activities.

Each approval is likely to require a slightly different process, but usually involves the characteristic stages outlined in Fig. 5.1, noting that some may not be required or are optional or informal. Some approval processes are routine and quick, but others are more complex and require significant time to complete. An approval to conduct a preparatory ecological burn under low-risk conditions, and in accordance with standard procedures, may be issued in a few days. Conversely, a proposal that involves significant risks to the conservation of a species or has potential effects on many other parties may take six months or even a year to be considered and processed. In general terms, as a key factor, the more parties affected by the activity, the longer it will take to approve.

The time required to receive a decision on an application may also be affected by how commonplace or unique the activity is considered. If an approval authority infrequently receives translocation proposals, it is important to establish early contact with key officers involved in assessing proposals, to reduce delays because of unfamiliarity. The purpose or kinds of considerations made at each step of the approval process by assessment officers and decision-makers are outlined below in Fig. 5.1.

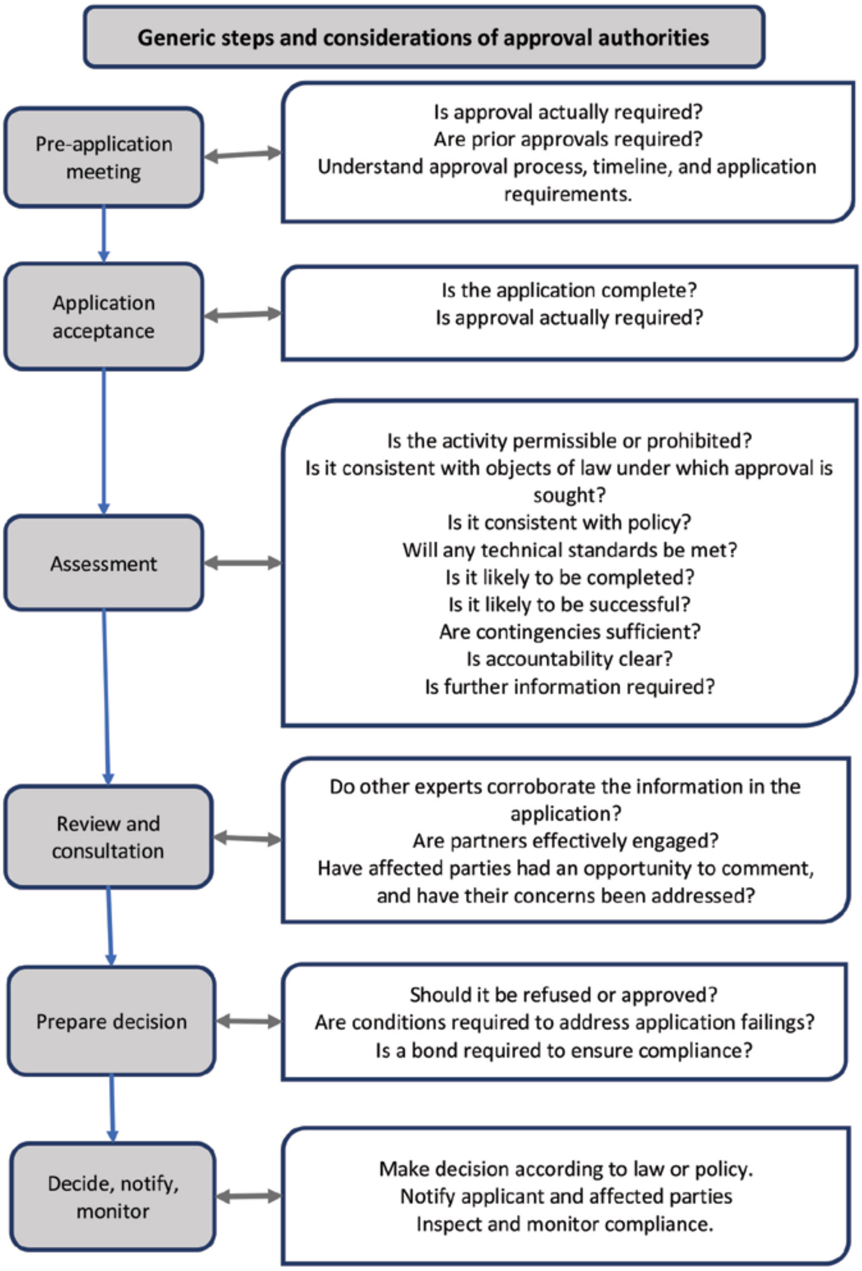

Figure 5.1 Steps involved in approval processes, and kinds of considerations made at each step.

5.3. Preparing a translocation proposal

A translocation proposal brings together the essential information necessary to understand who, what, why, where, how, and when a translocation is proposed. It not only provides an overall plan by which the translocation can be managed, it collates sufficient information on which an approver can evaluate an application for any approval required. The proposal provide sufficient information about the species and project for an informed decision to be made as to whether the translocation should proceed, and also provides a reference document against which to monitor progress and determine success, and communicate to others what is or was planned and why.

Your State or Territory conservation agency may have a specific template to inform applications for approval. If so, please discuss with them whether providing the translocation proposal template in these guidelines is sufficient to satisfy their application requirements.

A translocation proposal summarises:

- The target species, the type of translocation proposed and the project's objectives and performance criteria.
- Why the translocation is necessary for the conservation of the species or community, and why it is preferable to other conservation actions for the species.
- The key contributors to the development of the proposal.
- Roles and responsibilities for managing and conducting the activity, managing risk and implementing contingency plans if required, and ongoing site management and maintenance.
- Where and on whose land will the translocation occur, and where it is in relation to the species distribution and habitat.
- How: the donor and recipient sites or populations were chosen; genetics have been taken into account and will be managed; the ecology (including that of associated species) and ecosystem processes are provided for; risks (like disease or wildfire) are ameliorated; the monitoring, reporting, and communication will be carried out; and the project will be resourced for its operational life.
- Proposed timeline for project commencement and completion, and key milestones, and when does the exit strategy identify that the project should be abandoned or reversed.

A model template for a translocation proposal is provided in Appendix 2.

5.4. Translocation proposal review

The purpose of a review is to manage risk – to minimise the factors that cause failure and to maximise chances that the objectives will be achieved. A review of the translocation proposal is an important quality control step to check that the translocation is the best strategy to achieve target species conservation objectives, is scientifically well-founded, has adequate governance to manage the project, is technically feasible, and re-evaluates the assessment of financial (project completion) social and cultural risks. A review is in addition to any administrative checks to ensure that the proposal is complete and comprehensive.

Where a State or Territory government has established a formal review process, that process must also be used to review the translocation proposal. At the time of publication some government agencies had drafted or were developing operational policies or procedures that include risk-based review processes. Please contact the relevant agency (see Appendix 1) to confirm whether this is administratively required.

Generally, it is recommended that the translocation proposal be reviewed by assessors who, between them, have:

- knowledge and experience in translocation policy and procedures;
- experience in the manipulation and management of flora or vegetation; and
- experience in project and risk management.

Direct experience with or knowledge of the species is an asset in a reviewer or review team, but is not absolutely necessary for the purposes of a review. If the reviewers do not have experience with the species, then they should satisfy themselves that the key experts have participated in or have been consulted in the preparation of the plan.

In circumstances where particular social, cultural, or economic risks have been identified, engaging a reviewer with skills and experience in these areas should also be considered. Assessors should be as independent as possible, and, for high risk proposals, should not be selected from the key species experts or recovery team members who have contributed to the development of the translocation proposal.

In response to a reviewer's comments, a proposal may be abandoned, revised, or pursued. If revised or reviewed, the reviewer's further comments should be sought. A copy of the most recent comments provided by a reviewer should be attached to the final version of the translocation proposal's comments.

The following are examples of questions that could be asked of a reviewer(s), structured according to risk type. Generally, reviewers should be encouraged to express their comments in terms of their confidence that the matter of risk has been addressed to an acceptable level of likelihood and consequence, given the primary conservation plan's objectives for the target species.

5.4.1. Key questions for reviewers

- Are alternative management options more likely to achieve the primary conservation plan's long-term objectives (or other policy as identified under 5.1.2) for the conservation of the species?
- Do the benefits of the project outweigh any consequences of failure or other potential negative effects?
- Based on level of knowledge and technical feasibility, does the probability of success outweigh any consequences of failure or other potential negative effects?
- Does the project planning adequately address risks associated with species biology and ecology, project management, unforeseen events, and resourcing?

5.5. Recording and reporting

The direct and indirect conservation benefits of a translocation can be diminished by inadequate record-keeping. Keeping records of translocations is essential to:

- Manage any population established or supplemented by the translocation.
- Understand the role and relative importance of the population in the overall conservation of the species.
- Distinguish between a species' original distribution and occurrences, and places where it has been introduced.
- Learn from the successes and failures of the project and improve our practices.
- Communicate with partners and affected parties, and to share information and experiences with other practitioners.

Records include:

- The translocation proposal.
- Ongoing reports of the translocation, including monitoring reports (see Sections 6.5.5 and 8.6.3).
- Maps, diagrams and coordinates of translocation sites both as spatial layers and printed/digital products.

To avoid the loss of information and the risk of simply adding to the 'grey' literature, it is recommended that copies of the records should be held in publicly accessible repositories. If redaction is necessary (e.g. for reasons to do with landowner privacy, or sensitive species), the location of un-redacted records should be indicated on the public version. Full sets of records should be incorporated into State or Territory agency species management databases - to be held for each of the target species, and any State or Territory-based database of conservation translocation activities. Spatial data records should be submitted for inclusion in the relevant State or Territory database.

Please note that State and Territory conservation agencies have established policies for the management of sensitive data that guide the holding and disclosure of the specific location of species, culturally sensitive knowledge and information, and personal information where it is deemed sensitive.

Chapter 6 – Pre-translocation preparation

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Once the translocation proposal has been approved, there must be adequate preparation prior to planting. Appropriate preparation maximises the chances of translocation success. This involves many logistical aspects that would be coordinated by the team overseeing the translocation, which is often the Recovery Team (see also Section 3.1), and could take months or even years. It relies on the information that has been collected through the activities outlined in Chapters 1-4. This pre-planting preparation involves collection, storage, propagation and growing of appropriate plant material *ex situ*, site preparation and implementation of appropriate phytosanitary techniques throughout all these stages. A checklist summarising the necessary preparation is provided below.

Checklist for pre-planting preparation

The actual planting should not commence until the planting team can answer 'yes' to all of the following questions:

- ☐ Are appropriate trained personnel available for key stages e.g. propagation, planting (Section 6.1)?
- ☐ Are all personnel involved in the program adequately supervised and familiar with the translocation proposal (Sections 5.3, 6.1.1)?
- ☐ Is there adequate time available to ensure an appropriate outcome (Section 6.2)?
- ☐ Was the translocation source material sampled and labelled appropriately so that the identity of each clone/ accession can be tracked as outlined in Sections 3.5, 4.1, 6.4.4?
- ☐ Were the plants propagated under appropriate phytosanitary conditions to mitigate the risk of introducing pathogens (e.g. at a nursery accredited under the Nursery Industry Accreditation Scheme, Australia, or a facility of equivalent standard) (Section 6.4.3)?
- ☐ Has the recipient site been adequately prepared as outlined in Section 6.7?
- ☐ If the answer to any of the above questions is no then the risks of proceeding needs to be assessed prior to embarking on the translocation

6.1. Logistical assessment

Logistical assessment covers the administrative component of the project, addressing the staff required for the various stages of the project, their training needs and the financial commitment to the translocation, including long-term maintenance and monitoring. The materials supply chain (including plants) and its quality control are also logistical factors. It is important that these factors are considered before commencing translocation. Otherwise the opportunity to learn from the outcome (successful or not) of a translocation may be lost, or the procedure may end in failure simply because insufficient resources are available to maintain the site.

6.1.1 Personnel

A project coordinator or team leader should be appointed, to be responsible for the project. Preferably the coordinator should be a member of the Recovery Team established for the species or the region where the species occurs (Section 3.1).

The translocation will also require a diverse range of expertise to ensure that the translocation process is conducted correctly (Fig. 6.1). There is a range of specialists who will be able to contribute their expertise, as outlined in Chapter 3 and these may include:

- administrators;
- bush regenerators;
- horticulturists;
- translocation specialists;
- taxonomists;
- landholders;
- community groups and facilitators;
- ecologists; and
- geneticists.

Figure 6.1 ***Banksia brownii*** *planting team (Photo: L Monks).*

People with expertise relating to the species should be consulted or included in the project. Such experts are often associated with botanic gardens, herbaria, universities or conservation agencies (Appendix 1). There may also be private individuals who have an interest in the genus or family. Landowners should also be consulted and/or involved if planting is to occur within private land. Involving community or volunteer groups in planning and implementation can be beneficial to both the program and the community. The use and training of such people or groups is discussed in Chapter 9.

The number of personnel required through the different stages of the translocation should be estimated to allow sufficient allocation of resources for training and facilities.

6.1.2. Resource requirements

Continuous financial support is essential and must be available for the duration of the translocation including the long-term monitoring program – although in-kind labour support commitments can also play a role. The source(s) and security of funding for the duration of the project must be secured before proceeding. The number of translocations has been increasing in recent years and hence increasing levels of funding for translocations are likely to be required.

The financial assessment of the translocation program must include the cost of:

- pre-translocation research into biology and ecology;
- genetic and taxonomic studies, where necessary;
- surveys for source and recipient translocation sites;
- collection and where necessary storage of propagation material e.g. seeds;
- propagation and management of plants;
- co-translocating any necessary host or symbiont;
- site preparation (including control of threats such as grazing, fencing, restoration work and setting up any planned experimental treatments);
- fire management;
- travel;
- personnel training;
- planting equipment;
- machinery and transport for whole plant transplantation;
- after-planting management requirements including watering;
- long-term monitoring and evaluation programs; and
- allowance for inflation in the defined management period.

It is also important to confirm the availability of facilities necessary for the program. These may include:

- laboratories e.g. for seed germination, disease or genetic assessment;
- continuing linkage to sources of taxonomic, ecological and genetic expertise;
- germplasm storage facilities if propagation material needs to be stored prior to propagation e.g. seed bank; and
- suitable nursery facilities for propagation. This will normally involve accreditation of the facility under the Nursery Industry Accreditation Scheme and close compliance with its phytosanitation standards – if an unaccredited facility is proposed for use, its compliance with those standards should be fully investigated and its use justified in advance. The general requirement is that nursery hygiene is of sufficiently high standard to be confident that no pests or diseases will be introduced along with the species; see Appendix 1 for contact details).

6.2. Scheduling translocation activities

6.2.1. Timelines for translocation planning

The preparation time for a translocation can vary considerably and will be influenced by translocation proposal development and approvals, propagule collection, plant propagation and the time of year that is suitable for planting. Translocation proposal development and approval times will vary and be subject to the processes operating in the respective States or Territories. The timing for propagule collection will depend on the type of material required. For instance, if using seeds from a serotinous species or an *ex situ* seedbank repository, the propagules may be available as soon as required. Otherwise seed collection will need to occur when the seeds are ready. Be aware that there may be complications that require an adaptive strategy – for example unfavourable environmental conditions may see the loss of developing seeds and a change to vegetative propagation may be required which might result in a delay of several months before suitable cutting material is available. If using seeds, ensure that any seed pre-treatments (e.g. scarification, stratification, after-ripening) are fully documented, including the time required for these treatments (see Turner and Merritt (2009). For more information, consult a conservation seedbank (Appendix 1), or the Australian Seed Bank Partnership, (www.seedpartnership.org.au). Once plant material has been collected, the time necessary for propagation needs to be considered. Plants require sufficient time in the nursery in order to obtain a size and condition that is robust enough for handling during the planting phase, usually including a 'hardening off' period to adjust them to conditions more like the recipient site. Figure 6.2 and Table 6.1 provide examples of the different time periods that may be required using seed, cuttings or tissue culture to produce plants for translocation. Seed and nursery experts should be able to provide advice on potential times for the collection and propagation of the species (see also Section 7.1).

The best time of year to plant will depend on the site's climatic conditions and will also need to be incorporated into the schedule. For whole plant transplantation, the required timeframe depends on multiple constraints not the least of which can be the experience of the personnel involved. There may be pressure to conduct a translocation in a hurry (developers are often in a rush). Other constraints include the scale of the translocation, seasonality, the understanding of the ecology of the target species, the availability of a suitable recipient site, the timeframe of any approvals and consultation processes, the distance plants need to be moved and the availability of resources. This can take anywhere from a few weeks to as much as a year.

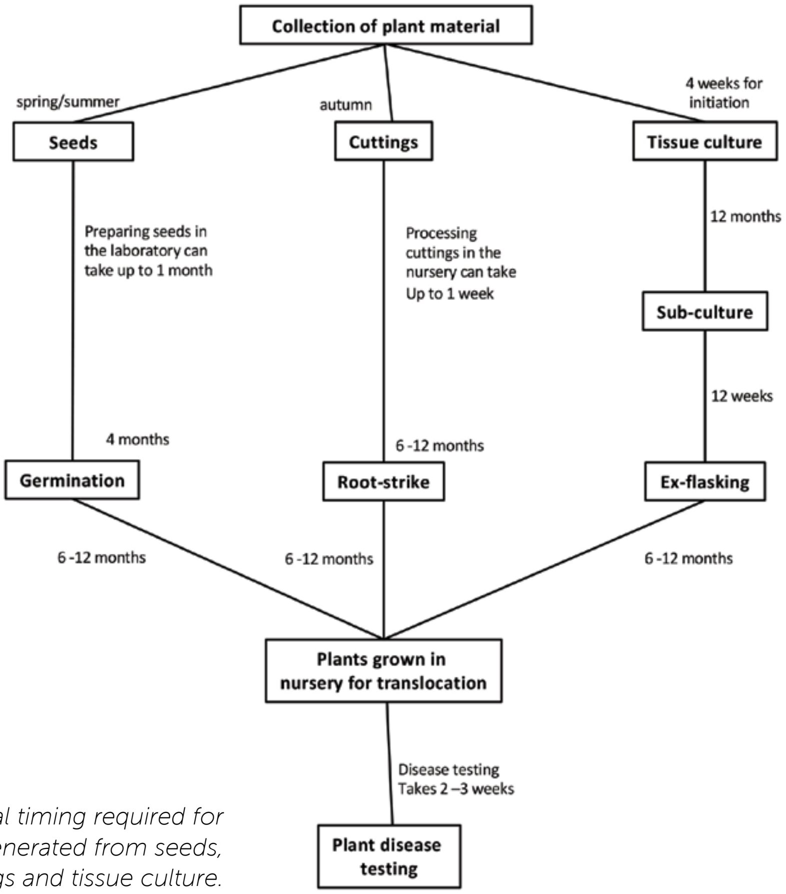

Figure 6.2 Typical timing required for plants to be generated from seeds, cuttings and tissue culture.

Table 6.1. Timeline showing the pre-planting preparation for three Western Australian species that require winter planting. The translocation site for the ***Banksia cuneata*** *occurs within a Threatened Ecological Community (TEC) and as such the approval time for the proposal was prolonged compared to the other two species. However, as* ***Banksia cuneata*** *is serotinous, seeds were able to be collected immediately after the proposal approval. For* ***Acacia cochlocarpa*** *and* ***Andersonia annelsii****, seed collection was delayed until November, when seeds were ready. The quick growth of the* ***Acacia*** *seedlings meant that the plants were large enough for planting the following winter. Conversely,* ***Andersonia annelsii*** *is extremely slow growing and required 18 months in the nursery to reach a size robust enough for planting out.*

Year 1	J	F	M	A	M	J	J	A	S	O	N	D
Acacia cochlocarpa	Transn proposal developed	Transn proposal submitted for review and approval			Transn proposal approved						Seed collectn	Seed germinn
Andersonia annelsii												
Banksia cuneata							Transn proposal approved	Seed collectn	Seed germinn	Nursery		

Year 2	J	F	M	A	M	J	J	A	S	O	N	D
Acacia cochlocarpa	Nursery					Planting at site						
Andersonia annelsii	Nursery											
Banksia cuneata	Nursery				Planting at site							

Year 3	J	F	M	A	M	J
Acacia cochlocarpa						
Andersonia annelsii	Nursery					Planting at site
Banksia cuneata						

6.2.2 Single versus staggered plantings

When to plant, depending on the condition of the plants and the climate at the recipient site, is discussed in Sections 6.1 and 7.1. However, consideration should also be given to the long-term timeframe, such as whether planting should occur over multiple years or different seasons. The species may naturally occur in multi-aged stands (see Section 3.2) and staggering planting over more than one year will create a multi-aged structure in the translocated population. Staggering also means planting may take place over a range of establishment conditions, thus reducing the chance that the translocation will fail due to an unfavourable season or event. Many translocations involve threatened species where propagules are extremely limited. Planting over multiple years allows some resources (e.g. seeds) to be kept in reserve for future plantings if the translocation does fail. For example, if all the plants die due to drought conditions in one year, resources are still available to plant in later years when the seasons are favourable (assuming seeds remain viable in storage). This method also allows for regular assessment of success and techniques before further resources are invested in the translocation process. Generally, staggered translocations give better protection against the potential consequences of adverse stochastic events

6.3. Collection of source material

Source material includes seeds, cuttings, whole plants, and the soil seed bank, as outlined in Section 3.5. The availability and the optimum time of year for collection of seeds and vegetative material is often overlooked (see Figure 6.2). These factors are major considerations when developing project milestones. Prior to collecting source material, source sites must be identified and a sampling strategy designed (Section 4.1) and the sort of plant material that will be collected (e.g. seeds, vegetative material) determined (Section 3.5) (Case Study 6.1). A voucher specimen should also be taken when collecting plant material for verification of the species identity, and then lodged with the relevant State/Territory herbarium. Plant material collection methodologies will vary among species and hence specific guidelines have not been provided here. The publication 'Plant Germplasm Conservation in Australia' (Offord and Meagher 2009) provides comprehensive guidelines for the different collection methods.

Seed collections are generally the most appropriate source material for translocation, however other options for producing plants include aerial and root cuttings, grafting, division and micropropagation (See Section 3.5.1).

6.3.1. How much material can be collected from each source plant?

When collecting material, it is important to remember that the source population should not be endangered further as a result of the collection event, and seeds should not be over-collected from any one plant or population (Figs 6.3, 6.4). As a guide no more than 20 percent of the mature fruits from any one plant should be removed; and no more than 10 percent of plant material from any one plant should be removed (Cochrane *et al.* 2009; Guerrant *et al.* 2004). However, when collecting from threatened plant species we suggest that these values are at least halved and that only as much seed as required is collected (the amount of seeds or regenerative material required should have been decided when planning the translocation, see Section 4.1.2), unless also collecting for long-term seed banking. The amount of material that can be removed may be prescribed in some States and Territories, so check the permit conditions. Fruits or plant material should also be collected evenly from randomly selected plants occurring across the extent of the population, unless known fecundity and fertility data indicate otherwise. The optimal time to collect vegetative cuttings as well as the availability of appropriate vegetative material should be considered when developing project milestones. Given the necessity to minimise the impact of collection it may be necessary to collect propagation material over successive years in order to obtain sufficient quantity. Further discussion of collecting strategies is found in Guerrant *et al.* (2004) and Cochrane *et al.* (2009).

*Figure 6.3 Bagging seed pods of **Lambertia orbifolia** for later collection (Photo: L Monks)*

*Figure 6.4 Leonie Monks, Rebecca Dillon and Sarah Barrett collecting seeds from a **Lambertia orbifolia** translocation (Photo: D Coates)*

6.3.2. Collection of material and preparation for whole plant transplantation

This section relates to when one or more plants are removed from their natural habitat, typically with at least some of the surrounding soil. This material is normally planted directly into a selected recipient site. Plants are often salvaged from areas where the population is no longer amenable to other conservation measures, such as rapid population decline or habitat destruction. Transplanting may also be a strategy when plants cannot be successfully propagated from seeds, cuttings or tissue culture. It may be possible to transplant species that produce underground propagules such as rhizomes or tubers. Transplanted material may have advantages including use of reproductively mature individuals, the potential to translocate beneficial mycorrhizae/organisms at the same time and using genotypes already selected and adapted to local conditions (assuming the receiving site is nearby and has the same conditions as the donor site). However, transplanting entire plants from naturally-occurring populations has a low success rate as many plants die without successfully reproducing at their new location. There is also a risk of moving harmful organisms when conducting whole plant transplantation. Therefore, this method is generally viewed as a last-resort strategy to prevent the extirpation of a population.

The process of whole plant translocation is typically unique for each species and is therefore highly variable (Case Study 6.2). It will depend on the ecology of the target species and the characteristics of the site into which it is to be planted. A number of issues need to be considered for this type of translocation. There are different ways to approach transplanting, which depend on factors such as plant size, current weather conditions, available resources and where the plants occur at the source site. Consideration of these factors and development of a plan on how the planting will be carried out is essential during the preparation stage.

An initial population census needs to be conducted, using a careful targeted survey to identify what an individual is, and whether clumps may be one or more plants. For dioecious species it is also important to know the distribution of sexes to prevent the translocation disrupting any potential for reproduction at the recipient site. Once selected, ensure the individuals can be relocated reliably. While recording GPS waypoints will help, the recording accuracy involved in this process can result in searching for small plants over protracted periods of time. Using visual markers (i.e. flagged steel pins) placed systematically in relation to the location of a plant is relatively fool-proof, although in urbanised areas these can attract unwanted attention. Ideally markers need to be able to survive and be visually detectable for up to a year or more. Photos of each plant may also be helpful and may assist in detecting changes in health or recruitment.

Consider the logistics of how the plants are to be salvaged. The size of the plant to be moved will influence the technique used to carry out the operation. Small plants are generally relocated manually from the donor site. Large trees or shrubs are often transplanted using machinery such as excavators or tree spades (Fig. 6.5). Different methods may be used including gradual transplanting and direct transplanting. Gradual transplanting involves pruning of the root system to allow the tree to adjust to a reduced root system prior to excavation. This prolongs the transplanting process and if not properly implemented may increase physiological stress and weaken the tree before transplanting. Direct transplanting from the impact site to the recipient in a single operation is a fast and efficient method, particularly when substantial numbers of individuals require translocation. This requires trenching around the tree with an excavator or tree spade on an excavator, lifting it out of the ground with a soil-root ball, pruning of the trunk and branch system to re-balance with the reduced root system, and immediate planting into the recipient site and watering. Most sub-tropical rainforest species recover from this transplanting method by reshooting from dormant buds on the trunk and branches, and sometimes from the root system. Obligate seeder species from rainforest (e.g. pioneer species) and open forest ecosystems are less tolerant of soil-root disturbance and are more likely to transplant poorly.

The substrate in which the plants are growing will influence techniques for whole plant translocation. Rock crevices, for instance, provide a unique challenge. Consider the soil texture, whether it contains a high proportion of sand or clay. The sod that is excavated may be structurally stable or need support. It may be preferable to work while the soil is dry, or wet. Moist to wet soils are more amendable to an excavation, either by hand or using a machine, therefore plants at the salvage site may need to be watered prior to work commencing, or alternatively wait until rainfall results in suitable soil moisture levels.

The need for specialised equipment and transport should also be considered and planned for well ahead of the works (Fig. 6.6). Organising a translocation with larger machinery can be complicated and requires careful planning. A machine such as a tree-spade will excavate a relatively large volume of soil which, ideally, would be driven straight to the recipient site for planting directly out of the spade. This is plausible where plants are moved relatively short distances or if only a few plants are to be moved. However, if plants are to be removed from the spade for transport over larger distances, they must be supported in specialised containers, which support both the plant and soil during transport but also easily manipulated for planting. For example, excavated plants may be placed into specialised baskets. The basket is typically lined with hessian for additional support, and is both strong and biodegradable. Baskets can then be lifted (normally by crane) into a trailer or onto a truck for transport. At the recipient site baskets can then be lifted and placed into tree-spade excavated holes to either be planted with the basket as a whole unit or lifted from the basket using the hessian and planted with the hessian.

If the target species has soil stored seed, the soil seedbank may be moved while translocating whole plants. It is therefore worth understanding the seed morphology and ecology of the target species. While the transplant may not survive, the associated propagules may result in the establishment of new plants.

*Figure 6.5 Transplanting **Floydia praealta** (Ball Nut) using the direct transplant method during construction of the Ballina Bypass. Monotypic genus is endemic to lowland subtropical rainforest between Nambour (Qld) and Ballina (NSW). (Photo: A Benwell)*

*Figure 6.6 Lowering **Macadamia tetraphylla** transplant into truck for transport to receival site after excavation and pruning. Ballina Bypass translocation project. (Photo: A Benwell)*

6.3.3. Collection licence requirements

In Australia, the licences and permits required for collecting threatened plant material for propagation are governed by State or Territory legislation. Collection activities must comply with these laws, regulations and permit conditions. The collection of plant material may or may not be covered by the translocation licence or permit. The relevantState government conservation agency must be contacted to ensure that the appropriate approvals have been issued and that the collectors are aware of any relevant legislation. Licencing is discussed in more detail in Chapter 5.

6.3.4. Record-keeping requirements during propagation

It is vital that detailed records of the collection are made so that individual plants can always be traced (Fig 6.7). Records should at least document source plant location, date of collection, the amount of material collected from each plant, GPS co-ordinates, the number of plants sampled, and ecological notes on the habitat and condition of the sampled population. Ideally, where multiple plants are being sampled, GPS co-ordinates should be recorded for every sampled plant to track source material.

Vegetative (cutting or other tissue) material from different parent plants should not be mixed, and each batch of cutting material should be labelled in a manner that will enable it to be related back to collection records. This record system (usually a set of unique codes or accessions) should be maintained throughout the subsequent storage, propagation and translocation stages. Not every plant will necessarily require a separate label during the propagation process; for example, if several individuals have arisen from cuttings taken from a single parent plant, they may be identified as a group until planting.

When collections are made, plastic tags can be used for recording information, and should be written using pencil or permanent marker (see also Section 7.3.7). Alternatively, barcodes can be employed with collection information stored electronically and backed-up. It is also worth considering double-labelling the collection with a tag inside a bag and then re-written or barcoded on the bag. Permanent, non-fading tags should be used for plants in the nursery as some tags can fade over time under external environmental conditions. When a plant is large enough, a tag can be inserted into the pot which should remain with the plant when transferred to the translocation site. Continuity of personnel for plant handling and record keeping reduces the risk of human error.

Figure 6.7 It is essential to keep records of seed collection, such as in this field collecting book. (Photo: A Crawford)

6.4. Establishment and maintenance of an *ex situ* collection

Once plant material has been collected from the source population it may be used immediately to propagate plants for translocation or, in the case of orthodox seeds, stored until required (see Section 6.4.1). In some cases, stock plants may be established to be used as a source of material for future plantings (Fig. 6.8). This allows for the production of good quality stock plants that can be used as source material for sequential plantings, or as a source of seeds for longer term *ex situ* conservation. Particular attention should be paid to ensure that when *ex situ* collections are established in sufficient time so that the plants are given adequate time to grow before any translocation planting. It is important that the IUCN technical guidelines on the management of *ex situ* populations for conservation are adhered to (see https://portals.iucn.org/library/sites/library/files/documents/2014-064.pdf). Strategies and guidelines for developing, managing and utilising *ex situ* collections in Australia are found in Offord and Meagher (2009) and summarized below. Two principles for foremost consideration in this stage are strict maintenance of the material recording system tracking the information about the collection of the plant material (See Case Study 6.1) and the need for horticultural expertise to produce plants with the required quality to ensure translocation success.

Figure 6.8 Stock plants of ***Haloragis eyreana*** *held in the nursery for supply of cuttings. (Photo: M Jusaitis)*

6.4.1. Storage and propagation of seeds

Ex situ seed conservation has an important role to play in translocation as seeds of many species can be stored while seed propagation techniques are being established, or until plants are required for translocation. General guidelines for the processing and storage of seeds are provided below and further details are in Martyn *et al.* (2009). In addition, the FloraBank website (www.florabank.org.au) provides general guidelines on the preparation and storage of seeds.

Species with seeds that tolerate drying to below 10% moisture content before storing cold (5°C) or frozen (-18°C) are termed 'orthodox'. The following is appropriate for orthodox species (Martyn *et al.* 2009).

- If the species has dehiscent fruits (fruits that open to release seeds), dry the fruits and extract seeds as soon as possible following collection, taking care to avoid damaging the seeds. The methods for drying and extraction will vary among species (Gold 2014).
- Clean seeds (and indehiscent fruits – fruits that don't naturally open to release their seeds, hereafter seeds) by separating from waste material such as empty seeds and fruits, sticks, leaves and dirt. Methods for seed cleaning will vary and include: manual cleaning, sieving, blowing, winnowing and flotation (Fig. 6.9) (Terry and Sutcliffe 2014).
- Dry seeds using either air drying or artificial drying methods. It is vital that appropriate seed moisture content is achieved without loss of seed viability. It is recommended to use a cool, dry environment as excessive heat can damage the embryo and decrease viability. Established seedbanks dry seeds at 15-20% relative humidity and c. 15°C.
- Enclose seeds in appropriate air-tight packaging.
- Store packaged seeds in cool conditions such as a refrigerator (5°C) for short to medium-term storage (up to ten years) or freezer (-18°C) for long-term storage (> ten years). (Fig. 6.10) Lowering temperature and humidity prolongs the life of seeds in storage. Once seeds are placed in storage it is important that the temperature and moisture content remain constant.

Note that seeds of many species from wetter areas, such as rainforests, can only be stored for a short period of time and need to be germinated soon after collection. They cannot tolerate the drying necessary for long-term storage. These species are termed 'recalcitrant'. The determination of whether seeds of a species are recalcitrant or orthodox can be complex, but a rule of thumb is that larger seeds that lack endosperm and have thin seed coats relative to the overall size of the seed are likely to be recalcitrant. One way to determine recalcitrance is to dry a small sample of seeds at low relative humidity and determine if the seeds are still viable and can germinate (germinate following drying = orthodox) (Gold and Hay 2008).

Seed dormancy class and germination requirements should have been identified in the pre-translocation assessment phase (see Section 3.5). Seeds of many species are dormant at dispersal and require specific conditions to overcome dormancy. To propagate seeds under *ex situ* conditions, different treatments are used to overcome different classes of dormancy, for instance, hot water or scarification can overcome physical dormancy, whereas warm or cold stratification may overcome physiological dormancy. Once dormancy (if present) is overcome, seed germination requires appropriate light, temperature and moisture conditions. If optimum incubation conditions are unknown, then clues for appropriate germination temperatures can come from habitat conditions during germination. An experimental approach may be required. For more detailed explanations of seed dormancy and germination see (Baskin and Baskin 2014; Turner and Merritt 2009).

Figure 6.9 Seeds can be separated from fruits, chaff, and other non-seed material using sieves. (Photo: A Crawford)

Figure 6.10 To maintain seed viability, seeds may be able to be stored at sub-zero temperatures. (Photo: A Crawford)

6.4.2. Vegetative propagation

If seeds are not available or they do not germinate, plants may also be propagated vegetatively by aerial or root cuttings, division, grafting or tissue culture ('micropropagation') (see also Section 3.5.2). These are specialised techniques and should be carried out by an appropriate nursery or laboratory e.g. in a botanic garden or accredited commercial nursery or laboratory (Appendix 1). Principles of vegetative cutting propagation can be found in Hartmann *et al.* (2011) and tissue culture in Offord *et al.* (2009). As these are effectively 'cloning' techniques; it is important to ensure that there is appropriate genetic representation in the plants to be translocated (see Sections 3.3 and 4.1.2).

6.4.3. Phytosanitary considerations during propagation

Phytosanitary techniques should be practised throughout the entire translocation program. For a translocation to succeed it is essential to use healthy plants free of pathogens, pests and weeds. To achieve this aim, the highest standards of hygiene must be implemented at all times. The use of unhealthy plants will not only decrease the chance of translocation success but can also potentially have a detrimental impact on the habitat and species present at the recipient site.

Plants not raised under hygienic conditions should under no circumstances be used in a translocation program. Brief guidelines on appropriate phytosanitary techniques are provided below. It is strongly recommended that translocation proponents/teams actively inspect and confirm the phytosanitation procedures of facilities proposed for use, and seek independent advice where any doubt exists. The minimum standard for phytosanitation is a demonstrated compliance with prescribed processes under the Nursery Industry Accreditation Scheme (see www.NGIA.com.au/index.html for further information), which has been established with the aim of reducing the occurrence of pests, weeds and diseases (particularly, but not only, the pathogen *Phytophthora cinnamomi* and other damaging *Phytophthora* species) in nursery stock. As a general rule it is strongly recommended that propagation should be carried out by a nursery that is registered under the Nursery Industry Accreditation Scheme, Australia, but it is recognised that occasional cases will arise where the use of unaccredited nurseries or private specialist growers is appropriate. In cases where the use of non-accredited facilities is proposed, this should be explicitly justified in the initial translocation proposal (or in subsequent documentation), and critically assessed. In all conservation translocation projects, propagation services should (like all other supply-chain and process elements) be subject to quality checking by the proponents.

Phytosanitary guidelines for propagation

- Where possible, use propagation material from high up on the plant to avoid splash contamination (by root pathogens) from the soil, and use appropriate techniques for decontamination such as a short soak in dilute bleach solution (i.e. a minimum of 2 minutes soaking in a 1% bleach solution).
- Source all potting media or base ingredients from suppliers accredited under the Nursery Industry Accreditation Scheme, Australia. Potting mixes should comply with the Australian Standard AS 3743-2003.
- If purchasing raw materials, ensure they are fully composted prior to incorporation into a potting media (e.g. pine bark and sawdust) to reduce nitrogen draw-down, pathogens and weeds.
- Potting media ingredients should be pasteurised (minimum one hour steaming to reach 60º C plus a further 30 minutes held at this temperature, then natural cooling) to eliminate pests, pathogens and weeds.
- Ensure potting mixes are mixed and stored in well ventilated, clean (sterilised or disinfected) conditions.
- Where they are required, add fertilisers to the potting mix after pasteurisation to avoid toxic amounts being released.
- Pasteurise or disinfect using NIASA approved methods all pots and trays (if reusing) and store them in hygienic conditions.
- Clean all benches with an appropriate disinfectant (for example; Phenosol (2 percent solution), Phytoclean®).
- Disinfect propagation hoods and tools before use with solutions such as 80% methylated spirits, Phytoclean® or sodium hypochlorite (1 percent chlorine solution).
- Do not place dirty tools or materials on benches.
- Especially for plants generated by tissue culture, use deionised water for watering, graduating to rain water, then suitable tap water. All water must be free of pathogens.
- Treat vegetative cuttings and cutting media with a systemic fungicide.
- Inspect plants regularly for pests and diseases, and where appropriate seek expert advice for identification and treatment.

- Use fungicides when necessary, adhering to the Fungicide Resistance Management Strategies (Anon 1995) to avoid resistance build up. The same principles should apply to use of pesticides.
- Harden off the plants as soon as possible to reduce the incidence of fungal disease and insect attack. Final hardening off should be outside on disinfected open wire benches well off the ground to avoid splash contamination from the soil or hard standing area.
- Isolate the propagation site to reduce the risk of contamination by diseases, pests and weeds.
- If possible, have plants tested for *Phytophthora cinnamomi* with an accredited laboratory at least two weeks before planting.
- Transport plants in clean vehicles with all contact points disinfected and avoid contact with dirt prior to getting to site.

6.4.4. Propagation monitoring and recording

To provide data on the most effective methods of propagation for use in future translocation programs, the *ex situ* component must be well documented. Ensure all personnel involved are appropriately trained and aware of the importance of record keeping. Activities and information on success or failure should be documented for:

- source population (Chapter 4), location and collection numbers;
- the kind of material used, e.g. seeds or cuttings, if seed, has it been stored, for how long and under what conditions;
- types of cuttings used i.e. softwood/hardwood and material condition;
- season in which material is collected;
- technique of vegetative propagation e.g. pre-treatments such as bleach-soaking, as well as type and concentration of root stimulating growth regulator (‘hormone’) used;
- seed dormancy class and treatment techniques e.g. hot water, smoked water or gibberellic acid application;
- percentage strike of cuttings or germination of seed;
- propagation media;
- temperature(s) and humidity control of propagation area;
- germination speed and growth rates of seedlings and/or cuttings;
- amount of water and type of fertiliser;
- success of different individuals/provenances;
- methods used (or that need to be used) for the replacement of plants that failed to establish; and
- consider publishing or otherwise sharing findings.

To allow this information to be accurately recorded it is essential that a method of tagging plants that corresponds to the labelling system introduced during the collection of plant material is used (Fig. 6.11). The failure to adequately tag individual genotypes or accessions may mean that problems with the composition of the *ex situ* collection due to differential survival of genotypes go undetected.

Figure 6.11 Tagging system in a nursery ***Left:*** *Plant tag;* ***Right:*** *Plant tags and labelled pots. (Photos: D Taylor)*

6.5. Learning from the translocation – experimental design

Translocations involve substantial resources and using an experimental framework provides the opportunity to test ecological theories, compare management techniques and explore important research questions (Case Study 6.3). By using well-designed experiments, the impact and interactions of various factors on translocation success can be understood and translocation procedures and techniques can be refined and improved in future translocations. Experimental translocations can be conducted as small-scale pilot studies or, incorporated into the full translocation.

Experimental translocations could be used to:

- understand causes of plant rarity;
- elucidate the microhabitat requirements for plant survival and reproduction;
- determine how microhabitats can be manipulated to ensure population persistence;
- compare propagation or sowing techniques (Fig. 6.12);
- compare site preparation or post planting treatments (Fig. 6.13);
- test the outcomes of different seed sourcing strategies;
- assess the effect the number of individuals may have on likelihood of successful pollination; and
- test reproductive output and potential recruitment opportunities through increased pollination.

It should be noted that experimental translocations still require licences (see Section 5.2). They should always be carried out in collaboration with the Recovery Team or management authorities overseeing the recovery process for that species.

When designing an experiment, it is essential to also design a plan to monitor the experiment. For more information on monitoring, see Chapter 8.

Assistance in designing experimental translocations can be gained from consulting statistical textbooks (e.g. Crawley 2005; Dytham 2011; Hairston 1996; Hothorn and Everitt 2009; Krebs 1999; Lawson 2014; Ott and Longnecker 2015; Quinn and Keough 2003; Ramsey and Schafer 2012; Underwood 1997; van Emden 2008; Whitlock and Schluter 2014) or talking to a biometrician. Biometricians are often employed in mathematics or biological sciences departments at universities, research organisations or by State government conservation agencies (Appendix 1).

Figure 6.12 Experimental translocation to study the effects of different sowing techniques on germination of ***Haloragis eyreana****. (Photo: M Jusaitis)*

Figure 6.13 Left: Trial to study the effects of mowing, grading and herbicides on seed germination of ***Haloragis eyreana****; Right: Close-up of trial plots showing graded and mown plots in a study of seed germination in* ***Haloragis eyreana****. (Photos: M Jusaitis)*

6.5.1. Pilot studies

Small pilot trials can be conducted on the focal species or on a surrogate species (usually a closely related, common species). These studies should occur prior to the full translocation and are implemented to identify and address procedural, institutional, or logistical issues. Problem-solving prior to the full translocation can lower costs over the long term and save valuable propagation material. Similarly, monitoring these experimental *in situ* planting trials may also provide information that will allow refinement of processes for future translocations of that species or others. These pilot studies will still be considered as translocations in terms of licensing requirements (Section 5.2), and where possible should be designed to potentially contribute to the longer-term goals (enhancement or a viable new population).

6.5.2. Translocation as a scientific experiment

Experimental refinement of translocation methodologies can also be incorporated into full-scale translocations. If sufficient propagules are available, the incorporation of an experimental component will produce more information about the techniques that lead to positive translocation outcomes. It takes only a little extra thought and effort to arrange the plants within the translocation site in a way that allows the chosen experimental treatment to be tested (Section 7.3.4). The longer-term funding usually associated with a full-scale translocation compared to a pilot study may also provide a better opportunity to integrate an experimental component and ensure monitoring over a longer timeframe. The knowledge gained from implementing simple experiments to test the translocation techniques will be extremely valuable in planning future translocations.

6.5.3. Designing an experiment

Experimental design can be very simple, for instance, testing if tree guards improve plant survival, or very complex, testing multiple treatments and their interactions. The important point is, no matter how simple or complex, the experiment needs to be set up in a way that the information gathered is able to be analysed.

Experiments are used to test an idea or ‘hypothesis’. The hypothesis will determine the type of data that is required and the different ‘treatments’ (or conditions) that should be applied to plants. To test a hypothesis, a number of plants are given a specific treatment (these are called the ‘treatment’) and the same number of plants are not treated (these are called the ‘control’). The response (e.g. growth rate or survival) of the treated and control plants needs to be recorded at various points over time using the measures determined during the development of the hypothesis. At the end of the trial period the results from the plants given the treatment and control plants can be compared to establish whether the treatment has had any effect.

To ensure that the findings are statistically valid the treatments need to be replicated (repeated). Plants are either given a treatment (i.e. fenced) or not given a treatment (i.e. not fenced) and are turned treated and control plants respectively. Collectively, the group of treated and control plants are called an ‘experimental plot’ or ‘experimental block’ (Fig. 6.14). However, in the natural world a site is never perfectly uniform; for example, a site may be on a slope or have differences in soil types. These differences must be accounted for when setting up any experiment. Randomly placing the plants given the treatment within the experimental plot ensures they are not planted in one clump. An experimental plot should then be replicated and arranged throughout the site (see Fig. 6.15). Plants given the same treatment should not all be planted in one block as this is pseudoreplication and the experiment cannot be statistically analysed.

The number of plants required, and the number of times each experimental block needs to be repeated, should be determined by the methods and statistical tests that will be applied to the data. It is best to consult a biometrician or a statistical textbook to decide what statistical test is required. The results from a well-designed experiment should help to make decisions about refining the techniques to be used during future translocations.

Figure 6.14 ***Arthraxon hispidus*** *translocation, Tintenbar to Ewingsdale project. Applying annual pasture treatments to experimental blocks. (Photo: A Benwell)*

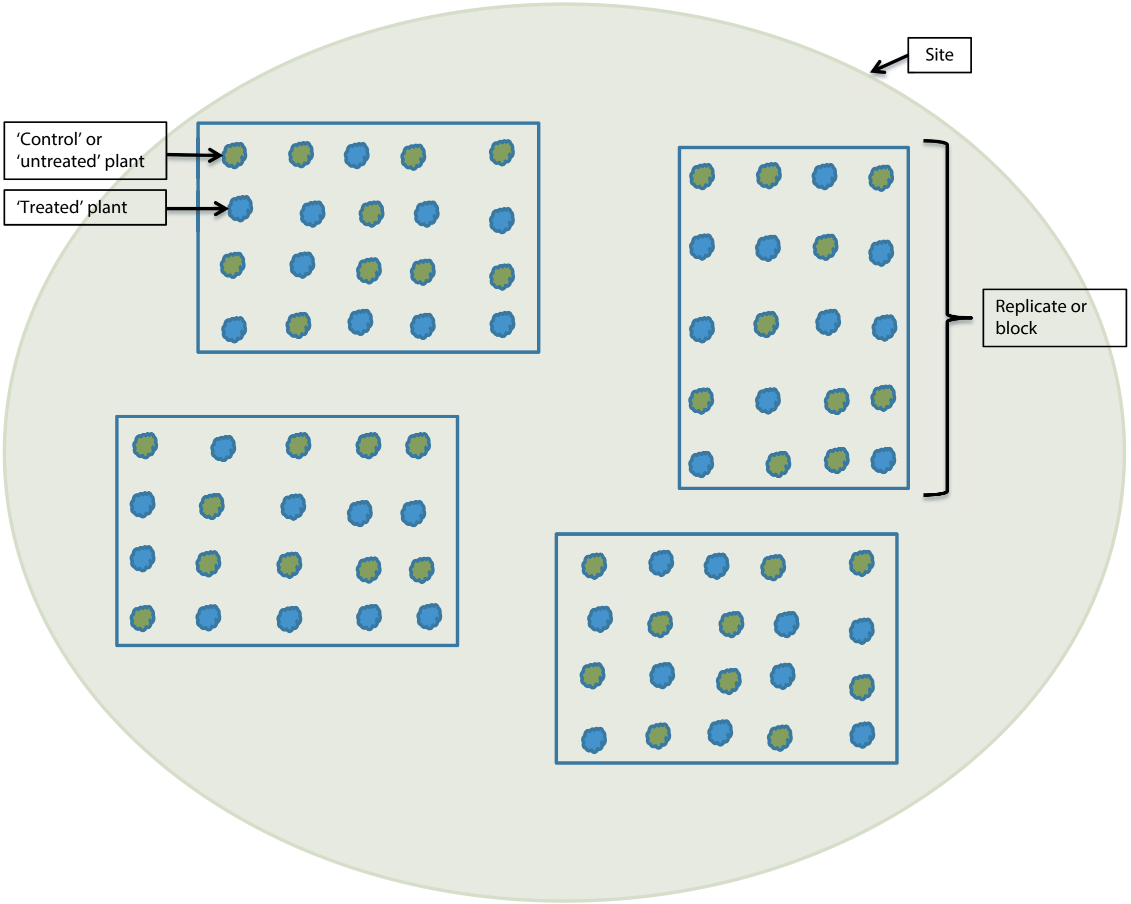

Figure 6.15 Example of experimental design layout showing treated (blue) and control (green) plants, and layout of four replicates (blocks) across the site. Spacing between plants and between replicates will depend on the type of treatment(s) being applied, the adult size of the plants and the space available at the site.

6.6. Identification of post-translocation management, monitoring and evaluation methods

6.6.1. Ongoing management

When planning the translocation project, after-planting care and habitat management must be considered. Following planting, it is likely that the plants will need some form of short-term horticultural care and it is also likely that habitat management and threat abatement will be required over a longer time period. This post-translocation care and management needs to be identified when planning a translocation as it is vital that sufficient resources and funds are available. In addition, it is advisable that the horticultural care and management is incorporated into any experimental design. The ongoing care of translocated plants and habitat management are discussed in further detail in Section 7.4.

6.6.2. Monitoring and evaluation

During the planning phase, it is important that a monitoring and evaluation schedule is designed to assess the success or otherwise of the translocation. Monitoring and evaluation are an essential component of all translocation projects. Criteria for determining success will need to be identified and it is important that these criteria are included in the translocation proposal. During the preparation stage, it is also necessary to identify resources and funds to be available for the implementation of post-translocation monitoring. Failure to identify criteria for determining success will make it difficult, if not impossible, to determine whether a translocation program was successful and hence worthwhile. Importantly, a plan that links particular monitoring results to particular management actions should be developed. Post-translocation monitoring and evaluation are discussed in Chapter 8.

6.7. Pre-translocation site preparation

The selection of recipient sites was outlined in Chapter 4. Once a recipient site has been selected it must be prepared so that it is in a suitable condition (Case Study 6.4). The biological, ecological and habitat requirements identified in the pre-translocation assessment should be satisfied in the site preparation. It is particularly important to remove or control threatening processes. As in all stages of translocation, hygiene procedures must be strictly adhered to, particularly when using machinery for soil preparation, fire control, installation of infrastructure and other activities that involve the movement of soil or plant material (Chapter 7: Section 7.3.1).

As identified in the pre-translocation assessment, the following actions should be completed before translocation takes place:

Accurate identification of the translocation recipient site. The area should be clearly marked on a map and the boundaries defined, to ensure that the translocation occurs in the right place and to assist with monitoring, management and any future plantings at the translocation site. It may also be useful to take pre-translocation photos for future reference. Preparation of the recipient site for a whole plant transplantation includes identifying where and how plants are to be planted. Clear communication with the workforce is essential and it is important to mark planting locations, movement corridors and no go zones at the recipient site to guide activities. Planning and coordination of the logistics of the salvage activity is key to a good outcome.

Amelioration or removal of threats. Any threats that have caused the species to become extinct at a natural site or reduced the population size (e.g. weeds, run-off, inappropriate fire regime) should be removed, ameliorated or controlled at the recipient site (Figs 6.16, 6.17). These measures may take some time (weed control over successive seasons, for example) and should commence well before planting. For whole plant and topsoil translocations, controlling weeds at the source is essential to reduce the risk of weeds being moved to the recipient site. Weed control at the extraction site should ideally occur for up to 12 months prior to transplantation. It may be possible to stimulate soil-stored weed seeds (e.g. using fire or watering) followed by control measures to minimise the unwanted spread of weeds.

Soil preparation. In some cases, the preparation of the soil to create a suitable planting environment is desirable. For example, hand tools may be used to loosen small areas of topsoil when planting seeds. Ripping areas with compacted soil such as disused paddocks can greatly aid in both planting and plant establishment. Fertiliser is also added in some rainforest environments. Check with local bush regeneration or translocation experts to decide what soil preparation may be suitable for the soil and ecosystem type.

Appropriate regeneration/restoration of habitat. Any required modification/rehabilitation (such as weed control, or planting of associated species to replicate habitat or combat fragmentation) should be carried out at this stage. This is a complex and site-specific topic, and rehabilitation guidelines (e.g. Clarke *et al.* 2010; Keenelyside *et al.* 2012; Standards Reference Group 2017) or other useful references (Bennett *et al.* 2000; Buchanan 2016; Munro and Lindenmayer 2011; Peel 2010) should be consulted.

Fire. If the species occurs naturally in fire-prone vegetation types such as heath and shrublands, implementing a prescribed burn (planned burn, ecological burn or controlled burn) at the site prior to planting may be considered. The application of fire creates suitable conditions for seedling establishment through increased soil fertility and decreased plant competition. However, these conditions are also ideal for weed establishment. Assessment of the effect of fire on the site's natural values will ensure negative impacts are avoided. The benefits and risks of using fire should be considered carefully. Local bush fire authorities and conservation agencies will be able to provide information on procedure and implications for conducting a controlled burn at the site.

Establishment of buffers, where necessary and possible. Consideration should be given to the purpose of the buffer and the environment around which it will be established. Buffers can be used to minimise further weed invasion or reduce wind speed, thereby giving plants a greater opportunity to establish.

Implementation of site protection measures. Any necessary protection measures - such as fences, bollards or large rocks should be installed at this stage to exclude herbivores or minimise human access (Figs 6.18, 6.19, 6.20, see also Section 7.4). The installation of a fire break can also provide protection from wildfire. The recipient site should already have secure tenure or appropriate long-term protection through a covenant or conservation agreement (Section 4.2.4).

For whole plant transplantations consider the potential ground impact at the recipient site if machinery is to be used, particularly if soils are wet and can be readily disturbed or compacted by the activity. To protect the recipient site this would normally require working when the soil is dry, as it is structurally more tolerant of any surface activity. To reduce the impact of using heavy machinery use existing disturbances such as tracks or weedy areas where possible to access planting sites. Planning where machinery can move or park and how often vehicles can cross an area is essential to minimise the impact on the recipient site.

Figure 6.16 *Weed control to reduce plant competition around transplanted* ***Acanthocladium dockeri****. (Photo: M Jusaitis)*

Figure 6.17 *Hand weeding the Floyds Grass (****Alexfloydia repens****) receival site, Bonville project. (Photo: A Benwell)*

Figure 6.18 *Sturdy fencing to exclude herbivores from a population of* ***Prostanthera eurybioides****. (Photo: M Jusaitis)*

Figure 6.19 *Small-scale fencing to exclude herbivores from an experimental translocation of* ***Haloragis eyreana****. (Photo: M Jusaitis)*

Figure 6.20 *Fencing to exclude herbivores from the translocation site for* ***Acacia unguicula*** *and* ***Acacia imitans****. (Photo: L Monks)*

6.8. Planning for and anticipating a cancelled or delayed translocation – implications for the plant material already prepared.

Inevitably some translocations will be cancelled or delayed due to weather, site conditions and other factors. In this case opportunities should be considered for ensuring the effort and investment made are not wasted, by exploring alternative uses for the plant material. This is particularly relevant given many threatened species require considerable effort to collect plant material in readiness for translocation work, and each collection event has potential risk of impact for *in situ* populations. Some options or alternative uses may reduce the need to revisit natural populations for subsequent collecting. Typically, the plants are reused *ex situ* as a backup living collection (Offord and North 2009). Botanic gardens are well placed to do this as they have the capacity for managing scientific and database–linked collections and are increasingly active with the exchange of plant collections. Another option is to re-purpose the plants as plant orchards where they are then used to produce larger quantities of seed or non-seed propagation material increasing the potential for future translocation options. For whole plant translocations that are not able to be directly transferred to the recipient site transplants may need to be held at a nursery and consideration must be given to minimising stress during this transit phase and ensuring hygiene procedures continue to be followed. For any of these options, there are implications for resources, so investing thought and integrating them into the planning stages will reap rewards and avoid the potential waste of the plant material. This will deliver a more strategic approach to what can be an unpredictable process – delivering a successful and effective translocation. Yet another option is to establish display and interpretive plantings at a publicly accessible site, to publicise the recovery program to the community and build support.

6.9. Importance of communication and appropriate supervision

As for all stages of a translocation program, it is vital that all people involved in the translocation preparation are given the necessary information and are provided with adequate supervision. Everyone involved should be familiar with the content of the translocation proposal, no matter how minor their involvement. It is important that all those involved in the project are aware of the necessity for adherence to these Guidelines (e.g. importance of phytosanitary techniques and maintenance of labelling systems). Any changes to the timing of the translocation, for example due to altered propagation times, plant condition, weather conditions etc. should be regularly communicated to those involved. For whole plant transplantation it is essential that the workforce understands that the recipient site is not a construction zone and activity within a conservation zone needs to be minimised and carefully considered. These constraints need to be clearly communicated to the workforce on site and a supervisor needs to be appointed to control or approve any activity.

Case Studies

Case Study 6.1 - Collecting material

Excerpt from South East NSW Bioregion Working Group** et al. **(in press).

When collecting seeds or cuttings for translocation, a critical and often overlooked factor is the ability to link *ex situ* individuals to parentage or wild origin which identifies the population source and potential genetic diversity available. A genotype collecting method can be used to help address many of these issues.

The key objectives of a genotype collection method is to provide a user friendly tool that will:

- Be able to trace source populations and have control over genotype selection for future translocations.
- Maximise the chance of a successful collection event and enable populations' locations and specific plants sampled to be readily revisited (where applicable) for follow-up collecting.
- Enable each individual/team to be armed with a user-friendly guide and reference to enable efficient and effective collecting and to ensure that a standard protocol for field collections is adopted.
- Be appealing and practical for a wide audience with the goal of it being adopted and used widely and as a standard, which will enable better comparative analysis across projects and easier access to key standardised information and terminology.

Genotype collecting or 'maternal genotype collecting' is the term for when collections from multiple maternal genotypes are sampled and accessioned individually, rather than mixing the collections from multiple plants within the population. Hence, each parent plant has its own unique code, and germplasm (e.g. seeds, cuttings) from each individual plant are collected and stored separately. It ensures that existing and future users of the germplasm have access to material from a known source and linked to key information.

This collection method is useful for conservation projects that require adequate representation of the genetic diversity found in wild populations, and require control of that diversity.

Collection method checklist

When sampling using a genotype collecting method the following protocols should be used:

- Establish the extent of the population. This should be the first step before collecting commences.
- If feasible, make an estimate of the size of the population e.g. '<50 plants' or '50-100 plants' and over 200 m^2 etc. Noting this may not be practical or possible if the population covers a considerable distance/area and/or the vegetation is dense and of mixed species of similar height.
- Once extent of the population is known (or estimated), aim to sample plants from across this population.
- Determine a minimum distance between sampled plants, ideally greater than 10 m. (To reduce the chance of collecting closely related samples). Topography and extent of population can influence this distance.
- Record the estimated minimum distance in the field book records for the collections.
- If tagging of sampled plants is an option, aim to tag an agreed number of plants with unique labels. This should be done in numeric order and ideally be spread out across the sample area.
- Try to place the tag in a visible place as these plants may be revisited in the future for re-collecting and research. An option to assist re-visiting the plants sampled is to attach a piece of flagging tape so that it is approximately 150 mm to 200 mm long. This helps to relocate the tags when re-visiting and re-collecting.
- If tags are not being used, identification and location will be covered by each field book entry.
- Collect a herbarium specimen containing flower or fruit.

When sampling material in the field:

Vegetative material:

- Write a plant label; include the plant name and collection number (these can be pre-written to save time in the field).
- Place the label in the cutting bag. It is good practice to duplicate the collection number on the bag in case the label goes missing.
- Take the cuttings.
- Lightly mist the cuttings, seal the bag and avoid crushing during transportation. Keep as cool as possible and out of direct sunlight.

Seed:

- Seed dispersal can be unreliable and we suggest bagging the developing seeds and revisiting to harvest.
- Check pollination has occurred and early seed development is in progress. Avoid bagging flowers as this will prevent pollination and reduce seed set.
- Place 3 to 4 bags (ideally) on a single plant.
- The seed collection event is only recorded at harvest. This involves the creation of the field notes. It is always separate to the cutting field notes.
- To harvest; cut the bags from the plant and write the collection number on each bag.
- Tie all the bags harvested from one plant together so it is clear they come from the same maternal genotype.

*Figure 1 Discussing the implementation of the genotype collecting method with all partners prior to collecting **Pomaderris bodalla**, near Merimbula NSW, part of a multi-partner conservation project. (Photo: R Snashall)*

Case Study 6.2 - Multiple methods applied for translocation of threatened plant species impacted by a highway upgrade

Excerpt from Benwell (2018).

The Warrell Creek to Urunga (WC2U) project is a 42km section of the Pacific Highway upgrade on the Mid North Coast of NSW. Like many development translocations that require vegetation clearing, this project involved the translocation of several threatened plant species. The WC2U project impacted on six threatened species of varying growth form and habitat requirements, including two rainforest vines, a rainforest tree, a swamp grass, an epiphytic orchid and a floodplain herb (*Marsdenia longiloba, Tylophora woollsii, Niemeyera whitei, Alexfloydia repens, Dendrobium melaleucaphyllum* (Fig. 1) and *Artanema fimbriatum*, respectively).

Translocation methods employed included salvage transplanting (Fig. 2), seed and cutting propagation and direct seeding. An experiment comparing type of propagation (seeds versus vegetative) and fertilizer addition (i.e. horticultural techniques) on establishment of the vine *Marsdenia longiloba* was incorporated into the translocation project.

Monitoring of translocation results will be carried out for five to ten years. The translocation results were generally successful at least in the short-term (<5 years). Receival site and horticultural technique were the key determinants of translocation outcomes. Several characteristics of the site needed to be considered in selecting a suitable receival site including the type of habitat present, ecological requirements of the species being translocated, logistical feasibility, whether threatening processes can be controlled, tenure and prospects for long-term population or stand viability. A major spin-off of the translocation project was better understanding of the ecology, life history and population dynamics of these threatened species.

Figure 1 Flower of ***Dendrobium melaleucaphyllum*** *(Large-flowered Spider Orchid) endangered orchid of lowland swamp forest and rainforest in NSW. (Photo: A. Benwell)*

*Figure 2 Excavating a soil-root ball around a small Rusty Plum tree (**Niemeyera whitei**) during transplanting. (Photo: A Benwell)*

Case Study 6.3 - An experimental translocation led to an unexpected discovery

Excerpt from Jusaitis (2018a).

Haloragis eyreana, a small perennial herb with a stoloniferous rootstock, is endemic to the southern Eyre Peninsula, South Australia. *H. eyreana* has rather specific habitat requirements, being found in low lying, disturbed areas subject to inundation or water runoff during winter. We wanted to examine the influence of planting-site proximity to the water table on translocation success. This case study describes a translocation trial that led to the serendipitous discovery of an ideal microsite for plant establishment and ongoing recruitment of this species.

A series of five trenches were excavated at each of four locations along the Bratten Way. Trenches were approximately 0.4 - 0.5 m deep and 0.7 m wide, and separated by four crests about 5 m long and 0.5 m wide (Fig. 1). Two crests were left at natural soil level (high crests) and two were lowered by scraping about 200 mm of soil from the surface (low crests). All excavated soils were removed from each site.

In August, 2003, ten plants (2-5 cm high) were transplanted onto each crest, a total of 40 plants per location. No planting took place in the trenches. At the same time, 20 plants were transplanted as controls in undisturbed soil near each excavation. Survival and regeneration of *H. eyreana* at the two soil levels (high, low) and at the control sites were monitored annually for nine years. Plant recruitment in the trenches was also monitored.

Although plant survival on low crests and in controls was generally slightly higher than on high crests, the number of original transplants in all treatments declined steadily over 4 years, till none remained alive. However, during year 3, recruitment of new seedlings and sucker regrowths was observed around the original transplants on all crests. The total number of regenerants did not vary significantly between high or low crests, ranging between 1-5 plants/m^2 over years 4-8. Natural recruitment was also observed in trenches during year 3, and from then the number of plants increased exponentially so that trenches averaged 18 plants/m^2 by year 8. In 8 years, the population was increased by over 1000 new plants regenerating at four new sites within the population range.

Figure 1 Layout of ***Haloragis eyreana*** *translocation trial showing the four crests (High, Low, High, Low) and interstitial trenches on the day of translocation. (Photo: M Jusaitis)*

Case Study 6.4 - Site preparation benefits

Excerpt from Bickerton** et al. **(2018).

Acanthocladium dockeri is a clonal shrub with six populations in South Australia (Fig. 1). Many of the populations are on roadsides, adjacent to agricultural land and most in degraded weedy habitats. Given the limited area of occupancy, fragmented habitat and inferred decline, the species was listed as Critically Endangered under the EPBC Act.

The aims of the translocation were to: establish three self-sustaining subpopulations of mixed genotype *A. dockeri*; increase the species' extent of occurrence; engage the community in the translocation process and increase awareness of the Spiny Daisy Recovery Project through partnership with Banrock Station.

All populations are clonal, reproducing vegetatively. Seed viability is very low, and propagation attempts using seeds have failed. Cuttings were collected from the six remnant populations in spring 2013 and propagated at the Banrock Station nursery. Cuttings were dipped in rooting hormone and potted into trays with a mix of peat moss, vermiculite and perlite. When cuttings were large enough they were transferred to 90mm tubes to develop larger root systems. One week prior to planting, the translocation sites were rotary-hoed to 20 cm depth. This tillage destroyed the major weeds e.g. onion weed (*Asphodelus fistulosus*), and no other immediate weed control was necessary. Individuals were planted 50 cm apart, in rows 1 – 1.5 m apart (Fig. 2). Each clone was planted as a group, and native species were planted between the clone groupings. Rows were named and tagged.

Growth, survivorship and establishment were monitored quarterly in Year 1, biannually in Years 2-3, and annually thereafter, recording: survival of translocated individuals; number of ramets per individual; growth of plants and ramets as per Clarke and Haase (2012), i.e. height, width and perpendicular width; and presence and abundance of flowers and fruits. The monitoring methods will change in 2018 as it becomes increasingly difficult to determine each new ramet's source plant. The new method will measure percentage coverage of Spiny Daisy within a 1m^2 quadrat placed around each original plant.

Spiny Daisy benefits greatly from soil disturbance. Soil tillage prior to planting allowed plants to thrive and spread more quickly.

*Figure 1 **Acanthocladium dockeri** leaves, flowers and spines (E Rees)*

*Figure 2 Banrock's **Acanthocladium dockeri** site **Left**: before (June 2014) and **Right**: after (February 2018). (Photos: D Bickerton & T Field)*

Chapter 7 – Implementing the translocation and ongoing maintenance

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This chapter identifies the steps to be taken in organising and conducting translocation plantings. The necessary steps and considerations are summarised in the checklist below.

Planting should not commence until all the following questions can be answered in the affirmative:

- ☐ Have appropriate approvals for the translocation been obtained from the relevant authority (Chapter 5)?
- ☐ Has an assessment of the most appropriate time to plant occurred (Section 7.1)?
- ☐ Are there sufficient personnel to carry out the planting? Have personnel (staff and volunteers) to help on the day been organised (Section 6.1.1)?
- ☐ Is the condition of the plants ideal (Sections 6.2, 7.1 and 7.2)?
- ☐ Have equipment and materials for planting been arranged (Section 7.3)?
- ☐ Has a weed/pest/disease hygiene plan been prepared for the translocation site (Section 7.3.1)?
- ☐ Has a data sheet ready to track plants during the planting process been prepared and has a tagging system been designed to uniquely identify each plant after planting (Section 7.3.2 and 7.3.7, also see Section 6.5.5)?
- ☐ Has appropriate transport to get the plants on site with minimal damage been organised (Section 7.3.3)?
- ☐ Has the planting layout been prepared (consider the factors outlined in Section 7.3.4)?
- ☐ Have owners or managers of land at, and adjacent to, the translocation site been contacted to let them know when the planting will occur (Section 7.3.5)?
- ☐ Have the procedures for the planting day been discussed with staff and volunteers who will be assisting with the planting (Section 7.3.5)?
- ☐ Has a plan for after-planting care of the translocated plants been prepared (Section 7.4)?
- ☐ Have habitat management and threat abatement provisions been made prior to planting as well as in an ongoing capacity after translocation (Sections 6.7 and 7.4)?

7.1. Timing and conditions for planting

The translocation should take place when conditions are optimal to support survival and growth of the plants. General factors to consider include **conditions at the translocation site** and the **condition of the plants** to be planted. There may also be specific requirements of the target species to take into account.

Translocation site factors to consider include:

- **Frost.** Is frost likely at the translocation site? Will this affect new plantings? If so, then planting should either be delayed until frosts no longer occur, or some protection must be given to the plants. It's worth noting that frost hardiness will often vary across species and hardening-off prior to planting is a critical factor.
- **Moisture/rainfall.** Soil moisture at the site must be sufficient for the plants to survive. Planting during the season of reliable rainfall, when soil moisture is adequate, will lessen the chance of plant losses due to water stress. Moist soil also facilitates the process of digging planting holes. Planting over multiple years can improve the chances of capturing a year of good or above average rainfall that will greatly assist plants in surviving their first summer or dry season (see also Section 6.2.2). For example, plants of *Acacia cretacea* translocated in South Australia in a year of extremely high rainfall survived and established successfully, whereas plantings carried out in drier years failed to survive (Jusaitis 2016). Consider whether water storage crystals might be used to prolong the period of soil water availability. The capacity to provide follow up watering during the establishment phase is another key consideration. Broadcasting of seeds may be another option to consider to compliment planting in sites with known variable weather events.

- **Temperature.** Are the daytime and night-time temperatures conducive to survival of the plants? There is little point in planting if it is so hot during the day that the plants wilt and die or are burnt. In southern Australia, late autumn and winter are generally the seasons with most favorable temperature and moisture conditions for planting.
- **Access to translocation site.** Remote translocation sites may be difficult to access if rain has made tracks boggy. If there is the potential for track damage, excessive soil compaction, or introduction of *Phytophthora* or other pathogens to the site, then consideration must be given to shifting the planting time (such as planting early in the winter/wet season) to avoid this.

The following factors relating to the **condition of the plants** may affect the timing of the translocation:

- **Age of plants.** There is much debate regarding the best age and size of plants for transplanting. This is a factor that will need to be decided on a case-by-case basis. The longer that plants are held in pots, the more likely they are to become pot-bound, and this should be avoided, particularly when transplanting woody plants. Preference should be given for using containers designed to help develop a well-structured root system. If plants show signs of becoming pot-bound then root pruning, repotting or re-growing should be considered before planting. Plants with a high canopy to root ratio could be more vulnerable during their first summer or dry season and therefore may require additional watering during their establishment phase. Staff from propagation facilities or experts on the family or genus may be able to provide more specific advice. However, if time allows, one of the best ways to determine the optimal age/size for planting is to carry out a simple experiment (Section 6.5).
- **Health of the plants.** Are the plants in suitable condition for planting? Plants must be healthy and free from weeds, pests and diseases to minimise any risk of transferring them to the translocation site. Plants showing symptoms of nutrient stress may require an application of fertilizer before planting.
- **Hardening off or acclimatisation.** Have the plants been taken out of the glasshouse or shade-house for long enough to ensure that they will be able to adjust to their new environment at the translocation site? Acclimatising plants for sufficient time in conditions similar to those experienced at the translocation site will increase the chance of a successful planting. This is particularly relevant where plants are grown some distance from the translocation site. A period of adjustment at or near the translocation site ahead of actual planting could prove very beneficial for establishment.

If a decision is made to cancel or postpone the planting, consideration should be given to alternative uses for the plants so the production effort is not wasted (see Section 6.8).

7.2. Preparing plants for translocation planting

To improve the chances of successful establishment of the translocated plants, several factors should be considered when preparing plants for planting. These factors will vary depending on whether plants are being raised at a nursery or being salvaged from a natural population.

7.2.1. When sourcing plants from a nursery

This section relates to plants that have been grown in a nursery from seed, cutting material or tissue cultured material. Factors to consider include:

- Label plants meticulously. The tracking of plants through the propagation process will also need to occur at the translocation site (Sections 6.3.4 and 7.3.2).
- Use plants that are not pot-bound (Section 7.1).
- Consider the size of the plants. If they are too small they may not be robust enough to withstand the transport to site or excessive damage may occur during planting.
- Remove any flowers or fruits prior to translocation to encourage vegetative growth and to eliminate the possibility of hybrid plants resulting from cross pollination in the nursery becoming established at the translocation site.
- Prune leggy or excessively elongated plants to reduce damage during transport and prevent excessive transpiration.
- Ensure plants have been hardened off for a sufficient length of time prior to planting (Section 7.1).
- For dioecious plants, ensure that the sex ratio of plants is correct.

7.2.2. When transplanting whole plants

When transplanting whole plants, the preparation of the plants for planting occurs at the same stage as the collection of the source material. For this reason, these steps are discussed together in Section 6.5.3.

7.3. Planting

When the time comes to plant there are numerous things to remember. Some of the important points are outlined below; however, a detailed plan for the day(s) should be developed for the target species in conjunction with the experienced horticulturist/propagator involved in the translocation project. A checklist should be used to ensure nothing is forgotten on the day (see Box 7.1).

Box 7.1 – Checklist for 'on the day' of translocation planting

- Implement disease hygiene plan.
- Give your volunteers and assistants sufficient training to carry out the tasks needed and to ensure they understand the safe working practices for the site (Sections 6.1, 7.3.5).
- Set out the plants at the site.
- Plant!
- Water all the plants with clean, fresh water to settle them into the ground.
- Make sure each plant is tagged and map the site. Record the location for each plant using a GPS where possible.
- Collect and count all the plant pots after planting to ensure all the plants have been planted. Cross check the number of plants and their unique code with the list of plants provided when plants were collected from nursery or source site.
- Apply any horticultural techniques, or threat abatement techniques you feel are necessary (e.g. fences, mulch, irrigation system, tree guards, soil wetting agents etc.).
- Conduct initial monitoring as outlined in monitoring plan (see Chapter 8 on developing monitoring plan).

7.3.1. Hygiene

Plant translocations have the potential to introduce weeds, pests and diseases to the recipient site. Anything entering the site, including plant material, soil, vehicles, equipment, clothing, and footwear, could be a vector. A risk assessment conducted during the planning stage should identify the potential risks to the site (see Section 4.4). The risk assessment can then be used to develop a hygiene plan for the translocation process to reduce the likelihood of weed and pathogen transfer (see also Section 6.4.3). This plan should be adhered to by all those involved in preparing, planting, monitoring and maintaining the translocation site.

A hygiene plan should include, but is not limited to, the following:

- The use of a nursery accredited by the Nursery Industry Accreditation Scheme Australia (NIASA) for the propagation of the translocated plants is essential to ensure plants are certified free of weeds, pests and diseases. Similarly, ensure all other materials taken onto the site such as mulch, soil, gravel, rock and sand, are sourced from NIASA accredited businesses and that materials conform to Australian Standards—for example, *AS3743–2003 Potting mixes* or *AS4454–2012 Composts, soil conditioners and mulches*. For an up-to-date list of accredited nurseries in the local area go to www.ngia.com.au/accreditation/niasa.asp.
- Hygiene procedures should be in place for any activities at the translocation site. All equipment, vehicles, clothing and footwear should be free from soil and organic matter on entry and exit. Clean equipment, vehicles and footwear can be sprayed with a 70% methylated spirits solution (diluted with water) to disinfect the surface of these items. Clothing, gloves, hats etc. should be washed with detergent and hot water between site visits.
- Consideration should be given to weed and disease occurrences in the surrounding landscape and entry routes planned to avoid travelling through infested areas into uninfested areas. Keep vehicle access to a minimum.
- Plan to avoid working in conditions that are conducive to weed and disease spread. For example, if working in a weedy site, avoid activities when weeds are seeding. If working at a site where the introduction of *Phytophthora* is a risk, plan to only conduct activities at the site when soil is less likely to adhere to tools and footwear, i.e. when soil is dry or moist rather than wet.

- Water for irrigation should be sourced from mains supply (or treated water) rather than dams or natural waterways where pathogens may be present.
- Be mindful of incidental contamination of plants and equipment through contact with potential sources e.g. placing plant pots on the ground where disease status is unknown. If hygiene of plants is compromised prior to planting out, they must not be used for translocation and should be clearly marked as such.

More detailed information on hygiene procedures appropriate for the risks specific to the project can be obtained through consulting relevant bodies such as the Australian Government's Department of Environment (e.g. www.environment.gov.au/biodiversity/invasive-species/publications/arrive-clean-leave-clean), State/Territory Department of Conservation or Primary Industries, Botanic Gardens or other expert groups (e.g. Dieback working group: www.dwg.org.au).

7.3.2. Keeping track of the plants during planting

It is important to track the plants throughout the planting process to avoid accidentally leaving plants behind at the propagation facility, source site or unplanted at the translocation site (Fig 7.1). Take the following steps to assist with tracking during collection from the propagation facility or source site, transport and planting:

- have a list of the plants with their unique codes;
- check plants off this list as the plants are loaded onto the transport;
- check plants off this list as the plants are unloaded at site;
- collect and count all the pots after planting to ensure no plants are left behind, unplanted; and
- cross check the list of plants that were brought to site with initial monitoring data.

Figure 7.1 ***Brachyscome diversifolia*** *plants ready for planting in the field. (Photo: M Jusaitis)*

7.3.3. Transport to site

Care should be taken to minimise damage to the plants when transporting them to the recipient site (Figs. 7.2, 7.3). Ensure that plants are kept cool to prevent dehydration, remain upright to avoid soil dislodgement, and are free from excessive rubbing or movement that can lead to foliar damage. Good planning will ensure that there is sufficient space and appropriate equipment (shelving/racks, boxes, packing materials, tie-downs, etc.) for transport, and that the time spent in transit is kept to a minimum (Fig. 7.4). It is critical that hygiene be considered for all transport options as part of the risk management for ensuring pathogens are not brought onto the site.

Figure 7.2 ***Haloragis eyreana*** *plants in tubes ready for transfer to the field for planting. (Photo: M Jusaitis)*

Figure 7.3 Carrying ***Wollemia nobilis*** *(Wollemi Pines) into the translocation site. (Photo: J Plaza)*

Figure 7.4 Transporting ***Banksia brownii*** *seedlings to the translocation site. (Photo: L Monks)*

7.3.4. Planting layout

When planning the placement of the plants at the translocation site there are numerous factors to consider, including the spatial layout, experimental design and site factors (Fig. 7.5). Once a planting layout has been planned, it can be helpful to physically mark the planting locations in advance of planting. Have contingencies in place as things don't always go to plan. Factors to consider include:

- If an experimental component is being added to the translocation (and this is recommended, as much valuable information can be gained), then plants will need to be arranged according to the experimental setup that has been chosen (Section 6.5) (Fig. 7.6). The experimental setup may also influence the layout through the need to install equipment or materials in a particular way. For example, an experiment to test the value of watering may constrain planting layout through the need to install irrigation pipes and water tanks.
- When clonal material such as cuttings are used, consideration must be given to laying out the clones in such a way that pollination between different clones is maximised (i.e. avoid planting clones/cuttings from the same parent next to one another).
- If the translocation is into natural vegetation, then consideration must be given to the proximity of translocated plants to naturally occurring plants. Factors such as competition (for light/shade, nutrients, water, and root space) and allelopathic activity (where plants produce chemicals that affect the growth of other plants) can affect the survival of the translocated plant. Sometimes the translocated plant may need the shelter or support of the natural vegetation. To get an understanding of where to position the translocated plants observe where the species occurs in relation to other vegetation at its natural location(s).
- Consider whether to group plants in clumps or space plants evenly. Optimal spacing between plants can be gauged from observing the spatial structure of the natural population, being aware that spacing may vary with the age structure of the population.
- For dioecious plants consider the layout of male to female plants.
- The plants may be laid out randomly to create a natural looking site. However, a random layout amongst natural vegetation can make it extremely difficult to find the plants again. It may be easier to plant in rows to facilitate monitoring and make it easier to find any recruits (Fig. 7.7). Rows can be contoured around any natural vegetation, taking advantage of the natural gaps between plants.
- The planting may be staggered over a number of years (Section 6.2.2), in which case gaps may need to be left at the site to fill at a later date.

Figure 7.5 Planting layout for ***Acanthocladium dockeri*** *plants protected by plant guards. (Photo: M Jusaitis)*

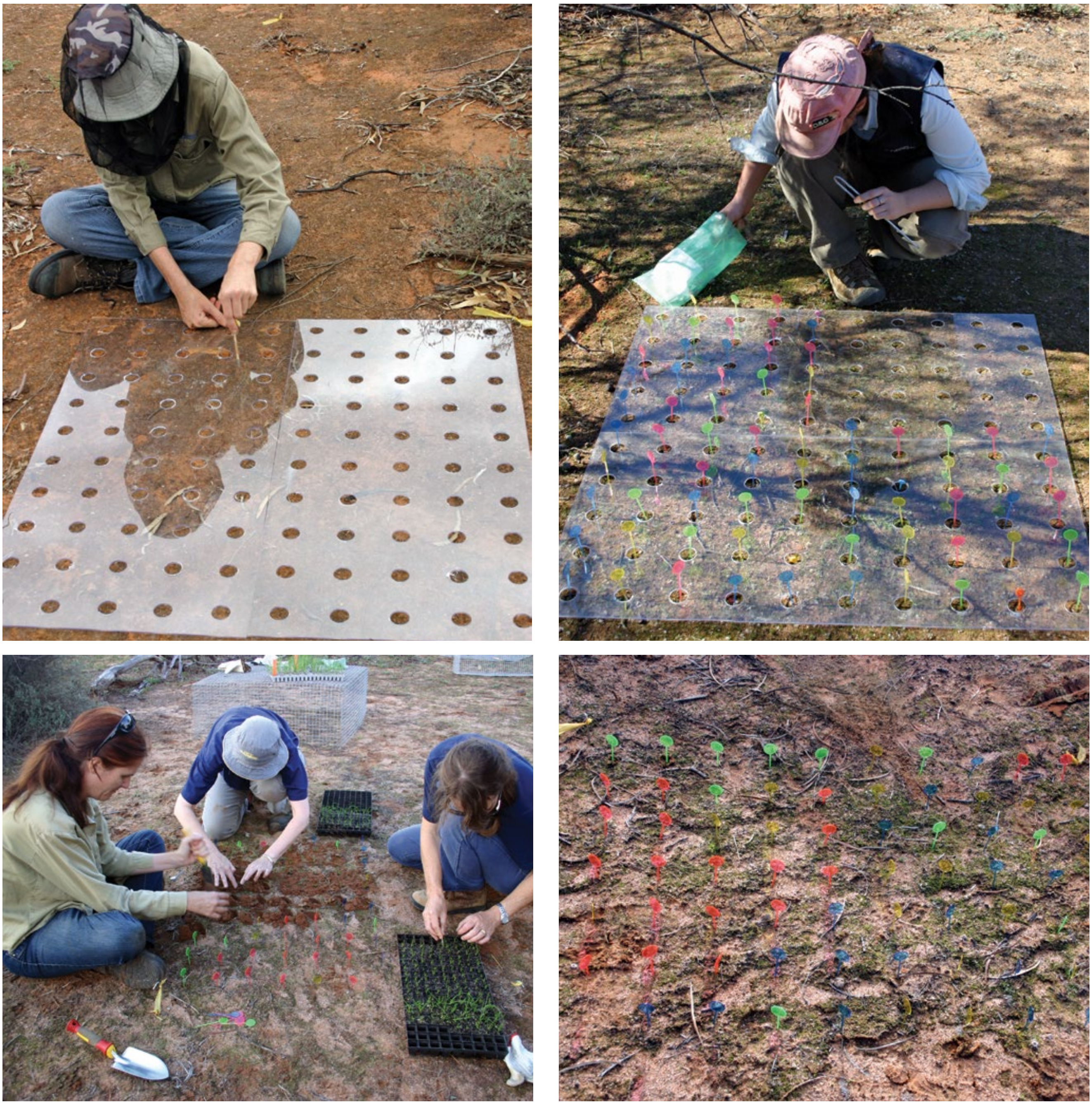


Figure 7.6 *Planting layout for an annual daisy,* ***Schoenia filifolia****. (Photos: L Monks and R Dillon)*

Figure 7.7 *A metre-square quadrat used for accurately placing plants makes it easy to locate the plants again for later monitoring. (Photo: M Jusaitis)*

7.3.5. Communication

There are many details regarding the planting with which the staff or volunteers assisting with the process will need to be aware. These include the weed/pest/disease hygiene procedures (Section 7.3.1); the importance of the tagging system for tracking the plants (Sections 6.3.4, 6.4.4 and 7.3.7) and the planting method (Section 7.3.6). It is vital that these procedures are clearly explained to people assisting in the planting and that there is sufficient supervision to ensure that these procedures are followed (Fig. 7.8).

It is also important to liaise with the owners or managers of the land in which the translocation is to occur about the timing of the translocation and any likely ongoing management requirements. There may also be a need to inform adjacent land owners, so that they are aware of the translocation. Signage may be useful to inform the community about the translocation (Fig. 7.9)

*Figure 7.8 Planting team for translocation of **Verticordia spicata**. (Photo: L Monks)*

***Figure 7.9 Left:** Signage may be helpful to inform the community about the translocation (Photo: L Monks); **Right:** This translocation sign along a roadside was labelled to inform road users and the community of its conservation significance. (Photo: M Jusaitis)*

7.3.6. Planting

Handling and emplacement of plants can affect successful establishment. It is best not to assume that all staff or volunteers assisting with planting know how to de-pot without damage and how to place an explant for best effect – training of all personnel is recommended.

Tubestock (Figs 7.10 – 7.16)

- A variety of tools may be used to establish tubestock and the choice will depend upon soil type and the size of plant containers. If the soil at the site is relatively soft or has been ripped prior to planting, a Pottiputki tool might be used. Trowels, shovels, mattocks and crowbars are other tools that can be used to create planting holes - the latter, particularly useful in hard or rocky ground.
- The hole should be dug in a way that will inflict minimal damage on the surrounding vegetation and soil structure. For most species, the hole should be dug to the same depth as the height of the root ball and at least twice as wide. There may be species specific requirements for the size of the hole (for example, some orchids can be planted simply by inserting a pencil into the ground to the depth of the orchid's tuber and firming the surrounding soil around the orchid (e.g. *Caladenia* spp., see Wright *et al.* (2009)). Consider placing the excavated soil from the hole in a neat pile so that is easily recovered when backfilling the hole. Breaking up the soil that is excavated from the hole prior to back filling will minimise the formation of large air pockets.
- Position the plant in the hole so that the soil level around the plant is slightly below the surrounding soil surface, thereby leaving a slight depression around the plant to facilitate watering (note: tuberous herbaceous species (e.g. orchids) should be planted level with the soil surface so that water does not pool around the plant, which could induce tuber rot).
- Tuberous, herbaceous species (e.g. orchids) usually have their potting mix removed prior to planting as the natural soil is often better for plant growth and soil moisture retention and will not 'sink' over time
- Backfill around the plant making sure that the soil is firmly pressed down. Watering before firming often helps eliminate any large air pockets.
- Care must be taken not to damage roots or tubers when planting some herbaceous species, particularly orchids. For example, Spider Orchids (*Caladenia* spp.) produce a new tuber on the end of a dropper root each season. If the dropper root is damaged, the Spider Orchid will not produce a new tuber and will die at the end of that growing season.

Whole plant transplant (Fig. 7.17)

- As mentioned in Section 6.3.2, salvage of small plants or seedlings can be carried out manually using a spade or shovel. The plant should be removed in a block of soil without breaking the soil and roots if possible, which requires careful excavation. If soil breakup occurs the plants leaves or shoot system should be pruned back. The plant should be watered during transplanting to minimise water stress. Alternatively, if conditions are hot and dry, the translocation practitioner may decide to put the plants into pots and stabilize them at a nursery until conditions improve (Section 6.8).
- The whole plant transplant of larger perennial plants may involve the excavation and movement of one or more cubic metres of soil. The removal of the whole plant and the excavation of the new planting site typically occurs using the same method (e.g. tree spade on an excavator). The planting holes should be a close match for the excavation from where the plant has been removed. Excavated material preferably sits either level with the natural ground surface or slightly lower. Excavations that are planted sitting higher than the natural ground surface can fall apart or erode at the margins leaving the target species root system exposed.
- Once planted, the soil plug associated with a whole plant transplant can often have gaps between it and the natural ground. Such gaps can result in a rapid loss of soil moisture and should be in-filled with material that can readily pour into the full depth of any gaps. Previous translocations have used either dry pulverized soil collected from the recipient site or sterile washed sand. This material should be washed into these gaps to eliminate any air pockets.

Transfer of topsoil containing seed

- Topsoil containing seeds can be transferred to a recipient site. This method of translocation should only be considered where it is known that a seed bank exists in the soil. Movement of soil between sites should always be carried out with great caution due to the potential to also move soil pathogens, either from the recipient site or through the tools or vehicles used to move the soil. It is essential that the source site is tested for disease (e.g. *Phytophthora*) prior to considering transfer of topsoil and that strict hygiene procedures are adhered to during the transfer.
- Soil can be removed by hand tools if it is a small amount, or by machinery if a sizable area is to be moved. Once at the recipient site the soil can be spread to a similar depth as that at the source site.

Figure 7.10 ***Banksia brownii*** *seedlings ready for planting. (Photos: L Monks (left), S Barrett (right))*

Figure 7.11 Planting ***Banksia brownii****.*
(Photo: L Monks)

Figure 7.12 A newly planted ***Banksia brownii*** *seedling with a tag.*
(Photo: L Monks)

Figure 7.13 *A newly planted* ***Wollemia nobilis****.* *(Photo: J Plaza)*

Figure 7.14 *Planting* ***Grevillea maxwellii****. (Photo: D Coates)*

Figure 7.15 *Planting* ***Androcalva bivillosa****.* *(Photo: L Monks)*

Figure 7.16 ***Acacia cretacea*** *planted at base of a spinifex plant to discourage herbivores. (Photo: M Jusaitis)*

Figure 7.17 *Rainforest trees can reshoot vigorously after heavy pruning, which greatly improves the survival during whole plant transplanting. (Photo: A Benwell)*

7.3.7. Uniquely identifying each plant after planting

As discussed in Sections 6.3.4 and 6.4.4, plants and plant material should be uniquely labelled from the time that propagation material is collected, to eventual planting in the field. Barcoding is an effective way of doing this, allowing detailed information on propagule origin, propagation techniques, and plant performance to be attached to a discrete barcode label, and tracked for the duration of the project.

At the planting stage each plant **must be allocated a unique code and labelled**, so that the origin and fate of each individual can be monitored (Figs 7.18 – 7.20). This code may be the one assigned during propagation, or another new code that is linked to the previous code used during propagation. This unique code assigned at planting will need to refer to information about the source material, and will also contain new information about planting (such as time and date of planting, location, any treatments applied, etc.).

Individual plants should be identified with a permanent tag, and a detailed site map should be drawn to allow accurate plant re-identification for future monitoring. Tags may be tie-on (e.g. aluminium or UV stabilised plastic) or free-standing (e.g. marking pins or stakes). Remember that the tag must be able to withstand fire if in a fire-prone area, and also tolerate chewing or removal by curious animals. The label must be waterproof and fade resistant. Metal tags can be inscribed or engraved, while UV stabilized plastic tags can be written on with permanent paint markers. If the tag is tied to the plant, ensure that it doesn't fall off too easily or strangle the plant as it grows. Alternatively, the tag may be attached to a stake or peg next to the plant. White recycled plastic stakes are good as they are resistant to termite attack, are UV stabilized, can be written on, and are easily seen in the bush. Other durable alternatives are metal fence posts or heavy duty tent pegs. Marking pins made from strong gauge wire with a rectangular plastic tag secured to the top are ideal and are available in a range of colours. Be mindful of where the tag is placed relative to the plants because as the plant grows, a tag placed too close to the base of the plant may not be found easily, and where plants spread and grow together, it may be difficult to trace tags to individual plants if they are placed too far away. An alternative technique is to bury a metal tag next to each plant and find it using a metal detector, although the repeated soil disturbance this would involve during monitoring may not be desirable.

For small plants, (e.g. orchids) an accurate method of locating and identifying plants is by triangulation. Two permanent pegs (e.g. metal star pickets) are positioned outside and to one side of the planted area and the distance to each plant is measured from both pegs, providing unique location data. A numbered plant tag can then be positioned next to each plant to provide finer-scale accuracy (e.g. 10 cm to the north of the plant).

To mitigate risks associated with losing tags, it is essential to draw a detailed site map showing the placement of individual plants in the translocation layout. Distances may be recorded from various local landmarks or strategically placed metal star pickets. Global positioning system (GPS) and computer-based mapping programs can assist with this (Fig. 7.21). Photographs taken of the site at planting will also assist in relocation and identification.

Figure 7.18 Paint, labels and pegs can be used to re-locate plants when monitoring. (Photo: M Jusaitis)

*Figure 7.19 Tent peg and potting label identifying seedling of **Haloragis eyreana**. (Photo: M Jusaitis)*

Figure 7.20 Tagging system for translocation of ***Eremophila nivea.*** *(Photo: R Dillon)*

Figure 7.21 Global positioning and flagging tape at Wollemi Pine translocation site. (Photo: C Offord)

7.4. After-planting care and ongoing site maintenance

7.4.1. Horticultural techniques for after-planting care of translocated plants

After planting, a program to care for the translocated plants should be implemented. Many people will argue that implementing after-planting care is simply gardening or creating populations that will never survive without ongoing horticultural care. Others believe that the propagation material is so precious that whatever is necessary should be done to ensure the maximum number of plants survive and a viable population is established. Whatever level of after-care is chosen, it is vital that the translocation program is not completely abandoned after planting. Lack of post-translocation care and ongoing monitoring are factors that commonly lead to failure of translocation projects (Dalrymple *et al.* 2012; Godefroid *et al.* 2011; Hall 1987). Post-translocation actions and monitoring should be documented to enable evaluation of translocation success. The post-planting after-care and long-term management need to be considered when preparing a translocation proposal (see Section 5.3).

Short-term after-planting care is likely to maximise the chances of success. However, it is important to understand the likely cause of plant deaths (for example weed competition, herbivory, below average rainfall) and provide controls for these threats (for example weeding, fencing, irrigation) otherwise there may be a risk of wasting resources or not implementing important plant protection measures.

It is also important to consider how long these after-planting care techniques are to be in place so that they can cease at an appropriate point. If a program of after-planting care is chosen, then it is strongly advised that this is done in an experimental way (Section 6.5), so that information can be gained as to how necessary this care is to the success of the translocation. Long-term management of the translocated plants may involve some of the techniques used during the after-planting care or it may involve a gradual reduction in management. Evaluation of the effectiveness of the after-care techniques and the need for ongoing management will be required at appropriate intervals following translocation planting. The timeframe for evaluation will depend on the life history of the species that has been translocated. There are a range of horticultural techniques that can be implemented to care for the plants and some of these are discussed below.

Mulching

The application of mulch may aid in moisture retention and weed suppression around translocated plants. There is an array of different types of mulch that can be used including: mulched tree loppings; wood chips (these must be aged to ensure any chemicals have leached out); sawdust; pebbles; weed suppression mats; various commercial mulch mixes; straw; and leaf litter found at the translocation site.

Whichever mulch is used, it must be verified to be free of weeds and diseases such as *Phytophthora*. If there is any uncertainty, then it is essential that the mulch is sterilised. Staff from propagation facilities or the person on the translocation team experienced in horticultural techniques should be able to assist in suggesting ways to sterilise. The thickness of mulch application is an important consideration. If it is too thin, the desired weed suppression and water retention outcomes may not be achieved and if too thick, the ability of water to penetrate may be limited. Periodically checking the permeability of the mulch following watering or rainfall by digging down to the soil is recommended.

Watering

Watering over the initial establishment phase can be beneficial in some areas of Australia (Dillon *et al.* 2018) and for some translocation methods. For salvaged whole plants, the shock to a plant associated with transplanting can result in mortality without regular, ongoing care. Management of drought stress is considered to be particularly important and regular watering may be essential.

If a decision is made to water the plants for a period of time following planting, then the source of the water and how to apply it need to be considered (Figs 7.22 – 7.24). When the translocation sites are in remote locations this can be difficult, especially when electricity to power pumps and run timer systems may not be accessible. Techniques that can be implemented include:

- Enlisting the help of locals to hand-water the site. This has the added bonus of someone regularly visiting the site and assessing the health of the plants.
- Installing a water tank and solar-powered pump operated on an automatic timer system.
- Having a gravity fed system from a water tank operated on an automatic timer system.

The system chosen will depend on the availability of people locally who are willing to help and the availability of funding. Irrigation companies are usually happy to help design an irrigation system to suit the needs and budget of the project. Deciding how frequently and how much to water is a difficult task. The period and frequency of watering may depend on the climatic conditions at the site. Whilst ideally the site selected has similar rainfall conditions to those experienced by wild populations of the target species, watering during hot and/or dry periods may be beneficial during the plants establishment phase. For example, if the site is exposed to seasonally dry conditions, providing weekly or fortnightly water during the first two dry seasons may mitigate losses during this time, especially if natural recruitment events of the species are linked to unseasonal or above average rainfall conditions. An experiment to find the optimum watering regime for the species could be beneficial. As with mulch, it must be verified that the water and the tank in which it is transported to the site is free from diseases such as *Phytophthora*.

Figure 7.22 Water tanks for ***Acacia imitans*** *translocation site. (Photos: L Monks)*

Figure 7.23 *Irrigation system for* ***Chorizema humile*** *translocation showing layout of pipes* ***(left)*** *and drippers* ***(right)****. (Photos: L Monks)*

Figure 7.24 *Watering* ***Caladenia hastata*** *plants after translocation. (Photo: G Pollard)*

Soil wetting agents and water storage crystals

In non-wetting soils, soil wetting agents can be used to improve the penetration and absorption of water into the soil (Fig. 7.25). Granular or crystalline water retaining agents (hydrogel crystals) can be sprinkled into planting holes before planting to provide a ready source of moisture available to the new plant and to extend the period of water availability in the root zone (Jusaitis 2016). Ensuring that these crystals are fully hydrated before use will allow the new plants immediate access to their stored moisture. These crystals can be effective for up to five years, absorbing water, then releasing it back to the plants as required, before biodegrading harmlessly. If dry crystals are used, be aware that they will swell on wetting, so ensure that the soil is pressed down firmly to discourage the new plant from lifting as a result of this swelling.

Figure 7.25 *Hydrogel granules in the planting hole may assist in retaining moisture in the root zone for a longer period if rainfall is insufficient. (Photo: M Jusaitis)*

Fencing

The use of fences to exclude herbivores can influence the success of the translocation (Dillon *et al.* (2018), see also Section 6.7). If long-term exclusion of herbivores is required, then the entire site may need to be fenced. Fencing a site not only provides protection to the translocated plants, but also protection for future recruits. The cost and feasibility of this, as well as the potential damage from installing the fence, needs to be assessed prior to choosing this option. The type of fence will depend on what needs to be excluded. If it is stock, then a ring lock fence may suffice. If kangaroos or wallabies are the target, then the fence must be high and strong enough to prevent animals jumping over or pushing under. If it is burrowing animals such as rabbits, then netting should be used, and the fence must fitted with an adequately wide skirt or be dug into the ground to a depth that prevents these animals digging underneath.

If grazing exclusion is not essential in the long term, then another option is to cage individual plants (Figs 7.26 – 7.28; Case Study 7.2) and carefully remove these cages once the plants have established, or not cage at all. An added advantage is that the cages can be reused on site. It is important to consider the risk of leaving cages or fencing in vegetation types that are prone to biomass competition in the absence of grazing (e.g. grasslands). If there is evidence of cages or fences impacting negatively on plants, ensure they are removed.

Figure 7.26 *Wire cage around* ***Prostanthera eurybioides*** *to discourage grazers. (Photo: M Jusaitis)*

Figure 7.27 Left: Wire basket used for grazing protection over planted ***Leionema equestre****;*
Right: Wire cage removed to show ***Leionema equestre*** *plants grazed to upper surface of cage. (Photos: M Jusaitis)*

Figure 7.28 Cage around planted ***Schoenia filifolia*** *subsp.* ***subulifolia****. (Photo: L Monks)*

Tree guards

Tree guards can be used to prevent frost damage, reduce wind and grazing damage and concentrate water catchment around the new plant (Figs 7.29 – 7.31; Case Study 7.1). Tree guards are available in various materials such as plain plastic, mesh and cardboard. Potential negative outcomes associated with the use of tree guards should be considered and include increased temperatures within plastic guards, loss and dispersal of tree guards under windy conditions, and plant damage if tree guard supports fail. Retrieval of the guards from the site once they are no longer needed should be included in the translocation proposal.

Figure 7.29 Plant guards protecting plants of ***Acanthocladium dockeri*** *from grazing and strong winds. (Photo: M Jusaitis)*

Figure 7.30 On particularly exposed sites, shade cloth shelters were used to protect rainforest plants from sun and wind. Tintenbar to Ewingsdale project. (Photo: A Benwell)

Figure 7.31 Wire cages were used to protect direct transplants of this species from grazer disturbance, provide a climbing frame and to facilitate monitoring at the Nambucca Heads to Urunga project. (Photo: A Benwell)

Pesticides

Where insect or other invertebrate herbivores may be a problem, the use of pesticides may be necessary to ensure the survival and good health of the translocated plants (Fig. 7.32). Staff from propagation facilities or the person on the translocation team experienced in horticultural techniques can be good sources of information about choosing a suitable pesticide. The impact of pesticides on other species at the site needs to be carefully evaluated. If the use of a pesticide under conditions at the translocation site is not specified on the label there may be a requirement to seek permission to use the pesticide off-label.

Figure 7.32 Top left: ***Acanthocladium dockeri*** *plants are threatened by introduced common white snails;*
Top right: Snails graze the epidermis and leaves of ***Acanthocladium dockeri*** *effectively ring-barking the shoots;*
Bottom left: Death of ring-barked shoots of ***Acanthocladium dockeri*** *caused by common white snails;*
Bottom right: Plants of ***Acanthocladium dockeri*** *treated with snail pellets to eliminate the threat caused by common white snails. (Photos: M Jusaitis)*

Addition of soil microbes

Adding soil microbes may be beneficial for some groups of plants. However, this needs to be considered a translocation of another species. The same considerations and planning carried out for the species which is the primary focus of the translocation program will also need to be carried out for the soil microbe.

Staking and tying plants

Sometimes it may be necessary to support the plant in some way. Typical support involves driving wooden or metal stakes into the ground next to the plant and tying the plant to the posts. Any support should be designed to strengthen the individual, and care should be taken so that it will not damage the plants, hamper growth or strangle the plants. If plants are small enough, or if leggy growth is pruned prior to planting, then supporting the plant through staking may be unnecessary.

Fertilisers

Whilst soil nutrients should be sufficient at a recipient site if it has been selected to closely resemble that of the natural populations, the use of fertilisers may be considered in scenarios where soil nutrients are suspected to be lacking (i.e. post-mined site with altered soil properties). The choice should be tailored to the species being translocated as several native plant species are sensitive to excess nutrients (e.g. phosphorus sensitivity in members of the Proteaceae family). Staff from propagation facilities or the person on the translocation team experienced in horticultural techniques should be able to advise on this matter. They should also be able to advise on the quantity of fertilizer, and how it is to be applied (for example, around the base of the plant, or in the planting hole). As with pesticide use, impacts on other organisms at the site should be considered. Changes in available nutrients can have detrimental effects on desirable plants or animals, and can also promote weed growth.

Wind and shade barriers

Barriers can be employed to reduce the intensity of wind around the plant as well as shade from the sun, thus reducing evaporation (Fig. 7.33). Where winds are strong, ensure these barriers are extremely well secured, otherwise they may damage the plants.

*Figure 7.33 Floyds Grass (**Alexfloydia repens**), an endangered grass endemic to the Coffs Harbour (NSW) area, has been successfully translocated on two highway development projects. This receival site at Warrell Creek has shade cloth fences to protect the grass from afternoon sun while establishing. (Photo: A Benwell)*

7.4.2. Site management

In addition to care of the translocated plants, following the translocation, it is likely that the habitat of the translocated population will also require some ongoing management, particularly of threatening processes, as for any natural population of a threatened species. These requirements should have been identified during the pre-translocation assessment (Chapter 3) and be included in the translocation proposal (Chapter 5). The required actions should also be outlined in a detailed site management plan that is to be made available to all those involved in the ongoing management and monitoring of a translocation project. Relevant activities may include weeding, bush regeneration, further plantings, maintenance of tree-guards, fences and other site protection measures, management of fire/disturbance and hydrological regimes, and management of biotic factors such as pollinators, mycorrhizae, and other organisms that may be associated with the species (Case Studies 7.1, 7.2, 7.3, 7.4). There may also be new problems at the site that will need to be addressed, such as erosion in newly exposed areas.

Management of the translocation site is vital, particularly during the early stages of plant establishment. All management actions should be clearly documented and the site management plan should be reviewed and revised as necessary, guided by the results of ongoing monitoring and evaluation (Chapter 8).

Where uncertainty exists as to a particular course of action, it is important that expert advice is sought. It is equally important to have ongoing communication with landowners and managers to ensure that they are aware of the importance of the translocated population, are provided with copies of the site management plan, and are kept informed of monitoring progress and outcomes.

The required management actions will depend on the ecology of the target species, threatening processes, and the degree of site disturbance, and may include:

- **Site protection:** Although site protection works may have been carried out prior to translocation (Section 6.7), the effectiveness of these measures needs to be evaluated and refined as required.
- **Habitat restoration:** Habitat restoration works may also have been carried out prior to translocation (Section 6.7). However, ongoing works may be required, particularly for weed removal. The translocation activity itself may lead to an increase in weed invasion as a result of soil disturbance and the potential for further ingress of weed propagules associated with human activity. Habitat restoration should always aim to encourage natural regeneration. Nevertheless, in situations where natural regeneration is not occurring, the planting of associated species may be required to restore structure, function, and species composition.
- **Management of fire/disturbance regimes:** Many Australian plant species require fire or physical disturbance to promote recruitment. In contrast, others require long periods without, or a total absence of fire or physical disturbance. Several papers (Abbott and Burrows 2003; Bradstock *et al.* 2002; Cary *et al.* 2003; Keeley *et al.* 2011) provide reviews on fire ecology and management. As with any natural population of a threatened plant species, long-term viability will depend upon the occurrence of an appropriate fire/disturbance regime. It may be necessary to implement a prescribed burn (also known as a planned, ecological or controlled burn), or it may be necessary to actively exclude fire from a site through prevention measures. In particular, for a translocated population it is important that fire is excluded until the translocated plants are able to withstand fire (for fire tolerant species i.e. re-sprouters), or until the population has built up a soil-stored seed bank (for fire sensitive species i.e. non-sprouters). Consideration must also be given to fire regimes required for other species (both flora and fauna) that occur at the site.

Case Studies

Case Study 7.1 - Management techniques

Excerpt from Moritz** et al. **(2018).

Prostanthera eurybioides is a small perennial shrub with two disjunct populations in South Australia (Monarto and Mt Monster). Seed was collected from seven sites across Monarto (within a 55 ha area of occupancy), germinated *ex-situ* and then were transferred to seedling tubes in the nursery.

Ten sites were identified in the Monarto area, within two km of existing remnant populations. At nine of the sites weeds were treated around the planting zone at least two weeks before planting. Seedlings were planted into a depression to increase water holding potential, watered in, a fertiliser tablet was provided and a corflute guard was installed. In the following year, additional seedlings were planted, and received the same treatments, except that both a corflute and larger mallee mesh guard were installed together in the second year.

Watering occurred twice over the first summer for all sites. Hand weeding occurred within the guards for the first two years. Mallee mesh wire guards (800 x 350 mm) replaced corflute guards after 12 months, as plants were outgrowing the guards.

We learned that: seedlings planted close to established vegetation did not survive, presumably due to water stress and competition from mature plants; plants need to be watered through the first two summers; and guards are essential as the plants are highly palatable and seemingly targeted for 'rubbing' by herbivores.

*Figure 1 Planted **Prostanthera eurybioides** flowering at 12 months. (Photo: K Moritz)*

Case Study 7.2 – Caging translocated plants improves translocation success

Excerpt from Collier and Garnett (2018).

Cassinia rugata is a multi-branched shrub that grows to about 1.5 m in wet (sedgy-) heathland (Fig. 1). It is known from two private properties in central north Tasmania. At one of these properties a translocation site was selected about 100 metres from a known population in sedgy heathland at that was burnt in April 2014. The site was similar to habitat where C. *rugata* occurs naturally, particularly in terms of seasonal inundation. Both seed and transplanted seedlings were used.

Transplanted seedlings were one-year-old plants that had germinated naturally. Seedlings selected were generally very close to adult plants or close to other seedlings. Each seedling was excavated using a bulb planter with a minimum diameter of 60 mm at the base (Fig. 2). The tool was rotated and pushed into the ground to a depth of about 110 mm and the resulting peaty soil was gently eased out while still inside the tube. This produced a consistent and stable cylinder of soil that included each seedling plant, or sometimes more than one plant.

At the selected site, plots were located 3 m apart along four transects that are also 3 m apart. Plots were randomly assigned to be one of the 10 plots for seed sowing or 20 plots for transplanting seedlings and then within these two groups, plots were randomly allocated to the caged or uncaged treatment. Each cage was constructed from high-quality netting, 60cm tall, with 4cm mesh spacing (Fig. 3). Lengths of netting were formed into a cylinder approximately 30 cm in diameter. Cages were secured to the ground with three galvanized metal stakes.

Monitoring data collected in January 2018 showed 28% of uncaged plants are still alive compared with 83% of caged plants. The median height of living uncaged plants was 394 mm, compared to 806 mm for caged plants. Combined results for plots where seed was sown indicate no significant difference between caged and uncaged conditions. Very few of the seedlings are healthy and robust, and appear to be struggling to complete with surrounding vegetation.

The translocation experiment demonstrates that translocation is feasible, and that caging of plants provides reduced plant mortality, increased plant height and resulted in earlier flowering. As the translocated plants were the only green vegetation at the site following the burn uncaged plants were targeted by grazers such as macropods and rabbits. The results show protection from grazing has a significant benefit on translocation establishment.

Figure 1 ***Cassinia rugata*** *flower head. (Photo: P Collier)*

Figure 2 Left: Excavated ***Cassinia rugata*** *seedling to be transplanted and bulb planter (Photo: R Garnett); Right: Translocated* ***Cassinia rugata*** *seedling at site 2. (Photo: P Collier)*

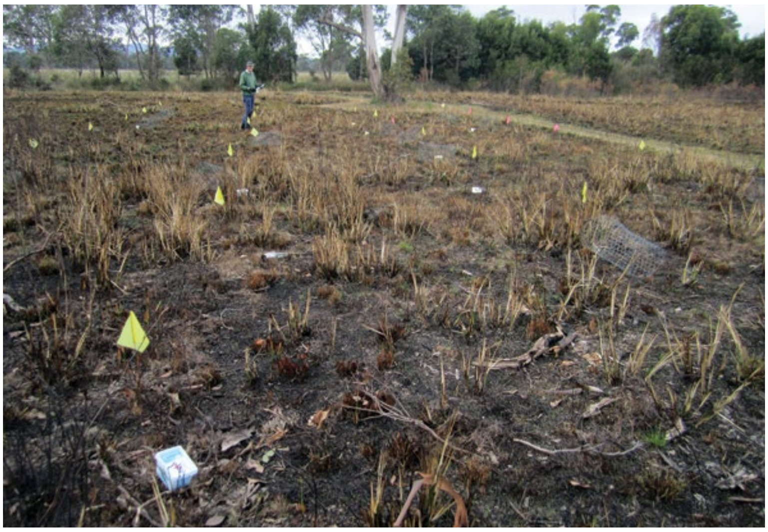


Figure 3 Site preparation, showing cages. (Photo: R Garnett)

Case Study 7.3 - Post-translocation management: burning stimulates recruitment from a translocation

Excerpt from Monks et al. *(2018).*

Acacia cochlocarpa subsp. *cochlocarpa* (Fig. 1) is known from just five small populations in Western Australia, confined to narrow linear remnants along road and rail verges. As a result of its rarity and the ongoing threats (habitat loss and significant habitat fragmentation through agricultural development, weed competition, spray drift, risk of accidental destruction during maintenance of the road verges), *A. cochlocarpa* was listed as Threatened with a ranking of Critically Endangered. The establishment of a translocated population in a new secure location was considered to be the most effective action to initiate successful recovery of the species.

The aim of the translocation was to establish a viable population of 200 mature adult plants, which was capable of undergoing natural population processes, such a producing viable seed and recruitment of subsequent generations.

Initially two sites were selected in nature reserves which contained similar vegetation associations and underlying geology as the natural populations. Plants were established initially using direct seeding, however, following poor success with this technique subsequent plantings used seedlings.

Whilst the monitoring of the two sites showed good survival, and flowering and fruiting occurring at rates similar to the natural population, there had been no recruitment during the decade and a half following planting. For the translocations to be considered successful the population must be able to recruit subsequent generations. This lack of recruitment was not unexpected as previous research had indicated that recruitment was largely confined to a post-fire period (Yates and Broadhurst 2002). However, in the fragmented, highly cleared landscape in which the translocation sites are located, fires are unlikely. So, the decision was made to carry out a management burn at the original translocation site to encourage recruitment (Fig. 2). One translocation site containing 183 adult plants was burnt in 2015 and follow up monitoring showed significant recruitment from the seed bank (>900 seedlings) and some survival and resprouting of a small number of adult plants. Seedling survival two years after the burn, was close to 80% and a small proportion of plants (25%) had become reproductive.

This research will be incorporated into a Population Viability Model that is being developed for the species. The model will aid decisions relating to long term population viability and what is the appropriate fire regime.

Figure 1 ***Acacia cochlocarpa*** *subsp.* ***cochlocarpa*** *(Spiral Fruited Wattle) seed pods. (Photo: L Monks)*

Figure 2 Implementing a prescribed fire on a translocated population of ***Acacia cochlocarpa*** *subsp.* ***cochlocarpa*** *(Spiral Fruited Wattle) to induce recruitment. (Photo: L Monks)*

Case Study 7.4 - The benefits of an experimental approach to implementing after-planting care

Excerpt from Elliott et al. *(2018).*

Ricinocarpos brevis is a shrub that has three natural populations in Western Australia. Research was undertaken prior to translocation to contribute to the understanding of the ecology and conservation of this threatened species.

Experimental translocations were implemented yearly from 2013 – 2017. Two propagation techniques were used: tubestock planting and direct seeding. Tubestock experiments investigated survival after planting, with plants given one of the following after-care techniques: shading, fertiliser, irrigation, propagation source (seed or cuttings), plant age, water holding crystals and biodegradable pots. Direct seeding experiments investigated the effect of factors such as aspect (north or south-facing), and after-care treatments such as shade, irrigation, seed burial, seed enhancement (priming or pelleting) and water holding crystals. Each replicate (tubestock or seed) was individually fenced to protect against herbivory (Fig. 1). An automated, gravity fed irrigation system was maintained for one year (typically on one half of the experiment) to supply supplementary water for one summer for each year's translocation program.

Intensive monitoring of tubestock and direct seeding was conducted every second month after planting and involved quantification of seedling emergence, survival, growth, health, and reproduction.

Evaluation of the monitoring data showed that shading, irrigation increased seedling emergence, survival, plant health and growth. Older tubestock (8-18 months) establish better than younger tubestock (<6 months) due to reduced impact on root systems during planting. There was greater survival of tubestock derived from seed rather than cuttings. However, the magnitude of these increases depended on seasonal rainfall.

Investment in research provides critical information for successful plant establishment and an experimental framework that identifies and refines the best approach for future translocations.

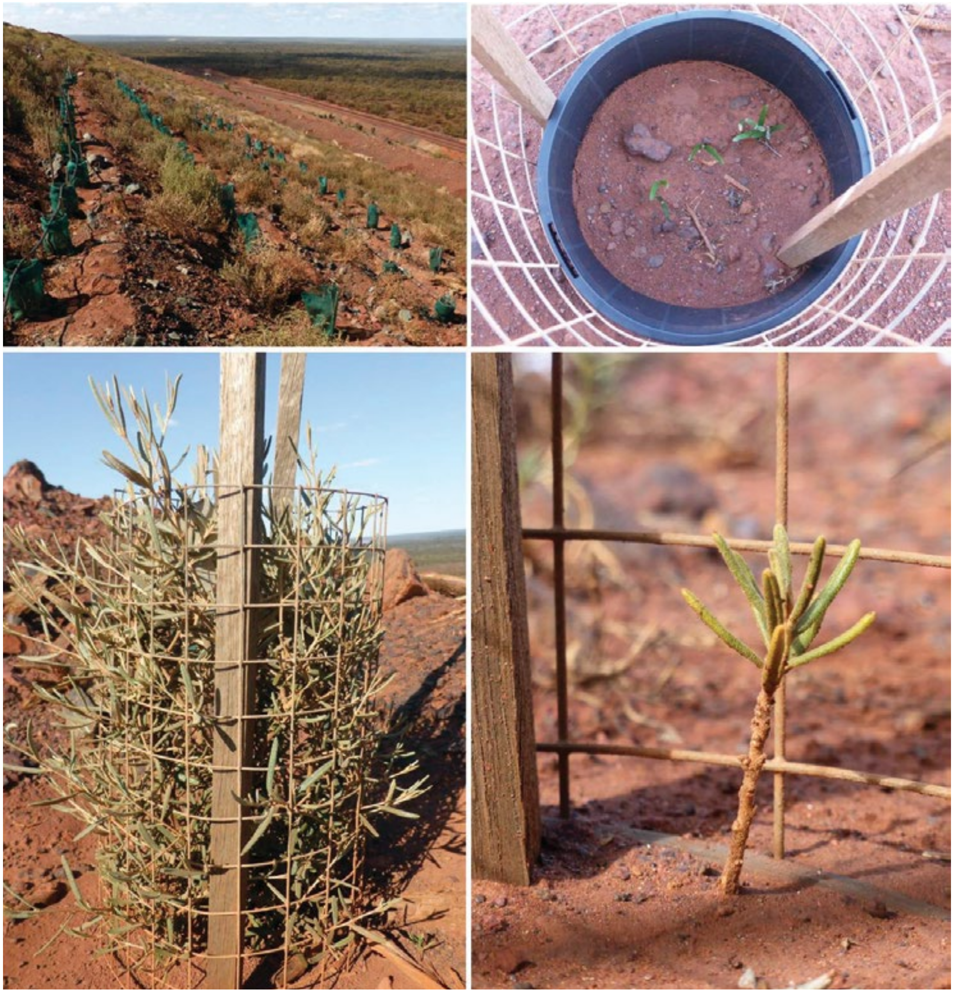


Figure 1 ***Ricinocarpos brevis*** *translocation images.*
Top left: *Translocation set up on waste rock landform, with gravity-fed irrigation (2017 translocation);*
Top right: *Newly emerged seedlings (~2-3 months old) in situ (2016 translocation);*
Bottom left: *Seventeen month-old greenstock plant (2015 translocation);*
Bottom right: *Two-year-old seedling that emerged in situ (2015 translocation).*
(Photos: C Elliott)

Chapter 8 – Translocation monitoring and evaluation

Authors: Heidi Zimmer, Tony Auld, Dave Coates, Joslin Moore, Jen Silcock, Noushka Reiter, Maria Matthes

Checklist for post-translocation monitoring actions

A translocation program should not commence or be approved until all of the following questions can be answered in the affirmative:

- ☐ Have specific criteria for determining translocation success (and progress towards success) been identified? (Section 2.4)
- ☐ Has a monitoring plan been prepared and peer reviewed in accordance with the guidelines in Section 8.1.2?
- ☐ Is the proposed monitoring methodology appropriate to the question being asked, and the life history of the translocated plant? (Sections 7.2, 7.3 and 7.4)
- ☐ Has care been taken to design monitoring so that data can be collected objectively (without bias), and to give the best chance of answering the monitoring question (design utlises before and after data, controls, reference populations, or treatment and non-treatment combinations)? (Section 8.1.2)
- ☐ Is there a knowledge management plan (i.e. clarify who is responsible for monitoring, have an established reporting procedure, and a method for data storage)? (Section 8.1.2)
- ☐ Have 'triggers' been identified for post-translocation management actions (e.g. a particular mortality or survival rate)? (Section 2.4.4)
- ☐ Have sufficient funds been secured to implement the monitoring, evaluation and post-translocation management?

Should the answer to any of these questions be no, a precautionary approach should be taken to continuing with the project, and the consequences of proceeding without the appropriate level of post-translocation actions should be considered.

8.1. What is monitoring?

Monitoring is the collection and analysis of repeated measurements with the goal of assessing progress towards an objective, and dealing with any issues as they arise (Elzinga *et al.* 1998).

The above principles for translocation monitoring were adapted from the strategic plan for the Australian long-term environmental monitoring network (Likens and Lindenmayer 2011).

An effective monitoring program will:

- generate quantified evidence of translocation success or failure against stated objectives;
- deliver information on population changes and the factors that may drive such changes;
- provide early warning of problems with the translocation;
- highlight ways to make future translocations more effective; and
- evaluate return on conservation investment.

The steps in designing and implementing a monitoring program are identical to conducting an ecological experiment (Keith 2000). An effective monitoring program will:

- define the question or problem;
- be simple and inexpensive with achievable goals capable of being maintained over the long term;
- be specific and quantifiable;
- provide the framework for defining specific tasks with data collection techniques able to be repeated over years and across personnel;
- provide data to answer the question.

The same monitoring principles will apply to all translocations, although the emphasis may change depending on the type of translocation, species involved and the questions being asked.

Two main types of monitoring are discussed in this chapter:

1. 'Surveillance monitoring' where the aim of monitoring is to detect population declines which initiates conservation management or further research (Nichols and Williams 2006). Surveillance monitoring is particularly relevant where there is the potential for unexpected problems (Wintle *et al.* 2010).
2. 'Diagnostic monitoring' where monitoring is designed so that reasons for problems (or successes) can be identified (Keith *et al.* 2018).

Further information on many of the key concepts underlying best-practice monitoring is provided by Legge *et al.* (2018) who review threatened species monitoring in Australia.

8.1.1. Why monitor?

Monitoring is an essential part of any translocation. Reasons for monitoring include:

- Gaining information on the status and trends of the translocated population.
- Determining whether a translocation has been successful and identifying reasons for success or failure.
- Evaluation and refinement of management.
- The terms of a permit legally require a monitoring program.
- The project team, or funding body, is interested in the outcome of the translocation, in terms of species conservation and or resource use efficiency.
- The project team, or funding body, is interested in outcomes of the investment into the translocation, and want to know whether this was a good use of resources.
- The unknowns. This may be the first time that this species will be planted into a natural (non-garden) environment, and it is unknown how the plants will respond to this new environment. It is also unknown what impact the translocated plants may have on the environment into which they are being introduced.
- Improving the understanding of the biology, life history and habitat requirements of the translocated species and the factors that influence its persistence.

Importantly, monitoring can also answer questions about which translocation conditions (e.g. microenvironment, initial plant size, management interventions) are more likely to lead to the desired outcomes (e.g. growth, survival, flowering), to inform future translocations and potentially modifications to current translocations.

If the explicit aim is to use monitoring to inform management, 'adaptive management' (Keith *et al.* 2011; Westgate *et al.* 2013) may be a useful framework (Case Study 8.1). Adaptive management is an approach that aims to meet management objectives while at the same time addressing the main uncertainties that undermine effective management (Walters 1986). (See also Section 2.4.4.) However, the use of adaptive management in the conservation of threatened species is uncommon because small population sizes and limited distributions do not lend themselves to statistically robust, replicated experiments (Lindenmayer 2018).

8.1.2. Translocation monitoring plans

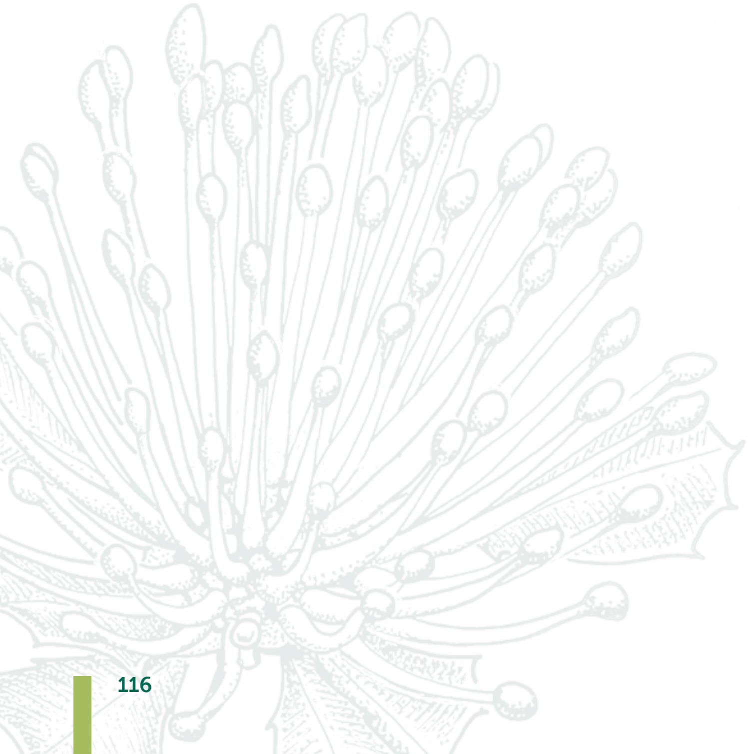
A translocation monitoring plan should be included in the translocation proposal (Section 5.3). The monitoring plan should be developed or reviewed by someone with experience in experimental design and the monitoring of natural or translocated plant populations. Key considerations are:

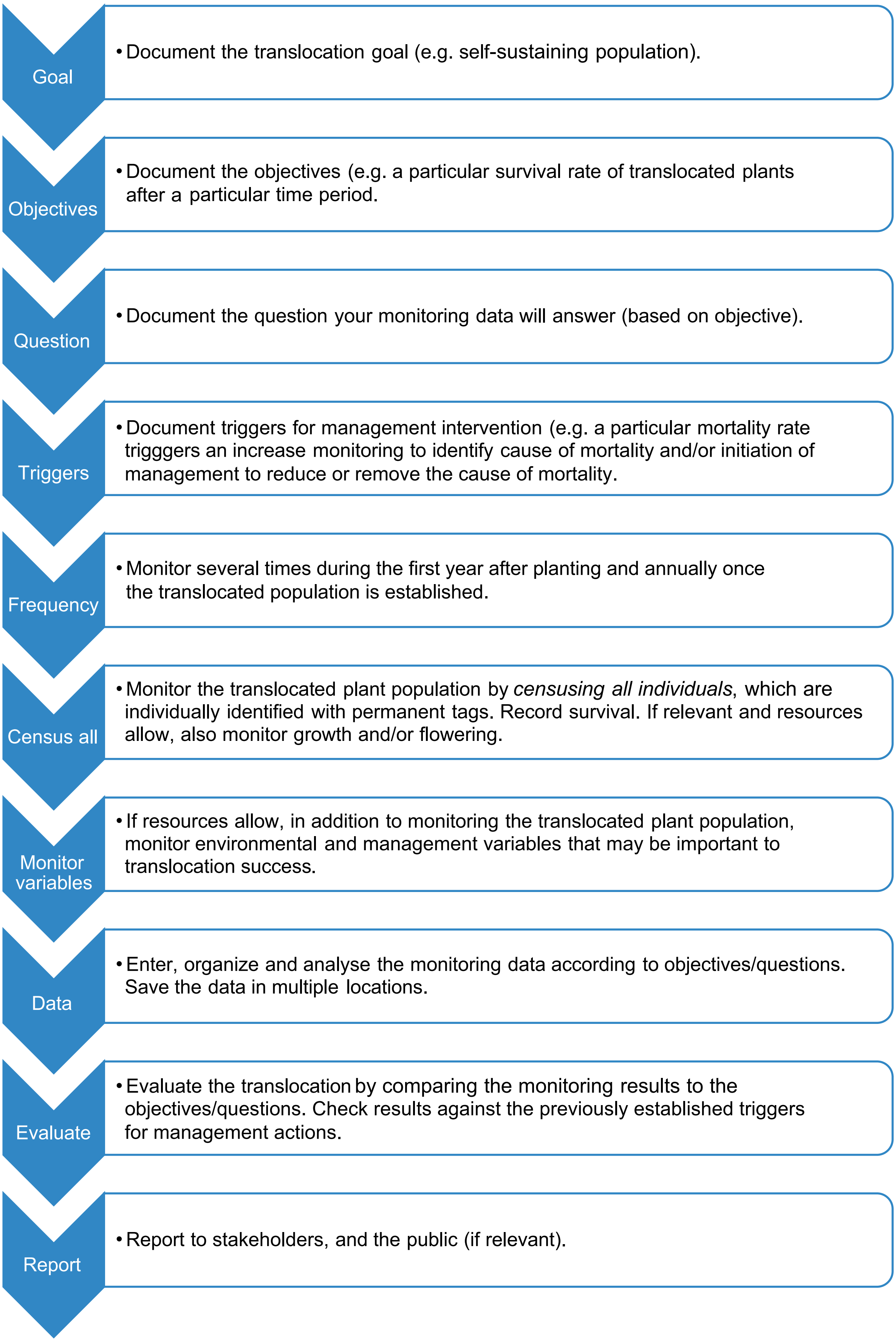
- What is the area that needs to be monitored? This is the geographic area in which the monitoring will focus (e.g. the recipient site(s), see also Section 8.2.2).
- What are the monitoring units? It is likely that each individual translocated plant will be monitored (Section 8.2.1). However, to analyse the monitoring data, plants may be considered as individuals or as groups of plants to which a treatment/management action/environmental condition is applied.
- Which environmental variables (e.g. microsite attributes such as light availability) or management treatment variables (e.g. weed cover in managed vs unmanaged sites)?
- Are monitoring units permanent or temporary? It is likely that plants will be permanently tagged, while sampling units at the recipient site (e.g. quadrats, transects) may be permanent or temporary.
- How many plants will be monitored? This is also referred to as the sample size. Sample sizes that are too small make it difficult to generate clear results and conclusions.

- How frequently will monitoring occur? This will depend on the variables being measured, the plant life-history, the time since planting and the season (Section 8.3).
- How will information on the cost and effort applied to the translocation be captured? This information is crucial for evaluating return on investment (Section 8.2.4). Provision of adequate resources for monitoring must be included in the initial feasibility assessment for translocation (Chapter 2). However, monitoring need not require massive inputs of time and resources.
- For how long will monitoring be required? This question is not an easy one and the answer will be determined by the criteria for translocation success (Chapter 2) and the generation length of the target taxon (Chapter 3). This question should be considered at the planning stage to ensure adequate resources are allocated and available. See also Section 8.3.

The monitoring plan needs to contain clear instructions and methods for monitoring, and a proforma data sheet to ensure consistent data collection as it is likely that different people will be involved in collecting data over the life of the project. Also ensure there is a process for timely data entry and analysis and instructions on data storage.

A summary of the main steps in translocation monitoring is provided in Fig. 8.1.





- Document the translocation goal (e.g. self-sustaining population).

- Document the objectives (e.g. a particular survival rate of translocated plants after a particular time period.

- Document the question your monitoring data will answer (based on objective).

- Document triggers for management intervention (e.g. a particular mortality rate trigggers an increase monitoring to identify cause of mortality and/or initiation of management to reduce or remove the cause of mortality.

- Monitor several times during the first year after planting and annually once the translocated population is established.

- Monitor the translocated plant population by *censusing all individuals*, which are individually identified with permanent tags. Record survival. If relevant and resources allow, also monitor growth and/or flowering.

- If resources allow, in addition to monitoring the translocated plant population, monitor environmental and management variables that may be important to translocation success.

- Enter, organize and analyse the monitoring data according to objectives/questions. Save the data in multiple locations.

- Evaluate the translocation by comparing the monitoring results to the objectives/questions. Check results against the previously established triggers for management actions.

- Report to stakeholders, and the public (if relevant).

Figure 8.1 A summary of the main steps in translocation monitoring

8.2. What should be monitored?

'It seems to us that the best response to the common question 'What should be monitored?' is 'What is the crucial question?'…' (Lindenmayer and Likens 2009).

'Rather than monitoring many things poorly, we should strive to monitor a few things well …' (Lindenmayer *et al.* 2015).

The translocation should have clearly established goals and objectives (Sections 1.3, 2.4). The ultimate goal of a threatened plant translocation is to establish a viable (self-sustaining) population. Objectives, the steps that track progress towards this goal, provide the basis for the questions the monitoring results will answer, and these answers facilitate evaluation and direct post-translocation management.

The main variables affecting the outcome of the translocation that need to be monitored are the translocated plants (Section 8.2.1), the recipient site (Section 8.2.2), and management (Section 8.2.3), expenditure (Section 8.2.4), a reference population (Section 8.2.5) and the *ex situ* population (Section 8.2.6).

8.2.1. Monitoring the translocated plants

The responses of the translocated plants will determine whether the translocation is successful. Considerations when deciding which response variable to measure include: Which stage of the life cycle is most vulnerable? Which stage of the life cycle is most likely to respond to management/treatment?

Whether plant survival, growth, flowering or something else should be monitored is determined by (1) the objective or question (see below in this Section) and (2) species life history (Section 8.2.1.1, 8.3). See also Box 8.1 for information on monitoring design. At it can often take years or decades for a translocated population to reach the ultimate goal of becoming self-sustaining, it is best to monitor population attributes that indicate progress towards this goal.

Monitoring questions need to be closely aligned with the objectives for the translocation (defined in Chapter 2). For example:

- 'What proportion of plants have survived the period since last monitoring?';
- 'What proportion of the plants are producing viable seed?';
- 'Is the proportion of plants producing viable seeds increasing?'.

Another alternative is to simply ask the general question:

- Has the translocation met the objective, or is it on track to meeting the objective?'. This approach relies on having detailed short- and long-term objectives in the translocation proposal (Chapter 5).

Questions can be more detailed (i.e. for diagnostic monitoring), and also more informative:

- 'To what extent is flower production in the translocated population higher in sunny or shady microsites?'; or
- 'To what extent is plant survival in the translocated population higher in plants that were watered, compared to plants that were not watered?'.

Response variables that are commonly included in monitoring translocated plant populations include:

- vegetative growth of plants;
- survival of plants over time (see Section 8.3 for information on timing and duration);
- survival of plants to flowering;
- presence/abundance of reproductive structures on plants;
- presence/abundance of seeds in the population or per plant;
- time to maturity (e.g. first flowering);
- presence/abundance of second generation (Fig. 8.2);
- population size;
- presence of storage organs that allow regeneration, e.g. bulbs, tubers, rootstocks, lignotubers, seeds.

Monitoring of survival, growth and reproduction can be used to develop population models including population viability analysis (PVA) models (Section 2.4.3) that can be used to predict population trajectory.

In many cases, it will not be difficult to use monitoring data to learn more about the target species and its translocation requirements. Indeed, simply monitoring the recipient site (Section 8.2.2) and recording management variables |(Section 8.2.3) alongside the translocated population may yield important insights, especially if the monitoring is well designed. More involved monitoring can include:

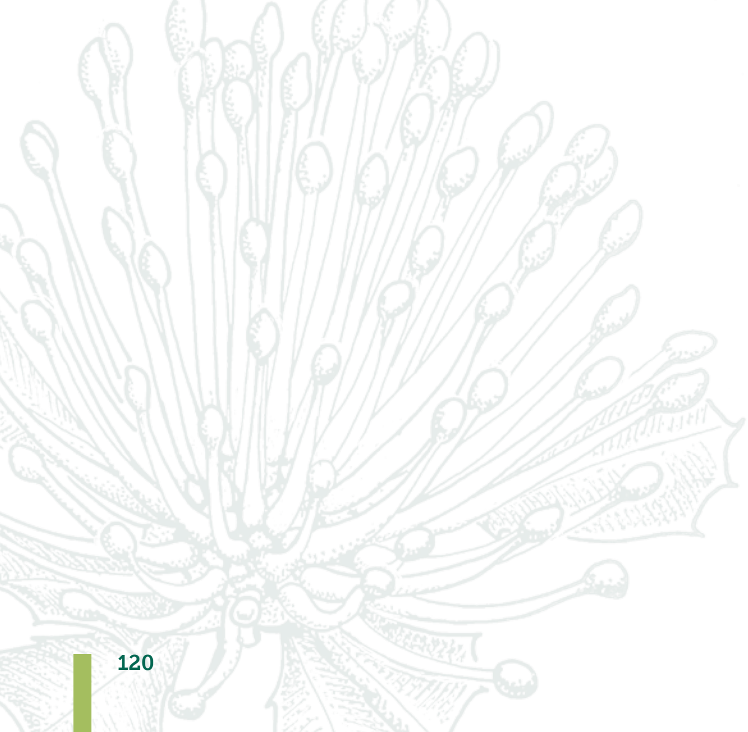
- Presence and characteristics of the soil seed bank, such as seed input, seed viability, or seed removal to unsuitable areas (e.g. to disturbed roadsides by disturbance-loving ants, burial to depths where germination will not be initiated, or seed predation (Dixon and Cook 1990)).
- Presence and characteristics of soil symbionts.
- Levels of genetic variation. Once the translocated plants have recruited successfully, it is important to know whether genetic variability has been maintained in the progeny compared to the source and other natural populations.
- Mating system parameters. Mating system parameters such as outcrossing rate and correlated paternity assessed using molecular approaches are useful indicators of inbreeding, reproductive output and long term population persistence and can also be used to infer pollinator presence and pollinator behavior. Ongoing mating system monitoring can provide valuable information on reproductive output and therefore translocation success (Monks *et al.* 2012).
- Variation in ecophysiological parameters indicative of plant health, especially those which exhibit variation before the health of the plant deteriorates, such as photosynthesis and respiration.
- Response to disturbance, e.g. fire, grazing, flood. Are standing plants killed? Can the population recover after the disturbance, e.g. visa regrowth or seedling recruitment? (Figs 8.3 – 8.5)

Figure 8.2 Left: Small quadrat suitable for monitoring seedling emergence on a small scale;
Middle: Larger metre-squared quadrat suitable for monitoring small, herbaceous, annual plants;
Right: Seedling recruitment of ***Brachyscome muelleri*** *(white flower) being monitored with the assistance of a quadrat.*
(Photos: M Jusaitis)

*Figure 8.3 Recruitment of seedlings of **Phebalium glandulosum**, first seen around translocated parent plants 18 years after translocation. (Photo: M Jusaitis)*

*Figure 8.4 Recruitment of **Grevillea batrachioides** seedlings after wildfire. (Photo: L Stumpher)*

*Figure 8.5 Monitoring direct-seeded translocations of **Veronica parnkalliana** following a prescribed burn. (Photo: M Jusaitis)*



8.2.1.1. General monitoring methods for plants

A) Survival

'Repeated census [of permanently tagged individuals] is the most reliable means of identifying trends in survival, growth and reproduction … and is more likely to reveal the correct causes of decline…' (Keith 2000).

Permanent tagging of individuals is strongly recommended for translocated populations of plants. Permanent tagging allows tracking of plants through time, linking pre- (e.g. supplier, date of propagation, paternity) and post-translocation (growth, injury, survival) information.

Permanent tags can be purchased from commercial suppliers, such as Forestry Tools (forestrytools.com.au).

Alternatively, translocated plants can be given a permanent identity without tagging, by recording their precise location. This can be done with a GPS (if the plants are far enough apart, e.g. >10 m between plants) or distance and bearings taken from permanent marker (i.e. steel post), or by mapping the location within a permanently marked quadrat.

Complete population census (surveying all individuals) is also strongly recommended for monitoring translocated plant populations. Complete census increases certainty in results, and avoids many of the errors that can be introduced using sub-sampling to estimate variables such as survival.

If a complete population census is not possible and all individuals are permanently tagged, then a random sample of plants can be surveyed, and inferences (e.g. decline) from this approach can provide the impetus for more detailed monitoring (i.e. full census).

B) Growth

There are many ways to measure growth including height (stem length), basal diameter, number of flowers, number of inflorescences, number of leaves, number of stems, number of leaf whorls, diameter of rosette and volume of plant (height x cover) (Figs. 8.6 – 8.9) (Elzinga *et al.* 1998). Sampling units can vary depending on planting design and research questions, but here we focus on measurement of individual plants.

Monitoring must be consistent. *It is critical to accurately describe how each measurement has been taken to ensure consistency among those responsible for monitoring the translocation.*

For measurements of plant height, from base to top of plant:

- Base of plant:
  - What to do if there is loose litter or soil; should this be cleared?
  - Consider marking point of measurement on larger plants.
- Top of plant:
  - Is this defined as the apical meristem, or the tallest green vegetation, or otherwise?
- What to do if the stems are not straight -
  - Is height or stem length being measured? What is more relevant?
- Canopy diameter:
  - Generally, this can be estimated with two perpendicular measurements, but this may vary if canopies are not generally round. Using E-W and N-S can improve consistency in measurements across years and among people measuring.

For plant diameter (girth) measurements:

- Ensure diameter tapes are not twisted and are kept horizontal around the plant.
- If diameter to be measured at breast height (DBH) (1.3 m), measure, rather than estimate, this height (on the tree, or on a person – some people even like to put a mark on their shirts at 1.3 m!).
  - Be consistent and give guidelines about where and how to measure DBH if the plants are on a slope (i.e. the location of 1.3 m height on the plant can vary depending where the measurer is standing (e.g. upslope, downslope or across slope)).

A key consideration in deciding what to measure is species life history, including whether the species is perennial, ephemeral or clonal. Clonal species predominately propagate asexually, for example by rhizomes, suckering and bulb replication. For clonal species, more so than perennial or ephemeral species, it is likely to be difficult to differentiate between individuals. Clonal species may need to be monitored by measurements of abundance other than counts of individuals, such as frequency quadrats or point transects (Elzinga *et al.* 1998). Genetic analysis to identify individuals may also be appropriate in some cases.

Figure 8.6 Monitoring the response of ***Arthraxon hispidus*** *to different pasture treatments on the Tintenbar to Ewingsdale highway project. Treatments included slashing, cattle grazing and idle. Abundance was recorded as crown cover in grids of plots laid over each treatment. (Photo: A Benwell)*

Figure 8.7 Monitoring height of ***Grevillea calliantha****. (Photo: R Dillon)*

Figure 8.8 Left: Measuring the height of translocated ***Dodonaea subglandulifera****;*
Right: Measuring the height of translocated ***Leionema equestre****. (Photos: M Jusaitis)*

Figure 8.9 ***Endiandra muelleri*** *subsp.* ***bracteata*** *(Rusty Walnut) five years after salvage by direct transplanting on the Yelgun to Chinderah, highway project. From an initially bare pruned trunk (tallest stem) the tree is reforming a crown including several stems growing from the base. (Photo: A Benwell)*

8.2.2. Monitoring the recipient site

There are two main reasons for monitoring the recipient site. First, it can help *explain* the responses (e.g. growth, survival) of the translocated population with respect to site variables (e.g. light, soil, disturbance regimes), which are considered explanatory variables. Second, it will allow identification of any negative impacts of the translocated population on the site. Recipient site monitoring should incorporate the whole area occupied by the translocated population.

8.2.2.1. Explaining changes in the translocated population

'In many instances, it is as important to monitor threats and other covariates as it is to monitor threatened species. It may be sufficient to only monitor threatened species … when ecological processes are very well understood.' (Wintle 2018).

The focus of monitoring recipient site variables is usually to explain changes in the translocated population, within the site (or among sites) and through time. This is diagnostic monitoring (Section 8.1). For example, to answer the question 'To what extent is flower production in the translocated population higher in sunny or shady sites?' Here the recipient site variable is light availability, to which the plants in the translocated population are responding with variation in flower production.

Recipient site variables that may be similarly used to explain variation in translocated plant success within and among sites are:

- light availability, sun/shade;
- soil pH and nutrients;
- soil moisture;
- climate -
  - rainfall (annual, seasonality);
  - temperature (maximum, minimum);
- presence and abundance of other species/vegetation types; and
- disturbances e.g. grazing or browsing by animals, fire or flooding.

The spatial scale at which these variables are measured can vary from within a site (individual plantings or microsites, groups of plants), among sites to a comparison of natural versus translocated sites. How these environmental variables are measured depends on the question being asked, and the spatial and temporal scale of variation. For example, light availability may be highly variable within a site, whereas soil type may only differ among sites.

Quadrats and transects may be used to sample recipient site variables, such as the presence and abundance of local species. Permanent rather than random quadrats/transects are recommended for monitoring recipient sites, so that results reflect changes with time rather than changes associated with quadrat/transect placement.

Lastly, the outcomes of management actions at the site may be monitored within the translocation monitoring program. This may include: habitat restoration (e.g. planting other species), weed removal, feral animal and pathogen control, management of stormwater run-off, drainage, erosion and siltation. As with monitoring the translocated population, it is useful to structure the monitoring of management outcomes around previously established goals/objectives/questions.

8.2.2.2. Identification of negative impacts on recipient site

Potential foci for monitoring impacts of the translocated population on the recipient site include:

- Negative impacts on native species at the recipient site, e.g. through competition, overshading etc. Part of the site selection process (see Chapter 4) will be assessing if there are any significant flora or fauna at potential recipient sites that may be impacted by the translocation. If a site with extant significant species is chosen then targeted monitoring of these species (e.g. survival, growth, recruitment) should be considered;
- Introduction of pests and weeds;
- Introduction of pathogens particularly Phytophthora dieback (*Phytophthora cinnamomi*) and myrtle rust (*Puccinnia psidii*);
- Positive impacts on the recipient site, such as increased resources for nectar-eating birds or small mammals (and therefore increased presence or abundance of these species);
- Changes to abiotic factors:
    - soil pH and nutrients;
    - soil moisture;
    - sun/shade;
    - soil temperature or microclimate under translocated plants; and
    - hydrology.
- Changes to vegetation community composition.

8.2.3. Management variables

Translocated plant responses (e.g. growth, survival) can be influenced by management actions (e.g. fencing). Like environmental variables, management actions may vary within a recipient site, or among different recipient sites, or between recipient and natural sites. Importantly, a plant response can only be attributed to a management action if there is a comparison with an unmanaged/control site. Replicated managed and control sites will provide statistical confidence in the result obtained.

Management variables that may be considered within diagnostic monitoring or adaptive management programs include:

- Actions -
    - fencing: this could be presence or absence of fencing, or use of different types of fencing, such as fencing for domestic stock, or fencing for domestic stock and rabbits.
    - watering: this could be presence or absence of watering, or watering at different frequencies (daily, weekly), or with different amounts;
    - weeding;
    - planned burns;
    - site preparation; and
    - fertilising.
- Planting techniques.
- Propagule type (e.g. direct seeding, seedlings, cuttings).
- Plant supplier -
    - if plants were sourced from multiple suppliers
- Plant pre-treatment (e.g. acclimatisation).

8.2.4. Monitoring expenditure

Monitoring the costs associated with a translocation project enables the evaluation of cost-effectiveness and return on investment, providing an effective way to communicate resource needs to managers and policy-makers. These data can also be used in planning future translocations. Capturing costs associated with a translocation project need not be complex and may simply consist of a data sheet that captures the initial intervention/start-up costs and on-going costs (monitored annually) (Cook *et al.* 2017). In addition to direct costs (money spent), costs may also be incurred indirectly, for example, through staff time or use of infrastructure. Capturing these different components is important for fully costing a project.

8.2.5. Monitoring a reference population

A reference population (i.e., a "wild" or "natural" population), where one is available can provide useful benchmark data against which to judge the success of the translocation. Reference populations can be monitored using the techniques described above (Section 8.2.1.1). Data on survival rates of different life stages, fecundity and recruitment of natural populations can be compared to translocated populations. These data can be used before translocation (i.e. to inform the number of plants required for translocation e.g. through PVA; section 2.4.3), and in direct comparison, to track the progress of the translocated population (e.g. survival rates, age/size at first viable seed production). These data can also inform specific thresholds which will trigger actions (Section 2.4.4).

Consider establishing the same monitoring program, for response and explanatory variables, at both the translocated and a reference populations. Concurrent measurements between translocated and reference populations will allow assessment of the role of landscape-scale variables on both the translocated and the reference population (e.g. drought may cause increased mortality in both populations).

8.2.6. Monitoring the *ex situ* source collections

The *ex situ* collection(s) should be maintained and monitored until the translocation is deemed to be successful as it may be needed to supplement initial plantings. Detail on monitoring *ex situ* collections is provided in Section 6.4.4. It is important that records of the establishment and survival of each clone be kept for the entire duration of an *ex situ* collection.

8.3. Timing and duration of monitoring

8.3.1. Timing of monitoring

Timing of monitoring (time of year and frequency of monitoring) will be guided by the monitoring question, the species life history and the environment in which the species occurs.

As discussed in the sections above, the primary focus of monitoring is typically the translocated population. For this reason, a key consideration is species life history: whether the species is perennial or ephemeral and its mode of reproduction (clonal, seed etc.). Getting the timing of monitoring right is critical for ephemeral or geophytic species. Ephemeral species are defined as species where above-ground abundance fluctuates in response to plant life history in combination with environmental conditions and/or disturbance regimes. Abundance can vary by an order of magnitude between these fluctuations. Examples of ephemeral species include many orchids, mature individuals of which may spend many years dormant underground; annual species, with germination responsive to climate; arid and semi-arid short-lived species which fluctuate in response to the amount and season of rainfall; and obligate seeding species, that are killed by fire and recruit from seed. Monitoring of these species must be timed carefully to compare 'like with like' for example, post-fire abundance should be compared with post-fire abundance.

In addition, all monitoring plans should also allow (including costs built into the budget) for 'unplanned' monitoring visits such as after a fire, flood, high rainfall event, heatwave or drought, which may trigger large changes in germination and survival/mortality.

For perennial seeding species and clonal species the timing of monitoring is less critical. Long-lived perennial species are present year-round, however, it is worth considering the impact of variations in presence/visibility of the specific response variable that is being monitoring (e.g. the presence of flowers/seeds or new growth in spring).

The frequency of monitoring depends on the variation/rate of change in the variable of interest, which is determined by the species' life history and vital attributes. In general, it is recommended that monitoring is carried out 3 months after planting (to detect any major mortality), then yearly after that (Case Study 8.3).

In terms of monitoring the environment/recipient site, whether these variables are measured only once, during translocation establishment/planting design, or multiple times (e.g. annually, at the same time as population monitoring), or continuously, depends on the amount of variation that is expected. For example, soil nutrients may not vary in one year, whereas minimum/maximum temperatures are likely to vary between days and the most useful data may come from continuous measurement (e.g. deploying climate loggers to measure fine-scale variation in temperature and relative humidity in shady vs sunny microsites) (Fig 8.10).

*Figure 8.10 Data logging station set up at a **Brachyscome muelleri** translocation site to monitor climatic conditions. (Photo: M Jusaitis)*

8.3.2. Duration of monitoring

For how long should monitoring continue? This question must be considered at the planning stage to ensure adequate resources are allocated. The answer will be determined by the questions being asked, the life history of the target species (particularly generation length), and the trajectory of the translocation (Chapter 2 'Goals and objectives' and Chapter 3 'Biological and ecological assessment'). The translocated population should be monitored at least until it meets its objectives. See Case Study 8.2 and 8.3.

The success of mitigation translocations (i.e. development translocations, salvage translocations, enforced translocation as per Chapter 2) is often poorly known due to a lack of information on reproduction and long term survivorship. Plants may be well established after two or three years but may not have the opportunity to set seeds, or have had suitable climatic conditions for germination. Long-term monitoring is important in the evaluation of any translocation as moving plants threatened by development to another location only to have them die there 20 years later without any reproduction is just as much a failure as the plants dying within a few weeks of translocation.

Box 8.1 Monitoring design

The following list is a combination of 'tips and tricks' and basic principles of experimental design.

1. **Defining the question.** Defining the question (or questions) will identify "what" should be monitored (Section 8.2). A simple (or surveillance) monitoring program will have identified a response of the translocated plant to measure (e.g. growth, survival, flowering, germination of new recruits), and a diagnostic monitoring program will also monitoring of site variables (i.e., environment and management variables).
2. **Concept diagrams** can help identify the variables that might affect the translocated population (i.e. explanatory variables), and how these variables interact. The goal of experimental design is to focus on one variable (or a small number of variables), while controlling all the other variables (either by holding them constant, or by stratifying the sampling). See Fig. 8.11.

   'First, we believe that it is essential to develop a robust conceptual model of the ecosystem that is being targeted for long-term research and monitoring. This step provides the framework around which to pose questions and gather data to answer those questions' (Lindenmayer and Likens 2009).

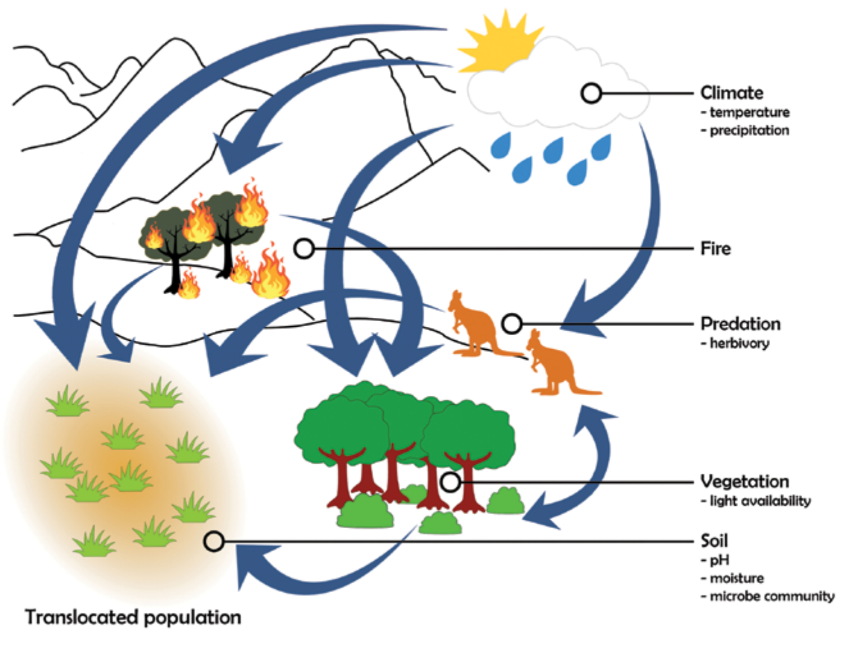


Figure 8.11 There are numerous environmental variables that may influence the outcome of a translocation, as illustrated in an example of a translocated population. The potential for direct (e.g. climate) and indirect factors (e.g. increased fire risk from a hot and dry climate) should be considered during the planning phase, and whether appropriate management strategies can be incorporated into the translocation project.

3. **Sampling, sample size and power.** In translocation monitoring, it will often be possible, and indeed desirable, to count/measure the entire population (i.e. population census). When all individuals in a population are censused, sampling is not required, and therefore the errors associated with replicate sampling are not introduced. Sampling is what we do when a census is not possible. How to decide what and where to sample? The number of samples taken depends on the amount of variation in what is being sampled; the larger the variation, the more samples required to get an accurate (and statistically significant) estimate. Statistical approaches such as power analysis (Gibbs *et al.* 1998) can give an estimate of how many samples needed to detect a change of a particular magnitude, within a particular margin of error.
4. **Sampling methods** There are several basic, statistically-sound sampling methods that that can be considered: random sampling, stratified random sampling or systematic sampling – if the project does not plan to census the entire population. The details of these methods, potentially useful for sampling soil, light and other microclimatic factors at the recipient site, are covered more comprehensively in other resources (e.g. Elzinga *et al.* 1998).

5. **Controls and contrasts between treatments.** If the goal of the translocation is to learn about the effects of different conditions or treatments, it will often be necessary to have one or more controls. For example, to answer the question 'What is the influence of fencing on the survival of translocated seedlings?', both unfenced (control) and fenced (treatment) seedlings, and replicates of each, will be needed. If there are no unfenced (control) seedlings and all the fenced seedlings survive then, statistically, seedling survival can not be attributed to fencing. There may be concern in allocating scarce seedlings to controls and treatments deemed less likely to be successful – the benefits of knowledge gained and future resource efficiencies must be weighed against risks to establishment of a successful translocated population.
6. **Before and after comparisons** are usually discussed alongside controls. In the case of monitoring translocated populations, monitoring before and after is less applicable, except where treatments are applied after the translocation has been initiated, (e.g. fencing applied 1 year after translocation). However, to assess the response of the recipient site to the translocated population, it would be worthwhile to collect before data (e.g. soils, species composition).
7. **Flexibility.** While changing the monitoring program should be avoided, the monitoring program may need to be altered to include variables that appear to be influencing translocation success. On the monitoring form, leave space for general observations, such as evidence of pest plants and animals at the site, evidence of any damage to translocated plants (e.g. browsing, disease), or even recent climatic conditions (e.g. if it has been very hot, or wet). Although they are typically not statistically analysable, these notes may give insights over time and may form the basis of future adaptive management trials.
8. **Stay up to date/ Continuous evaluation.** Enter and analyse the monitoring data immediately after each monitoring visit, so that any problems (or successes) can be identified as quickly as possible. See also Section 2.4.4.

8.4.Technology for monitoring

8.4.1. Using GIS and GPS

A Geographic Information System (GIS) is a mapping tool that allows overlaying of the points of interest (e.g. the translocated population) with other mapped environmental variables (e.g. soil, elevation). It is useful for providing visual representations of these data, and may give insights into previously undetected relationships. Global Positioning System (GPS) allows the determination of the exact location of points of interest in the field, with data collection typically via a handheld GPS unit, although there will be some uncertainty (1-10 m) in such measures depending on the type of GPS used. Common brands of handheld GPS units are Garmin and Navman..

There are also a number of Apps that may be useful:

- Mobile Topographer: accurate GPS locations using smartphones, via GPS averaging. play.google.com/store/apps/details?id=gr.stasta.mobiletopographer&hl=en
- Avenza maps: allows access (pre-downloaded) to detailed maps on smartphones. play.google.com/store/apps/details?id=com.Avenza&hl=en

GIS has applications in:

- Locating individual plants – if the resolution/error of the location data is at an appropriate scale (e.g. equal to or less than 1 m), using a GPS.;
- Providing data on (depending on layers available);
  - elevation;
  - aspect;
  - hydrology/proximity to permanent water;
  - climate;
  - predicted climate;
  - soil/regolith/geology;
  - vegetation type/structure; and
  - fire regime history.

The resolution of the translocated plant/population location data and of the layers available will dictate whether it will be possible to conduct useful analysis of within-site variation, or if only among-site comparisons (in the case of multiple recipient sites) will be possible.

8.4.2. Permanent photo points

Fixed photo points – clearly marked by steel pickets and with direction of photo noted and kept consistent – will assist with monitoring changes in the habitat and translocated plants. If it is not possible to monitor the fate of all translocated plants then individuals in permanently marked photo points, replicated across the site, should be monitored. Small plants and surrounding vegetation can also be monitored over time using overhead photographs (e.g. delineated by a permanently marked 1 m^2 quadrat).

There are a number of apps that can be useful in monitoring permanent photo points:

- PhotoMon
    - www.nacc.com.au/photomon/ and
    - play.google.com/store/apps/details?id=com.appiphany.nacc
- Open Camera stamps the photos with angles and directions, this is useful for permanent photo points.
    - play.google.com/store/apps/details?id=net.sourceforge.opencamera&hl=en

8.5. Interpretation of monitoring data

After each round of monitoring:

- enter the data;
- organize, analyse and evaluate the data according to relevant questions or objectives; and
- communicate the results.

8.5.1. Statistical analysis

The statistical method used to analyse the data will be determined by the monitoring design. Advice on statistical analyses is beyond the scope of this reference, but there are a range of other references that can be used to guide the statistical analyses (see Section 6.5).

8.5.2. Evaluation and action

The translocation can be evaluated by comparing the monitoring data with the objectives (these may also be referred to as targets, benchmarks or references), and triggers for management. Refer back to the 'plan' (Section 2.4.4). The evaluation section of this chapter is brief because translocation and monitoring planning and design (as described in this chapter) make evaluation straightforward.

Questions (and associated actions) that can be considered during evaluation:

- Has the monitoring data answered the question, or is the progress towards answering the question 'on track'?
- Do the results trigger any **management actions** for the current translocation (e.g. fencing, watering, weeding)?
    - If a problem is detected: *'Have courage to act. Management interventions enacted with imperfect knowledge but supported by monitoring increase knowledge and are more likely to benefit threatened species than inaction.'* (Radford *et al.* 2017)
- Can the monitoring results be explained, or is **further investigation** (e.g. collecting data on other previously-unmeasured variables) required?
- Do the results lead to **recommendations for future translocations?** If a management-relevant question has been posed, such as 'Is survival of translocated plants higher in shade or in sun?' then clear and evidence-based recommendations for future translocations can be made accordingly.
- Assess the methodology and cost effectiveness of the translocation program: What has been the benefit to the species? How much has the program cost?

Other benefits from the translocation may include (from Pavlik 1996):

- increased knowledge of the threatened plant species;
- development of new management techniques;
- initiation of debate on conservation policy; and
- community education.

8.5.3. Reporting and data management

Look back at the monitoring principles in Section 8.1. Although the page space devoted to reporting here is limited, it is no less important than data collection. Reasons for reporting monitoring results include:

- To motivate management actions if required (as established in Section 2.4.4).
- To share the experience with other translocation practitioners, so they may follow your successful methods and avoid your mistakes.
- To engage the community in threatened species conservation. Because translocation is a hands-on action, it provides a great avenue for community engagement (Chapter 9).
- Because it is required under permit or licence conditions.

Potential communication media include: technical reports, newsletter articles, scientific journal publications, databases (e.g. Atlas of Living Australia) and social media.

Monitoring data should be collated, accessible and up to date. Monitoring data should be stored in multiple locations, and the locations of these data should be known by more than one person (e.g. the translocation working group). Data sheets should be clearly annotated, so that any person joining the monitoring program later can understand what was done.

Look ahead:

- Identify the date of next monitoring (e.g. Should there be a departure from schedule?).
- Identify the person responsible for the next monitoring. Succession planning is important. Many successful monitoring programs cite a 'champion' or a core group of committed people as the reason for their success (Legge *et al.* 2018).

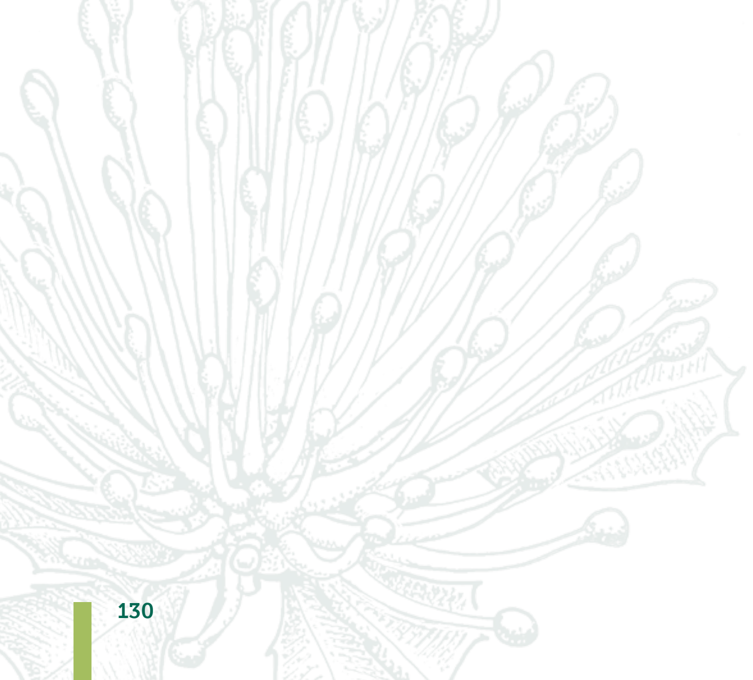
8.6. Worked example for monitoring (Wollemi Pine)

8.6.1. Background

The Wollemi Pine (*Wollemia nobilis*) is a critically endangered tree species. In August 2012 (late winter), we undertook an experimental translocation of 191 Wollemi Pines. The recipient site was a warm temperate rainforest site on land managed by the Blue Mountains Botanic Garden, NSW. The source material was from the Australian Botanic Garden (101 plants) and a commercial supplier (100 plants). The smallest plants had a mean height of 27 cm, while the tallest plants had a mean height of 104 cm. The planting was designed to investigate the effect of varying light availability at the recipient site – from the deep shade, beside the creek, at the bottom of the gully, to the large canopy gaps at the rainforest-woodland transition. Previous work had indicated that light availability was important in Wollemi Pine recruitment (Offord *et al.* 2014; Zimmer *et al.* 2014). The experimental translocation was designed to inform future translocations, especially about microsite selection. Further information about pre-translocation decision making, including selection of source material and the recipient site, can be found in Zimmer *et al.* (2016).

Questions:

1. How does growth (stem length, branch number) and survival of translocated *W. nobilis* vary along a light gradient?
2. How does the effect of light on *W. nobilis* growth and survival vary with plant size?



8.6.2. Monitoring methods

8.6.2.1. Measurements of plants

The response variables monitored were:

- growth (stem length and number of branches); and
- survival

Each translocated Wollemi Pine was permanently tagged, using an aluminum tag with a Royal Botanic Gardens barcode, attached to the base of the plant using a fine wire (Fig. 8.12).

Figure 8.12 Aluminum tag with individual barcode. (Photo: H Zimmer)

Stem length was measured with a flexible, retractable builders' tape (Fig. 8.13). Stem length was measured from the base of the plant to the top of the apical meristem, following the main stem. This is because the stems were not always straight (measuring tape follows the stem; hence, 'length' rather than 'height') and sometimes branches were higher than the apical meristem. Sometimes the change in stem length is negative - this is attributed to litter accumulating around the base of the stem. Measurements from the visible base of the stem (rather than disturbing the soil and litter), to reduce potential damage to the stem, as well as limit potential contact with *Phytophthtora* spp..

Plants were only recorded as dead when no part of the plant was green (Fig 8.14). However, there was a space on the datasheet where recorders could note if the plant looked unhealthy.

Over the years, several plants have been noted as dead, only to later re-sprout (Fig. 8.15). This discovery led the team to leave dead plants in the ground, just in case.

Figure 8.13 Measuring translocated Wollemi Pine with a flexible builders' tape. (Photo: H Zimmer)

Figure 8.14 Dead Wollemi Pine. (Photo: H Zimmer)

Figure 8.15 *Wollemi Pine that has died back and resprouted. (Photo: H Zimmer)*

8.6.2.2. Monitoring the recipient site

Baseline data describing the recipient site were collected during the pre-translocation recipient site assessment. At the site-scale, we collected soil data to check whether the soil was suitable for Wollemi Pines. Wollemi Pines require low pH soil. We also compared climate data (temperature and rainfall) between the wild site and translocation site.

The planting was designed such that groups of six or seven Wollemi Pines would be planted together in what we referred to as 'gaps' (i.e. rainforest canopy gaps) (Fig. 8.16 and 8.17). At gap-scale we estimated canopy openness using hemispherical photos (further information in Zimmer *et al.* (2016)). This allowed us to answer the questions about the effect of light availability on survival and growth.

Figure 8.16 *Recipient site, with Wollemi Pine in foreground and warm temperate rainforest and sandstone outcrop in the background. (Photo: H Zimmer)*

Figure 8.17 *Recipient site showing Wollemi Pine and microsite (gap) label. (Photo: H Zimmer)*

Ongoing monitoring of environmental conditions at recipient site includes three climate loggers (temperature and humidity), in one each of a high-, moderate-, and low-light gap. These loggers are downloaded during annual monitoring (Figs 8.18, 8.19).

In addition, soil properties and soil microbial community were sampled at half of the plants (spread across all gaps) at planting, and at 12 and 24 months. The aim of this work was to identify the soil properties mediating initial Wollemi Pine survival and growth, and to identify if Wollemi Pine had – or could gather – a species-specific soil microbial community (Rigg *et al.* 2017). Wollemi Pines did indeed form a species-specific soil microbial community, and the air-filled porosity (a soil property) was related to growth.

Figure 8.18 Climate logger at Wollemi Pine site. (Photo: C Offord)

Figure 8.19 Downloading climate logger in the field. (Photo: H Zimmer)

8.6.2.3. Management variables

All translocated Wollemi Pines received the same management interventions. Watering at planting and one month after planting, and cages at planting, to protect against herbivores and lyrebird disturbance (Fig. 8.20). Cages were removed after 9 months because they were constricting plant growth and no herbivore or lyrebird damage had been observed.

Figure 8.20 Caged Wollemi Pine. (Photo: H Zimmer)

8.6.2.4. Costs of monitoring

Monitoring the Wollemi Pine experimental translocation takes two people approximately one full day of fieldwork annually. This allows for travel into the site, and growth and survival monitoring of all plants.

8.6.2.5. Monitoring the reference population

The seedlings at the Wollemi Pine wild site are censused approximately once every five years, measuring growth (stem length, number of branches) and survival (Zimmer *et al.* 2014).

8.6.2.6. Monitoring the ex situ population

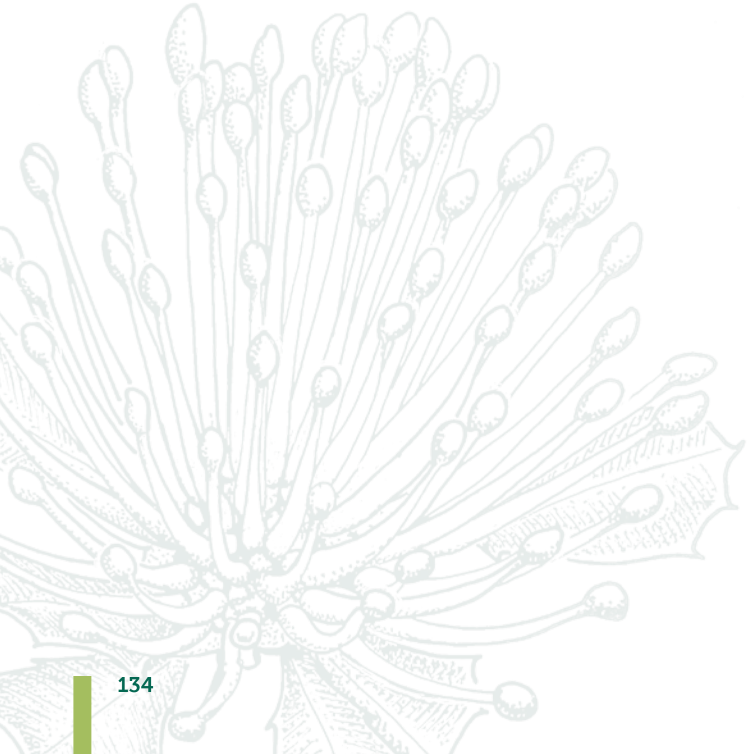
The *ex situ* population is maintained at the Australian Botanic Garden where it receives comprehensive care and attention as one of their most high-value collections.

8.6.2.7. Timing of monitoring

The translocated Wollemi Pine population was monitored intensively for the first 6-months post planting (four visits), less intensively for the period from 6-18-months post planting (four visits). From 18 months post-planting the translocated population has been monitored (approximately) once per year, in February.

8.6.2.8. Duration of monitoring

Monitoring of the translocated population of Wollemi Pines will continue at least until the population is deemed self-sustaining.



Case Studies

Case Study 8.1 - Monitoring informs adaptive management and reveals population increases

Excerpt from Briggs (in press).

Grevillea wilkinsonii (Fig. 1) was discovered as recently as 1982. The species, endemic to south-east New South Wales is a large shrub. The first plantings of this species into the wild date back to 1993 when staff from the ANBG undertook a small trial planting on a Travelling Stock Reserve (which also contained part of the natural population) and on adjoining private land (Site 1). The 1993 planting of eight plants on private land had done particularly well - expanding from eight plants to 350 adult and sub-adult plants plus at least another 100 seedlings by 2012 (Taws 2013). Subsequent plantings were commenced in 2000 (Site 2) and 2008 (Sites 3 and 4).

Techniques have been modified over the years leading to continual improvement. In 2010 an OEH officer had success in growing the species from seeds and these individuals were found to have a stronger root system and have more vigorous foliage growth than cutting progeny. Thus from 2010 onwards plantings have generally involved progeny grown from seeds as this also has the advantage of including greater genetic diversity. Water crystals are added to reduce the frequency of watering. Hand watering of about 16 L per plant about every three weeks after planting through until March has increased survival rates from about 50% to about 95%.

Annual counts of survivorship have been carried out at all planting sites commenced since 2000. Every few years a census of the total population (natural and planted) is conducted. The population count includes assigning individuals to one of three height class categories (<0.2 m, 0.2–1 m and >1 m).

Natural recruitment from the first two translocation plantings has been so successful that 87.3% of the 2017 total population of 1,517 plants is comprised of plantings and the progeny of plantings (Briggs unpublished data, Taws 2018). The proportion of plantings and the progeny of plantings of the total population is expected to increase further over time. Figure 2 shows the overall positive population trend since 1998, including a breakdown of the number of plants that are natural and those that are planted or derived from plantings.

Figure 1 ***Grevillea wilkinsonii*** *flowers (Photo: J. Briggs)*

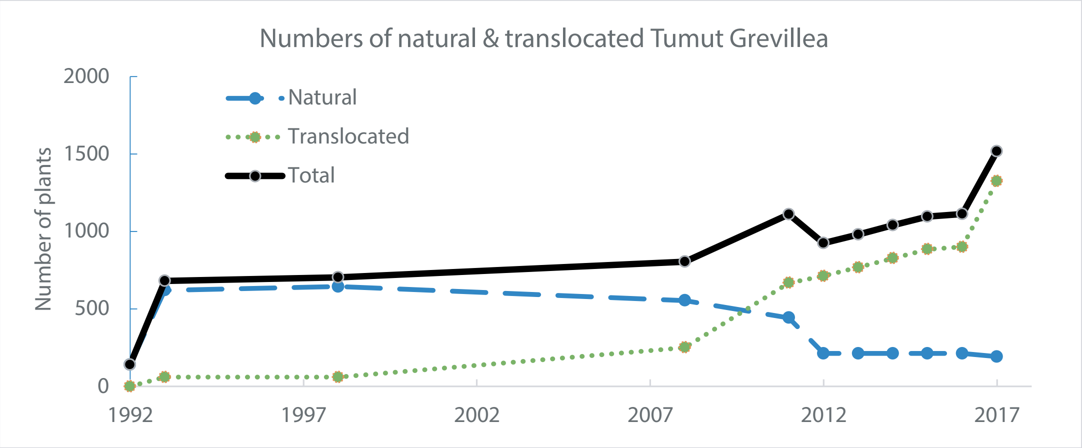


Figure 2 Numbers of ***Tumut Grevillea*** *growing naturally and of planted origin.*

Case Study 8.2 - Long term monitoring revealed some unexpected results

Excerpt from Jusaitis (2018b).

Prostanthera eurybioides (Fig. 1) is a small perennial shrub endemic to South Australia with two disjunct populations (Mt Monster and Monarto). Translocation trials were conducted at both population centers with the aim of enhancing natural populations while at the same time testing various techniques and management options (Jusaitis 2010). This case study focusses on a trial originally designed to examine the influence of herbivory on translocant establishment, but long-term monitoring additionally revealed an intriguing interaction of climate with herbivory (Jusaitis 2012).

Seeds collected from plants at the Mount Monster population were germinated and raised in our nursery. Twelve-month old seedlings were transplanted from tubes into replicated, paired, fenced and unfenced plots. Fenced plots (3 x 3 m) were enclosed by a chicken-wire fence to exclude rabbits and kangaroos.

Plant survival, growth (height, width) and seedling recruitment were monitored over 17 years (1995-2011). Frequent grazing damage was observed on unfenced plants over this time, although this rarely proved fatal once plants were established, as grazed plants were able to regenerate with a new flush of growth when grazing was relaxed. By year 7, survival had stabilized at 96% (fenced) and 67% (unfenced), remaining at those levels for the next 4 years (Fig. 4).

In year 11 (2006), the translocation site experienced its lowest rainfall on record, followed by 2 years of below average rainfall. This severe drought resulted in a dramatic loss of fenced plants, while having no effect at all on survival of unfenced plants (Fig. 2.4). In the early stages of drought stress, fenced plants experienced dieback of stems, followed by shoot regeneration after seasonally favourable conditions. However, prolonged drought reversed this recovery and resulted in the death of many fenced plants.

The explanation for this death of fenced plants is that the fenced (hence ungrazed) plants were larger than the unfenced plants, and had greater leaf surface area, higher transpiration losses and increased susceptibility to water stress. Thus, although it was tempting to abandon monitoring after the population had been stable for 5 years, the next 5 years revealed an unexpected result which suggests that this plant is far more tolerant of grazing than was first thought (Figs 3, 4).

Figure 1 Flowers of ***Prostanthera eurybioides****.*
(Photo: M Jusaitis)

Figure 2 Fenced translocants of ***Prostanthera eurybioides*** *showing dieback of 13-year old plants during a prolonged period of drought. (Photo: M Jusaitis)*

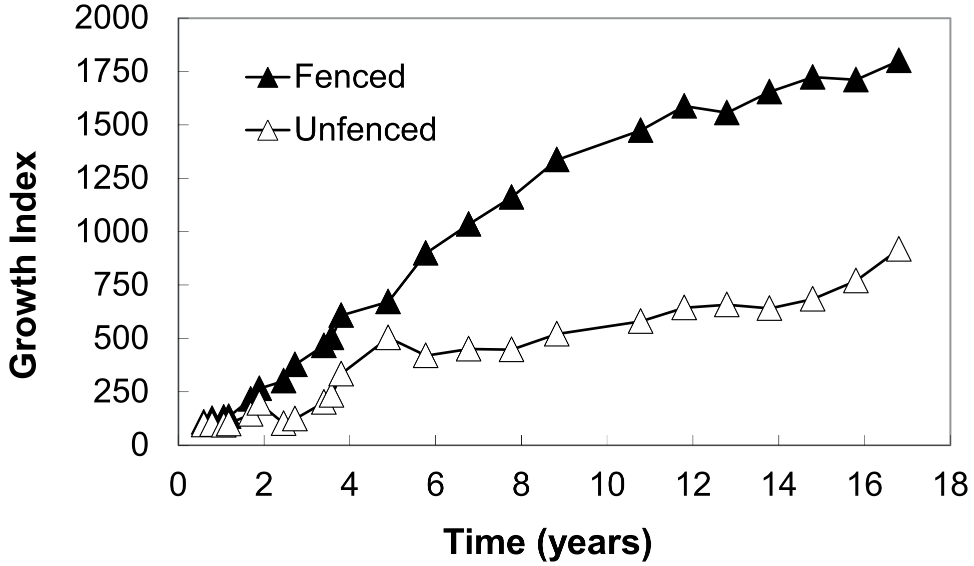


Figure 3 *Growth of* ***Prostanthera eurybioides*** *translocants in fenced and unfenced plots over 17 years. Growth Index is the average of height, widest width and orthogonal width.*

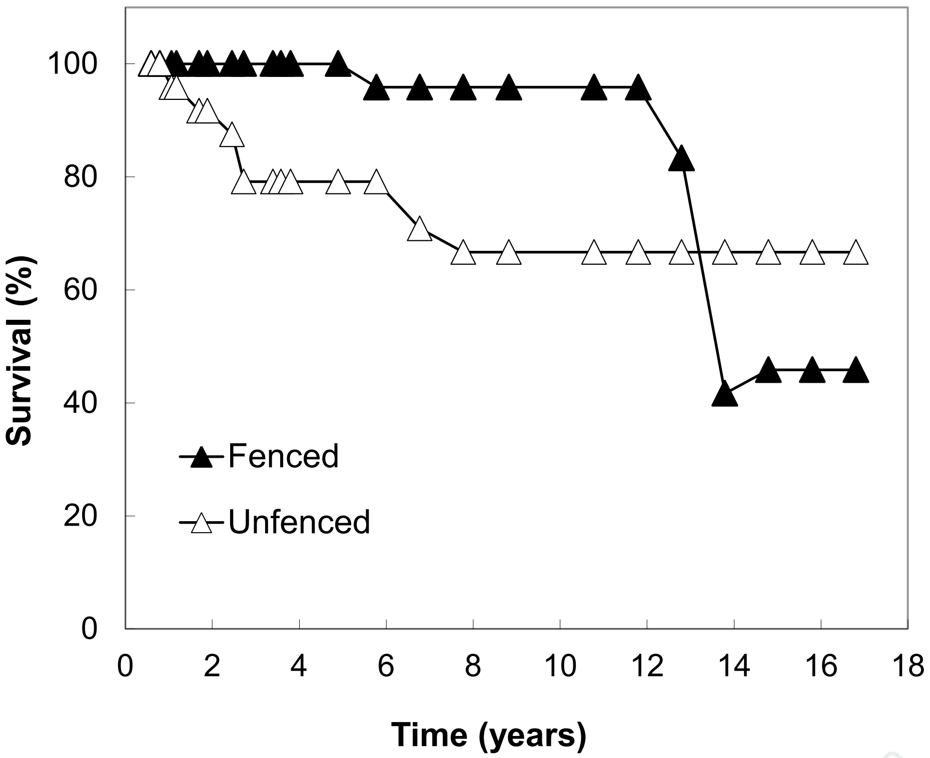


Figure 4 *Survival of* ***Prostanthera eurybioides*** *translocants in fenced and unfenced plots over 17 years.*

Case Study 8.3 – Long term monitoring has assisted in management of genetic diversity and has detected the recruitment of the second generation

Excerpt from Dixon and Krauss (in press).

The Corrigin Grevillea (*Grevillea scapigera*) (Fig. 1) was first collected in 1954, and has been known from only 13 small, mainly degraded roadside populations restricted to a 50 km radius area around the Wheatbelt town of Corrigin in WA, and in 1986 was presumed extinct. In 1989 a single, grafted plant was identified in RBG Sydney and was brought to Kings Park in Perth where it was initiated successfully into *in vitro* culture. The following year, naturally occurring plants were discovered near Corrigin, and at the time, up to 35 living specimens were known in the wild.

The Corrigin Grevillea is difficult to propagate by conventional horticultural methods. However, semi-hardwood cuttings, at the correct stage of growth, gave good strike rates. Tissue culture facilitated the production of a large number of plants in a relatively short time (Bunn and Dixon 1992). Genetically selected clones were secured in vitro and have also been cryopreserved to ensure long-term protection of diverse germplasm. Seed germination treatments were trialled, and a precise method of scarification has been shown to be the most effective.

Initial genetic analysis was carried out on all known plants at the time (Rossetto *et al.* 1995) and showed high genetic variability and little differentiation among surviving populations. This suggested that existing plants comprised a single genetic provenance, and that plants could be pooled with little risk of outbreeding depression. Ten genotypes that included over 87% of the known genetic variability were chosen for propagation to establish the translocated population (Rossetto *et al.* 1995).

A key step was the appointment of a recovery team, which included researchers from Kings Park, staff from the (then) WA Department of Conservation and Land Management (CALM), the Australian Nature Conservation Agency and members of the local community. The involvement and enthusiasm of the local community was very important and interest was kept high through regular meetings and site visits with local Landcare groups and schools.

Several sites were selected, two reintroduction sites where the species was present in low numbers, and three sites within the known range and with similar vegetation and soil types, but where the species hadn't been recorded. The first planting was carried out in 1993.

Monitoring continued every month following planting to record information on survival and growth rates, flowering patterns, numbers of flowers and seed produced as well as damage caused by pests such as rabbits, parrots and seed eating insects. Monitoring for the first 2 years indicated vast seasonal variations which may in part be due to the quality of the greenstock (plants) at time of planting, vagaries of the weather (lack of rainfall) and wide variation between clones. Monitoring was then reduced to twice a year, and also recorded seedling recruitment.

Genetic erosion between founders and offspring was assessed in 1999 at one translocated site (Krauss *et al.* 2002). Poor genetic fidelity in the founding population was found, and significant erosion of genetic variation. Ultimately, the genetically effective population size of the founding translocated population was estimated to be 2. Our results highlighted the difficulty of maintaining genetic fidelity through a large translocation program. This genetic erosion was addressed by avoiding over-represented clones and increasing the numbers of poorly represented clones, by recovering them from *ex situ* cryogenically or tissue culture stored germplasm. Ayre (2014) showed that measures implemented to control the erosion of genetic diversity have been successful, with heterozygosity constant and mean effective number of alleles increasing in third generation plants. However, further research is required to identify the intensity of inbreeding depression associated with elevated inbreeding in these translocated populations, and to assess the long-term consequences.

Through this translocation project, we learned:

- It is possible to establish new populations of this species.
- Using an experimental framework when establishing translocations can provide critical information for long term translocation success.
- Fencing, weed control and summer watering improves survival of planted seedlings.
- Good quality (weed free, biodiverse, well vegetated) sites are important for translocation purposes.
- Network (contact people) on a regular basis to maintain professional and voluntary partnerships. Volunteers were essential due to the volume of work, lack of resources and to obtain funding (grants).
- Rabbit proof fencing was critical, with a minimum area of 0.2 ha to allow expansion of plantings and/or future inclusion of other rare species on site if desired.
- Irrigation systems significantly improved survival rates, increased growth rates, flowering and seed production, but can reduce the life span of plants (Dixon and Krauss 2001).
- Large numbers of plants en mass can lead to an increase in seed predation.
- It was important to monitor on a regular basis e.g. once a month at least for the first 2 years. This includes checking on pests/diseases, fencing and maintaining watering systems.
- Monitoring genetic variation can assist in management of genetic diversity through time.
- Maintaining genetic stock for a long period e.g. cryostorage and/or seed storage is critical for managing worst-case scenarios of extinction in the wild.
- Plants generated from cryostored material performed well on site and produced large quantities of viable seed.
- Monitoring for multiple generations (>20 years for *G. scapigera*) is required to determine if translocated populations are naturally self-sustaining in the long-term.

The original aim, which was to establish 3 self-sustaining translocated populations, was met and exceeded with the establishment of >200 adult plants each, in secure, threat free sites (Fig. 2). In 2014, there were an estimated 455 individuals across all translocation sites – at one site there were 150 plants present in 2014, all but two from *in-situ* germination. Seed burial trials, initiated in 2003, show seed viability remains very high after 14 years, averaging 76%. Sites have not been actively managed for several years, and after >20 years of active management now appear to be self-sustaining. Indigenous species are outcompeting weeds, and this is a critical element for sustained success.

Figure 1 ***Grevillea scapigera*** *inflorescences. (Photo: S Krauss)*

Figure 2 ***Grevillea scapigera*** *translocation site 1: Twenty years after the site was ripped, fenced and planted. Planting continued for several years and the majority of experiments were conducted on this site due to ease of access. Plants continue to germinate, flower and seed between disturbance events. Native vegetation covers most of this former airstrip. (Photo: B Dixon)*

Chapter 9 – Community participation and support

Authors: Nathan Emery, David Taylor, Bob Makinson, Noushka Reiter, Tom North, Lucy Commander, Stephen Van Leeuwen

9.1. The value of community support

For plant conservation outcomes to continue to underpin the maintenance and enhancement of our natural capital, communities need to be aware, engaged, involved, and indeed for as many as possible, to become strong advocates for our biodiversity. Not only can translocation projects benefit from community participation, but also translocations provide a unique hands-on way for reconnecting communities with plant conservation efforts.

Practical support

It is widely accepted in the plant conservation industry that successful long-term species recovery projects can rarely be achieved without public community support. Consequently, where funding and resources are limited, there is a need to carefully apportion resources to gain best effect in recovery actions, including translocations.

Successful plant recovery actions depend on four factors:

- **Threat abatement:** removing or reducing the threatening processes that have caused decline so that less money and energy are needed to maintain a low threat level.
- **Ecological understanding:** this requires a good understanding of the biology and ecology of the species or system being worked upon but noting that lack of knowledge should not impede recovery actions where populations are considered likely to go extinct in the near future without some remedial action.
- **Letting the plants do the work:** using the natural resilience of species and vegetation communities to establish or re-establish viable (self-reproducing over the long term) populations and vegetation communities.
- **Maintenance of effort:** single funding cycles are rarely adequate for anything other than short-term threat abatement.

It is especially in the last factor that community involvement can make the difference between success and failure.

Raising the profile of translocation

While not all translocations require significant community participation across multiple stages of the project, it is important to note that both large and small contributions from the community make a difference for the long-term success of the project. Endorsement and support are often equally as valuable as direct participation, especially where these resonate into local networks, councils, media, NRM bodies, and land-manager networks such as Landcare. In fact, community participants have the potential to become advocates for their translocation project and for nature conservation in general.

Recognition of the importance of community support

Community engagement in any translocation is recognised internationally in Section 5.2 of the IUCN Guidelines for reintroductions and other conservation translocations V 1.0 (IUCN/SSC 2013). The need for community engagement is also recognised in the Australian Government's *Australia's Biodiversity Conservation Strategy 2010–2030*, as priority 1, 'Mainstreaming biodiversity' (Natural Resource Management Ministerial Council 2010). Furthermore, public motivation was shown by the 93% of people 'very' or 'somewhat' concerned about species loss in the latest of a series of robust public opinion surveys (NSW Office of Environment and Heritage 2015), providing confidence that wide public support is available. Many State and federal funding bodies in Australia require or favour a community component in translocation projects e.g. *Saving Our Species* in NSW, National Landcare Program funding, or as a specific part of the translocation proposal. Community engagement is also at the heart of Principle 6 ('Social aspects are critical to successful ecological restoration') of the *National Standards for the Practice of Ecological Restoration in Australia* (Standards Reference Group 2017). There are now calls for community support and engagement to be included as a primary outcome of plant translocations, including during population monitoring, rather than simply being part of the translocation planting (Parker 2008).

9.2. Recognising culture, knowledge, and connections

Connecting a species recovery project with the history and continuing traditions of an area can resonate with many people who may not otherwise feel any contemporary affinity with the project, or whose engagement is easier and more meaningful if the cultural element is well-recognised. This may apply to people of any cultural lineage, but may be particularly important for Indigenous engagement. The forms of recognition of cultural significance depend on context. The AIATSIS Guidelines for Ethical Research in Australian Indigenous Studies (AIATSIS 2012), while mainly intended for that particular research field, contain general principles for engagement with Indigenous communities, interests, and knowledge which are relevant for other fields including ecological restoration. Many other guideline documents also exist – project practitioners should seek the early advice of cultural heritage officers in the relevant agencies, of Land Councils and prescribed Indigenous Body Corporates and of existing community contacts.

Heritage and historical considerations for the post-European settlement period are often also relevant to ecological restoration projects, and local historical societies and libraries can often help with these.

9.3. What sort of community involvement?

The most meaningful sorts of community support and involvement in recovery actions are those that:

- are fully integrated with the responsible conservation agencies;
- are informed and guided by good scientific knowledge and land-management practices;
- are co-designed and delivered with the cultural authority of traditional owners, especially when the recipient site is on aboriginal lands;
- lead to continued commitment of community members, including land owners and managers;
- are based on inclusive and cooperative participation of different community sectors and government agencies; and
- provide best practice examples that help to leverage similar support for other translocation projects and conservation initiatives.

The community can make a valuable contribution to all stages of a translocation program right from the start (Case Study 9.1; see chapters within Section 5 of Legge *et al.* (2018)). One of the key areas that community supporters can make a major difference is in assessing whether translocation is even necessary. Biological surveys should always be an initial component of any recovery planning process (Section 2.3.2); but these can be time-consuming and expensive. Yet time, energy, and funding invested at this early stage place subsequent recovery actions on a much firmer footing. Community involvement and engaging local knowledge can considerably increase the survey area improving the chances that any other occurrences of the threatened species will be found. In Western Australia, for example, local volunteers are assisting with survey efforts of Rare Flora, and using an app to record plant distribution (WWF 2018). Community members can record sightings of plants through the Atlas of Living Australia (www.ala.org.au), and in some States, e.g. in New South Wales through the Bionet (www.environment.nsw.gov.au/wildlifeatlas/upload-sightings-bionet.htm).

Potential sources of different forms of community support should be scoped during the initial planning stages of a translocation project. 'The community' is not an amorphous mass – it is important for communication and involvement strategies to identify different sectors and to identify groups with different stakeholder interests and different skillsets and the potential contribution of these to the project goals. The nature of their stakeholder role also determines when and how they should be brought into the decision-making process – landowners or managers, including Indigenous land stakeholders, need to be involved from a very early stage in decision-making and design of translocation proposals. Sources of field-skilled personnel may include Landcare networks, NRM bodies, local government staff and State agencies, local ecological consultants, nursery personnel, Friends groups, traditional owners ranger teams and Indigenous bio-cultural knowledge holders, and native plant societies. For all field operations, careful and explicit training and attention to quality of work, safety and hygiene are essential.

For example, while children (or unskilled adults) participating in plantings makes for good media, it may not be best practice for de-potting and handling plantings into a wild site where correct handling is essential to maximise survivorship; these activities may, however, be suitable at a demonstration site. With the correct training and supervision the community has the potential to provide assistance in many of the labour-intensive aspects of a translocation program including site preparation (Section 6.7), planting (Section 7.3), after-planting care (Section 7.4) and long-term monitoring (Chapter 8) (Figs 9.1 – 9.3). The 'Who Cares about the Environment' survey in NSW (NSW Office of Environment and Heritage 2015) lists environmental activities conducted by volunteers with 14% of respondents taking part in a Landcare or Bushcare project/tree planting/other restoration, indicating that community members are already keen to be involved in plant conservation projects.

Local community participants working on a translocation project can provide:

- an important element of stability and continuity for the project;
- local knowledge and contacts;
- better anticipation of opportunities to build up local community interest and tap local resources;
- better recognition of problems;
- more resources (human and material) to add to those available through official funding channels;
- a wider communication network;
- a sense of stewardship over a translocated population; and
- a local 'watchdog' role for unexpected impacts or threats.

Sources of endorsement and other general support (including in-kind and sponsorship) may include local councillors and members of parliament, local firms, corporate volunteer programs, NRM bodies, local universities and post-secondary colleges.

Figure 9.1 Community group transplanting ***Prostanthera eurybioides*** *at a translocation site near Murray Bridge. (Photo: B Sorensen)*

Figure 9.2 Planting ***Acanthocladium dockeri****. (Photo: C Tourenq)*

Figure 8.5 Volunteers from the North Rothbury community being briefed by the translocation team as part of the ***Persoonia pauciflora*** *planting day in 2016. (Photo: C Offord)*

9.3.1. Citizen Science

Citizen science has become a buzz word over the last twenty years to highlight the participation of the community in the recording of data for research. It has grown out of the volunteer and amateur field naturalist community and a recognition of the value of the observations that these people and groups have contributed to a number of ecological fields. It is an approach that neatly combines ecological research with environmental education and natural history observations. Over the past decade it has seen exponential growth with the use of the internet and 'apps' as tools for recording sightings, measurements and population data for a range of biota and ecological indicators.

For plant conservation, citizen science projects will have four major elements: (1) initiator of the project, professional researcher, conservationist or agency with remit for the species; (2) scale and duration of the project, whether local, regional, State or national and short or long term; (3) types of questions being asked, ranging from nature of data collection to hypothesis testing, and (4) goals, which include research, education, and behavioural change (e.g. stewardship) (Dickinson and Bonney 2012).

The best citizen science projects play on the two basic human tendencies of altruism and a willingness to collect data of personal value. The value of social connection in maintaining individual involvement in a project should also not be underestimated. Keeping the science simple and repeatable is also key. Importantly, it makes sense to adopt a practise that acknowledges and credits citizen science participants when reporting project outcomes.

The Australian Citizen Science Association (www.citizenscience.org.au) and the Australian Citizen Science Project Finder through the Atlas of Living Australia (www.ala.org.au) are good places to start for those wishing to engage with Citizen Science.

9.4. How to manage and maintain community involvement

Community involvement in translocation actions, and support for them, cannot be assumed. It always requires engagement, effort and acknowledgement. Having an individual assigned to engage with the community and - community group representatives assists the engagement process and help future activities flow smoothly. This might involve initially raising awareness for opportunities of community involvement in plant conservation, before a period of continuing negotiated commitment to shared conservation goals and actions. There are a wide range of tools and resources available to initiate community engagement. Traditional methods include face-to-face or phone conversations with community leaders or members of council, distributing questionnaires or surveys, site visits, brochures, education nights, local press engagement, and attending community forums. Many of these can be conducted online via forums and social media networks. Indeed, the rapid rise in social media use means that many relevant groups can be more easily contactable, such as native plant or wildflower societies, local environmental centres, and residential communities. It can be beneficial to initially engage with a representative contact who can then help arrange a meeting with the wider community group. It is important during initial engagements to be clear and positive about existing and future possibilities and outcomes for community involvement. Be prepared to work with community groups to adapt project tasks based on mutual needs, as consultation is not engagement. Remember a good first impression is key!

In working with threatened species it is particularly important that those guiding translocation processes (i.e. the official recovery or translocation team: see Section 3.1) and community volunteers and supporters make sure they understand each others' priorities and mandates, and that roles and responsibilities are agreed in the early states of planning, and subsequent priorities and actions will evolve over the course of a project. This is often done in the creation of a recovery team where roles and responsibilities are assigned by the members. The recovery or translocation team (or the responsible conservation agency officers if there is no broad team) need to communicate effectively with the community partners about the official and scientific processes at work, and reach a cooperative understanding on what are shared and separate responsibilities and capabilities, how these are documented and reported, what training, quality-control and safety considerations apply, and how difficulties are to be aired and resolved. These needs are best met in a moderately structured environment where team members from disparate backgrounds are in regular direct contact and are part of a collective and well-documented process. The Commonwealth's *Recovery team governance - Best practice guidelines* (Commonwealth of Australia 2017) provide practical guidance.

The best way to maximise the chances of recovery project personnel being able to hear about, recognise, and seize opportunities for widening support, is to develop an inclusive spirit within the team and the supporting community group, that both helps current members settle and work well with each other, and is capable of welcoming new partners (as individuals or organisations) into the circle.

Community groups practising these sorts of precautions, providing sound training of their own members, and taking a measured and thorough attitude to their planning, can have a big effect in raising the standard of translocation. The community group itself becomes the role model.

Involvement can be fun, and physically, intellectually and emotionally rewarding. It needs to be so (most of the time) to help maintain enthusiasm and spirit. Mutual support within the group is also important. The bonding that develops between team members in a situation like this pays off wonderfully when things go right – celebrate when the survivorship rate of transplants is on-target; when the last, most reluctant residents come to an information night and have a good time; when the translocated plants produce a second generation of seedlings. The satisfaction for groups and for individuals of knowing that a species is likely to have been saved from imminent extinction or decline is one of the strongest motivating factors for their future commitment to conservation. Some of what we do as conservationists is for the world of which we are part, and some of it is for us.

Translocation actions should never be conducted by individuals working alone or by groups working independently of – or in conflict with – the official recovery team or responsible conservation agency. The recovery team (Section 3.1), or the responsible conservation agency officer when a recovery team does not exist, is the place for decisions to be made as to whether translocation actions are possible, necessary, affordable, and likely to succeed. Translocations conducted without the explicit agreement of the recovery team or State conservation agency are much more likely to harm the species or ecological community and are less likely to gain funding support.

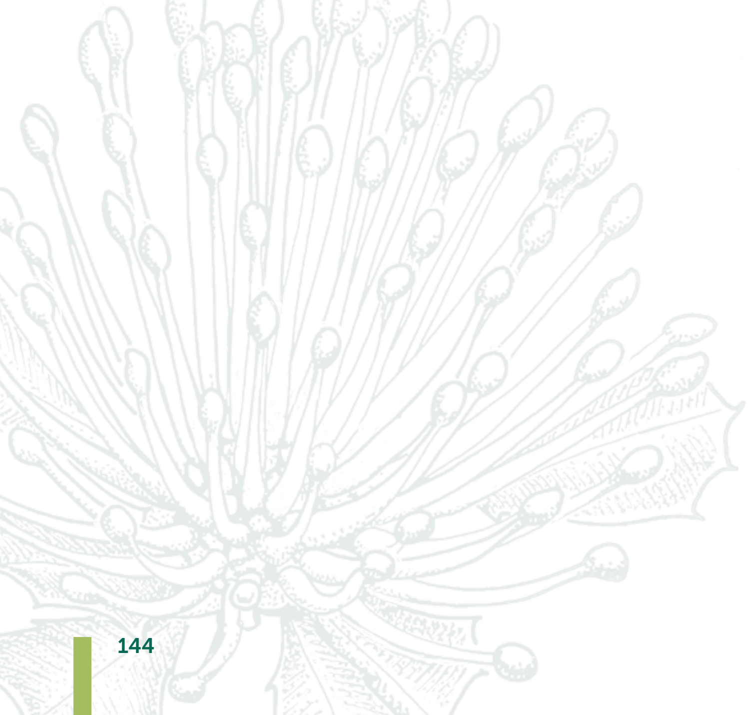
Any work on threatened species sites, including translocation, requires attention to a special set of precautionary rules:

- Field biosanitation: precautionary disinfecting of tools, equipment, vehicles and boots should be a mandatory part of procedure before visits to a threatened site.
- Frequency of visits: too many people too often may lead to trampling of seedlings, damage of surrounding vegetation, drawing unwanted attention to a site, or aggravation of landowners.
- The health and safety of all involved: volunteers and professionals; it is necessary to think through the safety implications of what people have been asked to do, assess their skills and ability to do it, provide appropriate training and where necessary insurance coverage, and minimise the risk involved.

9.5. Capturing the achievements and recognising partners

One often overlooked element is how we capture the collaborative effort. A short video interviewing community members or specialists, and capturing significant events and forums can be used to acknowledge people, spread the word and put a face to those working together, both locals and beyond. Such material can be developed over time to continue the story and for handing over to future project custodians. Remember that consent is always needed for those involved in video and audio recordings, and that cultural sensitivities may apply to the use of images of deceased participants.

The recognition of partner organisations and individuals, whether by periodic letters of thanks, media and social media mentions, or mention and presence at events, is an essential part of a successful project, and provides a springboard for further collaborations. With large community groups it is helpful to provide both acknowledgement and updates through their newsletters, social media accounts and public presentations.



Case Studies

Case Study 9.1 - The important contribution of volunteers to translocation projects

Excerpt from Reiter and Thompson (2018).

The Orchid Conservation Program at the Royal Botanic Garden Victoria is a collaboration between many stakeholders and partners. Working across multiple levels of government, not for profit organisations and community groups enhances the outcomes of the program. Partners include: Royal Botanic Gardens Victoria, Adelaide Botanic Gardens, Parks Victoria, Department of Environment Land Water and Planning, Trust for Nature, Australian Network for Plant Conservation, The Australian National University, NSW Office of Environment and Heritage, Murray Local Landcare Services, Wimmera Catchment Management Authority, Nillumbik Shire, Project Platypus, Australasian Native Orchid Society Vic Branch (ANOS) and many volunteer groups.

ANOS Vic has been a key community partner in the Orchid Conservation Program since its inception (Reiter *et al.* 2012). On a yearly basis, volunteers contribute over 2500 skilled hours of work on the RBGV Orchid Conservation Program and many more on local community orchid conservation activities with other partner organisations. Many of the volunteer's field activities are co-ordinated through ANOS Vic's own volunteer Orchid Conservation Officer. Potential volunteer involvement activities are taken to ANOS Vic's committee at the start of the year to allow adequate planning of events.

Volunteers have varying levels of skills when starting with the program and an important part of their induction is therefore training. Training of the volunteers includes not only the tasks that they are performing but providing background knowledge on the species they are working with. Learning continues during the activities and sharing of knowledge between volunteers and stakeholders is ongoing.

Activities onsite at the RBGV laboratory and nursery include: germination counts, data entry, flasking seedlings, and potting orchids. Field activities include: surveys for new populations, planting translocations, tagging individual plants (for later monitoring), monitoring translocated plants, weeding at important sites, site maintenance, fencing sites, and surveys for orchid pollinators.

Importantly, with translocations we make a concerted effort to take volunteers back to these sites to assist with monitoring and post-translocation maintenance, allowing everyone to see the results of their hard work.

Figure 1 a) ***Caladenia fulva*** *b)* ***Thelymitra mackibbinii*** *c)* ***Caladenia colorata****. (Photos: N Reiter)*

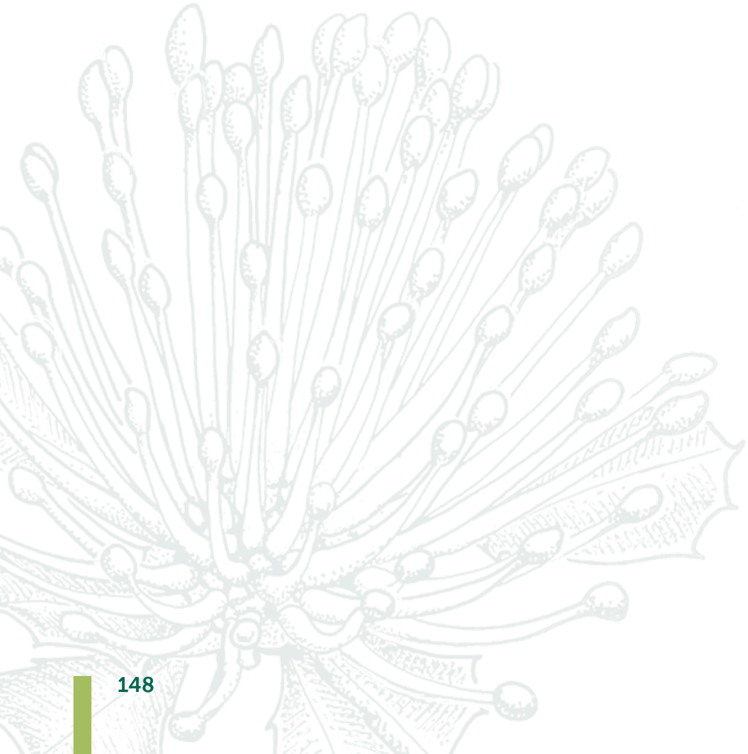
Figure 2 a) Monitoring set up ***Caladenia colorata*** *conservation translocation b) volunteers caging* ***Caladenia fulva*** *conservation translocations c) volunteers potting orchids in the RBGV nursery d) volunteer hands planting* ***Caladenia fulva*** *e) volunteers planting* ***Caladenia versicolor****. (Photos: N Reiter (A, C, D, E) and C Young (B))*

Glossary

abiotic	non-living components of the natural world such as geology, soils, climate etc.
allele	one of two or more alternative forms of a gene that occupy the same position on a chromosome.
allelopathy	the suppression of growth of one plant species by another due to the release of toxic substances.
biodiversity	the variety of life forms, the genes they contain and the ecosystems they form.
bottleneck	a sudden restriction in population size for one or more generations is often followed by a genetic bottleneck, where gene diversity is also lost and followed by increased inbreeding.
buffer zone	an area adjacent to or adjoining remnant vegetation that minimises the impact of activities or events outside the remnant.
clone	an individual produced asexually from a single parent.
cohort	a group of individuals of the same age, recruited into a population at the same time.
corridor (vegetation)	a linear area of vegetation linking other larger remnants of vegetation.
cryptic	a taxon that looks very similar to another taxon; a taxon that is difficult to locate because of its size or morphological appearance.
demographic stochasticity	random variation in the birth and death of individuals; changes to the structure and size of a population; more pronounced in small populations.
dioecious	having separate male and female flowers on separate plants.
differential GPS	differential Global Positioning System; the process of correcting GPS data against a known reference station.
DNA	the genetic material of most living organisms.
DNA fingerprinting	a method employed to determine differences in DNA characteristics among individuals. These can be used to identify single individuals from the rest of the population.
ecotone	a transitional zone, or marginal area, between two plant communities.
edaphic	of the soil, substrate or topography.
environmental stochasticity	random and unpredictable environmental processes and events causing change in community or landscape structure, such as a catastrophic event.
ephemeral	a plant with a short life cycle
ex situ	out of the original place; the maintenance of living plant material away from the wild.
evolutionary significant unit	genetically differentiated units within the same species. ESU usually evolved as a consequence of restricted or no historical gene flow between units.
extant	existing or living at the present time.
extinct	taxa not located in the wild during the past 50 years, or not found in recent years despite thorough searching.
founder effect	change in genetic composition of a population due to its origin from a small number of individuals (i.e. a single generation bottleneck).
gene	the functional unit of heredity; the part of the DNA molecule that encodes a single enzyme or structural protein unit.
gene flow	exchange of gene diversity among individuals or populations.
generation length	average age of all breeding individuals.
genet	genetically distinct individual (opposite of ramet).

genetic diversity	the sum total of all genetic variation for a population, taxon or other taxonomic rank.
genetic variability	variation in the genetic composition between individuals, populations or taxa.
genotype	the genetic constitution of an individual, fixed except under certain conditions (mutation).
genotype collecting	collections from multiple maternal genotypes are sampled and accessioned individually, rather than mixing the collections from multiple plants within the population (also/or 'maternal genotype collecting').
geophyte	a perennial plant which has an underground storage organ e.g. a bulb, corm or rhizome (adj: geophytic).
germplasm	the genetic material that carries the inherited characteristics of an organism.
habitat	the place or type of site where an organism occurs naturally.
heterozygous	having two different alleles or gene-forms at a given locus of a pair of chromosomes (opposite of homozygous).
homozygous	having the same allele at a given locus of a pair of chromosomes.
hybrid	the progeny of a cross between different taxa.
inbreeding	the mating of individuals related by descent, usually causing a reduction in gene heterozygosity and diversity.
inbreeding depression	a reduction in vigour and fitness due to inbreeding.
in situ	the original place; pertaining to the maintenance of plants in the wild.
introgression	the incorporation of genes of one species into the gene pool of another, usually through the backcross of fertile hybrids to the more abundant species.
in vitro	in an artifical environment (such as a test tube).
mutation	a change within the genetic system (by either a gene or chromosome) which produces in the mutant (or variant) a slight or profound effect.
mycorrhiza	a non-pathogenic association of a fungus with a vascular plant or bryophyte.
orthodox seeds	seeds can be dried, without damage, to low moisture content (also known as desiccation tolerant).
outbreeding depression	reduction in fitness due to the mating of individuals adapted to different environmental conditions.
phenotype	the observable aspect of an organism representing the variable expression of a relatively unchanging genotype to varying environmental conditions.
pollination vector (pollinator)	the mode by which pollen is successfully transferred from the anther to the stigma of the same flower or another flower.
propagule	a unit of vegetative reproduction (includes seed, spores, or vegetative matter capable of independent growth).
provenance (genetic)	area identifying genetic distinction and usually thought to represent genetic adaptation to local environmental conditions.
ramets	plants formed by asexual reproduction; physically but not genetically distinct individual (i.e. part of a clone – opposite of genet).
recalcitrant (seed)	seeds that do not survive drying to any large degree, and are thus not amenable to long-term storage.

recovery plan	recovery plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities. The aim of a recovery plan is to maximise the long term survival in the wild of a threatened species or ecological community. Recovery plans should state what must be done to protect and restore important populations of threatened species and habitat, as well as how to manage and reduce threatening processes. Recovery plans achieve this aim by providing a planned and logical framework for key interest groups and responsible government agencies to coordinate their work to improve the plight of threatened species and/or ecological communities.
self-sustaining (population)	a population of plants that maintains itself without external assistance.
stochasticity	see **demographic stochasticity** and **environmental stochasticity**.
symbionts	two organisms living together to their mutual benefit.
taxon (taxa)	the named classification unit to which individuals are assigned e.g. genus, species, subspecies, variety etc.
viable population	a group of plants of the same species that possesses the ecological, demographic and genetic attributes required to persist in both the short and long term.



References

Abbott I, Burrows N (2003) 'Fire in ecosystems of south-west Western Australia: impacts and management. Symposium proceedings (Volume I), Perth, Australia, 16-18 April 2002.' (Backhuys Publishers: Leiden, The Netherlands).

AIATSIS (2012) Guidelines for Ethical Research in Australian Indigenous Studies. Revised second edition. Canberra, ACT.

Anderson SH, Kelly D, Ladley JJ, Molloy S, Terry J (2011) Cascading Effects of Bird Functional Extinction Reduce Pollination and Plant Density. Science 331(6020), 1068-1071.

Anon (1995) Fungicide resistance management strategies 1995. Avicare Fungicide Resistance Action Committees.

Arlidge WNS, Bull JW, Addison PFE, Burgass MJ, Gianuca D, Gorham TM, Jacob C, Shumway N, Sinclair SP, Watson JEM, Wilcox C, Milner-Gulland EJ (2018) A Global Mitigation Hierarchy for Nature Conservation. *BioScience*, 68(5), 336–347.

Auld TD, Keith DA (2009) Dealing with threats: integrating science and management. Ecological Management & Restoration 10 S79-S87.

Australian Government Department of the Environment and Energy (2018) Recovery Plans. http://www.environment.gov.au/biodiversity/threatened/recovery-plans

Australian National Herbarium (2015) Vera Scarth-Johnson (1912-1999) Obituary. https://www.anbg.gov.au/biography/scarth-johnson-obit.html

Ayre B (2014) Genetic erosion and its consequences for the recovery of *Grevillea scapigera*. Honours Thesis, The University of Western Australia.

Baskin CC, Baskin JM (2014) 'Seeds. Ecology, Biogeography, and Evolution of Dormancy and Germination.' (Academic Press: San Diego, California, USA).

Batty AL, Dixon KW, Brundrett M, Sivasithamparam K (2001) Constraints to symbiotic germination of terrestrial orchid seed in a mediterranean bushland. New Phytologist 152(3), 511-520.

Bennett A, Kimber S, Ryan P (2000) Revegetation and wildlife - A Guide to Enhancing Revegetated Habitats for Wildlife Conservation in Rural Environments. Bushcare National Research and Development Program Research Report. Environment Australia, Canberra.

Benwell A (2018) Threatened plant translocation case study: Translocation of threatened flora for the Warrell Creek to Urunga upgrade of the Pacific Highway, Mid North Coast NSW. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc 27(1), 15-19.

Bickerton D, Field T, Tourenq C, Moritz K (2018) Threatened plant translocation case study: *Anthocladium dockeri* (Spiny Daisy), Compositae. Australasian Plant Conservation: Bulletin of the Australian Network for Plant Conservation 26(4), 6-9.

Binks RM, Millar MA, Byrne M (2015) Contrasting patterns of clonality and fine-scale genetic structure in two rare sedges with differing geographic distributions. Heredity 115(3), 235.

Booth TH, Williams KJ, Belbin L (2012) Developing biodiverse plants suitable for changing climatic conditions 2: Using the Atlas of Living Australia. Ecological Management & Restoration 13(3), 274-281.

Bortesi L, Fischer R (2015) The CRISPR/Cas9 system for plant genome editing and beyond. Biotechnology advances 33(1), 41-52.

Botanic Gardens Conservation International (1995) 'A handbook for botanic gardens on the reintroduction of plants to the wild.' (Botanic Gardens Conservation International: UK).

Bower CC (1996) Demonstration of pollinator-mediated reproductive isolation in sexually deceptive species of *Chiloglottis* (Orchidaceae: Caladeniinae). Australian Journal of Botany 44(1), 15-33.

Bradstock RA, Williams JE, Gill MA (2002) 'Flammable Australia: the fire regimes and biodiversity of a continent.' (Cambridge University Press: Cambridge, UK).

Bragg JG, Supple MA, Andrew RL, Borevitz JO (2015) Genomic variation across landscapes: insights and applications. New Phytologist 207(4), 953-967.

Breed MF, Stead MG, Ottewell KM, Gardner MG, Lowe AJ (2013) Which provenance and where? Seed sourcing strategies for revegetation in a changing environment. Conservation Genetics 14(1), 1-10.

Briggs J (in press) Threatened plant translocation case study: *Grevillea wilkinsonii* (Tumut Grevillea), Proteaceae. Australasian Plant Conservation: Bulletin of the Australian Network for Plant Conservation

Broadhurst L, Driver M, Guja L, North T, Vanzella B, Fifield G, Bruce S, Taylor D, Bush D (2015) Seeding the future–the issues of supply and demand in restoration in Australia. Ecological Management & Restoration 16(1), 29-32.

Broadhurst LM, Lowe A, Coates DJ, Cunningham SA, McDonald M, Vesk PA, Yates C (2008a) Seed supply for broadscale restoration: maximizing evolutionary potential. Evolutionary Applications 1(4), 587-597.

Broadhurst LM, Young AG, Forrester R (2008b) Genetic and demographic responses of fragmented *Acacia dealbata* (Mimosaceae) populations in southeastern Australia. Biological Conservation 141(11), 2843-2856.

Brown A, Marshall D (1995) A basic sampling strategy: theory and practice. In 'Collecting plant genetic diversity: technical guidelines' (Eds L Guarino, V Ramanatha Rao and R Reid) pp. 75-91. (CAB International: Wallingford).

Brown G, Vleck K (2010) Pollination biology of the Sexually Deceptive Threatened Orchids *Caladenia richardsiorum*, and *Caladenia hastata*, and their pollinators. Report to the Australian Orchid Foundation.

Brundrett MC, Scade A, Batty AL, Dixon KW, Sivasithamparam K (2003) Development of *in situ* and *ex situ* seed baiting techniques to detect mycorrhizal fungi from terrestrial orchid habitats. Mycological Research 107(10), 1210-1220.

Buchanan R (2016) 'Restoring natural areas in Australia.' (NSW Government, Department of Primary Industries).

Bunn E, Dixon KW (1992) In vitro propagation of the rare and endangered Corrigin Grevillea, *Grevillea scapigera* A. S. George (Proteaceae). HortScience 27(4), 261-262.

Bunn E, Turner S (in press) Threatened plant translocation case study: *Symonanthus bancroftii* (Bancroft's Symonanthus), Solanaceae,. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc.

Byrne M, Macdonald B, Coates D (1999) Divergence in the chloroplast genome and nuclear rDNA of the rare Western Australian plant *Lambertia orbifolia* Gardner (Proteaceae). Molecular Ecology 8(11), 1789-1796.

Byrne M, Stone L, Millar MA (2011) Assessing genetic risk in revegetation. Journal of Applied Ecology 48(6), 1365-1373.

Cary G, Lindenmayer D, Dovers S (2003) 'Australia burning: fire ecology, policy and management issues.' (CSIRO Publishing: Collingwood, Australia).

Caughley G, Gunn A (1996) 'Conservation Biology in Theory and Practice.' (Blackwell Science: Melbourne).

Clarke A, Haase B (2012) *Acanthocladium dockeri* (Spiny Daisy) Monitoring Manual. Natural Resources Northern and Yorke, Clare, SA.

Clarke I, Stokes Z, Wallace R (2010) Habitat restoration planning guide for natural resource managers. Government of South Australia, Department of Environment and Natural Resources, Adelaide.

Coates D, Dillon R, Barrett S (2018) Threatened plant translocation case study: *Banksia brownii* (Feather Leaved Banksia), Proteaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc 27(1), 3-6.

Coates DJ, McArthur SL, Byrne M (2015) Significant genetic diversity loss following pathogen driven population extinction in the rare endemic *Banksia brownii* (Proteaceae). Biological Conservation 192(December 2015), 353-360.

Cochrane A, Crawford AD, Offord CA (2009) Seed and Vegetative Material Collection. In 'Plant Germplasm Conservation in Australia: Strategies and Guidelines for Developing, Managing and Utilising Ex situ Collections. (Eds CA Offord and P Meagher) pp. 35-62. (Australian Network for Plant Conservation: Canberra, Australia).

Collier P, Garnett R (2018) Threatened plant translocation case study: *Cassinia rugata* (Wrinkled Dollybush), Asteraceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc 26(4), 21-24.

Commander L, Merino-Martín L, Golos P, Stevens J, Elliott C, Miller B (2017) Sinosteel Midwest Corporation Practitioner Restoration Manual Version 1. Botanic Gardens and Parks Authority. http://www.smcl.com.au/docs/Sinosteel_Restoration_Manual_March_2017.pdf

Commonwealth of Australia (2017) Recovery team governance—Best practice guidelines. https://www.environment.gov.au/biodiversity/threatened/recovery-teams

Cook CN, Pullin AS, Sutherland WJ, Stewart GB, Carrasco LR (2017) Considering cost alongside the effectiveness of management in evidence-based conservation: A systematic reporting protocol. Biological Conservation 209(May 2017), 508-516.

Crawley M (2005) 'Statistics-An introduction using R ' (John Wiley & Sons Ltd: England).

Dalrymple SE, Banks E, Stewart GB, Pullin AS (2012) A meta-analysis of threatened plant reintroductions from across the globe. In 'Plant reintroduction in a changing climate' (Eds J Maschinski and KE Haskins) pp. 31-50. (Springer).

Department of Parks and Wildlife (2017) Granite Banksia, *Banksia verticillata* Interim Recovery Plan 2017–2022. Interim Recovery Plan No. 379. Department of Parks and Wildlife, Western Australia.

Dickinson JL, Bonney R (Eds) (2012) 'Citizen Science: public participation in environmental research.' (Comstock Publising Associates: Ithaca and London).

Dillon R, Monks L, Coates D (2018) Establishment success and persistence of threatened plant translocations in south west Western Australia: an experimental approach. Australian Journal of Botany 66(4), 338-346.

Dixon B, Krauss S (2001) Translocation of Grevillea scapigera: is it working? Danthonia 10(2), 2-3.

Dixon B, Krauss S (in press) Threatened plant translocation case study: *Grevillea scapigera* (Corrigin Grevillea), Proteaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc

Dixon PM, Cook RE (1990) Science, planning and the recovery of threatened plants. Endangered Species Update 6(10), 9-14.

Doyle C, Pellow B, Hood H, Rapmund R, Viler M (in press) Threatened plant translocation case study: *Hibbertia spanantha* Toelken & A.F.Rob (Julian's Hibbertia), Dilleniaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc.

Dytham C (2011) 'Choosing and using statistics: a biologist's guide.' (John Wiley & Sons: United Kingdom).

Elliott C, Wilkinson K, Lewandrowski W, Stevens J, Turner S (in press) Threatened plant translocation case study: *Tetratheca erubescens*, Elaeocarpaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc.

Elliott C, Wilkinson K, Turner S (2018) Threatened plant translocation case study: *Ricinocarpos brevis*, Euphorbiaceae. Australasian Plant Conservation: Bulletin of the Australian Network for Plant Conservation 26(4), 12-15.

Elzinga CL, Salzer DW, Willoughby JW (1998) Measuring & Monitoring Plant Populations. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1016&context=usblmpub

Emery NJ, Hillier P, Offord CA (2018) Threatened plant translocation case study: *Persoonia pauciflora* (North Rothbury Persoonia), Proteaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc. 26(4), 18-21

Falk DA, Holsinger KE (Eds) (1991) 'Genetics and conservation of rare plants.' (Oxford University Press: Oxford).

Fenster CB, Armbruster WS, Wilson P, Dudash MR, Thomson JD (2004) Pollination Syndromes and Floral Specialization. Annual Review of Ecology, Evolution, and Systematics 35(1), 375-403.

Field DL, Ayre DJ, Whelan RJ, Young AG (2011) The importance of pre-mating barriers and the local demographic context for contemporary mating patterns in hybrid zones of *Eucalyptus aggregata* and *Eucalyptus rubida*. Molecular Ecology 20(11), 2367-2379.

Frankham R (2015) Genetic rescue of small inbred populations: meta-analysis reveals large and consistent benefits of gene flow. Molecular Ecology 24(11), 2610-2618.

Frankham R, Ballou JD, Eldridge MD, Lacy RC, Ralls K, Dudash MR, Fenster CB (2011) Predicting the probability of outbreeding depression. Conservation Biology 25(3), 465-475.

Frankham R, Ballou JD, Ralls K, Eldridge M, Dudash MR, Fenster CB, Lacy RC, Sunnucks P (2017) 'Genetic management of fragmented animal and plant populations.' (Oxford University Press).

Frankham R, Bradshaw CJA, Brook BW (2014) Genetics in conservation management: Revised recommendations for the 50/500 rules, Red List criteria and population viability analyses. Biological Conservation 170(February 2014), 56-63.

Gallagher R, Randall R, Leishman M (2015a) Trait differences between naturalized and invasive plant species independent of residence time and phylogeny. Conservation Biology 29(2), 360-369.

Gallagher RV, Makinson RO, Hogbin PM, Hancock N (2015b) Assisted colonization as a climate change adaptation tool. Austral Ecology 40(1), 12-20.

Gibbs JP, Droege S, Eagle P (1998) Monitoring populations of plants and animals. BioScience 48(11), 935-940.

Godefroid S, Piazza C, Rossi G, Buord S, Stevens A-D, Aguraiuja R, Cowell C, Weekley CW, Vogg G, Iriondo JM, Johnson I, Dixon B, Gordon D, Magnanon S, Valentin B, Bjureke K, Koopman R, Vicens M, Virevaire M, Vanderborght T (2011) How successful are plant species reintroductions? Biological Conservation 144(2), 672-682.

Gold K (2014) Post-harvest handling of seed collections. Technical Information Sheet_04, Royal Botanic Gardens Kew. https://www.kew.org/sites/default/files/04-Post-harvest-handling.pdf

Gold K, Hay F (2008) Identifying desiccation-sensitive seeds. Technical Information Sheet 10, Millennium Seed Bank Project, The Royal Botanic Gardens, Kew. https://www.kew.org/sites/default/files/10-Desiccation%20tolerance%20web.pdf

Greening Australia (1999) 'Management principles to guide the restoration and rehabilitation of indigenous vegetation.' (Greening Australia: Sydney, NSW).

Gregory R, Failing L, Harstone M, Long G, McDaniels T, Ohlson D (2012) 'Structured decision making: a practical guide to environmental management choices.' (John Wiley & Sons: Chichester, UK).

Guerrant EO, Fiedler PL, Havens K, Maunder M (2004) Revised Genetic Sampling Guidelines for Conservation Collections of Rare and Endangered Plants. In 'Ex situ plant conservation supporting species survival in the wild' (Eds EO Guerrant Jr, K Havens and M Maunder) pp. 419-438. (Island Press: Washington).

Hairston NGS (1996) 'Ecological experiments.' (Cambridge University Press: Cambridge).

Hall LA (1987) Transplantation of sensitive plants as mitigation for environmental impacts. In 'Conservation and management of rare and endangered plants' (Ed. TS Elias) pp. 413-420. (Californian Native Plant Society: Sacramento, USA).

Hancock N, Gallagher R (2014) How ready are we to move species threatened from climate change? Insights into the assisted colonization debate from Australia. Austral ecology 39(7), 830-838.

Hancock N, Harris R, Broadhurst L, Hughes L (2018) Climate-ready revegetation. A guide for natural resource managers. Version 2. Macquarie University, Sydney. http://anpc.asn.au/resources/climate_ready_revegetation.

Harcourt AH, Coppeto SA, Parks SA (2002) Rarity, specialization and extinction in primates. Journal of Biogeography 29(4), 445-456.

Harper JL (1977) 'Population biology of plants.' (Academic Press: London).

Harris S, Arnall S, Byrne M, Coates D, Hayward M, Martin T, Mitchell N, Garnett S (2013) Whose backyard? Some precautions in choosing recipient sites for assisted colonisation of Australian plants and animals. Ecological Management & Restoration 14(2), 106-111.

Hartmann HT, Kester DE, Davies FT, Geneve R (2011) 'Hartmann & Kester's Plant Propagation: Principles and Practices.' (Prentice Hall/Pearson).

Hogbin PM, Peakall R (2000) The effective management of threatened flora: lessons from the case of *Zieria* 'prostrata' ms. Pacific Conservation Biology 6(3), 238-244.

Hothorn T, Everitt BS (2009) 'A handbook of statistical analyses using R.' (Chapman and Hall/CRC Press).

IUCN (1987) 'The IUCN position statement on translocation of living organisms: introductions, re-introductions and re-stocking.' (International Union for Conservation of Nature and Natural Resources).

IUCN Standards and Petitions Subcommittee (2017) Guidelines for using the IUCN Red List categories and criteria. Version 13. http://www.iucnredlist.org/documents/RedListGuidelines.pdf.

IUCN/SSC (2013) Guidelines for reintroductions and other conservation translocations. Version 1.0. IUCN Species Survival Commission, Gland, Switzerland.

Johnson SD, Steiner KE (1997) Long-tongued fly pollination and evolution of floral spur length in the *Disa Draconis* complex (Orchidaceae). Evolution 51(1), 45-53.

Jordan R, Hoffmann AA, Dillon SK, Prober SM (2017) Evidence of genomic adaptation to climate in *Eucalyptus microcarpa*: Implications for adaptive potential to projected climate change. Molecular ecology 26(21), 6002-6020.

Jusaitis M (2010) Enhancement of Monarto Mintbush populations in South Australia by translocations. In 'Global Re-introduction Perspectives: Additional case-studies from around the globe. (Ed. PS Soorae) pp. 306-310. (IUCN/SSC Re-introduction Specialist Group: Abu Dhabi, UAE).

Jusaitis M (2016) Reinforcement of a population of chalky wattle on Eyre Peninsula, South Australia. In 'Global Re-introduction Perspectives: 2016. Case-studies from around the globe. (Ed. PS Soorae) pp. 246-251. (IUCN/SSC Re-introduction Specialist Group: Abu Dhabi, UAE).

Jusaitis M (2018a) Threatened plant translocation case study: *Haloragis eyreana* (Prickly Raspwort), Haloragaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc 27(1), 6-9.

Jusaitis M (2018b) Threatened plant translocation case study: *Prostanthera eurybioides* (Monarto Mintbush), Lamiaceae. Australasian Plant Conservation: Bulletin of the Australian Network for Plant Conservation 26(4), 15-17.

Keeley JE, Bond WJ, Bradstock RA, Pausas JG, Rundel PW (2011) 'Fire in Mediterranean ecosystems: ecology, evolution and management.' (Cambridge University Press: New York, USA).

Keenelyside K, Dudley N, Cairns S, Hall C, Stolton S (2012) 'Ecological restoration for protected areas: principles, guidelines and best practices.' (IUCN: Gland, Switzerland).

Keith DA (2000) Sampling designs, field techniques and analytical methods for systematic plant population surveys. Ecological Management & Restoration 1(2), 125-139.

Keith DA, Martin TG, McDonald-Madden E, Walters C (2011) Uncertainty and adaptive management for biodiversity conservation. Biological Conservation 144(4), 1175-1178.

Keith DA, Pellow BJ, Appleby M (2018) Monitoring threatened ecosystems and ecological communities. In 'Monitoring threatened species and ecological communities. (Eds S Legge, DB Lindenmayer, NM Robinson, BC Scheele, DM Southwell and BA Wintle) pp. 101- 126. (CSIRO Publishing: Clayton, Victoria, Australia.).

Krauss SL, Dixon B, Dixon KW (2002) Rapid genetic decline in a translocated population of the endangered plant *Grevillea scapigera*. Conservation Biology 16(4), 986-994.

Krebs CJ (1999) 'Ecological methodology. 2nd Edition.' (The Benjamin/Cummings Publishing Company: California).

Lawson J (2014) 'Design and Analysis of Experiments with R.' (CRC Press: Boca Raton, FL).

Legge S, Lindenmayer DB, Robinson NM, Scheele BC, Southwell DM, Wintle BA (Eds) (2018) 'Monitoring threatened species and ecological communities.' (CSIRO Publishing: Clayton, Victoria, Australia).

Leimu R, Fischer M (2008) A meta-analysis of local adaptation in plants. PloS one 3(12), e4010.

Likens GE, Lindenmayer DB (2011) A strategic plan for an Australian Long-term Environmental Monitoring Network. Austral Ecology 36(1), 1-8.

Linde CC, May TW, Phillips RD, Ruibal M, Smith LM, Peakall R (2017) New species of *Tulasnella* associated with terrestrial orchids in Australia. IMA fungus 8(1), 28-48.

Lindenmayer DB (2018) Difficulties in fitting an adaptive management approach to threatened species monitoring. In 'Monitoring threatened species and ecological communities' (Eds S Legge, DB Lindenmayer, NM Robinson, BC Scheele, DM Southwell and BA Wintle) pp. 397-406. (CSIRO Publishing: Clayton, Victoria, Australia).

Lindenmayer DB, Burns EL, Tennant P, Dickman CR, Green PT, Keith DA, Metcalfe DJ, Russell-Smith J, Wardle GM, Williams D (2015) Contemplating the future: Acting now on long-term monitoring to answer 2050's questions. Austral Ecology 40(3), 213-224.

Lindenmayer DB, Likens GE (2009) Adaptive monitoring: a new paradigm for long-term research and monitoring. Trends in Ecology & Evolution 24(9), 482-486.

Llorens T, Byrne M, Yates C, Nistelberger H, Coates D (2012) Evaluating the influence of different aspects of habitat fragmentation on mating patterns and pollen dispersal in the bird-pollinated *Banksia sphaerocarpa* var. *caesia*. Molecular Ecology 21(2), 314-328.

Llorens TM, Macdonald B, McArthur S, Coates DJ, Byrne M (2015) Disjunct, highly divergent genetic lineages within two rare *Eremophila* (Scrophulariaceae: Myoporeae) species in a biodiversity hotspot: implications for taxonomy and conservation. Botanical journal of the Linnean Society 177(1), 96-111.

Llorens TM, Yates CJ, Byrne M, Nistelberger HM, Williams MR, Coates DJ (2013) Complex interactions between remnant shape and the mating system strongly influence reproductive output and progeny performance in fragmented populations of a bird-pollinated shrub. Biological Conservation 164(August 2013), 129-139.

Long RL, Gorecki MJ, Renton M, Scott JK, Colville L, Goggin DE, Commander LE, Westcott DA, Cherry H, Finch-Savage WE (2015) The ecophysiology of seed persistence: a mechanistic view of the journey to germination or demise. Biological Reviews 90(1), 31-59.

Maron M, Hobbs RJ, Moilanen A, Matthews JW, Christie K, Gardner TA, Keith DA, Lindenmayer DB, McAlpine CA (2012) Faustian bargains? Restoration realities in the context of biodiversity offset policies. Biological Conservation 155(October 2012), 141-148.

Maron M, Ives CD, Kujala H, Bull JW, Maseyk FJ, Bekessy S, Gordon A, Watson JE, Lentini PE, Gibbons P (2016) Taming a wicked problem: resolving controversies in biodiversity offsetting. BioScience 66(6), 489-498.

McDougall K, Armstrong R, McAuliffe J, Taylor D (2018) Threatened plant translocation case study: *Pomaderris delicata* (Delicate Pomaderris), Rhamnaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc 27(1), 10-12.

McKay JK, Christian CE, Harrison S, Rice KJ (2005) "How local is local?"—a review of practical and conceptual issues in the genetics of restoration. Restoration Ecology 13(3), 432-440.

McLean EH, Prober SM, Stock WD, Steane DA, Potts BM, Vaillancourt RE, Byrne M (2014) Plasticity of functional traits varies clinally along a rainfall gradient in *Eucalyptus tricarpa*. Plant, Cell & Environment 37(6), 1440-1451.

Menges ES (2008) Restoration demography and genetics of plants: when is a translocation successful? Australian Journal of Botany 56(3), 187-196.

Menges ES, Gordon DR (1996) Three levels of monitoring intensity for rare plant species. Natural Areas Journal 16 227–237.

Millar M, Byrne M, Coates D (2010) The maintenance of disparate levels of clonality, genetic diversity and genetic differentiation in disjunct subspecies of the rare *Banksia ionthocarpa*. Molecular Ecology 19(19), 4217-4227.

Monks L, Coates D (2002) The translocation of two critically endangered *Acacia* species. Conservation Science Western Australia 4(3), 54-61.

Monks L, Coates D, Bell T, Bowles ML (2012) Determining success criteria for reintroductions of threatened long-lived plants. In 'Plant Reintroduction in a Changing Climate ' (Eds J Maschinski and KE Haskins) pp. 189-208. (Springer).

Monks L, Coates D, Dillon R (2018) Threatened plant translocation case study: *Acacia cochlocarpa* subsp. *cochlocarpa* (Spiral Fruited Wattle), Fabaceae. Australasian Plant Conservation: Bulletin of the Australian Network for Plant Conservation 26(4), 3-5.

Moritz K, Ainsley P, Bickerton D (2018) Threatened plant translocation case study: *Prostanthera eurybioides* (Monarto Mintbush), Lamiaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc 27(1), 12-15.

Munro N, Lindenmayer D (2011) 'Planting for wildlife: a practical guide to restoring native woodlands.' (CSIRO Publishing).

Natural Resource Management Ministerial Council (2010) Australia's Biodiversity Conservation Strategy 2010-2030. Australian Government, Department of Sustainability, Environment, Water, Population and Communities,, Canberra.

Neal JM (2007) The impact of habitat fragmentation on wild *Macadamia integrifolia* Maiden and Betche (Proteaceae) population viability. PhD Thesis, University of New England, Armidale.

Nevill PG, Tomlinson S, Elliott CP, Espeland EK, Dixon KW, Merritt DJ (2016) Seed production areas for the global restoration challenge. Ecology and evolution 6(20), 7490-7497.

Nichols JD, Williams BK (2006) Monitoring for conservation. Trends in Ecology & Evolution 21(12), 668-673.

NSW Office of Environment and Heritage (2015) Who Cares about the Environment? A survey of the environmental knowledge, attitudes and behaviours of people in New South Wales in 2015. Office of Environment and Heritage, Sydney.

OEH Saving our Species Program 2016 – 2021 Seed and *ex situ* conservation – information pack. RBGD Trust.

Offord CA, Meagher PF (Eds) (2009) 'Plant Germplasm Conservation in Australia: Strategies and Guidelines for Developing, Managing and Utilising Ex situ Collections.' (Australian Network for Plant Conservation Inc.: Canberra).

Offord CA, Meagher PF, Zimmer HC (2014) Growing up or growing out? How soil pH and light affect seedling growth of a relictual rainforest tree. AoB Plants 6 https://doi.org/10.1093/aobpla/plu011.

Offord CA, North TG (2009) Living plant collections. In 'Plant Germplasm Conservation in Australia: Strategies and Guidelines for Developing, Managing and Utilising Ex situ Collections' (Eds CA Offord and PF Meagher) pp. 149-161. (Australian Network for Plant Conservation Inc.: Canberra).

Ott RL, Longnecker M (2015) 'An introduction to statistical methods and data analysis. Seventh Edition.' (Cengage Learning, Inc Mason Ohio, United States of America).

Panaia M, Senaratna T, Bunn E, Dixon K, Sivasithamparam K (2000) Micropropagation of the critically endangered Western Australian species *Symonanthus bancroftii* (F. Muell) L. Haegi (Solanaceae). Plant Cell, Tissue and Organ Culture 63(1), 23 - 29.

Parker KA (2008) Translocations: providing outcomes for wildlife, resource managers, scientists, and the human community. Restoration Ecology 16(2), 204-209.

Pauw A, Bond WJ (2011) Mutualisms matter: pollination rate limits the distribution of oil-secreting orchids. Oikos 120(10), 1531-1538.

Pavlik BM (1996) Defining and measuring success. In 'Restoring diversity: strategies for reintroduction of endangered plants. (Eds DA Falk, CI Millar and M Olwell) pp. 127-156. (Island Press: Washington, DC).

Peel B (2010) 'Rainforest restoration manual for south-eastern Australia.' (CSIRO PUBLISHING).

Phillips RD, Peakall R, Retter BA, Montgomery K, Menz MH, Davis BJ, Hayes C, Brown GR, Swarts ND, Dixon KW (2015) Pollinator rarity as a threat to a plant with a specialized pollination system. Botanical Journal of the Linnean Society 179(3), 511-525.

Powell M, Accad A, Shapcott A (2014) Where they are, why they are there, and where they are going: using niche models to assess impacts of disturbance on the distribution of three endemic rare subtropical rainforest trees of *Macadamia* (Proteaceae) species. Australian Journal of Botany 62(4), 322-334.

Prober S, Byrne M, McLean E, Steane D, Potts B, Vaillancourt R, Stock W (2015) Climate-adjusted provenancing: a strategy for climate-resilient ecological restoration. Frontiers in Ecology and Evolution 3(65).

Prober SM, Potts BM, Bailey T, Byrne M, Dillon S, Harrison PA, Hoffmann AA, Jordan R, McLean EH, Steane DA (2016) Climate adaptation and ecological restoration in eucalypts. Proceedings of the Royal Society of Victoria 128(1), 40-53.

Quinn GP, Keough M (2003) 'Experimental design and data analysis for biologists.' (Cambridge University Press: Cambridge).

Ralls K, Ballou JD, Dudash MR, Eldridge MD, Fenster CB, Lacy RC, Sunnucks P, Frankham R (2018) Call for a paradigm shift in the genetic management of fragmented populations. Conservation Letters 11(2), e12412.

Ramalho CE, Byrne M, Yates CJ (2017) A Climate-Oriented Approach to Support Decision-Making for Seed Provenance in Ecological Restoration. Frontiers in Ecology and Evolution 595.

Ramsey FL, Schafer DW (2012) 'The statistical sleuth. Third Edition.' (Cengage Learning, Inc.: United States of America.).

Rasmussen HN (1995) 'Terrestrial orchids: from seed to mycotrophic plant.' (Cambridge University Press).

Rasmussen HN (2002) Recent developments in the study of orchid mycorrhiza. Plant and soil 244(1-2), 149-163.

Reiter N, Lawrie A, Walsh N (2013) The mycorrhizal associations of *Borya mirabilis*, an endangered Australian native plant. Muelleria 31(1), 81-88.

Reiter N, Lawrie AC, Linde CC (2018a) Matching symbiotic associations of an endangered orchid to habitat to improve conservation outcomes. Annals of botany https://doi.org/10.1093/aob/mcy094.

Reiter N, O'Brian N, Gibson M, Pitts D, Brown GR, Phillips R (2018b) Threatened plant translocation case study: *Caladenia hastata* (Nicholls) Rupp (Melbloms Spider-orchid), Orchidaceae: Pollinator rarity limit conservation translocation sites in a rare orchid. Australasian Plant Conservation: Bulletin of the Australian Network for Plant Conservation 26(4), 9-12.

Reiter N, Thompson R (2018) Threatened plant translocation case study: Involvement in the Royal Botanic Gardens Victoria's Orchid Conservation Program by volunteers from the Australasian Native Orchid Society Victoria Group. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc 27(1), 19-22.

Reiter N, Thomson R, Bedggood W, Jenek C, Cross R, Whitfield J, Lawrie A, Pollard G, Argall M, Johnson G (2012) Victorian orchid conservation. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc. 21(3), 12.

Reiter N, Vlcek K, O'Brien N, Gibson M, Pitts D, Brown GR, Bower CC, Phillips RD (2017) Pollinator rarity limits reintroduction sites in an endangered sexually deceptive orchid (*Caladenia hastata*): implications for plants with specialized pollination systems. Botanical Journal of the Linnean Society 184(1), 122-136.

Reiter N, Whitfield J, Pollard G, Bedggood W, Argall M, Dixon K, Davis B, Swarts N (2016) Orchid re-introductions: an evaluation of success and ecological considerations using key comparative studies from Australia. Plant ecology 217(1), 81-95.

Ricciardi A, Simberloff D (2009) Assisted colonization is not a viable conservation strategy. Trends in ecology & evolution 24(5), 248-253.

Rigg JL, Offord CA, Zimmer H, Anderson IC, Singh BK, Powell JR (2017) Conservation by translocation: establishment of Wollemi pine and associated microbial communities in novel environments. Plant and Soil 411(1), 209-225.

Robertson AW, Kelly D, Ladley JJ, Sparrow AD (1999) Effects of Pollinator Loss on Endemic New Zealand Mistletoes (Loranthaceae). Conservation Biology 13(3), 499-508.

Rosas-Guerrero V, Aguilar R, Martén-Rodríguez S, Ashworth L, Lopezaraiza-Mikel M, Bastida JM, Quesada M (2014) A quantitative review of pollination syndromes: do floral traits predict effective pollinators? Ecology Letters 17(3), 388-400.

Ross J (1999) Guide to best practice conservation of native grasslands. WWF (Worldwide Fund for Nature) Australia, Sydney.

Rossetto M, Henry RJ (2014) Escape from the laboratory: new horizons for plant genetics. Trends in plant science 19(9), 554-555.

Rossetto M, Weaver P, Dixon K (1995) Use of RAPD analysis in devising conservation strategies for the rare and endangered *Grevillea scapigera* (Proteaceae). Molecular Ecology 4(3), 321-330.

Schwartz MW (2003) Assessing population viability in long-lived plants. In 'Population viability in plants. Ecological Studies (Analysis and Synthesis). Vol. 165. (Eds CA Brigham and MW Schwartz) pp. 239-266. (Springer: Berlin, Heidelberg).

Sgro CM, Lowe AJ, Hoffmann AA (2011) Building evolutionary resilience for conserving biodiversity under climate change. Evolutionary Applications 4(2), 326-337.

Shapcott A (in press-a) Threatened plant translocation case study: *Macadamia jansenii* (Bulburin nut), Proteaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc

Shapcott A (in press-b) Threatened plant translocation case study: Wet and Dry subtropical Coastal Heath translocation. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc.

Shapcott A, Powell M (2011) Demographic structure, genetic diversity and habitat distribution of the endangered, Australian rainforest tree *Macadamia jansenii* help facilitate an introduction program. Australian Journal of Botany 59(3), 215-225.

Shefferson RP, Weiß M, Kull T, Taylor DL (2005) High specificity generally characterizes mycorrhizal association in rare lady's slipper orchids, genus Cypripedium. Molecular Ecology 14(2), 613-626.

Silcock JL (2018) Aboriginal translocations: the intentional propagation and dispersal of plants in Aboriginal Australia. Journal of Ethnobiology 38, 372-405.

Smith ZF, James EA, McDonnell MJ, McLean CB (2009) Planting conditions improve translocation success of the endangered terrestrial orchid *Diuris fragrantissima* (Orchidaceae). Australian Journal of Botany 57(3), 200-209.

South East NSW Bioregion Working Group, Martin H, North T, Guja L, Chong C (in press) Threatened plant translocation case study: Collections Management – Documenting conservation collections using a Genotype collecting method. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc.

Standards Reference Group (2017) National Standards for the Practice of Ecological Restoration in Australia. Second Edition. Society for Ecological Restoration Australasia, Available from URL: http://www.seraustralasia.com/standards/home.html.

Steane DA, Mclean EH, Potts BM, Prober SM, Stock WD, Stylianou VM, Vaillancourt RE, Byrne M (2017) Evidence for adaptation and acclimation in a widespread eucalypt of semi-arid Australia. Biological Journal of the Linnean Society 121(3), 484-500.

Steane DA, Potts BM, McLean E, Prober SM, Stock WD, Vaillancourt RE, Byrne M (2014) Genome-wide scans detect adaptation to aridity in a widespread forest tree species. Molecular Ecology 23(10), 2500-2513.

Swarts N, Dixon K (2017) Chapter 7 Herbaceous terrestrial orchid translocation. In 'Conservation Methods for Terrestrial Orchids. (J Ross Publishing).

Swarts ND, Sinclair EA, Francis A, Dixon KW (2010) Ecological specialization in mycorrhizal symbiosis leads to rarity in an endangered orchid. Molecular Ecology 19(15), 3226-3242.

Taws N (2013) Survey of the Tumut Grevillea, *Grevillea wilkinsonii* after Record Flood Heights in 2012. Unpublished report prepared for the NSW Office of Environment and Heritage, Department of Premier and Cabinet. Greening Australia.

Taws N (2018) Re-survey of the Tumut Grevillea, *Grevillea wilkinsonii*. Unpublished report prepared for the NSW Office of Environment and Heritage, Department of Premier and Cabinet. Greening Australia.

Terry J, Sutcliffe V (2014) Cleaning seed collections for long-term conservation, Technical Information Sheet_14, Royal Botanic Gardens, Kew. https://www.kew.org/sites/default/files/14-Seed-cleaning.pdf

Torreya Guardians (2018) http://www.torreyaguardians.org/index.html

Translocation Working Group (1997) 'Guidelines for the Translocation of threatened plants in Australia.' (Australian Network for Plant Conservation: Canberra).

Turner S, Best C, Barrett S (2013) Combining science with management: Understanding the seed ecology of 'Pearl-like Androcalva' underpins successful '*in situ*' regeneration by fire of this threatened species. Australasian Plant Conservation: Journal of the Australian Network for Plant Conservation 22(1), 19-21.

Turner S, Elliott C, Bunn E (in press) Threatened plant translocation case study: *Androcalva perlaria* (Pearl-like Androcalva) Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc.

Turner SR, Merritt DJ (2009) Seed germination and dormancy. In 'Plant Germplasm Conservation in Australia. (Eds CA Offord and PF Meagher) pp. 87–108. (Australian Network for Plant Conservation: Canberra).

Underwood AJ (1997) 'Experiments in ecology: their logical design and interpretation using analysis of variance.' (Cambridge University Press).

Vallee L, Hogbin T, Monks L, Makinson B, Matthes M, Rossetto M (2004) 'Guidelines for the translocation of threatened plants in Australia.' Second edn. (Australian Network for Plant Conservation: Canberra).

van Emden H (2008) 'Statistics for terrified biologists.' (Blackwell Publishing: USA, UK, Australia).

Van Kleunen M, Weber E, Fischer M (2010) A meta-analysis of trait differences between invasive and non-invasive plant species. Ecology letters 13(2), 235-245.

Vitt P, Belmaric PN, Book R, Curran M (2016) Assisted migration as a climate change adaptation strategy: lessons from restoration and plant reintroductions. Israel Journal of Plant Sciences 63(4), 250-261.

Walters CJ (1986) 'Adaptive management of renewable resources.' (Macmillan Publishers Ltd: New York, USA).

Warcup J (1971) Specificity of mycorrhizal association in some Australian terrestrial orchids. New Phytologist 70(1), 41-46.

Weeks AR, Sgro CM, Young AG, Frankham R, Mitchell NJ, Miller KA, Byrne M, Coates DJ, Eldridge MD, Sunnucks P (2011) Assessing the benefits and risks of translocations in changing environments: a genetic perspective. Evolutionary Applications 4(6), 709-725.

Westgate MJ, Likens GE, Lindenmayer DB (2013) Adaptive management of biological systems: a review. Biological Conservation 158(February 2013), 128-139.

Whitlock MC, Schluter D (2014) 'The Analysis of Biological Data.' 2nd edn. (Macmillan Learning).

Wintle B (2018) Why, what, how much, and is it worth it? Questions to answer before spending a penny on monitoring. In 'Monitoring threatened species and ecological communities' (Eds S Legge, DB Lindenmayer, NM Robinson, BC Scheele, DM Southwell and BA Wintle) pp. 211-223. (CSIRO Publishing: Clayton, Victoria, Australia.).

Wintle BA, Runge MC, Bekessy SA (2010) Allocating monitoring effort in the face of unknown unknowns. Ecology Letters 13(11), 1325-1337.

Wright M, Cross R, Dixon K, Huynh T, Lawrie A, Nesbitt L, Pritchard A, Swarts N, Thomson R (2009) Propagation and reintroduction of *Caladenia*. Australian Journal of Botany 57(4), 373-387.

WWF (2018) Search and Rescue. http://www.wwf.org.au/news/blogs/search-and-rescue#gs.zLSBG4Q

Yates CJ, Coates DJ, Elliott C, Byrne M (2007a) Composition of the pollinator community, pollination and the mating system for a shrub in fragments of species rich kwongan in south-west Western Australia. Biodiversity and Conservation 16(5), 1379-1395.

Yates CJ, Elliott C, Byrne M, Coates DJ, Fairman R (2007b) Seed production, germinability and seedling growth for a bird-pollinated shrub in fragments of kwongan in south-west Australia. Biological Conservation 136(2), 306-314.

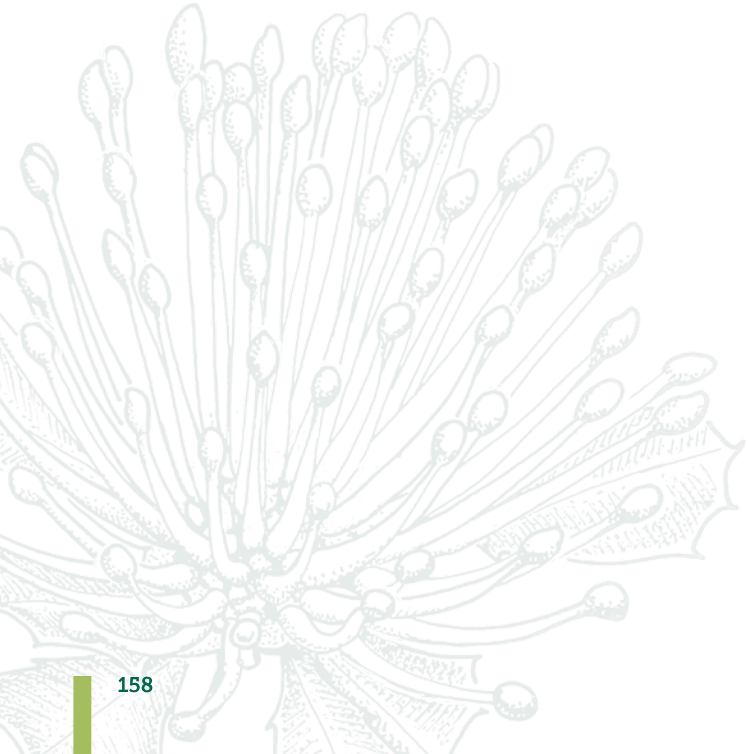
Ye Q, Bunn E, Krauss SL, Dixon KW (2007) Reproductive success in a reintroduced population of a critically endangered shrub, *Symonanthus bancroftii* (Solanaceae). Australian journal of botany 55(4), 425-432.

Young AG, Brown AH (1999) Paternal bottlenecks in fragmented populations of the grassland daisy *Rutidosis leptorrhynchoides*. Genetics Research 73(2), 111-117.

Zimmer H, Baker P, Offord C, Rigg J, Bourke G, Auld T (in press) Threatened plant translocation case study: *Wollemia nobilis* (Wollemi Pine), Araucariaceae. Australasian Plant Conservation. Bulletin of the Australian Network for Plant Conservation Inc.

Zimmer HC, Auld TD, Benson J, Baker PJ (2014) Recruitment bottlenecks in the rare Australian conifer *Wollemia nobilis*. Biodiversity and Conservation 23(1), 203-215.

Zimmer HC, Offord CA, Auld TD, Baker PJ (2016) Establishing a wild, *ex situ* population of a critically endangered shade-tolerant rainforest conifer: a translocation experiment. PloS one 11(7), e0157559.



Appendix 1. Conservation Agencies and Botanic Gardens

Federal

Department of the Environment and Energy - https://www.environment.gov.au/

Council of Heads of Australian Botanic Gardens (CHABG) - http://www.anbg.gov.au/chabg/

Australian Seedbank Partnership (ASBP) - http://seedpartnership.org.au/

Botanic Gardens Australia and New Zealand Inc - https://www.bganz.org.au/

CSIRO - www.csiro.au

Australian Capital Territory

ACT Government, Environment, Planning and Sustainable Development Directorate - http://www.environment.act.gov.au/

Australian National Botanic Gardens - https://www.anbg.gov.au/index.html

New South Wales

NSW Government, Office of Environment and Heritage - http://www.environment.nsw.gov.au/

The Royal Botanic Gardens and Domain Trust - https://www.rbgsyd.nsw.gov.au/

Northern Territory

Department of Environment and Natural Resources - https://denr.nt.gov.au/

George Brown Darwin Botanic Gardens - https://nt.gov.au/leisure/parks-reserves/george-brown-darwin-botanic-gardens

Queensland

Department of Environment and Science - https://www.des.qld.gov.au/

Brisbane Botanic Gardens Mt Coot-tha - https://www.brisbane.qld.gov.au/facilities-recreation/parks-venues/parks/brisbane-botanic-gardens-mount-coot-tha

South Australia

Department for Environment and Water, SA - https://www.environment.sa.gov.au/Home

Botanic Gardens of South Australia - https://www.environment.sa.gov.au/botanicgardens/home

Tasmania

Department of Primary Industries, Parks, Water and Environment - https://dpipwe.tas.gov.au/

Royal Tasmanian Botanical Gardens - https://gardens.rtbg.tas.gov.au/

Victoria

Department of Environment, Land, Water and Planning - https://www.delwp.vic.gov.au/

Royal Botanic Gardens Victoria - https://www.rbg.vic.gov.au/

Western Australia

Department of Biodiversity, Conservation and Attractions - https://www.dbca.wa.gov.au/

Botanic Gardens and Parks Authority - https://www.bgpa.wa.gov.au/

International

International Union for Conservation of Nature (IUCN) - https://www.iucn.org/

Reintroduction Specialist Group (RSG) - http://www.iucnsscrsg.org/

Botanic Gardens Conservation International (BGCI) - https://www.bgci.org/

Seed Conservation Directory of Expertise - https://www.bgci.org/plant-conservation/seedexpertise/

Botanic Gardens Australia and New Zealand (BGANZ) - www.bganz.org.au

Appendix 2. Template for a translocation proposal

Translocation Plan

1. Proponents, partners and approvals

1.1	Project title	Include species, location, type of translocation, year
1.2	Project manager	Name and contact details of person responsible for the translocation project.
1.3	Planning and implementation teams	Names and contact details for recovery team/ translocation working group / project planner if different to project manager. Names and contact details of implementation team, if different to project manager.
1.4	Experience and expertise	Relevant expertise and skills of those planning and implementing the translocation. Identify and describe how other relevant experts will be involved.
1.5	Partners	List partners and roles in project.
1.6	Other endorsements	List endorsements and reason for endorsement
1.7	Approvals required	List approval authorities and types of approvals required/granted

2. Proponents, partners and approvals

2.1	Primary conservation plan	Identify the primary conservation plan relevant to the species and its recovery objectives for the species. Attach or provide reference.
2.2	Conservation objectives	Detail the conservation objective of the translocation and explain how it contributes to or achieves the conservation objectives for the species. (See Chapter 1 for guidance).
2.3	Performance criteria	Detail the performance criteria for success or failure of the translocation over the short and long term. These should be a subset of performance criteria identified in the primary conservation plan. (See Chapter 1 for guidance).
2.4	Other options	Summarise why the translocation has the most conservation impact, a higher chance of success, and least potential negative consequences of all possible options. Attach supporting documentation.
2.5	Strategic alignment	Describe how the translocation is integrated with and aligns with other conservation actions being implemented for the species under the primary conservation plan.
2.6	Funding	Detail the sources of funding for the initial translocation and ongoing land management activities, and the period for which these funds have been committed.
2.7	Translocation timeline	Outline or attach project timeline and milestones.
2.8	Post-translocation management	Identify persons responsible for long-term management of the site and translocation.
2.9	Accountability for monitoring	Identify persons responsible for monitoring in the short term (up to ten years) and longer term
2.10	Exit decision	Who is responsible for deciding to cease the translocation and implementing the exit strategy?
2.11	Reporting	To whom and when will reports be provided. What will be reported?
2.12	Data management	Where will the data be held and who will be responsible for uploading and maintaining the data?

3. Consultation and engagement

3.1	Consultation	List affected parties (including neighbours, traditional owners, land users, etc.) and describe how their interests will be protected.
3.2	Communication	Outline how you will inform the community and partners about the progress of the translocation project including • Process and outcomes of the translocation, including debriefing and steps to inform future translocations, stakeholder communication and public engagement. • Describe how partners and stakeholders will be engaged in effective dialogue.
3.3	Community participation	List activities to promote engagement, participation, and community ownership, including: • Involvement in early planning decisions • Opportunities for key long-term roles • Participation in on-ground activities • Increasing knowledge of threatened flora conservation
3.4	Publications	What publications are expected to arise from the translocation project?

4. Species biology and ecology

4.1	Taxon to be translocated	Scientific and common name
4.2	Conservation status	List State, National and IUCN conservation status and reasons for status.
4.3	Historical and current distribution	Historic and current known distribution of this species including the most up to date information on number of populations and individuals remaining. Insert map if appropriate.
4.4	Biology and ecology	Provide an overview of the species ecology relevant to the translocation proposal, with particular emphasis on population and ecosystem processes. Identify key biological and ecological impediments to success, and how these will be managed. Examples include: **Phylogeny** How is the species related to other species at the donor and recipients sites, and is there a risk of hybridisation? If so, what are the potential effects and how will they be managed? **Biology** How long lived is your species? How long does it take to go from seedlings to adults and become reproductive? Are cultivation techniques established for your species? How long does your species take to cultivate? What time of year does your species flower? Does your species have a dormant stage in its lifecycle? Does your species reproduce by seed or vegetatively? Is a seed bank important for your species? **Pollination** Does your species require a pollinator to achieve seed set? If so what is the pollinator? **Mycorrhizal associations** Does your species require a mycorrhizal or rhizobial association in order to germinate or prosper? If so what is this? **Soil, hydrology and landform** What type of soil and geology is your species naturally found to grow in? Under what hydrological condition and what landform circumstances? **Vegetation community** What vegetation community is habitat for your species? Describe fire regimes and relevant ecological trajectory stages. **Climate** What type of climate/ rainfall/ temperature does your species inhabit?

5. The translocation

5.1	Previous translocations	Provide details of prior translocation attempts for this species and the extent to which they contributed to the objectives of the primary conservation plan.
5.2	Type of translocation	What type of translocation is proposed (see terminology for different translocations) (refer Chapter 1)
5.3	Translocation timeline, milestones and outcomes	Expand on the answer provided to 2.7. Describe the on-ground conservation outcomes of the translocation. What are the long term outcomes? What milestones will be used to assess progress? Include milestones for plant propagation, site preparation, the translocation itself and post-translocation management. Provide a timeline for the translocation. Include details of any trial or pilot experiments including how they will be used in decisions to proceed to a full translocation.
5.4	Selection and amount of translocation material	Identify how many plants/propagules will be translocated. Describe the criteria and reasons why the material was selected compared to other options. Explain how genetics, breeding system, or other factors have been considered during the selection process. Explain how and why the number of plants was selected. Describe their known or assumed genetic relatedness and representation of the species.
5.5	Origin of translocation material	Attach map of sites, cadastral details, or coordinates.
5.6	Transportation	Outline how the species will be transported to the recipient site.
5.7	Description of facilities	If the translocation includes a cultivation or propagation stage describe the location and nature of facilities.
5.8	Planting and establishment	Describe the planting method. Comment on the scientific rigour of the design. Include details of any experimental treatments, and how will the plants be tagged. Will the plants be watered, weeded or otherwise maintained?
5.9	Monitoring	Set out a framework for both short and long-term monitoring based on the objectives and milestones. Specify what plant traits/factors will be monitored at each event. Short-term monitoring must be adequate to prevent mortality from translocation shock.
5.10	Maintenance and adaptive management	What ongoing maintenance of the plants is planned? Identify how an adaptive management or experimental approach to the post-translocation monitoring and management will be implemented.
5.11	Exit strategy	What is your contingency plan to protect the species if the conservation objectives are unlikely to be met or the translocation is compromised or at risk of failure. Describe the exit strategy and the thresholds that trigger the exit strategy.

6. The recipient site

6.1	Recipient site decision	Describe criteria and reasons why the site was selected compared to other potential sites.
6.2	Description of recipient site	Describe location of recipient site, including map. Is the recipient site easy to access for management and monitoring?
6.3	Current land use, tenure and management	Describe past and current land-use and management of the sites, and how this will change. Identify the tenure and parties responsible for long-term management of the sites.
6.4	Alignment with historic or current distribution	Is the recipient site within the known and current distribution of the taxon? Is the recipient site within the past distribution of the species? If not, explain why.
6.5	Ecological suitability	Set out how the recipient site meets the habitat requirements of the species (e.g. carrying capacity, pollinators, soil and geology, hydrology, landform, vegetation composition, climate, light availability). Describe the site's ecological attributes that make it suitable for long-term population establishment.
6.6	Ecological maintenance	Describe the management activities required to maintain the ecological characteristics of the site. Include management associated with changes in drainage, soil stabilisation, vegetation removal or modification, fire regimes, etc.
6.7	Site preparation	Describe the site preparation required. Include details of earthworks, threat treatments, soil and vegetation management, structures, fences, ecological burns, signage, etc.

7. Impact and risk management

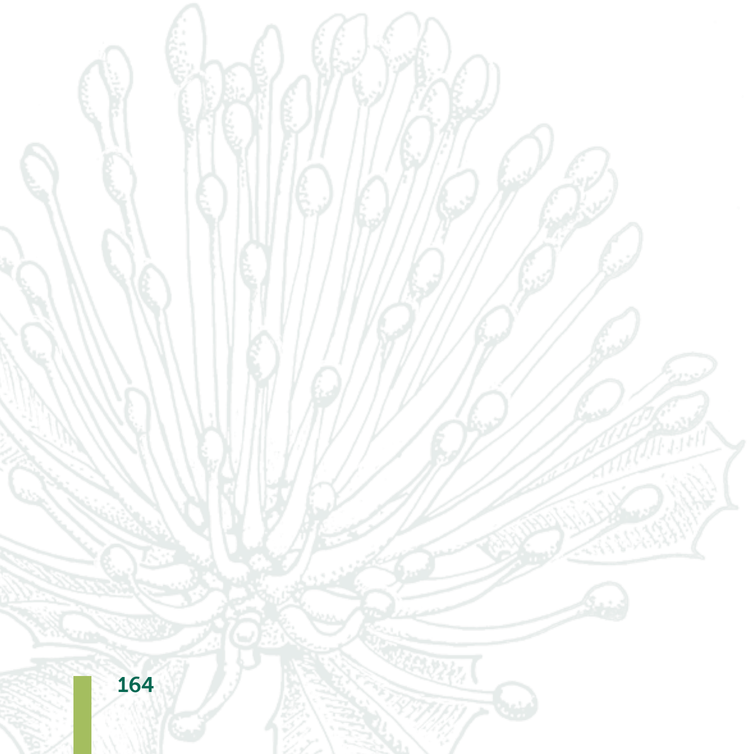
7.1	Impact of sampling or collection on source population	Provide an assessment of potential impacts of sampling on the source population(s), and how this will be monitored and managed.
7.2	Effect of the translocation on other populations of the species	Describe the effect of introducing new plants into an existing population and effects on populations near to the donor or recipient sites. Define the acceptable level of any effects. Describe how effects will be monitored and how unacceptable effects will be managed.
7.3	Effect of the translocation on the receiving environment	Describe the effect of the translocation on ecological, environmental, cultural or social values at the recipient site. Define the acceptable level of any effects. Describe how effects will be monitored and how unacceptable effects will be managed.
7.4	Accidental and inadvertent damage	How will the site be physically identified to avoid accidental damage? Is permanent signage warranted? Has the translocation site been identified as an asset or value on conservation agency, local council, and fire brigade, or other relevant government databases? Have they been advised of how the site should be protected?
7.5	Ecological threats to population persistence	Describe the threats to the species or impediments to population persistence at the sites, including pathogens, fire, herbivory, weeds, vegetation community dynamics, etc. Describe how these risks will be treated and identify the level of amelioration expected. Explain why this level is sufficient for long-term population persistence. For example describe phytosanitary measures for hygiene and quarantine of equipment, vehicles and people. Detail any other site-related risks that may affect the achievement of objectives and how they will be ameliorated.

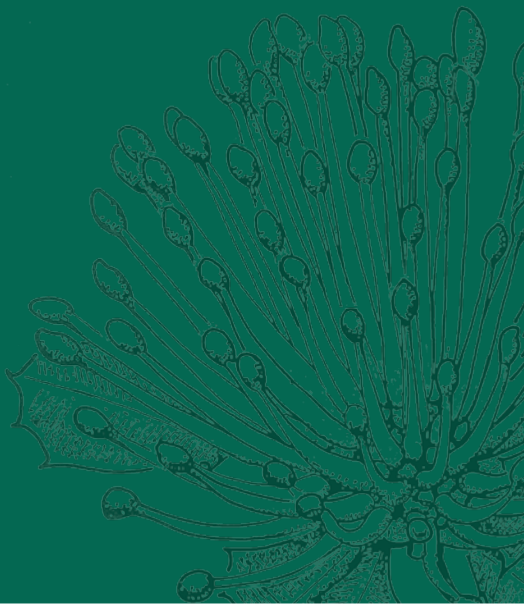
8. References

8.1	References	List relevant reference material.

9. Attachments

9.1	Attachments	List attachments.





Further information:

http://www.nespthreatenedspecies.edu.au/
http://www.anpc.asn.au

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National Environmental Science Programme

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